DEVELOPMENT OF EXPERT SYSTEM FOR CONTRACTUAL RISK SHARING IN TUNNEL CONSTRUCTION

A THESIS

submitted in fulfilment of the
requirements for the award of the degree
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DOCTOR OF PHILOSOPHY
in
WATER RESOURCES DEVELOPMENT

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled

DEVELOPMENT OF EXPERT SYSTEM FOR CONTRACTUAL RISK SHARING
IN
TUNNEL CONSTRUCTION

in fulfilment of the requirement for the award of the Degree of DOCTOR OF PHILOSOPHY, submitted in the Department of Water Resources Development Training Centre of the University of Roorkee, Roorkee, is an authentic record of my own work carried out during the period from September 1985 to February 1991, under the supervision of Dr. Mahesh Varma and Dr. Bhawani Singh.

The matter embodied in this thesis has not been submitted by me for the award of any other degree.

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ABSTRACT

Tunnel construction is a subject involving uncertainties arising due to the geology of the rock formations, efficiency and output of the tunnelling equipment and the management conditions. The resulting cost and time overruns are due to (1) job conditions, which cannot be altered; (2) breakdowns or other holdups, over which there is no control; and (3) poor management conditions which are within the competence of the project managers.

The need for undertaking a study of management factors leading to better advance rates in tunnelling has been explained in Chapter 1.

The literature available on various aspects of management factors related to the construction industry, particularly to subsurface construction, has been reviewed in Chapter 2.

There are many factors that affect the management conditions during tunnel construction all of which contribute to greater advance rates of tunnelling. An opinion poll was carried out among tunnelling experts representing both the owner (government) and the contractor, regarding the relative importance of the various management factors in tunnel excavation. The findings of the poll are reported in Chapter 3, as they apply to the three types of tunnels: (A) short tunnels, (B) long tunnels in good or poor rock, and (C) long tunnels in very poor rock or poor environment conditions. One of the factors is the sharing of risks which is unfortunately not given due importance in India.

Risks in tunnel construction arise due to a variety of causes. Thrusting all the risks on any one of the parties involved in tunnel construction, namely, the owner, the engineer, the contractor, the geologist and the insurer, will lead to adverse

situations culminating in costly litigation much to the detriment of the project. Equitable sharing of risks will result in a congenial atmosphere. The risk associated with a particular action should be borne by the party who took that action. Risks in underground construction appear at all stages - right from investigations, bidding and preparation of contract documents to actual construction. Chapter 4 discusses some aspects of sharing of risks in tunnelling contracts.

In Chapter 5, the utility of expert systems in construction engineering has been described. Also elaborated are the various features of the expert system shell EXSYS used in this study.

In Chapter 6, an expert system - ESSOR -- Expert System for Sharing of Risks, has been developed to determine whether the risks have been shared equitably by the different agencies responsible for the tunnel construction. The computer program usable on a personal computer may be used by the owner and the contractor, before, during or after the construction regarding the sharing of risks. ESSOR includes 1798 knowledge-based rules in the form of IF-THEN rules utilising a computer software EXSYS - a commercially available expert system package. A conceptual model of risk sharing has been presented. The clauses or provisions in a tender/contract document will either benefit or adversely affect the interests of the persons involved in any underground construction: government department, engineer, geologist and insurer - all collectively termed as the owner, and the contractor. The provisions can be fed into the expert system ESSOR, which will indicate at the end whether the sharing of risks has been equitable or not. The contract documents of two projects: Project A and Project B which involve tunnel construction, have been studied and the contract clauses fed into

ESSOR. The results of the test runs are included.

GAPS IN THE EXISTING KNOWLEDGE

From a review of the literature available on construction management, the following grey areas were identified:

1. The management factors that influence tunnel advance rates in India and how they affect tunnels of different lengths and varying site conditions need to be studied,

2. The relative importance of management factors on tunnelling rates in India needs to be understood,

3. An expert system for sharing of risks in underground construction, especially tunnels is not available,

4. No guide lines are available for energy management,

5. No reports are available on management consultancy in tunnelling,

6. Causes of failure to achieve projected targets particularly in tunnels in the Himalayan region have not been documented,

7. An urgent need exists to update technology of tunnelling in India,

8. No guidelines are available to suggest a reasonable amount of pre-bid investigations desirable in the Himalayas, which are noted for their geological complexities,

9. The type of contract best suited to all circumstances of a tunnelling project needs to be identified,

10. Documentation of causes of delays, type and duration of delays, phase of project in which delays occurred, is needed with recommendations for prevention of delays,

11. Actions to be considered by owners in an attempt to increase efficiency and productivity of underground construction projects need to be reported,

12. Factors favouring management of planning, design and construction 'by a single contractor (as opposed to separate firms for design and construction management) needs to be studied,

13. Suggestions to increase productivity of team members on a tunnel project (owners, design engineers, contractors, construction managers, and construction employees) need to be reported,

14. Organisation structure for long and short tunnels needs to be examined,

15. Improvements in contracting practices which are expected to have a strong influence on decisions affecting tunnel construction need to be suggested,

16. A satisfactory procedure for sharing inflationary effects needs to be evolved,

17. The extent of disclosures of subsurface information for prospective bidders needs to be studied, and

18. The acquisition of data and their availability after completion of the project should be ensured.

Of the various grey areas existing in our present knowledge, the following three areas have been covered in this study,

(1) The management factors that influence tunnel advance rates and how they affect tunnels of different lengths and varying site conditions in India,

(2) The relative importance of management factors in tunnelling rates in different site conditions in India, and

(3) The development of an expert system for sharing of risks in underground construction, especially tunnels.

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CHAPTER 1

NEED FOR THE STUDY

1.1. INTRODUCTION

In civil engineering practice, the area that has received scant attention of researchers is construction engineering and management, particularly the basic research, to develop its basic concepts. Only through such basic research will construction engineering and management advance to the level of perfection expected of the engineering profession.

The National Science Foundation (USA) and the Construction Research Council of the ASCE sponsored a workshop to discuss basic research needs in the construction industry. The workshop dealt with issues under:

(1) definition of basic research in construction engineering and management,

(2) basic research needs in construction engineering management,

(3) construction engineering analysis and design,

(4) construction engineering uncertainty, and

(5) construction engineering human resource management.

A summary of the list of research needs has been reported by Carr and Maloney (1983).

The primary concern in dealing with construction contracts is getting the work executed satisfactorily in the shortest time and at least expense to the owner-ensuring that a reasonable profit accrues to all other parties associated with the contract. Disagreements and delays which are directly related to the extra cost which the owner and the contractor must suffer may vitiate the best of intentions. The disagreements generally arise through inappropriate and defective contract documents.

Insufficient time for preparing and reviewing, laziness in searching out proper terms and language, inadequate recognition of risks or just ignorance result in inappropriate or defective contract documents. They may also result from rigid constraints and format requirements with which the engineer is not allowed to tamper.

The contract documents, including both drawings and specifications, should be carefully drafted to identify possible risks at the beginning.

Among today's most complicated and costly civil engineering projects, the construction of those built underground, especially tunnels, is a very difficult task which involves high risk.

Tunnel construction gets delayed in all cases leading to cost and time over-runs. The excesses are due to

(a) job conditions,

(b) breakdowns or other holdups, and

(c) management conditions.

The job conditions relate to the geology and its associated rock characteristics along the tunnel. These job factors are unalterable and greatly affect the tunnelling rate. Breakdowns due to failure of mechanical equipment and electric power cause delays in the tunnel cycle time. The breakdowns are dependent on the job and management conditions. Tunnel excavation rates may be greatly increased if the management conditions, such as overall job planning and equipment availability are improved. These conditions are within the competence of the project managers.

In recent years, the cost of constructing a metre of completed tunnel has increased tremendously. The increase may be attributed to a number of factors including, inflation, change orders resulting from unanticipated adverse subsurface conditions, lack of mutually equitable contracting practices in tunnel construction, and lack of standardisation of appropriate components of the tunnel system. Standardisation of tunnel construction diameter and consequently the tunnel construction equipment might lead to extending the life of construction equipment, and to better availability of spare parts, reducing the delay time from equipment breakdown (Hampton and McCusker, 1980).

The largest items of expense in some tunnels are related to human factors involved in contracting and executing the project (Singh et al, 1972).

A review of the adjuncts to tunnel engineering reveals that tunnel construction no longer remains a technology. A critical factor in its success pertains to the art of good project management.

The great importance of management conditions in driving tunnels at a faster rate has been realised by Singh (1986).

Rapid excavation being the primary objective in tunnel construction, great improvements have been made in the type of tunnel driving machines and their capacities and many tunnelling methods have been developed to govern difficult situations. Selecting the most suitable tunnelling method considering the unpredictable and non-uniform geology and allowing for mechanical breakdown of tunnelling equipment are just a few of the problems that may be faced during the execution of a tunnel project.

Adoption of faster and high capacity machines alone will not result in greater advances or pulls in tunnel driving.

A study of the total time that an equipment is available and its utilisation for tunnel advance shows that there exists enough scope to improve the advance rates in a given time by controlling many other factors mostly related to the management of the various planned activities in a round of advance.

Earlier investigators suggested models for simulating the muck handling system (Konya et al, 1973 and Mutmansky, 1974), and simulating the tunnel excavation based on field data and statistical models for cycle time data (Chauhan, 1982).

1.2. RISKS IN UNDERGROUND CONSTRUCTION

Underground construction is beset with a number of risks because of its inherent nature. Risks from the known and unknown geological and contractual characteristics affect the success of the tunnelling contract. The known characteristics may be assessed quite reasonably and adequate provisions made in the time and cost estimates in the contract to provide some degree of protection, safety and economy to the owner and the construction contractor. However, the unknown characteristics may not be assessed to any degree of certainty. The occurrence of the unknown may be accounted for, based on laws of probability.

The sharing of risks between the owner, the contractor, the engineer, the geologist and the insurer, equitably will lead to a welcome and happy ending of a tunnel project. To that end, the tender and the contract documents should be drafted properly, incorporate as many of the characteristics as possible in the specifications to cover all aspects of the execution programme as envisaged. Long drawn disputes and litigation in courts are least desirable in the execution of any contract. The ingenuity of the owner and engineer in drawing up the contract specifications may be helpful in avoiding disputes and litigation.

A contract document that transfers all the risk to the contractor will not be a healthy one, and the owner may expect to be embroiled in litigation, and thus be looked down in the public opinion. On the other hand, a contract in which the risks between the various parties are shared equitably will result in a happy ending to the tunnelling programme, with the owner and the contractor having established their credibility among themselves and in the public eye.

Artificial Intelligence may be advantageously used to evaluate whether the tender and the contract documents have been favourably drafted. This aspect has been elaborated in this study.

1.3. HEURISTIC APPROACH

With the development of the computer, and numerous software for various applications, Artificial Intelligence is finding greater use in a variety of subjects, like medicine, geology, engineering, flood forecasting, air transport and many others.

In the field of construction management and engineering, many decisions, such as, safety management, labour relations, bidding and risk evaluation and management are qualitative and subjective and complex in nature. Other areas in construction, be they material management or financial management, or others, often require decisions to be taken with little or incomplete data. These are areas where Artificial Intelligence or Expert Systems should be developed for speedy execution.

1.4. NEED FOR OPINION POLL

It was considered necessary to survey opinions of the experts of tunnelling in India. In this way relative importance of various management parameters could be justified. The need for an Expert System - ESSOR - "Expert System for Sharing of Risks", has also been felt for assessing whether the sharing of risks between the various parties to the tunnelling contract has been equitable or not. A knowledge based expert system with IF-THEN production rules has been compiled from various literature available on risk management and discussions with various tunnelling experts.

CHAPTER 2

REVIEW OF LITERATURE

2.1. CONSTRUCTION MANAGEMENT

Warszawski (1972) concluded that the difficulties inherent in realization of construction projects require a comprehensive training program for potential construction managers. It should deal with all aspects of construction management and may be supplemented by economics, management or construction technology, depending upon the framework of studies and the background of participants.

The need for research in construction management has been brought out by Paulson (1976).

Kettle (1976) has discussed the advantages and disadvantages of project delivery systems - an organisational concept which assigns specific responsibilities and authorities to people and organisations.

Barrie and Paulson (1976) described the findings and conclusions of the ASCE Task Committee on Management of Construction Projects and several practical matters related to their application in the procurement of construction facilities.

Maevis (1977) has reviewed pros and cons of construction management and discussed factors for the betterment of civil engineering projects.

Bhandari (1977) discussed computer applications in construction management to solve some of the complex problems confronting the construction industry and keep pace with today's vastly accelerated construction technology that has been brought about by the computer.

Kettle (1979) has described a standard specification for broad usage in construction management agreements as prepared by

ASCE Construction Division's Committee on Professional Construction Management (PCM).

The range of PCM tasks that may be utilised on major construction projects has been identified besides presenting the basic attributes that a PCM firm should possess in order for it to be effective (Subcommittee on Construction Management Organisation, 1979).

Tatum (1979) has proposed a set of criteria for performance evaluation of PCM in each project phase (conceptual, program planning, design, construction, and closeout and startup). A methodology for evaluation has also been proposed.

Barrie (1980) reviewed some of the controversial and undefined areas of construction management and suggested guidelines to consider if the partnership atmosphere necessary for successful PCM project performance is to be achieved.

Dressler (1980) described the three types of construction management prevalent in Germany:

(1) owner as construction manager - which is common with owners including government agencies, municipal agencies, etc.,

(2) design- management concept, also popular in Germany with private enterprises in which project owner delegates entire responsibility either to a general contractor or to a general designer, and

(3) three party approach - not often used in Germany. The three parties are the owner, one organisation assigned to design and management, and one consulting engineering firm.

Paulson and Akit (1980) discussed the managerial and administrative practices in Japan. A favourable climate for professional construction management form of contract in Japan is due to a cooperative and team-oriented solution to problems, whereas in the US, professional construction management must overcome strong traditions of adversary relationships.

Danladi and Horner (1981) have postulated that a relationship exists between construction efficiency and degree of management control on site. Within limits, as degree of control increases, it is likely that efficiency will improve. Points may be reached where

(1) marginal cost of increased management control is greater than the marginal saving resulting from improved efficiency or

(2) further increase in management control result in excessive interference in work cycle and a reduction in efficiency.

In either case, an optimum level of management control would exist at which total construction cost is minimal. Before intersite comparisons may be made, the factors affecting production or construction efficiency and site management control must be evaluated quantitatively.

Barrie (1982) discussed the three types of construction management alternates:

(1) AGC (Associated General Contractors of America) method,

(2) AIA (American Institute of Architects) method, and

(3) Professional Construction Management and choosing the right alternative for a particular project depending on the owner's real financial, quality, and schedule requirements and constraints to ensure that the organisational choice is compatible. He also presented a procedure whereby performance of construction management may be evaluated utilising a numerical system based on key factors in performance.

Warszawski (1984) described the major tasks in construction management leading to planning, control, organizing, coordinating and directing the project activities. Construction management must be viewed as a distinctive professional discipline with its own particular body of knowledge which requires study, updating and augmentation through an ongoing and methodical process. Owner's project management, contractor's project execution and construction company's corporate management have different interests and responsibilities.

Lammie and Shah (1984) have presented some practical management suggestions as follows:

(1) avoid criticising the cost of an adequate construction management field staff,

(2) consideration be given to the views of the field staff who focus on administration rather than contractual savings;

(3) the most difficult task in any project is to determine whether the contract should be terminated,

(4) after a bid is accepted, a detailed analysis should be made of unbalanced conditions in the bid to see if the contractor is using them to his advantage,

(5) the construction manager must know every detail of the project, even more than the contractor,

(6) the construction manager and the owner establish good rapport with local government representatives,

(7) personality conflicts between key participants in the job must be resolved if schedule and budget are to be met,

(8) the designer should have some responsibilities during construction,

(9) the resident engineer's offices should be staffed with adequate design personnel to make minor design changes right in the field,

(10) all disputes be resolved at the lowest possible level,

(11) the contractor should be encouraged to submit claims as the work progresses,

(12) insist on prompt submittal of the initial contractual schedule by the contractor, and

(13) do not encourage substitution of familiar products with new and unknown products.

Birrell (1985) has outlined the factors of construction management by general contractors and factors used by the main contractors to evaluate the performance of subcontractors.

Constructability improvement has been elaborated by O'Connor (1985) and by O'Connor and Tucker (1986).

The increasing importance of systematic planning in rapid underground excavation techniques has been brought out by Eberhardt (1974). Besides planning, the modern underground constructor is concerned with economic and competitive conditions, logistics and scheduling, efficient operating methods and equipment; and realistic, comprehensive, analytical risk evaluation.

Tunnelling is cyclic in nature and well adapted to the use of the project or process integrated system. Within the format of this program both upper level and field management may tinker with the project or process model by varying allocation of resources, costs or levels of production at which various components of the work are expected to be completed. Based on this capability of investigating various resources cost effective solutions may be developed without financial losses due to false starts in the field (Dabbas and Halpin, 1982).

Chauhan (1982) has developed a matrix for Job - Management factors under Good, Fair and Poor conditions and has suggested a range of values of these factors based on field data (Abusam, 1982) and results of simulation.

With good management, the Chinese tunnelling team on Taipingshao tunnel set a world tunnelling record of 1403.6 m/month for a *cross section of 6.7 sqm in Nov 1977 (Wei-wu and Shizhong,* 1985).

Construction management of large underground works has been elaborated by Khanna and Agrawal (1986).

Construction management in tunnel excavation has been discussed by Badarinath, Varma and Singh (1989a).

2.2. BIDS

The lowest bid which is the sum of a low cost structure and an efficient method of construction determines the cost-effective project, and in underground construction the structure and the feasible method of construction are closely interdependent (Sutcliffe, 1972).

Three types of bids prevalent in Japan are discussed by Paulson and Akit (1980) as:

(1) general competitive bid - not common in construction industry,

(2) selected competitive bid - most common type in public and private construction, and

(3) specified bid - where only one designated contractor may bid and get the contract.

At MARTA (Metropolitan Atlanta Rapid Transit Authority), it was found that the more flexibility that would be given to the contractor so that he might exercise his ingenuity in planning the work, the better the bid would be. The contractor would provide a better bid price if he had more control over his own work by the designer *providing in the bid documents more site access options* and fewer scheduled intermediate milestone completion points (Lamie and Shah, 1984). The goal must be to give the contractor maximum flexibility in setting his own schedule, and once that schedule is set by the contractor, to monitor it and require him to maintain the schedule that he himself initially set. Withholding of payments until recovery schedules were approved were the most effective provisions used by MARTA.

Lemley (1986) concluded that accurate in-depth geotechnical information provided by the owner and his engineers at the bidding stage of the project pays off many times over in time and cost effectiveness. If this preparatory work is coupled with a contractual environment which allows for reasonable risk sharing between all the parties involved, the project will have a substantially improved chance of being completed under budget and on time.

2.3. PREQUALIFICATION OF BIDDERS

Prequalification of bidders are recommended by NAS (1974), NAS (1978), Warszawski (1984) and ITA (1988).

Prequalification of bidders was employed on Eisenhower Memorial Tunnels (McOllough, 1981).

2.4. CONTRACTS AND CONTRACTING

Fox (1974) highlighted the conflicts that arise in subsurface construction contracts between the owner and the contractor. He has suggested that contracts be modified to include certain changes which would result in better work, fewer conflicts, lower costs and a more stable construction industry.

Contracting practices in European countries and US are compared by Ribakoff (1981) and he concluded that a successful contract for both owner and contractor is the product of a marriage between good contracting practices and good management organisation.

The types of contracts suitable for tunnel construction are reviewed by Ribakoff (1972), and Riggs (1979). The objectives of a contract are explained by Sutcliffe (1972).

If the construction industry is to develop its maximum technological potential, contracting practices which will encourage that development must be employed (Mathews, 1974).

The US National Committee on Tunnelling Technology has given recommendations on better contracting for underground construction which include:

(1) Sharing of risks and their costs between the owner and the contractor. The risks are both construction risks and financial risks,

(2) Handling of claims required to be expedited,

(3) Innovation in construction should be stimulated,

(4) The award of work to the qualified contractor should be assured, and

(5) Cost savings by other means should be realised (NAS, 1976).

The need for better management and better contracting in underground construction in US has been elaborated by Tillman (1981).

Contracting practices for tunnelling have been discussed in fair detail by Bhat (1986).

2.5. JOINT VENTURES

Ashley (1980b) presented the characteristics and theory of joint venture partnerships formed primarily for sharing construction-related risks, why an individual seeks a partnership to reduce the risk exposure; the advantages of a joint venture over an individual company in a competitive environment and an optimal allocation of risk on a construction project.

In joint venture partnerships, there is a greater spectrum in Japan than in the US. In case of joint ventures, the selection of bidder is made according to the ranking of major contractors so that minor contractors may bid large projects on the joint venture basis (Paulson and Akit, 1980).

2.6. TENDER AND CONTRACT DOCUMENTS

In drawing up the tender and contract documents in the pre-construction planning stage, great care and attention need to be given to subsurface and other investigation data provided or mentioned in these documents. Site investigations should be designed in relation to the special features and uncertainties of the ground, related to construction as well as design, with incremental costs of extra investigations justified by the expectation of a reasonably high benefit to cost ratio of the results obtained. The capacity to vary the scheme of construction in relation to changes in the ground is highly dependent upon the tunnelling technique (Tatum, 1979).

2.7. CHANGED CONDITIONS

The absence of a changed conditions provision in a contract, will induce the contractor to put contingency amount in his bid. Incorporation of a changed conditions clause is beneficial to the owner (Ribakoff, 1972).

The ITA recommends that a "Changed Conditions" clause be incorporated in all tunnelling contracts (ITA, 1988).

2.8. SPECIFICATIONS

In drawing the contract specifications, the objective must be to improve owner-contractor relations and reduce project costs. This is possible by having lower bids and fewer claims resulting from:

(1) reduced number of change orders by studying alternatives before the job is bid,

(2) fair and equitable specifications,

(3) advice sought from experienced construction supervisors while writing specifications which are tailored to the particular project,

(4) incorporation of changed conditions clauses,

(5) the provision of a fair system for reimbursement of overbreak beyond excavation pay lines,

(6) allowing the contractor have a voice in decisions regarding placement of temporary excavation supports,

(7) a technical committee, including a contractor's representative, provided to pass on matters of excavation supports,

(8) contract drawings not predicting physical conditions which may differ from those actually encountered, and

(9) quantities of support items given only for purposes of comparison of total bids and the specifications clearly saying so (Jacobs, 1971).

The importance of clear and unambiguous specifications is explained by Sutcliffe (1972).

The specifications should clearly establish the base price, labour index, materials index, base labour index, base material index, ratio for division of costs between labour and materials and provision for changes in price indicies (Riggs, 1979).

2.9. RESOLUTION OF CLAIMS

The Engineering Foundation Research Conference (EFRC) on Owner-Engineer-Contractor Relations in Tunnelling listed suggestions to reduce claims (Singh et al, 1972).

The common causes of claims in underground contracts are discussed by Sutcliffe (1972).

2.10. RESOLUTION OF DISPUTES

The desirability of resolving disputes without costly litigation in the courts is well established (Ribakoff, 1972).

Prompt settlement of disputes at the project or at lowest practical level with the minimisation of litigation is recommended by the EFRC (Singh et al, 1972).

Resolving disputes through arbitration are spelled out by NAS (1978) and Tillman (1981).

More and more owners are finding that arbitration may be costly and time consuming (Riggs, 1979).

An arbitration clause is generally included in contracts, sometimes by requirement of national law in some countries, while inclusion of such an arbitration clause is specifically prohibited by national law in many countries in Europe (Ribakoff, 1981).

McOllough (1981) suggested that the presence of the three-man Review Board to resolve disputes on Eisenhower Memorial Tunnels most probably precluded the development of other disputes during construction. The Board's presence, exerted an unwritten stabilising influence over both owner's and contractor's supervisory personnel which precluded potential for development of adversary relationship.

TARP (Tunnel And Reservoir Plan, USA) contracts did not permit arbitration as a means of final settlement of any disputes. Any dispute which could not be settled through administrative channels was settled through litigation (Neil and Dalton, 1981).

2.11. OWNER-ENGINEER-CONTRACTOR RELATIONS

Hammond and Bertelsen (1972) brought out the owner-engineer-contractor relationships in tunnelling. The tunnels of San Francisco Bay Area Rapid Transit District stand as excellent examples of quality construction resulting from the best efforts of owner, engineer and contractors cooperatively working together.

Some of the recommendations approved at the Engineering Foundation conference on owner-engineer-contractor relations in tunnelling are discussed by Singh et al (1972).

2.12. RAPPORT

The importance of gaining rapport and support quickly for a disruptive project from business, local organisations and utility concerns is brought out by Barnes and Leiser (1981).

McOllough (1981) compared the experience on the Eisenhower Memorial (twin) Tunnels. The first tunnel suffered both in time and cost due to various factors. The redesign of the second tunnel to accomodate difficult geological conditions encountered and re-negotiation of the original contract resulted in owner becoming intimately involved with the contractor's organisation and problems. This led to better rapport between the owner and the contractor.

2.13. PRODUCTIVITY

Gates and Scarpa (1972) applied the learning and experience curves to construction industry where the work is highly repetitive. Both the curves improve the production rates resulting in cost reduction.

Adrian and Boyer (1976) focussed attention on the development of a productivity model - MPDM - Method Productivity Delay Model, that provided the average construction firm with a means of measuring, predicting and improving a given method's productivity.

Based on a research study Borcherding et al (1980) concluded that:

(1) management may have to develop a motivational program that formally recognises craftsmen for quality and productivity, and

(2) whatever may be done to reduce the lost time due to materials, tools, or inspection delays, rework, crew interferences or overcrowded areas will improve job satisfaction as well as productivity.

Frein (1980) described the need to accumulate performance and production data from field reports for the contractor to develop the knowhow of his trade. Such data are required by the owner's management in analysing the accomplishments on the current job and for accumulating basic data for estimating future work.

Samelson and Borcherding (1980) examined several barriers to productivity described by foremen from five different construction sites as:

(1) waiting for decisions,

(2) waiting for materials and tools, and

(3) rework.

The barriers to production had negative outcomes such as:

(1) the lack of opportunity to finish jobs,

(2) the necessity for looking busy with nothing to do, and

(3) the building of things which will later often have to be torn out.

Profitability, as a measure of productivity used most frequently, has some serious drawbacks. Such a measure assumes that the estimate is flawless and that work conditions do not vary from job to job. Productivity based on worker hours is also a common measure. This measure assumes that work conditions are essentially the same when different project units are compared. Productivity assessed by work sampling is a useful measure of performance (Choromokos and McKee, 1981).

In order to improve production and to successfully eliminate restrictive work practices in construction, Marino (1981) suggested management must organise and plan construction activities effectively. Management must analyse the effects of delays as they occur and develop historical data for future use.

Ashley et al (1983) have introduced a new decision making methodology, crisis decision analysis as an appropriate tool for aiding the project manager in these strategic judgements. Adoption of crisis decision analysis for an example tunnel construction problem where surface settlement exceeded allowable limits demonstrates the methodology's strengths as well as its applicability.

Bresnen et al (1984) quote Borcherding who cited engineering design features, short construction lead times and too elaborate planning and scheduling systems, as principal causes of lower production because of too much time lost during planning stage.

Kellogg et al (1981) have suggested a heirarchy model, salient features of which are:

(1) Effectiveness not efficiency is the major issue. Increased productivity is got by working smarter, not necessarily harder. The problem is to establish a climate for the most effective operation considering all elements of the work process,

(2) Maximising total production is more important than achieving high production in the component parts,

(3) Production may be enhanced by controls, but due to the extreme variability of the construction environment, it is

difficult to transfer or duplicate or even maintain these systems for long periods of time.

(4) Production improvement or understanding developed for one type of construction or even one job may not be transferable in part or in whole to another,

(5) Production improvement has to be a part and concern of the total management system and must involve viable mechanisms for data feedback, feed-forward and retrieval,

(6) Production measurement methods for construction must be carefully tailored to the situation under study if they are to be meaningful.

Thomas et al (1986) concluded that more research is needed into the understanding of the parameters and factors before learning curve models may be effectively used for estimating and predictive purposes of repetitive work.

2.14. WORK SAMPLING

Thomas and Daily (1983) demonstrated the use of three activity sampling techniques:

(1) work sampling,

(2) the group timing technique, and

(3) the 5-min rating.

The key procedural aspects of how each method may be used are also discussed.

Thomas et al (1984) have presented some theoretical aspects of work sampling (time and motion study) to enhance the understanding and usefulness of work sampling as a surrogate productivity measure. The study indicated that work sampling may be used as a reliable estimator of construction productivity.

Liou and Borcherding (1986) have verified the effectivenes of work sampling as a productivity indicator; the usefulness of work sampling information as a predictor in the productivity projection model and the verification of the prediction power of the model.

2.15. MOTIVATION

Schrader (1972) reiterated that motivation of the construction craftsman could prove to be a great boon in the fight to keep down the cost growth of construction production. He has suggested a program that may be used to add to present knowledge of motivation in construction.

Hazeltine (1976) concluded that construction management may motivate construction workers to work productively by capitalizing on the motivation potential that already exists in the construction environment and a primary requirement of any successful motivation program is a willingness of all management personnel to discover, learn and apply appropriate motivation basics.

Laufer and Jenkins (1982) described managerial approaches to motivate construction workers and concluded that construction management would benefit from a general move toward a more participative decision-making style of leadership.

Maloney and McFillen (1986a,1986b) reported their findings which indicate that the motivational climate in construction industry was very poor.

2.16. FINANCIAL INCENTIVE PROGRAM (FIP) FOR WORKMEN

Washington Metropolitan Area Transit Authority (WMATA) introduced a performance incentive program into the contract for the Washington Metro. The incentive focussed management's attention, induced competition and improved field office performance (Egbert, 1981).

Laufer and Borcherding (1981) concluded that FIP in construction could materially raise productivity, lower production costs, shorten construction time and increase the earnings of the workers.

Maloney (1983) suggested that a financial incentive program may be a feasible means of improving worker productivity if three conditions are satisfied, namely:

(1) the worker's effort must be primary determinant of worker's output,

(2) increased pay must be contingent upon improved performance, and

(3) the worker must associate high anticipated satisfaction with the increased pay.

Stukhart (1984) has suggested various models for awarding incentives.

2.17. OPERATION SUPERVISION

Borcherding and Oglesby (1974) suggest the need to concentrate effort on each level of supervision to insure that the work is planned and inspected regularly so that workmen may be productive as the job unfolds.

2.18. TRAINING OF PERSONNEL

Scheduling games are available for training personnel involved in construction (Scott and Cullingford, 1973). The models simulate a civil engineering site on which the type of job and number of activities may be varied. The games may be used to simulate any project provided that sufficient data are available. The teams being trained consider four sets of constraints:

(1) Sequence period, i.e., no activity may begin unless all activities upon which it depends are complete,

(2) Availability of men from the pool. During the decision period the teams decide the numbers of workmen to be held in the

labour pool. If there are insufficient men than required, then the activity is passed over till enough men become available,

(3) Availability of equipment - similar to men, and

(4) Materials - players order the materials for each activity. If materials have not been ordered when work on the activity may begin, then it gets delayed until order is complete, i.e., the material is ordered as soon as it is found to be missing.

Use of planning and scheduling techniques developed by Scott and Cullingford (1973) will help site management to achieve the objective of successful completion of a project within the target period which is beneficial to the owner and the contractor.

Stanford's Civil Engineering Construction faculty has developed three powerful analytical tools for application in construction, namely:

(1) low cost field portable time lapse motion picture photography and related analytical modelling techniques for documentation, analysis and improvement of construction operations,

(2) computer based simulation modelling for design, testing and analysis of systems of equipment and methods for field operations, and

(3) interactive man-computer graphics systems and heuristic modelling approaches for simulation of operations and for solving large scale problems in project planning and control. With these tools crews could more actively experiment with new concepts when they are trained (Paulson 1978).

Frein (1980) discussed the importance of training and development of personnel in accomplishing the current work load and in building an organisation for future operation of the department and its field activities.

2.19. SIMULATION

Realising the potential of simulation and gaming as tools in construction management education, the construction game - CONSTRUCTO - has been developed (Halpin and Woodhead, 1970, and Halpin 1976).

Borcherding (1977b) described, Cost Control Simulation - CCS, a computer program wherein the management trainee is required to make decisions that are subsequently disturbed due to weather, material shortages, wage increases or other factors.

Halpin (1977) has applied CYCLONE (CYCLic Operations Network) which is a valuable aid in allowing the formulation of preconstruction scenarios and management strategies when complex construction processes are encountered in modelling job site processes.

Harris and Evans (1977) have developed a simulation game for site managers that simulates the important effects of varying production. The game has been widely used for the education and training of students and industrial managers attending the post graduate program in construction management at Loughborough University, UK.

A project manager using MUD - Model for Uncertainty Determination - can produce samples of activity and project times for single simulation of the project and output a statistical summary of the results of multiple simulation which gives estimates of the mean and standard deviation of the activity and project times that may be used in determining a reasonable project schedule (Carr, 1979).

Dabbas and Halpin (1982) presented a computerised system "PROMAX" for integrating project and process level planning and management. Simulation is used at the process or technological level to determine the durations of project level activities. Variations in resource allocation and cost and their impact on schedule and cost at project level may be studied using the system.

Ahuja and Nandakumar (1985) have used a computer model to simulate the expected occurrence of the uncertainty variables such as environment, space congestion, and workmen absence which affect activity durations. From these activity duration distributions, the probability of achieving completion time of the original project and probability of completing the project at any other time is computed.

A simulation model for tunnel construction costs - TCM - Tunnel Cost Model (Moavenzadeh and Markow, 1976) enabled the estimator to assess what are two critical uncertainties in tunnelling:

(1) geology along the tunnel line, and

(2) advance rate.

The model provides the user with a rapid, efficient and accurate means of analysing alternative tunnel locations or construction options. The model has the capability to simulate tunnelling costs, completion times and risks.

Ashley (1980a) has presented simulation modelling as an alternate analysis approach to planning repetitive unit construction projects as in tunnel construction. The model demonstrates how crew size, equipment allocation and learning effects may be manipulated by a manager to gain insight into construction operations.

Two essential features of administrative practices in tunnelling in order to provide proper encouragement to innovative and economical tunnelling, according to Muirwood and Sauer (1981) are that there should be:

(1) a continuity in the decision making at all stages so that the full implications of decisions in early stages of planning and design are understood, and

(2) appropriate provision for variation so that the greatest possible benefit may be derived from modifying the working scheme in relation to the ground characteristics and from a study of its behaviour during execution of the work.

Chauhan (1982) has used field data from Beas-Sutlej Link tunnels to simulate the tunnel excavation process. He has developed a matrix for Job and Management factors evolved from field data and simulation results.

Kavanagh (1985) discussed SIREN (SImulation of REpetitive Networks) - a computer based model of repetitive construction such as in tunnels. SIREN allows complex projects with numerous activities to be easily modelled by site or office personnel besides modelling crew and equipment availability, learning curve effects and the environment as well as doing a Monte-Carlo simulation.

Using CYCLONE simulation systems, Touran and Toshiyuki (1987) have shown that tunnel advance rate in small diameter tunnels is not only a function of TBM penetration rate, but is a function of the complex interaction between TBM, muck handling system, rock competence and tunnel diameter. They have quantified the impact of these factors on the tunnel advance rate. They believe that their simulation models may be successfully used in planning, scheduling and estimating tunnelling jobs.

2.20. ORGANISATION STRUCTURE

Staff in project management in Japan is 2-5 times that on US projects since design function is carried on in the field in Japan (Paulson and Akit, 1980).

Khanna and Agarwal (1986) have suggested an organisation structure for the construction of a large diameter long tunnel which is shown in Fig. 2.1.

Tatum (1986) described a method for practical application of expanded views in the systematic design of project organisation structure. His conclusions highlight the benefits of designing an organisation rather than letting it evolve.

2.21. MANAGEMENT STYLE

Badawy (1984) reiterated that flexibility of managerial style is clearly a requirement for achieving consistently good results. *While some traits of successful managers, such as* aptitude and intelligence may be innate, managerial skills may be learnt. Developing the right adaptability between the individual's skills and the requirements of the situation is what counts.

2.22. LEADERSHIP

Hinze and Kuechenmeister (1981) identified four distinct styles of leadership grouped under

(1) initiation,

(2) consideration,

(3) concern for results, and

(4) concern for people.

Leadership on construction site and styles of management or leadership affect the performance. Bresnen et al (1984) advocated providing adequate support and assistance to the workforce and establishing a cooperative atmosphere among all levels and parties involved as conducive to enhanced performance. The position power of the leader in group-tasks determines the

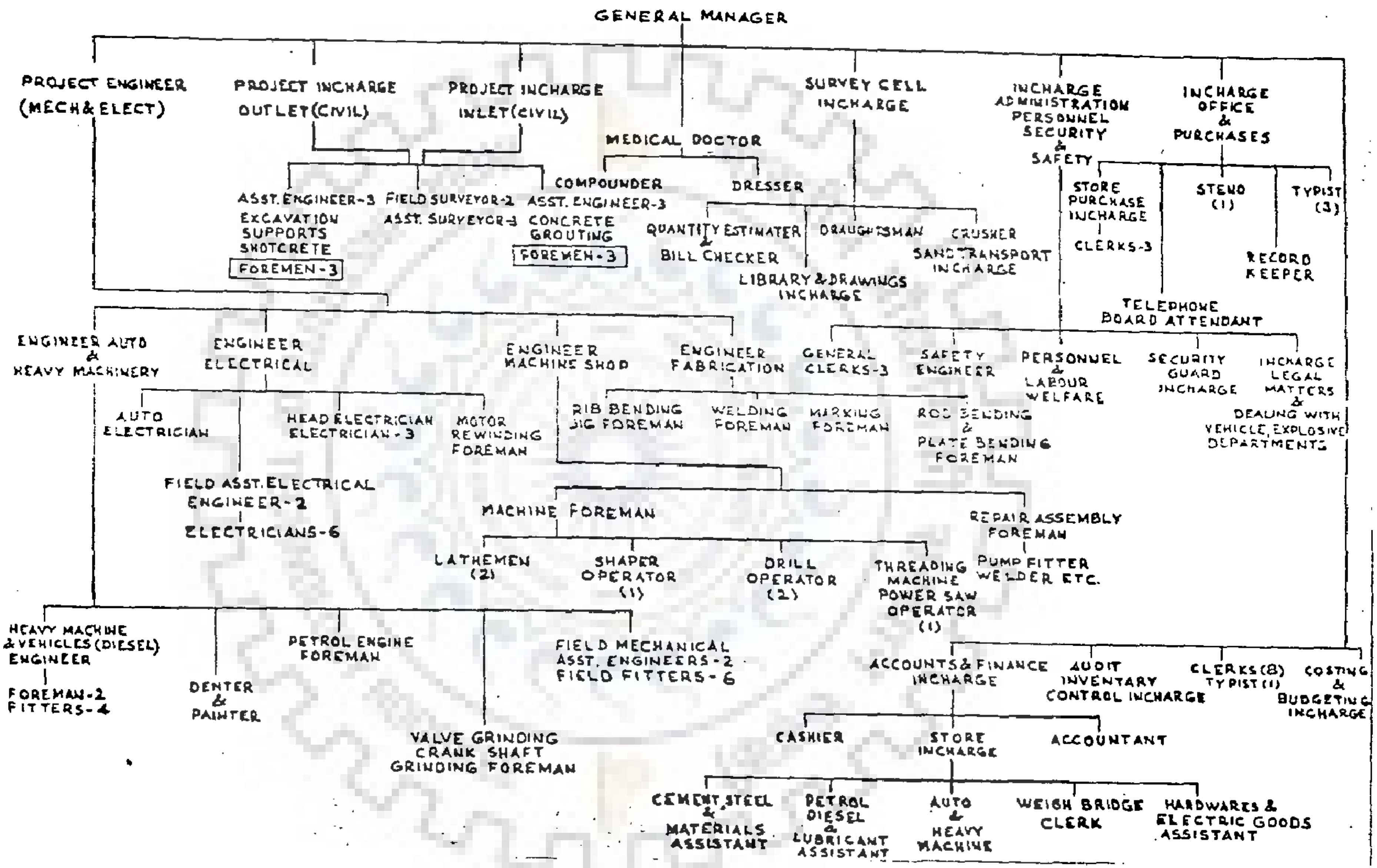

Fig. 2.1. Orga isation for large diameter and long tunnel (Khanna and Agarwal, 1986).

extent to which his actions prove effective.

Borcherding (quoted by Bresnen et al, 1984) identified an "inborn ability for leadership" as a trait identified by construction firm owners as important.

2.23. DECISION MAKING

Dressler (1974) has developed a model for linear projects to aid in decision making by exposing possible consequences of a decision that has associated probabilities related to time savings, time delays and project costs.

Borcherding (1977a) concluded that when participative decision making no longer takes place on large projects, supervisors and especially workmen lose their enthusiasm towards construction work and productivity is reduced.

In Japan (Paulson and Akit, 1980), decisions are made by consensus approach. It takes time to achieve consensus, but once achieved it assures total commitment to the successful outcome of the decision, and implementation is almost assured.

Ayyub and Haldar (1985) have developed a decision analysis framework considering the information on relative risk, along with the information on cost, benefits and consequences of each construction strategy. They have proposed a method of fuzzy composition of the consequences of failure of construction operations and the probabilities of failure.

2.24. COORDINATION

Owners and contractors in European contracts appear to work more as a team than they do in US (Ribakoff, 1981).

In Columbus, Ohio, labour and management established operation MOST which encompasses a variety of activities and has been very successful and is being copied in various locations throughout the US (Maloney & Jones, 1984).

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Vlatas (1986) concluded that high costs, project delays and contractor claims were due to a lack of partnership between the owner and the contractor. The adversarial attitude that owners take in their dealings with contractors must be changed to one of team work and the contractor's strengths should be utilised to identify deficiencies in the plans and specifications, and to help eliminate claims.

2.25. JOB PLANNING

When the project management system is correctly employed, the updated final activity durations of past projects, provide a basis of activity duration determination of future projects (Kawal, 1971). This method may be used in some cases; but past duration (activity) records are not easily implemented on new projects, because:

(1) projects differ in definition and scope,

(2) resources available are not consistent from one project to another, and

(3) project conditions change.

Three methods of treating past records of production data: moving average, exponential smoothing and probability model are available.

Crew task assignment sheets presented by Parker and Oglesby (1972), might be used to further insure detailed forethought by each foreman with good communication with his crew.

Delays contributing to lowering productivity are reduced by planning the work to efficiently utilise manpower. Waiting time and excess travel time may be reduced by providing adequate materials, tools and supervision at the work place (Marino, 1981).

All evidence available suggests that we need more involvement of job site managers -- especially foremen in the planning process. Weekly group meetings of general contractors and subcontractor's foremen with project managers must be common practice in construction. Elements of the general job schedule should be presented to the foremen so that at least a 2- or 4-week look-ahead review by them is possible. In the same meeting, weekly team goals could be agreed upon by each group (Olson, 1982).

Systematic planning of undergound works is important for rapid underground excavation. The contractor faces economic and competitive conditions which demand exacting planning logistics and scheduling. Detailed schedules based on critical path method, bar charts or other methods must be drawn up and systems developed to monitor these schedules with timely progress reports, daily bulletins, etc. (Eberhardt, 1974).

Selinger (1980) has developed an algorithm for planning the construction process of linear projects like tunnels. The method based on the labour requirement and feasible crew size rather than on activity durations determined in advance, allows for continuity between activities and so is more suitable for the practical needs of a linear construction site.

The services essential for rapid tunnel construction include provision of ventilation, compressed air, lighting, water supply, electric supply, drainage and dewatering; fire protection, signalling system, communication and measures for dust control (Badarinath, 1988).

Among the innovations emerging in tunnel excavation are NATM (New Austrian Tunnelling Method), steel fibre reinforced shotcrete, both of which may replace steel supports sets and TBM (Tunnel Boring Machines). Though NATM is being used on Indian tunnels in a very limited way, the TBM was used to drive only one tunnel and it may not be employed in this country for some years due to its exhorbitant cost.

2.26. CRITICAL PATH METHOD OF PLANNING

While the use of CPM was a contractual requirement on Bay Area Rapid Transit (BART), many instances were evident that this useful tool was not being effectively used to develop its full potential. Experienced personnel using proven management techniques and operating under favourable contract conditions produced excellent results for both owner and contractor (Hammond and Bertelsen, 1972).

The velocity diagram as a construction management tool is used in Germany and is popular. It is particularly suited to linear construction sites especially tunnels. It is not too well known in US. The bar chart is still the most commonly applied tool to plan and control construction operations in Germany despite its drawbacks. Even very complex projects are managed successfully using just the bar chart for time control if the organizational environment has been defined accordingly (Dressler, 1980).

In Japan, though advanced computer drawn CPM diagrams and other techniques are available, the field engineers use the same types of hand made bar charts, and tabular weekly schedules (Paulson and Akit, 1980).

2.27. SYSTEM ENGINEERING AND ANALYSIS SECTION (SEAS)

Through systems engineering methods, the required reliability, maintainability, dependability and safety performance for the major systems involved have been spelled out clearly by Barnes and Leiser (1981).

The management structure for the South California Rapid Transit District project incorporated a System Engineering and

Analysis Section which provided system wide criteria, coordination between the design divisions and assured the compatibility and most efficient interrelationship between all of the subsystems making up the project (Gallagher and McFarland, 1981).

2.28. SELECTION OF PLANT AND EQUIPMENT

An economic service life of construction equipment considers

(1) mathematical models,

(2) certain factors and their effects,

(3) particular kinds of equipment, and

(4) methods used by contracting firms in determining economic service life.

The model proposed by Douglas (1975) is widely considered as most appropriate for finding the economic service life of construction equipment as it covers all factors:

(1) time value of money,

(2) inflation,

(3) future development as reflected in higher productivity, and therefore increased revenue, lower operation and maintenance costs, and higher prices,

(4) effect of equipment ageing on productivity, revenue and operation and maintenance costs,

(5) downtime, and

(6) taxation.

The economic service life is gotten by finding the replacement cycle maximising the present value of the profits to an infinite horizon (Selinger, 1983).

Selection of tunnelling equipment for Indian projects has been presented (Badarinath, 1988). The size and type of equipment selected for the actual driving operation, their rates of production and other essential services are included. The production figures are lesser than the rates claimed and quoted by the equipment manufacturers.

2.29. EQUIPMENT AVAILABILITY AND PREVENTIVE MAINTENANCE

The maintenance of heavy construction equipment is a vital function for many construction contractors. A regular, structured preventive maintenance program results in

(1) reduced field breakdowns,

(2) more efficient equipment and operator utilisation,

(3) elimination of unnecessary parts damage,

(4) reductions in inventory requirements,

(5) more productive mechanics, and

(6) longer-lasting repairs.

The benefits and reasons for using a well defined project management program have been found to

(1) reduce unscheduled equipment downtime,

(2) increase on-shift, and overall equipment availability,

(3) increase shop and mechanic efficiency and quality,

(4) pinpoint machine deficiencies and initiate improvement,

(5) facilitate warranty requests from a manufacturer,

(6) aid new equipment selection and specifications, and

(7) improve predictability of inventory demand requirements (Ibbs and Terveer, 1984).

Katoch (1974) has provided check lists for the preventive maintenance of tunnelling equipment which ensures greater availability of the equipment and consequently higher production.

2.30. ENVIRONMENTAL CONDITIONS AND HOUSE KEEPING

The most properly designed and environmentally sound project may have severe effects once construction begins, if protection of the environment is not a major concern of the construction management engineer. Not only is environmental planning before and during the design stages necessary to insure that adequate protective measures are incorporated in the plans and specifications, it must continue during construction. (Spivey, 1974).

Essential services for rapid tunnel construction (Badarinath, 1986) and monitoring and control of the environment during tunnel construction have been discussed by Badarinath and Varma (1987).

2.31. RISK

Carr (1977) demonstrated the effect of views of the owner and the contractor of the risk involved in a project and the financial attitudes of different owners and contractors upon the price each would pay to avoid an uncertainty in the final cost of the project.

Diekmann et al (1982) have suggested a procedure to analyse contractor risk in unit price contracts. It requires only that the item quantities be described by estimates of their variance in addition to their expected values. The procedure then generates a complete description of risk in terms of the probability distribution of the present worth of profit for different pseudo-optimal sets of unit prices.

Ahuja and Arunachalam (1984) have proposed a Risk Evaluation Model (REM) to systematically evaluate the uncertainty of resource availability and generate several alternatives having varying project completion time, completion cost and performance probability. REM may aid a contractor in "bid/no bid", decision making, an enterpreneur in investment decision making, and a consultancy organisation in corporate planning.

Kadkade (1986) discussed the management of risks and losses as viewed by a contractor.

2.32. SHARING OF RISKS

Sharing of risks between the various parties involved in underground work has been a topic for engineers and researchers for last one decade. The sharing of risks for differing site conditions particularly in underground construction has received considerable attention over the years.

Hammond (1979) has identified a number of specific actions to minimise risks.

Sharing of risks is an important aspect of owner-engineer-contractor relationships because when a risk is shared, all parties have an incentive to minimise it (Sutcliffe, 1972).

While planning underground construction operations, the owner should consider besides -- local conditions, construction methods, labour, equipment availability, personnel, wage increase, material and equipment cost, finance and schedules -- the risks involved in the construction. Known and unknown risk exposures are difficult factors to determine and evaluate. However, an attempt should be made to forecast such risks and make provisions in time, cost, personnel and equipment contingencies or other allowances (Eberhardt, 1974).

It is not enough simply to do a so-called "good job" in producing design, construction or equipment. To produce good results the project must be done with reasonable concurrence of all parties concerned, and they must all be constantly involved on an intelligently informed basis. The needs of society, and the attendant difficulties and risks involved in fulfilling these needs, are indeed great, so too are the benefits to be realised. There is a need for sharing of risks on large projects which are subject to risks of a nature and magnitude unknown in the past (Everson, 1978).

The interests of the construction industry would be well served if more attention were directed to creating a construction team comprising owners, engineers, contractors and insurers each contributing his special expertise to common problems and each bearing risks relating to his capabilities. The scramble to avoid risks by throwing them back and forth has in too many instances made the construction scene a battlefield for lawyers, rather than an opportunity to accomplish useful and lasting works. Among the most important and most difficult to define factors in evaluating and allocating risk are the reputations of the parties to the contract. The interests of the construction industry would be well served if more attention were directed to creating a construction team composed of owners, engineers, contractors and insurers, each contributing his special expertise to common problems in underground construction and each sharing risks related to his capabilities (Kuesel, 1979).

Contract types and clauses concerning changed conditions, variations in quantities, extension of contract time, liquidated damages and timely resolution of disputes, and cost escalation due to inflation are a beginning in the incorporation of risk sharing in contractual arrangements for construction. All these measures of sharing the risks in construction help to mitigate against the time worn relationship between the owner and the contractor (Riggs, 1979).

A study conducted at MIT between September 1977 and August 1978, explored the cost implications of risks and their assessment to the various parties in transportation construction. To achieve this, the researchers sought to understand, interrelate, and quantify these risks (Levitt et al, 1980).

The subject of risk involves responsibility, liability and accountability. Risks in construction work stem from three basic factors -- safety,time and cost, with the first two impacting on the last -- cost. The basic principle of risk relationships is that the party taking the risk should assume the liability and either suffer the consequences or reap the benefits therefrom, depending on the outcome of the endeavour (Egbert, 1981).

The weighted average cost of capital is an appropriate approach when all projects have risks equal to the overall firm's risk. However, under varying conditions of risk the contractor, as also the owner, should have the concept of risk and return tradeoff for project selection decisions. A new procedure for selecting projects, called the market model approach (a modified form of the portfolio approach), which considers project selection under risk conditions has been developed (Kangari and Boyer, 1981).

Numerous mathematical decision models have been formulated in an attempt to analyse construction risk. Ibbs and Crandall (1982) have introduced a theory which facilitates analysis of complex decisions and selection of consistent courses of action. An illustrative decision problem is solved, not only to explain the mechanics of the theory, but to demonstrate that construction risk is a function of competitive economics as well as project related characteristics.

By thoughtful management, some risks involved with subsurface construction may be overcome, others reduced and still others shared in such a manner that their overall cost to the owner is minimised. When innovative methods, equipment, or materials are introduced, certain risks may increase to the point that advancement of the state-of-the-art is discouraged. In such cases, the owner, and society in general, may benefit from a reallocation of these risks. By recognising the various classes of risk and deliberately setting out to manage them effectively, the construction industry may optimise its service to the society (Mathews, 1974).

Large projects involving underground construction typically require enormous amounts of capital, especially where basic infrastructure is lacking and as much as 8 to 15 years to execute. Further, delays are universal and costly on these projects. High discount rates to allow for inflation reduce the return on long-life projects. Developmental programmes make it increasingly difficult in obtaining finances for execution of large projects. The hazards and uncertainties involved have lead to lesser number of superprojects actually being implemented. With proper allocation of the risks (Hull, 1978) and funding, it should be possible to execute superprojects.

Casey (1979) has identified the nature of risks involved in undergound construction projects as seen from the contractor's point of view. He has categorized construction risks under four groupings -- physical; capability; economic; and political and societal. The role played by the owner, the contractor and the engineer/designer in the project and the responsibility of each has been brought out. Owners need to understand that a fair contract with an equitable allocation of the risks according to the ability to assess and manage them has to ultimately serve the owner's benefit in lower costs and earlier completion dates.

2.33. WRAPUP INSURANCE

Barnes and Leiser (1981) expressed that wrapup insurance on MARTA contributed to a better coordinated safety program, attracted more contractors to bid the jobs, helped to obtain lower bids and have reduced claim and change order activity.

2.34. COORDINATED INSURANCE PROGRAM (CIP)

Ashley (1980c) focussed attention on CIP, programs characterised by project owner, purchase and mutual sharing of insurance deductibles and their applicability to major construction projects. He also presents a summary example that highlights the major factors influencing insurance decisions and a risk analysis approach to program selection.

2.35. FINANCIAL MANAGEMENT

According to Hammond and Bertelsen (1972), providing substantial mobilisation payment provisions in the contract, the contractor's capital requirements reduce. Financial conditions conducive to more competitive bidding are thus established.

Reinschmidt and Frank (1976) have developed a cash flow management computer program which should be useful on all kinds of construction projects in which cash flow is a critical problem. The automatic scheduling against cash flow constraints provides answers to questions like what will be the effect on project duration and total cost if expenditures must be limited? The use of probability distribution on the cost estimates and activity durations allows project managers to assess the reliability of their projections and to estimate the likelihood of exceeding any given budget level. The program is not suitable for detailed construction scheduling/monitoring, but may be of assistance in project financial planning.

The owner must establish before inviting bids, a sound financial basis for the project and timely availability of all necessary financial and other resources for the prosecution of the tunnel contract (Singh et al, 1972).

The financing of underground works must be done on a sound footing and the engineer must play a leading role in insuring that the owner is aware of this. If a contractor knows that he may operate largely on the owner's money, the bid and overall cost to the owner is likely to be reduced. Contract provisions providing for early money for the contractor will attract more bids and save money for the owner (Sutcliffe, 1972).

Contractors on TARP were permitted to bid mobilisation costs and to receive early payment. Prompt progress payments made 15 calendar days after the contractor made the request enabled the tunnel to be completed slightly ahead of schedule and within award prices and with an excellent safety record (Niel and Dalton, 1981).

2.36. DATA MANAGEMENT SYSTEMS AND INFORMATION FLOW

A proper cost control system serves dual purpose as a management information system and a historical cost and production record for future estimating (Eberhardt, 1974).

The Industrial Construction Ministry, Romania has developed "PLU" - for scheduling start up and control of construction projects and "SICOP" (no expanded forms of the two words are available) to get superior results in construction by reducing project durations, making better use of resources, incrementing labour productivity and decrementing cost/price by means of overall management development (Halpin and Tutos, 1976).

Burger and Halpin (1977) discussed the help needed by managers in controlling information flow at the project level between the project personnel and interfacing groups and the new tools available for the management of information on large construction projects.

Data management systems to incorporate performance and production data all pertaining to construction equipment are tools for the management (Frein, 1980).

From a computer bank, the applicable contract specifications are selected and inapplicable provisions do not appear on MARTA (Barnes and Leiser, 1981).

Advances in data management and information flow could greatly enhance the coordination and efficiency of the entire construction process and increase the productivity (Moavenzadeh, 1985).

2.37. EXPERT SYSTEMS

Potential applications of expert systems in the area of construction project monitoring and control are described by McGartland and Hendrickson (1985).

Expert systems for risk analysis have been discussed by Kangari (1987).

A knowledge based expert system for conventional tunnelling has been developed by Chui (1988).

2.38. GAPS IN EXISTING KNOWLEDGE

From the foregoing review of the literature available in construction management and tunnel construction, there are some gaps in our existing knowledge. They are as follows:

1. The management factors that influence tunnel advance rates in India and how they affect tunnels of different lengths and varying site conditions need to be studied,

2. The relative importance of management factors on tunnelling rates in India need to be understood,

3. An expert system for sharing of risks in underground construction, especially tunnels is not available,

4. No guide lines are available for energy management,

5. No reports are available on management consultancy in tunnelling,

6. Causes of failure to achieve projected targets, particularly, in tunnels in the Himalayan region have not been documented,

7. An urgent need exists to update technology of tunnelling in India,

8. No guidelines are available to suggest a reasonable amount of pre-bid investigations desirable, in the Himalayas, which are noted for their geological complexities,

9. The type of contract best suited to all circumstances of a tunnelling project needs to be identified,

10. Documentation of causes of delays, type and duration of delays, phase of project in which delays occurred, is needed with recommendations for prevention of delays,

11. Actions to be considered by owners in an attempt to increase efficiency and productivity of underground construction projects need to be reported,

12. Factors favouring management of planning, design and construction by a single contractor (as opposed to separate firms for design and construction management) need to be studied,

13. Suggestions to increase productivity of team members on a tunnel project (owners, design engineers, contractors, construction managers, and construction employees) need to be reported,

14. Organisation structure for long and short tunnels needs to be examined,

15. Suggest improvements in contracting practices which are expected to have a strong influence on decisions affecting tunnel construction,

16. A satisfactory procedure for sharing inflationary effects needs to be evolved,

17. The extent of disclosures of subsurface information for prospective bidders needs to be studied, and

18. The acquisition of data and their availability after completion of the project should be ensured.

Of the various grey areas existing in our present knowledge, the following three areas have been covered in this study,

(1) The management factors that influence tunnel advance rates and how they affect tunnels of different lengths and varying site conditions in India,

(2) The relative importance of management factors in tunnelling rates in different site conditions in India, and

(3) The development of an expert system for sharing of risks in underground construction, especially tunnels.

CHAPTER 3

MANAGEMENT CONDITIONS SIGNIFICANT IN TUNNEL CONSTRUCTION

3.1. CONSTRUCTION MANAGEMENT

Management aspect in tunnelling has not received its due attention in the past in India. The inevitable time and cost overruns are because tunnel construction takes place in sensitive environment and underground works require special equipment, techniques and skills. Thus, tunnels are particularly sensitive to management practices.

3.2. BETTER MANAGEMENT PROCEDURES

Management problems arise in each phase of a project and some persist from the start to the end of its implementation.

Better management procedures and practices applied by agencies responsible for underground projects may resist increases in cost and serious delays in achieving schedules. Thus, in 1976, three federal agencies in USA requested the National Research Council to study how the management of such projects could be improved. The US National Committee on Tunnelling Technology under the National Academy of Sciences was, thus, formed. The sub-committee on management of underground construction projects, a wing of the above Committee, developed a study procedure for examining all aspects of management in underground construction.

During the study, 39 critical problems likely in construction management of tunnel projects were identified. The sub-committee concluded that:

(1) the management problems in tunnelling are similar to those met in other projects but have some additional, specific characteristics;

(2) the characteristics of tunnel projects vary due to depth below ground level, geology and the size of the structure; and

These management factors have been discussed by Badarinath, Varma and Singh (1988). Delays in tunnel construction may be attributed to the geological conditions prevailing. When the rock is good, a steady progress may be maintained. If, however, the rock stratum is poor, it calls for constant vigilance. Once a tunnel alignment has been selected, the rock formations have come to stay.

Table 3.1 gives the tunnelling rates in India for tunnels of different sizes (Badarinath, 1988).

Table 3.1 Tunnel excavation rates in India

Name of tunnel	Diameter (m)	Rate of advance (m/day)	
		Average	Maximum
1. Beas	10.67 (e)	1.95	3.46
2. Bhadra	4.39 (f)	4.60	N.A.
3. Giri	3.66 (f)	3.00	N.A.
4. Ichari-Chibro	7.00 (f)	Shaft end: 1.50	3.24
		Adit end: 2.00	4.96
5. Koyna HRT	6.90 (e)	4.16	4.40
6. Koyna TRT	8.50 (e)	3.16	4.64
7. Lakhwar	5.00 (e)	1.68	2.52
8. Loktak	4.70 (e)	1.80	2.48
9. Malabar Hill	3.50 (f)	with TBM 2.40/hr	16.68
10. Pandoh-Baggi	9.14 (e)	2.96	4.40
11. Tungabhadra	6.70 (e)	2.13	4.00
12. Uhl	3.70 (e)	1.65	4.36

Note: (f) = finished, (e) = excavated, N.A. = not available.

It may be observed that the tunnelling rates are much less than what has been achieved on tunnels of similar size in other countries. It is obvious that tunnelling rates ought to be improved if the vast hydroelectric potential in India is to be harnessed for overall economic development. The answer is to improve the management conditions. If the management conditions are improved and well maintained, good advance rates could still be achieved inspite of adverse geology. In such situations management consultants with long experience working in similar tunnels should be consulted.

The factors are discussed in the following paragraphs.

3.4. JOB PLANNING

Long tunnel projects require more than two working faces which are provided by shafts and adits. Adits are preferable to shafts for providing facilities and attaining overall speed and economy. Job layout of essential services like compressed air, water, electric power, etc. is important and must be well thought out in order to reduce the losses. Field workshops for grinding of drill bits, greasing and lubricating the rock drills, repair facilities, etc. should be located near to the tunnel portal to save on the travel time for the maintenance staff.

3.5. SELECTION OF PLANT AND EQUIPMENT

Plant and equipment of adequate size and number should be selected on the basis of magnitude of work, number of headings and planned achievements. A choice has to be made between a fewer number of larger capacity units with associated higher outputs and costs but greater delays from breakdowns, and a larger number of smaller units with lesser output and lower costs. Whether rail or rubber tyred haul equipment is to be adopted depends on length, size, grade and method of construction of tunnel. Double tracks or lanes are generally preferred. Heavy rails should be used to avert derailments and loss of time.

Light and hand held rock drills with pusher legs are easy to handle and manoeuvre though slow, but heavy drills mounted on ladders are not easy to operate though faster in working.

3.6. EQUIPMENT AVAILABILITY AND PREVENTIVE MAINTENANCE

Compressed air for pneumatic equipment should be supplied at the optimal pressure at the delivery end. Pressure drops should be avoided by preventing air leakage at the joints. In the case of electrically operated equipment the required voltage should be adequate. If there is considerable voltage drop stepup transformers have to be installed at appropriate places inside the tunnel in case the tunnel is deep inside the rock or transformers placed on the surface with cables led through intermediate shafts along the alignment in shallow tunnels. Minimum breakdown times lead to high availability of equipment so essential for steady and sustained progress. A regular preventive maintenance schedule should be followed.

3.7. ENERGY MANAGEMENT

Construction power from the grid is never totally reliable. Diesel power to supplement the grid supply should be arranged. Optimum utilisation from both sources is essential. Sufficient buffer stocks of petroleum products - petrol and diesel - must be available to avert wild-cat strikes by the suppliers. The head race tunnel of the Lakhwar-Vyasi Hydroelectric project in U.P. is facing many problems for want of sufficient quantities of diesel and petrol for the transport of supervisory staff. Haul vehicles which depend on diesel are the worst affected. Even though the project is owned by the government an assured supply of diesel has not been maintained.

3.8. OPERATION SUPERVISION

Frequent inspection by a senior owner's engineer would motivate the supervisory staff and the contractor. Daily inspection of the tunnel face by the site engineer would have an effect similar to the above. The assistant engineer and the geologist must remain mostly at the tunnel face to tackle day to day problems and ensure steady progress. Supervision of drilling and blasting operations avoids rock overbreaks and secondary blasting, leading to greater economy in construction and lesser delays. Rapid exchange of muck cars at the loader improves loading and hauling operations which results from proper supervision. Other operations requiring supervision are scaling, marking profile and drill holes for improved tunnel driving rates. Prompt attention to non-essential delays due to mechanical, electric supply or electric machinery failures, derailments and tunnel maintenance improves tunnelling rates.

3.9. ORGANISATION STRUCTURE

An established organisation with experienced people would be able to handle problems as they arise. Newly recruited engineers should be included in such organisations so that they may be trained for future projects. Selection and placement of new recruits is necessary for improving the construction speed.Good but firm leadership characterised by fairness, impartiality, concern for employee welfare, open communications, giving credit to employees' efforts to improve working would result in higher progress. Clear lines of authority and communication need to be established within the organisation. Responsibility should be delegated to the lowest possible implementing level to render the individual answerable to delays and loss of production. Lack of communication, both vertical and lateral, hinders conveyance of information on critical problems and their solution. Communication gap between senior and junior officers and workers results in lack of exchange of information and lower progress. Orders should be communicated in full detail so that ambiguity in understanding of orders is eliminated. A strong leadership in the management team must develop a definite program to maintain high morale and a sense of commitment to success in all the members. Determination in top manager would develop a sense of responsibility in all his team mates. One competent assistant engineer in charge of the tunnel heading would help in achieving greater progress due to his personal involvement and repose of confidence in his capability indicated through assigning to him added responsibilities on the project.

3.10. COORDINATION

Coordination of all tunnelling activities is very important because of the limited construction space at the tunnel face. Lack of communication and coordination leads to delays. The use of networks is useful, especially in coordination and procurement of construction material.

Civil, mechanical and electrical wings under one single authority mean greater coordination while quality control section under another division independent of construction wing ensure good workmanship.

3.11. SINCERITY AND PUNCTUALITY OF STAFF

Prompt shift change-over at the heading improves progress. Some essential delays such as extension of tracks and services, surveys, etc., are times when the workers who are not directly involved in such activities may take rest and resume their work promptly after the other teams have done their job.

3.12. TRAINING OF PERSONNEL

Management implies training. Training of supervisory staff under senior engineers would acquaint them with management problems and how to resolve them. A continual process of training tests a person before he gets a top job. Training of drillers in proper holding, alignment and thrust will reduce drilling time. Training in charging holes would avoid delays, misfires and accidents. Likewise, training of mucker operator, and training of the crew for setting ribs or rock bolts or for spraying shotcrete would reduce cycle times. The maintenance crew should be trained to repair/lubricate the various parts of the equipment to improve equipment availability and efficiency on the construction job.

3.13. INCENTIVES TO WORKMEN

Peck has stated: "If you want to bring about a change, make sure it is profitable". This applies to tunnel construction as well. The physical dangers, the confined space and the working atmosphere all require to be compensated in some way to the workmen if a steady rate of progress is to be maintained. Incentives, either rewarding or punitive, improve progress and the quality of work on construction. Public groups against the project would show less apathy if equal employment opportunity is given to the minorities and local populace or communities.

Workers should be given bonus in direct proportion to the effort applied, the earnings of which should not be limited in any way. Bonus schemes may lead to substandard work, hence penalties should be included and enforced. A progress bonus slab may be offered for every additional driven length achieved per month (say 5 m or so). Incentive bonus may be given for rib erection, rock bolting, etc., that involve special skill and risks. A performance bonus for attaining annual target benefiting all classes of work force would induce the workmen to do better.

In India no work seems to get going without giving the workers a bonus. If the same rate of bonus is maintained for a long time then lethargy sets in and a higher rate of bonus has to be introduced to keep up the same rate of progress, let alone increase the productivity.

3.14. MATERIAL MANAGEMENT

A central agency may maintain a proper inventory and schedule of procurement and achieve saving in time. Items fabricated by the contractor himself would greatly reduce construction delays.

3.15. FINANCIAL MANAGEMENT

Timely release of funds by the government would serve as a morale booster for the contractor. Delay in running payments to the contractor affects the workmen which certainly tells upon their efficiency. This has been observed in the head race tunnel of the Lakhwar-Vyasi project, currently under construction. Since the government funds are not being released in a regular and sufficient manner the contractor has even removed his equipment from the work site. This is certainly going to delay the project.

The project budget must be realistic, it must establish attainable goals and must be adhered to. Controls imposed by funding agencies should relate only to the type and amount of support subject only to audit reviews for eligible use of funds. Strict control of project expenditures is an inherent obligation of the project management team which should have the determination to use and control them.

3.16. RAPPORT

Rapport between the owner and the contractor would reduce the adversary relationship and increase progress. Team spirit within the crew upholds their morale resulting in far more positive and productive actions than achieved by individuals. Team spirit is very much lacking in India in government departments because of lack of mixing of top executives among junior staff and workers and a rigid heirarchy. Very few top officers associate themselves with the subordinates and their problems.

Rapport between top managers and shift engineers helps in drawing achievable schedules. If the top authority maintains proper human relations it will result in the desired progress and achievement of targets.

The fear of retrenchment in the beginning forces the workers to work well but the same fear at the end of the project reduces their output with the hope that they will be retained longer. Project labour agreements would ensure continuity and avoid labour disputes.

3.17. ENVIRONMENTAL CONDITIONS AND HOUSEKEEPING

Fans at the portal and boosters should maintain proper ventilation and environmental conditions. Proper ventilation with extra air thrown onto the face would reduce the inside temperature and help maintain progress of work.

Adequate lighting at the work spots and general lighting in other portions of the tunnel is needed for speed and safety.

Special dewatering arrangements should be provided and maintained especially when the tunnel is going downgrade from the portal and at places of excessive seepage. Due to the failure of the dewatering pumps, the approach adit to the Kalawar inspection gallery of Yamuna Hydel Scheme Stage II, Part II got flooded and some tunnelling equipment got buried in the slush resulting in considerable loss of time in salvaging the equipment before regular operations could be resumed.

Safety gear, such as, helmets, gloves, gumboots, torches, etc. should be given to all workmen and their use made mandatory. In this country the workmen pay scant attention to proper dress on the work site. Unless an accident occurs, no workman likes to wear the safety apparel issued to him.

Job cleanliness and proper housekeeping is necessary because of the confined space in which workers are employed. The tunnels, in India, are usually congested and repeated instructions are required to keep the work place neat and tidy.

3.18. HEALTH AND SAFETY IN WORK

Underground traffic should be properly regulated to ensure smooth movement of vehicles and thus avoid accidents. The Bureau of Indian Standards and ITA have prepared codes and safety regulations which ought to be followed in underground construction.

Dry drilling of rock leads to silicosis because of inhalation of rock dust. Therefore, wet drilling should invariably be adopted.

Electrical installations should be properly guarded against fire and electrocution, both of which are detrimental to tunnel driving.

Vibrations in mechanical equipment cause headaches and high frequency vibrations are reported to be the cause of partial paralysis. Frequent tightening of bolts on machines should be carried out as a matter of regular maintenance to prevent loosening and vibrations.

3.19. SHARING OF RISKS

The owner/department being the bigger partner, it should share maximum risk on a construction project. However, equitable sharing of risks would be most desirable on any project. Tunnelling experts in India have given a low priority to this aspect of construction management. The ITA has given recommendations for contractual sharing of risks in underground construction. These recommendations should be adopted on Indian tunnelling projects.

Equitable sharing of risks means that the party bearing a greater part of the risk should be entitled to a greater share of the benefits or profits and the other parties should have no objection to it. If the sharing of risks is not equitable then there would be an imbalance between the risks actually borne and the profits made by the parties which may lead to disputes or litigation and consequently to delays and a higher project cost.

By including a clause covering adjustment in unit price for unknown conditions, the contractor is not tempted to escalate his item rates to cover the risk of adverse underground conditions.

Full disclosure to the tenderers of all subsurface data available with the owner/department will lead to lower contract cost.

Disclaimer clauses relieving the owner of responsibility for the accuracy of the underground data furnished should be deleted. If the disclaimer clauses cannot be eliminated completely from a contract at least their number should be reduced to minimize malpractices.

Departments should seek bids only from contractors having rigorous technical and financial prequalification. In the earlier projects constructed in this country this was unknown, but it has now been realised that prequalification of bidders is as much a part of the construction as selecting a suitable contractor. The practise of calling pre-qualification tenders by prospective bidders is being adopted in all new projects.

Authority to settle claims, commensurate with the scope of the project, should be delegated to both the representatives of the owner and of the contractors in the field.

The decision of whether to use wrapup insurance should remain with the owner.

3.20. MONITORING TUNNELLING ACTIVITIES

Project management should include a monitoring system which may see that action is taken in proper time to avoid problems. Monitoring and control of the environment is needed to avoid impairment of health due to abnormal and long exposures to foul and contaminated atmosphere. In the Loktak tunnel in Manipur, the presence of methane gas during excavation called for continuous monitoring of the tunnel atmosphere to prevent any accidents.

3.21. MISTAKES IN PLANNING AND CONSTRUCTION

Physical errors in marking alignment, drilling and blasting, etc. lead to time and cost overruns due to rework. Delayed decisions could lead to costly and undesirable effects on work progress. This was seen on the Chibro-Khodri tunnel where the decision to change the 9 m dia tunnel in the thrust zone to three tunnels of 3.6 m dia was taken at a later stage when the works on all the other components of the project were almost complete. This led to the delay in commissioning the project.

3.22. INSTRUMENTATION PROGRAMME

An instrumentation programme to probe strata in advance of tunnelling in poor rocks and to study the adequacy of supports would result in safety and economy. The owner's rock instrumentation monitoring data may supply data that may provide sufficient time to plan and remedy a potential structural problem. Instrumentation was carried out in the Chibro-Khodri tunnel of the Yamuna Hydel Scheme Stage II, Part II at the Kalawar heading to study the behaviour of the thrust zone that was lying along the tunnel alignment. Sufficient time was available to the owner to find a solution to the design of the tunnel lining before the main excavation could reach that section of the tunnel.

Instruments for monitoring rock stresses could be useful in designing future projects in a similar rock/soil structure.

3.23. DATA MANAGEMENT SYSTEMS

A cell in the management structure devoted to project control and management information system would help develop and maintain project budget and schedules and provide current and accurate information on project progress and other statistics.

3.24. OTHERS

Innovations and new technology should be encouraged through more imaginative contractual arrangements. In long tunnels a number of contracts should be awarded for different reaches and lengths to introduce an element of competition and encourage better performance.

The practice in US to mention the owner's estimated cost in the tender specifications should be adopted in India also. This leads to increased biddability inviting competitive tenders.

The incentive system "value engineering" should be adopted with the department and the contractor sharing the cost saving equally.

3.25. MANAGEMENT FACTORS AND THEIR IMPORTANCE

As a part of this study, it was found necessary to assess the relative importance of various management factors listed above. A form was prepared and circulated to a number of experts in tunnelling to rank the different factors. The form circulated has been given in Appendix A. When the list of factors was first drawn up only nineteen factors were listed and the respondees were requested to indicate/suggest additional factors not envisaged by the author. However, only the 19 factors originally listed were ranked by the respondees. While ranking the factors, the respondees were requested to assign them appropriate numbers or ranks in ascending order of importance, i.e., the least important factor was to be numbered as 1 and the most important as 20.

Tunnel construction was categorised under three headings:

A. Short tunnels ≤ 500 m,

B. Long tunnels in good or poor rock conditions, and

C. Long tunnels in very poor rock and environment conditions.

Table 3.2 shows the details of the responses received from persons involved in tunnel construction.

Table 3.2 Details of questionnaires sent and responses received

Experts representing	A	B	C
A. Questionnaire sent to			
1. Government agencies or departments	97	97	97
2. Contractors	12	12	12
Total	109	109	109
B. Responses received from			
1. Government agencies or departments	33	35	32
2. Contractors	5	5	5
Total	38	40	37
Responses as % of total mailed	35	37	34

The importance of the various management factors in tunnel construction by the respondees is given in Table 3.3. With the recent Gulf crisis, there has been a lot of pressure on oil in the international scene, and the crunch in this country has assumed formidable proportions overnight. Thus, another factor - energy management - has been included in the list of the 20 factors in this study and has been assigned the fourth position in the order of importance, quite arbitrarily, irrespective of the relative importance of the other factors.

The importance scores have been obtained by subjecting the responses received from the tunnelling experts to non parametric statistical tests to test the null hypothesis that all the responses fall within the same population. Of all the non parametric statistical methods available (Siegel and Castellan, 1988) the best method was the Wilcoxon Signed Rank Test which has a power efficiency of 95%. One set of responses in each of the three cases: A, B and C failed to satisfy the null hypothesis and so was rejected from the analysis to arrive at the final importance scores shown in Table 3.3 and depicted in Figs. 3.1, 3.2, and 3.3. From the table and the figures it may be noticed that the twenty management factors assume different importance

Table 3.3 - Management factors and their importance scores

Management Factor	Importance scores		
	Tunnel A	Tunnel B	Tunnel C
1. Job planning	19	19	20
2. Selection of plant and equipment	18	19	18
3. Energy management	17	17	17
4. Equipment availability and preventive maintenance	16	17	16
5. Operation supervision	14	13	14
6. Organisation structure	13	13	12
7. Coordination	13	12	12
8. Sincerity and punctuality of staff	12	11	11
9. Training of personnel	11	11	12
10. Incentives to workmen	10	10	10
11. Material management	10	10	9
12. Financial management	9	9	9
13. Rapport	9	9	8
14. Environmental conditions and house keeping	8	8	8
15. Health and safety	7	7	8
16. Sharing of risks	7	6	7
17. Monitoring of tunnelling activities	5	5	5
18. Mistakes in planning and construction	5	4	5
19. Instrumentation programme	4	4	6
20. Data management systems	3	2	2

scores in tunnels driven through different formations and tunnels of different lengths. There are ties between certain management factors denoting that they have the same importance score, relatively speaking. However, the order of the management factors

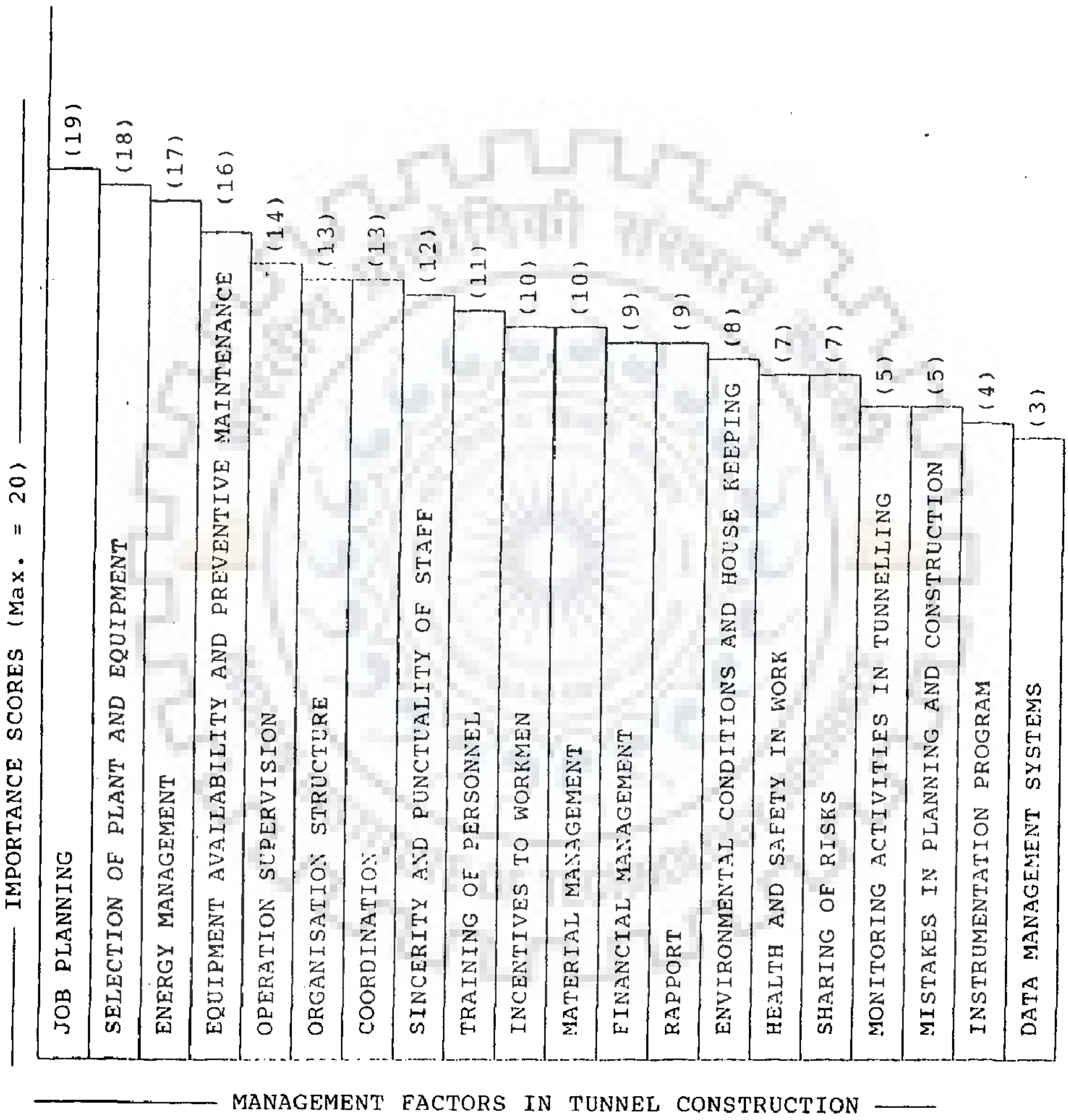


Fig. 3.1. Importance score of management factors in short tunnels ≤ 500 m according to responses of tunnelling experts.

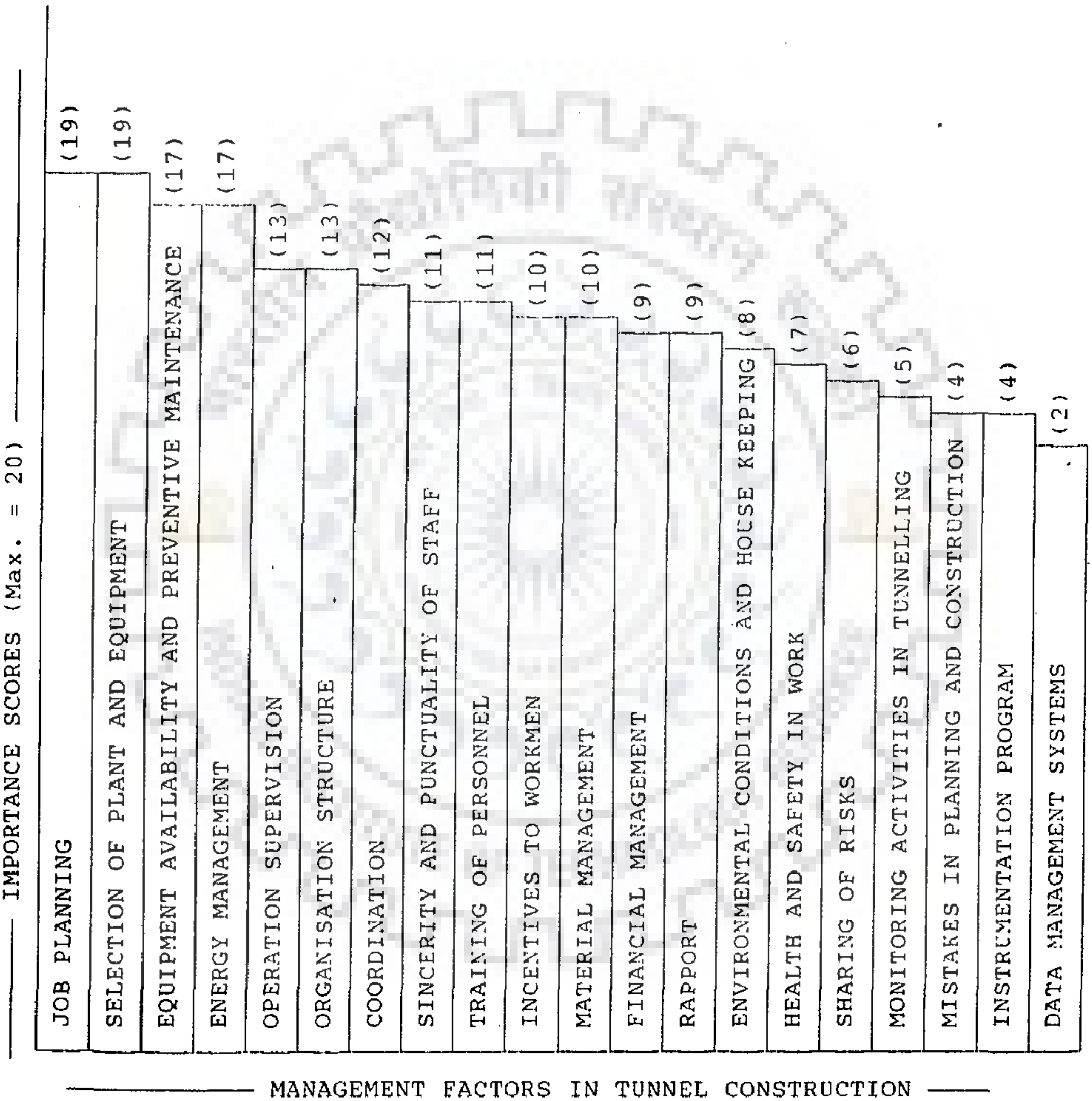


Fig. 3.2. Importance scores of management factors in long tunnels in good or poor rock conditions according to responses of tunnelling experts.

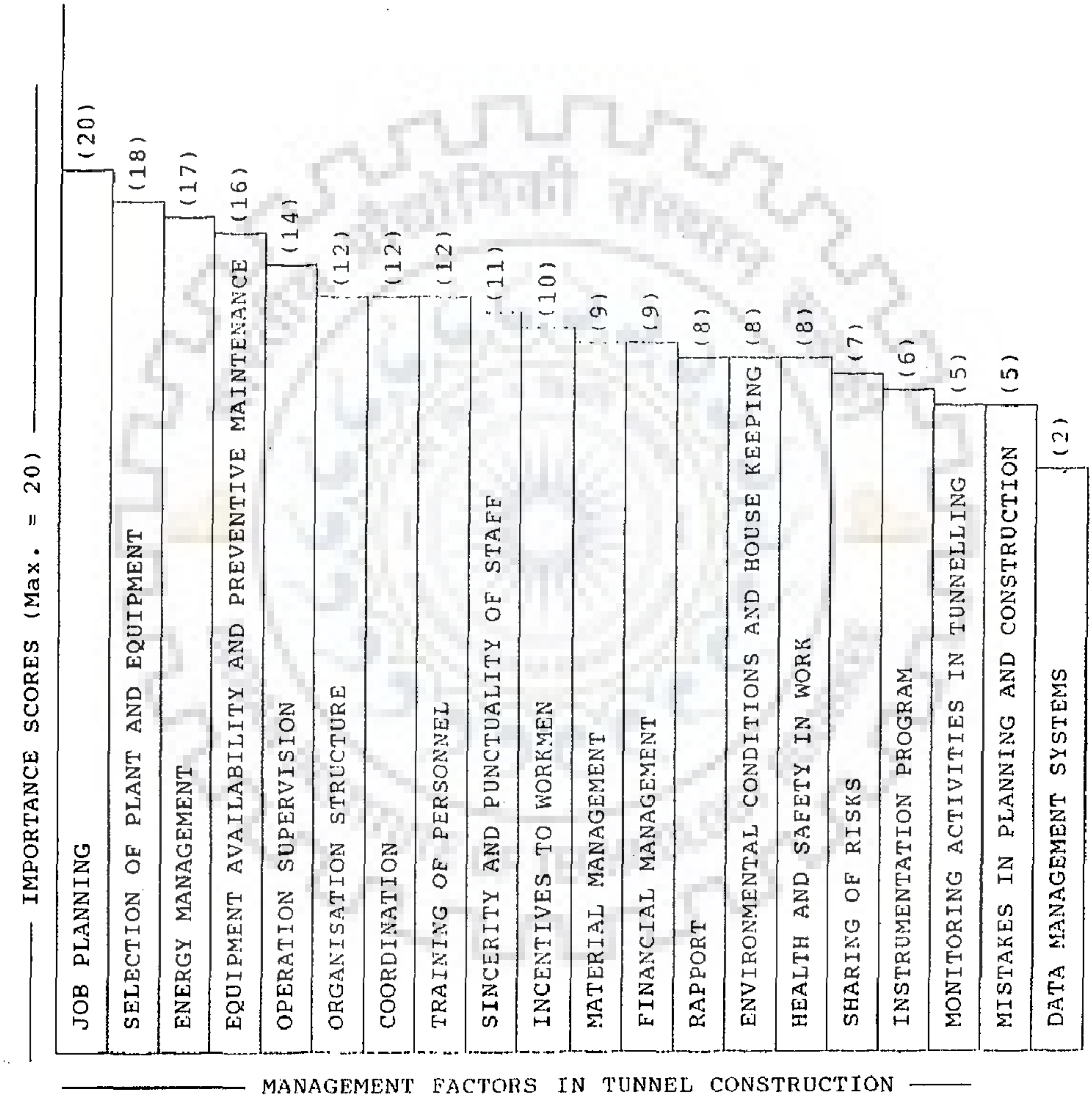


Fig.3.3. Importance scores of management factors in long tunnels in very poor rock or poor environmental conditions according to responses of tunnelling experts.

are different, though marginally, in the three cases of tunnels: A, B and C. It may be noticed that there is no importance score of 20 in tunnels A and B nor is the importance score equal to 1 in either of the three tunnels. This is due to the variations in the responses received and the analysis by Wilcoxon Signed Rank Test.

Figs. 3.1, 3.2 and 3.3 are the graphical representation of the importance scores of the management factors in India and shown in Table 3.3.

Figs. 3.4 through 3.22 show the histograms of the different management factors and the importance scores of the various management factors from the responses of the tunnelling experts. The figures are listed in Table 3.4.

Table 3.4 - Histograms of responses

No.	Figure	Details
1.	3.4	Histogram of job planning (H-1)
2.	3.5	Histogram of selection of plant and equipment (H-2)
3.	3.6	Histogram of equipment availability and preventive maintenance (H-3)
4.	3.7	Histogram of operation supervision (H-4)
5.	3.8	Histogram of organisation structure (H-5)
6.	3.9	Histogram of co-ordination (H-6)
7.	3.10	Histogram of sincerity and punctuality of staff (H-7)
8.	3.11	Histogram of training of personnel (H-8)
9.	3.12	Histogram of incentives to workmen (H-9)
10.	3.13	Histogram of material management (H-10)
11.	3.14	Histogram of financial management (H-11)
12.	3.15	Histogram of rapport (H-12)
13.	3.16	Histogram of environmental conditions and house keeping (H-13)
14.	3.17	Histogram of health and safety in work (H-14)
15.	3.18	Histogram of sharing of risks (H-15)
16.	3.19	Histogram of monitoring of activities in tunnelling (H-16)
17.	3.20	Histogram of mistakes in planning and construction (H-17)
18.	3.21	Histogram of instrumentation programme (H-18)
19.	3.22	Histogram of data management systems (H-19)

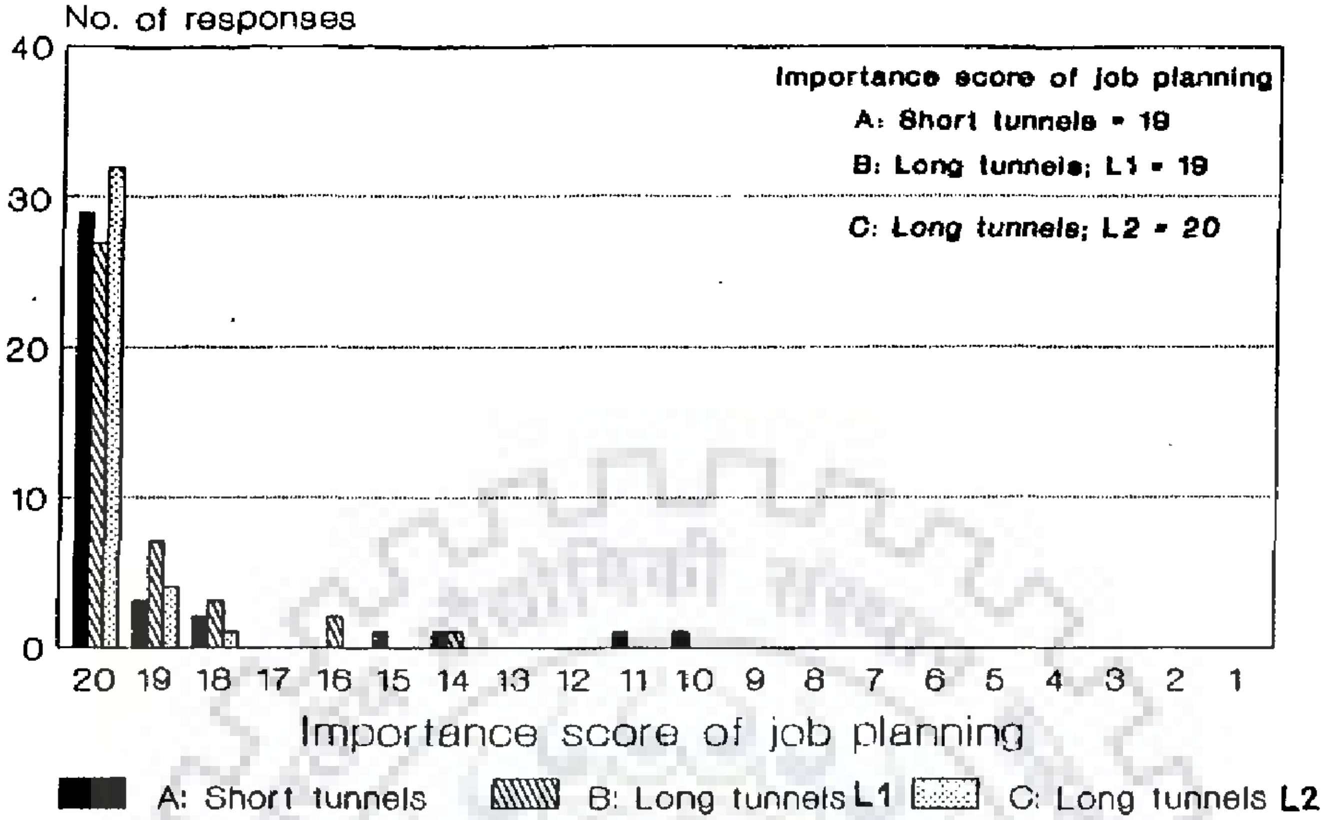


Fig. 3.4. Histogram of job planning.

H - 2

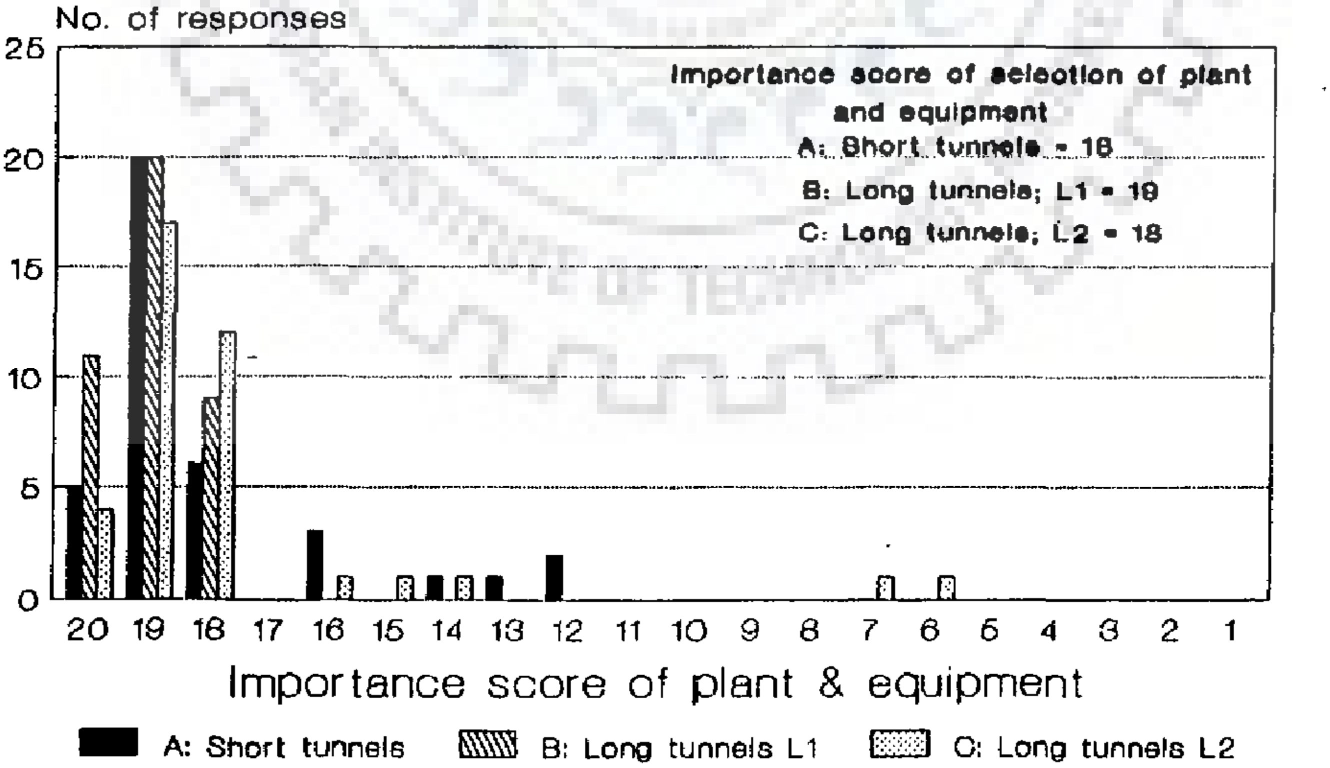


Fig. 3.5. Histogram of selection of plant and equipment.

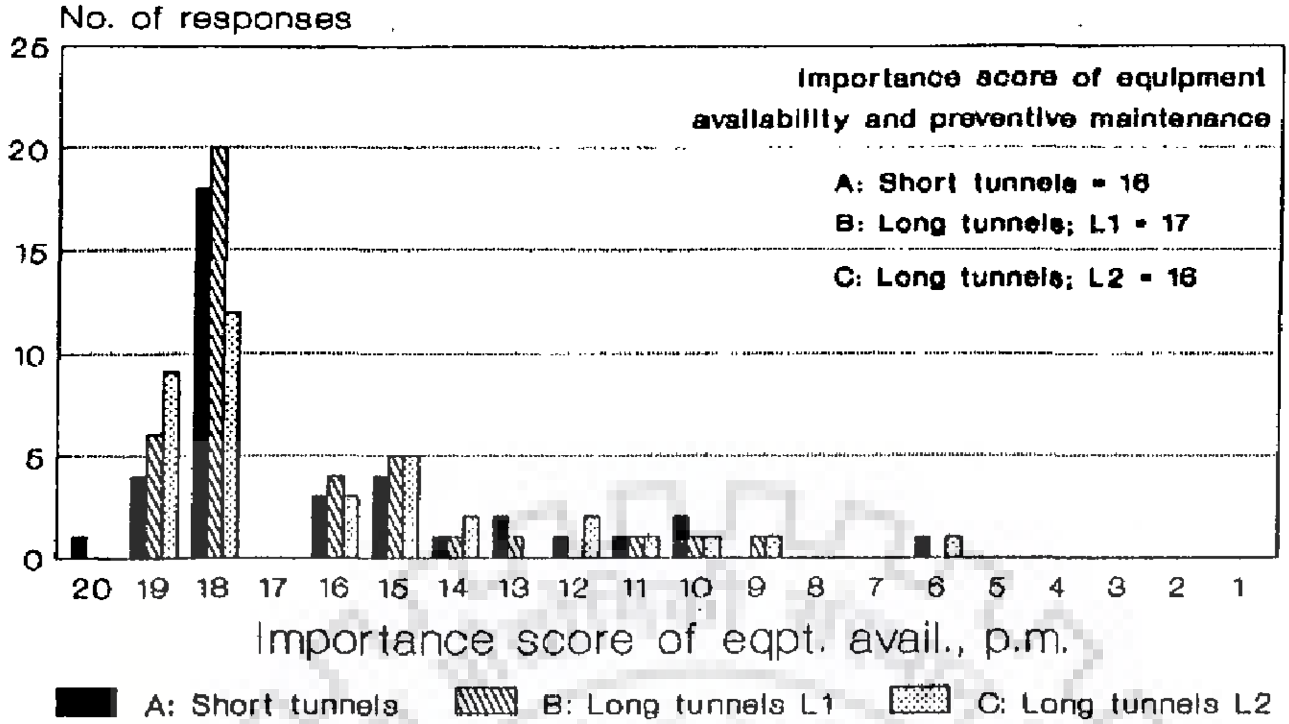


Fig.3.6. Histogram of equipment availability and preventive maintenance.

H - 4

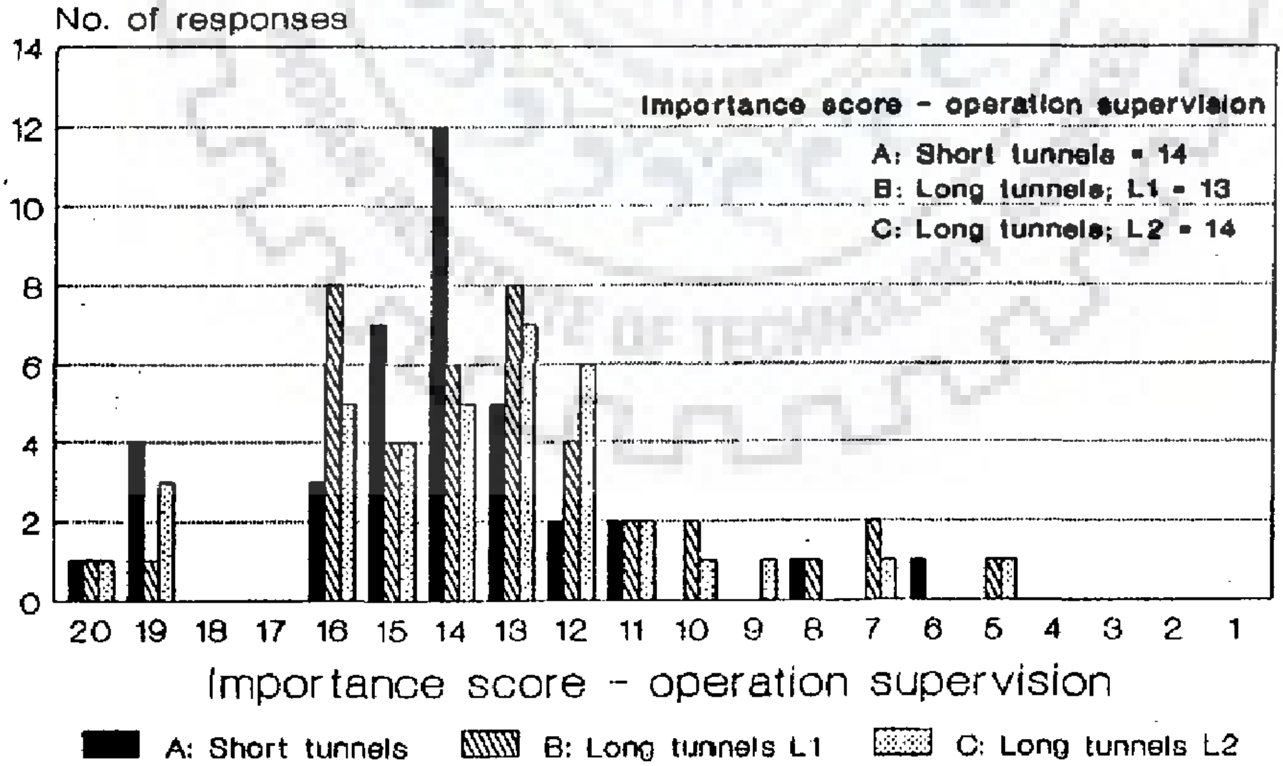


Fig. 3.7. Histogram of operation supervision.

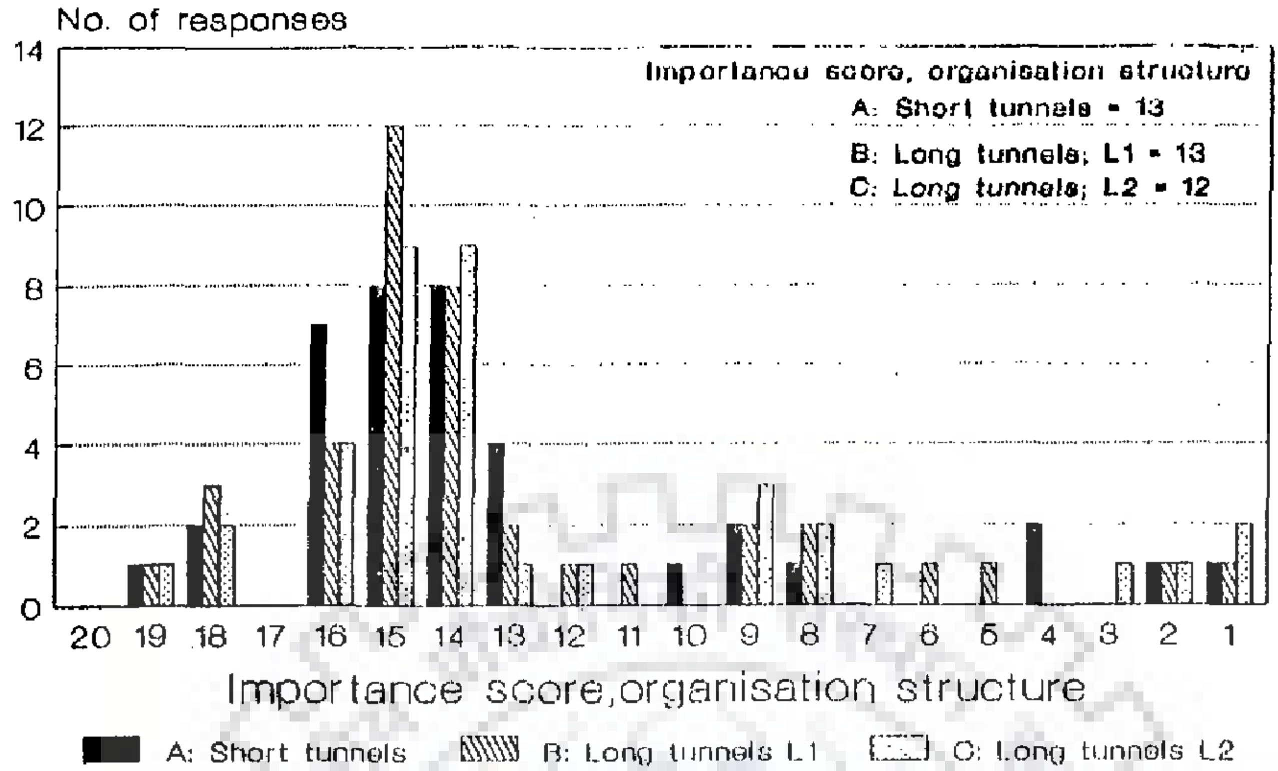


Fig. 3.8. Histogram of organisation structure.

H - 6

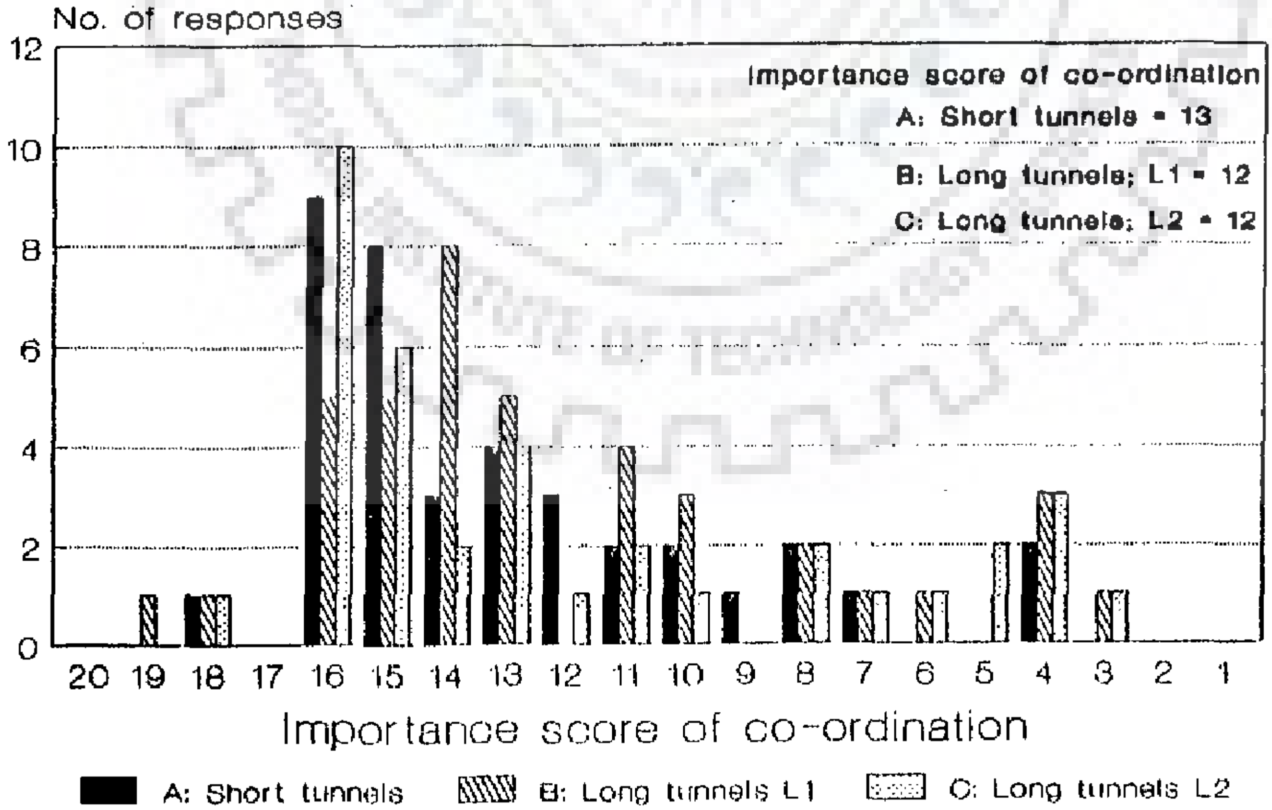


Fig. 3.9. Histogram of co-ordination.

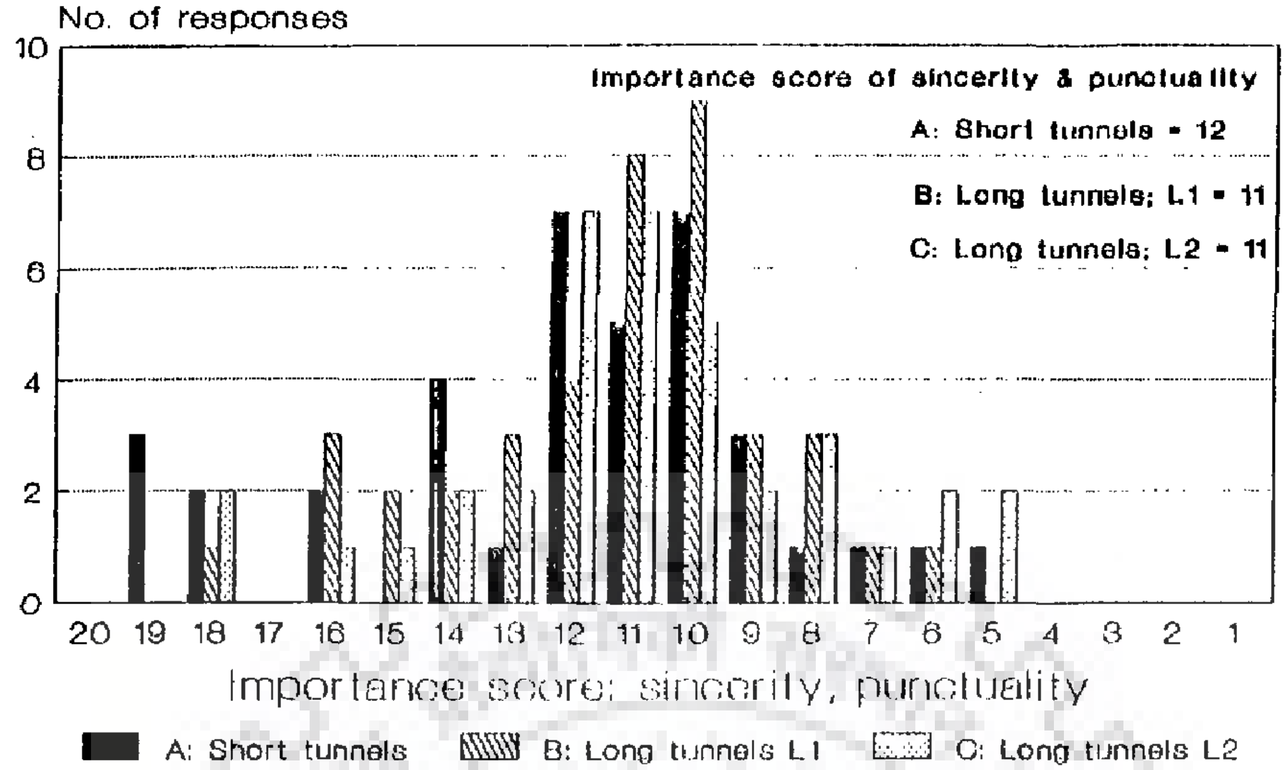


Fig. 3.10. Histogram of sincerity and punctuality of staff.

H - 8

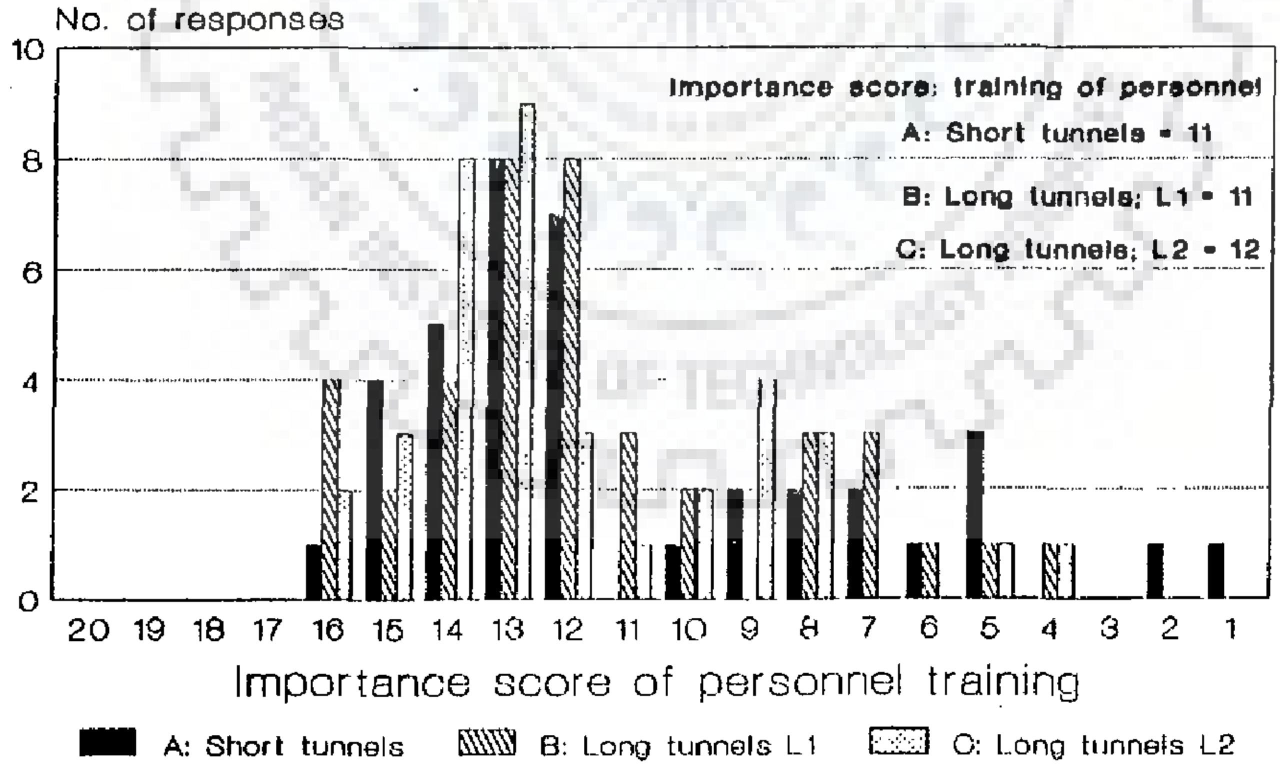


Fig. 3.11. Histogram of training of personnel.

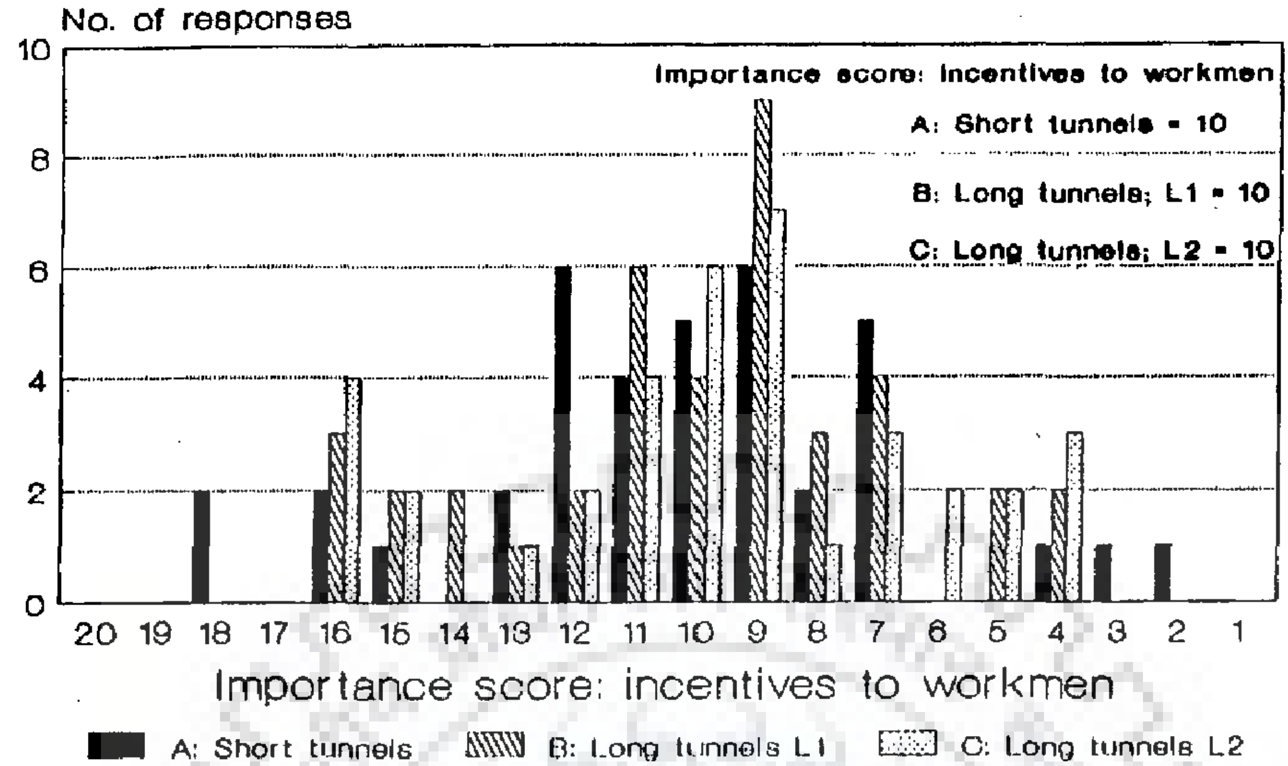


Fig. 3.12. Histogram of incentives to workmen.

H - 10

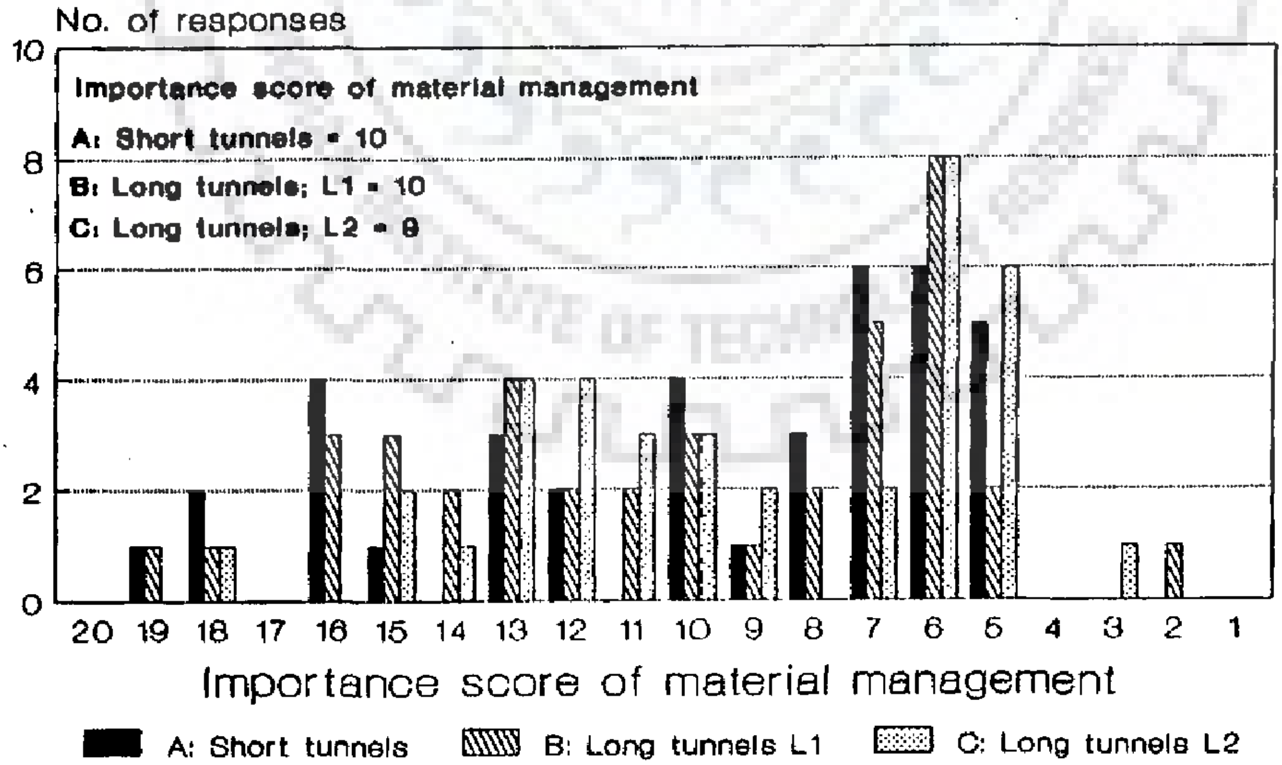


Fig. 3.13. Histogram of material management.

H - 11

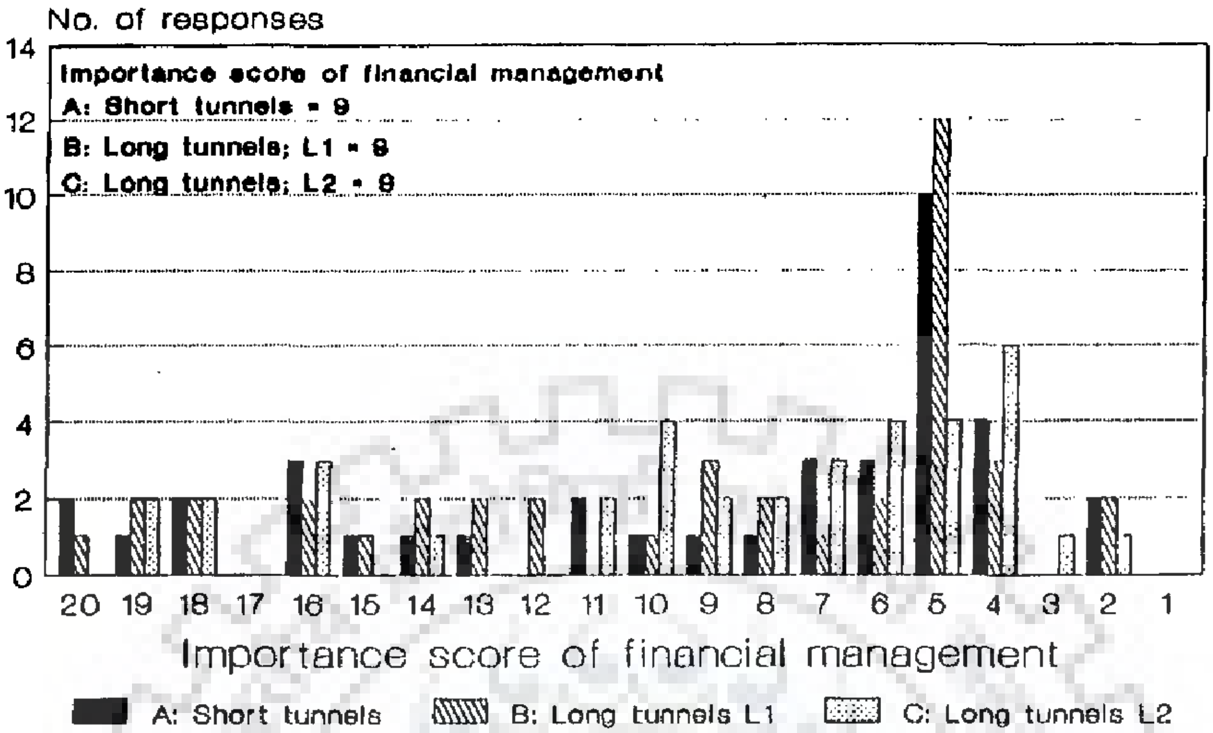


Fig. 3.14. Histogram of financial management.

H - 12

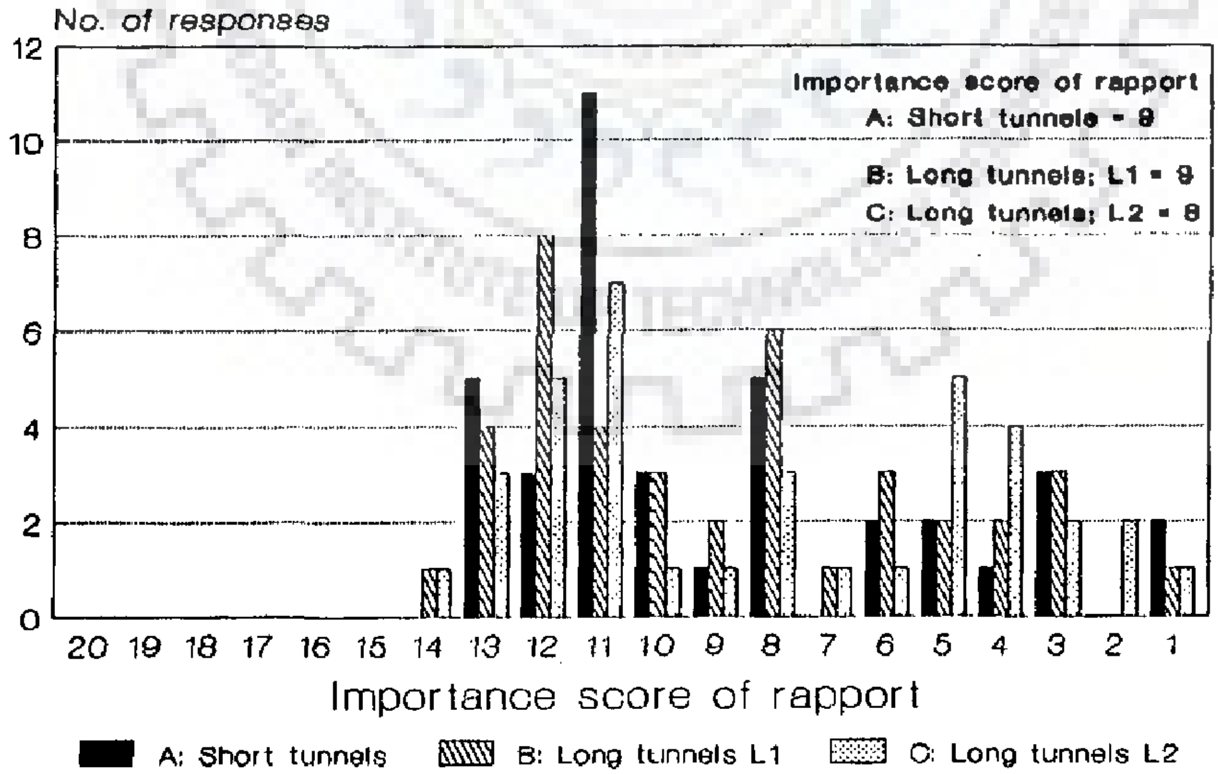


Fig.3.15. Histogram of rapport.

H - 13

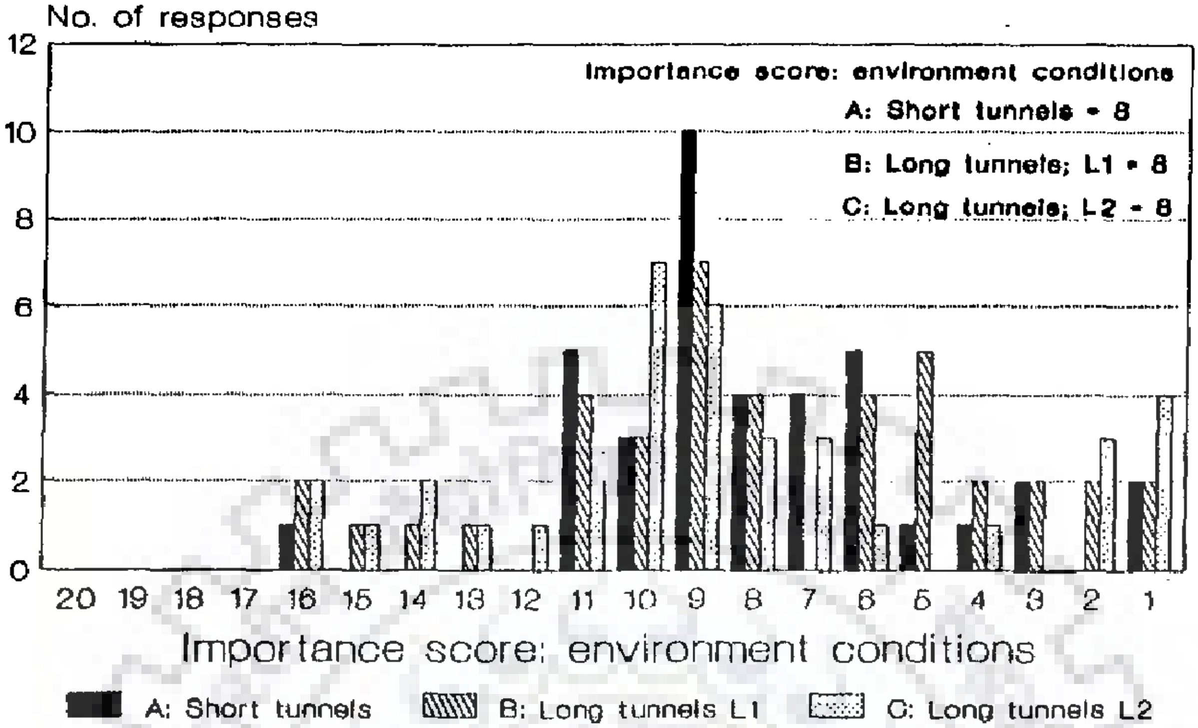


Fig. 3.16. Histogram of environmental conditions and house keeping.

H - 14

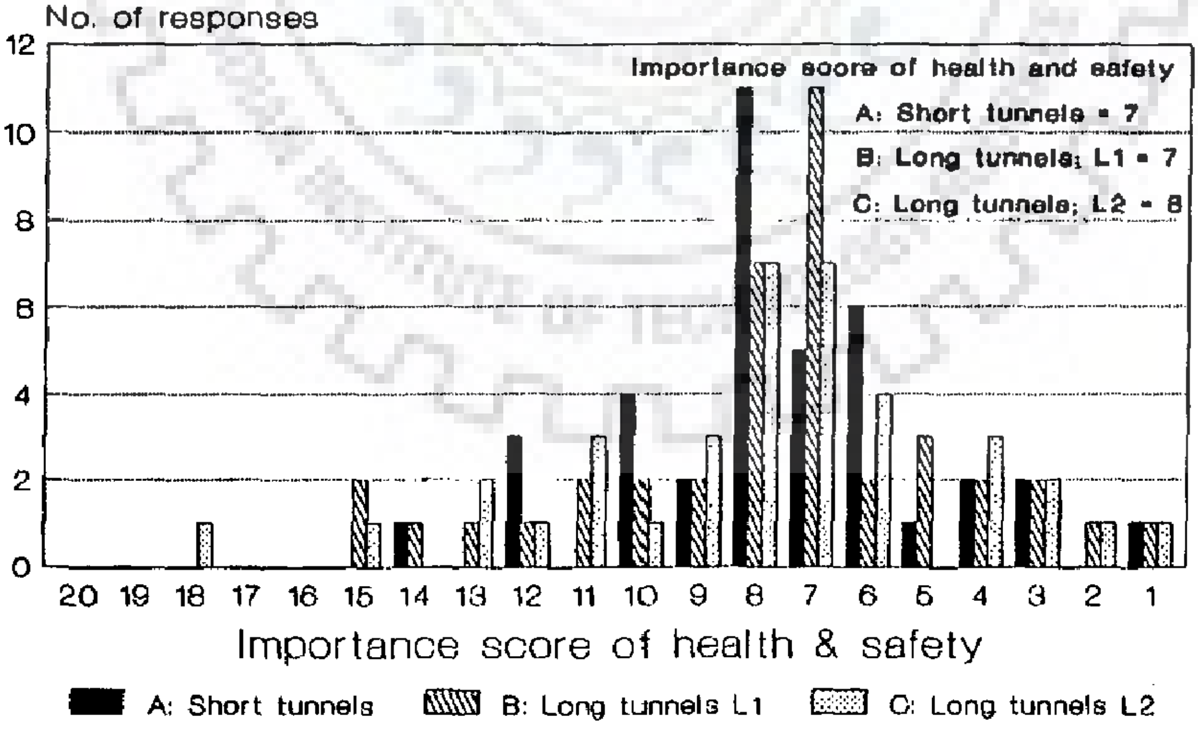


Fig. 3.17. Histogram of health and safety in work.

H - 15

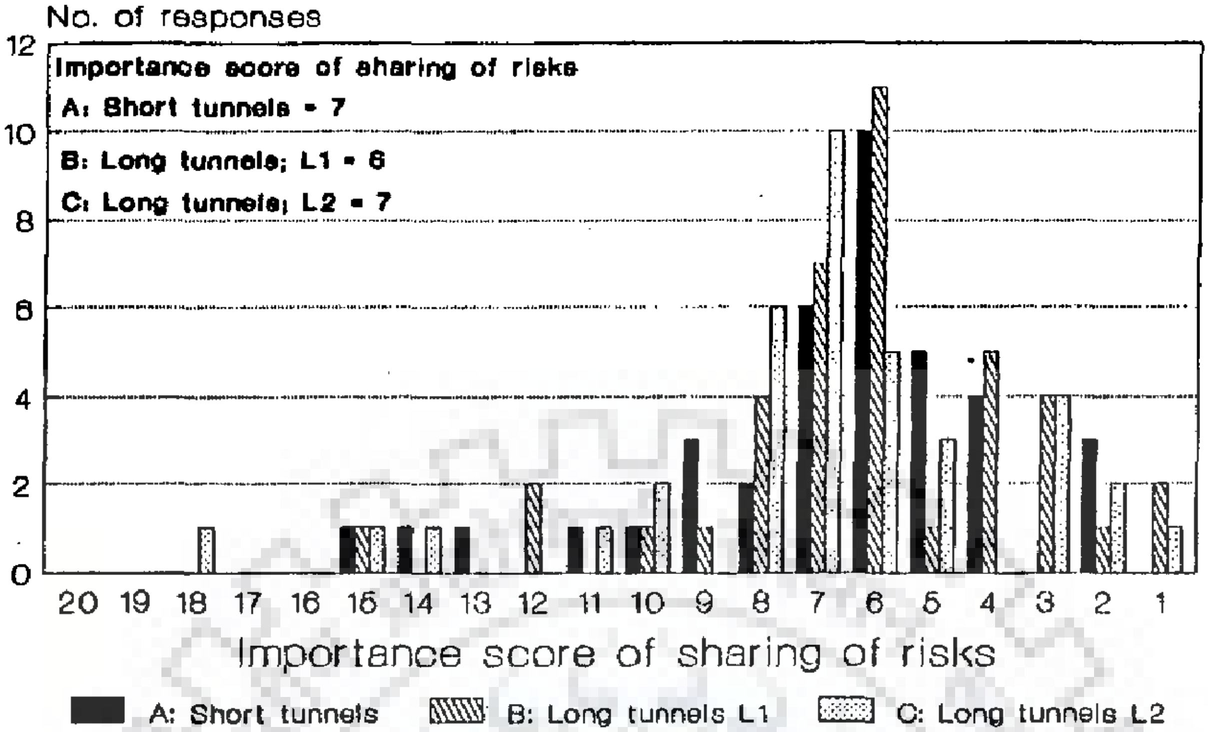


Fig. 3.18. Histogram of sharing of risks.

H - 16

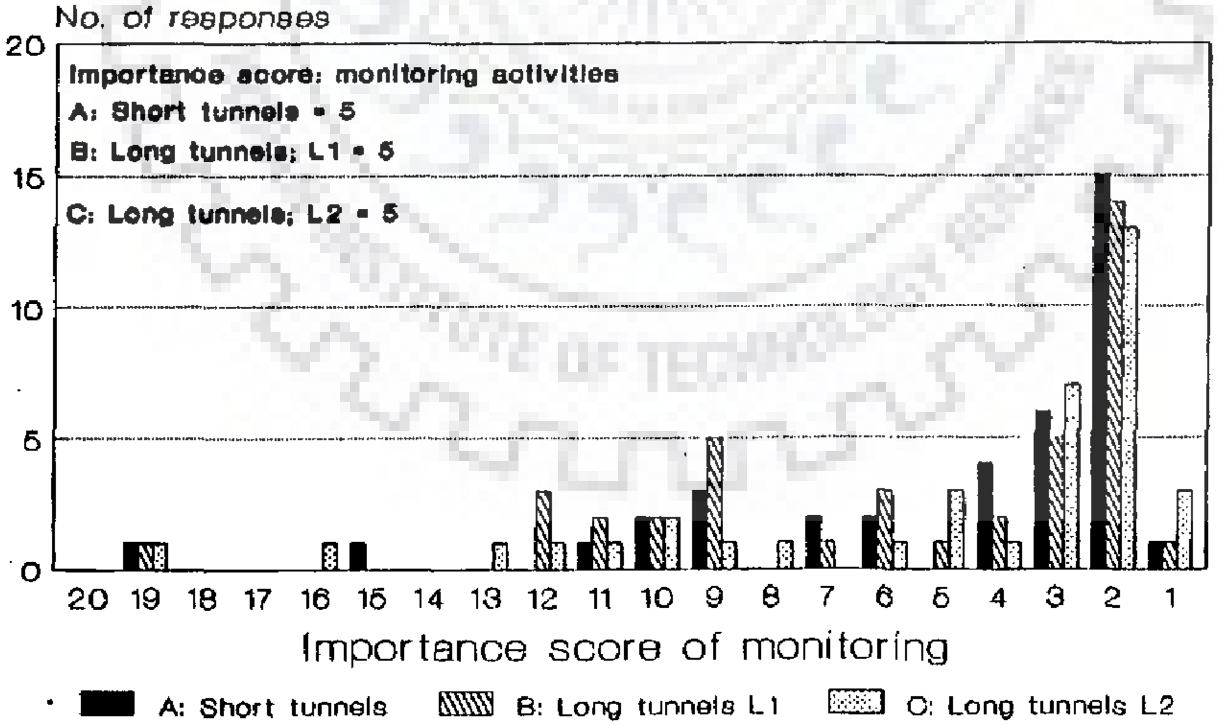


Fig.3.19. Histogram of monitoring tunnelling activities.

H - 17

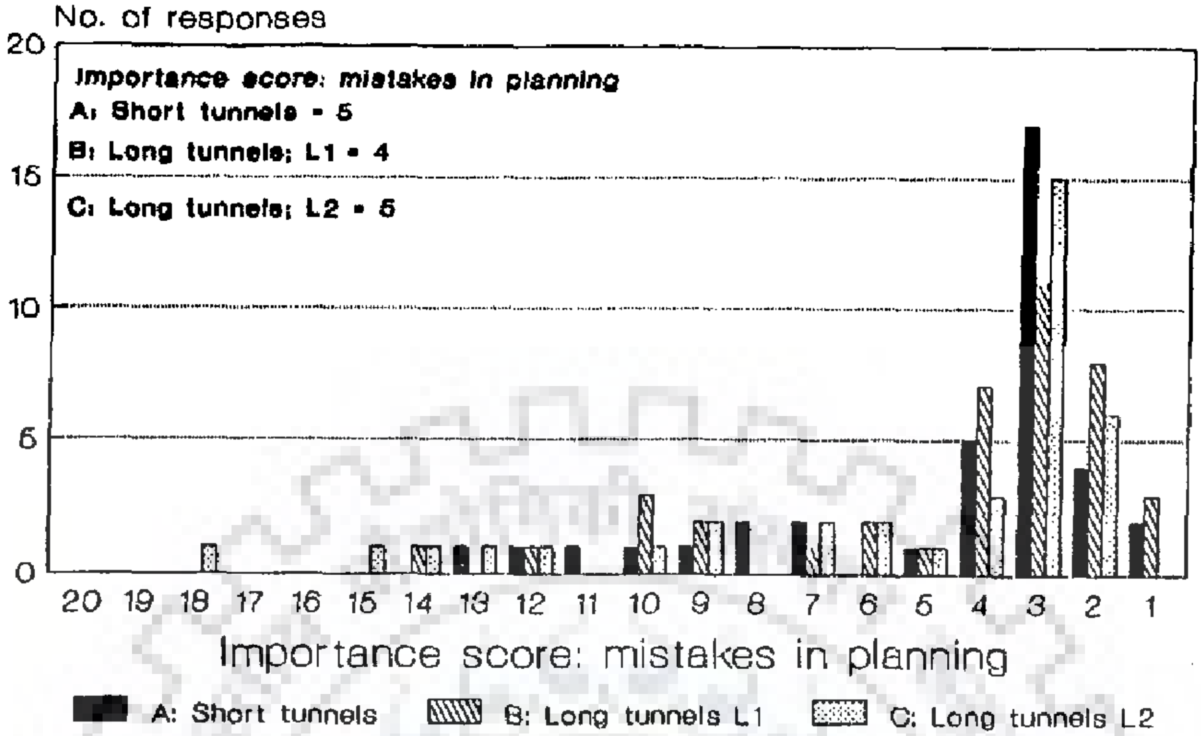


Fig.3.20. Histogram of mistakes in planning and construction.

H - 18

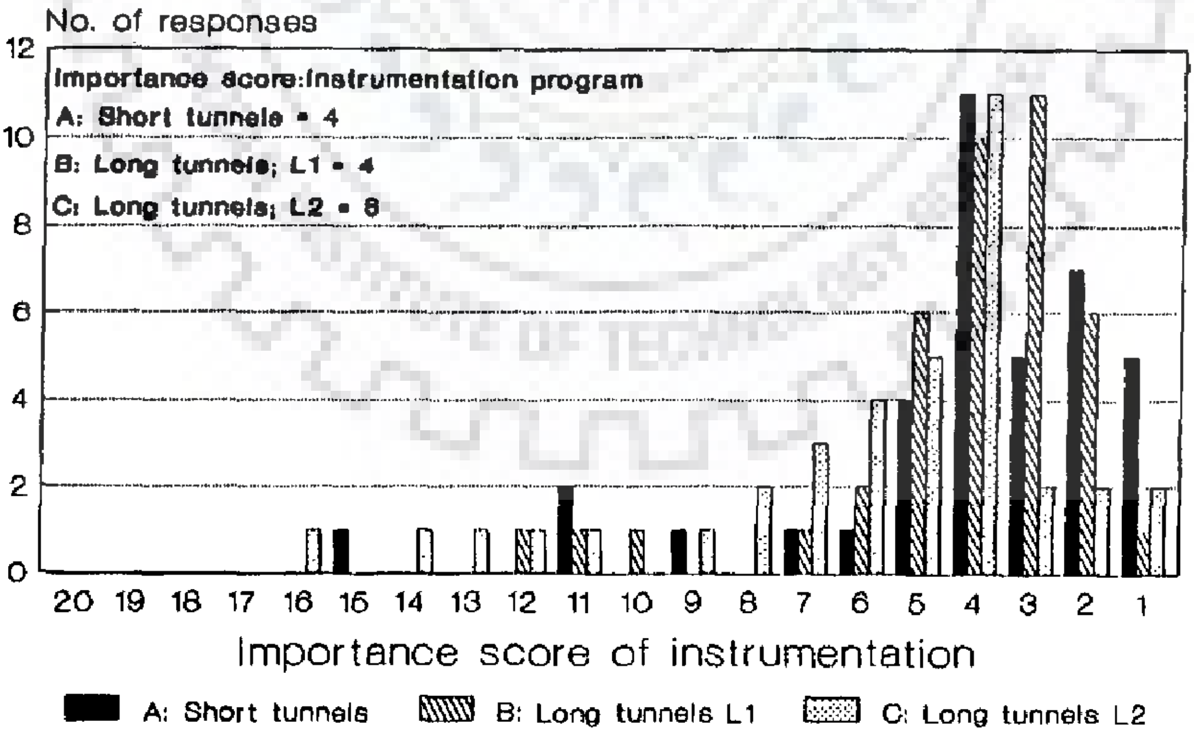


Fig.3.21. Histogram of instrumentation programme.

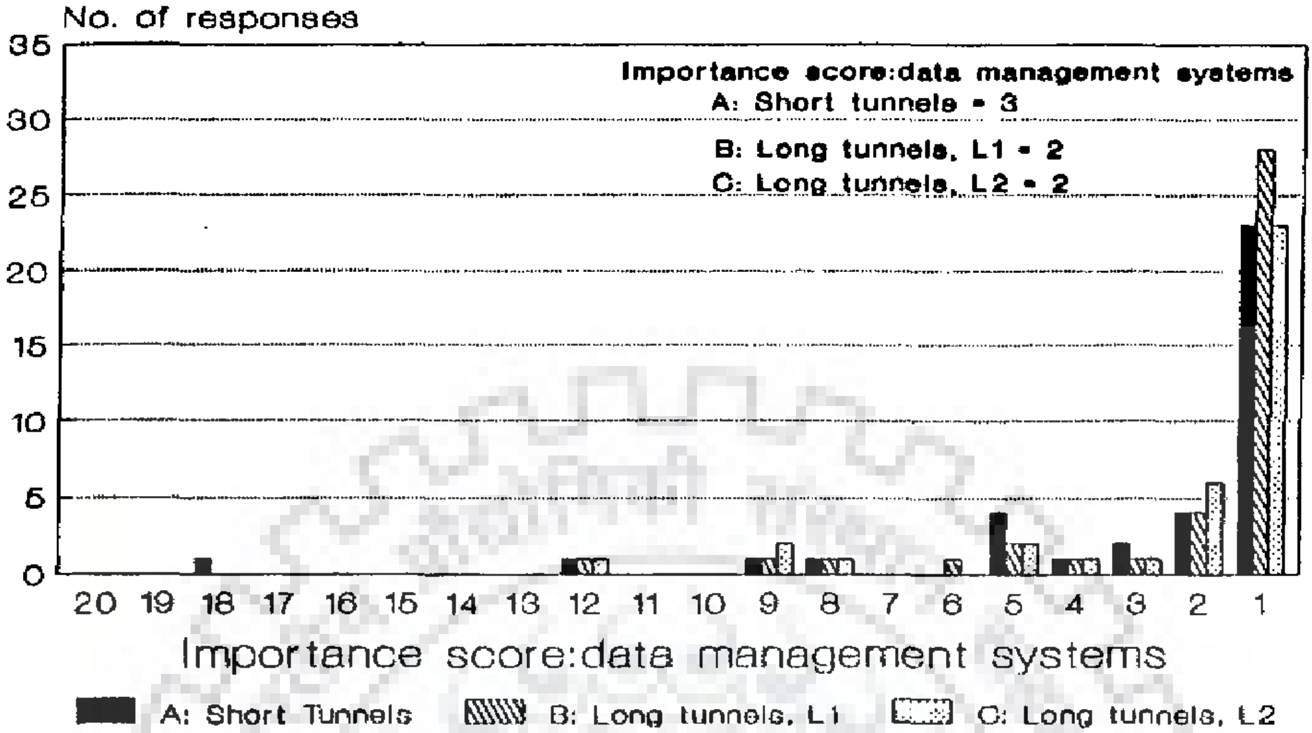


Fig. 3.22. Histogram of data management systems

CHAPTER 4

RISK SHARING IN TUNNELLING CONTRACTS

4.1. RISK

Risk is a basic element of life. Life without risk is inconceivable and undesirable. If all risks were eliminated, the construction industry would cease to evolve. With the hope of greater profit, the contractor develops a new method accepting the risk that the method may not result in loss of anticipated profit. Without this element of risk he would lack the initiative and the incentive to select new techniques or execute them. The owner also assumes some risk when sponsoring a project, which may result in nullifying the projected benefits.

While many risks in construction are inevitable, not all are. Careful, thorough and detailed planning and engineering will identify most of them and ways may be devised for avoiding some (the knowns) and lessening the trauma from those that are expected but cannot be foreseen clearly enough to avoid completely (the unknowns). The greatest need for sharing of risks is for occurrences that are not expected. The execution of these plans through the construction phase must be directed toward decisive action that will meet the planned objectives including the management of risks. Plans and the methods for managing risks must be kept uptodate and revised to meet the actual situations which arise.

Earlier, risks in tunnelling were smaller and lesser and could be more easily classified and borne or handled by the various participants in a more equitable manner. But today's huge complex and imbalanced risks can not be borne solely by one of the partners. Hence, means for allocating and sharing these risks should be evolved for the common good of the project construction organizations and its beneficiaries. The actual size and probability of the risk involving cost, time, credibility, reputation and ability to perform are unknown but real. The existence and impact of these risks should be appreciated and means of mutual benefit found. Most risks are evaluated, minimised or eliminated and the cost of doing this should be compared with an assessment of the original risk.

Contributions have been made by many countries towards the object of defining the sources of risk in a contract and in establishing how best, in the interest of the common good, these are shared among the parties concerned. The latter, sharing of risks, which builds upon practice in the UK and largely accepted in Austria and other European countries has a number of essential features, the most important of which are

(1) Generally attribute acceptance of risk to the party best able to control its incidence or, for minor risk, to make reasonable provision for its cost,

(2) Provide appropriate encouragement to use methods of construction that show best prospects, in the available knowledge at any time, of an economic result,

(3) Provide appropriate flexibility for change in construction methods to follow the range of variation in ground and other conditions foreseeable by a knowledgeable engineer,

(4) Simple and equitable arrangements for disposal of disputes.

The managerial principles for economic tunnelling resulting in a cheaper, faster and more reliable project to the owner; greater scope for the ingenuity of the engineer and upon the contractor with greater confidence for a fair return for his skill and resources have been described by Muirwood and Sauer (1981).

The International Tunnelling Association (ITA) Working Group on Contractual Sharing of Risks, in cooperation with the International Federation of Consulting Engineers (FIDIC) is preparing a standard contract for tunnelling work. The assessment of risk and its sharing in tunnelling has been brought out by Duddeck (1987). He discussed three categories of risks - functional, structural and contractual - and how they relate specifically to the design and engineering of underground openings. He stressed for an urgent need for improved methods of risk assessment because the causes of functional and structural failures are complex and often interrelated. He proposed a number of recommendations concerning risk assessment.

The Norwegian practice of risk sharing in tunnelling contracts has proved successful in that 80% of their proposed 2600 km of tunnels have been driven with equivalent time risk sharing built into the contracts. No disputes with relevance to changed ground conditions have been reported in the period after the risk sharing provisions were accepted in their contracts (Kleivan and Aas, 1987).

Sharing of risks in tunnelling contracts and management of risks have been discussed by Badarinath, Varma and Singh (1988,1989).

A survey of opinions of tunnelling experts in India indicated a low priority to sharing of risks whereas the ITA has realised its importance and brought out recommendations on sharing of risks. It is true in the author's opinion that sharing of risks should be given greater weightage in any tunnel construction.

Tunnelling projects are subject to risks of a magnitude previously unknown. Risk is defined as "the possibility of loss, injury, disadvantage or destruction". That is, risk is an adverse chance. It is necessary to have information as to how the problems arise and with whom, what is the nature of the risks and how to alleviate them. Risks that are either undefined or unrecognised prior to the award of a contract cause much grief later. Owners (used synonymous with government departments) should realise that a fair contract with equitable sharing of the risks according to the ability to assess and manage them would lead to earlier completion dates at lesser costs. The current contracting practices lead many tunnelling projects to wind up with tremendous increases in estimated cost, financial disasters, disputes and litigation. The situation is aggravated by the energy crisis, economic uncertainty and shortage of materials and equipment. At the same time, if our industries are to develop their maximum technological potential, we must employ contracting practices which will encourage that development. Hithertofore, all risks were allocated by the owner to the contractor in India. This attitude resulted in:

(1) contractors adding high contingencies in their bids to cover the costs of risks, and

(2) contract claims leading to litigation.

Thus, the owners recognised that they were paying for risks twice -- once in the tender and again in the claims.

The first and most important task of risk allocation is to identify and understand the risks -- some common and some special ones to each tunnelling project.

Risks in underground construction are related to a number of factors listed below:

1. Acts of God,
2. Accidents,
3. Acceleration or suspension of work,
4. Agencies involved,
5. Allocation principles of risks,
6. Costs,
7. Construction and construction failure,
8. Contract,
9. Contractor/owner inherent,
10. Changed conditions,
11. Defective design/work,
12. Decisions,
13. Delays,
14. Data,
15. Disclosures of information,
16. Disclaimers,
17. Design of supports,
18. Deductions,
19. Economic disasters,
20. Environmental,
21. Evaluation,
22. Escalation,
23. Equipment,
24. Funding and financial failure,
25. Groundwater,
26. Inflation,
27. Innovation,
28. Information,
29. Insurance,
30. Investigation,

31. Labour,

32. Materials,

33. Management,

34. Managerial competence,

35. Physical risks,

36. Political and societal,

37. Public disorder,

38. Planning and scheduling,

39. Pilot works,

40. Quantity variations,

41. Related to capability of individuals,

42. Regulations,

43. Reimbursements,

44. Resolving problems,

45. Responsibilities,

46. Site access,

47. Subsurface conditions,

48. Subcontractor failure,

49. Shared risks,

50. Sociological problems,

51. Support systems,

52. Third party delays,

53. Union strife, and

54. Water problems.

4.2. MANAGEMENT OF RISK

Most contractual problems pertaining to tunnel construction are associated with risks and its management. Unless the subject is fully understood, it will be difficult to adopt contracting practices best suited to a particular job. In the beginning there should be experienced and careful planning and knowledge of the risks concerning all parties and a recognition of what may be allotted and, if to share, on what terms. In this context, the owner has much greater control over the economics of risk than does the contractor. He formulates the contract and decides how to allocate or share the risks. He may increase or diminish the contractor's risk by his contractual provisions and the way they are drafted. He may also affect the contractor's risk by his administration of the contract and his supervision of the work.

Fig. 4.1 represents the risks and risk sharing in tunnelling contracts. The risks in tunnelling contracts are related to the 19 factors recommended by the ITA (1988). The risks inherent in these factors should be shared equitably between the contractor, the owner, the engineer, the geologist and the insurer.

Fig. 4.2 is a conceptual model of risk sharing. The clauses or provisions in a tender/contract document will either benefit or adversely affect the interests of the persons involved in any underground construction, namely, contractor, owner, engineer, geologist and insurer. The clauses may be fed into the expert system ESSOR, which will indicate at the end of the run whether the sharing of risks has been equitable or not. The parties involved share the risks inherent in underground construction in different proportions. For equitable sharing of risks, the party taking the greater portion of the risk/s should be entitled to a greater share of the benefits or profits due to increased costs. If the profits to a party are not commensurate with the amount of risk taken by it, it will be inequitable sharing of risks. ESSOR has been developed considering the five parties mentioned above. However, in India, only two parties are involved in any contract - the contractor and the government which is the owner. The

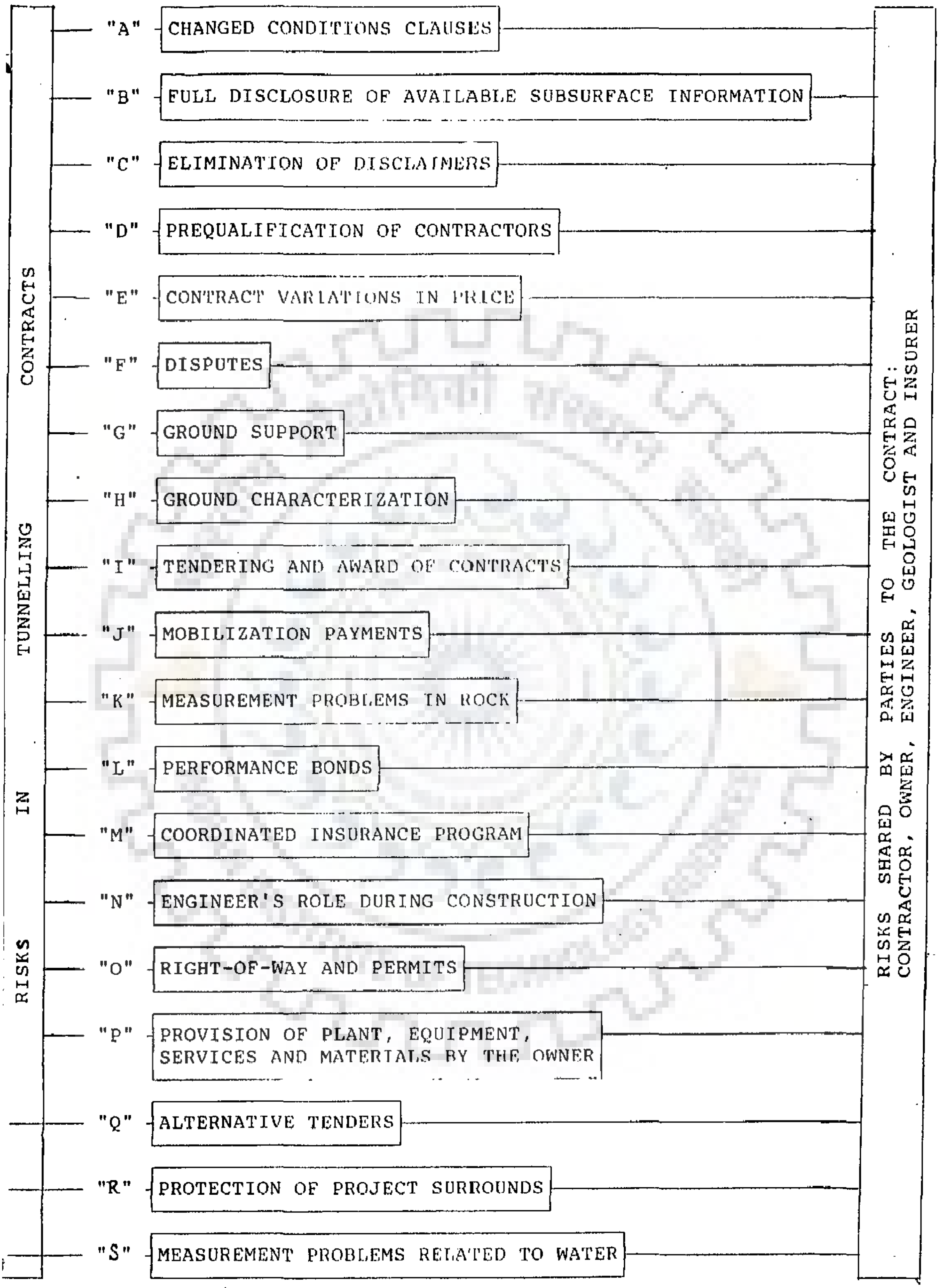


Fig.4.1. Risks and risk sharing in tunnelling contracts.

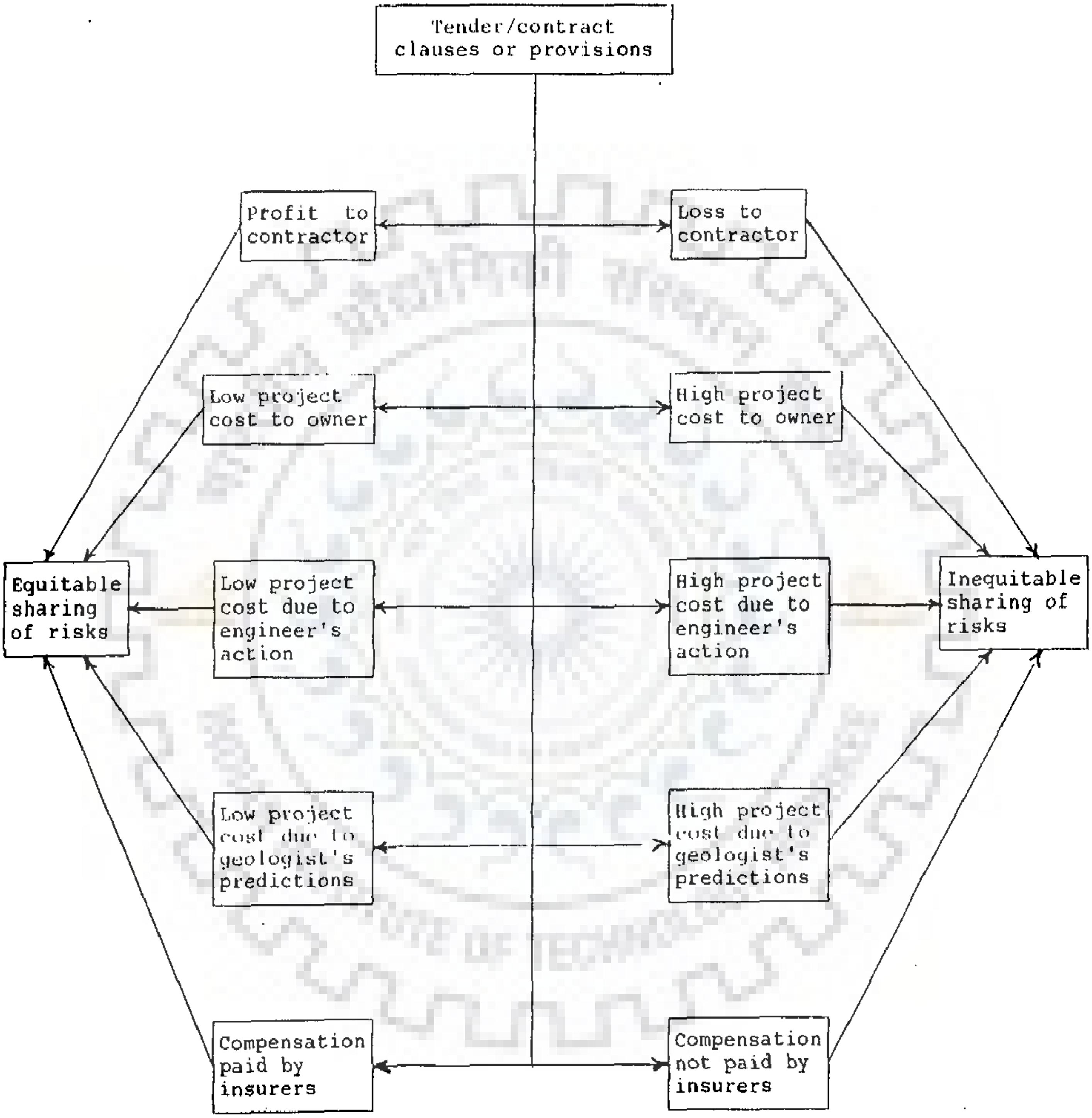


Fig. 4.2. Conceptual model of risk sharing.

engineer, the geologist and the insurer are all employees of the government. Hence, the risks are shared by only two parties - the contractor and the government.

Fig. 4.3 shows the relation between risk sharing and contract types. The types of contracts could be turnkey, lump sum with fixed price, lump sum with price escalation, measurement of items, target amount and cost reimbursement contracts. Each of these types has the risks shared between the owner and the contractor complementary to each other.

The features of minimising project cost (Sutcliffe, 1972) are shown in Fig. 4.4. The total cost of the tunnel is a function of the economic factors and risk sharing. If the investigations are thorough, the geological uncertainty is reduced as a result of the investigations, risks are shared by the owner and the contractor equitably and if the contractor is qualified then the project cost can be minimised. However, excessive qualifications of the contractor would increase the project cost.

4.3. CONSTRUCTION PLANNING AND RISK

Owners should eliminate the known risk rather than try to transfer it. An active pre-contract construction planning would eliminate construction hurdles before they become sources of construction delays and disputes. This aspect is better done by the owner who has more time and is in a better negotiating position with respect to many government agencies. By allocating the risk of negotiating all construction permits to the contractor, the owner would convert risk into a certainty rendering the negotiations to be more hurried, less effective and more costly than if he himself had done the home work before calling tenders.

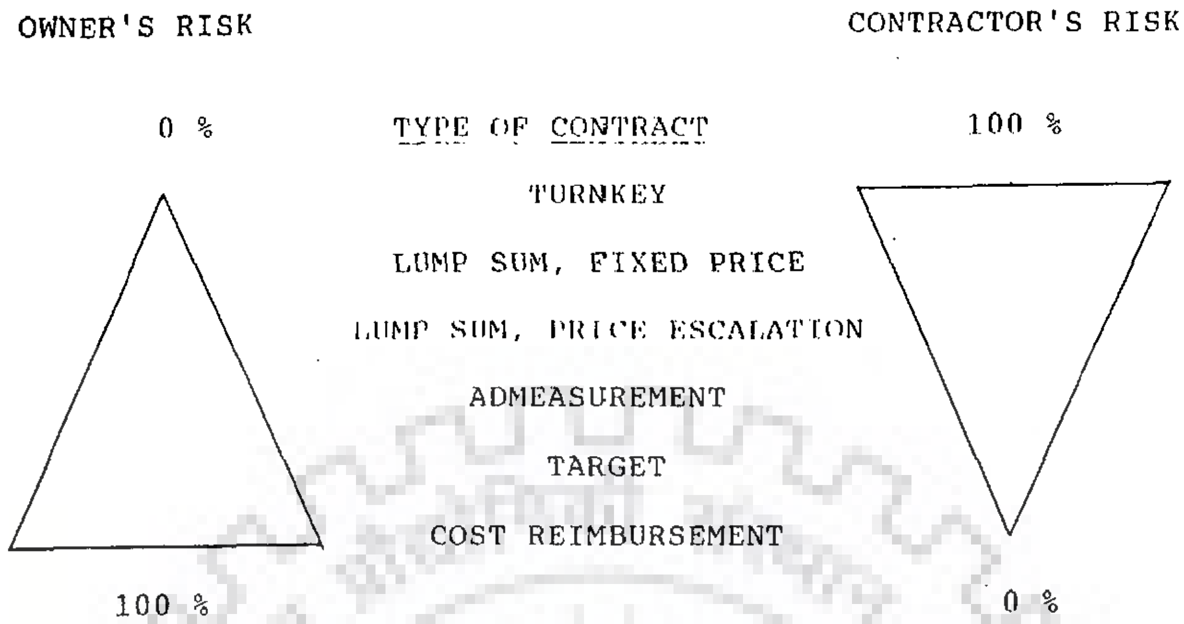


Fig. 4.3. Risk sharing and contract types (Kuesel, 1979).

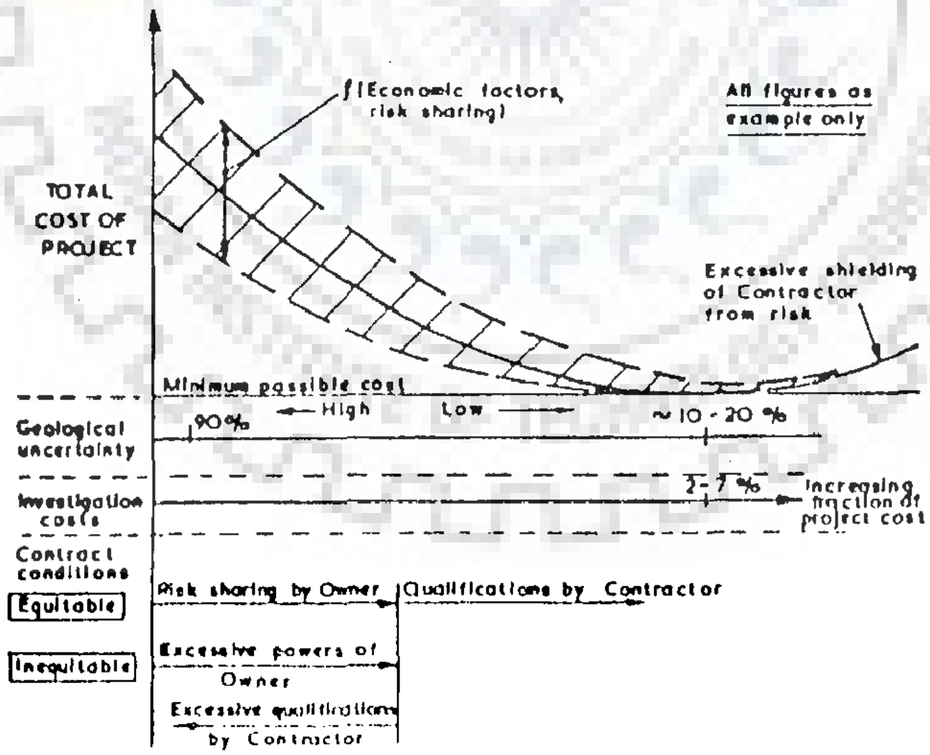


Fig. 4.4. Features of minimising project cost (Sutcliffe, 1972).

4.4. TIME AND COST ESTIMATES

Usually tunnel projects take 5-10 years from the start of conceptual design till delivery of the scheme to the owners. A casual observer may consider it too long a period, but they are in most cases quite short accounting for the complexities of the project. In early optimistic days of the project, the owner must make estimates of time and cost stretching over many years, but actually based on little solid information. The early estimates are publicised and become frozen. Any subsequent changes even though based on more accurate data later available are suspect in the public eye and result in a loss of reputation of the engineer and his profession. The time of completion is affected by confusion in risk assessment. Owners assess penalties for late completion, but contractors inflate their bids for unreasonable schedules and fight back through the courts much to the detriment of the owner. Thus, sufficient time should be allotted for the tunnel project after careful thought and based on the construction times of similar completed projects. While imposing a penalty on the contractor for late completion the opposite should be included, that is, payment of a bonus for early completion at a still higher rate to serve as an incentive. Delays and costs due to the owner's decision and approval processes and for his change-overs on which the owner himself may have little control, should be allowed in the contract. Means for providing necessary reimbursement and time and for reducing or eliminating costly standby time should be found. The contractor should recognise them and provide measures for equitable risk sharing without including such risk factors into his bid.

CHAPTER 5

EXPERT SYSTEMS IN CONSTRUCTION MANAGEMENT

5.1. EXPERT SYSTEMS

Expert systems which have the ability to handle *incomplete and uncertain data besides the advantage of* communicating with the user in the natural language have been gaining wide popularity in a wide variety of fields.

Expert systems alternatively called Artificial Intelligence have been applied in business, medicine, finance, commerce, communications, air traffic, geology, defence, space, mathematics, chemistry, speech, military systems, natural languages, hardware and software, agriculture and engineering (Bartee, 1988).

5.2. EXPERT SYSTEMS IN CONSTRUCTION ENGINEERING AND MANAGEMENT

Expert systems in the field of construction are being developed and very few operational expert systems are currently available. Most of the expert systems are available on microcomputers with knowledge base rules and are executed using commercial expert system shells. Appendix B-1 summarises the state-of-the-art of the expert systems in construction. Appendix B-2 includes hardwares used in the development of expert systems while Appendix B-3 shows the softwares used. Appendix B-4 lists the various areas addressed in the state-of-the-art expert systems (Mohan, 1990).

Some of the potential expert system application areas in construction are:

1. Design of construction methods,
2. Concrete mixing and placement,
3. Constructability evaluation,
4. Temporary facilities layout,

5. Project planning, scheduling and control,

6. Project management,

7. Construction quality control,

8. Construction company management,

9. Equipment selection, diagnosis and repair,

10. Human resources management,

11. Operational problems in constructed facilities,

12. Materials management, and

13. Legal issues.

Fig. 5.1 depicts a conceptual model of expert systems. A conceptual model, which provides a unified approach to the problem of risk sharing is represented. The critical elements of the model are:

(1) The User (U) who accesses and controls the flow of information in the system,

(2) The Knowledge Base (KB) for rules and application knowledge,

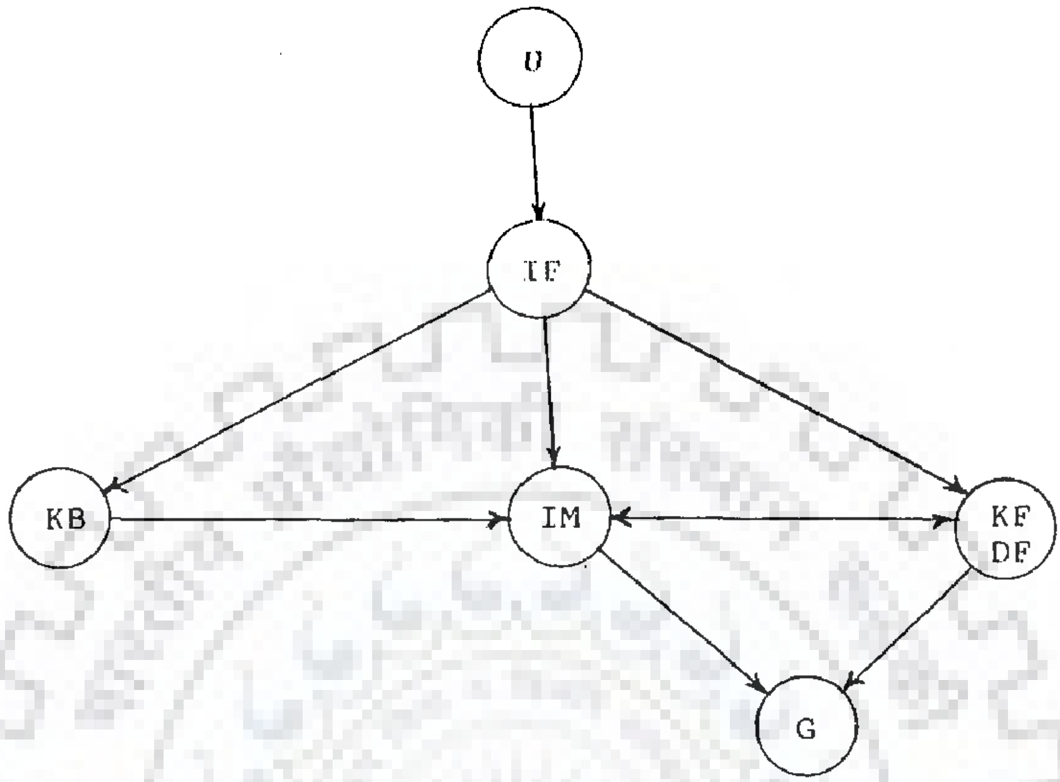
(3) The Inference Mechanism (IM) for knowledge processing and modification,

(4) The database for both the user known facts (KF) and deduced facts (DF) from the inference procedure, and

(5) The user Interface (IF) which coordinates and communicates the operational processes and explanations to the user.

5.3. EXPERT SYSTEM SHELL - EXSYS

EXSYS is a commercially available expert system development package. Expert systems are computer programs using Artificial Intelligence which replicate the exchange of questions put forth by the user and the answers given by a human expert to resolve a problem. With expert systems developed with EXSYS, the



U = USER
IF = INTERFACE
KB = KNOWLEDGE BASE
KF = KNOWN FACTS
DF = DEDUCED FACTS
IM = INFERENCE MECHANISM
G = GOAL

Fig. 5.1. Conceptual model of expert systems.

user is asked questions related to the particular problem. The user may answer the questions by selecting one or more answers from a list of possible options or by entering the required data. The questions are asked by the comupter in succession till a final conclusion is reached. If the user has some doubts, the expert system may explain how and why a particular conclusion was arrived at.

Expert systems comprise two main parts - knowledge base and inference mechanism. The commercially available EXSYS expert system includes the inference mechanism for analysing the knowledge base developed by the expert system developer. The expert system developer is only required to provide the knowledge base in the particular field of usage.

The EXSYS package has a rule editor with the help of which the expert system knowledge bases are developed. More detailed information on command options are available on help screens. The input may be in the form of normal English language text or an algebraic expression.

The input is made by picking out an item or items from a list of options and there are a number of choices in assigning and combining probability values.

The EXSYS programs are written in the C language and may be run with 640 K RAM and one disk drive with PC - DOS. Hard disks and the full available memory of the computer may be used.

The EXSYS development package comprises five main programs:

1. EDITXS.EXE The program for developing editing and testing one's own expert system knowledge bases,
2. SHRINK.EXE A utility package to compress the size of an edited knowledge base, rearrange the data in a

form for rapid access and remove unused variables and formulae,

3. FASTER.EXE A utility program to rearrange the order of rules for maximum speed in backward chaining,

4. MERGE.EXE A utility package to combine two knowledge bases into a single knowledge base,

5. EXSYS.EXE The runtime program for running existing expert system knowledge bases.

Fig. 5.2 shows a flow chart of an expert system. When the user calls the particular expert system, the computer reads from the expert system and stores the IF-THEN rules as the knowledge base. The computer asks the user various questions regarding the subject of the expert system. The questions are, in fact, the IF parts of the knowledge base. The user has the option of selecting one or more of the questions which will be stored by the computer to supply information to its inference mechanism. When all the questions regarding the subject have been answered by the user, the computer will compute the overall probability of all the possible choices and display/print the result of the users responses.

5.4. THE KNOWLEDGE BASE

Conclusions are reached by expert systems working with knowledge. The knowledge is in the form of rules that both the computer and the user may understand. The set of rules used to solve a particular problem is called the knowledge base.

Rules are the way to depict knowledge by which the conclusion is reached by the program. A rule consists of 5 parts: an IF part, a THEN part, an optional ELSE part, an optional NOTE and an optional REFERENCE part.

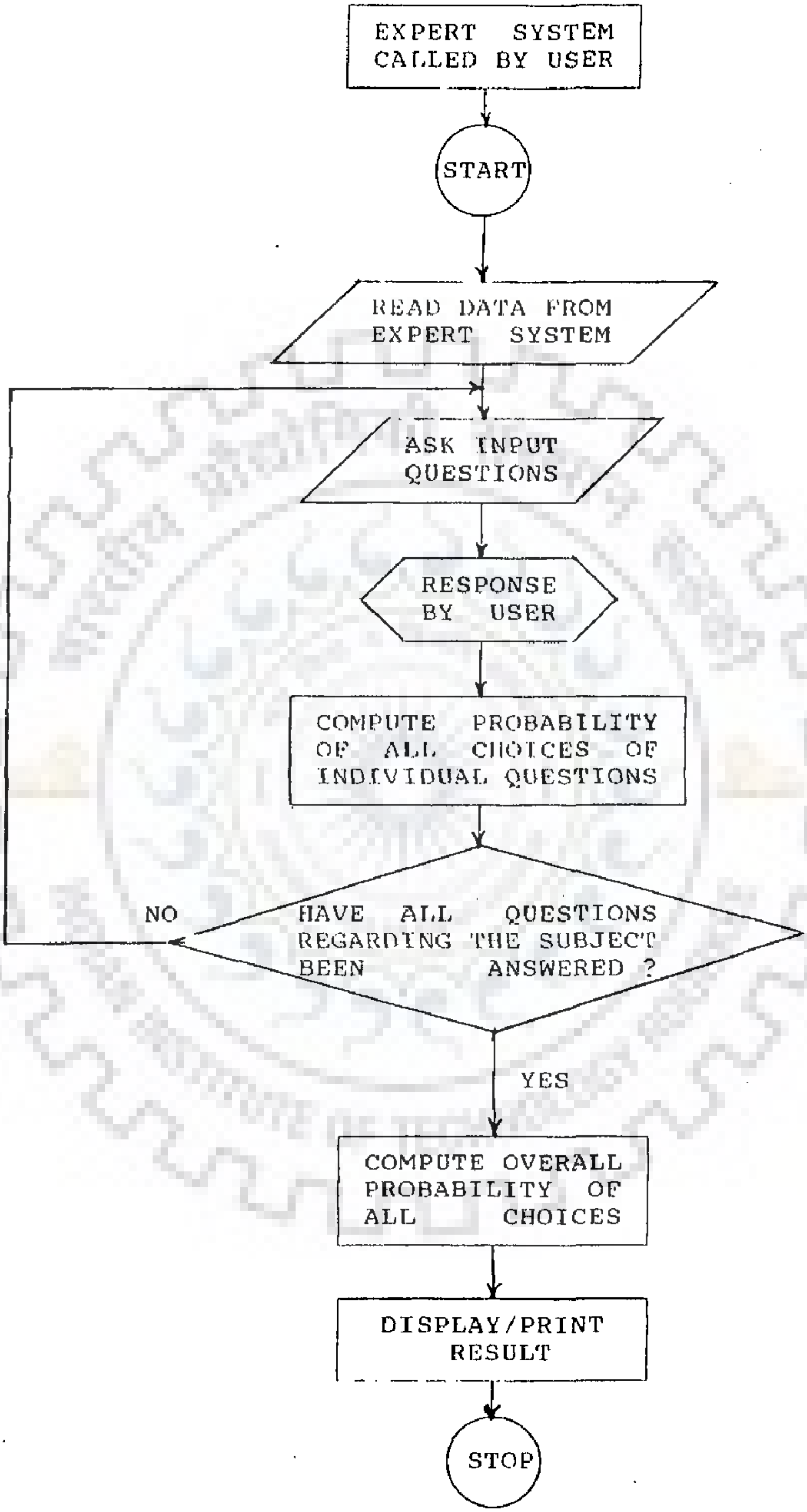


Fig. 5.2. Flow chart of an expert system.

5.5. DEVELOPMENT OF EXPERT SYSTEM PACKAGE

A number of expert system languages or shells created by software engineers and developers are currently available for developing an expert system. These are indicated in Appendix B-3.

EXSYS is a generalized expert system development package commercially available. Expert systems developed with this package will ask the user questions relevant to a subject. The user replies by choosing one or more answers from a list or by entering a numeric value. The computer will continue to ask questions until it arrives at a conclusion. The conclusion may be the selection of a single solution or a list of possible solutions arranged in order of likelihood. The computer can explain in English, how it reached its conclusion and why.

Expert systems may be developed with EXSYS for any problem that involves a selection from among a definable group of choices where the decision is based on logical rules. The rules can involve relative probabilities of a choice being correct. Any subject where a person or a group of persons having special expertise needed by others is a possible area for EXSYS.

Expert systems deal with knowledge rather than data and the files they use are called knowledge bases. The rules that the program uses are IF-THEN type rules. A rule consists of a list of IF conditions in normal English sentences or algebraic expressions and a list of THEN conditions that are mere statements or sentences about the probability of a particular choice being the appropriate solution to the problem. If the computer determines that all of the IF conditions in a rule are true it adds the rule's THEN conditions to what it knows to be true. The computer determines what additional information it needs and how best to get that information. If possible, the computer will derive information from other rules rather than by asking the user. This ability to derive information allows the program to combine many small pieces of knowledge to reach logical conclusions about complex problems. The rule editor allows the rules to be easily modified, added or deleted.

The final goal of an expert system is to select the most appropriate solution to a problem based on the data furnished by the user. If more than one solution is possible the program will provide a list of the possible solutions arranged in order of decreasing probability.

Essentially all of the instruction necessary to run an expert system knowledge base is provided by the program and all output is in normal English. Little or no training is required to run an already developed knowledge base. There is even a knowledge base included that can help if one is having trouble running the program.

5.6. RUNNING EXPERT SYSTEMS

EXSYS knowledge bases can be run by anyone with essentially no training other than how to start the program. However, EXSYS offers many options when requesting information about what the computer is doing and why.

All knowledge base files for EXSYS are kept in two parts: one with a .RUL filename extension and one with a .TXT filename extension. Both files must be on the same disk (or RAM disk) for the program to work.

To run EXSYS place the work disk, in drive A and turn the computer on or press the Ctrl, Alt and Del keys together if the computer is already on. The screen displays the DOS prompt A>. Then type EXSYS <filename> or in this case ESSOR, without extension. If just EXSYS is entered without a filename, the program will display the title screen and ask the user for a filename in which case the user types ESSOR.

The program will always load the portion of the knowledge base contained in the .RUL file into the memory. If there is insufficient memory to run the knowledge base, the computer will indicate so. The program then checks if there is adequate memory to read the .TXT part of the knowledge base into memory. If space is adequate, the .TXT file will be read into memory and the program runs much faster.

If there is insufficient memory to load the .TXT file in memory, an error message will not be given, yet the program will run correctly. The program will access the .TXT file from the disk as it is needed. In this case the disk with the knowledge base must remain in the disk drive while the program is running.

Once an acceptable filename and the knowledge base files have been loaded, the computer will ask if the user wishes instructions on how to run EXSYS. If the user has not run the program in a while, he may wish to refresh himself on the program and presses [Y]. If he does not wish the program to display instructions he presses [N] or just the [ENTER] key.

5.7. RECOVERING DATA

The computer will then ask if the user wants to recover data from a previous run stored on the disk. The EXSYS runtime program lets the user store the data he has entered up to that point, leave the program and be able to return to that point at a later time. If the data thus stored is to be recovered then [Y] is pressed. The user will then be asked for the filename of the file holding the stored input data. The program will read in the data and, after displaying the starting title screens, return to where the user left off. If he does not wish to recover stored data he presses [ENTER] or [N].

5.8. EXSYS DISPLAYS

The computer displays the subject of the knowledge base and the author. Any key may be pressed. The program may display information explaining the knowledge base the user will be running. This display is an option selectable by the knowledge base author.

The program asks if the user wishes to have the rules displayed as the program determines them to be true. The default value will have been selected by the knowledge base author and will be displayed. The program runs faster if it does not have to display the rules; however, the rules show the user how the program is progressing and may help to educate the user. Regardless of the user's selection he will still be able to see the rules through the use of the "WHY" command or when the final selection of choices has been made.

5.9. INTERACTING WITH EXSYS

The computer will start asking questions relevant to the subject area of the knowledge base. This is how the program obtains the data needed to make a decision. There are two types of questions the user may be asked: multiple choice and numeric value.

Multiple choice questions will display a statement ending in a verb, followed by a numbered list of possible completions of the sentence. The number or numbers of the choices is/are entered for the user's situation and [ENTER] is pressed. If more than one number is chosen, the numbers are separated by a comma or with a space. If numbers outside the range of the list are entered, the computer will re-ask the question and not get past the question until it is answered.

The other type of information the user may be asked for is a numeric value. There will be an explanation of what information the program needs and a space to enter the value. A numeric value including a decimal point may be typed and [ENTER] pressed. However, ESSOR has only multiple choice questions and no numeric value inputs.

The computer will continue asking questions till it has obtained enough information to determine that all the IF conditions in a rule are true. If the computer determines that any of the IF conditions in a rule are false, it will reject the rule and go to the next appropriate rule.

5.10. RULES

Rules are the representation of the knowledge of the expert system. A rule is one or more statements in the IF part followed by one or more statements in the THEN part with a note, if necessary, to highlight some key point. The statements are plain English sentences or algebraic expressions and are just the sort of questions the computer has been asking the user. There may also be "choices" in the THEN part. Choices are the possible solutions to the problem the expert system was written for. Choices are indicated by a text statement followed by "-Probability=" and either 0, 1 or a ratio. A well written rule should be easy to read.

There are three main systems available in EXSYS for assigning the probability value. Only one system can be used in a given knowledge base.

5.11. 0 OR 1 SYSTEM

If the value following the "Probability=" is a 0 or 1 the user is in this system. A value of 0 means absolutely no and eliminates the possible solution from further consideration. A value of 1 is equivalent to absolutely yes and selects that solution for inclusion in the final list of solutions. There is no real probability in this system; only yes or no.

5.12. 0-10 SYSTEM

If the value following the "Probability=" is a ratio where the denominator is 10, the user is in this system (e.g. Probability = 5/10). This is the most generally useful system and the one most often encountered. In this system 0/10 is equivalent to "absolutely no" and locks the value at 0/10 regardless of any other value the choice may have received. A value of 0/10 eliminates the choice from further consideration. A value of 10/10 is equivalent to "absolutely yes" and also locks the value for the choice at 10/10 regardless of any other values the choice may have received. Values of 1 to 9 represent degrees of certainty ranging from "very probably no" to "very probably yes". The values from 1 to 9 DO NOT lock the value and are averaged to give the final value for a choice.

For example, if a choice appears in three rules that had true IF parts with values of 3/10, 8/10 and 4/10, the final value for the choice will be the average: 5/10. If the values found were 3/10, 9/10 and 0/10, the 0/10 would prevail and result in a final value of 0/10 regardless of the other values. Likewise, if the values were 1/10, 3/10 and 10/10, the 10/10 would lock the value at 10/10 regardless of the previous lower values. Values of 1-9 are averaged to a final value ONLY if not over-ridden by a 0/10 or 10/10. The first 0/10 or 10/10 prevails and will not be changed even by another 10/10 or 0/10.

5.13. 0-100 SYSTEM

If the ratio following "Probability=" has a denominator of 100 the user is in the 0-100 system. In this system values of 0 to

100 can be assigned but the values of 0 and 100 DO NOT lock the value. *The value can be computed as an avergae of the* probabilities or can be combined as dependent or independent probabilities. The author of the knowledge base has to select the appropriate method of combining values.

In the development of ESSOR the 0-10 system has been adopted since it is the most popular system.

5.14. ASKING ABOUT RULES

When a rule is displayed the user has the option of asking how the computer knows a condition in the IF part is true. To do this the line number of the IF condition is entered. The computer will respond with one of four responses.

1. The computer will display the rule or rules that allowed it to derive the information. A rule used for derivation will have information about the condition the user is asking about in its THEN part. The user can then keep asking how the computer knew that rule's IF conditions were true and so on. If the user asks about a condition that is an algebraic expression, the values of each of the variables in the expression will be displayed. The user may then ask how those values were derived by entering the number of the value.

2. If the user asks the program how it knows a condition is true that it did not derive, but determined by asking the user for input, the computer will respond that the user told it the information was true.

3. The user can ask for information about a condition that is several conditions down in the list and which the computer may not have yet tested. (This can occur when the user asks the computer WHY in response to its question.) If this is the case, the computer will respond that it does not yet know if that

condition is true or not.

4. In certain situations where the computer has just derived new information, it may tell the user that the condition the user is asking about is false and the rule will be eliminated.

Rules often have references for the source of the knowledge (e.g. personal observation, book, article, etc.). If, when a rule is displayed, the user presses [R] the computer will display the reference for the rule if one was entered by the person that developed the knowledge base.

When the user has finished examining the rule, he presses [ENTER] to continue with the expert system. The computer will continue asking questions.

5.15. USING "WHY"

If the user wonders why the program needs to know the information it is requesting, the user can ask it by typing WHY, instead of making a selection from the list of values, and press the [ENTER] key. The program will respond by displaying the rule it is trying to determine the validity of. The user may ask the program about the IF conditions or reference as described above. After the user has finished examining the rule he presses [ENTER]. The program may now have the question originally asked redisplayed or it may display another rule. If the latter is the case, it is because the first rule displayed was being used only to derive information needed by the second, and the second is the rule actually being tested. (One of the first rule's THEN conditions will be in the new rules IF conditions.) All of the options about asking for information on the rule are again available. The program will continue showing the rules it is using to derive information until it reaches the base rule it is trying to apply. This rule will have at least one choice in its THEN part.

The [ENTER] key is pressed to continue the program. If more than one rule was displayed, each time [ENTER] is pressed, the user will go one rule up the list being used in the derivation. The user will then be reasked the question the user responded to with "WHY".

5.16. SAVING DATA WITH "QUIT"

The user has the option of storing the data he has input into the program, exiting the program, and being able to return to the same point later. This can be useful if the user needs to look up information needed by the program or if he must leave the program but does not want to lose the data he has already input. He can select to store the data by entering QUIT in response to any of the computer's requests for data. The program will then ask for the name of the file to store the data in. A filename upto 8 characters but not the name of the knowledge base is entered. If a file already exists, with the name chosen, it will be erased and replaced with the new data. The user will then be asked if he wishes to return to the program or exit to DOS. The data input may also be stored by pressing [Q] when the sorted list of choices is displayed.

5.17. DISPLAY OF THE CONCLUSIONS

The program will continue asking questions until it has considered all of the possibilities the person who wrote the knowledge base put in and it will then display its results. Just prior to the display of the results, the program may display the information interpreting the meaning of the values assigned to the choices. The inclusion of this explanation is an option available to the knowledge base author. The choices will then be displayed arranged in order by final value. The most likely first, next most likely second, etc. Only choices that received a final value greater than 0 will be displayed. The user may also find other statements or calculated values displayed. These will be displayed as a statement or a statement followed by a numeric value.

The choices that are in the list will each have a probability value. This is the final value obtained by combining the values from all of the rules used that had that choice in them. ONLY the numerator will be displayed (e.g. 3 not 3/10).

This final value can be used as a confidence factor for a variety of purposes. A value of 9 or 10 should give a high confidence in the identification. A comparison of the values indicates the relative likelihood of the choices. (e.g. If the first choice gets a 9 and the second an 8, both are almost equally likely. On the other hand, if the first choice got a 9 and the second a 3, the first is much more likely than the second.) The user may also find text statements with no associated numeric value displayed. These are not choices and will always appear after the list of choices regardless of their degree of certainty. If the screen has a colour card attachment such statements are displayed in a different colour from the choices.

The user may also have numeric values calculated by the program displayed. There will be a text statement followed by a number. Like the text statement described above, the display of variables ALWAYS comes after the list of choices and is a different colour.

When the final sorted list of choices is displayed, the user has several options. In the initial display, only choices that received a value greater than zero will be displayed. The user has the option of having all choices that were found in rules, even those with a final value of zero, displayed by pressing the [A] key. If the user has pressed the [A] key to have all choices displayed and would prefer to only see the ones with values greater than zero the [G] is pressed. If no rules in the knowledge base applied to a choice, it has no value and even the [A] key will not display it.

5.18. ASKING HOW A CONCLUSION WAS REACHED

The user can ask the computer how it arrived at its final value for a specific choice or why a statement is displayed. If the line number for any choice or statement is entered, the computer will respond by displaying all of the rules it used to determine the value of that choice or statement. The user again has all of the options in requesting more information about each of the rules as discussed above. If the user wishes to learn why a choice not displayed was eliminated by being given a probability value of 0, [A] is pressed to have all choices displayed. Then the line number of the choice in question is entered.

5.19. CHANGING THE SORT CRITERIA

If the knowledge base being used is based on the system that uses choice values from 0-100, the user has the option of changing the way the final value of the choices is calculated. To change the sorting criteria [S] is pressed. If the knowledge base is not based on choice values from 0-100, the computer will respond that there is no alternate sorting criteria for the data. If it is based on the 0-100 system the user will be given the option of selecting average value [A] or combining the data as a dependent [D] or independent probability [I].

5.20. CHANGING AND RERUNNING THE DATA

EXSYS provides a very easy way to test and analyse the effect the user's input had on the final list of choices. He can change one or more of his answers, while holding the remainder constant, rerun the data and see what effect the changes have on the final outcome. The current value for the choices can be saved for comparison with the new values.

To change the data [C] is pressed. The user will be asked if he wishes to save the current values for comparison with the new ones he will be calculating. The program will then display a list of all of the information he provided by answering questions. The number of the statement he wants changed is entered and the program will reask that question. The question is answered with the new values that he wishes to try. The computer will return to the display of all of the information that the user told it. Statements are continued to be changed until the data is the way he wants it, then he presses [R] to rerun the data. If, due to the changes, the program now needs more information it will ask for it. The rules will not be displayed during the rerun. The program will then display the new list of choices. If the user opts to have the previous values saved for comparison, they will be displayed in parenthesis.

The user can change the data again in almost the same way. The only difference is that when he presses [C] he will be given 3 options:

1. Keep the original values for comparison
2. Keep the most recently calculated values for comparison
3. Do not keep any comparison data.

The ability to change and rerun the data allows expert system models to be built and tested and to see if an answer that the user was not sure of is vital to the final outcome, or really has little effect.

5.21. STORING THE RESULTS

The user can store the input provided to reach the conclusions by pressing [Q]. This is the same as using the QUIT option when entering data. The data input will be stored in a disk file and the user will be able to return directly to this point. This is particularly useful if the user wants to experiment with the "change and rerun" command.

5.22. PRINTING THE RESULTS

The user may wish to save a printed copy of the results of the run. To do this he presses [P]. He will then be asked if he wishes to have the data he told the computer also printed. If he presses [Y] he will have both the final sorted list of choices printed along with all of the data he provided the computer in answer to its questions.

5.23. EXITING THE PROGRAM

When the user has finished examining the choices he presses the [D] key. He will then be given the option of running the program again with either the same or a different knowledge base file.

The program can fully explain how it arrived at its conclusion. If the user disagrees with the computer's rules, it may indicate a problem or error in the rules. To correct this, the user should contact the person that wrote the knowledge base or if the user wants to try changing it himself,he can edit the rules with EDITXS.

5.24. DIRECTING EXSYS OUTPUT TO A FILE

It is possible to direct the output from the runtime program, EXSYS.EXE, to a disk file. When this option is used, the program wil automatically write the results of the run to the disk file, along with the data input by the user, and exit to DOS. This allows EXSYS to be combined in a series of operations controlled by a batch file. Potentially, with all data needed by EXSYS can be provided by an external program, EXSYS can be used to analyse the data and write it to a disk and another program could read and use the EXSYS results.

There are several differences between the way EXSYS normally runs and the way the program runs when the option to direct the output to a file is selected:

1. The program will NOT pause for the user to press a key except when user input of data is required.

2. If an external program provides all input needed, EXSYS will not require any user action and will complete its analysis and write the results to the disk.

3. The title screens and results will be displayed on the screen but will flash by very quickly.

4. The user will be able to ask what rules were used to determine the conclusions or perform a "Change and Rerun". If the user is asked for input he will be able to ask the program "WHY" the data is needed.

5. The program will automatically drop back to DOS once the results are written to the file.

To direct output to a file, the command

OUT=<filename>

is added to the line when EXSYS is called. For example:

EXSYS <filename> OUT=<output file name>.

The rule file name is the name of the knowledge base. Output file name is the name of the file that EXSYS will write the results to. (OUT= MUST BE IN CAPITALS).

The command line EXSYS B:ESSOR OUT=A:RESULTS would run the knowledge base ESSOR from drive B and write the results of the run to the disk file RESULTS on drive A.

The output can NOT be directed to a file if the user calls the program with just EXSYS and then answer the program's prompt for the file name.

The instructions and information for running the expert system ESSOR by a User is given in Appendix C.

CHAPTER 6

DEVELOPMENT OF EXPERT SYSTEM FOR SHARING OF RISKS - ESSOR

6.1. INTRODUCTION

In this study the expert system shell - EXSYS has been used to develop the knowledge base. The knowledge base relates to the sharing of risks in underground construction, especially tunnel excavation.

The expert system for sharing of risks - ESSOR - deals with sharing of risks between the owner, engineer, contractor, geologist and the insurer; the objective being to resolve the disputes amicably without having to resort to litigation and lawsuits in courts, which benefit neither the owner nor the contractor, but the lawyers.

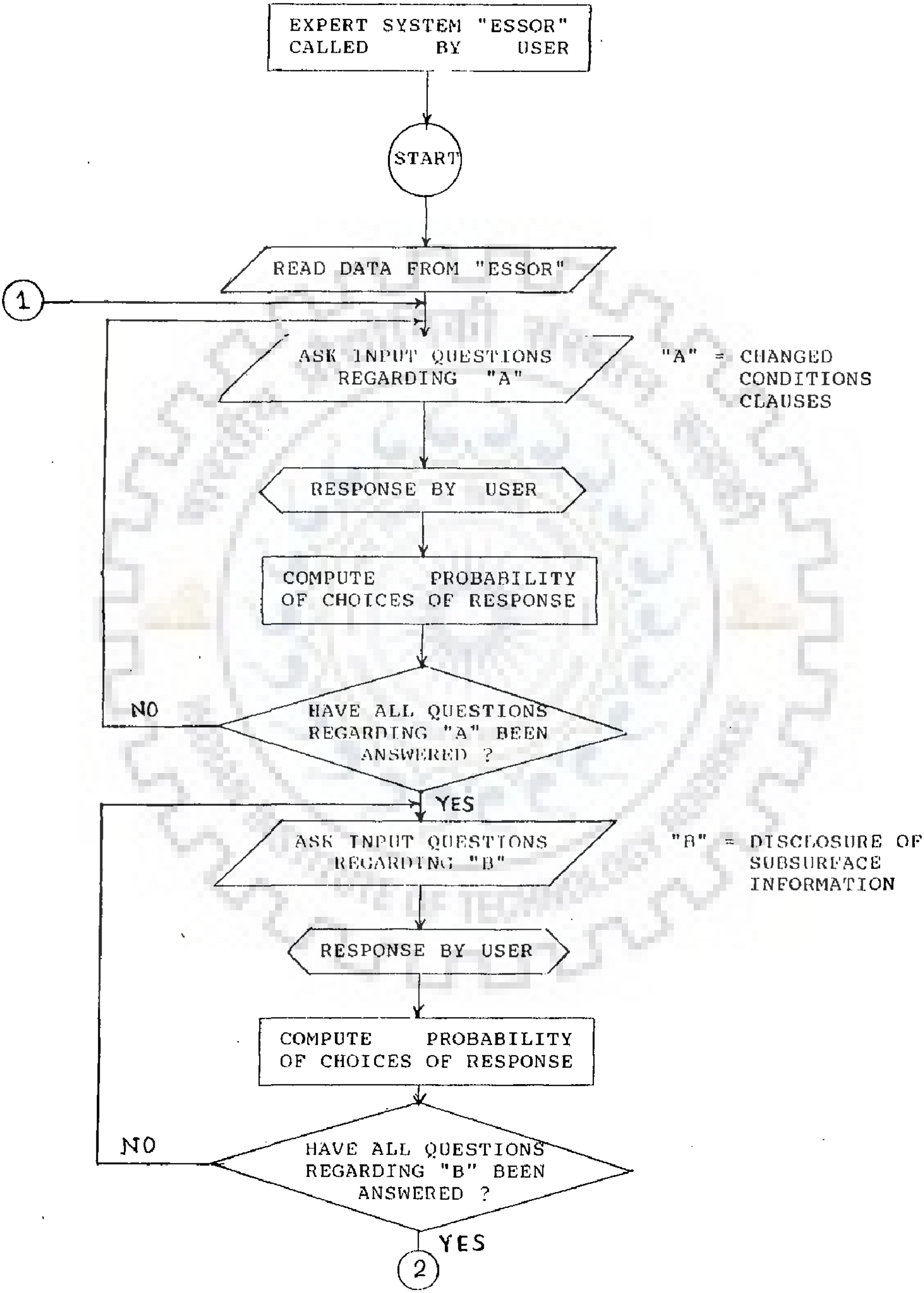
ESSOR may be used in the bidding stage, the contracting stage, during investigation and actual construction of the tunnel by both the owner and the contractor. The program has been tested to examine whether the provisions of the contract of civil works of two tunnelling projects have been properly framed to share the risks equitably between the various parties and what would be the outcome of risk sharing, to serve as examples.

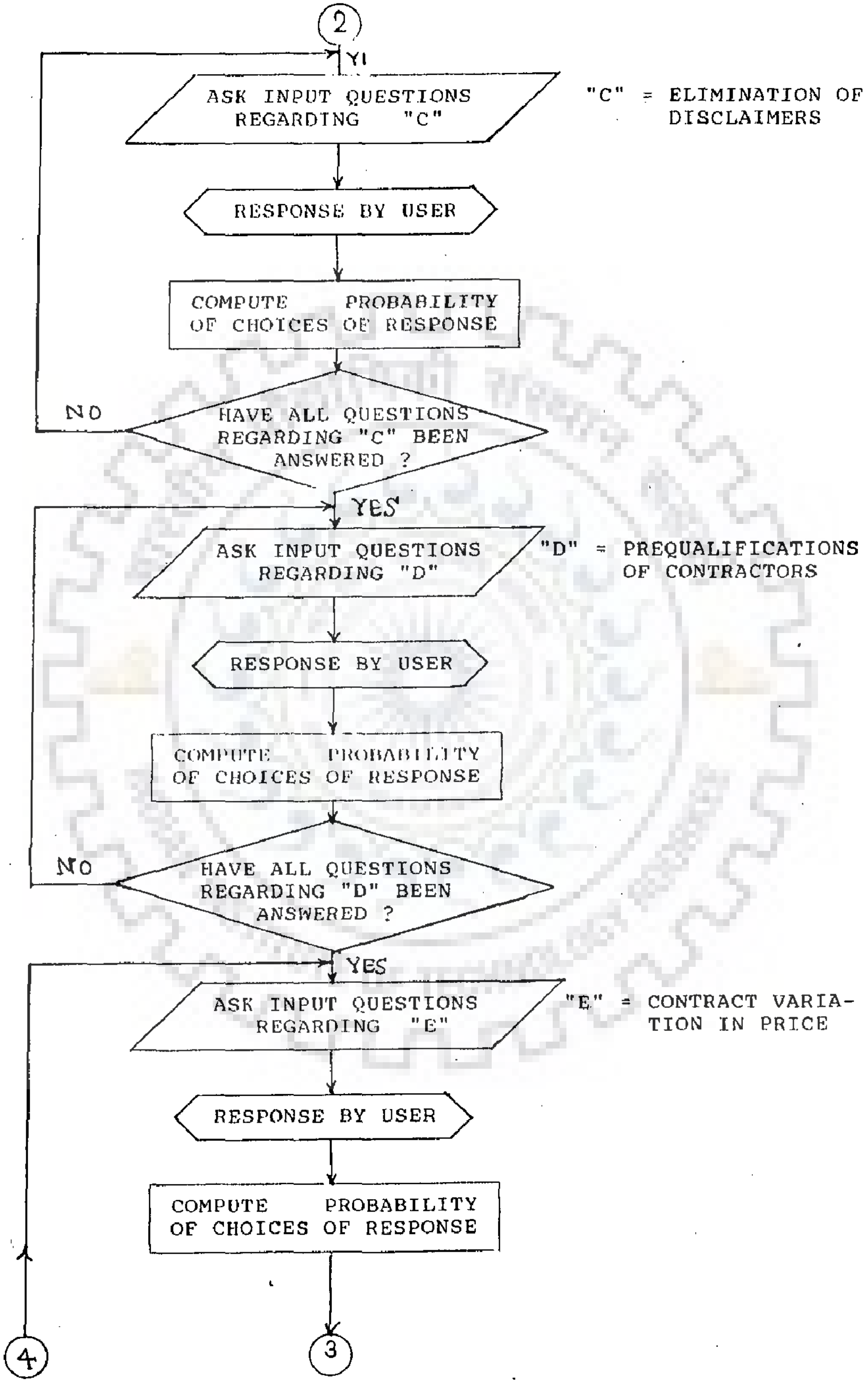
The expert system - ESSOR - reveals whether a tunnelling contract has the risks of the project justly and fairly shared between the owner, the engineer, the contractor and the geologist responsible for the execution of the project. Equitable sharing of risks benefits all the parties to the contract and concerned with the project, leading to the project being completed within reasonable time and expenditure.

Fig. 6.1 shows a flow chart of Expert System - "ESSOR".

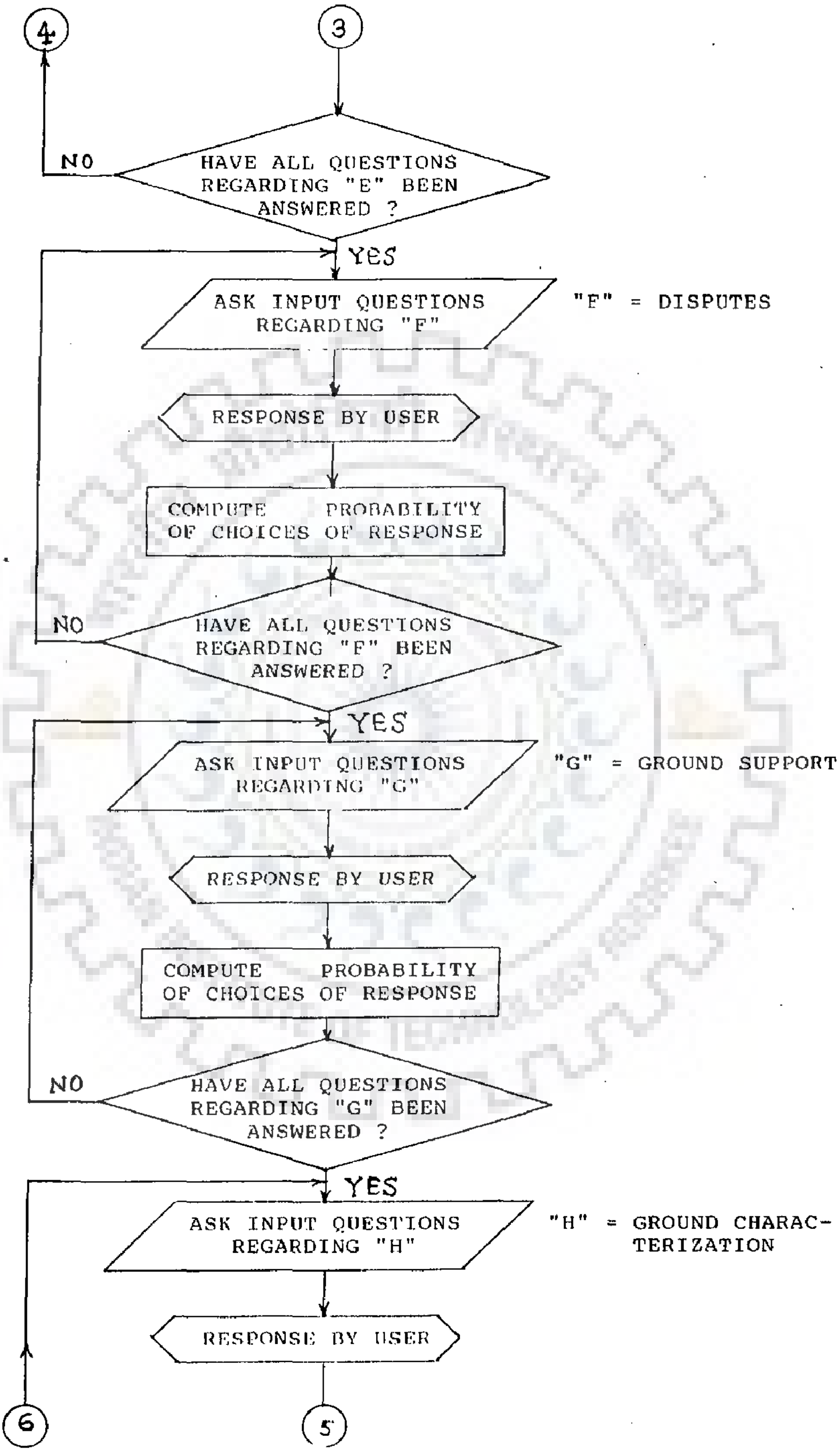
6.2. THE EXPERT SYSTEM - ESSOR

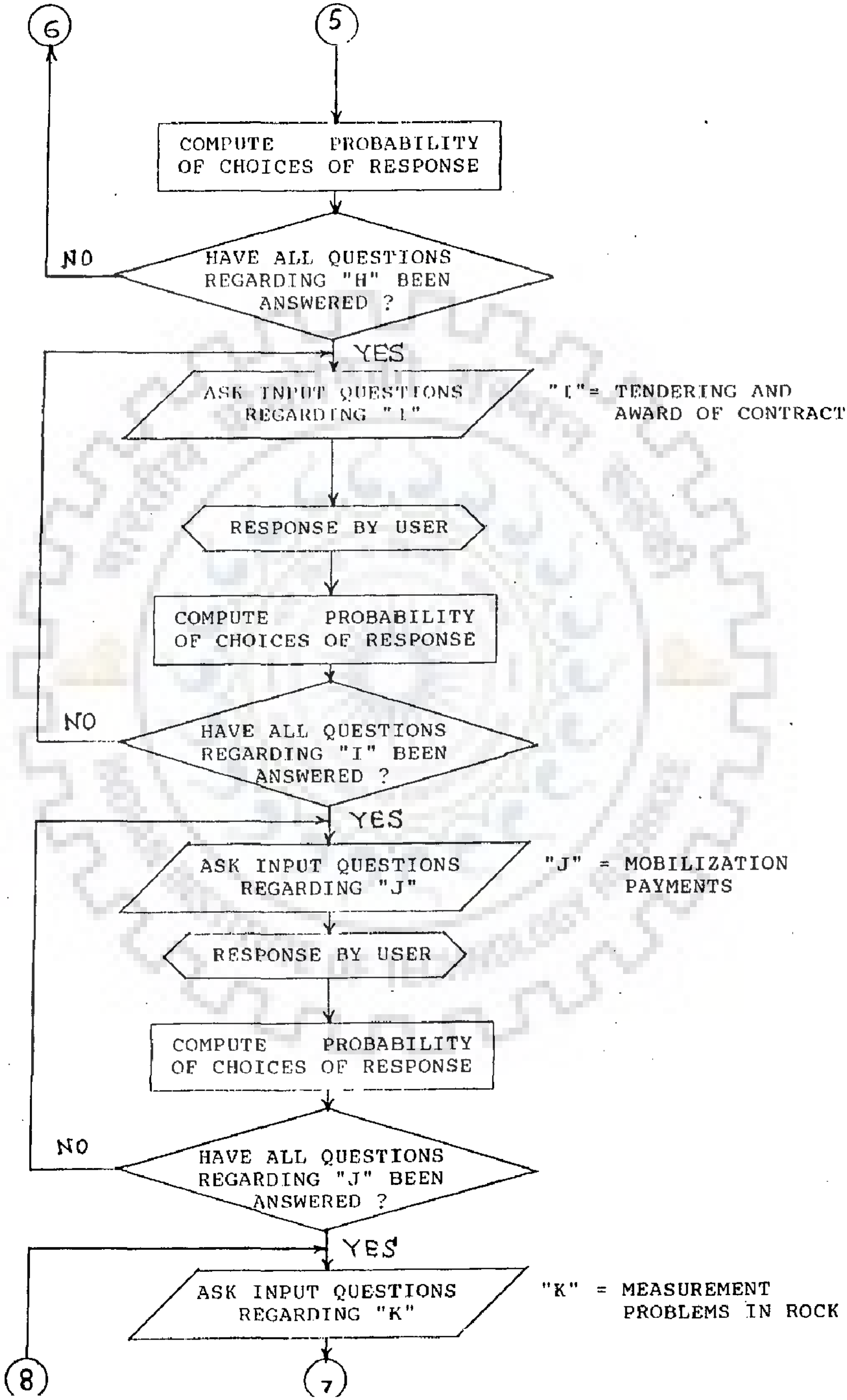
The need for an expert system - ESSOR - "Expert System for

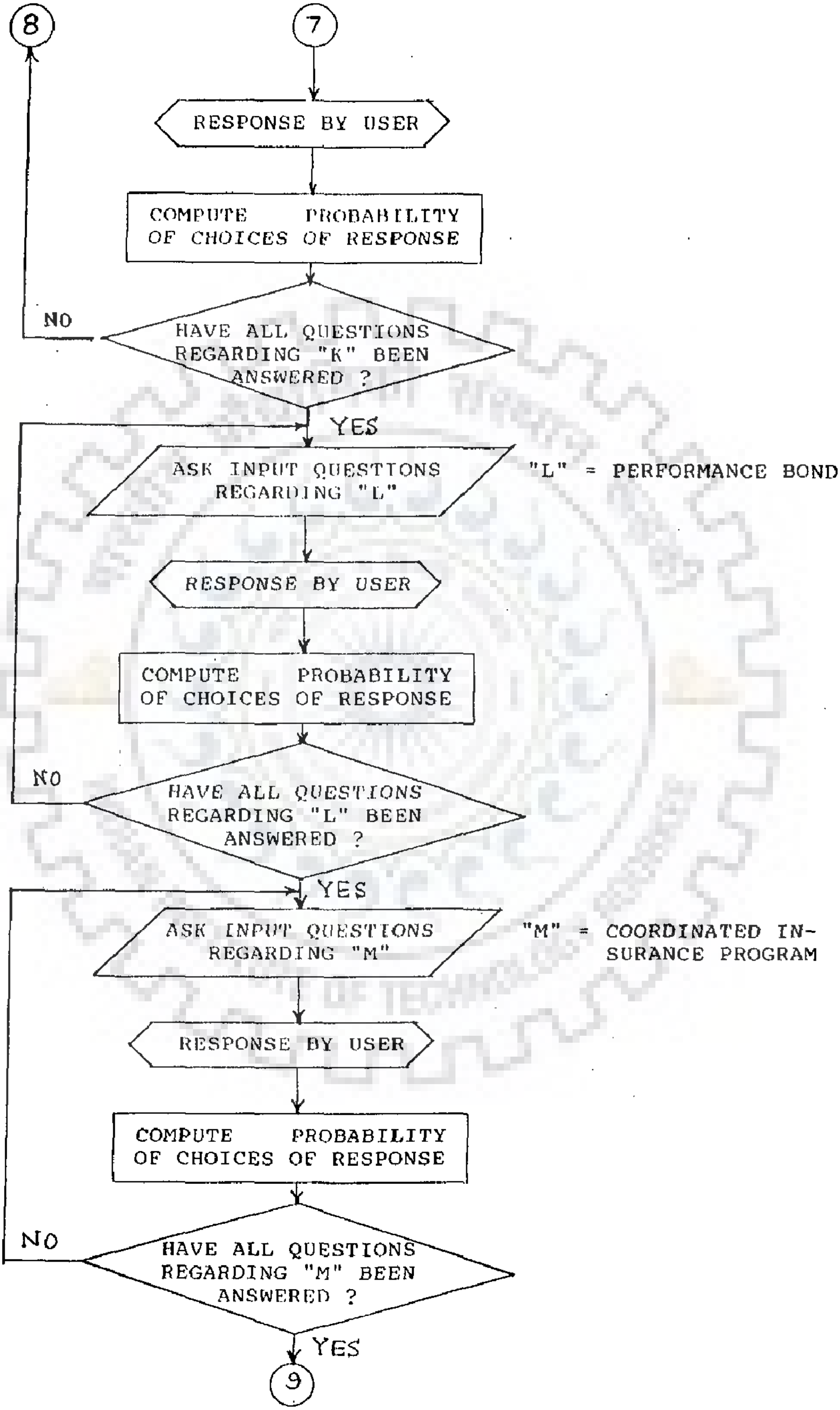

EXPERT SYSTEM "ESSOR" CALLED BY USER
START
READ DATA FROM "ESSOR"
1
ASK INPUT QUESTIONS REGARDING "A"
"A" = CHANGED CONDITIONS CLAUSES
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
NO
HAVE ALL QUESTIONS REGARDING "A" BEEN ANSWERED ?
YES
ASK INPUT QUESTIONS REGARDING "B"
"B" = DISCLOSURE OF SUBSURFACE INFORMATION
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
NO
HAVE ALL QUESTIONS REGARDING "B" BEEN ANSWERED ?
YES
2

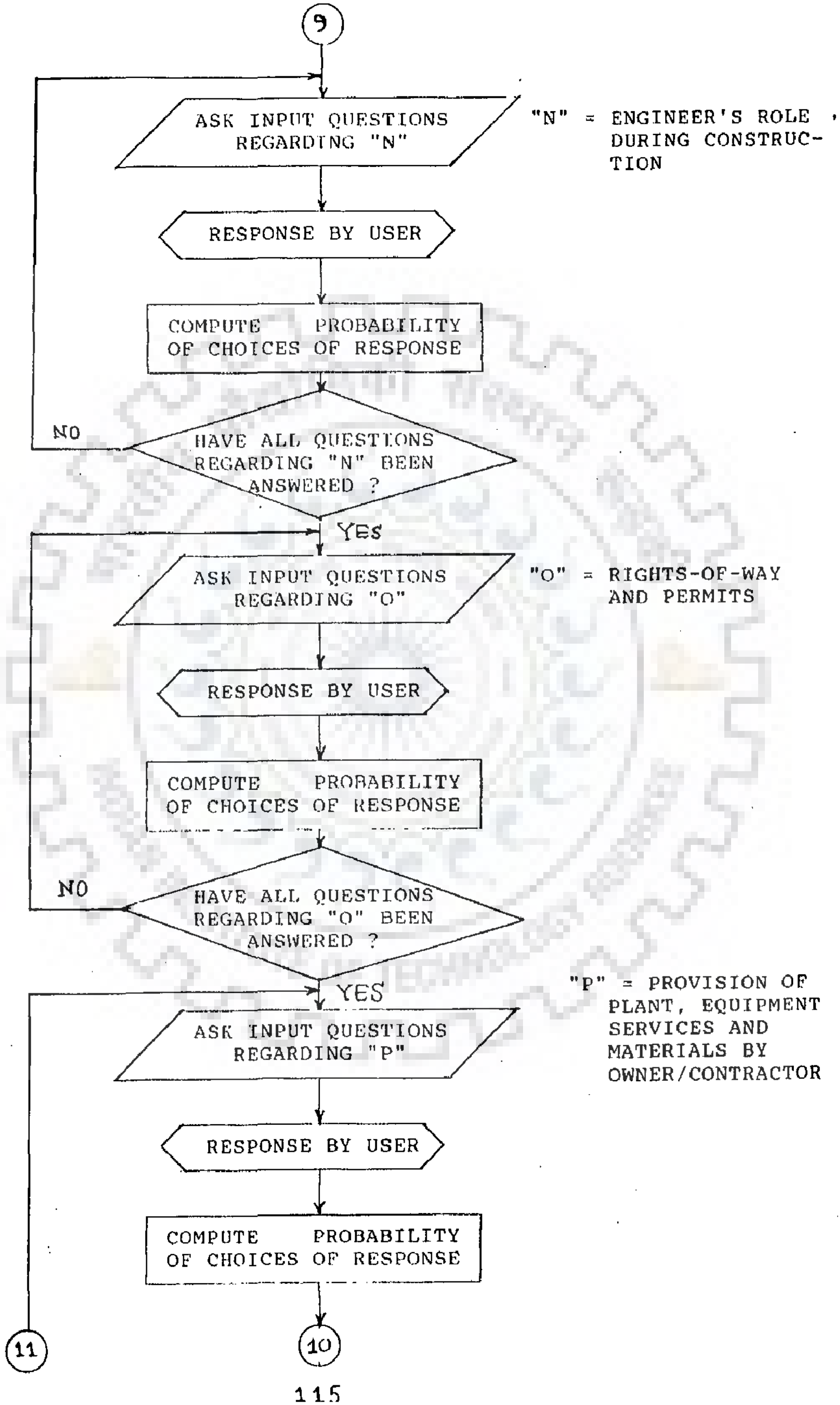


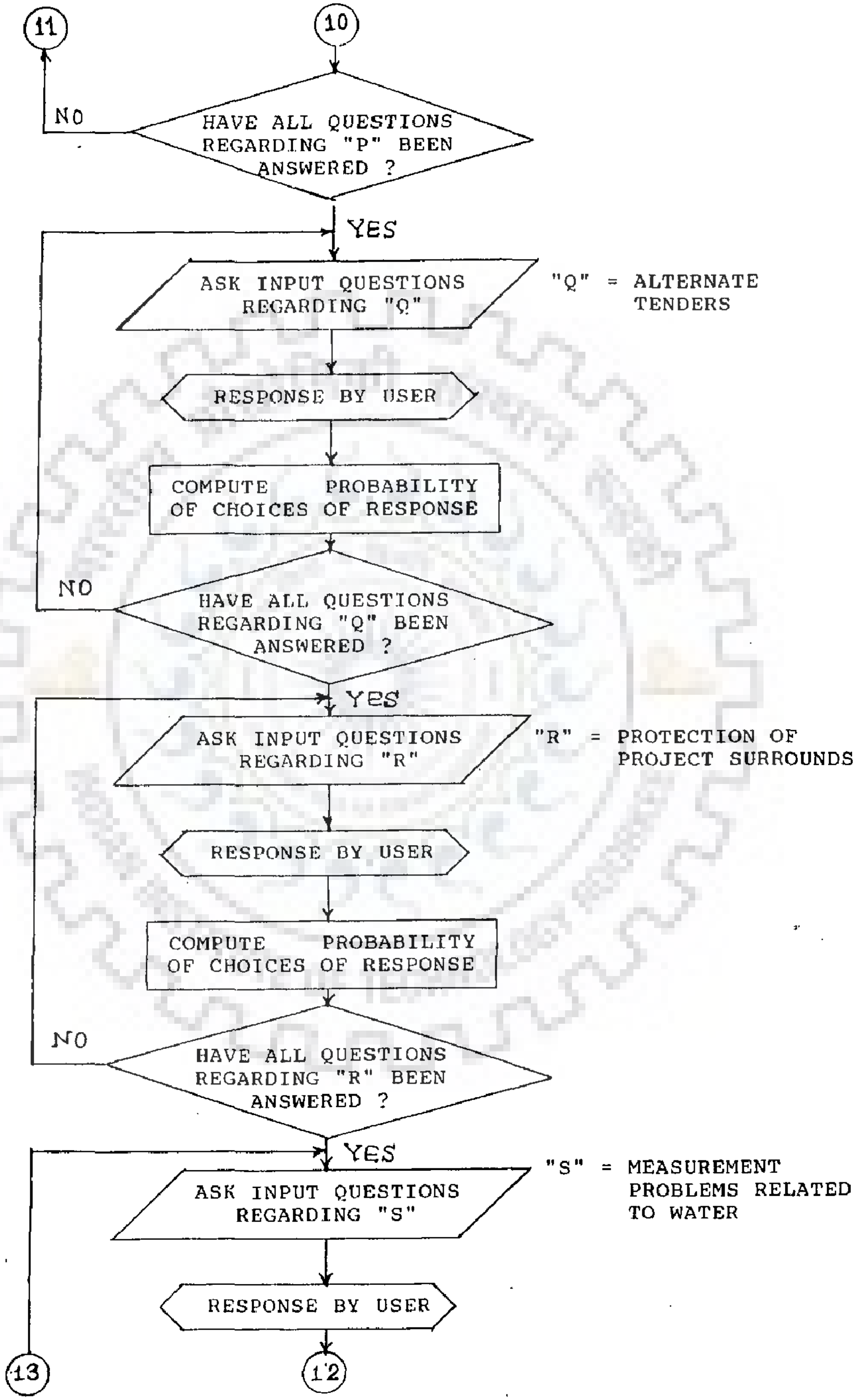
2
YI
ASK INPUT QUESTIONS REGARDING "C"
"C" = ELIMINATION OF DISCLAIMERS
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
HAVE ALL QUESTIONS REGARDING "C" BEEN ANSWERED ?
NO
YES
ASK INPUT QUESTIONS REGARDING "D"
"D" = PREQUALIFICATIONS OF CONTRACTORS
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
HAVE ALL QUESTIONS REGARDING "D" BEEN ANSWERED ?
NO
YES
ASK INPUT QUESTIONS REGARDING "E"
"E" = CONTRACT VARIATION IN PRICE
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
4
3


4
3
NO
HAVE ALL QUESTIONS REGARDING "E" BEEN ANSWERED ?
YES
ASK INPUT QUESTIONS REGARDING "F"
"F" = DISPUTES
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
NO
HAVE ALL QUESTIONS REGARDING "F" BEEN ANSWERED ?
YES
ASK INPUT QUESTIONS REGARDING "G"
"G" = GROUND SUPPORT
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
NO
HAVE ALL QUESTIONS REGARDING "G" BEEN ANSWERED ?
YES
ASK INPUT QUESTIONS REGARDING "H"
"H" = GROUND CHARACTERIZATION
RESPONSE BY USER
6
5


6
5
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
NO
HAVE ALL QUESTIONS REGARDING "H" BEEN ANSWERED ?
YES
ASK INPUT QUESTIONS REGARDING "I"
"I" = TENDERING AND AWARD OF CONTRACT
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
NO
HAVE ALL QUESTIONS REGARDING "I" BEEN ANSWERED ?
YES
ASK INPUT QUESTIONS REGARDING "J"
"J" = MOBILIZATION PAYMENTS
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
NO
HAVE ALL QUESTIONS REGARDING "J" BEEN ANSWERED ?
YES
ASK INPUT QUESTIONS REGARDING "K"
"K" = MEASUREMENT PROBLEMS IN ROCK
8
7


8
7
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
NO
HAVE ALL QUESTIONS REGARDING "K" BEEN ANSWERED ?
YES
ASK INPUT QUESTIONS REGARDING "L"
"L" = PERFORMANCE BOND
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
NO
HAVE ALL QUESTIONS REGARDING "L" BEEN ANSWERED ?
YES
ASK INPUT QUESTIONS REGARDING "M"
"M" = COORDINATED IN-SURANCE PROGRAM
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
NO
HAVE ALL QUESTIONS REGARDING "M" BEEN ANSWERED ?
YES
9


9
ASK INPUT QUESTIONS REGARDING "N"
"N" = ENGINEER'S ROLE DURING CONSTRUCTION
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
HAVE ALL QUESTIONS REGARDING "N" BEEN ANSWERED ?
NO
YES
ASK INPUT QUESTIONS REGARDING "O"
"O" = RIGHTS-OF-WAY AND PERMITS
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
HAVE ALL QUESTIONS REGARDING "O" BEEN ANSWERED ?
NO
YES
ASK INPUT QUESTIONS REGARDING "P"
"P" = PROVISION OF PLANT, EQUIPMENT SERVICES AND MATERIALS BY OWNER/CONTRACTOR
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
11
10


11
10
NO
HAVE ALL QUESTIONS REGARDING "P" BEEN ANSWERED ?
YES
ASK INPUT QUESTIONS REGARDING "Q"
"Q" = ALTERNATE TENDERS
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
NO
HAVE ALL QUESTIONS REGARDING "Q" BEEN ANSWERED ?
YES
ASK INPUT QUESTIONS REGARDING "R"
"R" = PROTECTION OF PROJECT SURROUNDS
RESPONSE BY USER
COMPUTE PROBABILITY OF CHOICES OF RESPONSE
NO
HAVE ALL QUESTIONS REGARDING "R" BEEN ANSWERED ?
YES
ASK INPUT QUESTIONS REGARDING "S"
"S" = MEASUREMENT PROBLEMS RELATED TO WATER
RESPONSE BY USER
13
12

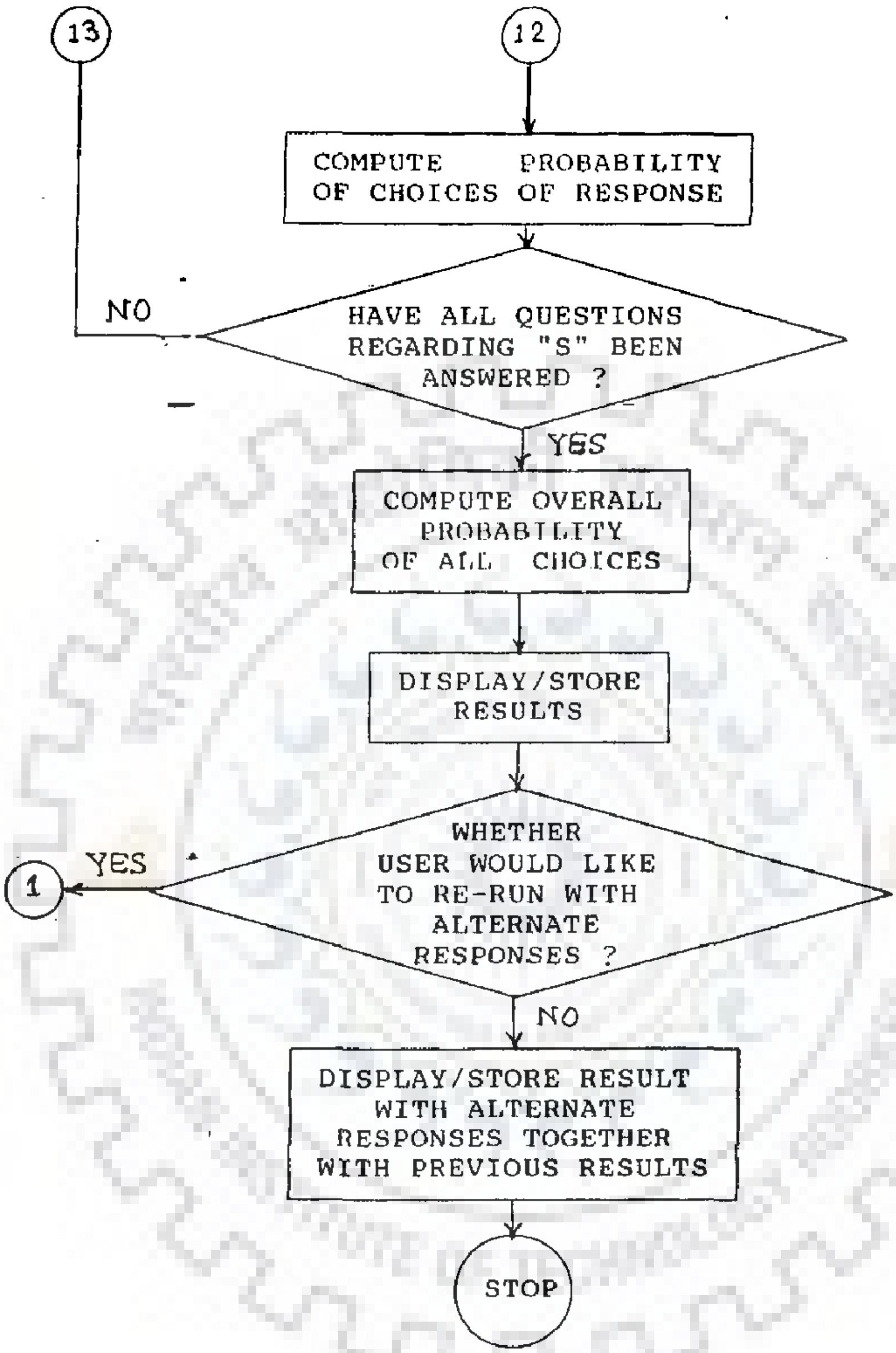


Fig. 6.1. Flow chart of Expert System - "ESSOR".

Sharing Of Risks" has been felt for assessing whether the sharing of risks between the various parties to the tunnelling contract has been equitable or not. A knowledge based expert system with IF-THEN production rules has been compiled from various literature available on risk management and discussions with different tunnelling experts. The expert system has been developed to determine whether the risks have been shared equitably by the different agencies responsible for the tunnel construction. The computer program usable on a personal computer may be used by the owner and the contractor, before, during or after the construction regarding the sharing of risks. ESSOR includes 1798 knowledge-based rules in the form of IF-THEN rules utilising a computer software EXSYS - a commercially available expert system package or shell. A sample output of a few rules of ESSOR are included in Appendix D. The complete knowledge base is included in this thesis in the form of a floppy disk which is write protected. The clauses or provisions in a tender/contract document will either benefit or adversely affect the interests of the parties involved in any underground construction: owner, contractor, engineer, geologist and insurer. The provisions can be fed into the expert system ESSOR, which will indicate at the end whether the sharing of risks has been equitable or not. The contract documents of two projects: Project A and Project B which involved tunnel construction, have been studied and the contract clauses fed into ESSOR.

The expert system has been explained by flow diagrams. It is a user friendly package suitable for training management officers and trainees for preparing contract documents and in improving existing management conditions.

A typical question asked by the computer while executing the package EXSYS ESSOR will be, say:

" A changed conditions clause in the tunnelling contract is

(1) incorporated

(2) not incorporated

(3) ... don't know/can't say".

The user may select any one or more of the above choices: (1), (2) and/or (3), which will be used by the computer for its inference. In fact, these are the IF parts of different knowledge based rules. If the user is not sure what should be his choice he may type "WHY 1" at the prompt of the cursor and the computer will display the actual rule as:

"Rule number 2:

If (1) a changed conditions clause in the tunnelling contract is incorporated

Then (1) the best long term interests of both owners and contractors will be served

and the sharing of risks is not equitable - probability = 1/10

and the risk is shared by the contractor - probability = 5/10

and the risk is shared by the owner - probability = 5/10

Note: The International Tunnelling Association recommends a changed conditions clause be incorporated in all tunnelling contracts.

Reference: "ITA Recommendations on Contractual Sharing of Risks", Tunnelling and Underground Space Technology, Vol 3, No 2, pp 103-140, (1988)."

With (2) as the user's choice the relevant rule reads as:

"Rule number: 249

If (1) a changed conditions clause in the tunnelling contract is not incorporated

Then (1) the best long term interests of both owners and contractors will not be served

and sharing of risks will not be equitable - probability = 9/10".

And, if the user responds with (3), the relevant rule reads as:

"Rule number: 1357

If (1) a changed conditions clause in the tunnelling contract is ... don't know/can't say

Then (1) there is no effect/repurcussion".

The knowledge based rule will have an optional NOTE and REFERENCE text for the information of the user. By the forward and backward chaining capability of the EXSYS computer package, the computer will ask further questions based on the responses selected by the user, say (1), (2) and/or (3). All the responses by the user will be utilised by the program to compute the final output of the run.

If the user feels he should have selected one or more or the alternate choices or he wishes to know the outcome with the alternate responses, he may rerun the program by pressing any appropriate number/s for the input of the first run. The computer will again present the IF part of the original question as above and the user may make his alternate choice/s. By pressing 'R', the computer will again compute and display the final output.

A typical output of the test run is as follows:

"Sharing of risks is not equitable: probability = 1/10
"The risk is shared by the owner: probability = 5/10
"The risk is shared by the contractor: probability = 5/10".

If the user wishes the computer to display the output of the previous run and the second run with alternate responses/choices, he may give appropriate instructions to the computer and the computer will display the results of the two runs, i.e., the current run and the previous run.

The knowledge based rules are so framed that ITA recommendations form one of the choices. The second choice is one that is contradictory to that particular recommendation. The third choice is "... don't know/can't say" in case the user or a beginner does not find any appropriate clause/provision in the tender/contract document or he is not sure what his choice should be (whether 1 or 2).

In any test run, the computer will ask and process approximately 50 to 60 % of the knowledge base for its inference and compute the average of the probability values and list them out as the final result. A test run of ESSOR takes about 20 minutes at the terminal for entering the responses and obtaining the result. At the end of the test run - ESSOR - will give the message: "The sharing of risks between the various parties connected with the project shows the outcome of the contract and how it will benefit them".

6.3. APPLICATION OF "ESSOR" ON TUNNELLING PROJECTS

The expert system - ESSOR - has been test run for purpose of illustration with the assumed contract conditions of two projects: Project A and Project B comprising tunnel construction. These contract conditions are given in Appendices E and F. The sample output of a test run of ESSOR is presented in Appendix G along with the test results of the run in Fig. G-1.It is found that the sharing of risks has been effected in the following manner for Project A:

1. The sharing of risks is not equitable: Probability = 7/10
2. The risk is shared by the contractor: Probability = 3/10
3. The risk is shared by the owner: Probability = 7/10

The results for application on Project B are as below:

1. The sharing of risks is not equitable: Probability = 6/10
2. The risk is shared by the contractor: Probability = 4/10
3. The risk is shared by the owner: Probability = 6/10.

The results are shown in Table 6.1.

Table 6.1 Sharing of risks

Risks shared	Sharing of risks	
	Project A	Project B
1. The sharing of risks is not equitable	7/10	6/10
2. The risk is shared by the contractor	3/10	4/10
3. The risk is shared by the owner	7/10	6/10

Fig. 6.2 depicts the histogram of the risks shared on projects A and B and shown in Table 6.1. The variation in the inequitable sharing of risks in the two projects is found to be due to difference in contract clauses of the two projects. In both projects the contractor was to take insurance for third party risks of claims and demands. However, in Project A the claims and demands have been qualified by the phrase "just or unjust", whereas in Project B there is no such qualifying phrase which may put the contractor on his guard while quoting his rates. Further, no clause to cover special risks was included in the contract document of Project B though it was there in the document of Project A.

The effect of risks not being shared equitably is given by Rule Number 552 which reads:

"If:

(1) Sharing of the risk/risks is not equitable

Then:

(1) It may lead to disputes".

From Fig. 6.2, it is clear that sharing of risks is not equitable

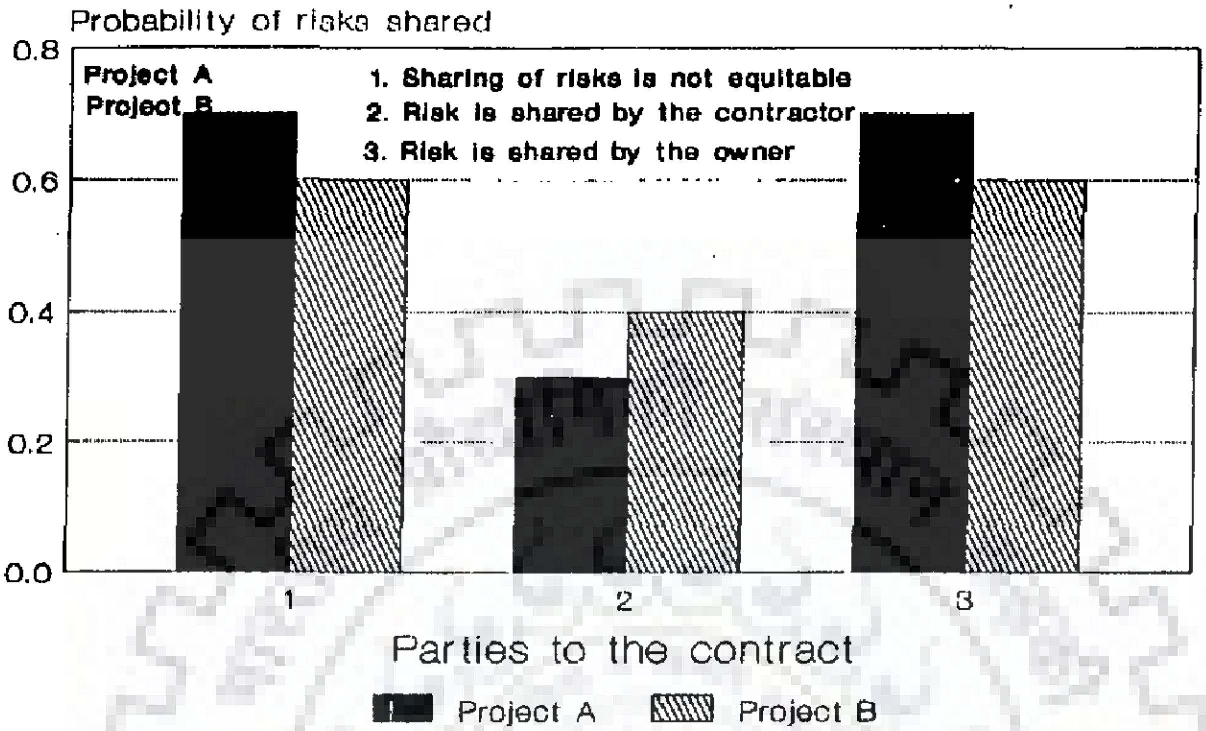


Fig. 6.2. Histogram of risks shared on Projects A and B.

in either of the projects, viz., Project A and Project B. Thus, there is every likelihood of disputes arising after the execution of the tunnel contract.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1. DISCUSSION OF RESULTS AND CONCLUSIONS

From this study, the following conclusions may be drawn.

7.2. MANAGEMENT PARAMETERS

The relative importance of the various management parameters in improving rates of tunnelling has been derived from an opinion poll of tunnelling experts representing both owners (government) and contractors. Histograms have been drawn from the statistics collected from a questionnaire circulated among 37 experts and shown in Figs. 3.4 through 3.22. The various management factors in tunnel construction have been ranked according to their importance for three types of tunnels: (A) short tunnels ≤ 500 m; (B) long tunnels in good or poor rock conditions; and (C) long tunnels in very poor rock or poor environmental conditions.

7.3. EXPERT SYSTEM FOR RISK SHARING

(1) The best strategy is to draw contracts that are fair and equitable, to administer them in the same spirit, to perform them honestly and expeditiously and above all for achieving and maintaining good owner-engineer-contractor relationship.

(2) The expert system methodology may be used to determine the extent of risks shared between the owner, the engineer, the contractor, the geologist and the insurer.

(3) The expert system ESSOR (Expert System for Sharing Of Risks) has been developed using 1798 knowledge based rules on the basis of the recommendations of ITA for contractual sharing of risks and experts in the field of tunnelling. The knowledge based rules have been enclosed with this thesis on a floppy disk.

(4) The contractual practices for two sample tunnelling

projects: Project A and Project B have been evaluated by ESSOR for purpose of illustration. It is found that the owner's share of the risks is higher than the contractor's in either case.

(5) The inequitable sharing of risks in the two projects is due to difference in contract clauses of the two projects. In both projects the contractor was to take insurance for third party risks of claims and demands. However, in Project A the claims and demands have been qualified by the phrase "just or unjust" with the result that the contractor is put under greater risk. A natural consequence of this is that he may quote higher rates for the work. In Project B, since there is no such qualifying phrase, the contractor has to bear lesser degree of risk. This is shown by the values given in Table 6.1 where the degree of inequality in risk sharing between the two parties is smaller for Project B than for Project A.

The degree of inequality is more for Project A also due to the fact that a clause to cover special risks is included in contract document of Project A while there is no such clause for Project B.

(6) The Expert System may be used to educate construction engineers and the owners of tunnelling projects and others involved on how to improve the contract documents for mutual benefit of all concerned.

7.4. CONCLUSIONS

The illustration of risk sharing among two assumed projects, viz., Project A and Project B analysed using ESSOR is found to indicate that the sharing of risks is directly affected by conditions of contracts for construction of tunnels. By a judicious selection of contract conditions for construction of tunnelling projects, it would be possible to ensure equitable sharing of risks among the parties involved. This may result in reducing the project cost and construction time as also litigation which is found to be a common occurrence in such projects.

The study is an attempt to indicate a new direction in contract management for construction of tunnels.

7.5. RECOMMENDATIONS FOR FURTHER WORK

The study has revealed some problem areas where further research seems to be necessary. They are:

A. General:

1. No guide lines are available for energy management,

2. No reports are available on management consultancy in tunnelling,

3. Causes of failure to achieve projected targets should be determined, particularly, in tunnels in the Himalayan region,

4. There is an urgent need to update technology of tunnelling in India,

5. No guidelines are available to suggest a reasonable amount of pre-bid investigations desirable in the Himalayas, which are noted for their geological complexities,

6. The type of contract best suited to all circumstances of a tunnelling project should be evolved,

7. Systematic documentation of causes of delays, type and duration of delays, phase of project in which delays occurred, should be carried out with recommendations for prevention of delays,

8. Actions to be considered by owners in an attempt to increase efficiency and productivity of underground construction projects need to be reported,

9. Factors favouring management of planning, design and construction by a single contractor (as opposed to separate firms

for design and construction management) need to be studied,

10. Suggestions to increase productivity of team members on a tunnel project (owners, design engineers, contractors, construction managers, and construction employees) need to be reported,

11. Organisation structure for long and short tunnels needs to be examined,

12. Improvements in contracting practices which are expected to have a strong influence on decisions affecting tunnel construction should be studied,

13. A satisfactory procedure for sharing inflationary effects should be evolved,

14. The extent of disclosures of subsurface information for prospective bidders needs to be studied, and

15. The acquisition of data and their availability after completion of the project should be ensured.

B. Specific to this study:

1. The management factors must be reviewed from time to time to establish their relative importance as newer factors come to light as in the case of energy management in this study,

2. Interrelationships, if any, between the various management factors should be established,

3. A comprehensive expert system should be developed for all the twenty management factors as identified in Fig. 3.1,

4. ESSOR should be improved from time to time as more feed back from user agencies become available,

5. ESSOR should be updated to include other factors related to contractual sharing of risks that may be identified later,

6. Correlation between probability of inequitable sharing

of risks with likely increase in cost should be evolved,

7. The recommendations of ITA regarding contractual sharing of risks should be modified for Indian conditions where the contracts involve only two parties - the owner (which is the government) and the contractor, and

8. *More tunnelling contracts should be studied* to establish the validity of the proposed method.

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ANNEXURE – A

Part I Summary of Management Factors In Tunnel Construction

Note : Please give for each of the factors listed below, in the three cases, a rank serially between 1 and 20 which in your opinion is appropriate considering its importance in tunnel construction. Least important factor may be given a rank of 1, and the most important factor a rank of 20, i.e. in the ascending order of importance.

Sl No	Management Factors	Ranking for: Short tunnels (less than 500m)	Ranking for: Long tunnels: Good or poor rock conditions	Ranking for: Long tunnels: Very poor rock and environment conditions
1	2	3	4	5
1	Job planning			
2	Selection of plant and equipment			
3	Equipment availability and preventive maintenance			
4	Co-ordination			
5	Organisation structure (departmental and contractor)			
6	Operation supervision			
7	Training of personnel			
8	Rapport			
9	Sincerity and punctuality of staff			
10	Incentive to workmen			
11	Environmental conditions and housekeeping			
12	Health and safety in work			
13	Sharing of risks			
14	Material management			
15	Financial management			
16	Instrumentation programme			
17	Mistakes in planning and construction			
18	Monitoring activities in tunnelling			
19	Data management systems			
20	Any other factor (please specify)			

Signature
Name
Designation
Address

STATE-OF-THE-ART EXPERT SYSTEMS IN CONSTRUCTION
(Mohan, 1990)

(a) Name of Expert System
(b) System input
(c) System output
(d) Knowledge structure, tools, developer organisation, and key contact

---

(A) Operational Expert Systems

1. (a) WELDING ADVISOR
   (b) Type of materials involved; Weld geometry
   (c) Estimate of welding supplies; Any special-equipment list; Appropriate welding procedure
   (d) Rule-based (150 rules); IBM PC-class microcomputer; LOTUS 1-2-3; K.Reinschmidt, Stone Webster Engineering Corp.(SWEC) Boston, Mass. 6 man-months.

2. (a) WELDING DEFECT ADVISOR
   (b) Weld procedure; Code requirements; Site conditions; Conditions of failed weld
   (c) Causes of weld defects; Individual defects; System defects; Advice to prevent poor welds
   (d) Rule-based (150 rules); IBM PC-class; EXSYS shell; K. Reinschmidt, SWEC, Boston, Mass. 6 man-months.

3. (a) KNOW-HOW Transfer Method
   (b) Work packages; Risks
   (c) Possible risks; Risk reduction
   (d) HITAC M-200 (Hitachicomputer) PROLOG; K.Niwa, Advanced Research Lab, Hitachi Ltd., Japan.

4. (a) SAFEQUAL
   (b) Accident experience; Safety-management practices
   (c) Prequalification of contractors
   (d) IBM PC; Deciding Factor; R.E.Levitt, Building Knowledge Systems, Inc. Stanford, Calif.

5. (a) HI-COST; Cost Estimating from Preliminary Design
   (b) Preliminary design alternatives
   (c) Cost estimate based on preliminary design
   (d) PSRL, LISP AND C; Carnegie Mellon Univ., Pittsburgh, Pa.

6. (a) HOWSAFE: Safety Analysis System
   (b) Personnel procedures
   (c) Social safety rating of a construction firm
   (d) IBM PC; Deciding Factor; R.E.Levitt, Stanford Univ., Stanford, Calif.

7. (a) PUMP PRO: Centrifugal Pump Failure Diagnosis
   (b) Data on the pump condition, etc.
   (c) Identification of the symptoms and causes of pump failure; Tutorials on microcomputers; Suggestions for remedies

(d) Rule-based; MAIDS AI language, G.Finn, SWEC; Boston, Mass.

(B) Operational Prototypes

8. (a) BERT - Brickwork ExpeRT
(b) Design of brickwork cladding; Brick data base (Graphical form)
(c) Comments on design quality; Suggestions for improvements; Best design solution
(d) IBM PC, AutoCAD, MUFL; J.Bowen et al, Dept. of Constr. Management & Computer Science, Univ. of Reading, U.K.

9. (a) MASON
(b) Basic duration estimate; Crew size; Quality of materials
(c) Masonry-construction duration; Recommendations for crew composition; Maximum-productivity estimate
(d) Heirarchical, Rule-based; OPS5; C.Hendrickson et al, Civil Engineering, Carnegie Mellon Univ., Pittsburgh, Pa.

10. (a) CRANES
(b) Site plan
(c) Possible crane locations; Crane size and type; Cost of alternative solutions
(d) AMDAHL., and PDP-11: PROLOG, C.Gray et al, Dept. of CM, Univ. of Reading, U.K.

11. (a) PROPICK - Selection of a Contract Type
(b) Project objective
(c) Conflicts in project objectives; Appropriate form of contract
(d) PC, Deciding Factor; D.S.Barrie, CM consultants, Diablo, Calif.

12. (a) DSCAS - Differing Site Conditions Analysis System
(b) Differing site conditions
(c) Entitlement with justification; No entitlement
(d) Rule-based; IBM PC; ROSIE; Diekmann, Univ. of Colorado, Colo., and US Army CERL, Champaign, Ill.

13. (a) PLATFORM
(b) Activity name, duration, successors, and potential risks
(c) Automated schedule updating
(d) Frames & rules; XEROX 1108; KEE; R.E.Levitt, Stanford Univ. and J.Kunz, IntelliCorp, Calif.

14. (a) PLATFORM - III
(b) Project data
(c) Project feasibility under certainty
(d) Frames; XEROX 1108; KEE; R.E.Levitt, Stanford Univ. & J.Kunz, IntelliCorp, Calif.

15. (a) Predicting Time and Cost of Construction During Initial Design
(b) Activity details and resources
(c) Time and cost of activities

(d) IBM PC; PROLOG; C.Gray, Dept. of CM, Univ. of Reading, UK.

16.(a) Military Construction Army-Cycle Analysis
(b) Data on army facilities
(c) Status of each project
(d) IBM PC; GC LISP; R.D.Locher, MIT and S.Kappes, US Army, CERL, Champaign, Ill.

17.(a) Construction Schedule Analysis
(b) Project and activities data
(c) Status of project schedule; Revision of activity durations
(d) IBM PC, PERSONAL CONSULTANT PLUS; W.East, US Army, CERL, Champaign, Ill.

18.(a) CALLISTO: An Intelligent Project Management System (For Large Projects)
(b) Project knowledge; Activity duration; precedence; resources; project constraints
(c) Constraint-directed negotiated approaches to activity management, resource management, configuration management
(d) KNOWLEDGECRAFT; A.Sathi, Carnegie Group, Pittsburgh, Pa.

19.(a) Interpreting Collective Agreements in the Building Industry
(b) Type of absence; Sick-child care; Work accident; Normal sickness; Definition of extre holidays in the agreement
(c) Amount of sickness pay of the employee
(d) Rules; PC; GURU & INSIGHT2+; J.Jonni, Tech Research Centre (VTT), Itatuulentie 2, Finland

20.(a) ELSIE; Expert System for Strategic planning of Construction Projects
(b) Client's Project scope; Client's needs; Aesthetics and quality; Design flexibility; Environmental factors; Client's brief
(c) Initial budget; Procurement options; Optimum project durations; Profitability of the project
(d) SAVIOUR shell; IBM PC/AT; P.Bradon, Univ. of Salford, U.K.

21.(a) CGS-DSC: A Claims Guidance System - Differing Site Condition Claims
(b) Final-payment status; Claimed conditions; Site conditions; Contract provisions
(c) Contractor's chance of entitlement with explanation
(d) PC; PERSONAL CONSULTANT PLUS; M.Kim, US Army, CERL, Champaign, Ill.

(c) Developmental Expert Systems

22.(a) SITEPLAN: Layout of Temporary Construction Facilities
(b) Available space
(c) Project-site layout; Updating of site plan

(d) Blackboard Architecture; XEROX 1108 7 1186; KEE; I.Tommelin Civil Engg., Stanford Univ., Stanford, Calif.

23.(a) IPMS85/2: Intelligent Project Management System
(b) Job time and cost monitoring data
(c) Evaluation of project personnel
(d) Rule-based, IMST written in LISP, R.D.Locher, MIT, Mass.

24.(a) CPO-ES: Construction Project Organisation Design
(b) Project details
(c) Appropriate project organisation; Evaluation of existing project organisation
(d) PC; Deciding Factor; Rudolf Burger Motor Columbus Consulting Engineers, Inc., Baden, and ETH, Zurich, Switzerland.

25.(a) ICT: Time Estimating System
(b) Loose definition of project scope
(c) Project-time estimate
(d) DEC mainframe; DEC's new AI developmental language; Alan Stretton, Civil & Civic, Australia and DEC, USA.

26.(a) KB for Repeating Construction Project Success
(b) Project details; Resource constraints; Project objectives; Strategy under consideration
(c) Preferred planning and execution strategy; Likelihood of success
(d) Microcomputer; M-1 shell; D.B.Ashley; Univ. of Texas, Austin, Tex.

27.(a) Risk Management Expert System
(b) Project details
(c) Project risks
(d) Rule-based; PC; INSIGHT2+; R. Kangari; Civil Engg., Georgia Inst. of Tech., Atlanta, Ga.

28.(a) IRIS: Intelligent Construction Risk Identification System
(b) Project data
(c) Identification of risks on a construction project
(d) Microcomputer; M-1 shell; D. Ashley; Civil Engg., Univ. of Texas, Austin, Tex.

29.(a) Vertical Construction Schedules
(b) Project data
(c) Correctness of a given schedule
(d) Frame-based; T1 Explorer & IBM PC/AT; ART, Primavera; C.W.Ibbs; Univ. of Illinois and US Army CERL.

30.(a) Maintenance Advisor for Old Elevators
(b) Data of malfunctioning elevators
(c) Diagnosis and suggested repair strategy for malfunctioning elevator
(d) IBM PC; Expert-Ease shell; A. Stretton, Elevators Pvt. Ltd. Australia.

:

31.(a) CONSTRUCTION PLANEX
(b) Project data
(c) Project activities, duration estimates, network; Cost estimates; Cost schedules; Appropriate technology; High-rise buildings: activity planning assocaited with site preparation, excavations, foundation construction, and structural erection

(d) Frames; TI Explorer; Knowledgecraft on Common LISP; C.Hendrickson, Civil Engineering, Carnegie Mellon Univ., Pittsburgh, Pa.

32.(a) GHOST: A Project Schedule Generator
(b) Set of construction activities
(c) Precedence among activities; Project schedule
(d) Blackcoard architecture; IMST framework - an ES environment developed at MIT, LISP; R.D.Locher, MIT, Mass.

33.(a) Expert System for Repainting of Wooden Facades
(b) Category of deterioration; Type of previous paint; Current paint brands
(c) Types of paint to be used
(d) ES/P Advisor and INSIGHT+2; PC; 70 rules; 4 man-months, Tech. Res. (VTT), Itatuulentie 2, Finland.

34.(a) Expert System for Choosing the Type of Ready-Mix Concrete
(b) Environmental class; Water-impermeability requirements; Frost-proof requirements; Corrosion-proof requirements; Spacing between rebars; Type of structure; Compressive strength class; Production equipment
(c) Warning if compressive-strength requirement is too low; Recommendations about appropriate concreting techniques; Information about the use of admixtures; Maximum size of aggregates
(d) PC; INSIGHT2+; 189 rules; Tech. Res. Centre, (VTT), Itatuulentie 2, Finland.

35.(a) FDES: Failure Diagnosis Expert System (Construction errors)
(b) Component properties; Component geometry; Loading conditions; Postfailure appearance
(c) Causes of failure; Type and extent of failure; Design errors; Failure-trigerring events
(d) Microcomputer; EXSYS shell; F.C. Hadipriano, Civil Engg., Ohio State Univ., Columbus, Ohio.

36.(a) Expert System for the Construction and the Resolution of Multicriteria Dwelling Design Problems
(b) Representation of the building project
(c) Design parameters with the following viewpoints: Architectural; Acoustical; Thermal; Economical
(d) PC; PROLOG; Rule-based interfaced with CAD'X2A'; P.Le Gauffree, Institut National Des Sciences Appliques De Lyon, 69621 Villeurbanne, Codex, France.

37.(a) ESEMPS: Expert System for Earth Moving Plant Selection
(b) Task definition, soil type, topography; Job condition
(c) Best equipment type; Best equipment make; Best equipment size; Cost of recommended equipment
(d) PC; SAVOIR shell; Rule-based; F.Harris, The Polytechnic, Wolverhampton, U.K.

HARDWARE USED IN EXPERT SYSTEMS DEVELOPMENT
(Mohan, 1990)

Hardware	Number of expert systems that used it
IBM PC class of microcomputer	24
XEROX 1108/1110	3
T1 Explorer	2
DEC Mainframe	1
PDP - 11	1
Hitac M-200	1
Other LISP machines	5
Total	37

APPENDIX B-3

DISTRIBUTION OF SOFTWARE USED IN EXPERT SYSTEMS DEVELOPMENT
(Mohan,1990)

Expert system language/shell	Number of expert systems using it
1.Expert-system shells	
DECIDING FACTOR	4
INSIGHT2+	2
M-1	2
EXSYS	2
PERSONAL CONSULTANTS PLUS	2
SAVOIR	2
EXPERT-EASE	1
ROSIE	1
GURU	1
ES/P Advisor	1
Subtotal	18
2.Expert-system environments	
KEE	3
KNOWLEDGECRAFT	2
ART	1
OPS5	1
Subtotal	7
3.AI programming languages	
PROLOG	4
LISP	3
Subtotal	7
4.Other / proprietary languages	5
Total	37

CONSTRUCTION AREAS COVERED IN STATE-OF-THE-ART EXPERT SYSTEMS
(Mohan, 1990)

Broad area covered	Number of expert systems
1. Project planning, scheduling, and control	11
2. Project management	9
3. Construction management	6
4. Equipment management	4
5. Legal issues	3
6. Human-resources management	2
7. Concrete-mixing and placement	1
8. Temporary-facilities layout	1
Total	37

APPENDIX C

USER'S INSTRUCTIONS AND INFORMATION FOR THE EXPERT SYSTEM "ESSOR"

C.1. MINIMUM HARDWARE REQUIREMENTS

System Unit: IBM PC, XT, AT or any compatible 320 K RAM* (640 K RAM preferable) DOS 2.0 or higher

Disk Drive: One floppy disk drive** (Two floppy disk drives and a hard disk preferable).

* *The full available memory is required. EXSYS needs an* extra 64 K for every 700 rules, each with about 6 to 7 conditions. A knowledge based expert system with 5000 rules can be run on an IBM PC with 640 K RAM.

** It is preferable to use the program EXSYS with a hard disk. However, a second floppy drive is advantageous.

Monitor: Monochrome or colour/graphic display.

Printer: Necessary to prepare the report/results.

C.2. PROGRAM AND DATA DISKETTES

Program Disk

The EXSYS package comprises three diskettes: RUNTIME, EDITOR and UTILITY. For running the expert system "ESSOR", only the RUNTIME DISKETTE (copy protected) is required.

The knowledge base files developed are contained on other diskettes.

ESSOR.RUL: The file contains the rules of the expert system

ESSOR.TXT: The file contains all text information, for example; NOTES, REFERENCES, etc.

These diskettes cannot be write-protected.

C.3. DATA DISK

If a hard disk and two floppy disk drives are available, then it is desirable to use a separate data diskette. The data diskette should be formatted and must always be put in Drive B:.

When the user is running the expert system and replying the interactive questions, the user can quit the system and save up the input data to a file named by the user using the command "QUIT". The data disk will usually contain files and in this case, program diskette cannot be write-protected.

C.4. USER GUIDE FOR RUNNING THE EXPERT SYSTEM

To run expert system "ESSOR", the user must place the backup copies of the EXSYS RUNTIME diskette in Drive A: and the knowledge base diskettes with "ESSOR.RUL" and "ESSOR.TXT" copied onto the hard disc, Drive C: or go to the directory with "ESSOR.RUL" and "ESSOR.TXT" in Drive A: and data diskette in Drive B: (if available). Then the user can type in either

EXSYS

or

EXSYS Drive: ESSOR.

If the user types EXSYS only, the system will ask them to input the knowledge base he wishes to run. The user must then answer giving fully the drive and path designator.

Since the expert system is interactive, the user can read the instructions displayed on the monitor by the system and work with them.

If the user desires to have a hard copy of the run, then he must set the printer ready for the printing.

When the user wishes to quit the system and save up the data for later use, he may type "QUIT" to answer the question (refer the instructions given on the screen).

For more detailed information, the user may refer to the EXSYS - User's Manual (Research Group, 1986).

C.5. RULES MODIFICATION

In order to be able to modify the rules in the expert system "ESSOR", the user must first learn the format of the rules, procedures for creating and modifying the rules and the use of the editor provided by the EXSYS package in the EDITOR diskette.

To run the editor, the user should insert the EDITOR diskette of EXSYS package in Drive A: and the knowledge base diskette with "ESSOR" in Drive B: or go to a directory containing EDITXS.EXE on the hard disk (C:) and place the knowledge base diskette with "ESSOR" in Drive A:. Then the user can type in either

EDITXS

or

EDITXS Drive: ESSOR.

If the user types just EDITXS, the system will ask him to input the knowledge base that he wishes to edit. The user must then answer giving fully the drive and path designator.

Once, the user enters the editor, he can modify or add or delete or rearrange the order of the rules as he likes using the instructions displayed on the monitor and the User's Manual.

ANNEXURE D

ESSOR - SAMPLE OUTPUT OF KNOWLEDGE BASE

Subject:
EXPERT SYSTEM FOR SHARING OF RISKS - "ESSOR"

Author:
H.S.BADARINATH

Starting text:
THIS EXPERT SYSTEM REVEALS WHETHER A TUNNELLING CONTRACT HAS THE RISKS OF THE PROJECT JUSTLY AND FAIRLY SHARED BETWEEN THE OWNER, THE ENGINEER, THE CONTRACTOR AND THE GEOLOGIST RESPONSIBLE FOR THE EXECUTION OF THE PROJECT. EQUITABLE SHARING OF RISKS BENEFITS ALL THE PARTIES TO THE CONTRACT AND CONCERNED WITH THE PROJECT, LEADING TO COMPLETING THE PROJECT WITHIN REASONABLE TIME AND EXPENDITURE.

Ending text:
THE SHARING OF RISKS BETWEEN THE VARIOUS PARTIES CONNECTED WITH THE PROJECT SHOWS THE OUTCOME OF THE CONTRACT AND HOW IT WILL BENEFIT THEM. IN THE PRESENT CASE THE SHARING OF RISKS HAS BEEN EFFECTED IN THE FOLLOWING MANNER:

Uses all applicable rules in data derivations.

RULES:

RULE NUMBER: 1

IF:

THE DEGREE THAT OUR VALUE PLACES THE BENEFIT OF USE HIGHER THAN THE RISK

THEN:

IT IS SAID TO BE SAFE RELATIVE TO THE EXTENT TO WHICH WE UNDERSTAND RISKS INVOLVED
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10
and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 2

IF:

A CHANGED CONDITIONS CLAUSE IN THE TUNNELLING CONTRACT IS INCORPORATED

THEN:

THE BEST LONG TERM INTERESTS OF BOTH OWNERS AND CONTRACTORS MAY BE SERVED
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10
and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

NOTE:
THE INTERNATIONAL TUNNELLING ASSOCIATION RECOMMENDS A CHANGED CONDITIONS CLAUSE BE INCORPORATED IN ALL TUNNELLING CONTRACTS.

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 3

IF:

A CHANGED CONDITIONS CLAUSE IN THE TUNNELLING CONTRACT IS INCORPORATED

THEN:

SUCH A CLAUSE INDUCES CONTRACTORS TO AVOID INCLUDE LARGE CONTINGENCY SUMS IN THEIR TENDERS TO COVER THE RISK OF ENCOUNTERING ADVERSE GROUND CONDITIONS
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10
and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

NOTE:

THE INTERNATIONAL TUNNELLING ASSOCIATION RECOMMENDS A CHANGED CONDITIONS CLAUSE BE INCORPORATED IN ALL TUNNELLING CONTRACTS.

REFERENCE:

"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 4

IF:

A CHANGED CONDITIONS CLAUSE IN THE TUNNELLING CONTRACT IS INCORPORATED

THEN:

THE OWNER DOES NOT HAVE TO PAY A WINDFALL PRICE WHEN ONLY NORMAL CONDITIONS ARE ENCOUNTERED AND HE PAYS AS IF THE TRUE CONDITIONS WERE ORIGINALLY KNOWN
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10
and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

NOTE:

THE INTERNATIONAL TUNNELLING ASSOCIATION RECOMMENDS A CHANGED CONDITIONS CLAUSE BE INCORPORATED IN ALL TUNNELLING CONTRACTS.

REFERENCE:

"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 5

IF:

A CHANGED CONDITIONS CLAUSE IN THE TUNNELLING CONTRACT IS INCORPORATED

THEN:

THE CONTRACTOR DOES NOT SUFFER ANY DISASTER WHEN UNANTICIPATED CONDITIONS ARISE
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10

and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

NOTE:
THE INTERNATIONAL TUNNELLING ASSOCIATION RECOMMENDS A CHANGED CONDITIONS CLAUSE BE INCORPORATED IN ALL TUNNELLING CONTRACTS.

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 6

IF:
A CHANGED CONDITIONS CLAUSE IN THE TUNNELLING CONTRACT IS INCORPORATED

THEN:
BOTH PARTIES, i.e. THE OWNER AND THE CONTRACTOR, FURTHER BENEFIT BY THE CREATION OF A PROCEDURE TO CONVEY INFORMATION FOR RESOLVING DISPUTES BY NEGOTIATION RATHER THAN LITIGATION
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10
and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

NOTE:
THE INTERNATIONAL TUNNELLING ASSOCIATION RECOMMENDS A CHANGED CONDITIONS CLAUSE BE INCORPORATED IN ALL TUNNELLING CONTRACTS.

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 7

IF:
UNKNOWN CONDITIONS, NOT NORMALLY EXPECTED, ARE ENCOUNTERED

THEN:
AN ADJUSTMENT IN THE CONTRACT PRICES IS REQUIRED TO BE MADE
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 9/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 3/10
and THE RISK IS SHARED BY THE OWNER - Probability= 7/10

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

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and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

NOTE:
THE INTERNATIONAL TUNNELLING ASSOCIATION RECOMMENDS A CHANGED CONDITIONS CLAUSE BE INCORPORATED IN ALL TUNNELLING CONTRACTS.

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 6

IF:
A CHANGED CONDITIONS CLAUSE IN THE TUNNELLING CONTRACT IS INCORPORATED

THEN:
BOTH PARTIES, i.e. THE OWNER AND THE CONTRACTOR, FURTHER BENEFIT BY THE CREATION OF A PROCEDURE TO CONVEY INFORMATION FOR RESOLVING DISPUTES BY NEGOTIATION RATHER THAN LITIGATION
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10
and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

NOTE:
THE INTERNATIONAL TUNNELLING ASSOCIATION RECOMMENDS A CHANGED CONDITIONS CLAUSE BE INCORPORATED IN ALL TUNNELLING CONTRACTS.

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 7

IF:
UNKNOWN CONDITIONS, NOT NORMALLY EXPECTED, ARE ENCOUNTERED

THEN:
AN ADJUSTMENT IN THE CONTRACT PRICES IS REQUIRED TO BE MADE
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 9/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 3/10
and THE RISK IS SHARED BY THE OWNER - Probability= 7/10

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 8

IF:

A CHANGED CONDITIONS CLAUSE IN A TUNNEL CONTRACT IS INCLUDED

THEN:

THE RESULTING CONSTRUCTION COSTS MAY BE LOWERED
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10
and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 9

IF:

A CHANGED CONDITIONS CLAUSE IN A TUNNEL CONTRACT IS INCLUDED

THEN:

THERE MAY BE MORE NUMBER OF CONTRACTORS WILLING AND FINANCIALLY ABLE TO ENGAGE IN SUCH WORK
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10
and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 10

IF:

A CHANGED CONDITIONS CLAUSE IN A TUNNEL CONTRACT IS INCLUDED

THEN:

UNDERGROUND RISK CONTINGENCY COST FROM TENDERS MAY BE ELIMINATED
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10
and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 11

IF:

A CHANGED CONDITIONS CLAUSE IN A TUNNEL CONTRACT IS INCLUDED

THEN:

THE OWNER PAYS LESS FOR THE COMPLETED PROJECT AND RECEIVE ACTUAL MONEY VALUE FOR WHAT WAS CONTRACTED TO BE CONSTRUCTED

and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10

and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10

and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

REFERENCE:

"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 12

IF:

FULL DISCLOSURE OF ALL AVAILABLE SUBSURFACE INFORMATION, INCLUDING BOTH FACTUAL AND INTERPRETATIVE DATA IS MADE TO THE TENDERERS

THEN:

THE INCORPORATION OF A CHANGED CONDITIONS CLAUSE IN A TUNNEL CONTRACT IS CONSISTENT WITH THE DISCLOSURE

and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10

and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10

and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

NOTE:

THE INTERNATIONAL TUNNELLING ASSOCIATION RECOMMENDS THAT ALL AVAILABLE SUBSURFACE INFORMATION INCLUDING BOTH FACTUAL AND INTERPRETATIVE DATA, BE FULLY DISCLOSED TO BIDDERS FOR ALL TUNNELLING CONTRACTS.

REFERENCE:

"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 13

IF:

A REASON IS SOUGHT FOR DISCLOSURE OF INFORMATION

THEN:

THE OWNER IS THE ONLY PERSON WHO HAS ADEQUATE TIME TO SUFFICIENTLY EXPLORE, ANALYSE AND STUDY AVAILABLE SOURCES OF INFORMATION REGARDING UNDERGROUND CONDITIONS

and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10

and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 14

IF:

THE CONTRACTORS ARE REQUIRED TO CARRY OUT EXPLORATION, ANALYSE AND STUDY INFORMATION REGARDING UNDERGROUND CONDITIONS FOR EVERY PROJECT THEY SUBMIT TENDERS

THEN:

THE CONTRACTOR'S RATES MAY NOT BE ECONOMICALLY FEASIBLE OR PRACTICABLE
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 9/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 8/10
and THE RISK IS SHARED BY THE OWNER - Probability= 2/10

NOTE:
THE CONTRACTORS GENERALLY DO NOT HAVE THE MEANS OF ACCESS OR THE TIME TO CARRY OUT MEANINGFUL SUBSURFACE INVESTIGATIONS DURING THE RELATIVELY SHORT TENDER PERIOD.

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 15

IF:

THE CONTRACTORS ARE ACTUALLY TO MAKE THEIR OWN EXPLORATIONS

THEN:

THE CONTRACTORS' TENDERS WOULD HAVE TO INCLUDE THIS COST, RESULTING IN AN INCREASED EXPENSE TO THE OWNER WITHOUT A CORRESPONDING BENEFIT TO THE OWNER
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 9/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 2/10
and THE RISK IS SHARED BY THE OWNER - Probability= 8/10

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 16

IF:

DISTINCTION BETWEEN FACTUAL DATA AND INTERPRETATIVE DATA DOES NOT EXIST CLEARLY

THEN:

THE OPINIONS OF THE OWNER'S SPECIALISTS SHOULD BE CLEARLY IDENTIFIED TO THE EXTENT POSSIBLE
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10
and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 17

IF:

DISTINCTION BETWEEN FACTUAL DATA AND INTERPRETATIVE DATA DOES NOT EXIST CLEARLY

THEN:

THE OPINIONS THAT ARE SIGNIFICANTLY RELIED UPON BY THE DESIGN ENGINEER SHOULD ALSO BE IDENTIFIED
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10
and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 18

IF:

ALL SUBSURFACE INFORMATION IS MADE AVAILABLE

THEN:

THE RESULTING TENDERS MAY BE BETTER AND MORE COMPETITIVE
and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10
and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10
and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

REFERENCE:
"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 19

IF:

ALL SUBSURFACE INFORMATION IS MADE AVAILABLE

THEN:

FEWER DISPUTES MAY ARISE BECAUSE SUCH DISCLOSURE WILL PROVIDE A BETTER BASIS FOR DETERMINING WHETHER A CHANGED CONDITION HAS BEEN ENCOUNTERED DURING CONSTRUCTION

and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10

and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10

and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

REFERENCE:

"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

RULE NUMBER: 20

IF:

ALL SUBSURFACE INFORMATION IS MADE AVAILABLE

THEN:

IN THE LONG RUN, IT MAY RESULT IN LOWER CONTRACT PRICES

and THE SHARING OF RISKS IS NOT EQUITABLE - Probability= 1/10

and THE RISK IS SHARED BY THE CONTRACTOR - Probability= 5/10

and THE RISK IS SHARED BY THE OWNER - Probability= 5/10

REFERENCE:

"ITA RECOMMENDATIONS ON CONTRACTUAL SHARING OF RISKS", TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY, VOL. 3, NO. 2, pp 103-140, (1988).

ESSOR - SAMPLE OUTPUT OF TEST RUN

1. THE SHARING OF RISKS IS NOT EQUITABLE :6/10
2. THE RISK IS SHARED BY THE CONTRACTOR :3/10
3. THE RISK IS SHARED BY THE OWNER :7/10

THERE IS A RISK

THE RISK TAKEN WITH REGARD TO BENEFITS IS COMPARABLE TO ROUTINE RISKS, i.e., THE RISKS ARE LESS THAN THE BENEFITS

A TUNNEL IS DRIVEN IN ANY FORMATION

DESIGN ALTERNATIVES ARE PRESENTED BY EXPERT OPINIONS OR KNOWLEDGEABLE PERSONS

THE PRESENTATION AND EXPLANATION OF ENGINEERING DATA IS MADE AND EXPLANATION OF DESIGN PROBLEMS IS GIVEN BY EXPERT OPINION OR KNOWLEDGEABLE PERSONS

THE DEGREE THAT OUR VALUE PLACES THE BENEFIT OF USE HIGHER THAN THE RISK

A CHANGED CONDITIONS CLAUSE IN THE TUNNELLING CONTRACT IS INCORPORATED

UNKNOWN CONDITIONS, NOT NORMALLY EXPECTED, ARE ENCOUNTERED

A CHANGED CONDITIONS CLAUSE IN A TUNNEL CONTRACT IS INCLUDED

FULL DISCLOSURE OF ALL AVAILABLE SUBSURFACE INFORMATION, INCLUDING BOTH FACTUAL AND INTERPRETATIVE DATA IS MADE TO THE TENDERERS

A REASON IS SOUGHT FOR DISCLOSURE OF INFORMATION

THE OWNER WHO HAS ADEQUATE TIME TO SUFFICIENTLY EXPLORE, ANALYSE, AND STUDY AVAILABLE SOURCES OF INFORMATION REGARDING UNDERGROUND CONDITIONS DISCLOSES ALL SUBSURFACE INFORMATION

THE CONTRACTORS ARE REQUIRED TO CARRY OUT EXPLORATION, ANALYSE AND STUDY INFORMATION REGARDING UNDERGROUND CONDITIONS FOR EVERY PROJECT THEY SUBMIT TENDERS

THE CONTRACTORS ARE ACTUALLY TO MAKE THEIR OWN EXPLORATIONS

DISTINCTION BETWEEN FACTUAL DATA AND INTERPRETATIVE DATA DOES NOT EXIST CLEARLY

THE OPINIONS THAT ARE SIGNIFICANTLY RELIED UPON BY THE DESIGN ENGINEER ARE IDENTIFIED

ALL SUBSURFACE INFORMATION IS MADE AVAILABLE

MORE DISPUTES MAY ARISE BECAUSE ABSENCE OF SUCH DISCLOSURE WILL PROVIDE A POOR BASIS FOR DETERMINING WHETHER A CHANGED CONDITION HAS BEEN ENCOUNTERED DURING CONSTRUCTION

A CHANGED CONDITIONS CLAUSE IS INCLUDED IN CONSTRUCTION CONTRACTS

FULL DISCLOSURE OF ALL AVAILABLE SUBSURFACE INFORMATION IS MADE IN THE TENDER DOCUMENTS

THE OWNER IS RELIEVED OF THE RESPONSIBILITY FOR THE ACCURACY OF THE UNDERGROUND INFORMATION FURNISHED

DISCLAIMER CLAUSES ARE NOT ELIMINATED

DATA IS SUPPLIED FOR CONTRACTUAL PURPOSES

THE OWNER IS PREPARED TO GUARANTEE THE ACCURACY OF THE DATA SUPPLIED

FOR CONTRACTUAL PURPOSES

THE DATA MAY NOT BE GUARANTEED, BUT IT SHOULD NOT BE EXPRESSLY DISCLAIMED, AND IT SHOULD NOT BE REGARDED AS BINDING FOR THE PURPOSES OF A CHANGED CONDITION DETERMINATION, RATHER IT SHOULD BE CONSIDERED AS ONE FACTOR TOGETHER WITH ALL OTHER EVIDENCE

THE INTERPRETATION OF THE GROUND IS TO BE MADE

THE OWNERS ENGAGE IN WELL CONCEIVED AND WELL EXECUTED UNDERGROUND INVESTIGATIONS THAT WILL BE SUFFICIENT BOTH FOR DESIGN AND CONSTRUCTION PURPOSES

THE MARGIN OF UNCERTAINTY OF INFORMATION IS REDUCED

THE ADDED TIME AND EXPENSE OF A THOROUGH SITE INVESTIGATION IS INCURRED IN THE BEGINNING

THE INFORMATION ABOUT THE SUBSURFACE IS MORE ACCURATE

THE OWNERS SEEK BIDS FROM CONTRACTORS WHO HAVE SATISFIED A RIGOROUS TECHNICAL AND FINANCIAL PREQUALIFICATION PROCEDURE

WORKS OF UNDERGROUND CONSTRUCTION ARE CARRIED OUT IN A DEFINITE AND A CONGENIAL ENVIRONMENT

REALISTIC BIDS ARE TO BE PREPARED

UNDERGROUND CONDITIONS DO NOT CHANGE RAPIDLY OR ABRUPTLY

TENDERS FOR UNDERGROUND WORKS ARE ACCEPTED FROM ALL CONTRACTORS WHO CHOOSE TO SUBMIT THEM

AN UNQUALIFIED TENDER WITH ITS UNDESIRABLE EFFECTS IS REJECTED

THE TENDERS ARE RECEIVED FROM CONTRACTING ORGANISATIONS THAT HAVE DEMONSTRATED IN A FORMAL MANNER THEIR CAPABILITIES

THE CONTRACTORS HAVE THE AVAILABLE ADEQUATE FINANCIAL RESOURCES AND PERSONNEL WHO ARE WELL QUALIFIED AND EXPERIENCED IN THE TYPE OF WORK TO BE PERFORMED

THE FIRMS DEMONSTRATE THAT THEY HAVE PREVIOUSLY COMPLETED SIMILAR WORK PROPERLY AND WITHIN THE ALLOWED TIME

PRE-QUALIFICATION PROCEDURES ARE NOT USED

THE PRICES ARE STEADY OR VARY IN A PREDICTABLE MANNER

VARIATION IN PRICES CLAUSE, PREFERABLY OF THE INDEX REIMBURSEMENT TYPE AND APPLICABLE TO: LABOUR SUPERVISION AND STAFF; MATERIALS USED IN SIGNIFICANT QUANTITIES (WHETHER PERMANENT, TEMPORARY OR EXPENDABLE); ENERGY; AND EQUIPMENT INCORPORATED IN THE WORKS IS INCLUDED IN TUNNELLING CONTRACTS

PRICES VARY SIGNIFICANTLY AND PREDICTABLY

THE TENDERERS FOR TUNNELLING WORK MAY OVERESTIMATE THIS RISK AND THUS CAUSE THE OWNERS TO PAY MORE THAN NECESSARY FOR THE WORKS

THE CONTRACTOR HAS TO BE PROTECTED AGAINST THE CONSEQUENCES OF PRICE FLUCTUATIONS

THE CONTRACT PROVISION IS OF THE INDEX REIMBURSEMENT TYPE

THE DEGREE OF UNCERTAINTY WITH REGARD TO PRICES INCREASES NONLINEARLY WITH THE DURATION OF THE WORKS

PROVISION IN THE CONTRACT IS MADE FOR THE INDEX REIMBURSEMENT TYPE

THE ASSUMED RATIOS OF RESOURCES USED AND IN THE ASSUMED DISTRIBUTION OVER TIME VARY

TENDER ASSESSMENT PROBLEMS ARISE

INDEPENDENT INDICES ARE NOT AVAILABLE

INDEX REIMBURSEMENT OR DETAILED REIMBURSEMENT TYPE OF PAYMENT IS ADOPTED

FULL REIMBURSEMENT IS ACCEPTED

FULL REIMBURSEMENT IS INFLATIONARY

THE CONTRACTOR'S BUYING AND LABOUR BARGAINING INCENTIVES AND POWERS ARE REMOVED

PARTIAL REIMBURSEMENT IS NOT ACCEPTED

PARTIAL REIMBURSEMENT MAY HELP TO CONTROL INFLATION

A HIGH FIXED ELEMENT IS USED

IT MAY HELP TO CONTROL INFLATION

THE FORMULAE USED IN PRICE VARIATION CLAUSES ARE AS REPRESENTATIVE AS POSSIBLE OF THE PRICE STRUCTURE OF THE WORKS

CONTRACT DISPUTES IN UNDERGROUND CONSTRUCTION ARE TO BE FULLY RESOLVED

BETTER CONTRACTING PRACTICES ARE EMPLOYED

UNANTICIPATED GEOLOGICAL CONDITIONS ARE ENCOUNTERED

SUFFICIENT MONEY AND TIME TO DEVELOP GEOLOGICAL INFORMATION ARE NOT SPENT BY THE OWNER

DISCLAIMER CLAUSES ARE USED IN THE CONTRACT

POOR CONTRACTING PRACTICES ARE EMPLOYED

THE PARTIES TO THE CONTRACT BELIEVE THAT MEANS BY WHICH THE RISKS ARE SHARED IN THE CONTRACT IS INEQUITABLE

CONTRACTS FOR UNDERGROUND CONSTRUCTION EMPLOY "DIFFERING SITE CONDITIONS" CLAUSES WHICH PROVIDE FOR THE FULL DISCLOSURE OF ALL AVAILABLE SUBSURFACE INFORMATION AND WHICH AVOID THE USE OF DISCLAIMER CLAUSES

THE RESOLUTION OF DISPUTES OR, AS A MINIMUM, AGREEMENT AS TO THE FACTS, IS ACHIEVED BY PERSONS AT RELATIVELY LOW LEVELS ON THE ORGANISATION CHARTS OF THE DIFFERENT PARTIES

THE DISPUTE OR PROBLEM IS PASSED ALONG TO PEOPLE HAVING GREATER RESPONSIBILITY AND THEREBY, SPENDING MORE TIME IN THE DISPUTE

DISPUTES ARE TO BE RESOLVED THROUGH LITIGATION

DISPUTES AND THEIR COSTLY CONSEQUENCES ARE TO BE MINIMISED

THE CONTRACTING PARTIES ACCORD THE AVOIDANCE OF AND RESOLUTION OF DISPUTES A HIGH PRIORITY

THE CONTRACTING PARTIES DELEGATE APPROPRIATE AUTHORITY TO REPRESENTATIVES ON THE WORKSITE TO RESOLVE DISPUTES AS THEY ARISE

DISPUTES ARE TO BE RESOLVED AS THEY ARISE AT JOB SITE

THE JUDGEMENT OF THE REFEREES OR MEDIATORS ARE BINDING UPON THE PARTIES

THE JUDGEMENTS OF THE REFEREES OR MEDIATORS ARE MERELY ADVISORY IN NATURE

QUALIFIED AND EXPERIENCED REFEREES ARE PRESENT OR MEDIATORS ARE

INDIVIDUALS OF HIGH STATURE

REFEREES OR MEDIATORS ARE RETAINED

THE REFEREES OR MEDIATORS ARE SUCH WHO HAVE THE TIME TO DEAL WITH DISPUTES OR CHANGES IMMEDIATELY

THE MATTERS REFERRED TO THE REFEREES ARE NOT SPECIFIC OR ARE NOT CLEARLY IN DISPUTE

MEDIATION IS NOT POSSIBLE

THE ARBITRATOR'S DECISIONS HAVE THE FORCE OF DECISIONS BY COURTS AND CAN BE OVERTURNED ONLY IN MOST EXTREME CIRCUMSTANCES

THERE IS A LACK OF CLEAR ASSIGNMENT OF RESPONSIBILITY FOR THE PROVISION OF GROUND SUPPORT

GROUND SUPPORT BENEFITS THE CHARACTER OF THE GROUND, THE PERMANENT SUPPORT REQUIRED AND THE CONSTRUCTION METHODS SELECTED BY THE CONTRACTOR

GROUND SUPPORT SYSTEMS ARE ADOPTED

THE COMPETING CONTRACTORS ARE ALLOWED TO USE THEIR INGENUITY AND ESTABLISHED TECHNIQUES AND EXPERIENCE AND AVAILABLE MATERIALS AND EQUIPMENT TO PROPOSE THEIR OWN CONSTRUCTION METHODS AND GROUND SUPPORT SYSTEMS

THE ACTUAL SUBSURFACE CONDITIONS DIFFER FROM THE REFERENCE CONDITIONS ASSUMED IN THE TENDER INVITATION AND DESIGN

IN THE TENDER AND CONTRACT DOCUMENTS, THE ASSUMED CHARACTER OF THE GROUND THROUGHOUT THE CONSTRUCTION SITE IS DEFINED

IN THE TENDER AND CONTRACT DOCUMENTS, THE PARAMETERS REQUIRED FOR THE DESIGN OF GROUND SUPPORT ARE DEFINED

IN THE TENDER AND CONTRACT DOCUMENTS, THE STRUCTURAL BENEFIT DERIVED FROM THE GROUND SUPPORT IN THE DESIGN OF THE PERMANENT STRUCTURE IS DEFINED

IN THE TENDER AND CONTRACT DOCUMENTS, THE BILLS OF QUANTITY FOR GROUND SUPPORT COVERING A REASONABLE RANGE OF SITE CONDITIONS IS DEFINED

IN THE TENDER AND CONTRACT DOCUMENTS, METHODS TO TAKE ACCOUNT OF CHANGES IN THE QUANTITY OR TYPE OF THE GROUND SUPPORT DICTATED BY THE ACTUAL SITE CONDITIONS WHEN THEY DIFFER FROM THOSE ASSUMED ARE DEFINED

DURING THE ACTUAL CONSTRUCTION, THE SITE CONDITIONS DIFFER SIGNIFICANTLY

THE RESPONSIBILITY FOR THE CHARACTERISTICS OF THE SITE IS ASSIGNED TO THE OWNER

A REASONABLE PROGRAMME OF SITE INVESTIGATIONS IS ADOPTED BEFORE AND DURING THE DESIGN PHASE

TENDERS OR BIDS ARE BEING CALLED

THE OWNER PRESENTS TO THE PROSPECTIVE CONTRACTORS WITH DEFINITIONS OF THE CHARACTERISTICS OF THE CONSTRUCTION SITE, AS IT MAY VARY OVER THE EXTENT OF TUNNELLING OR THE LIMITS OF CONSTRUCTION

THE PRECONCEIVED CHARACTERISTICS OF THE CONTRACTOR'S WORK PLACE IS RECORDED AS A CONTRACT MATTER

THE CONTRACTOR ENCOUNTERS CONDITIONS THAT HE BELIEVES DIFFER MATERIALLY FROM THE PROJECT SITE CHARACTERIZATION AT A GIVEN LOCATION AS DEFINED BY THE OWNER IN ADVANCE OF CONSTRUCTION

THE DESIGN OF THE PERMANENT STRUCTURE MAY RESULT IN A PHYSICALLY SAFE

STRUCTURE

MATCHING OF ALL REASONABLY ANTICIPATED GROUND CONDITIONS (WITH RELATED DEFINITIONS OF GROUND SUPPORT AND DESIGNS OF PERMANENT WORKS) IS RECOGNISED IN THE CONTRACT DOCUMENTS

LINEAR UNIT PRICES ARE ESTABLISHED AND AGREED UPON FOR EACH SET

THE ACTUAL CHARACTERISTICS OF THE SITE AND ITS VARIATIONS DIFFER FROM THOSE ANTICIPATED THROUGH THE PRE-CONSTRUCTION SITE EXPLORATION PROGRAMME

THE OWNER ACHIEVES THE ADVANTAGES OF THE COMPETITIVE TENDERING OR BIDDING PROCESS, AND BOTH PARTIES ARE EQUITABLY SERVED

THE TENDERS FOR UNDERGROUND CONSTRUCTION HAVE BEEN INVITED

ANY TENDER IS TO BE ACCEPTABLE

THE UNPRICED QUALIFICATIONS INTRODUCE UNCERTAINTY AND, THEREFORE, ADDITIONAL RISK TO BOTH PARTIES IN ANY ENSUING CONTRACT

THE OWNER INSISTS ON TENDERS WITHOUT QUALIFICATIONS

THE TENDERERS MAY CREATE A CONGENIAL ATMOSPHERE NOT LEADING TO DISPUTES

THE QUESTION OF RESPONSIBILITY FOR A PARTICULAR RISK OR THE POSSIBILITY FOR A SAVINGS THROUGH SOME VARIATION IN METHOD ARISE

TENDERS BASED ON ALTERNATIVE METHODS OF ACHIEVING THE DESIRED RESULT ARE OFFERED and SHOULD BE CONSIDERED BY THE OWNER

THE BENEFITS ARE MORE THAN THE RISKS INVOLVED IN THE ALTERNATIVE METHOD

THE SUBMISSION OF ALTERNATIVE OFFERS OF CONSTRUCTION METHODS OR DESIGNS TO THE OWNER IS PERMITTED

THE TENDERER MAY HIKE HIS PRICE ON THE OWNER'S ORIGINAL PROPOSAL

THE OWNER IS READY TO ACCEPT THE RISKS ASSOCIATED WITH ALTERNATIVE OFFERS OF CONSTRUCTION METHODS OR DESIGNS NOT KNOWN TO HIM

THE CONSTRUCTION OF FINISHED WORKS AND THEIR RELATIVE ECONOMICS ARE CONSIDERED

THE OWNER'S TENDER INVITATION INDICATES CLEARLY WHAT IS EXPECTED TO BE INCLUDED IN THE TENDER OFFERS

PRIOR TO THE AWARDING OF THE CONTRACT THE AMBIGUITIES SHOULD BE CLARIFIED

PRIOR TO THE AWARDING OF THE CONTRACT, THE AMBIGUITIES ARE CLARIFIED

DETAILED PROGRAMME, METHOD STATEMENTS AND RESOURCE ALLOCATION CHARTS ARE INCLUDED IN THE TENDER DOCUMENTS

FORMAL SITE INSPECTION AND PRE-BID MEETINGS, BOTH JOINT AND PRIVATE ARE CONDUCTED

OFFERS TO CONSTRUCT A WORK INVOLVING UNDERGROUND CONSTRUCTION OF SOME MAGNITUDE AND DEFINITE RISKS ARE CONSIDERED

THE LOWEST TENDER IS SELECTED

THE OWNER MAY HAVE TO JUSTIFY HIS REASONS FOR REJECTING THE LOWEST OFFER

THE SUCCESSFUL CONTRACTOR HAS AT HIS DISPOSAL FEWER TOTAL RESOURCES TO COMPLETE THE WORKS OR TO MOBILISE IN THE EVENT OF THE UNEXPECTED

ALTERNATIVE TENDERS ARE REQUESTED OR ENCOURAGED

SOME TENDERERS HAVE NO CHANCE TO BE AWARDED THE CONTRACT

A TUNNELLING CONTRACT IS TO BE FULFILLED

MOBILIZATION PAYMENTS ARE MADE TO THE CONTRACTOR

THE CONTRACTOR IS REIMBURSED ONLY THROUGH MEASURED ITEMS AS THE WORK PROCEEDS

THE CASH-FLOW IMBALANCE IS REMOVED

ITEMS OF WORK TO BE CARRIED OUT EARLY IN THE PROJECT ARE PRICED HIGH

A MOBILIZATION PAYMENT IS ADOPTED BY THE OWNER

MOBILIZATION PAYMENTS ARE MADE

THE OWNER CAN OBTAIN LOAN MONEY AT A LOWER RATE OF INTEREST THAN CAN THE CONTRACTOR

DISCLOSURES OF A MAKEUP OF THE SUMS INCLUDED IN THE CONTRACTOR'S TENDER IS MADE FOLLOWING THE AWARD OF THE CONTRACT

THE ABSENCE OF DISCLOSURES MAY NOT ASSIST IN THE PRICING OF VARIOUS WORKS

ADVANCE PAYMENTS AT THE BEGINNING OF THE WORKS AND/OR ON SUPPLIES TO BE MADE ARE FORESEEN AND PROVIDED FOR

THERE ARE PROBLEMS RELATED TO THE MEASUREMENT OF THE WORKS

SEPARATE ITEMS ARE PROVIDED FOR SIGNIFICANTLY DIFFERENT CLASSES OF ROCK, UTILISING, AS FAR AS POSSIBLE, A STANDARD ROCK/SUPPORT CLASSIFICATION SYSTEM

OVERBREAK IN UNDERGROUND EXCAVATION OCCURS

ABNORMAL OVERBREAK OCCURS IN CERTAIN ZONES

THE RISK SHOULD BE SHARED EQUITABLY BY THE OWNER AND THE CONTRACTOR

THE MEASUREMENT OF WORK IS BASED ON A GEOLOGIC CLASSIFICATION SYSTEM APPROPRIATE TO THE GEOLOGY AS WELL AS TO THE TENDERED METHOD AND RATE OF EXCAVATION

THE NUMBER OF CLASSES OF GEOLOGIC CONDITIONS ARE RESTRICTED TO NO MORE THAN FIVE AND ALL THE CLASSES ARE BOUNDED BY UPPER AND LOWER LIMITS WITHOUT OVERLAP

THE BILLS OF QUANTITIES ARE STRUCTURED AND PRICED IN A PROPER MANNER

DISTINCTION IS MADE BETWEEN FIXED COSTS AND TIME-RELATED COSTS

CERTAIN ITEMS ARE INCLUDED AS A PRECAUTIONARY MEASURE WITH A VIEW TO NEGOTIATING CHANGES

A PRICE IS TENDERED FOR ANY BILLED ITEM

THE PRICE IS DEEMED TO BE SUFFICIENT TO COVER THE COST OF ALL ACTIVITIES IMPLICIT IN THAT ITEM

ITEMS COVER BOTH THE EXCAVATION AND FILLING OF OVERBREAK

ITEMS COVERING BOTH EXCAVATION AND FILLING OF OVERBREAK MEASURED PER UNIT AREA OF SPECIFIED EXCAVATION SURFACE FOR EACH ROCK CLASS ARE PROVIDED

THE GROUND IS DOUBTFUL

THERE IS A CONSENSUS THAT EXCESS OVERBREAK OUTSIDE THE NOMINAL EXCAVATED PROFILE WAS DUE TO PHYSICAL/GEOLOGICAL CONDITIONS BEYOND THE

CONTRACTOR'S CONTROL AND DID NOT ARISE FROM THE METHOD OF WORKING OR FROM CARELESSNESS

THE OWNER ELECTS TO MAKE USE OF PAYMENT LINES AND CLEARANCE LINES

THE OWNER REQUIRES THE CONTRACTOR TO FURNISH BONDS TO GUARANTEE THE SATISFACTORY COMPLETION OF THE WORK BY THE CONTRACTOR

ALL TYPES OF BONDS (BID AND PERFORMANCE) ARE AT A BALANCE BETWEEN THE RIGHTS AND THE OBLIGATIONS OF THE PARTIES AND AT A REASONABLE COVERAGE OF THE RISKS

THE VALUE OF THE BONDS ARE EXPRESSED AS A PERCENTAGE OF THE CONTRACT SUM

PRE-QUALIFICATION PROCEDURES OF THE TENDERERS ARE ADOPTED

PRE-QUALIFICATION PROCEDURES OF THE TENDERERS REDUCES THE SIZE OF THE PERFORMANCE BONDS

THE OWNER, THE DESIGN ENGINEER, THE CONTRACTOR AND THE GENERAL PUBLIC ARE EXPOSED TO ANY PHYSICAL HAZARDS AS A RESULT OF THE CONTRACTOR'S ACTIVITIES IN CONSTRUCTING THE WORKS

INSURANCE SCALED TO REASONABLY MATCH THE EXPOSURE ESTIMATED TO BE PRESENT FOR THE PARTICULAR TYPE OF WORK AND SITE CONDITION IS PROVIDED

THE CONTRACTOR PROVIDES INSURANCE COVER AS THE OWNER DEEMS NECESSARY AND WARRANTED, THE COST OF WHICH IS INCLUDED IN THE AGREED-UPON TENDER PRICES

A COORDINATED INSURANCE PROGRAMME IS DESIGNED, FURNISHED AND CONTROLLED BY THE OWNER

MANY CONTRACTORS ARE INVOLVED IN THE UNDERGROUND CONSTRUCTION WORKS

AN OWNER CONTROLLED COORDINATED INSURANCE PROGRAMME IS ENVISAGED

THE DESIGN ENGINEER IS NOT ALREADY COVERED AS A PART OF THE CONTRACTOR COVERAGE

THE DESIGN ENGINEER SHOULD BE COVERED AS A PART OF THE CONTRACTOR COVERAGE

THE CONTRACTOR'S INCENTIVE TO PROMOTE SAFETY IS TO BE MAINTAINED

CONTRACTORS WITH A GOOD CLAIM-LOSS RECORD ARE TO BE GIVEN A REWARD FOR SUCH PERFORMANCE

COMPETITIVE ADVANTAGE IS TO BE GAINED IN THE TENDERING PROCESS

AN OWNER IS EMBARKING ON THE CONSTRUCTION OF A TUNNEL OR OTHER UNDERGROUND WORKS

THE DUTIES AND RESPONSIBILITIES OF THE ENGINEER ARE TO BE STATED

A TUNNEL CONTRACTOR IS TO BEGIN WORK AND CARRY OUT THE CONTRACT

SUCH RIGHTS WHICH TAKE MANY FORMS AND INVOLVE THIRD PARTIES WHO CONTROL THE SURFACE AND THE SUBSURFACE SPACE NEEDED ARE EXTENDED

THE RISK IS TO BE MINIMISED

THE TENDER DOCUMENTS MAKE CLEAR THE RESPECTIVE RESPONSIBILITIES OF THE OWNER AND THE CONTRACTOR AND TO USE THE FACILITY THUS CREATED

ALL THE RIGHTS-OF-WAY AND PERMITS ARE TO BE OBTAINED

THE OWNER WHO HAS MORE TIME THAN THE CONTRACTOR TO OBTAIN THE RIGHTS REQUIRED AND ADVANCE INDICATION OF WHAT PERMITS MAY BE REQUIRED BOTH TO CONSTRUCT THE PROPOSED WORK AND TO OPERATE IT PROCURES THEM

THE RESPONSIBILITY FOR ACQUIRING ALL SUCH RIGHTS IS TAKEN BY THE OWNER

THE NEED FOR THE RIGHTS IS OCCASIONED SOLELY BY THE PARTICULAR METHOD OF CONSTRUCTION THAT A SPECIAL CONTRACTOR HAS ELECTED TO EMPLOY IS TAKEN BY THE CONTRACTOR

THE TUNNEL PROJECT IS NEAR EXISTING STRUCTURES

THE OWNER CAN IDENTIFY THE NEED FOR AGREEMENTS TO ALTER THE EXISTING FACILITIES TO OTHERS

THE OWNER CAN IDENTIFY THE NECESSARY RIGHTS TO STRENGTHEN THE EXISTING STRUCTURES IN SOME FASHION

THE OWNER CAN NOT IDENTIFY THE NEEDS FOR AGREEMENTS TO ALTER EXISTING FACILITIES TO OTHERS

TUNNEL CONTRACTS REQUIRE THE CONTRACTOR TO PROVIDE ALL PLANT, EQUIPMENT AND MATERIALS NECESSARY FOR THE COMPLETION OF THE WORK

THE OWNER MUST SPECIFY THE AGENCY WHICH WOULD PROVIDE THEM

CERTAIN MATERIALS LIKE STEEL AND CEMENT ARE CONTROLLED BY THE GOVERNMENT AND ARE NOT AVAILABLE FOR FREE AND READY PURCHASE IN LARGE QUANTITIES FROM THE MARKET

IT IS ADVANTAGEOUS FOR THE OWNER TO SUPPLY SOME ITEMS OF PLANT, EQUIPMENT, SERVICES OR MATERIALS

THE CONTRACTOR SHOULD SUPPLY SOME ITEMS OF PLANT, EQUIPMENT, SERVICES OR MATERIALS

THE OWNER SUPPLIES THOSE ITEMS OF PLANT, EQUIPMENT OR MATERIALS REQUIRING A LONG LEAD TIME FOR THEIR DELIVERY

THE OWNER SUPPLIES THOSE ITEMS MEANT FOR LONG TERM SUPPLY OF MATERIALS TO MORE THAN ONE CONTRACT

THE OWNER SUPPLIES MAJOR ITEMS OF PLANT UTILIZED ON MORE THAN ONE CONTRACT

THE OWNER SUPPLIES THOSE SERVICES THE PROVISION OF WHICH ARE COMMON TO MORE THAN ONE CONTRACTOR OR WHERE THE OWNER IS ALSO THE SUPPLY AUTHORITY

THE OWNER SUPPLIES THOSE MATERIALS OR EQUIPMENT TO BE USED FOR EXPERIMENTS

THE OWNER SUPPLIES THOSE ITEMS OF LOCAL RESOURCES THAT ARE REQUIRED TO BE USED

THE CONTRACTOR SUPPLIES THOSE ITEMS OF PLANT, EQUIPMENT OR MATERIALS REQUIRING A SHORT LEAD TIME FOR THEIR DELIVERY

THE CONTRACTOR SUPPLIES THOSE ITEMS MEANT FOR LONG TERM SUPPLY OF MATERIALS TO ONE CONTRACT

THE CONTRACTOR SUPPLIES THOSE MAJOR ITEMS OF PLANT UTILISED ON ONE CONTRACT

THE CONTRACTOR SUPPLIES THOSE SERVICES THE PROVISION OF WHICH IS FOR ONE CONTRACT OR WHERE THE OWNER IS NOT THE SUPPLY AUTHORITY

THE CONTRACTOR SUPPLIES THOSE MATERIALS OR EQUIPMENT NOT USED FOR EXPERIMENTS

THE OWNER DECIDES, UNDER CERTAIN CIRCUMSTANCES, TO PROVIDE PLANT, EQUIPMENT, SERVICES OR MATERIALS

THE CONTRACT DOCUMENT CLEARLY DEFINES THE OWNERSHIP OF THE PROPERTY (WHETHER PLANT, EQUIPMENT OR MATERIALS) TO BE PROVIDED BY THE OWNER

BEFORE, DURING AND AFTER COMPLETION OF THE CONTRACT

THE CONTRACT DOCUMENT CLEARLY DEFINES THE QUANTITY, QUALITY AND CONDITION OF PLANT, EQUIPMENT OR MATERIALS TO BE PROVIDED BY THE OWNER

THE CONTRACT DOCUMENT CLEARLY DEFINES THE TERMS UNDER WHICH PLANT, EQUIPMENT, SERVICES OR MATERIALS TO BE PROVIDED BY THE OWNER WILL BE MADE AVAILABLE, e.g. FREE OF CHARGE OR ON HIRE

THE CONTRACT DOCUMENT CLEARLY DEFINES THE CONTRACTOR'S OBLIGATIONS WITH REGARD TO MAINTENANCE, OPERATING COSTS, INSURANCE, ETC. OF PLANT, EQUIPMENT, SERVICES OR MATERIALS TO BE PROVIDED BY THE OWNER

THE CONTRACT DOCUMENT CLEARLY DEFINES THE PROCEDURE FOR INSPECTION, HAND OVER AND RETURN TO THE OWNER OF PLANT, EQUIPMENT, SERVICES OR MATERIALS TO BE PROVIDED BY THE OWNER

THE CONTRACT DOCUMENT CLEARLY DEFINES THE POINT OF DELIVERY AND RESPONSIBILITY FOR LOADING, TRANSPORT AND UNLOADING OF PLANT, EQUIPMENT, SERVICES OR MATERIALS TO BE PROVIDED BY THE OWNER

THE CONTRACT DOCUMENT CLEARLY DEFINES THE PROCEDURE FOR DEALING WITH ANY OVERSUPPLY OR SHORTAGE OF MATERIALS TO BE PROVIDED BY THE OWNER

THE OWNER DOES NOT HAVE THE TIME TO COMPARE THE BASIC OFFER WITH ALTERNATIVE OFFERS, EXCEPT ON THE BASIS OF TOTAL PRICE AND, THEREFORE, CAN NOT MAKE A FAIR EVALUATION OF THE OFFERS

THE EXPLORATORY WORKS AND DRAFTING OF THE CONTRACT DOCUMENTS MAY HAVE BEEN PERFORMED ON THE ASSUMPTION OF A PARTICULAR DESIGN AND A PARTICULAR METHOD OF CONSTRUCTION, AND THERE MAY NOT BE SUFFICIENT TIME OR MONEY FOR ADDITIONAL EXPLORATORY WORKS AND TENDER EVALUATION

THE DEGREE OF RISK TO BE BORNE BY THE OWNER IS INCREASED BECAUSE HE DOES NOT HAVE THE SAME LEVEL OF KNOWLEDGE ABOUT THE ALTERNATIVE DESIGN METHOD OR PRICING STRUCTURE AS DOES THE TENDERER

ALTERNATIVE TENDERS CAN GIVE BENEFITS TO THE OWNER

THE CONTRACTORS MAY HAVE AVAILABLE TO THEM, AT THE RIGHT TIME, RESOURCES OR EXPERTISE THAT WILL ENABLE THEM TO PROVIDE THE OWNER WITH A BETTER JOB, PERFORMED FASTER AND MORE ECONOMICALLY THAN WOULD BE POSSIBLE UNDER THE CONDITIONS SET FORTH IN THE ORIGINAL CONTRACT DOCUMENTS

DURING THE TENDERING PHASE THE CONTRACTOR SPENDS FAR TOO MUCH TIME AND MONEY ON PREPARING ALTERNATIVE BIDS AND THE TENDER IS REJECTED

DURING THE TENDERING PHASE THERE IS BREACH OF CONFIDENTIALITY

DURING THE TENDERING PHASE THE OWNER FAILS TO GAIN A FULL UNDERSTANDING OF THE IMPLICATIONS OF AN ALTERNATIVE OFFER

DURING THE TENDERING PHASE THERE IS A LOSS OF TIME IN EVALUATING ALTERNATIVE BIDS THAT MAY TURN OUT TO BE UNSATISFACTORY

DURING THE TENDERING PHASE THE CONTRACTUAL PHASE IS ENTERED WITH DOCUMENTS IN WHICH THE MEASUREMENT ASPECTS ARE NOT SUFFICIENTLY DEFINED

DURING THE EXECUTION PHASE UNFORESEEN CONDITIONS ARE MORE LIKELY TO OCCUR BECAUSE ALTERNATIVE OFFERS ARE SELDOM AS WELL-SUPPORTED BY EXPLORATORY WORKS AS THE BASIC OFFER WOULD HAVE BEEN

DURING THE EXECUTION PHASE THE OPPORTUNITY FOR SPECULATION BY THE CONTRACTOR IS GREATER

DURING THE EXECUTION PHASE THE RISK OF THE COMPLETED WORKS NOT PERFORMING AS INTENDED BY THE OWNER IS INCREASED

THE OWNERS RESPOND TO THE ALTERNATIVE TENDERS

THE OWNER DOES NOT SHARE THE RISKS ASSOCIATED WITH THE ALTERNATIVE TENDERS

THE OWNER IS NOT ENTITLED TO THE POTENTIAL BENEFITS OF ALTERNATIVE TENDERS

A TENDERER SUBMITS AN ALTERNATIVE OFFER

THE ALTERNATIVE TENDERS ARE ACCOMPANIED BY A BASIC OFFER IN ACCORDANCE WITH THE SPECIFICATIONS

IN CASE OF A MAJOR DEPARTURE FROM THE BASIC OFFER, SUBMITTAL OF A CONFORMING TENDER IS AGREED TO BY THE TENDERER

THE TENDERER IS OBLIGED TO DRAW UP CONTRACT DOCUMENTS THAT ARE COMPARABLE IN SCOPE, DETAIL, INTENT AND CONTENT TO THOSE PREPARED BY THE OWNER, FOR THE BASIC OFFER

THE TENDERER DOES INDICATE CLEARLY HOW THE RISKS ASSOCIATED WITH THE BASIC DOCUMENTS WILL BE ALTERED BY ADOPTING THE ALTERNATIVE OFFER

THE TENDERER DOES DEFINE THE RISKS THAT HE WILL BEAR IF THE ALTERNATIVE OFFER IS ADOPTED AS ALSO THOSE RISKS WHICH THE TENDERER WISHES THE OWNER TO BEAR

THE ALTERNATIVE TENDER ENTAILS A MAJOR DEPARTURE FROM THE DESIGN PREPARED BY THE OWNER

THERE IS INSUFFICIENT TIME FOR EXTENDING THE TENDER VALIDITY

THE ALTERNATIVE TENDER IS NOT ACCEPTED DUE TO INSUFFICIENT TIME FOR EXTENDING THE TENDER VALIDITY

THERE IS NO ABSOLUTE AGREEMENT THAT THE ALTERNATIVE DESIGN WILL PERFORM CORRECTLY

ALTERNATIVE TENDERS OFFER THE POTENTIAL OF A SHORTENED CONSTRUCTION PERIOD

THE UNDERGROUND CONSTRUCTION DOES NOT DEAL CLEARLY WITH THE PROJECT SURROUNDS

THE RISKS THAT MAY BE ENCOUNTERED DUE TO CONSTRUCTION ACTIVITIES HAVE TO BE ASSESSED

MAXIMUM AMOUNT OF INFORMATION IS OBTAINED DURING THE OWNER'S DESIGN PHASE

A JUDICIOUS SELECTION OF THE TYPE OF TEMPORARY WORKS AND OTHER SUPPORT STRUCTURES IS MADE

A JUDICIOUS SELECTION OF THE WORKING METHODS TO BE ANTICIPATED BY THE OWNER AND SELECTED BY THE CONTRACTOR IS MADE

A JUDICIOUS SELECTION OF THE QUALITY CONTROLS TO BE CARRIED OUT IS MADE

A JUDICIOUS SELECTION OF ANY NECESSARY MEASURES TO PROTECT OR REINFORCE THE EXISTING STRUCTURES THEMSELVES IS MADE

A JUDICIOUS SELECTION OF A SCOPE OF PRE-CONSTRUCTION SURVEYS TO RECORD THE EXISTING CONDITIONS OF NEARBY STRUCTURES, SERVICES AND THE PROJECT SURROUNDS, GENERALLY, IS MADE

THE PROJECT SURROUNDS HAVE TO BE PROTECTED

DESIGNS THAT ARE REASONABLY NEEDED FOR CONSTRUCTION ARE DEVELOPED BY THE OWNER

PROTECTION METHODS FOR ANTICIPATED METHODS OF CONSTRUCTION AND THEIR IMPACTS ON PROJECT SURROUNDS ARE DEVELOPED BY THE OWNER

STRUCTURAL, CONSTRUCTION AND MITIGATION METHODS TO PROTECT THE PROJECT

SURROUNDS AND TO BE INCLUDED IN THE TENDER DOCUMENTS AND TO BE PRICED BY THE TENDERER IS DEVELOPED BY THE OWNER

THE CONSTRUCTION METHODS OR OPERATIONS MAY OR DO PRODUCE ADVERSE IMPACTS ON PROJECT SURROUNDS BEYOND THOSE REASONABLY ANTICIPATED BY THE OWNER

ADVERSE IMPACTS ON PROJECT SURROUNDS BEYOND THOSE REASONABLY ANTICIPATED BY THE OWNER ARE PRODUCED BY THE CONSTRUCTION METHODS OR OPERATIONS

ADDITIONAL EFFORTS, DISTRESS AND DAMAGES CAUSED BY THE CONSTRUCTION METHODS OR OPERATIONS ARE BORNE BY THE CONTRACTOR

THE ENGINEER IS TO BE ALERTED AGAINST CONDITIONS THAT COULD ADVERSELY AFFECT THE PROJECT SURROUNDS OR THE INCOMPLETE WORK IN PROGRESS

THE ENGINEER IS ALERTED AGAINST CONDITIONS THAT COULD ADVERSELY AFFECT THE PROJECT SURROUNDS OR THE INCOMPLETE WORK IN PROGRESS

INITIAL RESEARCH PRIOR TO THE PRELIMINARY DESIGN IS TO BE CARRIED OUT

THE DESIGN ENGINEER IN AGREEMENT WITH THE OBJECT OWNER DEFINES A PROGRAMME OF GEOLOGICAL AND GEOTECHNICAL SURVEYS TO ESTABLISH RISK ELEMENTS SUCH AS MECHANICAL, GEOLOGICAL AND GEOTECHNICAL CHARACTERISTICS OF THE GROUND, MAJOR WEAKNESS ZONES, PRESENCE OF NATURAL OR ARTIFICIAL CAVITIES, THE GROUND WATER TABLE AND THE PRESENCE OF GAS POCKETS

THE GEOLOGIST INTERPRETS THE GROUND FEATURES PREDICTABLY AND ACCURATELY

THE RISK SHOULD BE BORNE BY THE GEOLOGIST

STUDIES ARE TO BE CARRIED OUT BEFORE PUTTING OUT TO TENDER

SITE INVESTIGATION STUDIES ARE CARRIED OUT BEFORE PUTTING OUT TO TENDER

THE CONTRACTOR IS TO ANTICIPATE THE METHODS TO BE USED

THE CONTRACTOR CAN PLAN HIS METHODS AND PROCEDURES PROPERLY

THE PROCEDURES AND METHODS ARE WELL KNOWN AND ESTABLISHED

THE CONTRACTOR BELIEVES THAT HE CAN PUT FORWARD ALTERNATIVE SOLUTIONS TO PROTECT THE PROJECT SURROUNDS

THE CONTRACTOR CAN DEMONSTRATE THAT THE ALTERNATIVE SOLUTIONS PROPOSED BY HIM WILL OFFER AT LEAST THE SAME DEGREE OF SAFETY AS THOSE PROVIDED FOR IN THE PROJECT

THE OWNER SHOULD NOT ACCEPT THE CONTRACTOR'S ALTERNATIVE SOLUTIONS TO PROTECT THE PROJECT SURROUNDS

THE NEIGHBOURING STRUCTURES POSE A THREAT OF INSTABILITY

REINFORCEMENT WORKS ARE PROVIDED

GROUND VIBRATIONS CAUSE DISTRUBANCE TO ADJACENT STRUCTURES

A SYSTEM FOR CONTINUOUS MEASUREMENTS OF VIBRATION LEVELS IS ESTABLISHED

THE ALLOWABLE VIBRATION LIMIT IS EXCEEDED

NO ACTION IS WARRANTED

GROUND WATER IS PRESENT

REMEDIAL MEASURES ARE TAKEN

DURING TUNNEL CONSTRUCTION WATER IS ANTICIPATED

THE NECESSARY MEASURES TO DEAL WITH WATER IS SPECIFIED IN THE CONTRACT

SPECIFIC BILL OF QUANTITIES IS PROVIDED IN SUFFICIENT DETAIL FOR THE CONTRACTOR TO DEVELOP A TENDER APPROPRIATE FOR CARRYING OUT THE WORK AS DEFINED

UNFORESEEN WATER PROBLEMS ARISE

BILL OF QUANTITIES FOR DEALING WITH WATER FOR THE PROJECT IS TO BE DRAWN UP

GROUND INVESTIGATIONS ARE CARRIED OUT

THE LOWERING OF WATER TABLE MIGHT BE A PROBLEM

DIFFERENT TYPES OF PRECAUTIONS THAT MAY BE TAKEN TO HANDLE WATER IN THE TUNNEL, OR AT THE CONSTRUCTION SITE ARE ANTICIPATED BY THE OWNER

THE GROUND INVESTIGATIONS ARE EITHER INADEQUATE OR INCORRECTLY DONE

THE OWNER DECIDES THAT DEALING WITH SOME AMOUNT OF WATER SHOULD BE INCLUDED IN THE UNIT PRICES FOR TUNNEL EXCAVATION

THE EFFECT OF CHANGES TO THE WORKS CAUSED BY VARIATIONS IN THE QUANTITIES OF WATER EXPECTED IS TO BE EVALUATED

LOST TIME IN PROLONGED DISCUSSIONS AND DISPUTES ARE TO BE AVOIDED LATER

H - 21

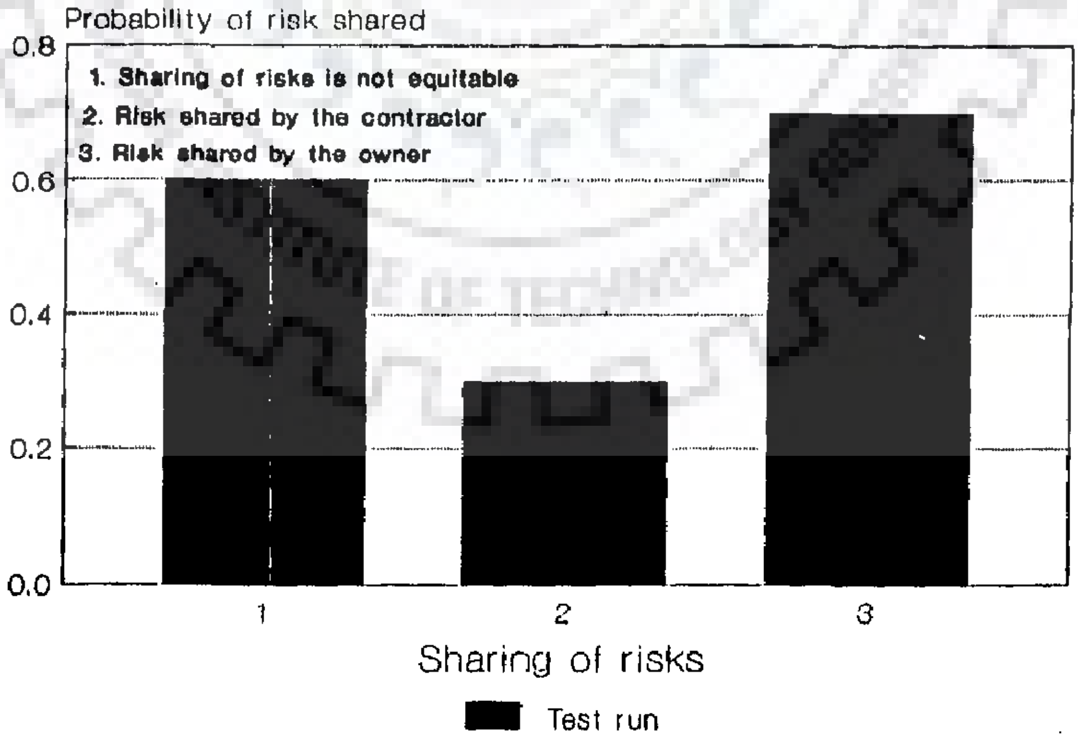

Fig. E -1. Histogram of sharing of risks.

PROJECT A: CONDITIONS OF CONTRACT

The following conditions are stipulated in the contract documents.

The general conditions and technical provisions of the contract besides covering all aspects of construction include the following provisions under "RISKS". Under the Contractor's Warranty, it is stated that "The contractor accepts all risks directly or indirectly connected with the performance of the contract with the exception of the limitations in clause 1.10 (a), 1.10A and 1.12 (c)".

These clauses read as follows:

"Clause 1.10 RISKS

"The contractor shall be the insurer of the Government's agents and employees against any and all of the following risks within the work area, whether they arise out of acts of commission or omission of the contractor or of third persons, excepting only those risks which result from affirmative wilful acts done by the engineer-in-charge subsequent to the submission of the contractor's proposals.

"(a) The risk of loss or damage to the work prior to the issuance of the certificate of final completion. -- In the event of any loss or damage to the work prior to the issuance of the certificate of final completion, the contractor shall promptly repair, replace and make good the work without cost to the Government, provided that the contractor will not accept loss or damage to the work due to:

"(1) Acts of God including earthquake and war,

"(2) Landslides and floods which occur after the specified lines and grades or open excavation has been attained and notified by the contractor and accepted by the engineer-in-charge within the agreed construction programme.

"(3) Storms, provided that the loss or damages is attributable to design of the works.

"(4) Defects in design.

"(5) Any damage to works at diversion dam site due to floods in the river exceeding 577 cumec during the working season, i.e., 31st October to 15th June.

"(b) The risks of injuries (including wrongful death) and damages, directly or indirectly to Government agents and their employees and to their property, arising out or or in connection with the performance of the work.-- The contractor shall indemnify Government as well as insure the latter's agents and employees for all such injuries, damages and losses resulting therefrom, within the works area arising out of or in connection with the performance of the work.

"The maximum limit of assurance for any individual claim under this clause will be Rs. 25,000 and the minimum limit will be Rs. 5,000.

"(c) The risks of claims and demands just or unjust by third party against the Government, their agents and employees arising or claimed to arise out of the performance of the work. -- The contractor shall take insurance for third party risks of all claims of loss of life and property in the work area, which includes all work site, the approach road, and other roads in the project area.

"The contractor shall indemnify the Government and the latter's agents and employees against and from all such claims and demands, and for all loss and expenses incurred by the Government in the defence settlement and satisfaction thereof. Neither the certificate of final completion nor any payment to the contractor shall release the contractor from his obligations in this respect.

"(d) Specific risks.-- Provisions elsewhere in the contract of specific risks or of particular claims for which the contractor is reasponsible shall not be deemed to be limited by the effect of the foregoing provisions nor to imply that the contractor is responsible for only risks or claims of the types enumerated in this clause.

"1.10A Special risks:

"Notwithstanding anything in the contract containing the provisions of "Special risks" mentioned hereinafter shall apply to this contract.

"(A) (i) The contractor shall be under no liability whatsoever whether by way of indemnity or otherwise for in respect of destruction of or damage to the works (save to works condemned under the provisions stipulated in subclause (B) hereof prior to the occurrence of any special risk hereinafter mentioned or temporary works or to property whether of the Government or third parties or for/or in respect of injury or loss of life in the work area which is the consequence whether direct or indirect of war hostilities (whether war be declared or not) invasion act of foreign enemies, rebellion, revolution, insurrection or military or usurped power, civil war or (otherwise than among the contractor's own employees) riot, commotion or disorder (hereinafter comprehensively referred to as "special risks") and the Government shall indemnify and save harmless the contractor against and from the same and against and from all claims, demands whatsoever arising thereout or in connection therewith and shall compensate the contractor for any loss of or damage to property of the contractor in the work area used or intended to be used for the purpose of the works and occasioned either directly or indirectly by said special risks.

"(ii) If the works or temporary works or any materials in the work area or (whether for the former or the latter) in inland transit to the work area shall sustain destruction or damage by reason of any of the said special risks the contractor shall nevertheless be entitled to payment for any permanant work and for any materials so destroyed or damaged and the contractor shall be entitled to be paid by the Government the cost of making good any such destruction or damage, whether to the works or the temporary works and of replacing or making good such materials so far as may be required by the engineer-in-charge or as may be necessary for the completion of the works on a prime costs basis plus such profit as the engineer-in-charge may certify to be reasonable.

"(iii) Destruction, damage, injury or loss of life in the work area caused by the explosion of impact of any mine, bomb-shell, grenade or other projectile, missile, munition or explosive of war shall be deemed to be a consequence of the said special risks.

"(iv) The Government shall repay to the contractor any increased cost of execution of works other than such as may be attributable to the cost of reconstructing work rejected under sub-clause (B) hereinafter or under any of the provisions of this contract prior to the occurrence of any special risks which is attributable to or consequent on or the result of any declared or undeclared war with India but the contractor shall as soon as any such increase in cost shall come to his knowledge, forthwith notify the E-in-C in writing within one month of the occurrence of the cause and the decision of the engineer-in-charge in respect of the claims will be final and binding on the contractor."

PROJECT B: CONDITIONS OF CONTRACT

The following conditions are stipulated in the contract documents of the project.

Under the Contractor's Warranty, it is stated that

"The contractor accepts all risks, connected with the performance of the contract subject to the limitations stipulated in Clause 'Risks/Accidents' of the conditions of contract.

"1.09 RISKS/ACCIDENTS

The contractor shall be the insurer of the Government and of the latter's agents and employees against any and all of the following risks within the work area, whether they arise out of the acts of commission or omission of the contractor or of third persons, excepting only those risks which result from affirmative wilful acts done by the engineer-in-charge subsequent to the execution of the contract.

"(a) The risk of loss and damage to the work occurring prior to the issue of the certificate of final completion including those arising out of the contractor's faulty workmanship, defective execution of work, inadequate upkeep, operations, negligence or otherwise due to contractor's acts of commision and/or omission. In the event of any such loss or damage the contractor shall promptly repair, replace and make good the work without cost to the Government.

"(b) The risk of injuries (including death) and damage and loss to Government, their agents and their employees and to their property arising out of or in connection with the performance of the work.

"The contractor shall indemnify Government and the latter's agents and employees for all such injuries, damages and losses resulting therefrom within the works area (which includes all work sites and roads in project area) arising out of or in connection with the performance of the work.

"(c) The risks of claims and demands by third party against the Government, their agents and employees arising and claimed to arise out of the performance of the work. The contractor shall take insurance for third party risks of all claims of loss of life in the work area, which includes all work sites and roads in the project area.

The Contractor shall indemnify the Government and latter's agents and employees against and from all such claims and demands and for all losses and expenses incurred by Government in the defence, settlement and satisfaction thereof. Neither the certificate of final completion nor any payment to the Contractor shall relieve the Contractor from his obligation in this respect.

"(d) Amount of Insurance: The Contractor shall take insurance to cover the following accidents under subclause (b) above:

1. Death,
2. Loss of two limbs, two eyes or one limb and one eye,
3. Loss of one limb and one eye,
4. Permanent disablement from injuries other than those named above,
5. Permanent partial disablement, and
6. Temporary total disablement".

SUGGESTED CHANGED CONDITIONS CLAUSE IN TUNNELLING CONTRACTS

(Extract from ITA recommendations)

The International Tunnelling Association recommends that a "Changed Conditions" clause be incorporated in all tunnelling contracts.

It is in the best long-term interests of both owners and contractors to incorporate a "Changed Conditions" clause in their contracts. Although the wording of such a clause may differ from one contract form to another, the intention is the same, viz. to require an adjustment in the contract price in the event that unknown conditions, not normally expected, are encountered.

The rationale for including a "Changed Conditions" clause induces contractors to avoid including large contingency sums in their tenders to cover the risk of encountering adverse underground conditions. Much of the gamble is thereby removed from underground construction. Furthermore, the owner does not have to pay a windfall price when only normal conditions are encountered, and the contractor suffers no disaster when unanticipated conditions arise. The owner only pays as if the true conditions were originally known. Both parties further benefit by the creation of a procedure to convey information (generally through the Engineer-in-charge) for resolving disputes by negotiations rather than litigation.

The long-term advantage of inclusion of a "Changed Conditions" clause in construction contracts relates, therefore, to lowered construction costs:

(1) Through the existence of more contractors willing and financially able to engage in such work; and

(2) By the elimination of underground risk contingency

costs from tenders.

The owner pays less for the completed project and receives actual money value for what was contracted to be constructed.

A few sub-clauses under Changed Conditions clause as described below are suggested for inclusion in tender/contract documents, of tunnelling contracts in India if they have not been considered by the owner:

"(a) The Contractor shall promptly, and before such conditions are disturbed, notify the Engineer-in-Charge in writing of: (1) subsurface or latent physical conditions at the site differing materially from those indicated in this contract, or (2) unknown physical conditions at site, of an unusual nature, differing materially from those ordinarily encountered and generally recognised as inhering in work of the character provided for in this contract. The Engineer-in-Charge shall promptly investigate the conditions, and if he finds that such conditions do materially so differ and cause an increase or decrease in the Contractor's cost of, or the time required for, performance of any part of the work under this contract, whether or not changed as a result of such conditions, an equitable adjustment shall be made and the contract modified in writing accordingly.

"(b) No claim of the Contractor under this clause shall be allowed unless the Contractor has given the notice required in (a) above, provided, however, the time prescribed therefor may be extended by the Government or the agency executing the contract.

"(c) No claim by the contractor for an equitable adjustment hereunder shall be allowed if asserted after final payment under this contract."

ELIMINATION OF DISCLAIMERS

It is consistent with the inclusion of a "Changed Conditions" clause in construction contracts to eliminate so-called "disclaimers" - i.e. clauses purporting to relieve the owner of responsibility for accuracy of the underground information furnished. If such disclaimer clauses are not eliminated, a conflict is created between the "Changed Conditions" clause and the disclaimer clause that will mitigate the intended elimination by contractors of contingency sums from their tenders to cover the uncertainty created by the disclaimer.

For contractual purposes, a distinction should be made between the data for which the owner is prepared to guarantee the accuracy, and the data that is provided for the tenderer's information. The former data should be binding on the owner. While the accuracy of the latter data is not guaranteed, it should not be expressly disclaimed, and it should not be regarded as binding for the purposes of a "changed conditions" determination; rather, it should be considered as one factor, together with all other evidence.

It is recommended that the owner should perform the interpretation of the ground by whatever means he adopts so that the geological information supplied in the bid documents is more realistic and the bidder may quote more reasonable rates.

Eliminating disclaimers should encourage owners to engage in well-conceived and well-executed underground investigations that will be sufficient both for design and construction purposes. By reducing the margin of uncertainty, this practice will benefit owners and thus permit better design and planning. The latter will, in turn, lead to more economical construction.

It is believed that, in the long run, the added time and expense of a thorough site investigation will be much less costly than the lost time and extra expenses incurred during construction in overcoming the consequences of incorrect information about the subsurface. The better the information about the subsurface, the less need there will be to disclaim responsibility for it; and the less frequently the owner will be faced with claims for "changed conditions" (ITA, 1988).

VITA

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