A SYSTEMS APPROACH TO TENDERING FOR CONTRACTS IN THE CONSTRUCTION INDUSTRY

A thesis submitted for the degree of

Master of Philosophy

by

ALI AKBAR SHARIFI

Department of Civil Engineering and Construction

The UNIVERSITY OF ASTON IN BIRMINGHAM

July 1985

TO MY FAMILY

THE UNIVERSITY OF ASTON IN BIRMINGHAM

A SYSTEMS APPROACH TO TENDERING FOR CONTRACTS IN THE CONSTRUCTION INDUSTRY

Thesis submitted for the degree of Master of Philosophy

By ALI AKBAR SHARIFI , 1985

SUMMARY

The main objective of this thesis is to approach the problems of tendering in the construction industry through the studied application of operational research/system analysis techniques. The early part of the thesis describe the construction industry and the problems which face competing construction firms.

A critical study of the published works on tendering/bidding strategy reveals its complexity; the Friedman versus Gates controversy is discussed in some detail, but no firm conclusions are made. Analytical and computerised simulation techniques are explained and compared with the aid of worked examples of the Friedman model(BIDMOD2) and the estimating error model(BIDMOD3).

Assumptions regarding the independence of model variables are clarified by the statistical analysis of three sets of tender data. Also, attempts to fit certain mathematical distribution to this data were made with a view to simplifying the random sampling process in the subsequent computer models. However, this analysis of data sets was generally inconclusive because the sizes of the samples are considered inadequate.

A computerised version of a modified Friedman model(BID20), which incorporates an allowance for estimating error is presented but then discarded because under certain conditions it is shown to be invalid. Finally, two bidding models BIDMOD9 and BIDMOD11 are presented, which incorporate both estimating error and "true-cost" ratio. A study of the effect of the "true-cost" ratio on the distribution of simulated bid/cost ratios was conducted in order to demonstrate the importance of this variable. These models are shown to give success ratios which fall between those suggested by the Friedman and Gates models. A comparison between the success ratios obtained by these models and one set of data indicates a fairly good approximation to the real world situation. A study of the possible effects of various strategies on annual cash-flow and turnover is also conducted.

KEY WORDS: CONSTRUCTION TENDERING SYSTEMS SIMULATION

ACKNOWLEDGEMENTS

The author wishes to express his deep gratitude and appreciation to his supervisor Mr. L.M. FORD , for his advice, guidance of every step in his work, and for giving generously of his time and knowledge, and to whom my gratitude passes all description.

I am also most grateful to the following, and very conscious of the debt I owe them :

To my family who have supported me wholeheartedly, and for their non-stop encouragement.

To my wife for her patience, understanding and moral support, and for urging me on to make an end.

To the managements of the construction firms, who provided me with a sympathetic hearing and access to their confidential files.

A final word of thanks to Mrs. L.M. Domone, the typist of this thesis, for her cheerful tolerance.

LIST OF CONTENTS

CHAPTER			Page

CHAPTER Page

CHAPTER Page

APPENDICES

APPENDIX | Page

LIST OF TABLES

TABLE		Page

Table		Page

LIST OF FIGURES

FIGURE		Page

FIGURE		Page

FIGURE		Page

Definition of Symbols

B_o	'our' bid (the bid of the contractor using the model)
B_i	bid of competitor i, i^{th} bid
V	value of profit
S	bias factor
C	'our' cost estimate
C'	'our' cost estimate corrected for bias
N_1	number of competitors on job 1
N_2	number of competitors on job 2
M_1	mark-ups for job 1
M_2	mark-ups for job 2
x	an appropriate exponent in the range of .5 - .8
C_1	cost estimate of job 1
C_2	cost estimate of job 2
y	an appropriate exponent in the range 0.15 - 0.30
L	lowest competitor's bid
$E(V/B_{o,\epsilon})$	expected value of profit conditioned on the bid amount and a prior experience
$F_i(B_{o/C})$	Cumulative distribution function evaluated at $B_{o/C}$
b_o	normalized value of 'our' bid
ℓ	normalized value of the lowest competitor's bid
$E(V/b_o)$	normalized expected profit given normalised bid
$F(b_o)$	cumulative distribution function evaluated at b_o
$f(b_o)$	density function evaluated at b_o
l_j	lowest competitor's bid/estimated cost
β_k	k^{th} regression coefficient
X_{jk}	k^{th} independent variable of j^{th} job
σ_ϵ	standard error of the estimate

σ^2	variance of prediction
X	matrix of independent variables
Y	vector of lowest competitors' bids expressed as fractions of 'our' cost estimate
X^T	transposed matrix of independent variables
E_r	r^{th} key competitor
E_{ave}	an average competitor
N_{key}	number of key competitors
N_{ave}	number of average competitors
Y'	bid price
f(x)	density function for a bid of x by a representative competitor
$F(Y')$	cumulative probability distribution
θ	arithmetic mean of competitive bids for the contract

CHAPTER ONE

Introduction

1.1 Introduction

Competitive bidding, based on tender documents prepared by client's professional advisors, is still the most common method of distributing the construction industry's contracts among the contractors willing to undertake the work.

The acceptance by the majority of clients, including central and local government and private clients, that competitive bidding is fair and will produce the lowest possible commercially viable tender price in the prevailing market conditions, ensures that this form of work distribution will continue for a long time.

The competitive bidding method for procuring work in the construction industry is as close to pure competition as we have in our economy. Each bid submitted by the different competing contractors is made up of a cost estimate and a mark-up which covers overheads, profit, and risk. The contractor submitting the lowest bid usually receives the right to the construction contract. In preparing bids in a competitive market, the more successful contractor adopts a strategy to outbid its competitors and win the job without underbidding excessively.

From the contractor's viewpoint, competitive bidding has the appearance of roulette : sometimes he wins when he thinks his price is high, sometimes he loses when his price is dangerously low. It is not surprising that some contractors believe , with some justification, that contracts are won or lost by sheer chance.

However, a fact that can not be denied is the existence of a relation between the bid price and the probability of winning the tender. Most of the bidding strategy models have concentrated on the determination of the principles whereby the probability of a contractor winning a particular contract can be estimated. From this, optimum mark-ups were determined and these were derived in an effort to maximize expected profit. Also, the minimization of the difference between the winning bid and the second lowest bid has been attempted; again as a means of improving profit margins.

Almost all of the approaches, used by different researchers in developing their bidding strategy models, involve the collection of the competitors' previous bids each time the individual contractor entered a bidding competition. Generally, all bidding strategy models require the analysis of the past behaviour of the contractor and his competitors in order to predict their future behaviour. To be able to perform such an analysis, a large volume of relevant bidding data is needed. Unfortunately, the major problem associated with bidding data is its availability, as most contractors are reluctant to give any information which can be used to discover their strategies and/ or their bidding behaviour.

The objective of this thesis is to approach competitive bidding, in the construction industry, systematically by using simulation techniques. However, before discussing this objective in more detail the systems approach will be explained briefly in the following section.

1.2 Systems Approach

The concept of a system has slowly emerged in the present century to assume a central importance in the thinking and approach of many scientists and technologists (1) . The impetus towards system thinking and the systems approach, has came from a recognition of the complex behaviour which can and does arise from both natural and man-made system (1) . Another stimulus, to adopt a systems approach, arose from attempts to predict and control the behaviour of the system instead of suffering from, or just reacting to, the gradually mysterious changes which occur in the surrounding physical, biological,social, economic and political climates (2) .

The systems approach is necessary because many problems which arise in an organisation are associated, not with a particular function in the organisation, but with the interaction between people, functions and departments (3,4) .

The systems approach unifies the role of management and worker because they will then be able to see themselves as jointly setting up and participating in a hierarchy of systems, in so doing behavioural science approaches will be very helpful in creating an environment in which change is possible. Changing people is not enough unless the system is put right as well (5,6)

A systems approach can help a manager by giving him a clear vision of his job, by adding greater purpose to his work, by achieving better relationships between his activities and by enabling him to make a more significant contribution to his organisation's overall objective. Systems problems appear intractable since little is known about systems, about system analysis, about control over systems behaviour, or about systems design. Systems thinking and the systems approach is now a growth area. Systems ideas appear in different guises in cybernetics, systems engineering, operational research, systems analysis, computer systems and many other fields (7) .

The above has emphasized the importance of the systems approach and the need for it. Now, as was mentioned earlier, this thesis attempts to approach competitive bidding problems systematically. It is also mentioned in the above that systems problems can be approached through operational research techniques and systems analysis. Hence, in order to approach tendering problems in the construction industry systematically, the operational research techniques will be employed to solve the problems by means of numerical methods.

1.2.1 Simulation

A widely used numerical method is simulation which uses random sampling in the solution process. It is also emphasized in the early part of this chapter that, to analyse the past behaviour of the contractor and his competitors in order to predict their future behaviour, it is necessary to have a large volume of relevant bidding data. However, as it will be seen later, obtaining such data is difficult and its accuracy is doubtful (see section 1.3). Therefore, in order to be able to examine the problems of competitive tendering /bidding in all its different aspects, computer simulation seems to be an ideal way of approaching the problem.

Simulation makes it possible to study and experiment with the complex internal interactions of a given system whether it be a firm, an industry, an economy, or some subsystem of one of these. Through simulation one can study the effects of certain informational, organisational, and environmental changes on the operation of a system by making alterations in the model of the system and observing the effects of these alterations on the system's behaviour. Detailed observation of the system being simulated may lead to a better understanding of the system and to suggestions for improving it, which otherwise would not be obtainable (8) .

The above has clearly indicated why computer simulation seems to be an ideal way to approach competitive bidding in the construction industry and the computerised simulation models which have been developed and used in this thesis will emphasize the importance of simulation techniques needed for approaching the tendering/bidding strategy systematically.

1.3 Research Methodology

It has been mentioned earlier in this chapter that, to analyse the past behaviour of a contractor and his competitors for predicting their future behaviour, it is necessary to have a large volume of relevant tendering data, preferably from different construction firms. There are different methods which can be used for securing the information needed (9). The two methods which have been used for this study are:

a) mail questionnaire,

b) interviewing.

Each of these two methods will be dealt with briefly here in order to point out the limitations and usefulness of its application.

a) Mail questionnaire: The questionnaire has the advantage of complete anonymity, speed of coverage and economy. In addition, some questionnaire results can be quantified. However, this method of collecting data suffers from many disadvantages, such as (9):

1. The response rate reported for mail surveys are much lower than interview surveys. The main problem is that of getting adequate response rates.

2. The questionnaire can be considered only when the questions are straightforward and simple to understand with the help of printed instruction.

3. Another technical disadvantage results from the fact that the different answers cannot be treated as independent (when the respondent who fills in the questionnaire can see all the questions before answering any of them).

Because of these disadvantages, the use of a mail questionnaire alone was not adopted by the researcher as a method for collecting the data required.

b) Interview: The personal interview is considered to be one of the most useful methods of collecting data, in social surveys (10). The main advantage of this method is that it yields a kind of information which can be accurately interpreted by suitably trained people, and which can form the basis for effective remedial action. However, this method has been suggested (11) to have the disadvantage of slowness and expense, and it introduces sources of error and bias (for example, the respondent may give inaccurate answers as a result of lacking the knowledge or misunderstanding the question, or he does not want to give the correct answer).

As can be seen each of the above methods has a number of strengths and weaknesses. Nevertheless, a combination of these two methods could be made which are thought to be be useful. Hence, the researcher found that interviewing with a guiding questionnaire was the most suitable method for collecting the necessary information regarding tendering strategy and which capitalised on the advantages and minimised problems that may arise if one method only was chosen. In addition, this method should ensure that all the questions are answered.

Initial contact was made with fifty construction firms and county councils by circulating a letter which briefly explained the main objective of the project and asked them to supply any useful information regarding this research (see Appendix 8.1).

The response to the letter was very poor. There was only three firms and one county council that responded to the letter and arranged for appointments for visits to their offices, and the rest of them either regretted that they were unable to help or did not respond.

In designing the questionnaire (which was used during the interviews to ensure that all of the respondents would be presented with the same set of questions) it was necessary to prepare the questions in such a way that would enable the researcher to examine the important aspects of tendering. The list of these questions is presented in Appendix (8.2).

During the interviews it was pointed out that any information obtained would be confidential and that it would not be assigned to a particular firm. Having said that, the researcher was allowed to tape the interview in order to help him to ensure that he got all their views, and to check on any piece of information needed later on.

Some of the information which was collected during these interviews, concerning tendering data, is presented in Appendix (1). Using these data the researcher carried out certain statistical analyses in order to investigate some of the important aspects of tendering strategy. However, as it will be seen later, the amount of information is insufficient to draw a general conclusion, as a general conclusion requires the analysis of a much larger volume of data.

As a result of this shortcoming it was then decided to use simulation technique for further investigation. This was achieved by assuming known statistical distributions for the important elements involved in tendering and to draw random samples from them. Here, some of the information collected during the interviews has been used, enabling the researcher to make a number of assumptions as required for developing the simulation programs. These simulation programs are then used to illustrate the influence of important parameters such as estimation accuracy and the applied mark-up.

1.4 Plan of presentation

In the following sections the work which has been carried out in this thesis will be described.

In chapter two, the most important characteristics of the construction industry are discussed. This chapter describes, in some detail, the functions of the different parties involved in construction contracts, the role of the contractor and sub-contractor, the different types of construction contracts and the different methods of selecting a contractor.

In chapter three,the relevant published works on the theory of competitive bidding are presented and discussed in detail. An attempt is made to compare all of these bidding models in a similar notation. This chapter ends with a discussion on the controversy over the Friedman and Gates bidding models; Lawrence Friedman and Marvin Gates are the two pioneer researchers in the competitive bidding field.

In chapter four, the application of both analytical and computerised simulation techniques is demonstrated by means of worked examples in order to illustrate the importance of tendering theory.

In chapter five, the three sets of data which were obtained from the construction firms (Appendix 1) have been analysed statistically and their analyses are shown.

In chapter six, the modified Friedman and Estimating Error models are described. The objectives of both the client and the contractor and the important factors affecting the competitive bidding in the construction industry are discussed. By using simulation techniques, two computerised simulation models were developed and the influence of important parameters such as the estimation accuracy and the applied mark-up were analysed through these simulation models.

In chapter seven, the results obtained through this study are discussed and some possible areas for further research are suggested.

Finally, the three sets of data obtained from the contracting firms, all the computer programs and their typical outputs, the initial invitation letter and the list of questions asked during the interview, are presented in Appendices.

CHAPTER TWO

THE CONSTRUCTION INDUSTRY

2.1 Introduction

This chapter deals with some of the most important characteristics of the construction industry. In it, is discussed in some detail, the functions of the different parties involved in building and civil engineering contracts, the role of the contractor and the sub-contractor, the different types of construction contracts and the different methods of selecting a contractor. The chapter ends with a brief description of civil engineering contracts in use.

2.2 Definition

A general definition of the construction industry is provided by Standard Industrial Classification Order XX (12) which covers:

> " Erecting and repairing buildings of all types. Constructing and repairing roads and bridges , erecting steel and reinforced concrete structure, other civil engineering works such as laying sewers gas and water mains and electricity cables , erecting overhead lines and line supports and aerial masts , extracting coal from open cast workings, etc.
>
> The building and civil engineering establishments of government departments , local authorities and new town corporations and commissions are included as well as on-site industrial buildings.

Establishments specialising in demolition work or sections of construction work such as asphalting, electrical wiring , flooring , glazing , installation of heating and ventilation apparatus, painting, plastering , plumbing , roofing , the hiring of contractors plant and scaffolding are included. This order also includes construction work carried out by employees of gas , electricity and water undertakings ".

2.3 Special characteristics of the construction industry

The construction industry has characteristics which, separately, are shared by other industries, but in combination appear in construction alone, making it worthy of separate treatment (13). These characteristics fall into four main groups:

i) the physical nature of the product;

ii) the structure of the industry, together with the organisation of the construction process;

iii) the determinants of demand; and

iv) the method of price determination.

The final product of the construction industry is large, heavy and expensive. It is required over a wide geographical area and is for the most part made especially to the requirements of each individual customer.

A large part of the components of the product are manufactured elsewhere by other industries. It is largely these product characteristics which determine the structure of the industry, including the large number of dispersed contracting firms and the separation of design in professional offices from construction firms, which has such important repercussions. The nature of the product, together with the structure of the industry it encourages, also means that each contract often represents a large proportion of the work of a contractor in any year, causing substantial discontinuities in the production function.

The work of the contracting part of the industry involves the assembly of a large variety of materials and components with implications for the relative importance of scarce resources.
Demand on the construction industry is for investment goods for which the ultimate use is:

(a) as a means to further production, e.g. factory buildings;
(b) as an addition to an improvement of the infrastructure of the economy, e.g. roads;
(c) as social investment, e.g. hospitals;
(d) as an investment good for direct enjoyment, e.g. housing.

The determinants of the demand for these categories of goods are different and need separate analysis. Moreover, government in some form, either central or local, is responsible for about half the demands on the industry and can affect directly or indirectly almost all the remainder.

This preponderance of government influence, together with the investment nature of demand, means that demand tends to fluctuate, particularly according to the state of the economy and the social and economic policies of the government, with consequent effect on the industry. There is some work, notably private speculative housing but also some commercial and industrial development, where the developer and the contractor are the same firm and hence where there is no overt price determination for the construction project. This probably accounts for a maximum of 15 percent of the work of the industry (13). The price which the developer charges for the finished product, whether it is a dwelling or office for sale, or an office or factory for rent, is influenced by many factors other than the price of the construction, such as the price of land, the price of capital and the system of taxation.

Because of the physical nature of the product, the structure of the industry and the characteristics of demand, the method of price determination is usually a discrete process for each project and for each piece of work subcontracted, either by tendering or by some form of negotiation. General economic theory deals inadequately with this type of price determination.

2.4 Organization of the construction industry

The construction industry is involved in three basic types of work, each with different and distinct characteristics and consequently, with substantial differences in the organization of work and in contractual relationship (14) .

2.4.1 Building work

This is frequently repetitive and generally above ground level with structural safety and aesthetic considerations tending to dominate the design process.

The promoter will normally employ an architect to design the building and the architect in turn may utilize the services of an independent structural engineer and a quantity surveyor.

There is still a predominance of small contracting firms in this section of the industry, and they employ a wide range of different tradesmen and crafstmen, e.g.,brick - layers, joiners, plumbers, glaziers. Building work is, consequently, labour-intensive and the cost of the work is largely derived from materials and labours.

2.4.2 Civil engineering

This is mainly concerned with roads, bridges, railways, tunnels, marine structures, and water works. Each project is normally a unique design, and the emphasis on control of water and working below ground level implies that there may be a great element of risk and uncertainty.

The promoter will normally engage a consulting engineer who is expert in the particular type of construction. It is normal for this engineer to undertake all design work, to supervise the working of the contractor(s), and to manage the realization of the project.

The contractor is then employed (as in building) only to construct the works. Civil engineering work frequently involves large-scale operations that may extend across a considerable area of country and , as such the work is highly mechanised and plant costs form a large element of the total construction costs.

Craft training is less important here; the operators and tradesmen are often proficient in a variety of skills.

2.4.3 Process plant erection

This is the third branch of the construction industry. Here the promoter will normally be expert in the design and operation of the plant and will frequently undertake both the basic design and management of the project.

The contractor(s) will then be responsible for detailed design, manufacture, site fabrication, and erection of the plant units.

The promoter may require that the plant offered and erected by the contractor shall achieve a specified operating performance. Much of the site work is repetitive, e.g., erection and lagging of pipework, and is labour intensive.

2.5 Parties of the contract

There are normally three parties involved in civil engineering contracts: the promoter, the engineer and the contractor; although on all-in contracts the roles of the engineer and the contractor are combined (15).
The normal parties involved in building contracts include the promoter, the architect, the quantity surveyor and the building contractor (16). The following sections briefly describe the functions of these parties.

2.5.1 Promoter

The promoter may be a government department, local authority, public corporation, nationalized industry, incorporated company, group of individuals or a private person. The promoter initiates the project and is responsible for providing the funds required to execute the project.

2.5.2 The architect

In building contracts the architect designs the building. This is usually done in collaboration with a team of specialists, i.e. quantity surveyor, structural, heating and electrical engineers (16).

2.5.3 The engineer

The engineer is appointed by the promoter to have overall engineering responsibility for the investigation and design of the project, and to supervise its construction (15). He exercises the power, reserved to him in that capacity, for the administration and timely completion of the contract.

2.5.4 The quantity surveyor

The quantity surveyor is responsible for ensuring that the architect and/or the engineer receives realistic cost advice throughout the design stage. He prepares the bill of quantities commencing at the drawings stage (16). He reports to the promoter and/or the architect on the tender prices and on the costs generally throughout the construction of the works on the site.

2.5.5 Contractor

The term contractor applies generally to any person, firm or company, or consortium of these, undertaking to perform civil engineering contracts (12). The building contrator, on the other, hand is responsible for erection of the building in accordance with the architect's drawings (16). Contractors may be broadly classified under two headings: the general contractor and the subcontractor.

2.5.5.1 **The general contractor**

General contractors are those who, on account of their knowledge and experience, are able to undertake responsibility for the execution of the whole of a project (15).

A general contractor assumes full centralized responsibility to the promoter for the delivery of a properly completed structure at a specified time and cost. He should be "thorough and experienced in organisation, pre-eminent in ordering, securing, assembling, and placing the inumerable materials and devices required on the modern construction project" (17).

2.5.5.2 **The Subcontractor**

There are a great number of specialised occupations needed in construction work and the demand for each speciality varies a great deal. If the general contractor were to attempt to retain a specialized staff, to perform all the necessary jobs involved in construction work, he would have difficulty in keeping such a staff busy all the time on his own work.

The sub-contractor, licenced in a specialized field, and having the particular tools and equipment needed for this work, including the appropriate labour agreements with the unions, can do his work better and more cheaply than could the general contractor in most cases. This specialization enables them to carry skilled staff and plant particularly suited to their work. The introduction of new processes and methods of construction is often due to the activities of such contractors and their employment can be of economic advantage to both promoters and the general contractors (15).

The amount of work sub-contracted by the general contractor varies with the type of work, that is according to how much specialized work is needed on each job.

2.6 Types of construction contract

Construction contracts are generally classified by reference to the method of payment by the promoter to the contractor, and these may range from a single lump sum to the actual cost plus a fee. The different types of contract offer different degrees of flexibility, incentive, and allocation of risk between the parties (14). The different types of construction contract are :

2.6.1 Lump sum contract

At one extreme, a single lump sum price may be quoted for the completion of the specified work to the satisfaction of the promoter by a certain date.

Use of this type of contract implies that design is complete and final, as there is no mechanism, within the contract, for adjustment of the price ,in consequence of variation in the promoter's requirements.

Such a contract might be used for the supply of a particular unit of process plant or material, or for a package deal in which the contractor is responsible for both detailed design and construction. Although the contract is awarded on the basis of a single lump sum price, in all but the smallest of the contracts, it is likely that payment of a proportion of this sum will be made to the contractor on the completion of each of a number of different stages of the work.

2.6.2 Cost reimbursable contract

Cost-reimbursable contracts are used when the requirements of the promoter are vague or when it is desirable for design to progress concurrently with construction.

Such contracts are also used when the promoter wishes to be directly involved in the management of the contract or to reduce the financial risk to the contractor.

2.6.3 Cost plus contract

A cost-plus contract is the extreme form of the cost reimbursable type and is so called because the contractor is reimbursed for all costs incurred during the fulfilment of the contract, plus an agreed fee to cover overheads and profits. The fee may be defined as a percentage of the agreed actual costs or as a fixed amount.

There is no financial risk for the contractor involved in a simple cost-plus contract and both parties may therefor suffer from a lack of momentum unless the promoter establishes effective controls, preferably by the operation of a joint planning team.

2.6.4 Admeasurement contract

Between the extremes described above lie the more common types of construction contract which facilitate competitive tendering but which incorporate some mechanism for the introduction and evaluation of changes in the work content of the contract.

2.6.4.1 Bills of quantities contract

A bill of quantities is used for the majority of building and civil engineering contracts in the U.K. Tenderers are required to enter unit prices against the estimated quantities of many items of completed work.

If there are no variations and the estimated quantities remain unchanged, the contractor will be paid the tendered sum, but all quantities are remeasured during the course of the contract, valued at the tendered rates, and the contract price adjusted accordingly.

2.6.4.2 Schedule of rates contract

A schedule of rates type of contract is similar to the bill of quantities, but the estimated quantities of work items are expected to be less accurate than those given in the former.

Consequently, it is common for separate rates to be quoted for labour, plant and materials, rather than being compounded against work items as in bills of quantities.

The contract price is derived by measuring the man hours, plant hours, and quantities of materials actually consumed, and then pricing them at the tendered rates. A schedule of rates is best suited to repetitive work and is frequently used in contracts for the erection of process plant.

Both bills of quantities and schedule of rates therefore offer systematic adjustment of the contract price for changes in quantity of work actually performed relative to the original estimate.

Almost all admeasurement contracts also offer a facility for the promoter to introduce and evaluate variations in the work defined in the tendered documents and for the contractor to claim additional payment should he incur extra costs due to circumstances that could not have been envisaged at the time of tendering.

2.6.5 Target contract

A promoter may introduce additional incentives into a contract by offering the contractor a bonus payment for the achievement of some previously defined targets in terms of time, cost, or performance.

Time or performance targets may be set in any type of contract. Thus, a contractor may earn a bonus for timely or early completion of the whole or some section of the works, in addition to the normal contractual payment related to work completed.

Obviously, the target and bonus/penalty will be selected to encourage the contractor to achieve the promoter's dominant objective.

Cost targets may be introduced into cost-reimbursable contracts to encourage efficient and economical working, something that is not always achieved in a simple cost- plus situation.

There are many examples of the successful use of such contracts for work involving exceptional risk or uncertainty and where there is a particular benefit to the promoter to be gained by direct involvement in contract management, early appointment of a contractor, and/or early completion of the project.

2.7 Methods of selecting a contractor

One of the matters to be dealt with in the contract planning exercise is the method by which the contractors for the project are to be chosen. This is particularly important as in most civil engineering and building contracts the contractor is selected on the basis of competetive tendering. Hence, the method by which the client selects the contractor is an important subject to be considered. Here, the options open to the client, when selecting the contractor for a construction contract, range from open tendering - when virtually any number of firms may submit a competitive bid - to direct negotiation with single firm.

In the following sections the methods which are most commonly used are described.

2.7.1 Open tendering

The full advantage of free competition with regard to price and other factors is obtained by open tendering (15).

One of the advantages of this method is that it permits any interested contractor to take part in tendering. However, this may result in the submission of a large number of tenders including some from firms of inadequate experience or unsatisfactory financial standing. Such tendering is not in the interest of either the client or the contractors since, by increasing contractors' overheads, it must, in the long run, tend to inflate prices for future work (15). Because, in open tendering, the number of firms submitting tenders is likely to be large and to include one or more very low bids, it is not surprising that the contract may be awarded to the contractor who is not suited to carrying it out and, while the initial price may be low, the final cost is likely to be substantially higher. The results of a statistical survey carried out by the Building and Civil Engineering Economic Development Committee (18) confirms this belief: open tendering projects were the least likely to maintain final costs close to the contract sum.

Another advantage gained by open tendering is that it allows the tender list to be made up without bias (16). This is the aspect which attracts local authorities who, because of public accountability, wish to demonstrate that they obtained the best bargain possible for public money and have shown no favouritism in selecting contractors. It is not surprising that, because of this fact, the method of open tendering is mainly used by certain public and local authorities (although not to a large extent or to the exclusion of other methods).

However, both the Simon Committee (Report on the Placing and Management of Building Contracts, 1944) and the Banwell Committee (Report on the Placing and Management of Contracts for Building and Civil Engineering Work, 1964) criticised the use of open tendering and, following their reports, government circulars have recommended its replacement by selective tendering. The results of the statistical survey by Building and Civil Engineering EDCs (18) also confirms the undue use of open tendering and shows that selective tendering is the main method of selecting contractors in both Building and Civil Engineering projects.

2.7.2 Selective tendering

In this method a short list of contractors, who are technically and commercially suitable to perform a specific job, will be selected by local authorities or private clients. This method has the advantage of eliminating the undesirable factors referred to in connection with open tendering (15).

The main objective of this method is to limit the number of contractors tendering to a sensible level. It is generally accepted as good practice that the number of contractors invited to tender should not be less than four nor more than eight (19).

Many local authorities maintain lists of contracts who are willing to undertake work of a specific type, within certain cost limits, and in particular geographic localities (16).

As it has been mentioned abve, the main advantage of this method is that the tender list is short. This means that only competent contractors will be invited to tender, and hence, the lowest tender can be accepted. It also reduces the risk of failure and cuts the cost of preparing estimates.

Finally, it enables competing contractors to include an adequate level of profit which in turn helps to give stability to the industry (16). As will be seen later in this thesis, if the number of tenderers for a particular contract is high the genuine competitor will have to reduce his mark-up in order to have any chance of success.

However, special care is required when selecting contractors in this method in order to make sure that favouritism does not influence the inclusion or exclusion of contractors from the list. Aother point to mention about selective tendering is that the tender prices are invariably higher than they would have been under open tendering (16).

In this method, in order to avoid the risk of inadequately experienced contractors tendering, an advertisement can be published inviting them to be prequalified for tendering. Prequalification of contractors is normally required to assist in compiling a list of firms qualified to receive invitations to tender (19). Contractors invited to prequalify should be asked to submit details of their experience relevant to the particular type of work in the location or circumstances applying. The amount of information requested should reflect the technical content of the works in question and the factors considered should be assessed under the following headings:-

(a) The contractor's financial standing: to make sure that he is financially stable and/or has the guaranteed backing of a larger group to withstand any financial problem that may occur during the contract.

(b) Technical and organizational ability: to ensure that the firm has adequate capacity and ability to undertake the works at the time in question.

(c) General experience and performance record: in order to make sure that the firm has had sufficient experience in the particular type and magnitude of works and has a satisfactory performance reputation.

The advantages of selective tendering on the basis of tender price are now widely recognized and this is reflected in the degree to which it is used (18).

Finally, it may be concluded that this method should be continued to be used for a high preportion of contracts because the competition aspect satisfies public accountability and the selective aspect can provide reasonable assurance of a contractor's competence.

Apart from open and selective tendering, there are other alternative procedures which can be employed for selecting and appointing contractors. An overriding need is that clients should consciously decide what approach is best suited to each project, or class of project, and that this decision be made early (18). The following section briefly describes some of the options open to clients for selecting the contractors.

2.7.3 **Negotiated tenders**

Negotiated contracts are usually entered into for a particular reason, e.g. the contractor has special management skills or can undertake particular works which require a high degree of technical competence, or is capable of completing the works within the required, restricted time period. Using this method the client selects only one main contractor with whom to negotiate.

Under a normal negotiated contract using a bill of quantities the contractor is selected at an early stage in the design process (16). This produces a better collaboration and joint involvement between the designer and contractor. Another advantage gained by this method is that the contractor can commence ordering materials, prefabricating work and programming so that an early start can be made on site and production can flow smoothly (16). However, the main disadvantage of this method is that the client can pay considerably more than under competition and clients need to consider this aspect more carefully.

The statistical survey conducted by the Building and Civil Engineering EDCs (18) indicated that only in housing was negotiation associated with better than average performance.

2.7.4 **Two-stage tendering**

In two-stage tendering usually three or four contactors with relevant experience are separately involved in detailed discussions with the client's professional advisors concerning the type and the scope of the work to be contracted. This method is used in the situation where early selection is needed but a good case cannot be made for negotiation with a single contractor without any competition. Two-stage tendering generally means that the first stage involves the competitive selection of the contractor, while the second stage involves the determination of the contract price based on pricing data obtained from the first stage.

Price competition is introduced by using either a bill of quantities or a schedule of rates, or by the submission of a priced bill of quantities of a recent project of a like nature when the tenderer was successful in competition (18). Advantages can be gained from designer-contractor collaboration during the design phase, and the early involvement of the contractor allows him better to plan the organization of the construction phase. However, the main disadvantage of this method is that, once selected, the contactor can change his level of pricing; although, this should not occur if the selection process has been properly managed and documented (18). The survey report by the Building and Civil Engineering EDCs (18) indicates that this method is used in only a small proportion of cases compared with the other methods mentioned earlier.

2.7.5 **Serial tendering**

Serial tendering has been broadly defined as an arrangement whereby a series of contracts is let to a single contractor. Using this method, the initial contract may be awarded by competition but contracts for subsequent stages are negotiated with the same contractor. This system allows a number of projects to be awarded to a single contractor following a competitive tender on a master bill of quantities, which then forms a standing offer open to the client to accept for a number of contracts (18). One of the advantages of this method is that it allows the client and the contractor to programme their workload in advance with more certainty (16). It also allows the contractor more time to plan the work on the site, so that it can be carried out more efficiently. This method could be used for a substantial part of the house building and school building programme (18).

The survey conducted by Building and Civil Engineering EDCs (18) showed that serial tendering is seldom employed and very few client bodies actually encourage its use.

2.8 British civil engineering contracts

As already mentioned, construction work of all types is normally undertaken by a contractor, a specialist in a particular field of work, who is employed for this purpose by the promoter. In most cases, the promoter will invite a number of suitable contractors to submit competitive tenders and will subsequently award the contract on the basis of the lowest tendered price. The promoter's objectives and requirements will provide the principal constraints on his contract strategy. A number of likely objectives (14) is listed below :

1. Completion in the minimum possible contract duration or at minimum cost.
2. Timely completion of the contract.
   (The promoter will not see any return from his investment until each engineering contract is completed.)
3. Quality.
4. Allocation, assessment and payment for risk.
5. Involvement in the management of the contract(s).
6. Involvement of the contractor in detailed design of the works included in the contract.
7. Use of capital.
8. Knowledge and administration of actual costs rather than tendered rates and prices.

The conventional procedures which have been developed for civil engineering works in the U.K. are now described.

In the traditional contract system, the promoter enters into a contract with the successful tenderer (contractor) for the construction of the works. He also engages a firm of consulting engineers to prepare the design, issue contract documents, assess the tenders, and supervise the work on site. The consulting engineer will normally be named as the engineer in the contract and, as such, is required to act in an independent and impartial capacity as administrator of the contract between promoter and contractor.

These contracts are usually of the admeasurement type, wherein the contract price is accumulated in a bill of quantities, which lists the constituent items of work each of which is priced. The quantities are stated to be the least estimate of the work to be completed under the contract that can be made prior to tender. All items are subsequently remeasured during the course of the works, and valued at the tendered rates. This type of contract therefore offers systematic adjustment of the contract price for changes in the predicted quantities of the work and is sufficiently flexible to permit the introduction of a limited amount of change and variation to the work originally defined in the contract. Some of the limitations on this much used and well tested approach may be listed below.

1. The engineer must be free to act in a truly independent manner.
2. The work included in the contract must be well defined, i.e. design should be substantially complete and the promoter's requirements should be adequately stated in the tender documents.
3. The probable extent of change and variation should not exceed about 20 percent of the tendered price.

Failure to satisfy any one of these three basic requirements will probably lead to a protracted dispute and may well affect the performance of the contract. The engineer fulfills several important roles in the traditional contract system. He is the link between design and construction, as it is he who passes design information to the contractor and who answers any queries. He then supervises construction of the works by ensuring that they are completed to line, level, and quality as defined by the designers in the contract documents.

At the same time, he is required to act independently - although directly employed by the promoter - interpreting and evaluating the contract. The latter requirement can only be satisfied if he is allowed to act professionally without restraint being imposed by the promoter.

Summarizing, the U.K. Civil Engineering Contract may, typically, be classified according to the following features:

1. The contract system is that requiring an independent engineer.
2. The contract is of the admeasurement type.
3. The contractor is selected by the process of competitive tendering.

CHAPTER THREE

REVIEW OF THE LITERATURE

3.1 Introduction

The method of competitive tendering, in which a number of contracting companies are invited to submit closed bids, is the one which is mostly used in awarding contracts and the lowest bidder is usually the successful one.

From the contractor's view point the competitive bidding, being random in nature, has the appearance of roulette, sometimes he can apply a very low mark-up , risking ending up with a loss but ensures obtaining the contract, or bid with a very high mark-up and hence ensuring making a profit but decreasing his chances of being successful bidder. It is clear that, knowledge of the probability of winning a tender associated with each particular mark-up would be very valuable to the contractor .

It is not surprising therefore that the subject of "competitive bidding" has attracted attention for research investigations of both the contracting companies themselves and a variety of academics in Europe and U.S.A. throughout many papers in learned journals since the mid 1950's.

Much of this effort has concentrated on the construction industry although there has also been work in other areas such as bidding for electrical generating equipment, oil drilling rights and gravel supply contract. However, the effect and impact on the industry of this kind is difficult to detect.

The concept was first introduced in 1956 by L.Friedman (20) and continued by others since then. The aim of most of the researchers has been the development of a "probabilistic model" which will predict the chances of winning in the type of competitive bidding that is common in the construction industry.

It has been commonly theorised that tenders submitted by contractors comprise of values allocated to two mutually exclusive components:-

(a) the cost estimate; and

(b) the mark-up.

The probabilistic models, mentioned above, have attempted to give guidance to bidders by providing statements of the type- "if you bid at a mark-up of 10 percent you have a 30 percent chance of winning the contract". Following on from these calculations of probability, previous researchers have also attempted to derive a mark-up which purports to represent " optimum mark-up ", i.e., the mark-up which in the long term will produce maximum profit.

The optimum mark-up theories so far derived have not taken into account the varying success a company might experience in filling its available capacity or budgeted turnover.

Therefore, recent work has suggested using the probability calculations, as a means of predicting the overall success ratio (number of jobs won/number of bids submitted), to control work acquired, by raising mark-ups when the order book is full and work is plentiful and by reducing mark-ups when the market and order book is depressed. The basic assumption of all calculations is that a relationship exists between the tender sum and the "probability" or "chance" of winning the contract.

The extreme cases are :

1) to bid very low and thus secure the job but make no profit or even lose money; and

2) to bid very high to ensure a high profit where the chance of winning is virtually nil.

Between these two extremes there are corresponding probabilities of success for each tender to be submitted.

A survey of the published literature in these areas will be presented and discussed in the following sections of this chapter. The chapter will end with a discussion of a controversy between the Friedman's and Gates' models who are the two pioneer researchers of bidding strategy.

3.2 Friedman's Model

The study of the competitive bidding process of the construction industry and the attempts at predicting the probable outcome of a bidding competition began in 1956 with Friedman's paper "A Competitive Bidding Strategy" (20).

One of the more interesting features of this model is the listing of the possible objectives of bidding. Briefly these are :

1. to maximize expected profit;
2. to recover a certain percentage of investment;
3. to minimize expected losses;
4. to minimize the competitors' profit; and
5. to win the contract, even at a loss, in order to keep production going.

He went on to point out that other objectives and combinations of the objectives might apply, but he adopted the objective of maximising total profit in the development of his model.

It will be observed that others who have written in this area have also adopted this objective. Furthermore, when the riskiness of the job is described in terms of probability distribution or cost of performing the work, and when the value is expressed in terms of " utility ", then the objective of minimising the expected losses will be the same as the objective of maximizing the expected profit.

Successful application of models with these objectives would seem to eliminate the remaining suggested objectives from further considerations.

Friedman first put forward the concept that there was a relationship between the mark-up applied at the time of tendering and the likelihood of winning the contract. Briefly, the process of preparing a bid is summarised as:

BID = COST ESTIMATE + MARK-UP

The cost estimate being a "scientifically" prepared estimate of the cost to the contractor in performing the work involved in the contract. The mark-up is a less "scientifically" prepared figure which reflects the contractor's profit expectations and his judgement of the market.

Friedman related mark-up to the probability of winning against a known competitor by collecting the competitors' previous bids in the form of (his bid)/(our cost estimate) . From these ratios he produced a cumulative frequency distribution like the figure (3.1) .

This established the concept of a continuation of mark-ups, from mark-ups which give a 100 percent chance of winning to mark-ups which produce no chance of winning, assuming that the competitor's behaviour is unchanged.

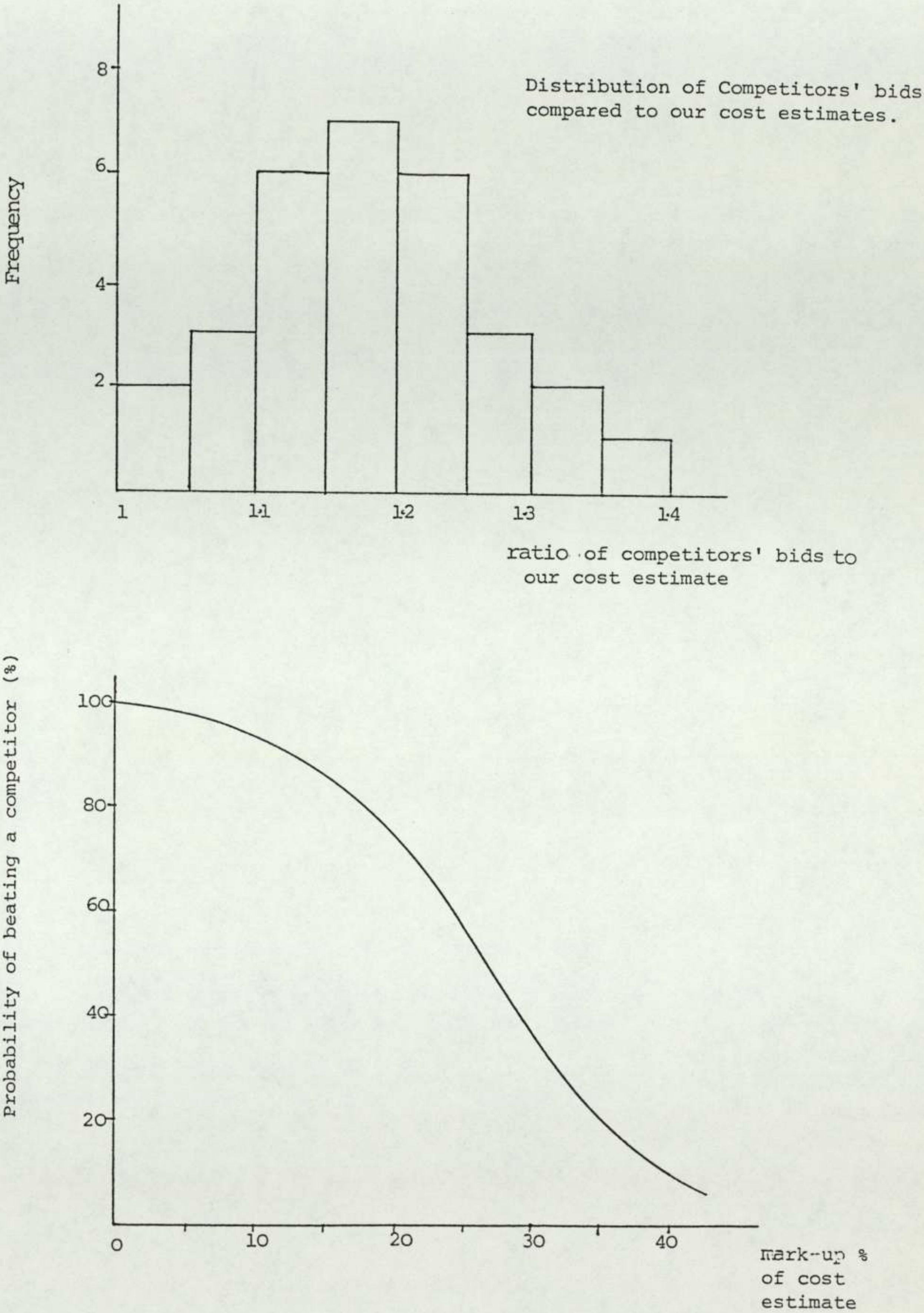


Figure (3.1) Probability of beating a competitor v mark-up.

However, if there is more than one competitor for the job then the probability of winning will be the probability of winning over the first competitor times the probability of winning over the second competitor, etc. , times the probability of winning over the last competitor. For example, if there are three competitors namely A , B and C, then the probabilty of winning P(M) for any specific mark-up (M) is equal to :

$$P(M) = P(A) x P(B) x P(C) \quad etc.$$

If identities and number of competitors are unknown, Friedman uses the concept of an "average" competitor. Here, the collected data would be aggregated into one "typical" frequency distribution likes Figure (3.2) which would give the probability of beating an "average" competitor for any specific mark-up (M) to be equal to :

$$P(M)=P(X1)$$

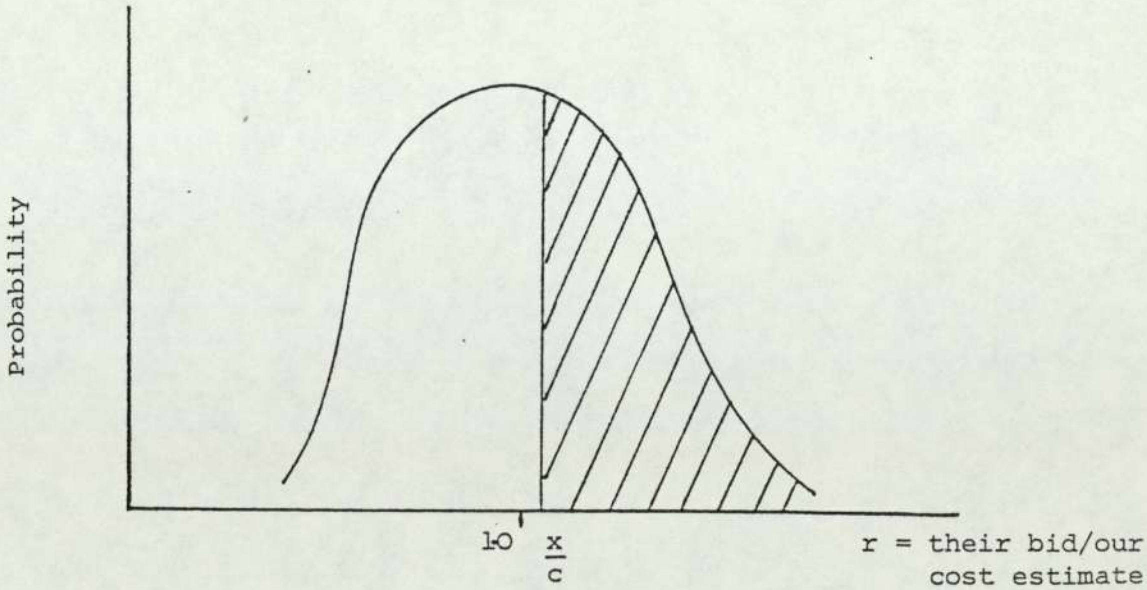


Figure (3.2) Bidding pattern of an average bidder.

Thus, the probability of winning the bid when bidding against n "average" competitors would be the probability of winning over one "average" competitor raised to the nth power. i.e.,

$$P(M)=P(X1)^n$$

The probability of winning the bid, thus, is a function of n the number of competitors, as well as the amount of the bid. The implicit assumption he uses to get these results is that the probability of winning over one competitor is independent of the probability of winning over any other competitor.

Unlike some of the authors that followed his work, Friedman recognised that the cost of performing the work is a random variable at the time that the bid is submitted; however, he did not incorporate in his model a means of expressing a preference for the variance of the probability distribution of this random variable.

Failure to consider the notion of variance preference leads to the unreasonable conclusion that the bidding strategy would be the same regardless of the degree of uncertainty attached to the construction cost estimate. In building works, each job for which a bid is submitted has a unique combination of labour, materials, equipment, supervision, subcontracted work, etc. Consequently, the cost of each job is a random variable whose behaviour is determined by a unique probability distribution(22).

There is no single distribution of the ratio of true cost to estimated cost that applies to all jobs without regard to the characteristics of the job as suggested by Friedman (22).

Friedman's model simply states that the expected value of the profit is the product of the profit at a given bid amount and the probability of winning with the bid amount.

The bias of the cost estimate is introduced as a factor by which the cost estimate is multiplied when the value of the job is determined. Letting B_0 be "OUR" bid amount and B_i , $i=1,2,3,\text{-----------},n$ be the bids of each of the other competitors, then, the value of profit is expressed as :

$$V=\begin{cases} B_0 - SC & \text{if } B_0 < B_1 ,\text{---------}, B_0 < B_n \text{ and S is known} \\ 0 & \text{otherwise} \end{cases} \quad (3.1)$$

where S is the bias factor, a random variable, and C is the cost estimate.

If h(S) is the density function of the probability density function of the ratio of true cost to estimated cost, then, the profit is expressed as :

$$V=\begin{cases} (B_0 -SC)\ h(S)\ dS = B_0 -C' & \text{if } B_0 < B_1 ,\text{-----------}, B_0 < B_n \\ 0 & \text{otherwise} \end{cases} \quad (3.2)$$

where C' is "OUR" cost estimate corrected for bias.

The evaluation of this model by Casey and Shaffer (34) assumed that the value of S was one. In other words, they assumed that there was no bias in the construction cost estimate. This assumption was made because there was no information avaiable to confirm a bias.

Friedman mentions that his bidding model was applied to a real situation but he gives no information about the type of application, the bidding situation, the industry or any of the details of applications.

As mentioned before, his model assumes, implicitly, that the probabilities of beating competitors are statistically independent. From the definition of independence :

probability(contractor beating A and B)=
prob.(contractor beats A) x prob.(contractor beats B)

Therefore, for ten evenly matched contractors competing for the same job, the probability of one of them being the winner is :

$$(.5)^9 = 1/512 \quad \text{which is very small.}$$

Also the sum of the probabilities of all ten contractors does not add up to unity which is hard to justify as one of them must win the contract. Another criticism of the model is that it includes, indiscriminately, all competitors past bids in its distribution.

As the winner is the lowest competitor, the inclusion of very high losing bids will affect the distribution . The profit according to his model is the difference between the estimated cost corrected for estimation inaccuracies and the bid amount, and no allowance is made for overheads.

3.3 **Park's Model**

Over the years, Park(26,27) has suggested the application of Friedman's model to the competitive bidding problems in the construction industry. Because of the absence of references, it is not clear that he was aware of the existence of Friedman's paper.

Park's objective is the same as Friedman's, i.e., to select a mark-up that maximises the expected value of total profit; but , unlike Friedman, he ignores the uncertainty associated with the cost of performing the work.

Although Park is probably the first author to suggest that a bidding model which maximises expected profits be used in the construction industry, but as Broemser(28) observed, his statistical methodology on his application is extremely primitive.

He makes the assumption that competitors' bids are independent, as is necessary in the Friedman model; however, he completely neglects to mention that he has made this assumption when applying the model so that one wonders if he actually knew that he was making this crucial assumption.

Furthermore, Park considered the number of bidders to be the only variableaffectingthe optimal mark-up until after his book (24) was published. In his other work (25) he suggested that both the number of bidders and the size of the job have some influences on the optimal mark-up. He has related the optimal mark-up of a job with a given number of bidders with the optimal mark-up for a job with a different number of bidders, by the following equation :

$$(N1/N2)^{x} = M2/M1 \qquad (3.3)$$

where N1 and N2 = Number of competitors on job 1 and 2

M1 and M2 = Mark-ups for job 1 and 2 ; and

x is appropriate exponent in the range of .5 to .8 .

In the same article, he related the optimal mark-up for a job with one estimated direct cost to the optimal mark-up on a job with a different estimated direct job cost by the following equation :

$$(C1/C2)^{y} = M2/M1 \qquad (3.4)$$

where C1 and C2 = Cost estimates of jobs 1 and 2

M1 and M2 are the same as the above; and

y is an appropriate exponent in the range of 0.15 and 0.30

Nothing is said of the methodology required to arrive at the optimal mark-up. He also illustrates the applicability of these equations in a sequential manner. Given the optimal bid for a reference job with a given number of bidders and a given cost estimate, he determines the optimal bid for a different job by first applying equation (3.3) and then equation (3.4).

Unfortunately, Park does not disclose how to determine the exact values of x and y in the equations (3.3) and (3.4). It is also not known whether the equation (3.4) assumes the same number of competitors for both jobs and what influence this number has on the relationship.

3.4 **Howard's Model**

Howard (29,30), like Friedman, considered the cost of performing the work to be a random variable at the time the bid is submitted. He used his decision analysis framework to arrive at the Friedman model.

In addition to this , he suggested that it is only necessary to bid lower than the lowest bidder among the competition.

In other words, instead of considering the probability of winning over each competitor on a job separately he looks at the probability of bidding lower than the lowest competitor, this is the probability of winning the job.

His objective is the same as Friedman's, i.e., to find the bid amount that maximises the expected value of the profit of the job. The profit, V, of a job is defined as the diffference between the bid amount and the cost of performing the work C , if the bid amount, B_0 , is less than the lowest competitor's bid, L .

$$V = \begin{cases} B_0 - C & \text{if } B_0 < C \\ 0 & \text{otherwise} \end{cases} \qquad (3.5)$$

Howard assumes that the cost of performing the work and the lowest competitor's bids are independent of "OUR" bid amount and that "OUR" cost is independent of the lowest competitor's bid

Having made these assumptions, he shows that the expected value of the profit is conditioned on the bid amount and a prior experience, ϵ , is

$$E(V/B_0, \epsilon) = (B_0 - C)\ P(L > B_0) \qquad (3.6)$$

Now if the bias factor, S , in the Friedman's model is assumed to be equal to one as assumed by Casey and Shaffer (34) , then the Friedman model is seen to be the same as Howard's equation.

3.5 Gates' Model

Marvin Gates (31,32) proposed a competitive bidding model of the type suggested by Friedman. Gates' objective is to maximise the expected profit to be realised from the job, i.e., the product of the profit that may be realised with a given mark-up and the probability of winning with that mark-up.

Like Friedman, he recognised that the true cost of performing the work is a random variable at the time that the bid is prepared; but he does not incorporate a measure of this randomness in his model.

The major difference between Gates' model and Freidman's model is the method by which the probability of winning with different bid amounts is assessed. Gates' claims that the probability of beating n known competitors is :

$$P\,(B_0 < B_1) \cap (B_0 < B_2) \cap \text{-----} \cap (B_0 < B_n) = \frac{1}{1 + \dfrac{1 - P(B_0 < B_n)}{P(B_0 < B_1)} + \text{-----} + \dfrac{1 - P(B_0 < B_n)}{P(B_0 < B_n)}} \qquad (3.7)$$

Unfortunately, he did not show the derivation of his equation for determining the probability of winning.Benjamin (22) has shown the nature of the reasoning required to derive the Gates probability assessment for the general case of n competitors.

He wrote this model in terms of the cumulative distribution functions of the competitors' bid-cost ratios :

probabilty of beating n known competitors =

$$\frac{1}{1+\frac{F_1(B_0/C)}{1-F_1(B_0/C)}+\ldots\ldots+\frac{F_1(B_0/C)}{1-F_n(B_0/C)}} \tag{3.8}$$

Where $F_i(B_0/C)$ = the cumulative distribution function evaluated at B_0/C .

Like Friedman, Gates also considers the case in which the identities of the competitors are unknown. He combines the bidding patterns of all competitors on all past jobs to develop the probability distribution of the typical competitor's bid-cost ratio .

The probability of beating n typical competitors is :

$$P(B_0 < B_1, \ldots\ldots\ldots\ldots\ldots\ldots, B_0 < B_n) =$$

$$\frac{1}{1+\frac{n(1-\text{prob. of beating the typical compt.})}{\text{prob. of beating the typical compt.}}} \tag{3.9}$$

No provision for estimation inaccuracies is made in the Gates' model and the profit is taken as the difference between the bid price and the estimated cost.

The sum of the probablities of winning for all competitors in any bidding situation, adds up to unity according to the Gates' model .

Hence, it can be argued that Gates arrives intuitively at a correct model. In his other paper (33) , Gates produced a detailed analysis of the spread (the difference between the lowest bid and the second lowest bid) on past bids.

He ran a regression analysis on the spread of several hundred highway jobs and found that the average percent age spread was related to the low bid. He then trades off the various amounts that he can add to his bid and the coresponding decreases in his chance of winning to determine his optimum bid.

Unfortunately, Gates did not say how to determine this probability of winning but feels that through the years, most contractors have come to estimate their chances of success at bidding.

He states that there is no evidence that the number of bidders, for a construction project, is in any way related to the magnitude of the cost of the job, and hence, he disagrees with Friedman and Park.

3.6 Casey and Shaffer Models

The models proposed by Casey and Shaffer (34) are essentially adaptations of the Friedman model. They have the same objective as the Freidman model, i.e., to maximize the expected profit.

As it has been mentioned before, they assumed that there was no bias in the construction cost estimate. In other words, the distribution of the ratio of true cost to estimated cost to be degenerate at a value of one. As a result of this assumption, the profit that will be realized, if the bid wins, is

$$V = \begin{cases} B_0 - C & \text{if } B_0 < B_1, \ldots\ldots\ldots, B_0 < B_n \\ 0 & \text{otherwise} \end{cases} \tag{3.10}$$

and not as defined by Eq.(3.1).

The objective is then to find the bid amount that maximizes the expected profit. This objective may be accomplished by using the multi-distribution model which takes advantage of the local nature of the construction industry in assessing the probability of bidding lower than all competitors.

In this model normal probability distributions of the ratios of the " competitor's bid/ our cost estimate " are constructed from the data obtained from previous tenders similar to Friedman's Model.

Here, it is assumed that, for a given bidding situation, the contractor expect n known competitors of unknown identity to bid also. Hence, the geometric mean of the probabilities of beating each of the known competitors with a given bid is considered to be the probability of beating an average bidder :

$$P(B_0 < B_{xl}) = \sqrt{\prod_{i=1}^{n} \left[1-F_i\,(B_0/C) \right]} \tag{3.11}$$

In which the subscript, xl, indicates an average competitor's bid.

The probability of submitting a low bid given that there are k average competitors is equal to :

$$P(B_0 < B_{xl})^k \tag{3.12}$$

Another model used by Casey and Shaffer for evaluation of the maximum expected profit was called : the one distribution model.

This model coresponds to Friedman's unknown competitors model with a bias correction of one, i.e., no provision is made for estimation inaccuracies.

They also assumed that the cost estimate was taken as eighty five percent of the bid price, hence, it can be assumed that their cost estimate contains provision for overhead.

3.7 **Broemser Model**

Broemser's Model (28), like Friedman's, seeks to maximize the expected value of a bid, but it is much more complex than Friedman's Model.

He also incorporates into his model Howard's idea that the bidder must only bid lower than the lowest competitor in order to win the contract. His linear model is adopted from a statistical decision theory approach suggested by Christenson (35) in both common notation and similar conditions of optimality.

Like Christenson, Broemser applies multiple regression analysis to determine the lowest competitor's bid relative to "OUR" cost estimate. The value of the profit, V , conditioned upon the bid amount is expressed as

$$(V/B_0) = \begin{cases} B_0 - C & \text{if } B_0 < L \\ 0 & \text{otherwise} \end{cases} \qquad (3.12)$$

where L is the value of the lowest competitor's bid.

Dividing through by the amount of the cost estimate yields the normalised value of the profit, conditioned upon the normalised value of the bid amount, i.e.,

$$(V/B_0) = \begin{cases} b_0 - 1 & \text{if } b_0 < \ell \\ 0 & \text{otherwise} \end{cases} \tag{3.13}$$

where ℓ is the normalised value of the lowest competitor's bid.

It follows then that the expected normalised value of the profit is

$$E(V/b_0) = (b_0 - 1)\, F(b_0) \tag{3.14}$$

where $F(b_0)$ is the complementary cumulative distribution function of the lowest competitor's bid defined by

$$F(b_0) = P(b_0 < \ell) \tag{3.15}$$

Taking the first derivative of the expression for the expected value of the profit with respect to the bid amount and equating it to zero yields the optimality condition at the expectation that is maximized. Broemser expressed his optimality condition as

$$\frac{f(b_0)}{F(b_0)} = \frac{1}{b_0 - 1} \tag{3.16}$$

where $f(b_0)$ is the first derivative of the cumulative distribution function evaluated at the

$$(B_0 / C = b_0)$$

This is the same expression for the optimality condition which has proposed by Christenson (35).

The regression model proposed by Broemser, for assessing the probability of winning with different bid amounts, is the only one of its sort to be recommended for use by the construction industry.

The dependent variable is the lowest competitor's bid expressed as a fraction of "OUR" cost estimate. The independent variables are those characteristics of the job which influence the profit that the contractor should expect from the job.

The distribution of the ratio of the lowest competitor's bid is determined by a standard normal linear regression of Eq. (3.14) which attempts to explain the behaviour of the low competitor by certain requirements or characteristics of the particular job.

The model yields a prediction of the mean value of the lowest competitor's bid to the contractor's cost estimate.

Broemser linear regression model (28:97) is :

$$l_j = \sum_{k=o}^{\infty} \beta_k X_{jk} \qquad (3.17)$$

where l_j = (the lowest competitor's bid/estimated cost) is the dependent variable ,

β_k = regression coefficient, and

the independent variables are :

$X_{j0} = 1$

$X_{j1} = (\text{estimated percent of cost not subcontracted})^{-1}$

$X_{j2} = (\text{estimated percent of cost not subcontracted})$

$X_{j3} = (\text{estimated percent of cost not subcontracted})^{2}$

$X_{j4} = (\text{estimated job duration})^{-2}$

$X_{j5} = (\text{estimated job duration})^{-1}$

$X_{j6} = (\text{estimated job duration/ estimated cost})$

$X_{j7} = (\text{estimated job duration/ estimated cost})^{-2}$

$X_{j8} = (\text{estimatd cost})^{-2}$

The subscript j indicates that the observed values of the dependent and independent variables are from the jth job used in estimating the regression coefficients, β_k , and the standard error of the estimate, σ_ϵ . All of the estimates are our contractor's estimate made prior to the bid. The first term is, of course, the regression constant. Independent variables 1, 2, and 3 describe how the mark-up varies with the amount of work a contractor does himself. Together they give the hypothesized curved relationship.

Independent variables X_{j4} to X_{j8} describe the size and intensity of the job. Taken together, they give the hypothesized curval relationship with the mark-up. The regression coefficient, β , is found by solving the normal equations:

$$\beta = (X^T X)^{-1} X^T \cdot Y \qquad (3.18)$$

where the superscript T indicates the transpose of the matrix, β , is the vector of regression coefficients, X is the matrix of n independent variables recorded for each of the m jobs, and Y is the vector of the lowest competitor's bids, for each of the m jobs, expressed as a fraction of "OUR" cost estimate.

The variance of the prediction is found by solving

$$\sigma^2 = \frac{(Y-X)^T (Y-X)}{m - n} \qquad (3.19)$$

A general contractor's bidding history over a period of one year was examined by Broemser in the developing his model. He performed sequential tests on his data. Three shortcomings were observed.

First, R^2 the coefficient of the multiple determination (or square of the multiple correlation coefficient) varied within the range of about 0.25 to 0.50 as additional data were considered in time.

Second, the values of the regression coefficients varied depending on the amount of bidding history that was considered in determining the coefficients,and thirdly, the success of the single bid model, as measured by the cumulative profits obtained by applying the model to data sequentially in time, varied with the amount of previous bidding history that was considered.

Broemser correctly indicates that the contractors ability to bid is constrained by his bonding capacity. He points out, too, that the contractor may have a number of self imposed constraints that limit the number or size of the jobs on which he is able to bid. These constraints may include a reluctance to handle more than a given number of jobs at any time, or refusing to attempt to perform more than a certain amount of volume of work at any time, or refusing to increase the number of field supervisory personnel in the organization who would be required to handle more jobs.

Having mentioned the shortcomings of the single bid model, he then selects which jobs to bid from a sequence of jobs and determines how much to bid on these jobs. He casts this sequential bidding problem as a constrained linear optimisation problem. Finally, there is no provision for estimation inaccuracies nor for overheads in Broemser's bidding model.

3.8 Morin and Clough Models

Morin and Clough (36), developed a computer programme OPBID (optimum bid) to evaluate the probability of success of a contractor in a particular bidding situation. This is also an adaptation of the Friedman model.

It differs from the other models in many respects, but the two principle points of differences are the evaluation of the project and in the assessment of the probability of winning. Whereas Broemser's Model seeks an optimum mark-up for overhead and profit, the OPBID model maximizes the expected profit only; and this is accomplished by subtracting a suitable allowance for general overhead from the mark-up.This model emphasizes six elements, namely : cost estimate, true cost, mark-up, number of competitors, identity of the competitors, and class of work (i.e., highway, building,etc.)

In this model, the identity of the competitors is not divided into known and unknown, as in the other models, but as being either key or average. The mark-up is assumed to consist of a fixed percentage for overheads and a variable percentage for profit.

The key competitors are identified on the basis of the ratio of their past bidding to the total number of biddings which were available to them. If this ratio is greater than an arbitrary key factor between 0 and 1 then, they are considered to be key competitors.

According to this model, the values of 0.4 and 0.5 yielded the best results. All other competitors are grouped into an average competitors. Unlike other models no attempt was made to fit known continuous distribution functions to the available data. Instead, a discrete function was used, which works for any contractor, as the data is the controlling factor. The following assumptions were made in developing the OPBID model :

1. The contractor's true cost is equal to his cost estimate.
2. Competitors will continue to bid as they have in the past.
3. There is no collusion among the competitors.
4. The submission of individual bids are statistically independent events.
5. The contractor can do work on all contracts that he wins.
6. The contractor's office overhead is prepared on the basis of project cost over all contracts won.

The probability of being the lowest bidder according to this model is given by :

$$\text{Prob. of winning} = \left[\prod_{r=0}^{N_{key}} P(E_r) \right] \left(P(E_{ave}) \right)^{N_{ave}} \qquad (3.20)$$

Where E_r = the rth key competitor

E_{ave} = an average competitor

N_{key} = number of key competitors

N_{ave} = number of average competitors

Morin and Clough tested their model to real-world data. Unlike Friedman (20) and Park(25) who suggested that the number of competitors is a function of the value of the cost estimate, they concluded that such a relationship does not exist between the job cost and the number of competitors. This does support the Gates' argument which contends that the number of competitors is not related to the cost estimate.

3.9 **Whittaker model**

Whittaker (37), argues that mathematics can not supersede judgement entirely and hence some allowance must be made for managerial judgement.

His model is based on the Friedman model and it is extended to allow for bias in cost estimates and the use of management judgement on market trends. In order to test his model, he gathered the data from four companies and developed his model for use in the building industry.

The following assumptions were made in developing Whittaker's MODEL :

1) All the bids are drawn from a distribution with known density

function and parameters. There is no knowledge among bidders about the individual bidding histories and other circumstances of their competitors and historical data may be used to forecast the parameters of the distribution, and its density function.

2) The number of competitors is known or may be estimated sufficiently accurately.

3) The expected value of the distribution of contract cost, C , is known.

This model also aims at maximizing the expected profit. The basic structure of the Friedman model with n competitors, ignoring the cost of estimating which has already been incurred and variations in the actual cost due to unforeseeable contingencies, is considered.
The objective is to maximize the profit which is the difference between the bid and the estimated cost. Hence,

$$E(V) = \max \left\{ (Y' - C)\ (1 - F(Y'))\right\}^{n} , \qquad (3.21)$$

$$F(Y') = \int_{0}^{Y'} f(x)dx$$

where $f(x)$ = the density function for a bid of x by a representative competitor

Y' = the bid price

C = the estimated cost

Data on fifty-seven individual contracts were studied by Whittaker. An S -shaped curve was found which fitted the data mentioned above. At a five percent level of significance (by X^2) :

$$Y' = (0.974449+0.1352319\ F(Y') - 0.005555/\ F(Y')\ ), \qquad (3.22)$$

where Y' = bid on contract

$F(Y')$ = cumulative probability distribution

θ = arithmetic mean of competitive bids for the contract

It is found that the distribution is practically uniform and so :

$$F(Y'/_{\theta}\ ) = 0.10+4.934 \left[(Y'/_{\theta}\ ) - 0.9029 \right] \qquad (3.23)$$

This distribution was used by Whittaker, to predict the probability of any specific bid being the winning bid provided the mean bid could be estimated to within the range of -3.5% to 1% .

The question of whether the contractor can estimate the mean bid to within the above range or to use the distribution accurately and adequately, was raised by a number of people. Among those were, Curtis and Maine (38), who argued that the statistical analysis used by Whittaker to derive his distribution was invalid.

An important contribution made by Whittaker and also supported and further explained by Fine (39), was to describe the potential effects of estimating inaccuracies. Both Whittaker and Fine use the concept that there is for a job a " true cost " and that estimators' predictions are aimed at " true cost " , but fall in a distribution around the "true cost ".

Given that competitive bidding selects the lowest bid then the winning bid is nearly always on the low side of true cost. It was concluded by Grinyer and Whittaker(41), that the estimate contributed most variability to a bid and the mark-up contributed much less variability.

In fact they quote a range of mark-ups of .35 percent about a mean. Thus the controlling variable was the estimate and in turn the estimating inaccuracies. The estimating error was considered to be uniformly distributed about the true tender cost and the profit was calculated by evaluating a break-even mark-up associated with each estimation accuracy and number of competitors.

They also concluded that there was no clear relationship between the number of competitors and the job cost.

Several other researchers have also contributed works towards bidding strategies. Among those are: Dean, Hanssman, and Rivett (42), who also introduced competitive bidding stategy models but not specifically for use by the construction industry. Statham and Sargent (43), supported the approach of determining an optimum mark-up model which was firstly introduced by Park (25).

However, it seems that they were no more successful than Park in having their ideas adopted. Fine (39) and Rickwood (44) have attributed the variability of a contractor's bid to estimating variability and mark-up variability. The estimating variability they assign to estimating errors, which in their view are mainly random and therefore the cost estimate is a random variable.

Rickwood (44), using simulations demonstrated that if you assume estimating accuracy to be zero, that is all contractors use the same estimate and the only variable is mark-up, then, Friedman tends to produce the more accurate estimate of the probability of winning. If, on the other hand, the mark-up is the same and the only variable is the cost estimate, then, Gates tends to be more accurate. He then proposed, but never tested, a weighted average of Friedman and Gates, the weighting representing the contribution to the total variability of the estimating and the mark-up variability.

McCaffer (45) sympathising with the approach of Whittaker (37) undertook a similar analysis. He took into account the criticism of Curtis and Maine (38) and produced distributions of bids for road and building works which were shown to be virtually normal distributions. The use of these distributions, or distributions of contracts grouped together by the number of bidders, made it possible to predict the lowest bid from an estimate of the mean bid. According to him, an accurate estimate of the either the mean bid or the lowest bid could provide the contractor submitting a bid with a reasonable measure of the probability of winning.

Fine (39) assumed that the only competitor to beat was the lowest one. His " low competitor " model involved collecting data (lowest bid/(our cost estimate) in each competition entered and creating one single Friedman type distribution. This clearly had the advantage that it avoided the difficulty of combining probabilities of different distributions. However, the problem with this approach as, it was emphasized by him, was that the distribution required a substantial amount of data before it become stable. Given that each competition entered would only produce one item of data, the lowest bid, it would take a long time before enough data was collected to stabalize the distribution. The length of time required would cast doubt on the value of the early data.

Another recent reference to the accuracy of the estimate as being the main controlling variable in determining the winning bid has been made by Barnes and Lau (46). They observed the accuracy of contractors estimating for contracts in the process plant industry. They found estimating accuracy ranged from a coefficient of variation of +6.1 percent at best to coefficient of variation of +18.4 percent at worst. They concluded that this inaccuracy made it impossible to obtain feedback from the real situations as to the effect of different pricing policies.

Another contribution to bidding strategy is made by Mercer and Russel(47). In studying gravel supply contracts, they demonstrated that contractor's relative prices changed with time, that is the lowest priced contractor did not remain the lowest priced contractor for all times. One of the difficulties in following their work as it was also mentioned by Whittaker (37) is due to the amount of data required. Another difficulty is that since each contract in the construction industry is virtually unique, then, it is much more difficult to detect different pricing policies when the product is so variable. Neverthless Mercer and Russel's observations are fact and should be taken into account. Finally, among the other works suggested for solving the competitive bidding problems are the game theory models. Among the people who proposed such models are :

Vickery (48), Wilson (49), and Greismer, Levitan, and Shubik (50). Of these , the paper by Greismer,Levitan, and Shubik could probably be extended to the competitive bidding problem in the construction industry.

3.10 <u>The controversy between Friedman and Gates Models</u>

It may be seen in the previous sections of this chapter, how

Friedman's Model for evaluating the probability of success assumed that the competitors' bids are statistically independent which led to the result that the sum of the probabilities of winning for all competitors does not add up to unity. On the other hand, the model propose by Gates assumed that the bids are dependent but had no mathematical proof. Neverthless it yields the probabilities of success that adds up to unity in any given tendering situation which is a true reflection of the actual situation, as one bidder must win the contract.

Since 1968 an acrimonious controversy over the basic assumptions used in bidding, particularly in the way that the probability of winning is computed, has appeared in the journal of American Society of Civil Engineering. The controversy serves to highlight the importance of the basic analysis and assumptions used in handling the whole range of bidding situations although most of the data quoted refers to civil engineering contracts. Further, because bidding results are sensitive to small changes and are often unstable, errors which may appear to be of a somewhat academic character can have a significant practical effect. Thus the study of this controvesy should serve as an important warning to anyone concerned with bidding and encourage a healthy distrust for articles on the subject. The controversy arose following the publication of a paper by Marvin Gates (31) that included a conjecture supported by construction industry data, that appeared to be at odds with Friedman's results.

As mentioned earlier, the objective of both Friedman's and Gates' models is to find the bid amount that maximizes the expected monetory value of the bid and the main difference between these two models is in the way that they determine the probability of winning with the bid. Friedman(20) found the probability of winning with a given bid to be the products of probabilities that the bid is less than the bids of the competitors. i.e.,

$$\text{probability of winning} = \prod_{i=0}^{n} P(B_0 < B_i)$$

where B_0 = the bid of the contractor using the model; and

B_i = the bids of the competitors.

While, Gates(19) proposed this probability to be equal to :

$$\text{probability of winning} = \left\{ \left[\sum_{i=1}^{n} \frac{1- P(B_0 < B_i)}{P(B_0 < B_i)} \right] +1 \right\}^{-1}$$

Which was stated to be a mathematical model of " coloured balls in the urn " . In his criticsm Gates states that Friedman's Model does not apply to competitive bidding in the construction industry, as it contradicts bidding experience and is mathematically incorrect. Furthermore, it gives probabilities which are far too small. Gates explained this by saying that if our company is competing against say seven evenly matched competitors, in the long run our company will win one eighth of the contracts. Whereas, Friedman's equation gives the probability of winning as one in 128, i.e., one over 128 as compared with one over eight for Gates' formula.

Gates also examines the Morin and Clough OPBID(36) and concluded that

" the rationale that the probability of winning over a groups of competitors is the products of the individual probabilities of winning over each competitor is incorrect ". Stark (51) in his paper expressed doubt about the Gates' Model and stated that it is not " the proper representation of the probability of winning ". However Gates responded to this criticism and stated that in the case of closely matched competitors his model yielded reasonable results.

In 1972 Rosenshine (53), produced his " resolution of controversy " in which he showed that both Gates and Friedman were correct. He stated that both models are correct in their own way, Friedman's Model expresses the probability of beating independent competitors at a given mark-up whereas Gates' Model describes the results of bidding competition.

He precedes this with a proof of Gates conjecture based on probability theory. However, this does not convince Dixie (54), the only U.K. author to feature so far in the controversy , who submits his own " final resolution of a controversy ". He involved the notion of conditional probabilities and Bayes' theorem to develop Gates' equation and concluded that both Friedman and Rosenshine are wrong and that Gates' formulae are the correct ones to use.

Fuerst (55) in 1976 in his paper " truth and comment " states that Friedman is correct and points out errors in both Dixie's and Rosenshine's works. This implies that Gates's formulae is incorrect unless the probabilities of beating a competitor are interpreted as conditional on either our company or the competitor's winning.

This is again rejected by Gates. In his other work called Monte Carlo Experiment, Gates concluded that, based on the results of this experiment, his formulae is correct and Friedman is wrong. Replying to

Gates' criticism Fuerst (55) stated that Gates misrepresents Friedman and does not underestand probability and can not do simulation properly.

Rickwood (44) also made an extensive study of this controversy. He concluded that Friedman's Model is more accurate when estimation inaccuracies are neglected and bids vary due to mark-up only. On the other hand, Gates' Model is more accurate when mark-ups are the same and the variation is due to errors in the cost estimate. The Costain Operation Research Group (40) , also arrived at the same conclusion. Rickwood also proposed a weighting average of the probability predicted by Friedman or Gates, in which weighting representing the contribution to the total variability of estimating variability and the mark-up variability.

One of the latest contribution towards this controversy is the paper by Benjamin and Meador (58). This paper compares Friedman's and Gates' Models. They developed a simulation model and tested it with the aid of data gathered from a contractor's 3-year bidding history.

As a result of the simulation experiment, they concluded that the Friedman model always leads to lower optimal mark-ups with less chance of winning. Because of this, Friedman model tends to win less jobs.

Although, this does not mean that the use of Friedman model will always result in greater total profit over a long run as compared with Gates model.

They also showed that on the average, it takes about twice the volume of work to realize about the same level of profit by the use of Friedman's Model than by use of Gates' formulae. Finally, they showed that Gates model gives a better fit to the frequency of winning.

3.11 Survey conclusions

In the previous section the controversy between the Friedman and Gates models has been discussed. These discussions have been done as it is seen that all the bidding strategy models developed by different authors have followed one of these two models. It is further mentioned that the controversy serves to highlight the importance of the basic analysis and assumptions needed in handling the whole range of bidding situations.

It was also noticed that all the bidding models described in this chapter are different in the way that the probability of success is computed. Furthermore it is seen that most of these probabilistic bidding models stem from the concept of maximizing the expected profit. Finally as it has been mentioned there is a disagreement between a number of authors on the possibility of the existence, and the type of relation between the job value and the number of bidders.

In order to discuss in more detail the importance of this controversy and the impact of the aforementioned a further investigation into the above areas will be conducted in the remaining part of this thesis.

CHAPTER FOUR

TENDERING THEORY: ANALYTICAL AND SIMULATION TECHNIQUES

4.1 Introduction

In this chapter the application of both analytical and computerised simulation techniques is demonstrated by means of worked examples in order to illustrate the importance of the theory of tendering.

4.2 The Friedman Model

In the following sections examples based on Friedman's model are fully described . The first example describes the case of contractor A bidding against a single competitor : contractor B.

The second example considers contractor A bidding against three different competitors. Finally , the third example considers contractor A bidding against two or more 'typical' competitors.

4.2.1 Example 1: Single Competitor

Assume that contractor A has been studying the bidding behaviour of contractor B . On every contract, on which contractor B has bid and on which contractor A has made a cost estimate, A calculates the ratio of B's bid to A's cost estimate. Assume that contractor A has sufficient information to enable him to construct a distinct probability density function (PDF) of such values. Such a hypothetical PDF is shown in Figure (4.1) .

Now, using Fig. (4.1) contractor A can estimate his probability of beating contractor B for varying mark-ups. For example, for a mark-up of 10 percent, i.e., for a bid/cost ratio of 1.10 , contractor A's probability of beating contractor B is the area of the PDF to the right of abscissa 1.10 . This value is equal to (4 +2.5+.5)x.1 = 0.7 . Similarly, a mark-up of 20 percent will give a probability of 0.30 , etc.

Generally, the bidding distribution pattern of contractor A could have been found simply by tabulating his bids on all jobs for which cost estimates were made, in each case relating the competitor's bids to the estimated job costs. Wide variations will be found in the bidding characteristics exhibited by different competitors; competitors' bids may range from less than half to more than double the estimated job costs, with the extreme variations most likely caused by errors or oversights on the low side, and by a complete lack of interest in getting the jobs on the high side.

From the PDF of the competitor's past bids, a probability curve can be constructed, giving the chances of underbidding contractor B with any given bid; see Figures (4.1) and (4.2).

Now a profit expectation curve can easily be developed from the

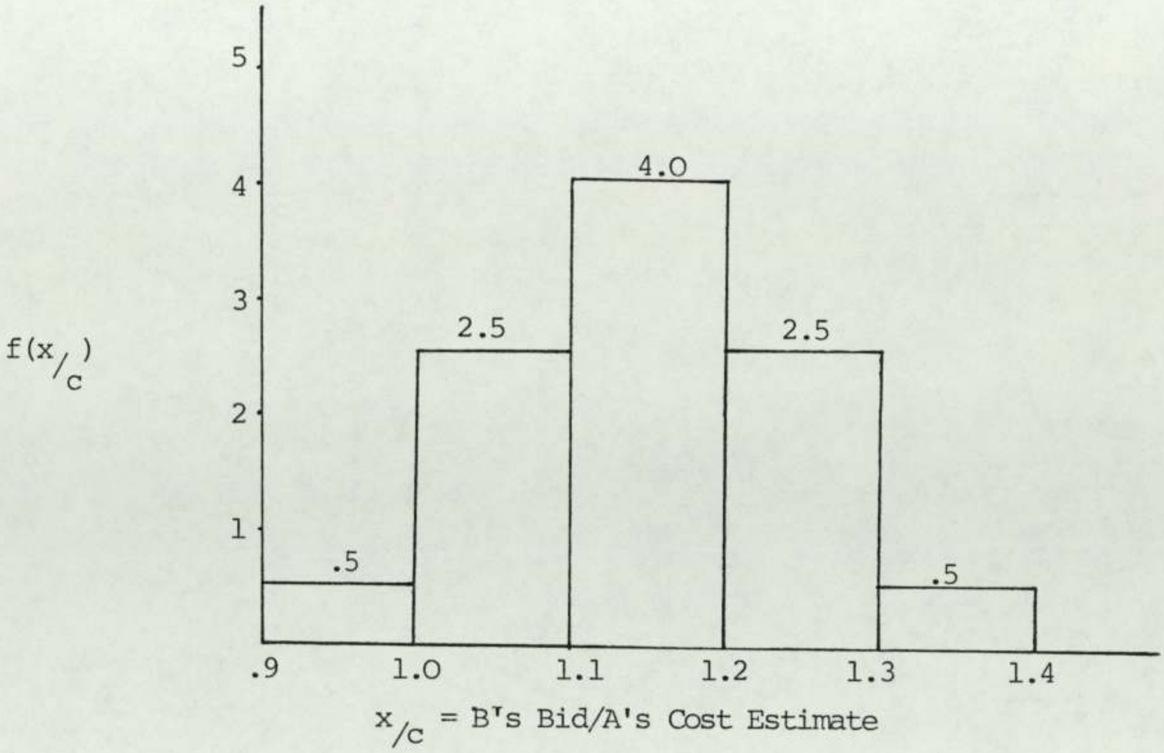


Figure (4.1) PDF of bid/cost ratios for competitor B.

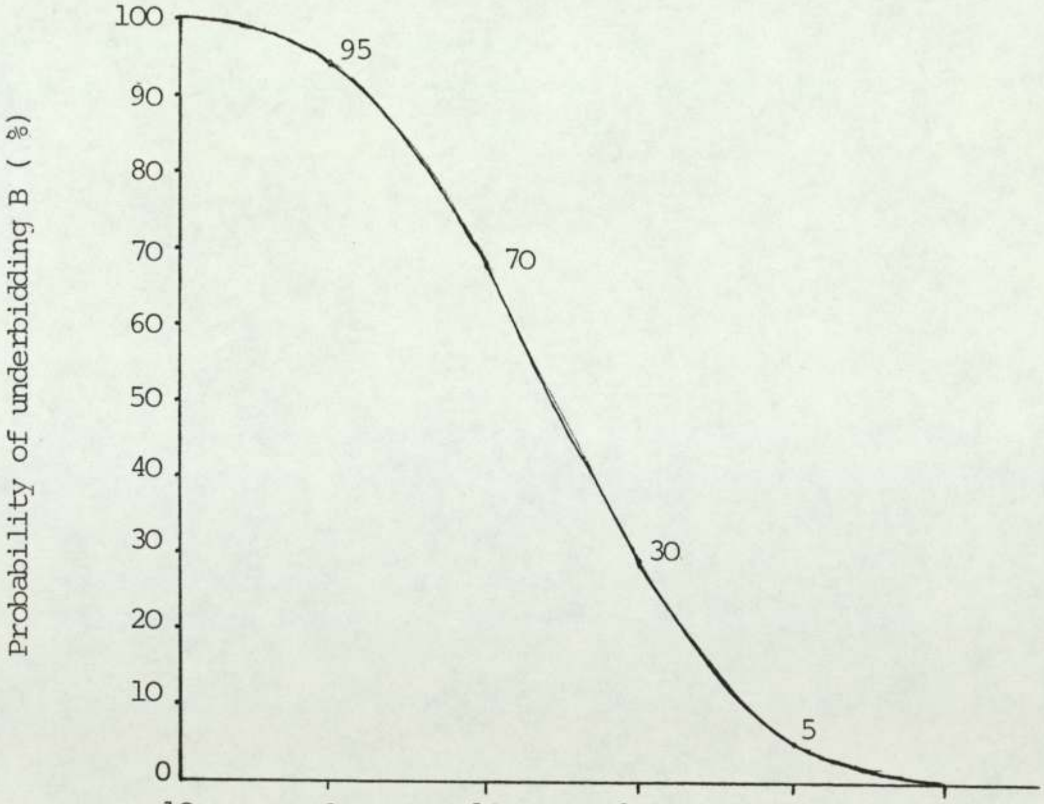


Figure (4.2) Percentage probability of A beating a single competitor B.

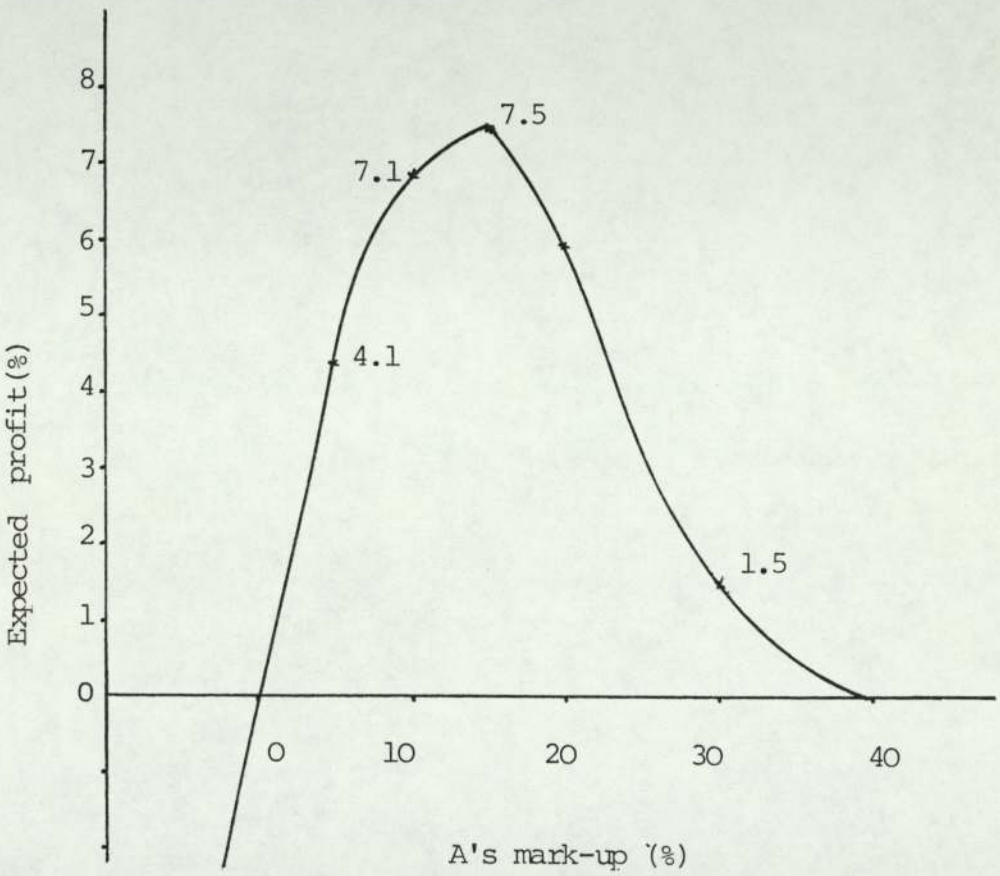
probability curve. Note that A's expected value of profit is equal to A's mark-up multiplied by A's probability of beating B at that mark-up. Figure (4.3) shows the profit expectation curve, which gives the average long run profit resulting from any given level of mark-up when bidding against a contractor B .
Note that the mark-up which maximizes expected profit is about 14% .

Figures (4.1) to (4.3) illustrate the bidding strategy of contractor A when he bids against one competitor. However, this is not always the case and, usually, bidding involves a number of competitors who bid against each other. Obviously, every competitor will exhibit different bidding characteristics; some bid consistently high, some bid consistently low, some spread their bids uniformly over a wide range, and some may bid within fairly well defined and narrow limits.

The strategy to be employed against each must therefore vary to take maximum advantage of each one's individual characteristics and weaknesses.

4.2.2 Example 2: Three Different Competitors

Figure (4.4) shows the PDF's for 3 different competitors B , C and D. Assuming the true cost is the same for all competitors, including us, then the probability of A beating all three with a mark-up of 10% is , abd , the product of the areas under the PDF's to the right of abscissa 1.10 , i.e., 0.70x0.45x0.85 = 0.27 .
The corresponding expected profit is : 10% x 0.27 = 2.7% .



Figure(4.3) Expected profit curve for A bidding against a single competitor(B)

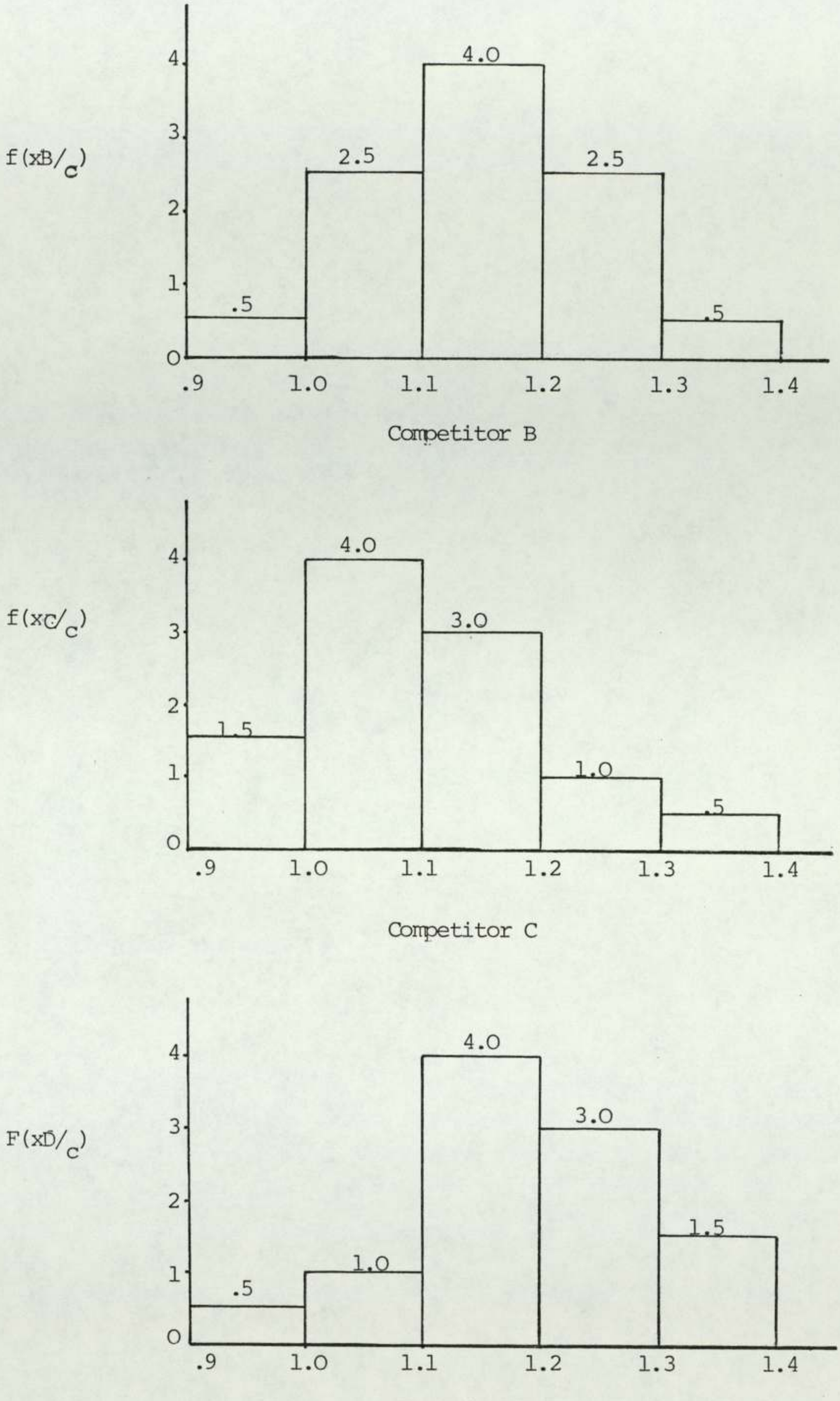


Figure (4.4) PDF's of Bid/cost ratio for 3 different competitors (B,C and D).

Similar calculation for a range of mark-ups can be made enabling Figures (4.5) and (4.6) to be constructed. The mark-up which maximizes expected profit is seen to be about 8% .
(Note that if estimating error is ignored then the expected profit always equals mark-up).

4.2.3 **Example 3: Two or more Typical competitors**

When individual competitors and their bidding characteristics can be identified in advance, the best results can usually be obtained by considering them individually as mentioned in the previous section. However, there are apt to be relatively few jobs on which all competitors can be identified, or where sufficient data are available to determine properly the bidding characteristics of all participants. In such cases the concept of the 'typical'- or average-competitor can be used to advantage. The typical competitor is simply a composite made up of all bids of all competitors, as such the typical competitor refers to no one competitor in particular, but to all competitors in general.

The concept of a typical competitor is specially valuable when bidding against numerous unknown competitors. By using this concept, the general level of bids likely to result in maximum profits can be identified, and used as a guide in setting an exact price, or in identifying the most potentially profitable jobs.
Figure (4.7) shows a hypothetical probability curve and expected value for different numbers of a typical competitor, as shown in Fig. (4.1) , while, Fig. (4.8) shows how the optimum bid and the

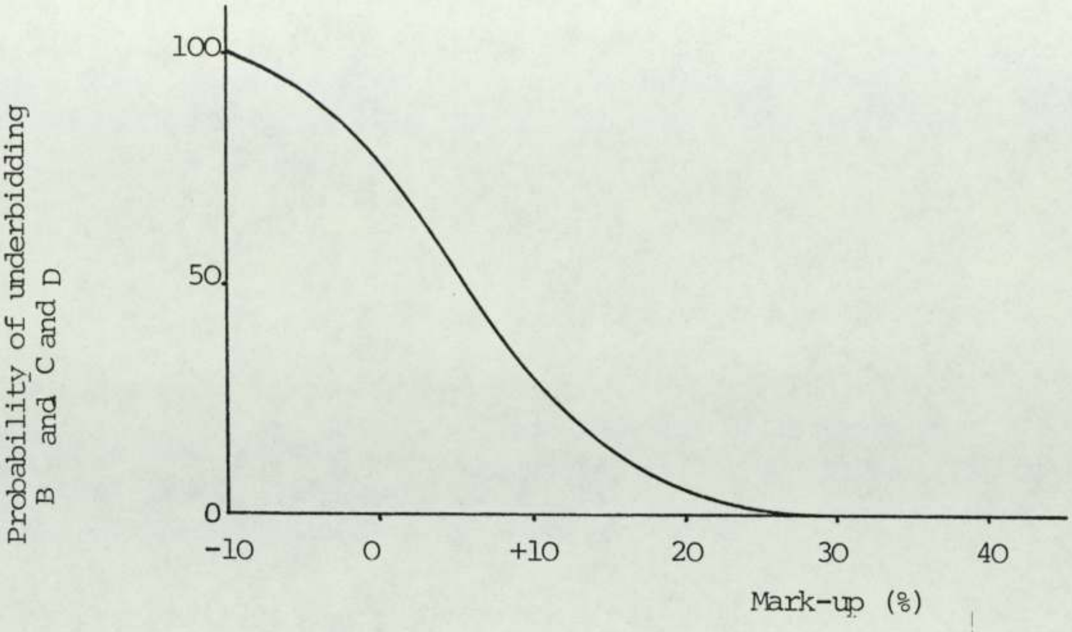


Figure (4.5) Percentage probability of A beating 3 different competitors (B,C and D).

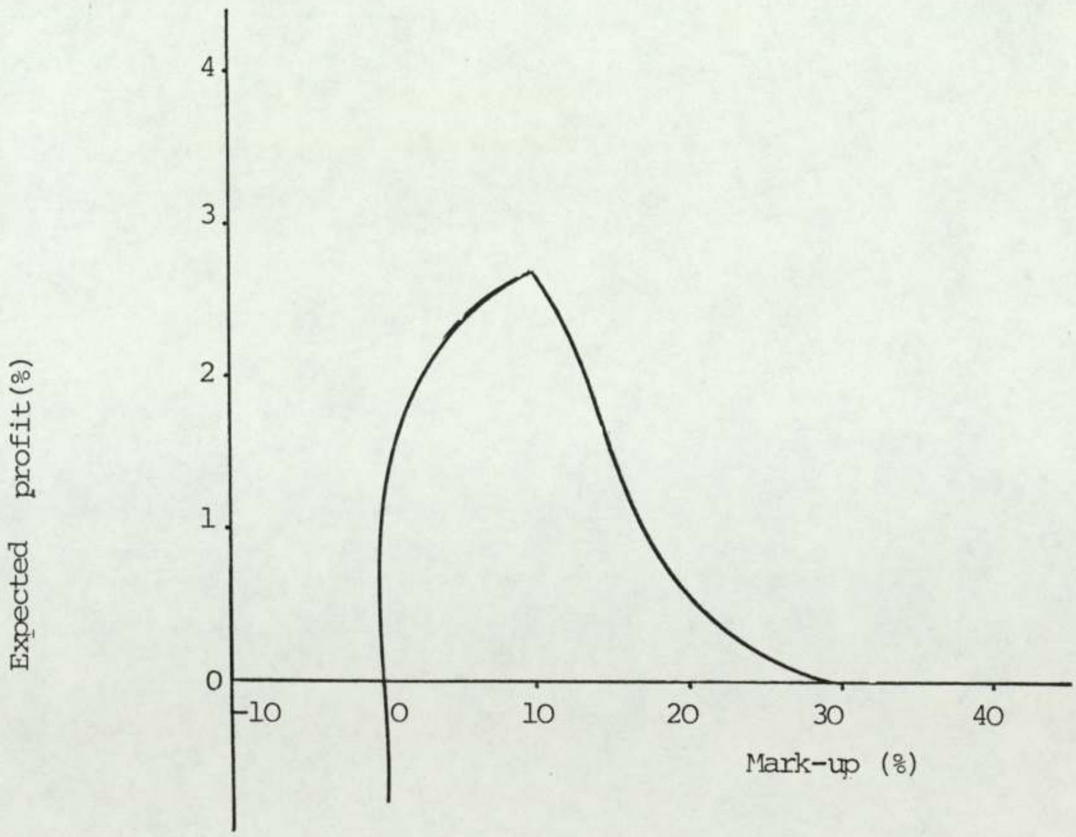
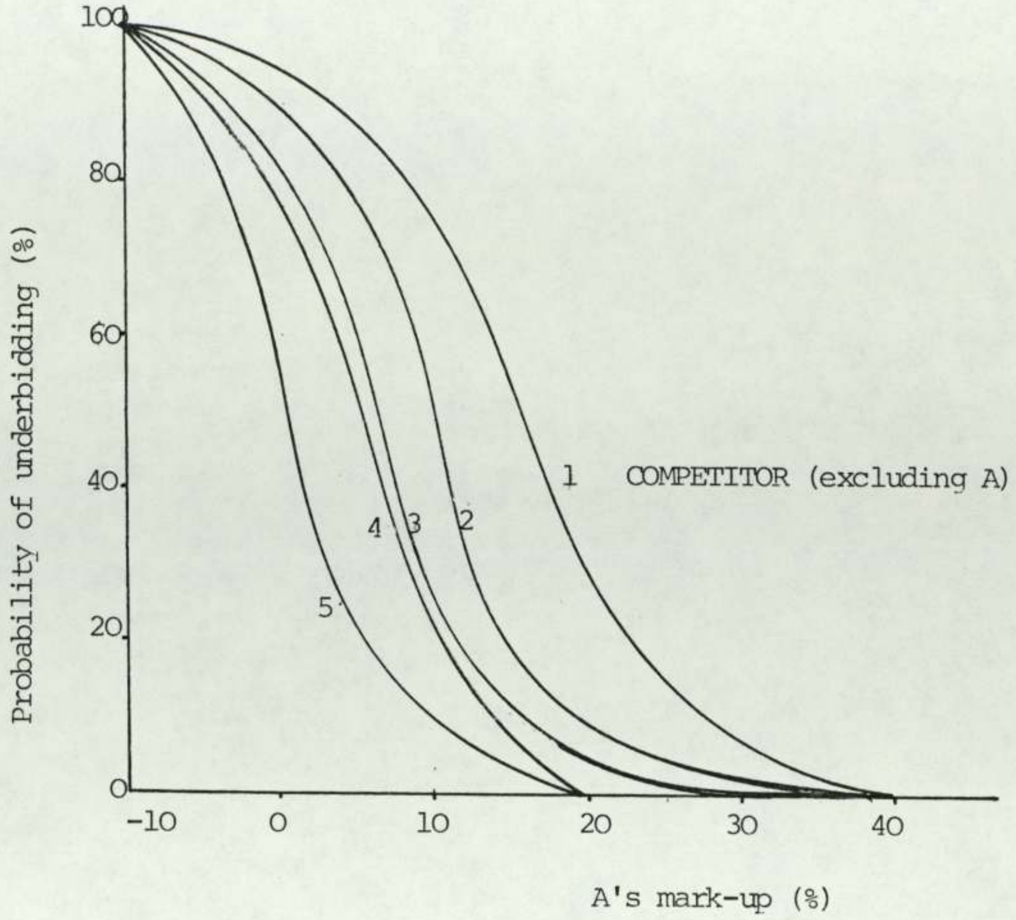


Figure (4.6) Expected profit curve (3 different competitors)



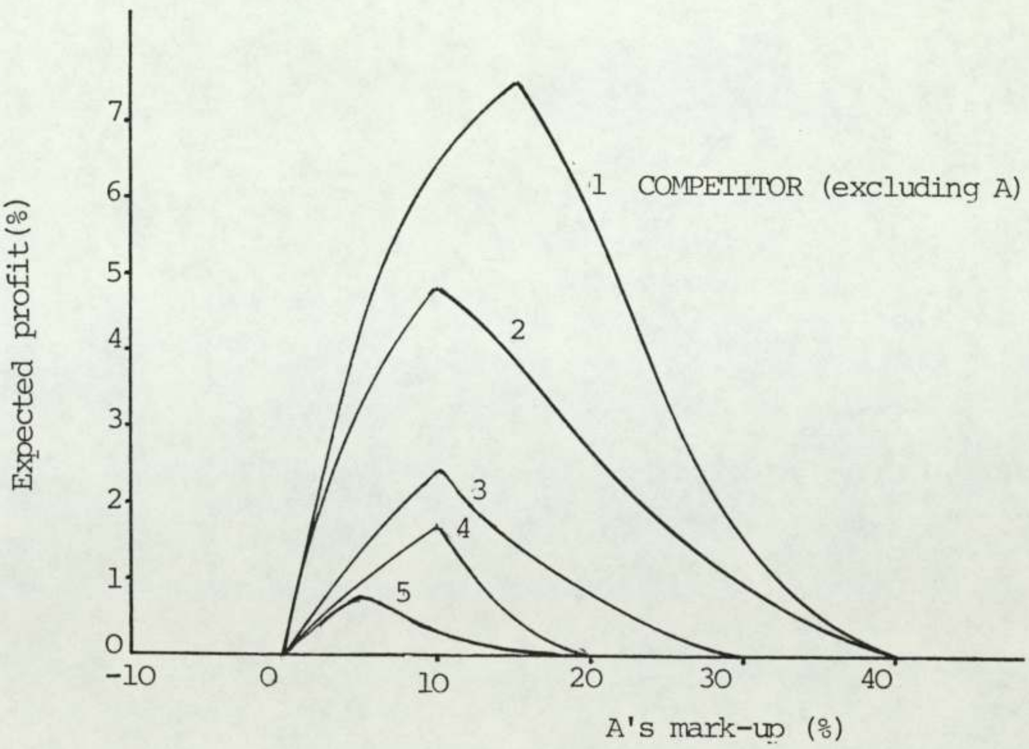
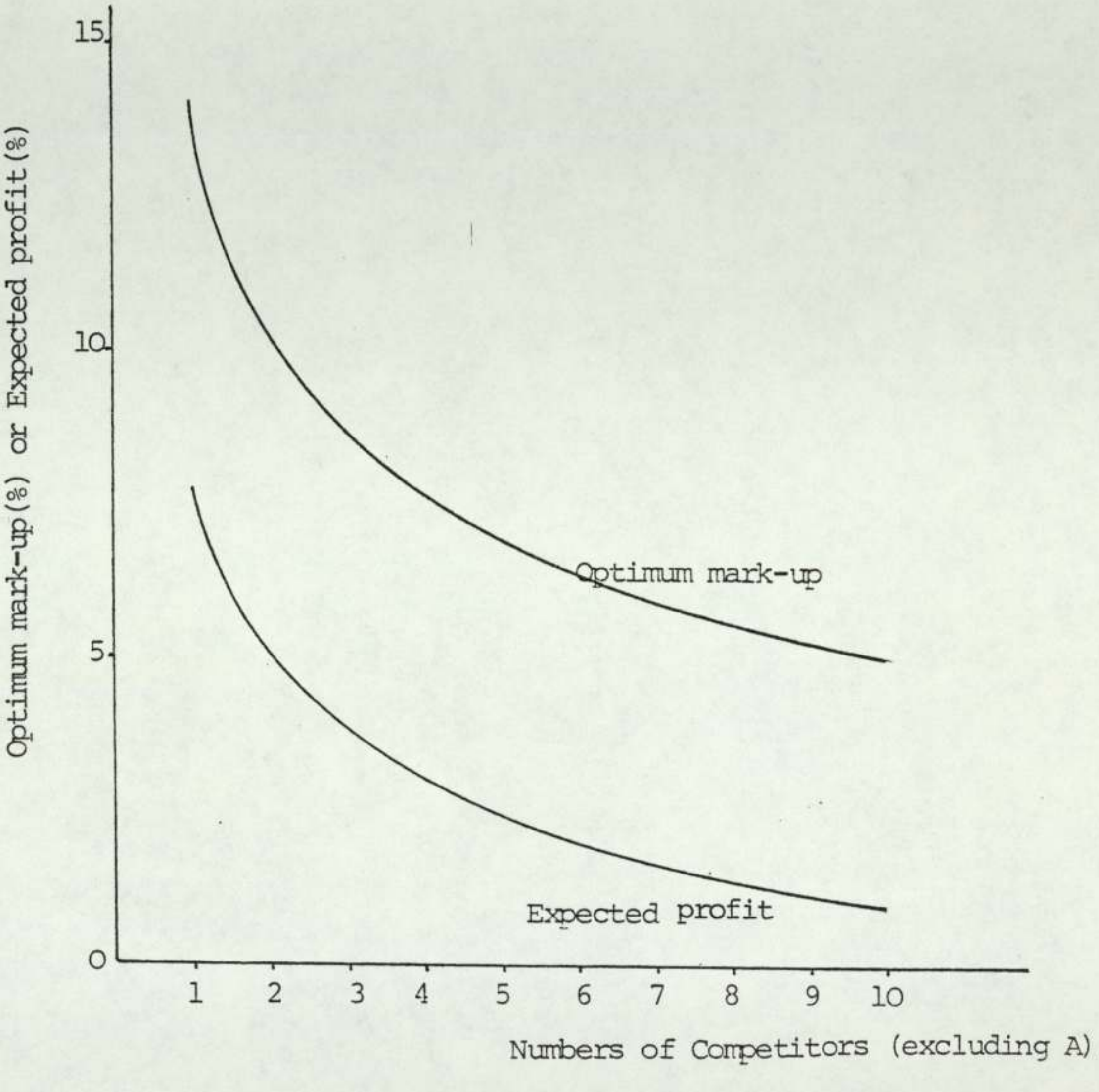


Figure (4.7) Probability of A beating varying numbers of a typical competitor and expected profit curves



Figure(4.8) Effect of number of competitors on optimum mark-up and expected profit expected profit can be compared for different numbers of typical competitors.

From Fig. (4.8) it can be seen as the number of bidders increases, both the optimum mark-up and the expected profit decreases, while, as the number of bidders increases, the expected profit more closely approaches zero - meaning that the low bids are approaching the direct cost of performing the work.
By computing the expected profit in different situations, jobs offering the most desirable profit opportunities can be easily identified.

What has been described in this section, is essentially, the Friedman Model, which has been illustrated using analytical derived results based on hypothetical data.

In the following sections, the computerised simulation technique will be used in order to develop the simple Friedman model and the estimating error model.
In the case of the Friedman Model, the analytical results serve as a check on the simulation results and assist in establishing the number of job simulations required to give a reasonable accuracy.

4.3 Computerised Simulation of The Friedman Bidding Model

The advantage of using computerised simulation over the analytical approach is that it enables a more detailed study of patterns of successes, etc., to be made, e.g., year - by - year .
A contractor could go bankrupt if a particular strategy indicated that

there were a significant number of instances of runs of two or three 'bad' years, as depicted by simulation, although the analytical results, on average, could not predict this danger. Having emphasized the importance of simulation technique in the following section the computerised simulation model, BIDMOD2, will be described.

4.3.1 BIDMOD2

Here, the simple Friedman bidding model (BIDMOD2) has been computerised although the 'exact' result can be obtained analytically. The full list of the simulation program, together with sample output are presented in Appendix (2) .

In developing this model it is assumed that the competition is against 5 typical competitors in which their distribution of bid/cost ratios may be presented by Fig. (4.1) .

Having made this assumption, the simulation programme was run for 200 and 500 jobs. The main objective of this simple Friedman's bidding model is to obtain the success ratios, i.e., to calculate the probability of winning at different levels of mark-ups. Table (4.1) shows the values of success ratios for 500 and 200 simulation run obtained from BIDMOD2 for a range of mark-ups from 0 to 15 percent compared with those obtained analytically.

The two methods of estimating success ratios compare reasonably well particularly above 5% mark-up. As a result of this experiment it was decided to adopt a simulation run size of 500 .

Table (4.1) Comparison of the results of success ratios for 200 and 500 simulation runs and the calculated ones

A's Percentage Mark-up	PERCENTAGE SUCCESS RATIOS								CALCULATED
	STREAM 3		STREAM 5		STREAM 7		STREAM 9		
	200	500	200	500	200	500	200	500	
0	78.5	83.8	74.5	82.2	84.5	86.2	74.5	82.2	77
2.5	55	61.4	50.0	60.0	63.5	64.8	53.0	60.2	55
5.0	37	40	34.5	39.4	42.5	42.8	35.5	38.8	38
7.5	24.5	27.6	20.5	26.6	26.5	29.0	23.0	27.0	26
10.0	15.0	17.6	12.0	16.8	16.0	18.4	15.0	17.2	17
12.5	8.5	8.6	7.0	8.2	7.0	8.2	8.0	8.2	8
15.0	2	4.4	2.5	4.2	3.5	4.6	3.5	4.6	3

4.4 The Estimating Error Model

Here, the computerised simulation technique will be used to derive the simple estimating error model. In the following sections the important factors which would cause the likely errors in estimating will be disussed and then the computerised estimating error model (BIDMOD3) will be demonstrated and its results presented.

4.4.1 Discussion

The simple Friedman model does not take into account any error that may occur when applying the model to real world situation. Hence, it is important to consider the estimating error when we are applying a bidding strategy model to real world data. A number of bidding models which have been based on the effects of likely errors in estimating were discussed in the previous chapter (37,45) .

However, it is important at this stage to mention the important factors which would cause the likely errors in estimating. Obviously, the true-cost of a job is the cost which could obtain if the job is completed exactly as predicted by the original design and specifications and unforeseen conditions and circumstances do not arise. This situation rarely, if ever, applies to civil engineering projects and variations in contract are the rule rather than the exception. Therefore, an estimate of the true cost must be made at the stage when the bid is being prepared.

The accuracy of this estimate depends on several factors and many of

the probabilistic models mentioned in the last chapter include some facility to take these errors into consideration.
Pim (59), summarises these errors as follows :

1. Errors of calculation.
2. Errors of quantity in :
   a) Bill items
   b) Rates and standards
   c) Magnitude of overheads
3. Errors of judgment in :
   a) Planning and method
   b) Assessing learning factor
   c) Estimating non productive costs
   d) Evaluating economic environment
   e) Guessing number of competitors
   f) Guessing attitude of competitors
   g) Assessing penalty of failure (or success)
4. Errors of policy in :
   a) Method of application of overheads
   b) Choice of market.

It is important to remember that the term error as used here does not necessarily mean that measurements or judgments are wrong. It means only that attitudes and abilities differ amongst competitors, so they will arrive at results which differ from each other and are also different from some theoretical standards assumed to be correct or true. It can then be argued that it is partially due to these errors that a successful contractor may end up with a smaller profit than the one implied by his mark-up.

A simple estimating model will now be described. In developing this model, a number of assumptions have been made. In the simple model it is assumed that the true cost of performing the job, C, is the same for all competitors. It is also assumed that the distribution of estimating error is uniform, e.g., an estimating error of ten percent would lead to a probability distribution function shown at Fig. (4.9a). If it is further assumed that all bidders apply the same mark-up of ten percent, then, the distribution of all possible bids is shown, at Fig. (4.9b) with the corresponding cumulative distribution function shown at Fig. (4.9c) .

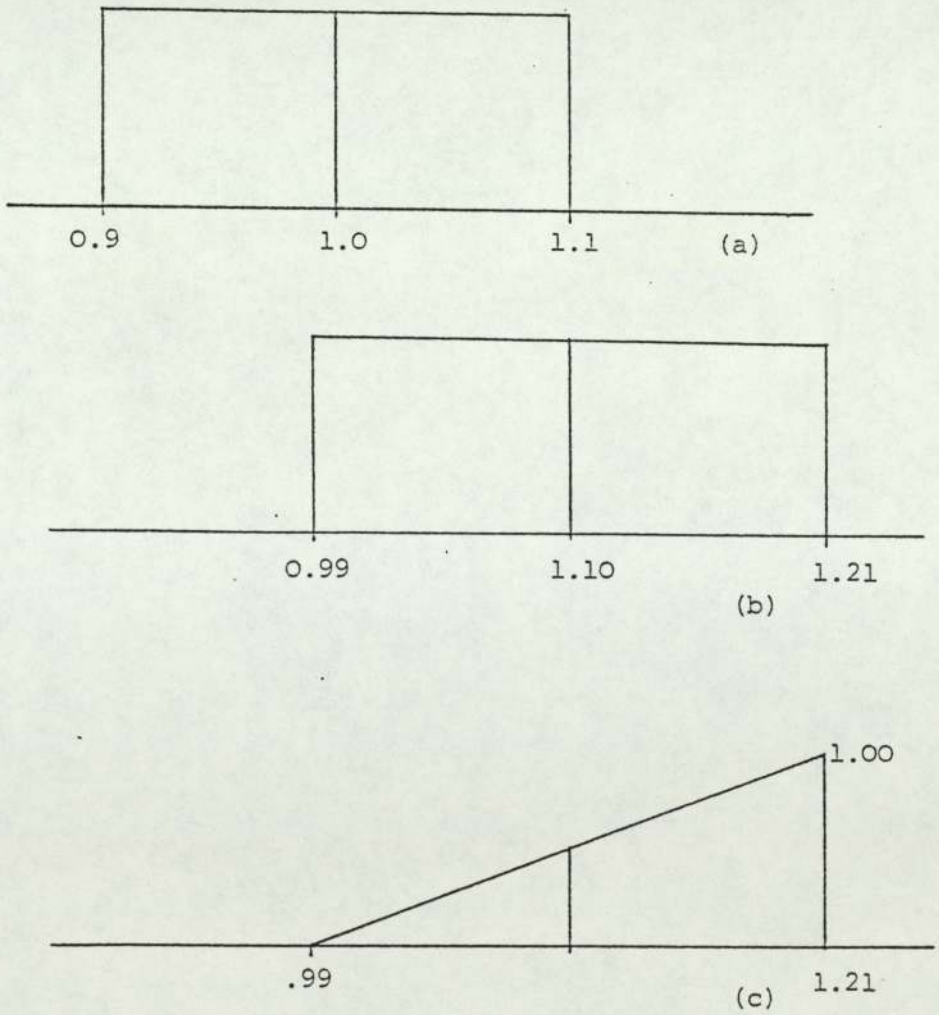


Figure (4.9) Probability density function of COST ESTIMATE, ALL BIDS, and cumulative distribution function of ALL BIDS.

4.4.2 BIDMOD3

A simple estimating error model called BIDMOD3 has been computerised and the full listing of the simulation programme and its sample output are presented in Appendix (3) .

This model involves obtaining sample bids from the cumulative frequency distribution, as shown in Fig. (4.9c) by means of a simple transformation :

$$BID = 0.99 + RF \ (1.21 - 0.99)$$

where RF is the random fraction in the range of 0 to 1.0 .

Further assumptions are :

1) The estimating error is assumed to vary according to a uniform distribution whose mean is the true cost, C .
2) Competition is between competitor A (US) and a fixed number (5) of typical competitors B (THEM) .
3) Competitor B's estimating error and mark-up are fixed at 10 percent whereas A's estimating error and mark-up may be varied for each run of 500 jobs. Here , it is assumed that A's estimating errors are zero, five, ten, and fifteen percent , and A's mark-ups vary between zero to sixteen percent within two percent increments.

Tables (4.2) to (4.5) show the results of this simulation model for zero, five, ten, and fifteen percent estimating errors respectively. Figures (5.10a, b,and c) show these results graphically.

Table (4.2) Simulation results of 'estimating error model' for 0% estimating error.

A's MARK-UP (%)	SUCCESS RATIO (%)	EXPECTED PROFIT (%) (ALL JOBS)	EXPECTED PROFIT (%) (JOBS WON)
0	81.4	0.0	0.0
2	46.0	2.0	0.9
4	26.6	4.0	1.1
6	18.4	6.0	1.1
8	7.2	8.0	0.6
10	3.8	10.0	0.4
12	1.8	12.0	0.2
14	0.4	14.0	0.1
16	0.0	0.0	0.0

Table (4.3) Simulation results of 'estimating error model for 5% estimating error.

A's MARK-UP (%)	SUCCESS RATIO (%)	EXPECTED PROFIT (%) (ALL JOBS)	EXPECTED PROFIT (%) (JOBS WON)
0	71.6	-1.2	-0.9
2	56.6	0.3	0.2
4	38.2	1.7	0.7
6	20.6	3.9	0.8
8	11.6	5.1	0.6
10	5.4	6.7	0.4
12	2.0	9.2	0.2
14	1.2	9.6	0.1
16	0.4	11.4	0.0

Table (4.4) Simulation results of 'estimating error model' for 10% estimating error.

A's MARK-UP (%)	SUCCESS RATIO (%)	EXPECTED PROFIT (%) (ALL JOBS)	EXPECTED PROFIT (%) (JOBS WON)
0.0	66.8	-3.5	-2.4
2.0	54.0	-2.4	-1.3
4.0	43.8	-1.2	-0.5
6.0	33.2	-0.5	-0.2
8.0	22.8	0.3	0.1
10.0	15.0	2.0	0.3
12.0	10.0	3.5	0.4
14.0	5.2	5.3	0.3
16.0	2.2	6.9	0.2

Table (4.5) Simulation results of 'estimating error model' for 15% estimating error.

A's MARK-UP (%)	SUCCESS RATIO (%)	EXPECTED PROFIT (%) (ALL JOBS)	EXPECTED PROFIT (%) (JOBS WON)
0.0	60.4	-6.3	-3.8
2.0	51.4	-4.6	-2.3
4.0	48.2	-4.2	-2.0
6.0	38.8	-3.0	-1.2
8.0	35.4	-2.8	-1.0
10.0	27.2	-0.7	-0.2
12.0	20.8	-0.9	-0.2
14.0	17.4	0.8	0.1
16.0	11.8	1.9	0.2

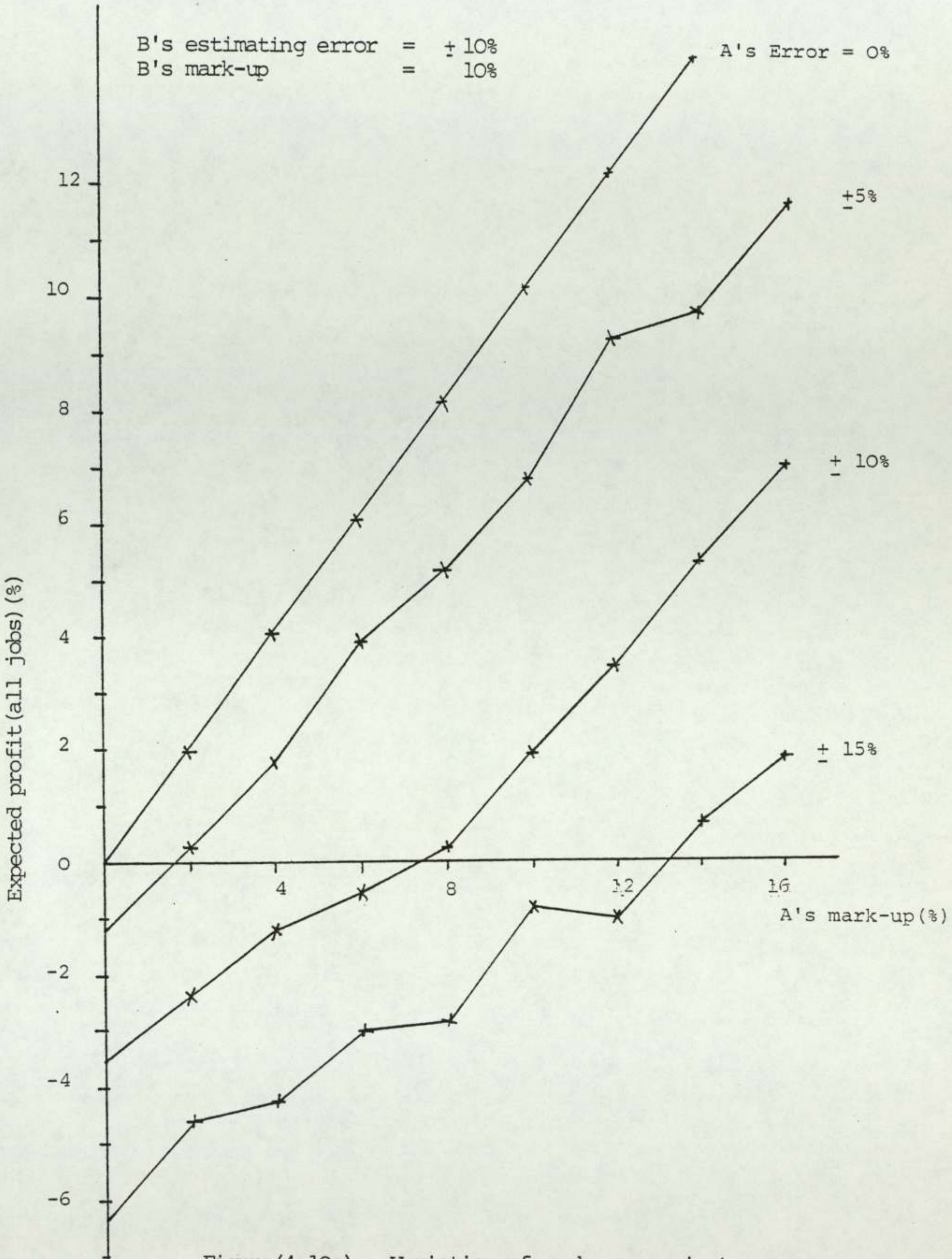
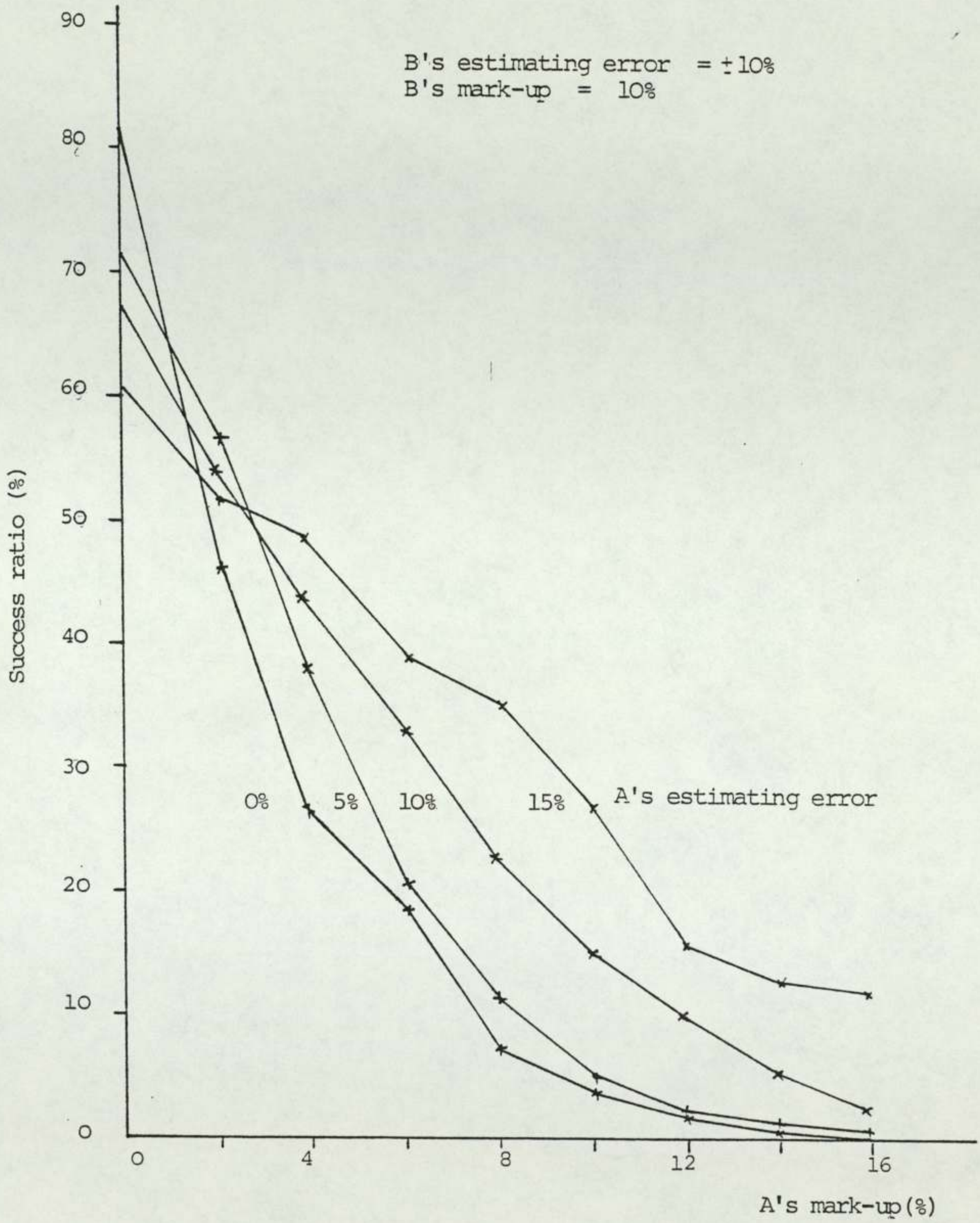
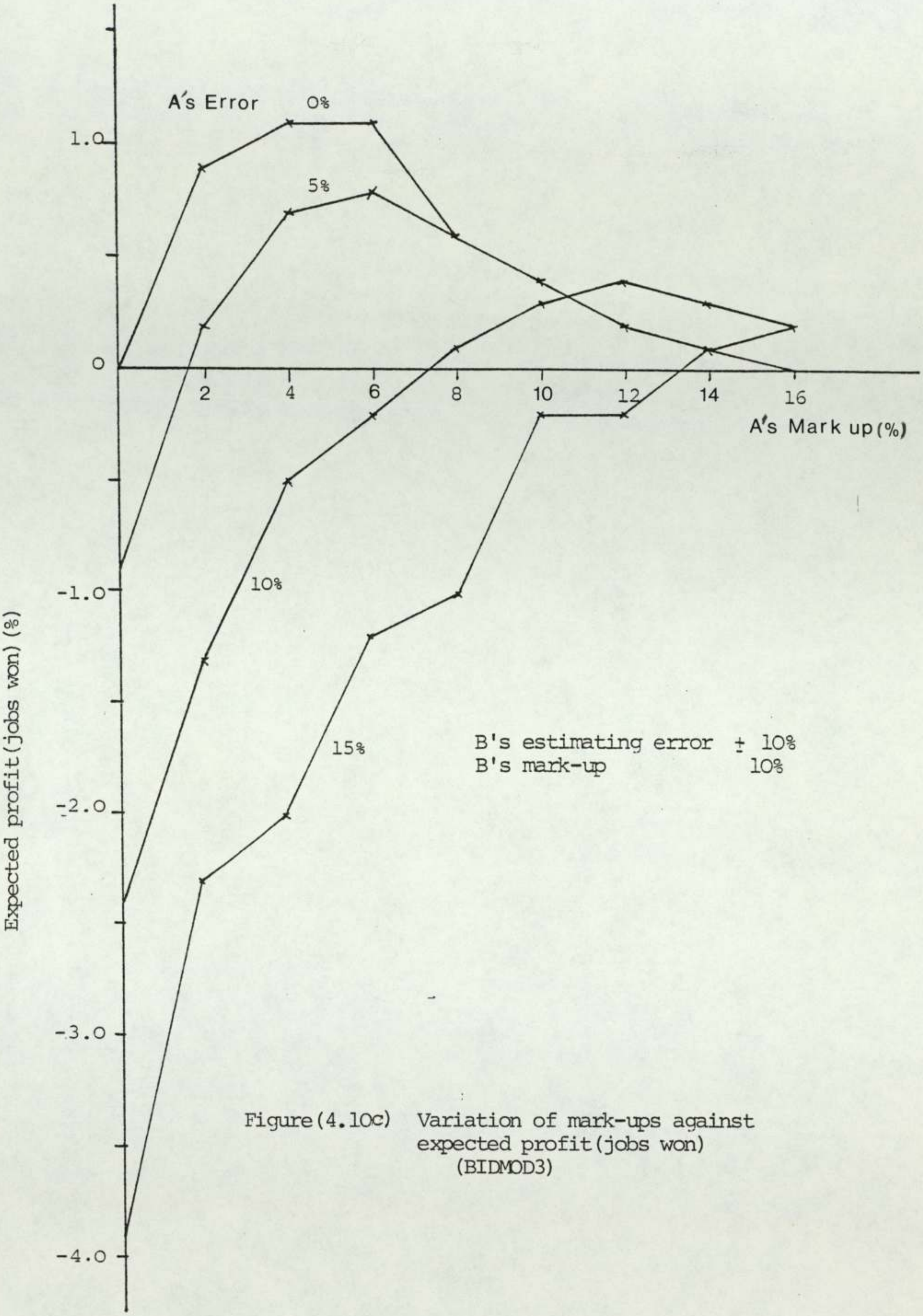


Figure (4.10a) Variation of mark-ups against expected profit (all jobs) (%) (BIDMOD3)



Figure(4.10b) Variation of mark-ups against success ratio (BIDMOD3)



Figure(4.10c) Variation of mark-ups against expected profit(jobs won) (BIDMOD3)

CHAPTER FIVE

STATISTICAL ANALYSIS OF DATA

5.1 Introduction

One of the disadvantages of the theory of bidding strategy is that it requires a large volume of correct and relevant data for the building of its model and the application of its various concepts.
A known statistical distribution may then be fitted to these data sets, which are considered as samples, and then analysis is performed on them. However, such data sets are expensive to prepare, difficult to obtain, and their accuracy is doubtful.

During the course of this research, several attempts were made to obtain data sets of actual bidding situations from contractors. Unfortunately, due to secrecy of bidding data and the fact that not many contractors or firms are willing to release their bidding data, only three sets were finally obtained.
Due to the limited amount of information in them and the fact that these data sets are not of adequate size or detail,it was not possible to apply and test most of the concepts and models described in chapter three.

For computerised simulation purposes only a few standard distributions may be conveniently inverted to facilitate rapid random sampling, these include the uniform distribution, the normal distribution, the

negative exponential distribution and the Poisson distribution.
In the following sections, the available data sets are described and certain statistical distributions are compared with them. The curve fitting experiments were conducted to test if a known statistical distribution describes a particular parameter and hence can be used in the future by a contractor to predict the behaviour of this parameter in a particular situation of interest.

A study of an individual contractor's bidding behaviour, with respect to the job value compared with his competitors will be conducted by examining the percentage spread and the average standardised bids. This will illustrate the possibility of improving the success ratios or the achieved profit.

5.2 Description of the data sets

Here, there are three data sets which were obtained from three major contracting firms and will be called, Firms A, B, and C .
The data set of firm A consists of the tender value of firm A and all his competitors for 47 tenders ranging between £5K and £15000K and all being for 'road' contracts .
Firm B's data set consist of the tender value of firm B and all his competitor for six tenders. For each tender value of firm B, his cost estimate and the number of competitors are given. The tender values ranging between £2540K and £26250K .
Firm C's data set consist of the tender value of this firm and his competitors for forty tenders ranging between £37K and £12653K . For each tender value of fims C, the mark-up applied and the number of

competitors are given.

These data sets are presented in Appendix (1) .

Now, the values to which a known statistical distribution is to be fitted, are plotted first and a visual fit is attempted. If the plotted values show a similarity to a known distribution function then the parameters of this distribution are evaluated and the goodness of fit is checked by methods like X^2 test or linear regression and correlation. However, if the plotted values do not indicate any fit with a known distribution, the fitting attempt is abandoned.

The following sections describe all these statistical analyses and where the abscissa represents the 'tender' values the scale is logarithmic in order to compress the data.

5.3 The tender values of the available data sets

The grouped frequencies of firm's A, B, and C tender values are evaluated in Tables (5.1), (5.2), and (5.3). These values are then plotted against the log of the average tender values. These are shown in Figures (5.1) , (5.2) , and (5.3) .

It will be seen that these curves do not appear to follow any common distribution function.

5.4 The winning tender values of the avialable data sets

A similar attempt was made for the winning bid of each tender in the data sets for firms A, B, and C . The frequencies are presented in Tables (5.4) through (5.6) .

These frequencies are then plotted against the log of the average winning tender values which are shown by Figures (5.4) through (5.6).

Again, they do not appear to follow any common distribution function.

Table (5.1) The grouped frequencies of tender values for firm A's data set.

GROUP NUMBER	TENDER VALUE RANGE IN £K	AVERAGE TENDER VALUE IN £K (x)	FREQUENCY	Log. (x)
1	1 - 2	1.5	0	0.18
2	2 - 5	2.5	0	0.55
3	5 - 10	7.5	2	0.88
4	10 - 25	17.5	4	1.24
5	25 - 50	37.5	7	1.57
6	50 - 100	75.0	2	1.88
7	100 - 200	150.0	13	2.18
8	200 - 500	350.0	22	2.55
9	500 - 1000	750.0	28	2.88
10	1000 - 2000	1500.0	38	3.18
11	2000 - 4000	3000.0	66	3.48
12	4000 - 8000	6000.0	56	3.78
13	8000 - 15000	11500.0	50	4.10

Table (5.2) The grouped frequencies of tender values for firm B's data set.

GROUP NUMBER	TENDER VALUE RANGE IN £K	AVERAGE TENDER VALUE IN £K (x)	FREQUENCY	Log. (x)
1	0 - 2000	1000	0	3.0
2	2000 - 5000	3500	19	3.55
3	5000 - 10000	7500	5	3.88
4	10000 - 20000	15000	9	4.18
5	20000 - 50000	35000	6	4.54

Table (5. 3) The grouped frequencies of tender values for firm C's data set.

GROUP NUMBER	TENDER VALUE RANGE IN £K	AVERAGE TENDER VALUE IN £K (x)	FREQUENCY	Log. (x)
1	10 - 25	17.5	0	1.24
2	25 - 50	37.5	11	1.57
3	50 - 100	75.0	18	1.88
4	100 - 200	150.0	63	2.18
5	200 - 500	350.0	30	2.55
6	500 - 1000	750.0	19	2.88
7	1000 - 2000	1500.0	32	3.18
8	2000 - 4000	3000.0	26	3.48
9	4000 - 8000	6000.0	19	3.78
10	8000 - 15000	11500.0	17	4.10

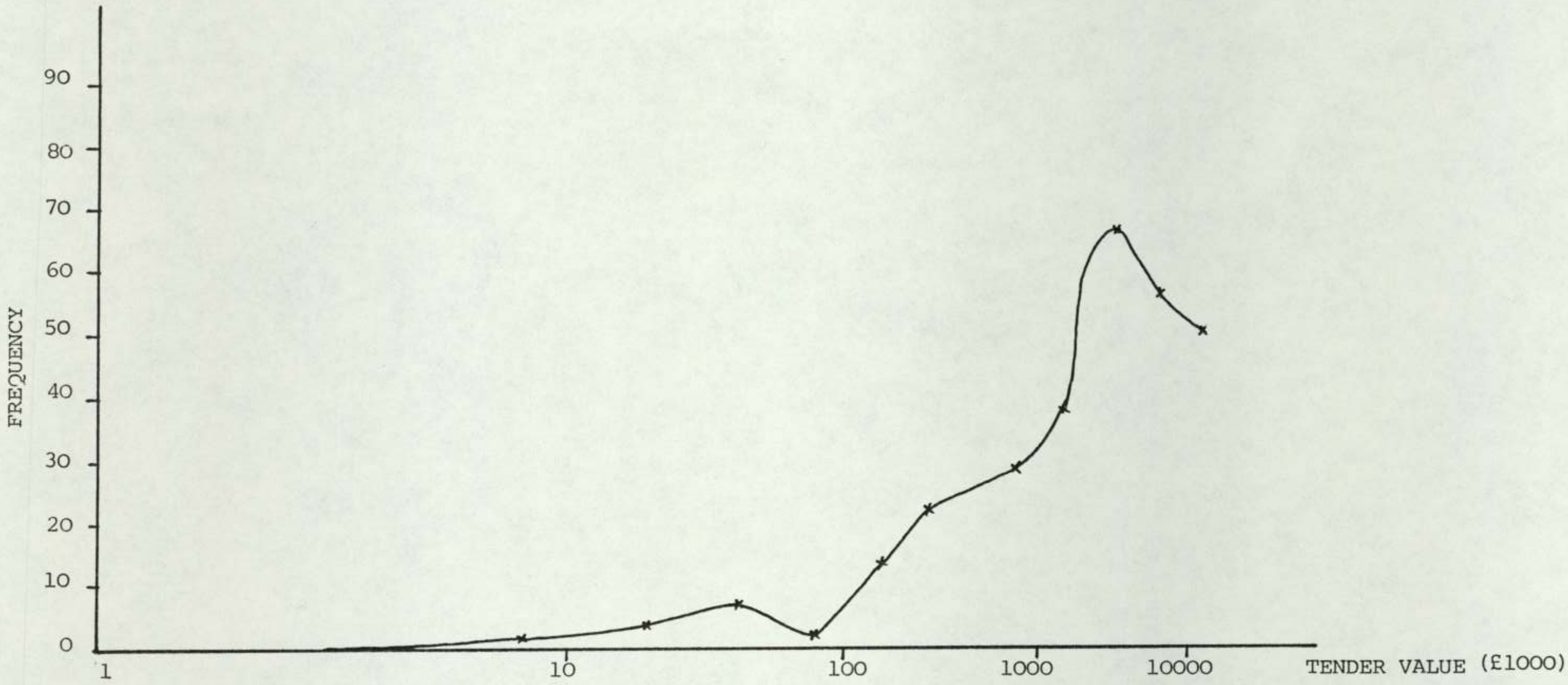


Figure (5.1) Distribution of the tender values for data set A

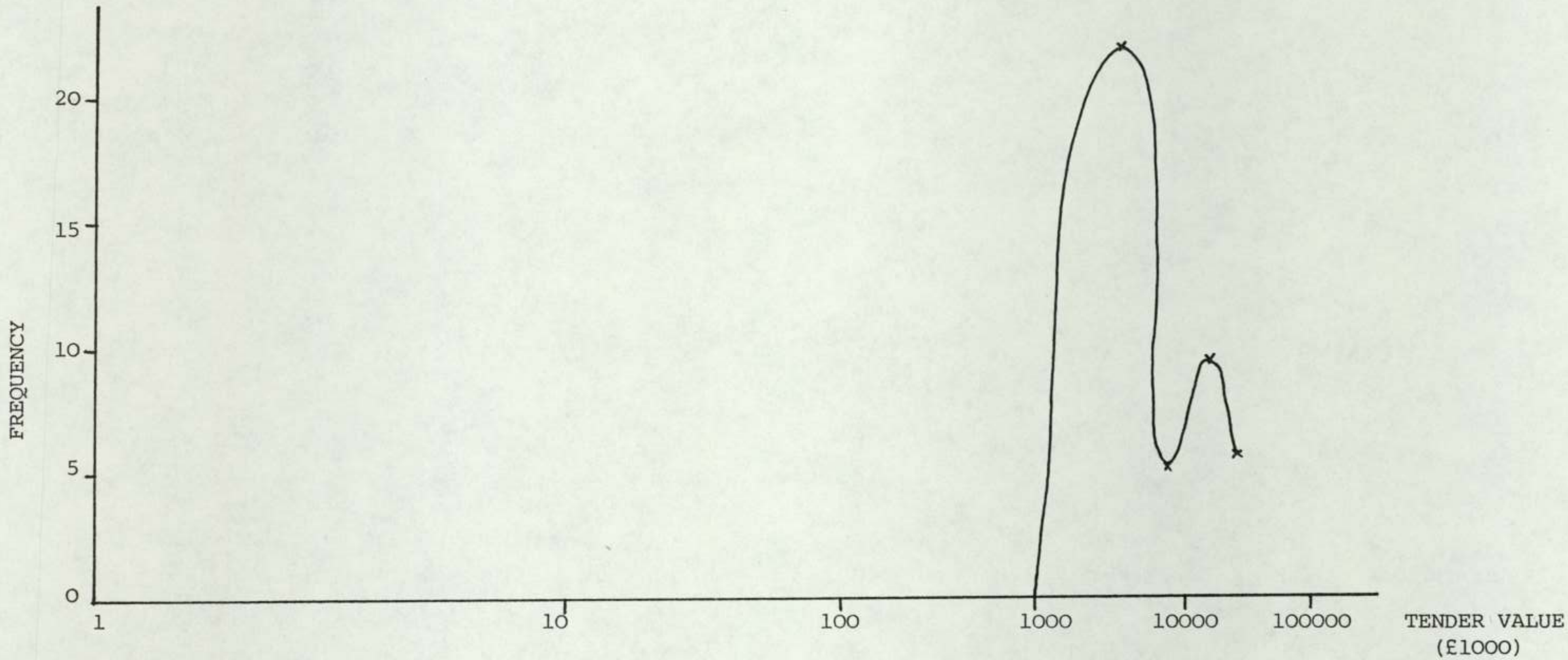


Figure (5. 2) Distribution of the tender values for data set B

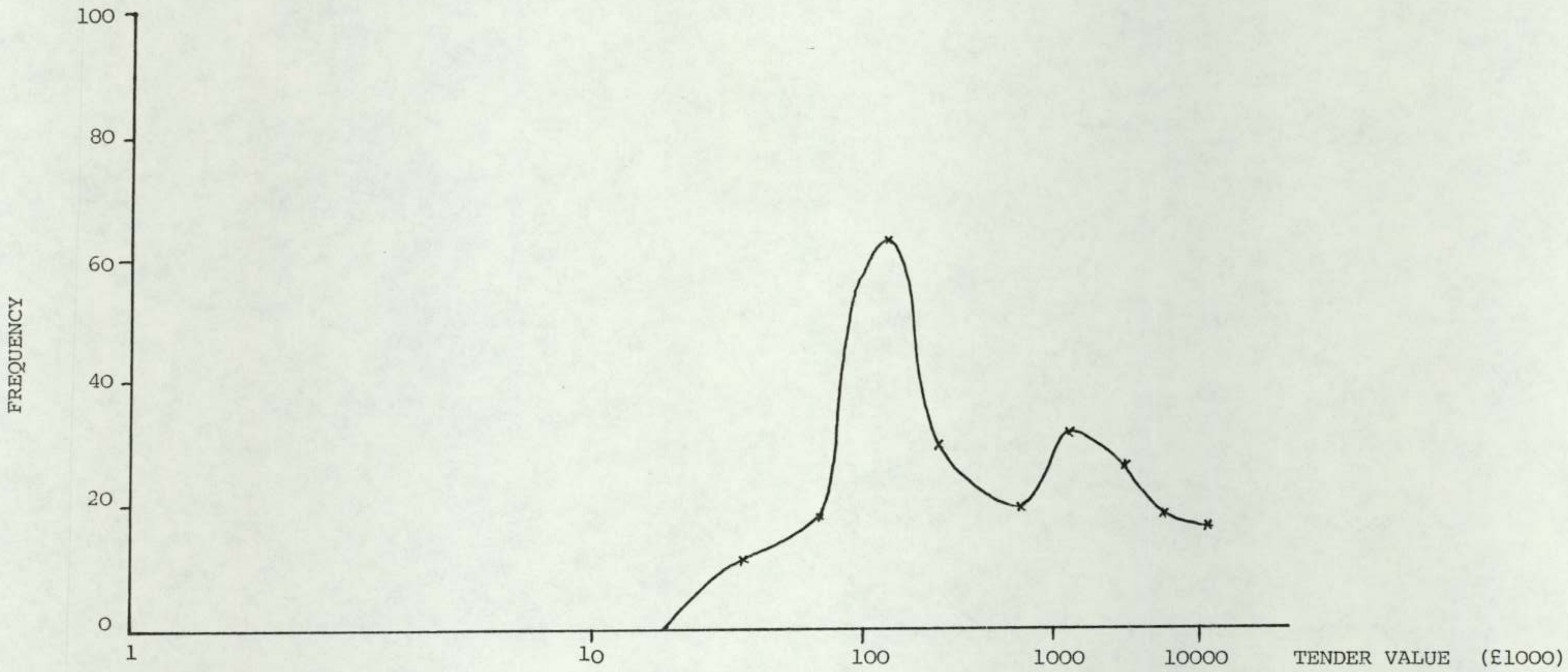


Figure (5. 3) Distribution of the tender values for data set C

Table (5. 4) The grouped frequencies of the winning tender values for firm A's data set.

GROUP NUMBER	WINNING TENDER RANGE IN £K	AVERAGE WINNING TENDER IN £K (x)	FREQUENCY	Log. (x)
1	1 - 2	1.5	0	0.18
2	2 - 5	2.5	0	0.55
3	5 - 10	7.5	1	0.88
4	10 - 25	17.5	1	1.24
5	25 - 50	37.5	0	1.57
6	50 - 100	75.0	1	1.88
7	100 - 200	150.0	2	2.18
8	200 - 500	350.0	5	2.55
9	500 - 1000	750.0	3	2.88
10	1000 - 2000	1500.0	10	3.18
11	2000 - 4000	3000.0	9	3.48
12	4000 - 8000	6000.0	10	3.78
13	8000 - 15000	11500.0	7	4.10

Table (5. 5) The grouped frequencies of the winning tender values for firm B's data set.

GROUP NUMBER	WINNING TENDER RANGE IN £ K	AVERAGE WINNING TENDER IN £ K (x)	FREQUENCY	Log. (x)
1	0 - 2000	1000	0	3.00
2	2000 - 5000	3500	3	3.55
3	5000 - 10000	7500	1	3.88
4	10000 - 20000	15000	1	4.18
5	20000 - 50000	35000	1	4.54

Table (5.6) The grouped frequencies of the winning tender values for firm C's data set.

GROUP NUMBER	WINNING TENDER RANGE IN £K	AVERAGE WINNING TENDER IN £K (x)	FREQUENCY	Log. (x)
1	10 - 25	17.5	0	1.24
2	25 - 50	37.5	2	1.57
3	50 - 100	75.0	3	1.88
4	100 - 200	150.0	10	2.18
5	200 - 500	350.0	6	2.55
6	500 - 1000	750.0	2	2.88
7	1000 - 2000	1500.0	6	3.18
8	2000 - 4000	3000.0	3	3.48
9	4000 - 8000	6000.0	5	3.78
10	8000 - 15000	11500.0	1	4.10

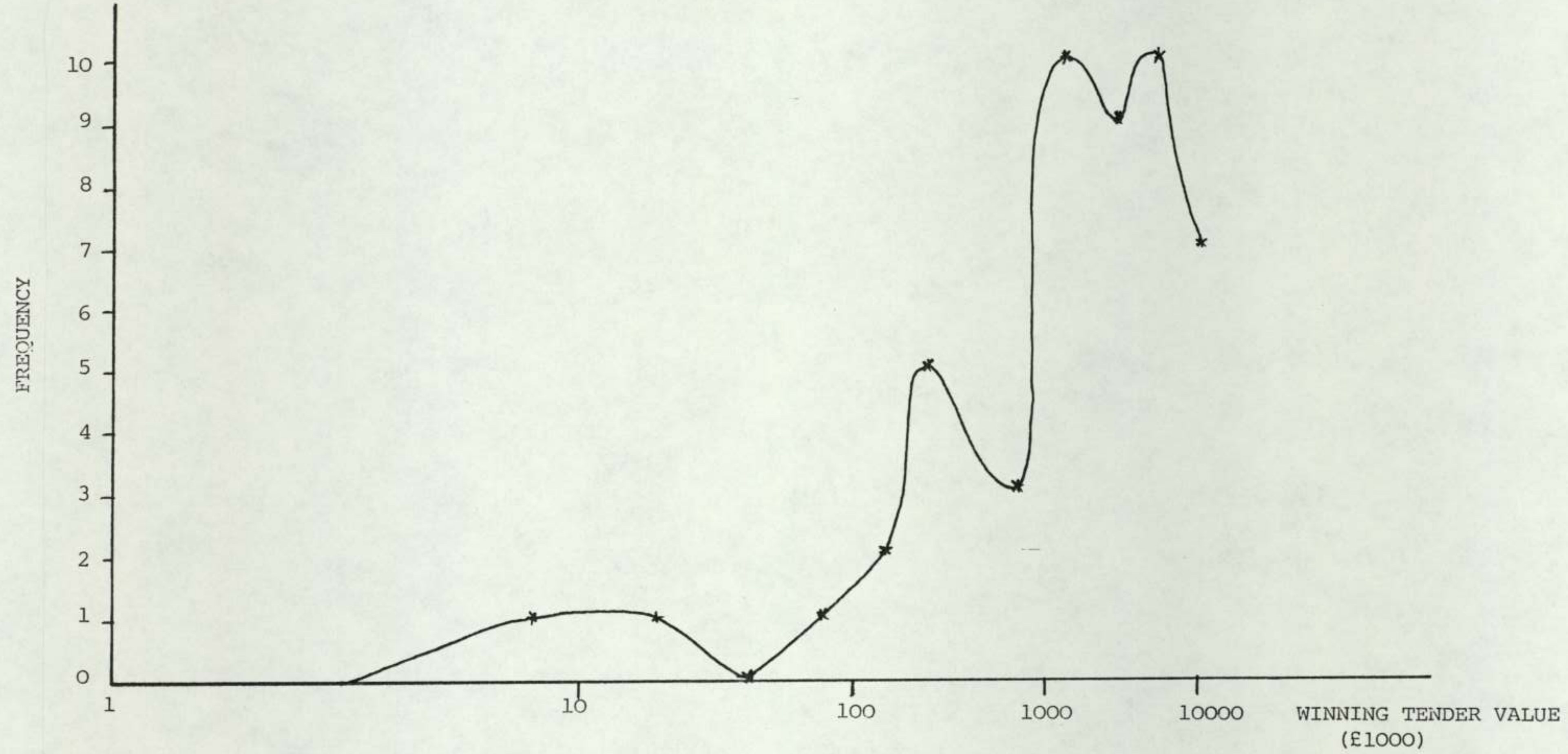


Figure (5. 4) Distribution of the winning tender values for data set A

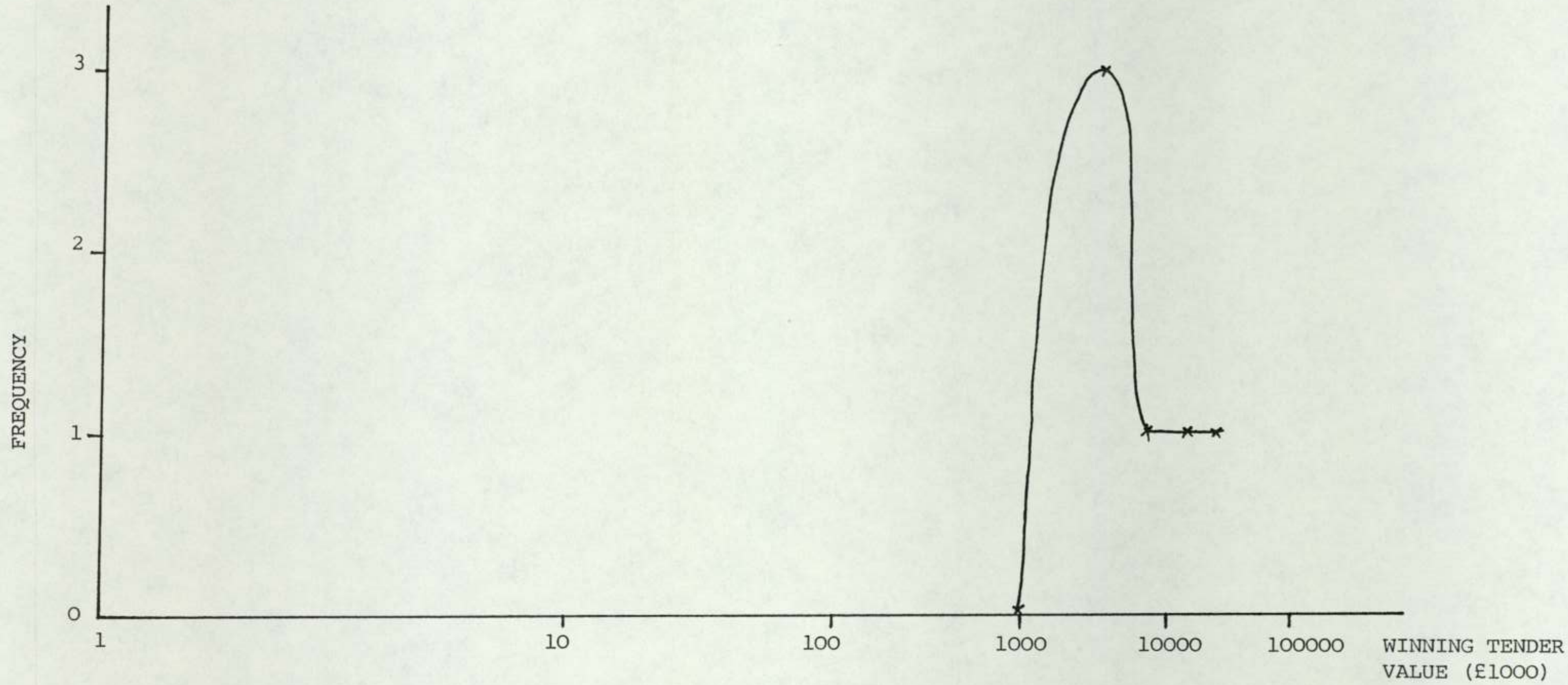


Figure (5.5) Distribution of the winning tender values for data set B

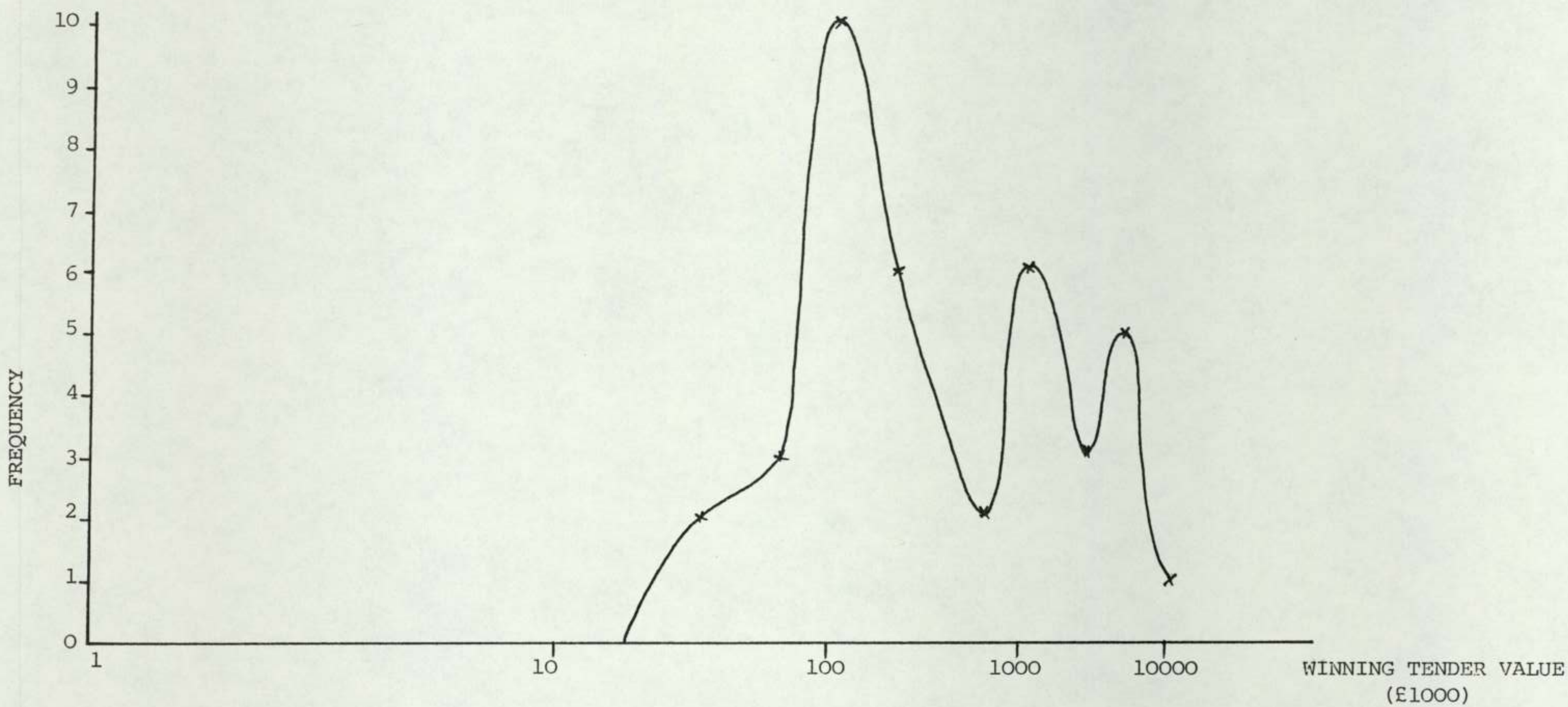


Figure (5.6) Distribution of the winning tender values for data set C

5.5 The distribution of the number of bidders

The frequencies of the number of bidders for each tender from the three available data sets are presented in tables (5.7) through (5.9). The frequency distribution and cumulative frequency distribution for each set of data can now be plotted.

Figures (5.7) through (5.9) represent these distributions for the three data sets. It must be noted that a discrete type distribution, only, can fit the number of bidders and the null hypothesis (H0) that the frequencies fit a Poisson distribution can be made.

If n is the size of the sample then for a Poisson distribution the expected frequency is :

$$e_i = \text{(expected frequency for ith element)} = n \left\{ \exp(-\bar{x})\, \bar{x}^{i} \right\} / i!$$

Note that $e_o = n \left\{ \exp(-\bar{x})\, \bar{x}^{o} \right\} / o! = n \exp(-\bar{x})$

5.5.1 DATA SET A (Fig.(5.7) and Table (5.7))

With reference to table (5.7) it may be shown that :

$E(X) = 276/47 = 5.87$ and $V(X) = 0.71$

For a perfect fit with the sample Poisson distribution(unshifted) E(X) is equal to V(X). An unshifted Poisson will clearly not fit the data. Try a shifted Poisson with a positive shift of 4 competitors, in this case the parameter, $\bar{x}$, will be $5.97 - 4 = 1.97$.

Expected frequency $= 47 \left\{ \exp(-1.97)\, 1.97^{i} \right\} / i!$.

Table (5.7) The frequencies of the number of bidders for firm A's data set.

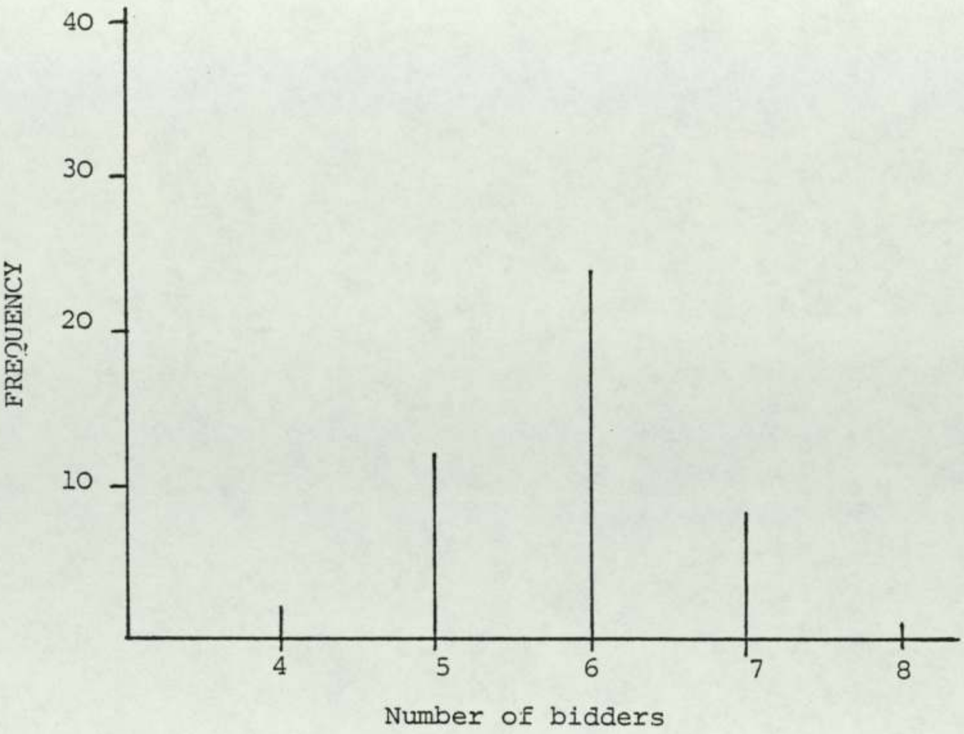
NUMBER OF BIDDERS (x)	OBSERVED FREQUENCY (o) (f)	fx	x^2	fx^2	EXPECTED FREQUENCY (e)		$X^2 = (O-e)^2/e$
4 (o)	2	8	16	32	7.24	7.55	4.08
5 (1)	12	60	25	300	13.55	14.14	.32
6 (2)	24	144	36	864	12.67	13.22	8.79
7 (3)	8] 9	56	49	392	7.89	8.23]	0.78
8 (4)	1	8	64	64	3.69	3.85]	
$\sum$	47	276		1652	45.04	46.99	13.97

Table (5.8) The frequencies of the number of bidders for firm B's data set.

NUMBER OF BIDDERS (x)	OBSERVED FREQUENCY (o) (f)	fx	x^2	fx^2	EXPECTED FREQUENCY (e)	$X^2 = (o - e)^2/e$
6	4	24	36	144		
7	1	7	49	49		
8	1	8	64	64		
$\sum$	6	39		257		

Table (5.9) The frequencies of the number of bidders for firm C's data set.

NUMBER OF BIDDERS (x)	OBSERVED FREQUENCY (o) (f)	fx	x^2	fx^2	EXPECTED FREQUENCY (e)	$X^2 = (o - e)^2/e$
0	0	0	0	0	.08	
1	0	0	0	0	.47	
2	1 6	2	4	4	1.46	1.53
3	2	6	9	18	3.06 9.89	
4	3	12	16	48	4.82	
5	11	55	25	275	6.07	2.50
6	7	42	36	252	6.38	0.41
7	7	49	49	343	5.74	0.28
8	6	48	64	384	4.52	
9	0	0	81	0	3.16	
10	1	10	100	100	2.00	
11	0 9	0	121	0	1.14 11.84	0.68
12	0	0	144	0	0.60	
13	1	13	169	169	0.29	
14	1	14	196	196	0.13	
$\sum$	40	251		1789	39.92	5.40



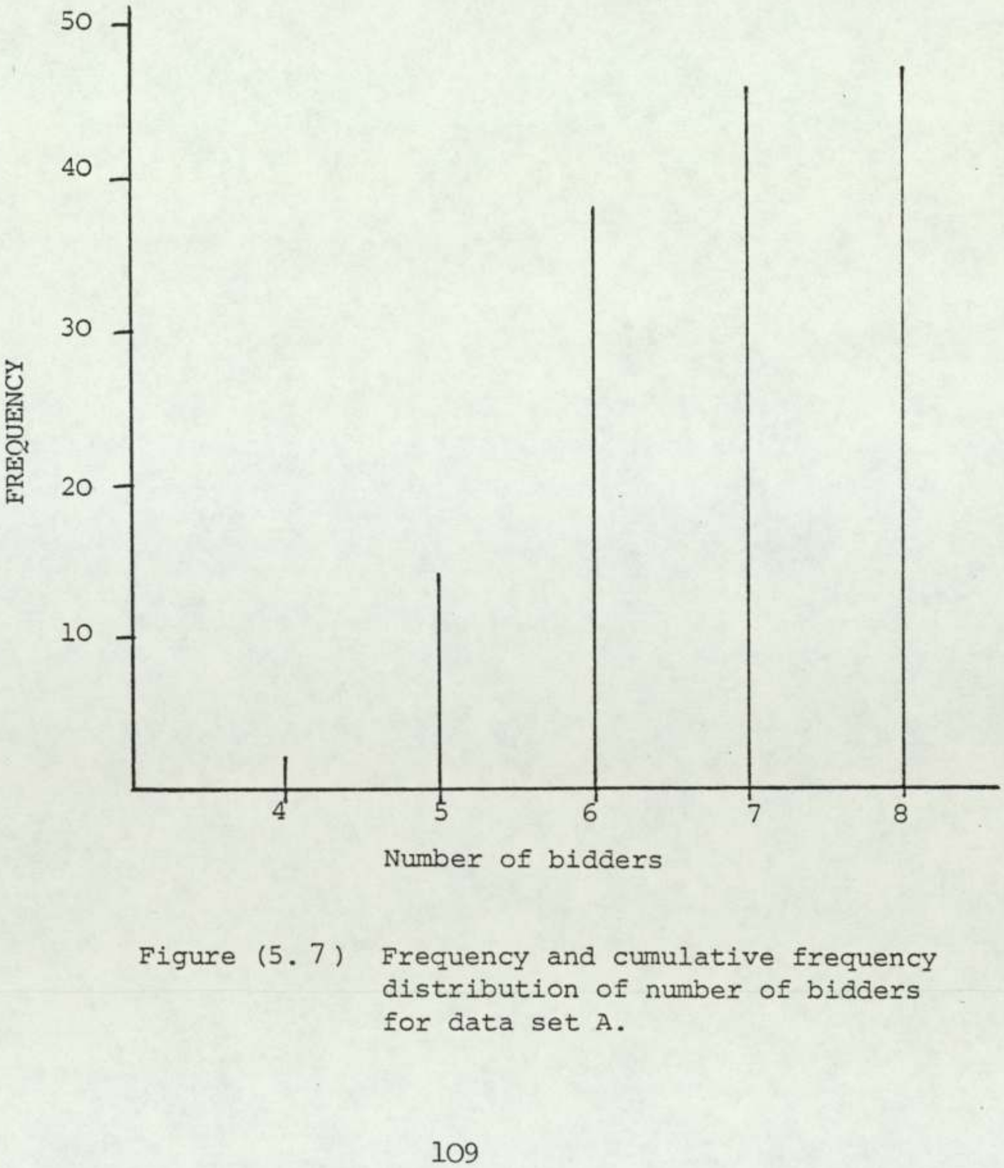
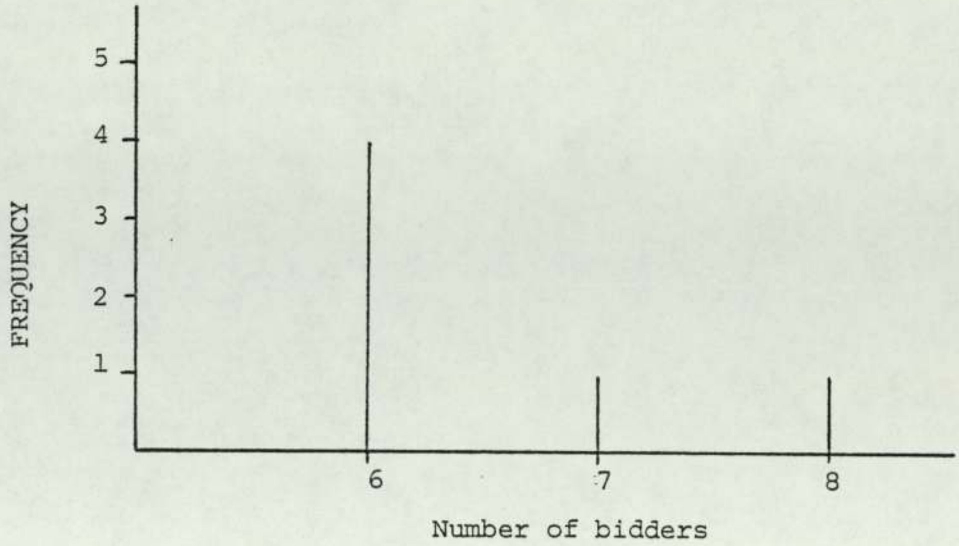


Figure (5. 7) Frequency and cumulative frequency distribution of number of bidders for data set A.



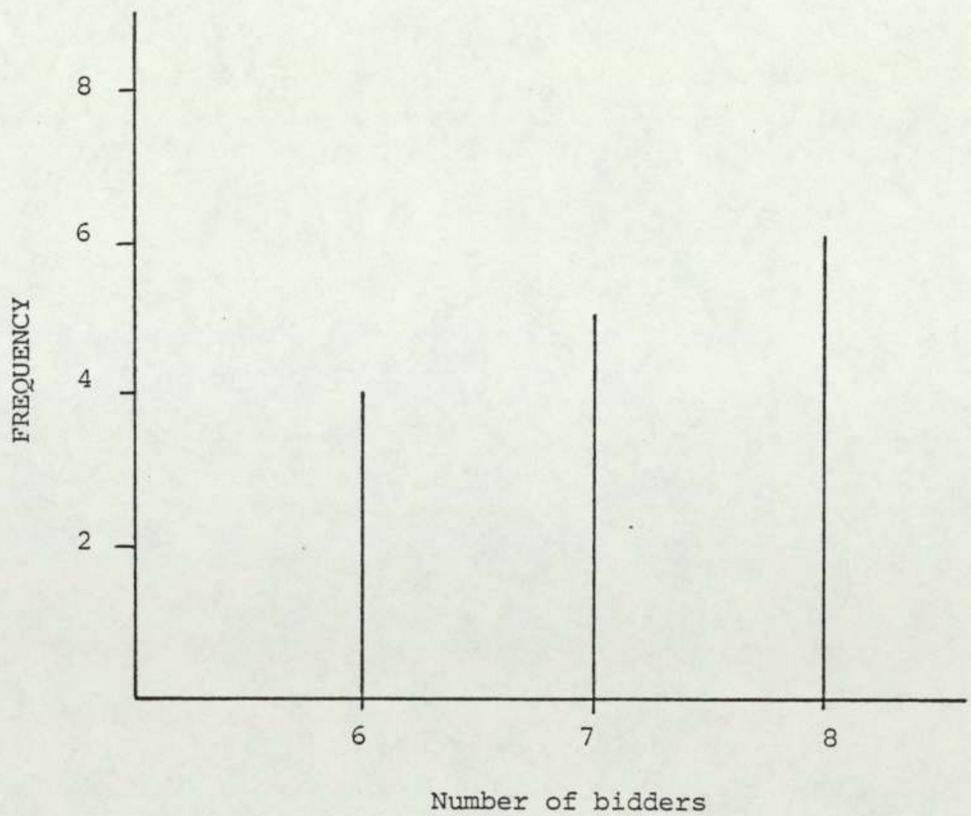


Figure (5.8) Frequency and cumulative frequency distribution of number of bidders for data set B

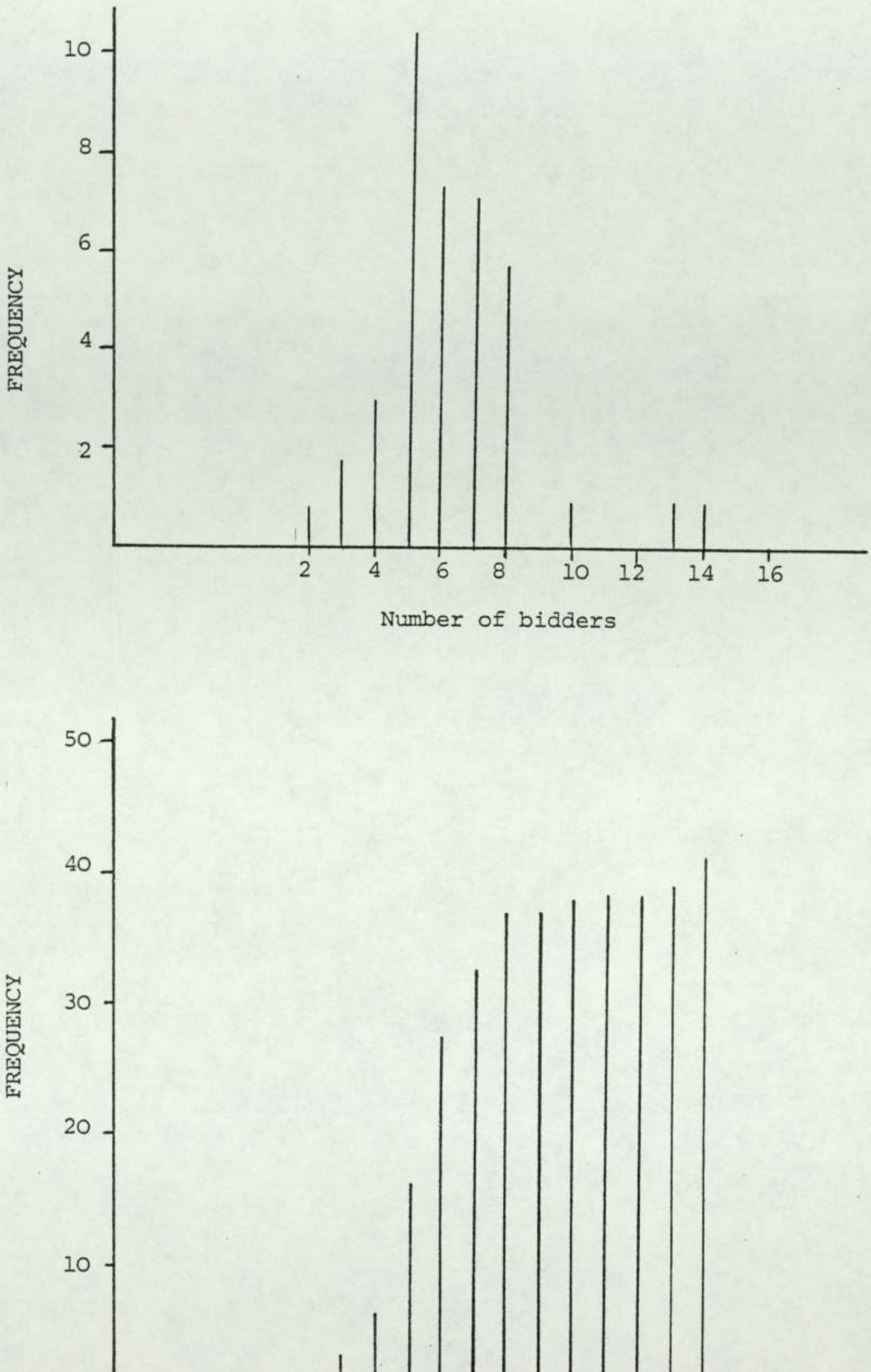


Figure (5.9) Frequency and cumulative frequency distribution of number of bidders for data set C.

Table(5.7) shows the calculations for a X^2 test of goodness-of-fit. The number of degrees of freedom is 4-2=2 and at the 5% level of significance X^2 given in statistical tables is 5.99 < 13.97 . Hence the null hypothesis is rejected.

5.5.2 DATA SET B (Fig.(5.8) and Table(5.8))

The amount of data is insufficient to carry out any meaningful statistical analyses.

5.5.3 DATA SET C (Fig.(5.9) and Table(5.9))

With reference to Table(5.9) it may be shown that :

$$E(X) = 6.275 \quad \text{and} \quad V(X) = 5.5$$

In this case an unshifted Poisson distribution appears likely to fit the data since $E(X) = V(X)$.

$$\text{Expected frequency} = 40 \left\{\exp(-6.275)\ 6.275^{i}\right\} / i!$$

Table (5.9) shows the calculations for a X^2 test of goodness-of-fit. The number of degrees of freedom is 5-2=3 and at the 5% level of significance X^2 given in statistical tables is 7.82 > 5.4 . Hence the null hypothesis is not rejected.

5.6 Distribution of bid/cost ratios for data sets

Here, a statistical analysis is performed to find out whether or not a known distribution function can be fitted to each of the avialable data sets which have been transformed into non-dimensional bid/cost ratios.

5.6.1 DATA SET A

As can be seen from this data, only A´s tender value and A´s competitors´ bids are known. To perform an analysis on the distribution of the ratio of competitors´ bids to A´s cost estimate, the following assumptions have been made :

1. Firm A applied a fixed 10 percent mark-up policy for every contract (this firm was unable or unwilling to reveal its estimated costs but suggested that the mark-ups were usually 10%).
2. Estimating inaccuracies are neglected and firm A´s cost is simply given by dividing their tender figures by 1.10 .

The frequencies of the competitors´ bid to A´s cost estimate are presented in table(5.10) . The frequency distribution and cumulative frequency distribution for data set A can now be plotted.
Figure (5.10) represent these distributions for A´s bidding data.
Now, with reference to table (5.10a) , it can be seen that :

$$E(X) = \overline{X} = 241.45/223 = 1.083 , \qquad V(X) = \sigma^2 = 0.022$$

$$\text{and} \qquad \sigma = 0.148$$

Table (5.10) The grouped frequencies of the ratio of competitors' bids to A's cost estimate.

COMPETITORS' BIDS / A's COST ESTIMATE	FREQUENCY	CUMULATIVE FREQUENCY	PROBABILITIES OF THIS RATIO	PROBABILITY OF THIS RATIO OR HIGHER
0.70 - 0.80	4	4	0.018	0.018
0.80 - 0.90	16	20	0.073	0.091
0.90 - 1.00	46	66	0.206	0.297
1.00 - 1.10	64	130	0.287	0.584
1.10 - 1.20	46	176	0.206	0.790
1.20 - 1.30	31	207	0.139	0.929
1.30 - 1.40	11	218	0.049	0.978
1.40 - 1.50	3	221	0.013	0.991
1.50 - 1.60	2	223	0.009	1.000

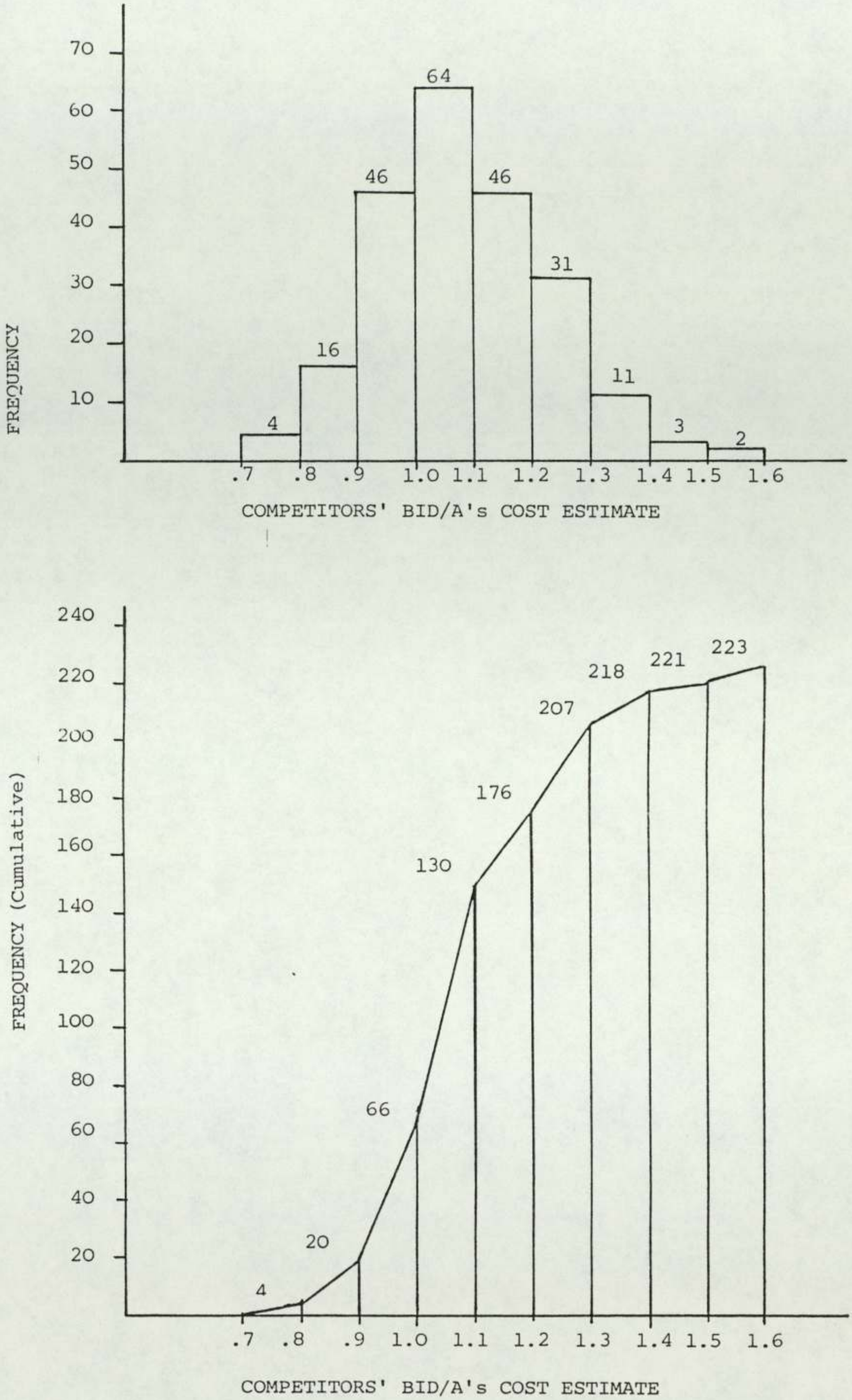


Figure (5.10) Frequency and cumulative frequency against competitors' bid/cost estimate for data set A.

Table (5.10a) The statistical results of the grouped frequencies of the ratio of competitors' bids to A's cost estimate.

GROUP NUMBER	COMPETITORS' BID / A's COST ESTIMATE	(x)	OBSERVED FREQUENCY (o) (f)	fx	fx^2	EXPECTED FREQUENCY (e)	= (o - e)/ e
1	0.70 - 0.80	0.75	4	3.00	2.25	4.85	0.15
2	0.80 - 0.90	0.85	16	13.60	11.56	17.55	0.14
3	0.90 - 1.00	0.95	46	43.70	41.52	40.28	0.81
4	1.00 - 1.10	1.05	64	67.20	70.56	58.74	0.47
5	1.10 - 1.20	1.15	46	52.90	60.84	54.37	1.30
6	1.20 - 1.30	1.25	31	38.75	48.44	31.94	0.03
7	1.30 - 1.40	1.35	11	14.85	20.05	11.92	
8	1.40 - 1.50	1.45	3 (7–9 combined: 16)	4.35	6.31	2.82 (7–9 combined: 15.16)	.05
9	1.50 - 1.60	1.55	2	3.30	4.81	0.42	
$\sum$			223	241.45	266.34	222.89	2.95

The null hypothesis (HO) that the distribution of bid/cost ratios for data set A will fit a Normal distribution can now be made.

The general equation given by a Normal distribution is :

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp. \quad -1/2 \left[\frac{x - X}{\sigma}\right]^2$$

Hence, the expected frequency will be given by :

$$(.10)(223) \quad \frac{1}{\sigma\sqrt{2\pi}} \quad \exp. -1/2 \left[\frac{x - X}{\sigma}\right]^2$$

Now from table (5.10a), the X^2 can be found to be equal to 2.95 . As the number of degrees of freedom is (7-2-1) = 4 , then from table statistics, for 5 percent level of significance and 4 degrees of freedom $X^2 = 9.49 > 2.95$.

Hence the null hypothesis is not rejected ; in fact the fitis very good.

5.6.2 DATA SET B

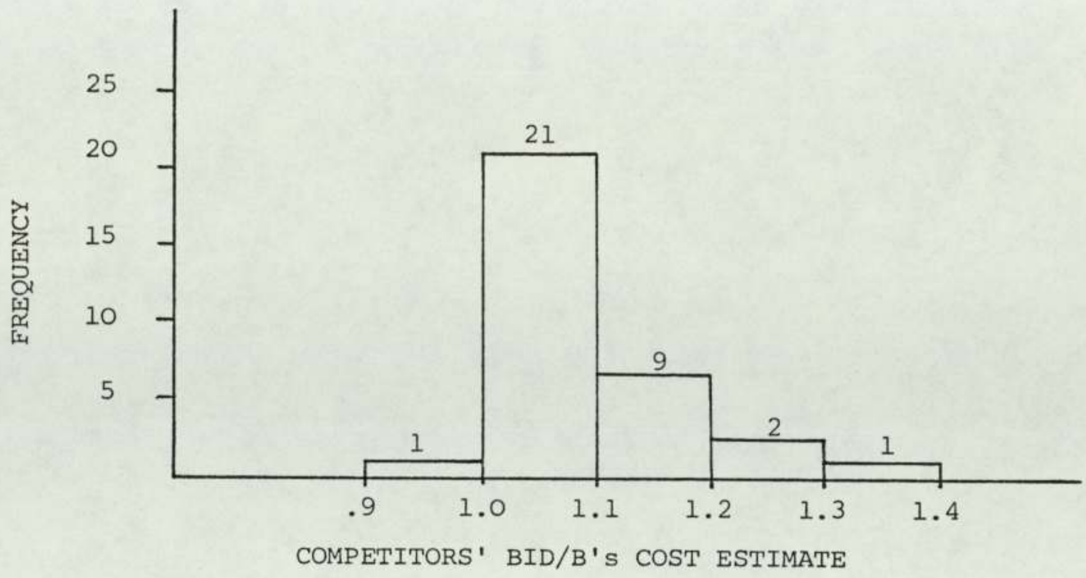
Again, the frequencies of competitors' bid to B's cost estimate are presented in table (5.11) and figure (5.11) illustrates these distributions. From table (5.11a)

$$E(X) = X = 1.094 \ , \qquad \sigma^2 = 0.006 \ , \text{ and } \ \sigma = 0.078$$

The amount of data is insufficient to carry out any curve fitting test.

Table (5.11) The grouped frequencies of the ratio of competitors' bids to B's cost estimate.

COMPETITOR'S BID / B's COST ESTIMATE	FREQUENCY	CUMULATIVE FREQUENCY	PROBABILITY OF THIS RATIO	PROBABILITY OF THIS RATIO OR HIGHER
0.9 - 1.0	1	1	0.029	0.029
1.0 - 1.1	21	22	0.619	0.648
1.1 - 1.2	9	31	0.265	0.913
1.2 - 1.3	2	33	0.058	0.971
1.3 - 1.4	1	34	0.029	1.000



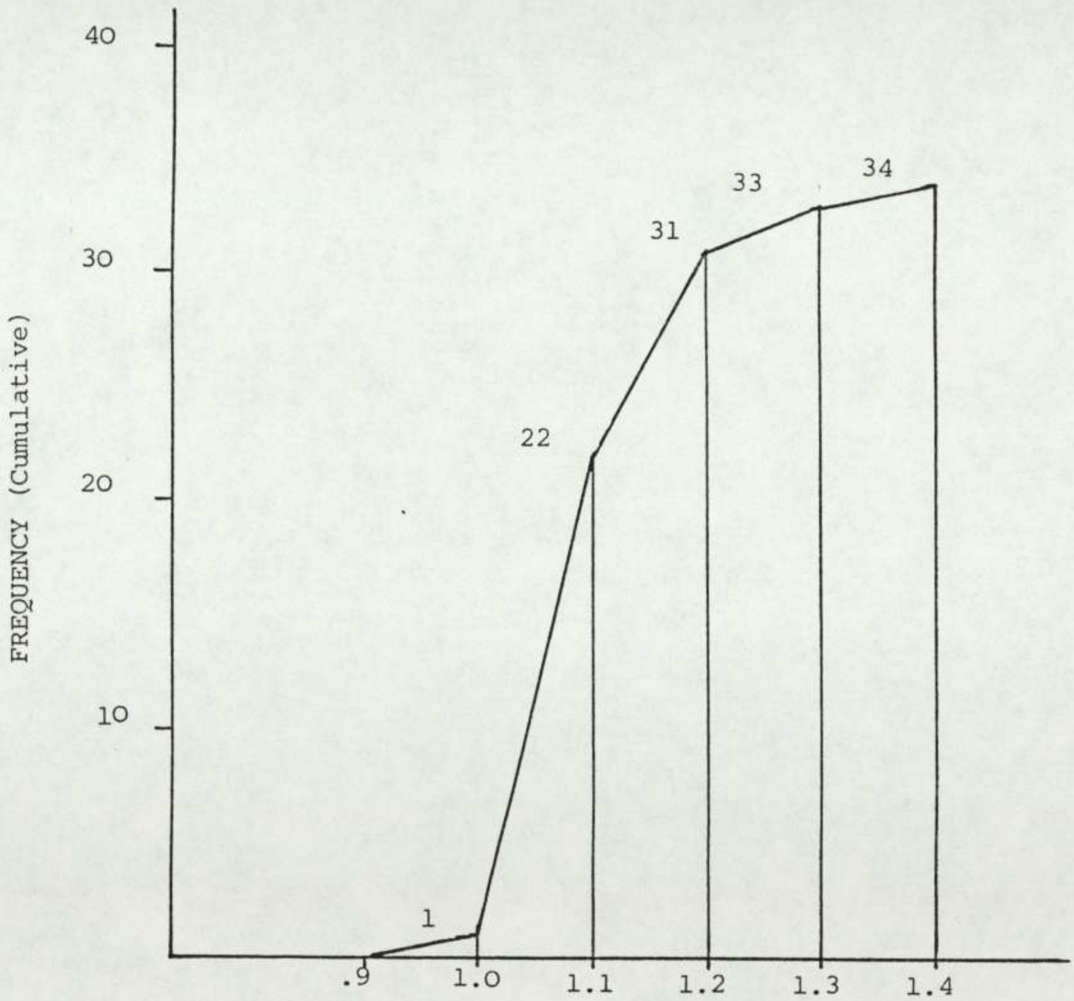


Figure (5.11) Frequency and cumulative frequency against competitors' Bid/Cost Estimate for data set B.

Table (5.11a) The statistical results of the grouped frequencies of the ratio of competitor's bids to B's cost estimate.

GROUP NUMBER	COMPETITOR'S BID / B'S COST ESTIMATE	(x)	OBSERVED FREQUENCY (o) (f)	fx	fx^2	EXPECTED FREQUENCY (e)	$X^2=(o-e)^2/e$
1	0.9 - 1.0	0.95	1	0.95	0.903		
2	1.0 - 1.1	1.05	21	22.05	23.153		
3	1.1 - 1.2	1.15	9	10.35	11.903		
4	1.2 - 1.3	1.25	2	2.50	3.125		
5	1.3 - 1.4	1.35	1	1.35	1.823		
TOTAL			34	37.20	40.91		

5.6.3 **DATA SET C**

Again, the frequencies are presented in Table (5.12) and Fig. (5.12) demonstrate these distributions.

Now, with reference to Table (5.12a)

$$E(X) = \bar{X} = 1.073 \quad , \quad \sigma^2 = 0.047 \quad , \text{ and } \quad \sigma = 0.218$$

The X^2 test again will be performed to prove the hypothesis. From Table (5.12a), this value is equal to 16.35 . However, from table of statistics, with (9-2-1) degrees of freedom and a 5 percent level of significance this value is equal to 12.60 .

Since 16.35 > 12.60 , then, the hypothesis (H0) is rejected. Therefore, the distribution of bid/cost ratios for data set C does not fit a Normal distribution.

5.7 The relation between the number of bidders and the job values

It was seen in the previous chapter that Friedman(20) suggested a linear relationship between the number of bidders and the job values by assuming that the higher job values attract more contractors.

Park(25) also assumes that the number of bidders is related to the tender values and hestatedthis relationship is parabolic.

Wade and Harris (64) also assume that a relationship exists between the number of bidders and the job values, but did not determine it.

Morin and Clough(36) were inconclusive about the existence of such a relationship. Finally, Gates(32) states that there is no evidence that the number of bidders, for a construction project, is in any way

Table (5.12) The grouped frequencies of the ratio of competitor's bids to C's cost estimate.

COMPETITOR'S BID / C's COST ESTIMATE	FREQUENCY	CUMULATIVE FREQUENCY	PROBABILITY OF THIS RATIO	PROBABILITY OF THIS RATIO OR HIGHER
0.5 - 0.6	4	4	0.020	0.020
0.6 - 0.7	7	11	0.035	0.055
0.7 - 0.8	9	20	0.045	0.100
0.8 - 0.9	14	34	0.070	0.170
0.9 - 1.0	36	70	0.180	0.350
1.0 - 1.1	38	108	0.190	0.540
1.1 - 1.2	49	157	0.245	0.785
1.2 - 1.3	21	178	0.105	0.890
1.3 - 1.4	9	187	0.045	0.935
1.4 - 1.5	6	193	0.030	0.965
1.5 - 1.6	2	195	0.010	0.975
1.6 - 1.7	3	198	0.015	0.990
1.7 - 1.8	2	200	0.010	1.000

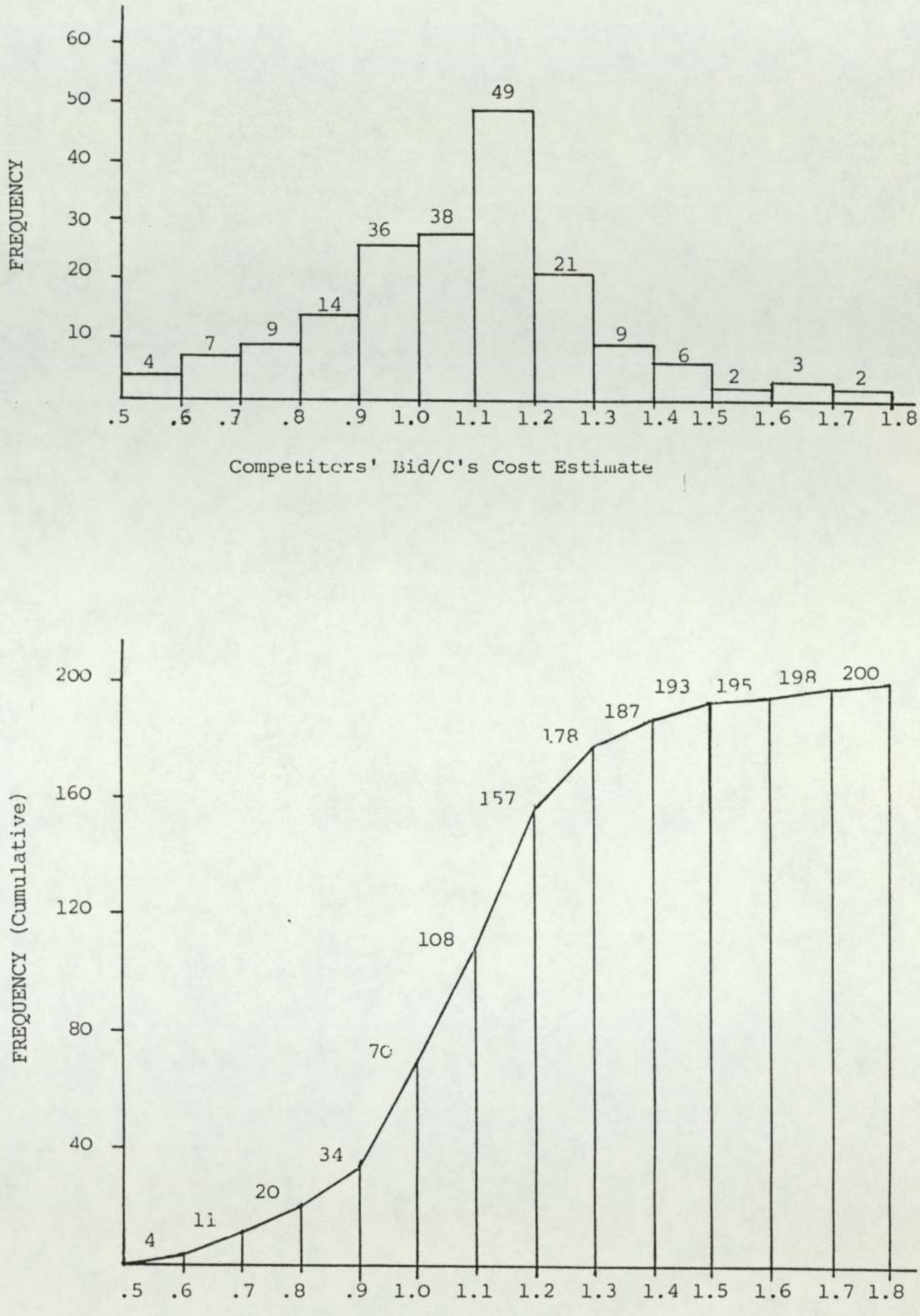


Figure (5.12) Frequency and Cumulative frequency against Competitors' Bid/Cost Estimate for data set C.

Table (5.12a) The statistical results of the grouped frequencies of the ratio of competitors bids to C's cost estimate

GROUP NUMBER	COMPETITOR'S BID / C's COST ESTIMATE	(x)	OBSERVED FREQUENCY (o) (f)		fx	fx^2	EXPECTED FREQUENCY (e)		$X^2 = (o - e)^2/e$
1	0.5 - 0.6	0.55	4	11	2.20	1.21	1.99	7.46	1.68
2	0.6 - 0.7	0.65	7		4.55	2.96	5.47		
3	0.7 - 0.8	0.75	9		6.75	5.06	12.06		0.78
4	0.8 - 0.9	0.85	14		11.90	10.12	21.54		2.64
5	0.9 - 1.0	0.95	36		34.20	32.49	31.16		0.75
6	1.0 - 1.1	1.05	38		39.90	41.90	36.38		0.07
7	1.1 - 1.2	1.15	49		56.35	64.80	34.37		6.23
8	1.2 - 1.3	1.25	21		26.25	32.81	26.23		1.04
9	1.3 - 1.4	1.35	9		12.15	16.40	16.12		3.15
10	1.4 - 1.5	1.45	6	13	8.70	12.62	8.07		0.53
11	1.5 - 1.6	1.55	2		3.10	4.81	3.26	12.67	
12	1.6 - 1.7	1.65	3		4.95	8.17	1.06		0.01
13	1.7 - 1.8	1.75	2		3.50	6.13	0.28		
TOTAL			200		214.50	239.48	199.0		16.35

related to the magnitude of the cost of the job.

The three available sets of data are used here to investigate if a linear relationship, between the number of bidders and the job values, exists by using a logarithmic transformation followed by linear regression and correlation

5.7.1 **Firm A's data set**

Here, the job values are grouped logarithmically. This is shown by table (5.13), while figure (5.13) shows the relationship between number of bidders and job values, where circles indicate the positions of the group mean. Now, the coefficient of linear correlation between the logarithms of the job values which has been grouped and the number of bidders within each job value range can be determined.

With reference to table (5.13a), the coefficient of correlation is given by :

$$r = \frac{N\sum fu_x u_y - \left(\sum f_x u_x\right)\left(\sum f_y u_x\right)}{\sqrt{\left[N\sum f_x u_x - \sum f_x u_x\right]\left[N\sum f_y u_y - \sum f_y u_y\right]}}$$

Where, N is the number of pairs of observations .

Now, for N = 47 , the value of r will be equal to 0.1283 .

As the number of pairs of observations is 47 , therefore, for a significant positive correlation at the 5 percent level, from table of statistics, r would have to exceed 0.2817 .

Table (5.13) The relation between the number of bidders and the job values for firm A's data.

NUMBER OF BIDDERS	4	5	6	7	8	9	JOB VALUE RANGE K	Log. JOB VALUE AVERAGE	Nr. of JOBS IN RANGE	AVER. Nr. OF BIDDERS IN JOB RANGE
		1					5 - 10	0.85	1	5
					1		10 - 25	1.20	1	8
							25 - 50	1.55	0	0
		1					50 - 100	1.85	1	5
			2				100 - 200	2.15	2	6
		1	2	2			200 - 500	2.50	5	6.2
		1	2				500 - 1000	2.85	3	5.7
		2	4	2			1000 - 2000	3.15	8	6
	1	4	6	2			2000 - 5000	3.50	13	5.7
	1	1	7	2			5000 - 10000	3.90	11	5.9
		1	1				10000 - 20000	4.20	2	5.5
$\sum$	2	12	24	8	1				47	

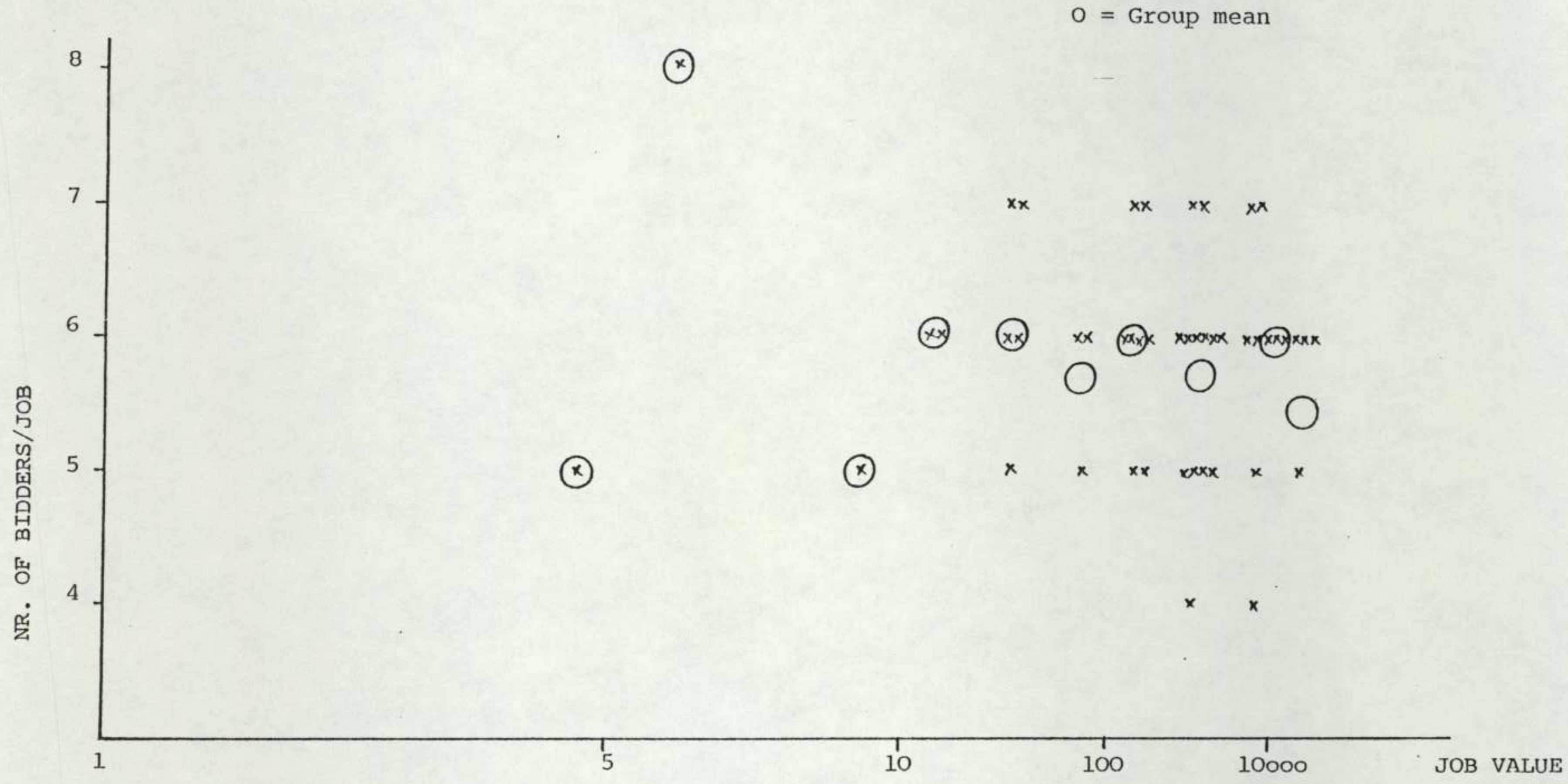


Figure (5.13) Log Job Value average agains Nr. of bidders
(Data A)

Table (5.13a) The results of firm A's data for calaculating the coefficient of correlation.

u_y	u_x	-2	-1	0	1	2	f_y	$f_y u_y$	$f_y u_y$	$f_y u_x u_y$
5			1(-5)				1	5	25	-5
4						1(8)	1	4	16	8
3							0	0	0	0
2			1(-2)				1	2	4	-2
1				2(0)			2	2	2	0
0			1(0)	2(0)	2(0)		5	0	0	0
-1			1(1)	2(0)			3	-3	3	1
-2			2(4)	4(0)	2(-4)		8	-16	32	0
-3		1(6)	4(12)	6(0)	2(-6)		13	-39	117	12
-4		1(8)	1(4)	7(0)	2(-8)		11	-44	176	4
-5			1(5)	1(0)			2	-10	50	5
f_x		2	12	24	8	1	47	-93	425	23
$f_x u_{x_2}$		-4	-12	0	8	2	-6			
$f_x u_x$		8	12	0	8	4	32			
$f\ u_x u_y$		14	19	0	-18	8	23			

Hence, the sample shows no linear correlation and therefore, there is no linear relationship between the number of bidders and the job values for data set A.

5.7.2 **Firm B's data set**

Here again, the job values are grouped logarithmically . The results of the grouped logarithms are tabulated against the number of bidders and been shown in table (5.14) . Figure (5.14) illustrates the relationship between the number of bidders and the log. of job values for data set B.

Similarly, the coefficient of correlation between the number of bidders and job values with (N = 6) can be found . This is equal to zero. However, from tables of statistics for 6 pairs of observations and 5 percent level of significance for correlation, the r would have to exceed 0.7067 . Therefore, the sample shows no linear correlation and there is no linear relation between the number of bidders and job values for firm B's data.

5.7.3 **Firm C's data set**

A similar attempt was made here to find out whether or not there is any linear relationship between the number of bidders and the job values for this particular set of data.

Job values again are grouped logarithmically and the results are tabulated in table (5.15) and figure (5.15) shows this relationship. By using table (5.15a), the coefficient of correlation between the number of bidders and the job values can be determined.

Table (5.14) The relation between the number of bidders and the job values for firm B's data

NUMBER OF BIDDERS	6	7	8	9	JOB VALUE RANGE K	Log. JOB VALUE AVERAGE	No. OF JOBS IN RANGE	AVER. No. OF BIDDERS IN JOB RANGE
	2				2000 - 3000	3.40	2	6
		1			3000 - 5000	3.60	1	7
			1		5000 - 10000	3.90	1	8
	1				10000 - 20000	4.20	1	6
	1				20000 - 30000	4.40	1	6
$\sum$	4	1	1				6	

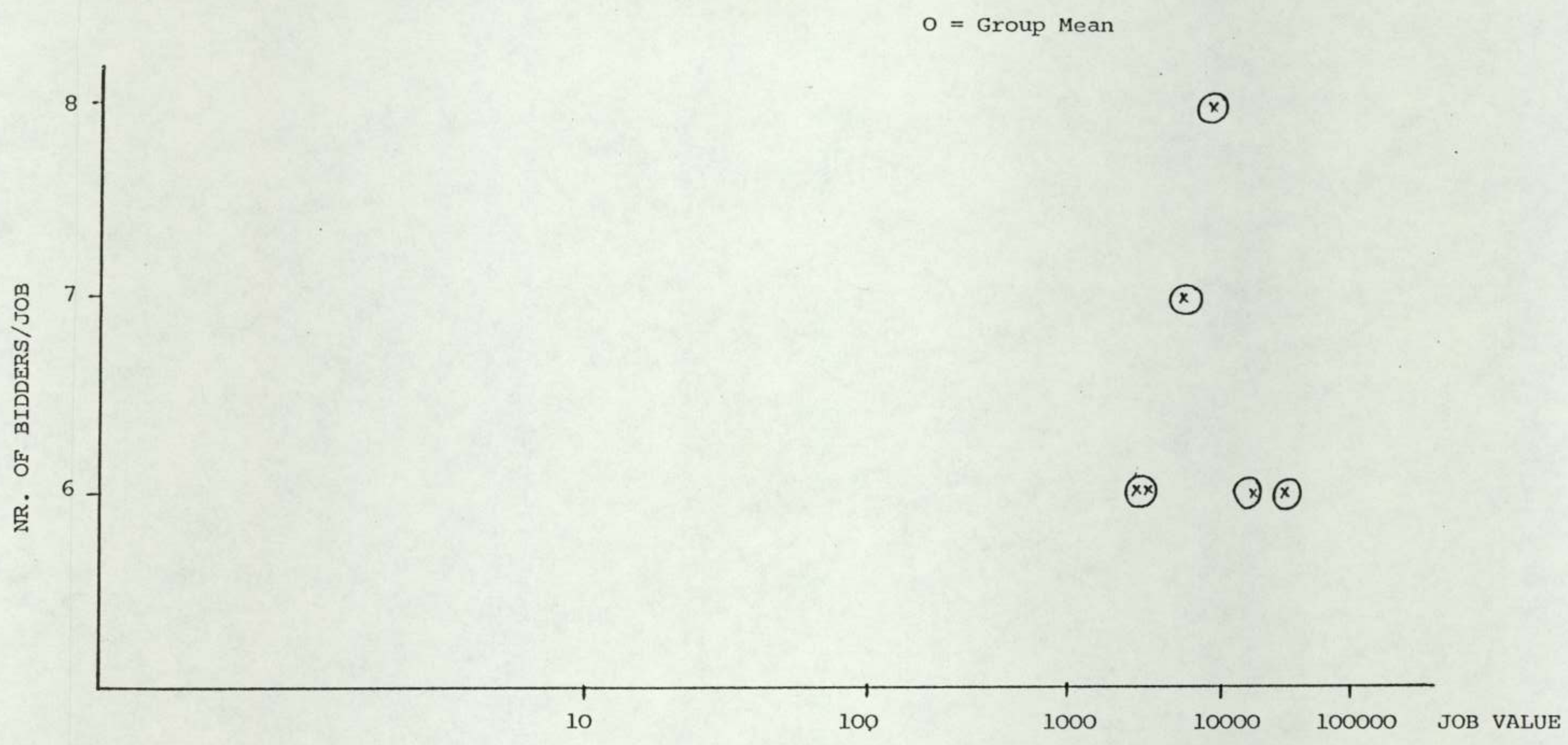


Figure (5.14) Log Job Values average against number of bidders.
(data B)

Table (5.14a) The results of firm B's data for calculating the coefficient of correlation

u_y	u_x	-1	0	1	f_y	$f_y u_y$	$f_y u_y$	$f u_x u_y$
2		2(-4)			2	4	8	-4
1			1(0)		1	1	1	0
0				1(0)	1	0	0	0
-1		1(1)			1	-1	1	1
-2		1(2)			1	-2	4	2
f_x		4	1	1	6	2	14	-1
$f_x u_x$		-4	0	1	-3			
$f_x u_x$		4	0	1	5			
$f u_x u_y$		-1	0	0	-1			

Table (5.15) The relation between the number of bidders and the job values for firm C's data

NUMBER OF BIDDERS	2	3	4	5	6	7	8	9	10	11	12	13	14	JOB VALUE RANGE K	Log. OF JOB VALUE AVERAGE	No. OF JOBS IN RANGE	AVER.No. OF BIDDERS IN JOB RANGE
				3										25 - 50	1.55	3	5
			1	2	1	1								50 - 100	1.85	5	5.4
		1		2	3	1	2					1		100 - 200	2.15	10	6.7
				1	1	1			1					200 - 500	2.50	4	7
	1					1	1							500 - 1000	2.85	3	5.7
		1	2	2	1								1	1000 - 2000	3.15	7	5.6
				1		1	1							2000 - 5000	3.50	3	6.6
					1	1	2							5000 - 10000	3.90	4	9.7
						1								10000 - 20000	4.20	1	7
$\sum$	1	2	3	11	7	7	6	0	1	0	0	1	1			40	

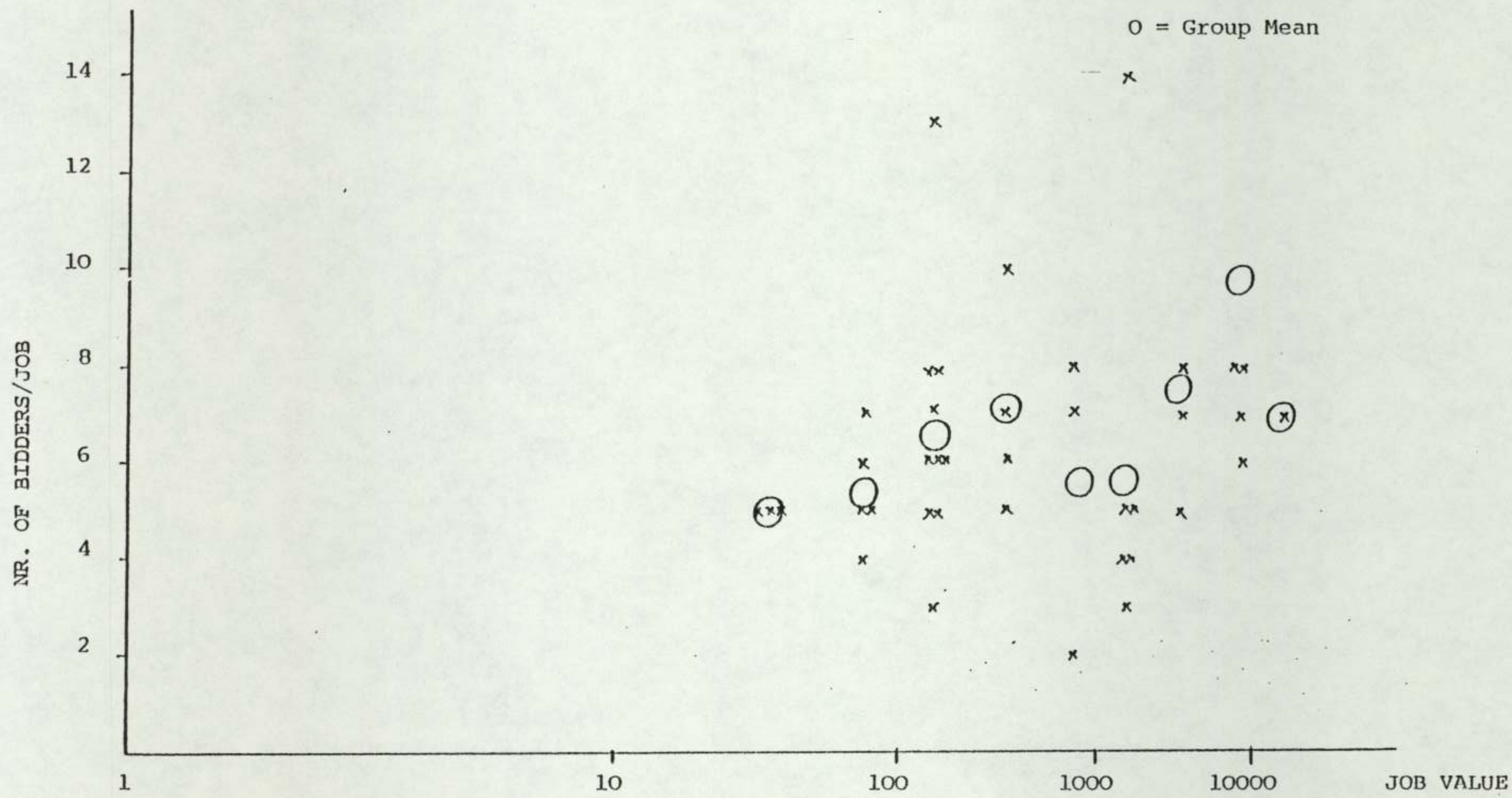


Figure (5.15) Log Job Values average against Nr. of bidders.
(data C)

Table (5.15a) The results of firm C's data for calculating the coefficient of correlation.

u_y	u_x	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	f_y	$f_y u_y$	$f_y u_y$	$f u_x u_y$
4					3										3	12	48	-36
3				1	2	1	1								5	15	45	-39
2			1		2	3	1	2					1		10	20	40	-26
1					1	1	1			1					4	4	4	- 4
0		1					1	1							3	0	0	0
-1			1	2	2	1								1	7	-7	7	15
-2					1		1	1							3	-6	12	8
-3						1	1	2							4	-12	36	9
-4							1								1.	-4	16	4
f_x		1	2	3	11	7	7	6		1			1	1	40	22	208	-69
$f_x u_x$		-6	-10	-12	-33	-14	-7	0		2			5	6	-69			
$f_x u_x$		36	50	48	99	28	7	0		8			25	36	337			
$f u_x u_Y$		0	-5	-4	-57	-12	3	0		2			10	-6	-69			

The number of pairs of observations is equal to 40 . Now, r = 0.15, with reference to tables of statistics for 5 percent level of significance, r would have to exceed 0.3044 . As this is not the case, then, the sample does not show any linear relationship and therefore, there is no linear relation between the number of bidders and job values for data set C .

5.8 Effect of job value on the coefficient of variation

As each bidder assumed his own method in estimating the true tender cost, the value arrived at is obviously not unique. This is due to the fact that each firm has his own estimating department with his own estimators and because they are working differently, then, it is no surprise that the final outcome would not be the same.

Furthermore, the mark-up applied by each bidder is based on his own considerations and therefore it is a variable too. These factors and several others (for example, the bidder does not want to win the contract), are responsible for the wide range in which the bids for a particular contract fall within.

The measure of this dispersion can be made by evaluating the mean and standard deviation of each contract. To include the job value in the picture, it is required to know the relative variability of the bid distribution with respect to the job value expressed as the mean of each contract. A commonly used measure for such cases is the Pearson's coefficient of variation given by (63) :

$$V = 100\ S/\ X$$

where, S= standard deviation of each contract

X= mean of each contract

V= coefficient of variation

During the course of this study, a computer programme has been developed in order to read all the data belonging to the data sets being saved in a separate file and to perform the statistical analysis on them. This program and its output are presented in Appendix (4). The results of this program were used to calculate the coefficients of variation which are plotted against the logarithm of the mean value of each contract.

5.8.1 DATA SET A

Table (5.16) shows these results for A's data. Now, the coefficients of variation for data set A will be plotted against the log. of the mean job values. This is shown by Fig. (5.16).

It is not expected to obtain an apparent functional relationship from this graph and hence correlation and regression techniques were applied to find out if there is a linear relationship between the two variables. Now the correlation coefficient (r) can be determined by using the following equation :

$$r = \frac{N\sum XY - (\sum X)(\sum Y)}{N\left[\sum X^2 - (\sum X)^2\right] N\left[\sum Y^2 - (\sum Y)^2\right]}$$

Hence, from Table (5.23), r can be found to be : r = 0.63

The number of degrees of freedom is (47-2) = 45 .

The value of r for 45 degrees of freedom and a 5 percent level of significance given in statistiacl tables is 0.2875 .

As 0.63 $>$ 0.2875 then, the correlation is significant at the 5% and a linear relation exists between the log. of the mean job values and the coefficients of variation for data set A.

The regression lines are, with reference to Table (5.16) ,

$$Y = 24.92 - 4.56\ X$$

$$X = 4.13 - 0.0864\ Y$$, and are drawn in Fig. (5.16).

Table (5.16) The statistical results of firm A's data set.

TENDER No.	A's BID IN £ K	MEAN BID IN £ K	LOG. MEAN BID (x)	STANDARD DEVIATION	COEFFICIENT VARIATION % (y_1)	PERCENTAGE SPREAD (y_2)	AVERAGE STANDARDISED BID	x^2	xy_1	y_1^2	xy_2	y_2^2
1	6696	6846	3.83	1310	19.13	3.23	.978	14.71	73.26	365.9	12.25	10.24
2	3976	3745	3.50	480	12.83	12.36	1.062	12.77	44.9	164.6	43.76	152.76
3	1587	1516	3.20	91	6.04	4.20	1.047	10.11	19.33	36.48	13.44	17.64
4	8496	8370	3.90	893	10.67	10.93	1.015	15.38	41.61	113.84	42.63	119.46
5.	9594	9890	4.00	630	6.37	5.13	0.970	16.00	25.48	40.57	20.52	26.32
6	4426	4148	3.60	354	8.53	9.15	1.067	13.08	30.70	72.76	32.94	83.72
7	3728	3653	3.56	212	5.79	9.08	1.021	12.67	20.61	33.52	32.32	82.44
8	10181	10506	4.02	568	5.41	2.65	0.969	16.16	21.75	29.26	10.65	7.02
9	3337	3604	3.55	369	10.24	7.68	0.926	12.65	36.35	104.85	27.26	58.98
10	10210	10501	4.02	739	7.04	4.61	0.972	16.17	28.30	49.56	18.53	21.25
11	2805	2903	3.46	267	8.18	5.73	0.966	12.02	28.30	66.91	19.82	32.83
12	7273	7185	3.86	503	4.95	2.60	1.012	14.90	19.10	24.50	10.04	6.76
13	1860	1800	3.25	99	5.53	8.28	1.033	10.59	17.97	30.58	26.91	68.55
14	129	108	2.03	15	14.55	2.66	1.194	4.12	29.53	211.70	5.40	7.07
15	6290	6231	3.80	420	6.74	0.24	1.009	14.39	25.61	45.43	0.91	0.05
16	1792	1819	3.25	239	13.17	4.75	0.985	10.62	42.80	173.44	15.44	22.56

/cont'd ...

TENDER No.	A's BID in £ K	MEAN BID in £ K	LOG. MEAN BID (x)	STANDARD DEVIATION	COEFFICIENT OF VARIATION % (y_1)	PERCENTAGE SPREAD (y_2)	AVERAGE STANDARDISED BID	x^1	xy_1	y_1^2	xy_2	y_2^2
17	438	469	2.67	55	11.79	13.95	0.933	7.13	31.48	139.00	37.25	194.60
18	5172	4995	3.70	317	6.34	5.78	1.035	13.68	23.46	40.20	21.38	33.40
19	14	11	1.04	3	31.58	78.20	1.273	1.08	32.84	997.30	81.33	6115.20
20	9072	9086	3.95	637	7.02	5.96	0.998	15.66	27.72	49.30	23.54	35.50
21	1923	2120	3.32	141	6.65	7.50	0.907	11.06	22.08	44.20	24.90	26.25
22	6262	6314	3.80	435	6.90	11.85	0.992	14.44	26.22	47.60	45.03	140.42
23	200	184	2.26	26	14.60	9.09	1.087	5.13	33.00	213.16	20.54	82.63
24	1868	1771	3.24	96	5.40	6.98	1.055	10.55	17.50	29.16	22.61	48.72
25	4642	4951	3.70	722	14.50	4.61	0.938	13.65	53.65	210.25	17.06	21.25
26	12504	12548	4.09	1789	14.20	4.01	0.996	16.79	58.08	201.64	16.40	16.08
27	456	527	2.70	79	15.14	0.52	0.865	7.04	40.87	229.20	1.40	0.27
28	390	314	2.49	36	11.52	3.93	1.242	6.23	28.68	132.70	2.78	15.44
29	1268	1171	3.06	124	10.60	6.78	1.083	9.42	32.43	112.36	20.75	45.96
30	2211	2139	3.33	103	4.80	6.38	1.034	11.09	15.98	23.04	21.25	40.70
31	525	497	2.70	33	6.78	9.87	1.056	7.27	18.30	45.97	26.65	97.42
32	567	615	2.78	49	8.12	0.76	0.922	7.77	22.57	65.93	2.11	0.57

/cont'd ...

TENDER No.	A's BID IN £ K	MEAN BID IN £ K	LOG. MEAN BID (x)	STANDARD DEVIATION	COEFFICIENT OF VARIATION% (y_1)	PERCENTAGE SPREAD (y_2)	AVERAGE STANDARDISED BID	x^2	xy_1	y_1^2	xy_2	y_2^2
33	189	165	2.22	12	7.80	1.37	1.145	4.91	17.32	60.84	3.04	1.87
34	9695	8488	3.93	804	9.40	4.72	1.142	15.43	36.94	88.36	18.55	22.28
35	12621	10978	4.04	963	8.70	4.20	1.150	16.32	35.15	75.69	16.97	17.64
36	326	346	2.54	55	15.90	30.68	0.942	6.44	40.4	252.81	77.93	941.26
37	4996	4739	3.67	327	6.92	0.34	1.054	13.51	25.04	47.88	1.25	0.115
38	656	670	2.82	69	10.35	5.25	0.979	7.98	29.02	107.12	14.80	27.56
39	4567	4603	3.66	401	8.73	0.38	0.992	13.42	31.95	76.21	1.40	0.144
40	2555	2354	3.37	137	5.84	3.61	1.085	11.37	19.68	34.10	12.16	13.03
41	3760	3784	3.58	218	5.78	0.92	0.994	12.80	20.7	33.40	3.29	0.85
42	29	26	1.41	6	23.12	30.83	1.115	2.00	32.6	534.53	43.47	950.50
43	642	758	2.88	102	13.56	7.97	0.847	8.30	39.05	183.87	22.95	63.50
44	2300	2257	3.35	168	7.45	2.57	1.019	11.25	24.95	55.50	8.60	6.60
45	3986	4206	3.62	265	6.32	5.45	0.948	13.13	22.87	39.94	19.73	29.70
46	1596	1568	3.19	206	13.17	6.95	1.019	10.20	42.01	173.45	22.17	48.30
47	10992	10453	4.02	602	5.76	2.84	1.052	16.15	23.15	33.17	11.42	8.06
$\sum$			153.96		469.91	377.50		527.90	1431.83	594178	1002.80	9793.[illegible]7

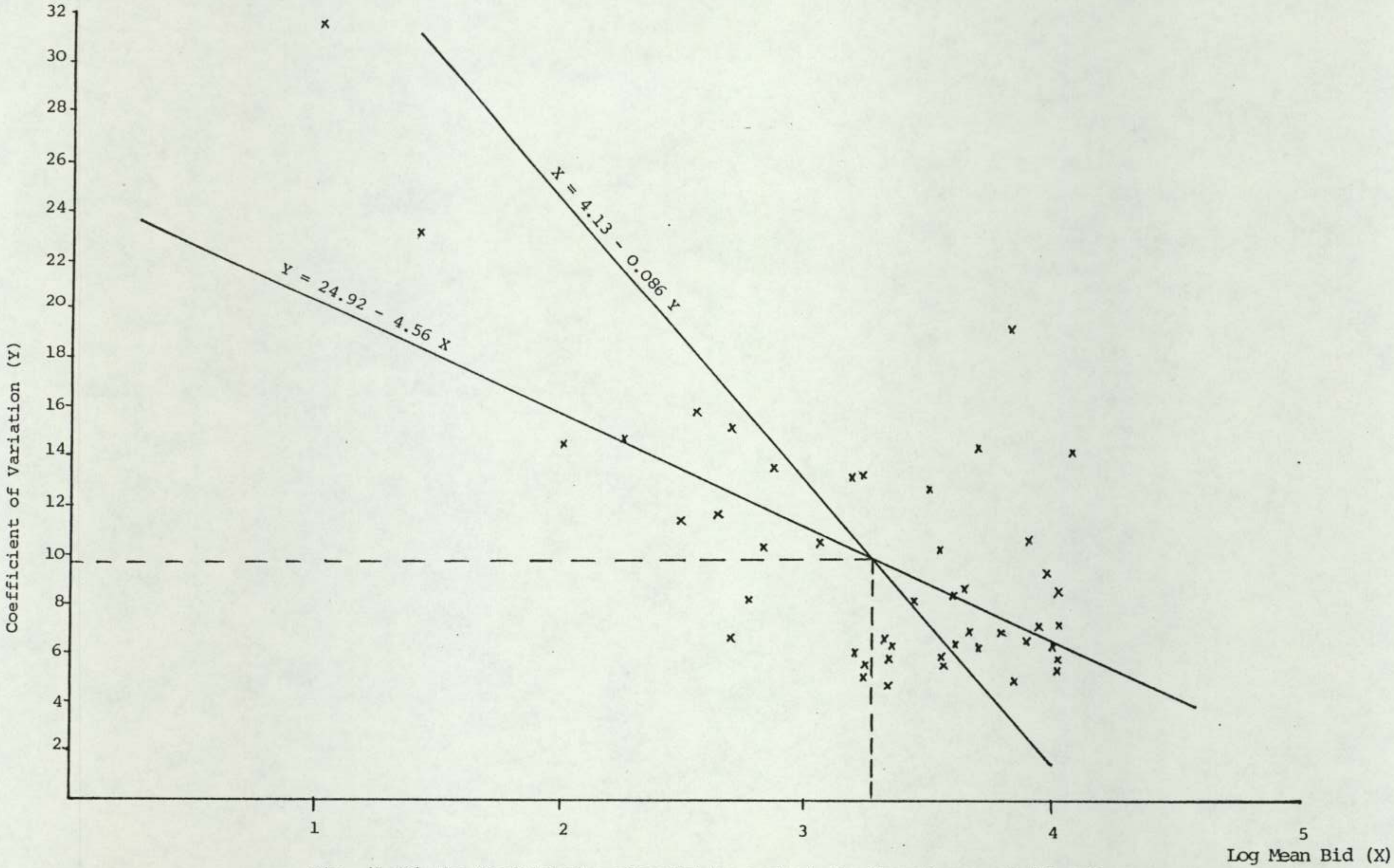


Fig. (5.16) The Coefficients of variation against the log of mean of job values for data set A.

The type of relationship given by the correlation lines of Fig. (5.16), is thought to be due to the fact that small contractors with low overheads bid for contracts with a low job values while bigger contractors are operating at the lower end of their market and submit bids based on an overestimation of the true cost due to their experience in this field.

It is no surprise that the contracts with high job values are tendered by experienced contractors specialised in that particular field and hence take more care in preparing their estimates due to the high element of risk involved.

5.8.2 DATA SETS B AND C

Similar attempts were made to investigate the existence of such a relationship for data sets B and C. The results of these investigation are shown in Tables (5.17) and (5.18) . The dispersion of the coefficients of variation against the log. of the mean job values are presented by Figures (5.17) and (5.18).

Now, with reference to Fig. (5.17), it can be seen that there is no obvious functional relationship between these two variables for data set B . Like before, the correlation and regression techniques are used for this particular data set. The correlation coefficient (r) can be determined similarly from Table (5.17). This is equal to :

$$r = 0.42$$

However, the value of (r) for (6-2) degrees of freedom and a 5% level of significance given in statistical tables should have exceeded 0.81. As $0.42 < 0.81$ hence, the correlation does not exist and there is no

Table (5.17) The statistical results of firm B's data set.

TENDER No.	B'S BID IN £ K	MEAN BID IN £ K	LOG. MEAN BID (x)	STANDARD DEVIATION	COEFFICIENT OF VARIATION% (y_1)	PERCENTAGE SPREAD (y_2)	AVERAGE STANDARDISED BID	x^2	xy_1	y_1^2	xy_2	y_2^2
1	2950	2872	3.46	179.3	6.2	11.81	1.027	11.97	21.45	38.44	40.86	139.48
2	2930	3110	3.49	224	7.2	0.34	0.942	12.18	25.13	51.84	1.19	0.12
3	3480	3583	3.55	216	6.0	0.60	0.971	12.60	21.30	36.00	2.13	0.36
4	10640	10573	4.02	205	1.9	0.87	1.006	16.16	7.64	3.61	3.50	0.76
5	23770	24150	4.38	118 2	4.9	0.70	0.982	19.18	21.46	24.01	3.07	0.49
6	8990	9768	3.99	750	7.7	0.22	0.920	15.92	30.72	59.29	0.88	0.05
$\sum$			22.89		33.9	14.54		88.01	127.7	213.19	51.63	141.26

Table (5.18) The statistical results of firm C's data set.

TENDER No	C's BID IN £ K	MEAN BID IN £ K	LOG. MEAN BID (x)	STANDARD DEVIATION	COEFFICIENT OF VARIATION% (y_1)	PERCENTAGE SPREAD (y_2)	AVERAGE STANDARDISED BID	x^2	xy_1	y_1^2	xy_2	y_2^2
1	75	48	1.68	15150	31	7.53	1.55	2.82	52.08	961	12.65	56.70
2	645	627	2.80	25808	4	5.99	1.03	7.84	11.20	16	16.77	35.88
3	440	505	2.70	45757	9	3.86	0.87	7.29	24.30	81	10.42	14.90
4	5849	5674	3.75	451845	8	4.88	1.03	14.06	30.00	64	18.30	23.81
5	116	126	2.10	7798	6	1.51	0.92	4.41	12.60	36	3.17	2.28
6	1092	1129	3.05	131910	12	5.53	0.97	9.30	36.60	144	16.87	30.58
7	6675	9681	3.99	2970998	31	13.23	0.69	15.92	123.69	961	52.79	175.03
8	209	225	2.35	11013	5	4.52	0.93	5.52	11.75	25	10.62	20.43
9	11262	11068	4.04	489040	4	4.30	1.02	16.32	16.16	16	17.37	18.49
10	216	128	2.11	41659	33	20.72	1.69	4.45	69.63	1089	43.72	429.32
11	321	345	2.54	67281	19	28.97	0.93	6.45	48.26	361	73.58	839.26
12	103	99	1.99	9768	10	2.12	1.04	3.96	19.90	100	4.22	4.49
13	147	144	2.16	35019	24	2.36	1.02	4.66	51.84	576	5.10	5.57
14	663	607	2.78	119382	20	16.29	1.09	7.75	55.60	400	45.30	265.36
15	1798	1848	3.27	128581	7	1.88	0.97	10.67	22.89	49	6.15	3.53
16	237	220	2.34	23463	11	3.58	1.08	5.49	25.74	121	8.38	12.82

/cont'd ...

TENDER No	C's BID IN £ K	MEAN BID IN £ K	LOG. MEAN BID (x)	STANDARD DEVIATION	COEFFICIENT OF VARIATION% (y_1)	PERCENTAGE SPREAD (y_2)	AVERAGE STANDARDISED BID	x^2	xy_1	y_1^2	xy_2	y_2^2
17	3000	2313	3.36	309522	9	1.71	1.30	11.32	30.24	81	5.75	2.92
18	68	82	1.91	14883	18	3.14	0.83	3.66	34.38	324	6.00	9.86
19	172	130	2.11	21578	17	4.65	1.32	4.66	35.87	289	9.81	21.62
20	6866	7649	3.88	466773	6	8.84	0.90	15.08	23.28	36	18.21	78.15
21	102	116	2.06	8861	8	9.10	0.88	4.26	16.48	64	18.75	82.81
22	193	190	2.80	21432	11	3.80	1.01	5.20	30.80	121	10.64	14.44
23	65	63	1.80	2779	4	1.56	1.02	3.25	7.20	16	2.81	2.43
24	1395	1343	3.13	62929	5	9.96	1.04	9.79	15.65	25	31.17	99.20
25	1400	1269	3.10	102535	8	4.76	1.10	9.63	24.80	64	14.76	22.66
26	154	155	2.19	9269	6	6.05	1.00	4.79	13.14	36	13.25	36.60
27	1184	1173	3.07	87658	7	0.18	1.01	9.42	21.49	49	0.55	0.03
28	48	45	1.66	3392	7	5.32	1.06	2.75	11.62	49	8.83	28.30
29	2248	2216	3.35	271735	12	4.66	1.02	11.19	40.2	144	15.61	21.72
30	3097	3376	3.53	282647	8	5.30	0.92	12.45	28.24	64	18.71	28.09
31	7788	8094	3.91	358081	4	.84	0.96	15.27	15.64	16	3.28	0.71
32	47	61	1.78	19692	32	3.67	0.77	3.19	56.96	1024	6.53	13.47

/cont'd...

TENDER No	C's BID IN £ K	MEAN BID IN £ K	LOG. MEAN BID (x)	STANDARD DEVIATION	COEFFICIENT OF VARIATION% (y_1)	PERCENTAGE SPREAD (y_2)	AVERAGE STANDARDISED BID	x^2	xy_1	y_1^2	xy_2	y_2^2
33	104	135	2.13	25689	19	10.40	0.77	4.54	40.47	361	22.15	108.16
34	4267	4677	3.67	235876	5	5.75	0.91	13.47	18.35	25	21.10	33.06
35	524	566	2.75	49246	9	4.71	0.93	7.58	24.75	81	12.95	22.18
36	194	253	2.40	35909	14	17.22	0.77	5.76	33.60	196	41.33	296.53
37	214	210	2.32	15799	8	11.54	1.02	5.39	18.56	64	26.77	133.17
38	1204	1199	3.08	20600	2	2.46	1.01	9.48	6.18	4	7.58	6.05
39	131	115	2.06	21354	19	2.00	1.14	4.24	39.14	361	4.12	4.00
40	997	1001	3.00	37558	4	2.93	0.99	9.00	12.0	16	8.79	8.58
$\sum$			108.7		476	257.82		312.28	1211.28	83.45	701.63	3013.19

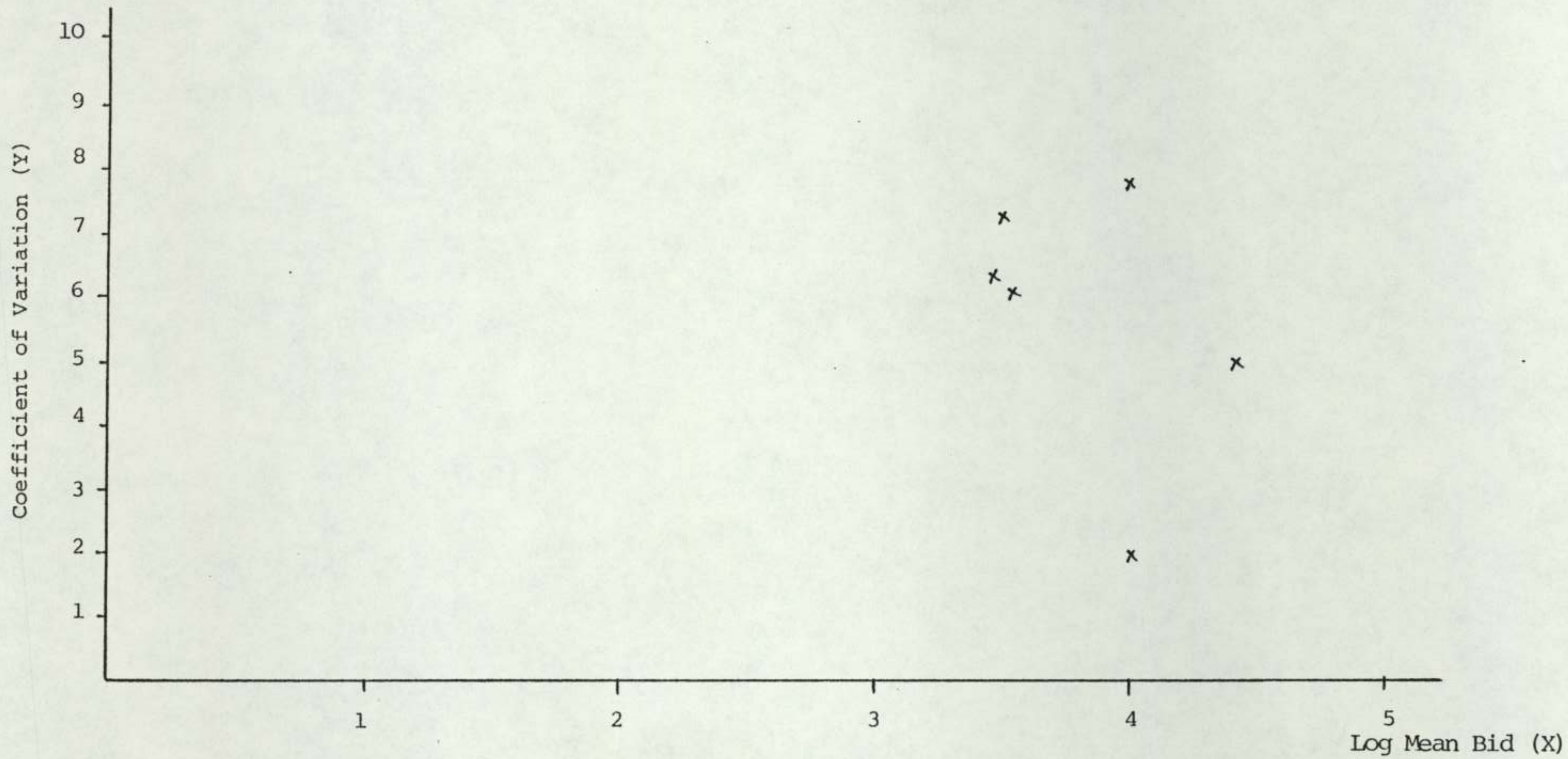


Figure (5.17) The Coefficient of variation against the log of mean of job values for data set B.

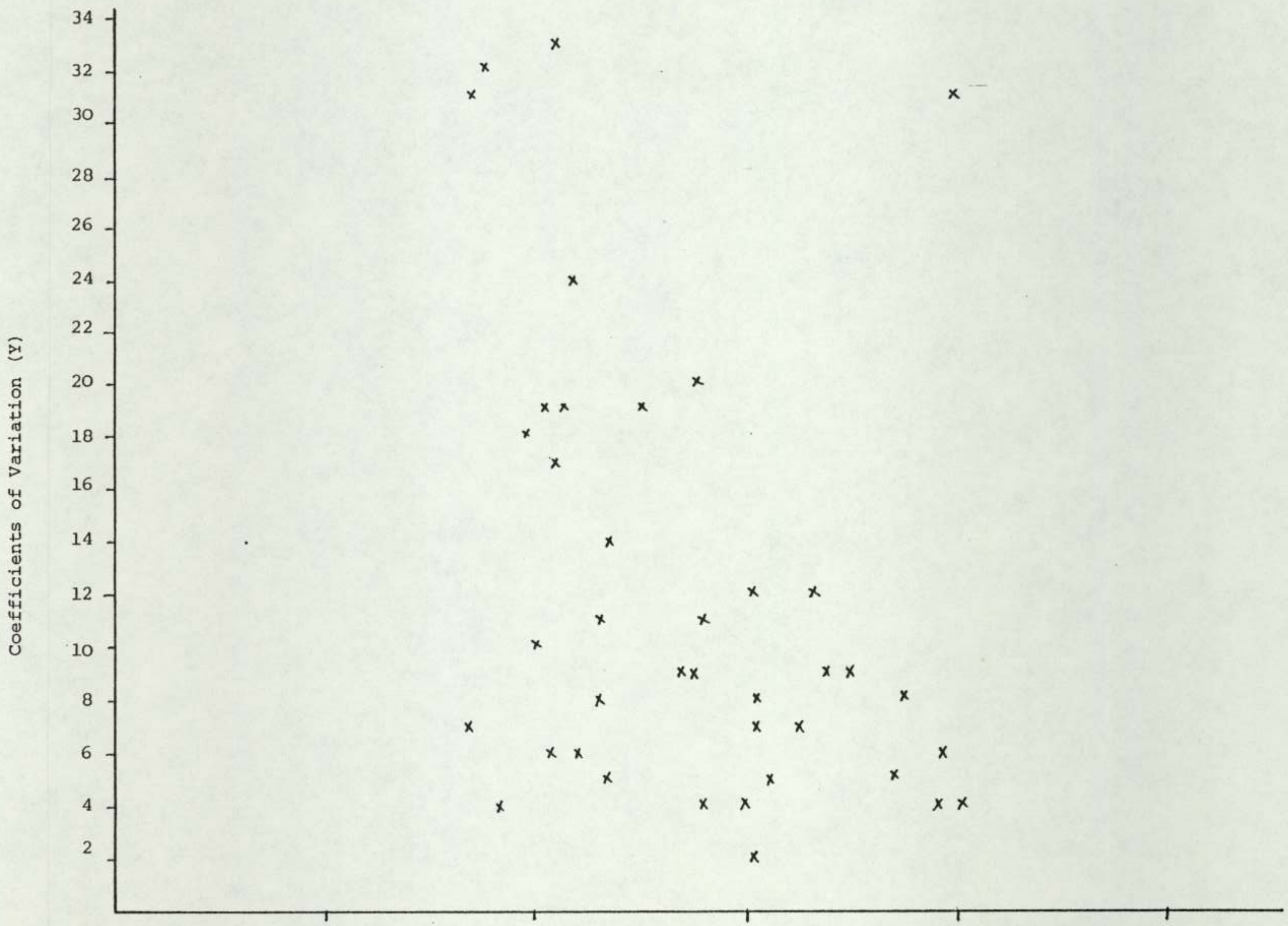


Figure (5.18) Coefficients of Variation against the log of mean job values for data set C.

linear relation between the two variable mentioned above for this particular data.

Finally, the coefficients of variation obtained from Table (5.18) are plotted against the log. of mean job values for C's data. This is shown by Fig. (5.18).
The correlation coefficient (r) is 0.15 . However, for (40-2) degrees of freedom and a 5 percent level of significance, (r) should have exceeded a value of 0.315 from statistiacl tables.
As $0.15 < 0.315$, then, the correlation is not significant and consequently, there is no linear relationship between the log. of mean job values and the coefficient of variation for data set C .

It was seen that only firm A's data indicate a linear relation between the two variables . McCaffer (45) , by studying 185 bids for building work contracts concluded that there is no correlation between the coefficient of variation and the job values. Hence, it can be said that the results of firm A's data, can very well be a special case and normally a study of a large number of data sets is required to establish if such a relationship exists.

5.9 <u>The effect of job value on the percentage spread</u>

The percentage spread is defined as :

$$\frac{\text{second lowest bid} - \text{lowest bid}}{\text{lowest bid}} \quad 100$$

The values for percentage spread which were calculated by use of the computer program mentioned before, are now plotted aganist the job values. Table (5.16) shows these results for firm A and Fig. (5.19) illustrate the dispersion of the percentage spread against the logarithm of mean job values. A study similar to section 5.7.7 is now conducted. With reference to Table (5.16), the coefficient of correlation (r) can be determined and it is equal to : $r = 0.59$. The number of degrees of freedom is $(47-2) = 45$. As before, the value of (r) from tables of statistics would have exceeded the value of 0.2875. Since, $0.59 > 0.2875$ therefore, the correlation is significant at the 5 percent level and a linear relation exists between the percentage spread and the job value for data set A .

The regression lines are :

$$Y = 40.51 - 9.92\ X$$

$$X = 3.55 - 0.0345\ Y$$

and are drawn in Fig. (5.19) .

The slope of the lines is greater than that of the coefficent of variation indicating that at the low job value side, there is a lot of money left on the table but it decreases rapidly as the job value is increased. This again can be due to the lack of care and inexperience in estimation for contracts with low job values which is not tolerated to the high job value end.

Similar attempts were made to find out about the existence of such a relationship for data sets B and C and the dispersions are shown in Figures (5.20) and (5.21).

Table (5.17) shows the values of percentage spread against the logarithm of mean of job values for data set B .

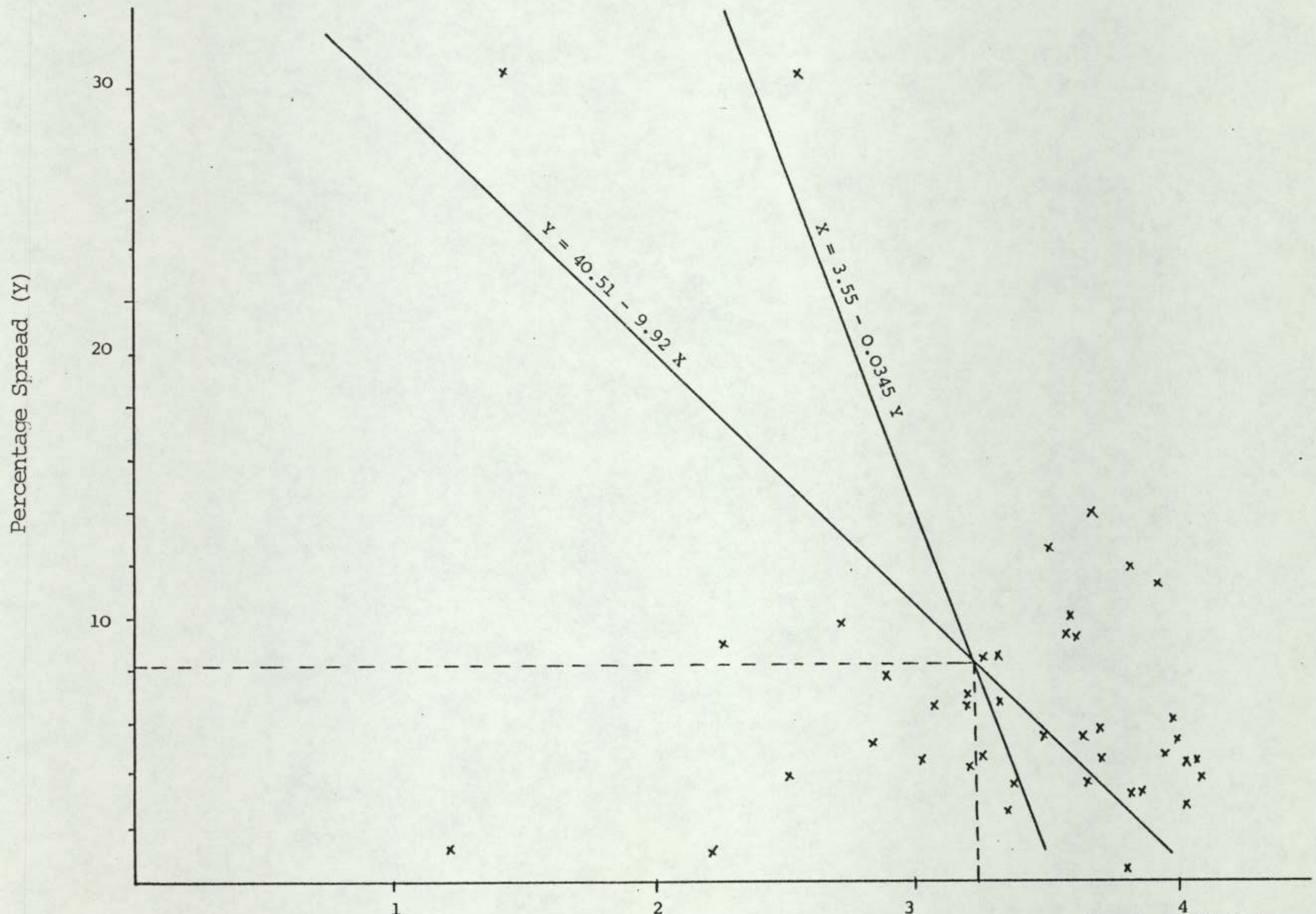


Figure (5.19) The percentage spread against the log of mean of job values fot data set A.

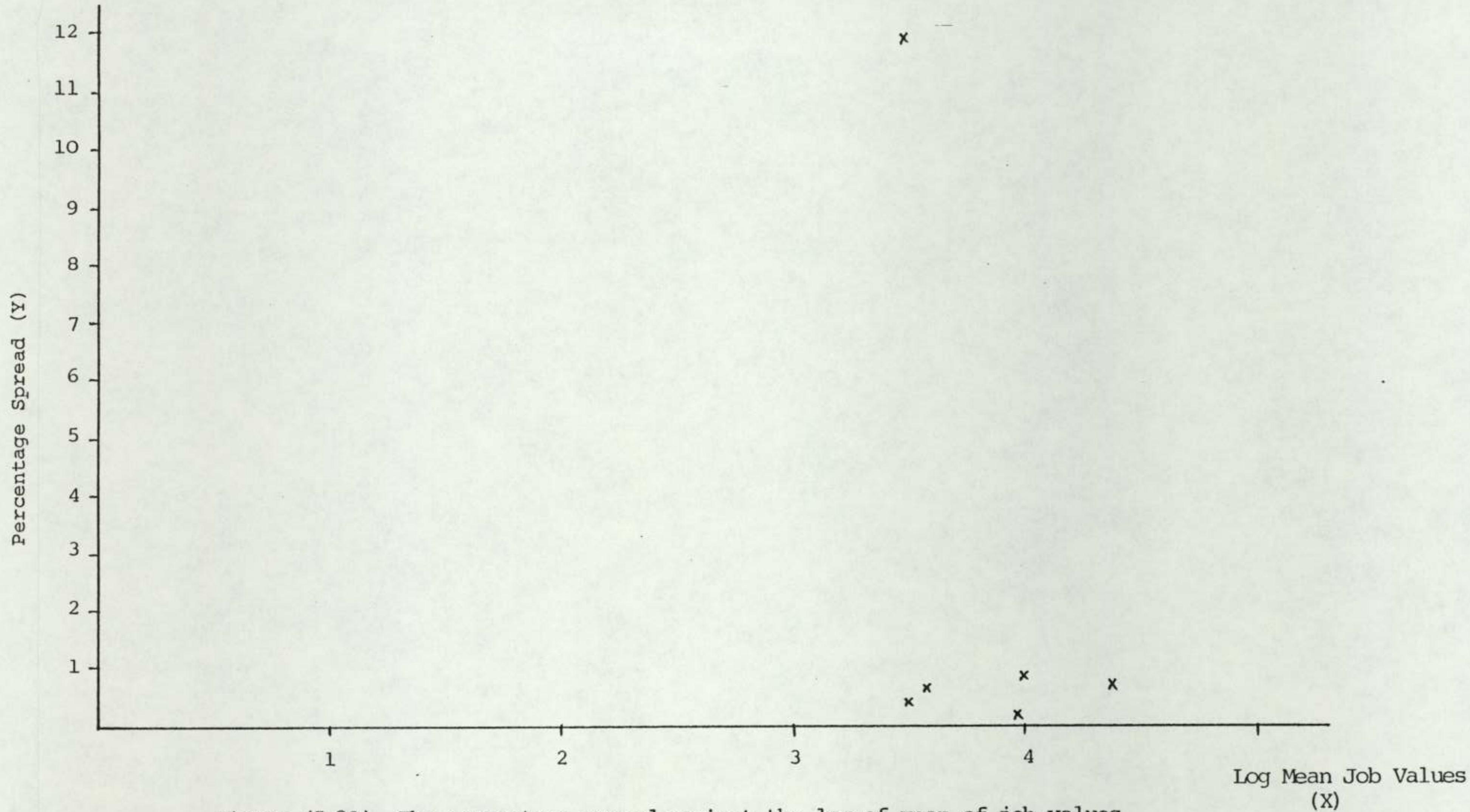


Figure (5.20) The percentage spread against the log of mean of job values for data set B.

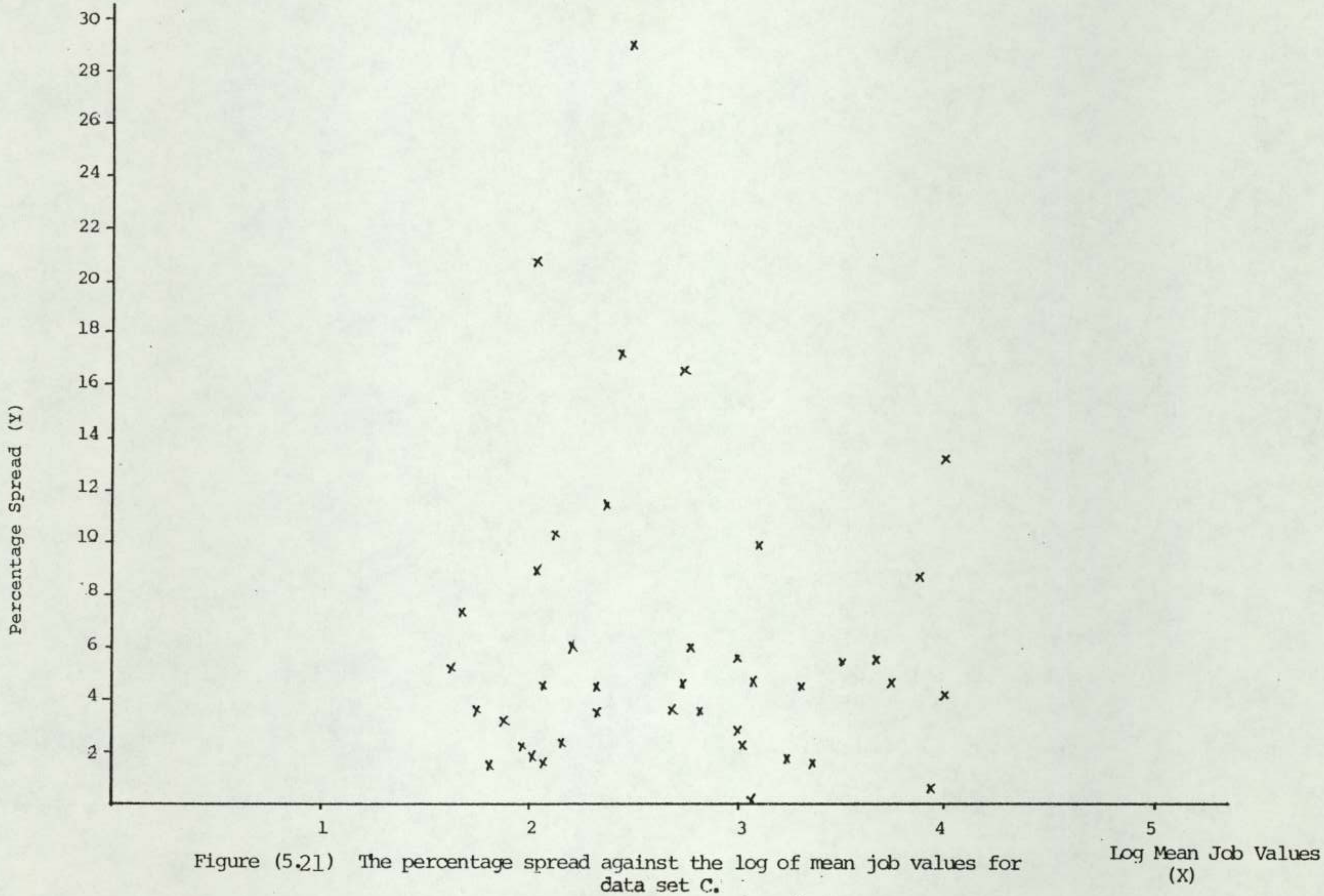


Figure (5.21) The percentage spread against the log of mean job values for data set C.

Similarly, the coefficient of correlation (r) for data set B can be found to be equal to 0.45 . As before, the value of r for (6-2) degrees of freedom and a 5 percent significant level, from the statistical tables should exceed 0.8114 . Because, $0.45 < 0.8114$, then, the correlation is insignificant and there is no linear relationship between the two variables for data set B .

Finally, the values of percentage spread which were obtained from Table (5.18) are now plotted against the logarithm of mean job values for data set C . This is shown by Fig. (5.21) .
Again, because there is no apparent relationship between the two variables from Fig. (5.21), the same method will be applied. Here, the correlation coefficient (r) is equal to 0.01 .
Similarly, the value of (r) from tables of statistics for (40-2) degrees of freedom and a 5 percent level of significance should exceed 0.315 . As this is not the case, then, the linear relation does not exist between percentage spread and the job values for firm C's data.

5.10 The effect of job value on average standardised bids

An average standardised bid is calculated by dividing the original bid by the mean of all bids for a given project. This value can be used in examining the behaviour of a certain competitor and that of all competitors as well.
McCaffer (45), suggests listing the average of these values of several bids for any competitor and check to see if that competitor normally bids below, above, or near the mean. Also, if the average of all competitors is close to unity, it means that their behaviour is

consistent, or similar , in estimating and marking-up tenders.
One approach which makes use of the average standardised bid and related to job values, is that suggested by Pim (59-62) and will be described briefly here. He suggested that the average of all tenders submitted for a given contract is taken as the true cost and the ratio of each competitor's bid to our bid is to be evaluated. The results are then plotted on a curve with job value on the X-axis and the ratios on the Y-axis . On every job value a line parallel to Y axis is drawn and the ratios of the competitors bid to ours are marked on it. The ratio of 1.0 which represents our bid is taken as the datum. Three lines, then, can be drawn; the higher trend line, the lower trend line, and the trend of bidders immediately above the datum. From the first two lines, the effects of job value on the bidding performance can be studied. The money left on the table by us and its variation with the job is shown by the difference between the third line and the datum.

However, this method does not show the variability of our bid with respect to the job value. Pim, then, suggested that to repeat the above procedure but this time using the average bid as the datum.
In other words, the mean of all tenders submitted for a given contract is taken as X-axis (the datum) and the ratios of our bid to mean is to be taken as Y-axis. Now this approach will be employed here for the three available sets of data.

Tables (5.16) through (5.18) show the values of average standardised bid against the mean job value for the three data sets.
Figure (5.22) shows the relationship of bids for data set A . Very few

of the points are close to unity and this indicates that firm A has no consistent policy especially at the lower priced jobs. There are 21 points below the unity and 26 above the unity suggesting that this firm has no policy to bid above or below the mean.

Both the upper limit and lower limit lines (lines enclosing all points) seems to converge towards unity as the job values increase. This would appear to suggest that at higher priced contracts, firm A takes extra care in preparing the bids. At low job values, the bids from firm A considerably deviate from the mean which could be due to various reasons, including insufficient time spent on preparing the bids. Furthermore, there may be a number of inexperienced competitors in the market, resulting in a distorted mean.

Both reasons are likely because contractors recently becoming known are generally inexperienced and tend only to bid for smaller jobs because of their limited resources. Also due to the lack of resources, smaller contractors or firms may be unable to allocate sufficient time to prepare bids.

Similar figures can be drawn for data set B . Fig. (5.23) shows the relationship of bids for firm B's data. Unfortunately, there are not enough points available to illustrate the effect of job values on the average standardised bids for this particular set of data. There are two points below and four points above the unity. Although, this may indicate that the firm B tends to bid under the mean, but due to the lack of more information the validity of this statement is questionable. Both the upper and lower limit lines are drawn with respect to the datum and they come down closer to each other as the job value increases. This demonstrates again that extra care is taken when preparing the bid for high job values.

Finally,a similar attempt was made to show the effect of job value on the average standardised bid for firm C's data.

Figure (5.24) shows this relationship. As it can be seen, there are 22 points above the unity and 17 points below the unity indicating that this firm has no policy to bid above or below the mean bid. The upper and lower limit lines are coverging towards unity as the job values increase.This again indicate that the preparation of bids at higher priced contract has been done more carefully. Unlike firm A, this firm has been spent more time on preparing its bids at low job values. This is clearly shown by Fig. (5.24) because the bids from this firm do not deviate as much as firm A from the mean bid.

Since most of the points drawn in Fig. (5.24) are very close to datum line (the mean bid), it may be concluded that the behaviour of firm C towards bidding is more consistent compare with the firms A and B and firm C is more consistent in estimating and marking-up his tenders.

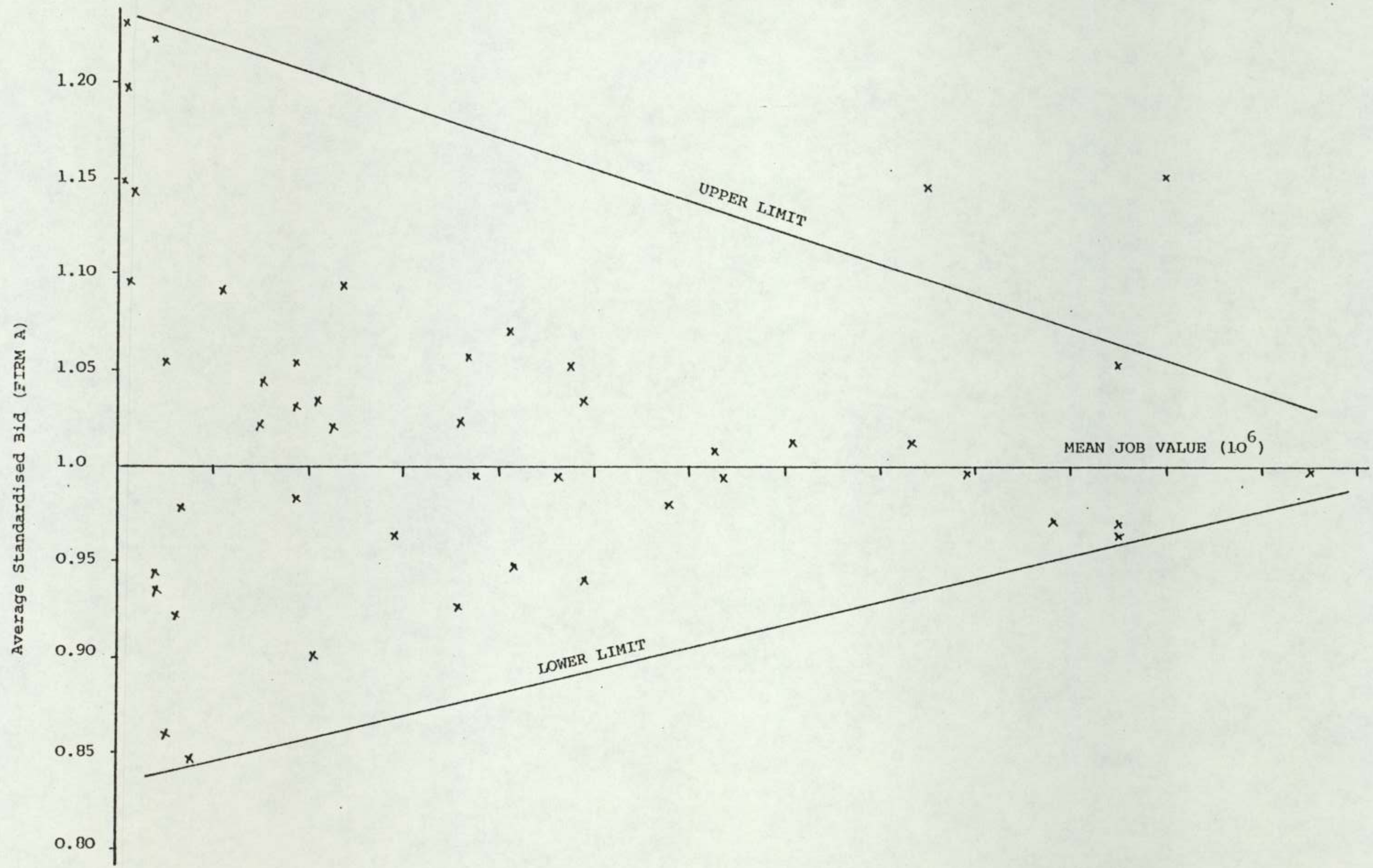


Figure (5.22) Average Standardised Bid against Mean Job Value for data set A.

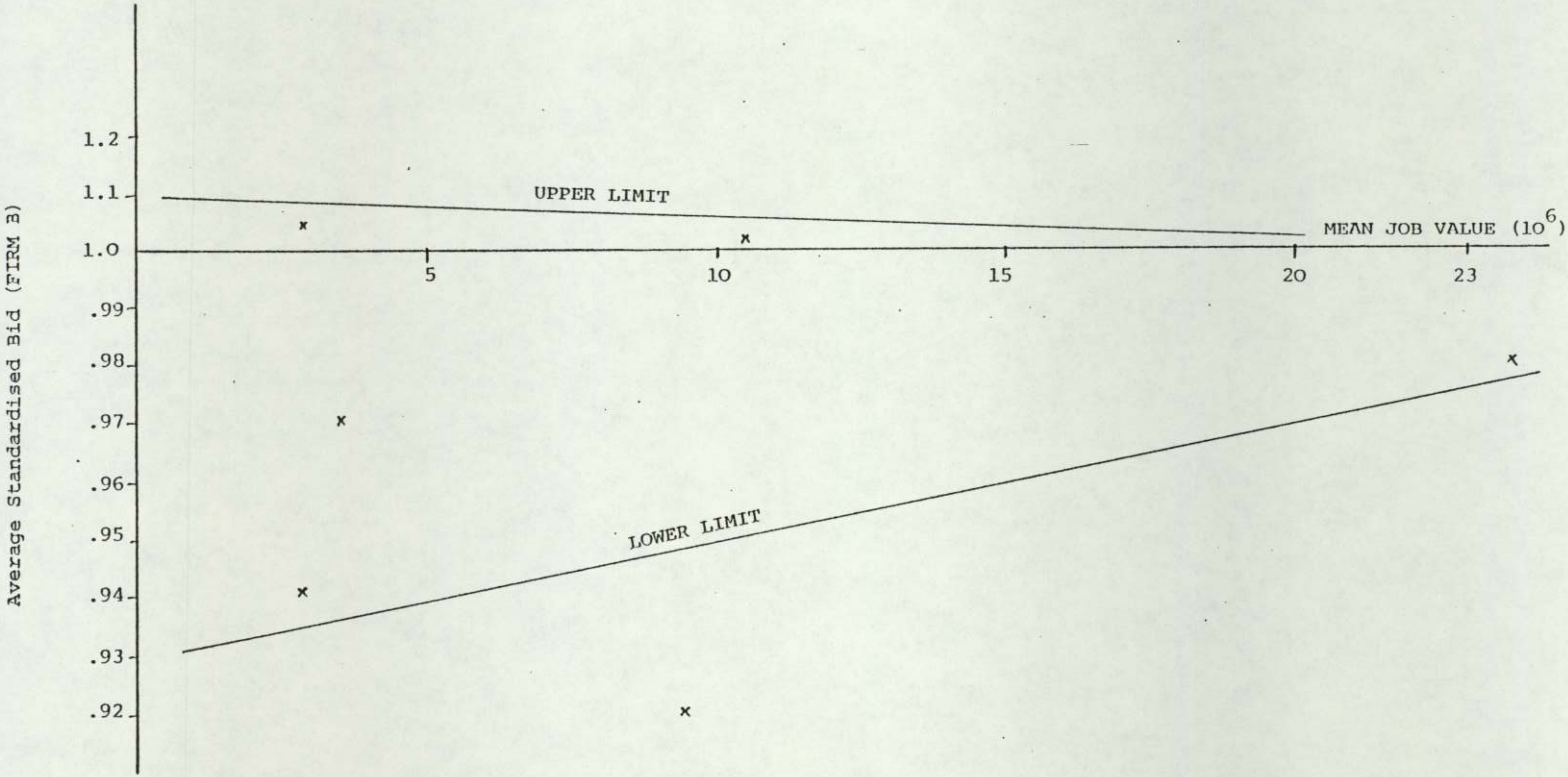


Figure (5.23) Average Standardised Bid against Mean Job Value for data set B.

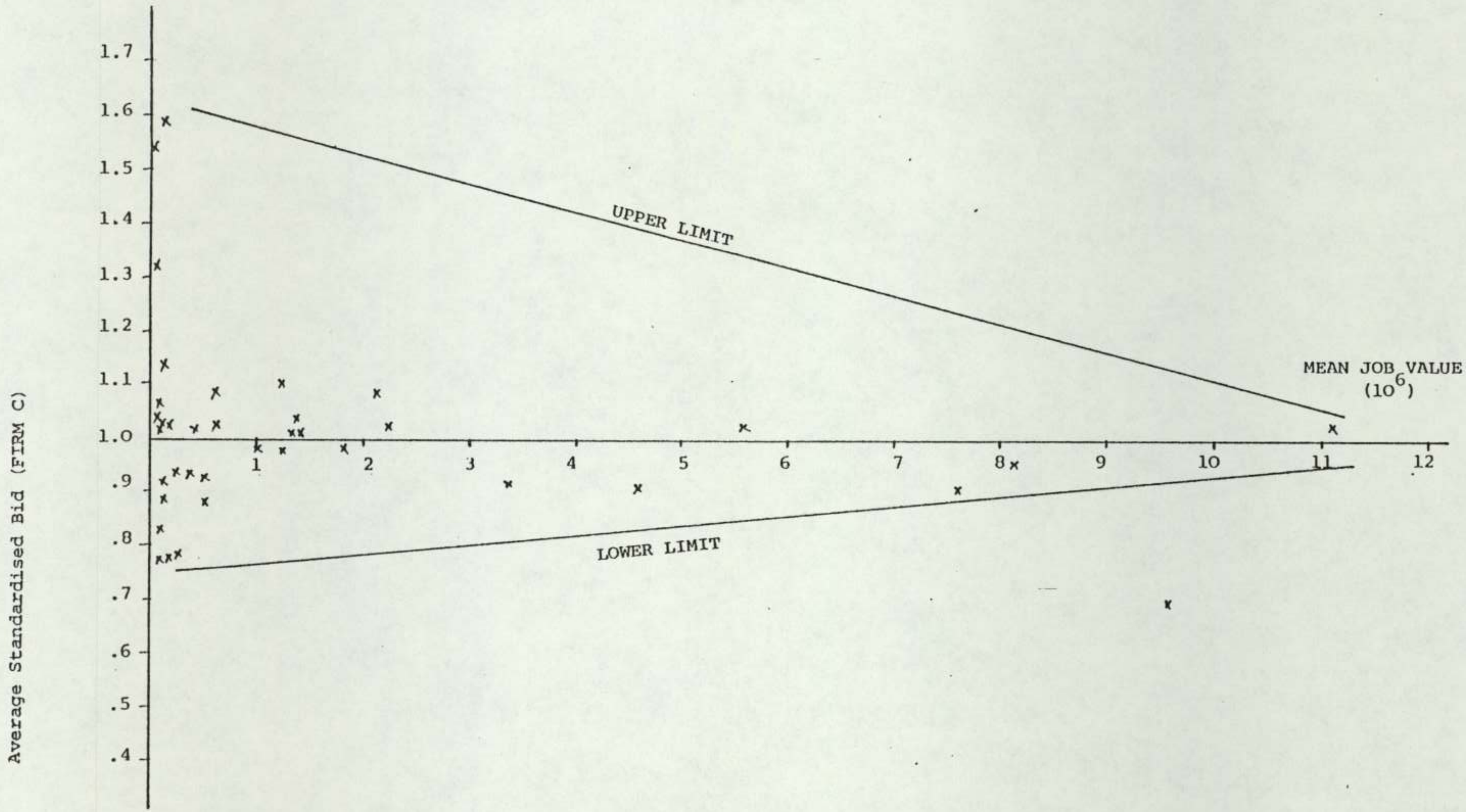


Figure (5.24) Average Standardised Bid against Mean Job Value for Data Set C.

CHAPTER SIX

THE MODIFIED FRIEDMAN AND ESTIMATING ERROR MODELS

6.1 Introduction

Competitive bidding is the purest type of competitive activity that can be found; it represents, essentially, what economists refer to as "perfect competition". Under such a system of near-perfect competition, no one individual or firm can control the price at which a contract is let, since the price will be set by the lowest bidder, and will be completely independent of the prices submitted by other competitors.
Since a contractor's bid on any given job exerts such an important influence on his chances of getting the job, a great deal of thought is required in deciding the exact amount of a bid. Being one percent too low or too high can considerably affect the outcome results.

Nearly all contractors employ a bidding strategy of some type. To be a low bidder, a contractor normally attempts to maximize his expected profit, by bidding at some point which affords him a moderate chance of making amoderate profit. Hence, by carefully studying the effect of his bid, both on his chances of getting the job and on the profit that can be achieved were he to receive the job, the contractor will be able to choose the best strategy.

Competitive bidding strategies have been applied successfully by many contractors; and, in many cases, an intuitively developed and applied strategy has resulted in highly profitable operations. But an objectively developed strategy, intelligently applied with benefit of a background of management experience, will show results far superior to any method founded upon intuition. A statistically developed competitive bidding strategy will prove an invaluable supplement to, but not a substitute for, informed management judgement. In this chapter, some of the most important aspects of practical approach to bidding strategy will be discussed. The factors that affect the bidding models will be described. The Friedman bidding model which incorporates the estimating error will be explained. Finally, two simulation models which are called BIDMOD 9 and BIDMOD11 are presented and the detailed results of these simulation models will be shown.

6.2 Information Requirements and Sources

A number of different competitive bidding strategies are employed on every job involving competitive bidding. They may be good bidding strategies, or bad bidding strategies, but nevertheless every bid submitted is the result of some individual's concept of what a bidding strategy should be.

For a good strategy to be applied effectively, however, some information is required regarding the amount and type of competition to be encountered on a job.

Ideally, the contractor should know the names of all competitors on a given job, and have accumulated, through experience, data regarding their bidding characteristics. In some cases, this ideal situation may exist, where perhaps a half-dozen contractors regularly compete with each other on certain types of work within a limited area. Usually, though, there will be some unknown or unexpected competition factors involved.

Most public works projects have public bid openings, so the interested and alert contractor has ample opportunity to accumulate data on his competitors for whatever jobs he bids. He should always record all competitors' bids on all projects for which he has prepared a detailed cost estimate.

However, the projects that are sponsored by private owners, where bids are not publicly tabulated or reported, may present problems in data collection. A few discreet enquiries regarding competitors and competitors' bids can still yield useful information. Again, any information on competitors' prices should be recorded. At least, a contractor who failed to get the job can assume that his bid was not low enough, or did not remain low enough, to get the job; and whoever got the job either bid lower initially or made enough additional concessions after the letting to end up being a low bidder. This information, too, is useful.

When the names of specific competitors are not known, simply having some idea of the approximate number of bids that will be submitted on a job will be extremely helpful in determining an appropriate mark-up. Sometimes the contractor's experience on similar jobs will be sufficient to enable him to estimate the probable number of competitors, based perhaps on the size and the type of job and on the correct economic condition of his industry.

Another useful source of information is the plan rooms of promoters, architects, engineers and service organizations. A competitor's estimators studying the plans of a forthcoming project provides an obvious and strong indication of that competitor's intention to bid for the job. Often the names, or at least the number, of contractors who have checked out plans for a specific project can be obtained. And subcontractors and material suppliers will know which contractors have asked for prices on a specific job.

All of this information could be useful to a contractor or a particular firm in preparing the bid that will be submitted by him.

6.3 Objectives

It was mentioned in the previous chapter that for a particular firm or a contractor to adopt any bidding strategy, its objectives must clearly be defined. However, before this it is worth discussing the objectives of the client in a bidding situation.

The client's objective is to enter into a contract that will ensure the completion of the work within the required time period at the lowest price consistent with an acceptable quality of workmanship. It is common but not universal practice to accept the lowest tender submitted. There should in practice be very few occasions on which the second lowest bid is thought to be preferable to the lowest bid, unless their tendered prices are extremely close. It is important to recognise that the tenders should only be sought and accepted from contractors who are thought to be capable of satisfactory completion of the contract in all its aspects. While the profitability of the contract may be of no immediate concern to the client, it may well have a secondary effect since frequently when contractors realise they are in a loss-making situation on a contract many difficulties arise and the contract may go sour. While this argument may have some merit, it is doubtful whether the principal is ever used in practice. It is, however, relevant to the question of the number of bidders who are invited or permitted to submit tenders for a particular contract. Although, by increasing the number of tenderers the chances of receiving a low bid will be increased, it also increases the chances of receiving a ridiculously low bid which consequently leads to a loss for the contractor and produces more difficulty for the client himself. Having considered the client's objectives, it is now possible to mention the contractor's objectives.

The most commonly stated objective will be the maximization of profit, but this in itself is not clear. First this might mean the maximisation of absolute profit in pounds per annum. It might mean the maximisation of profitability, that is, the profit as a percentage of turnover, or it might mean the maximisation of profit as a percentage of capital employed in the business.

While these three interpretations may lead to similar policies they are not exactly the same and the management of a contracting company should be clear as to which of these three interpretations of profit it is seeking. This is essentially a financial policy decision and should be taken at the highest level of the company. Whatever the objective of maximisation profit to be interpreted, it is particularly important to the shareholders of construction firms as they are

they are concerned with annual profits and annual turnover.
Another objective is that which seeks to increase the level of operation of the company, that is, to increase its turnover. Obviously the turnover will be maximised by submitting a large number of low bids thereby ensuring a high success rate, but of necessity at the same time accepting that many contracts will be undertaken at low profit or even at a loss.

If the estimating practice and management characteristics of a firm remain sensibly the same over a period of years, then, the profit on turnover is also likely to remain fairly constant, provided also that the market and certain other political and economical conditions remain stable.

The size of a firm, measured in terms of the number of full-time head office based staff, the investment in buildings and plant, etc., may be linked perhaps rather loosely to its turnover. This implies that for a particular size of a firm, there is likely to be a 'target' turnover. If the 'target' turnover is excessively underachieved, then, a large portion if not all of the gross annual profits will be required to cover head office charges.

On the other hand, an excessively high turnover may severely stretch the capacity of the firm, resulting perhaps in inadequate control of site operation, causing poor relations with the client.

This would result in poor future prospects of being invited to bid by that particular client.

However, a 'target turnover ratio' (the ratio of actual turnover to the target turnover) of greater than unity would appear, in the short term, to improve net profit.

From time to time there will be subsidiary objectives expressed by a contractor. He may have a particular desire to be successful in tendering for a contract in order to obtain experience of work of a particular type or in a new geographical area. He may also at times seek to keep his competitors out of a particular area or even to deprive them of work altogether.

6.4 Developing the Competitive Bidding Strategy

The development of a competitive bidding strategy is a straightforward process, once the general principles are understood and the apporopriate data have been collected and analysed. Again, the goal of a conventional competitive bidding strategy is to find the optimum combination of the profit resulting from getting a job at a given price, and the probability of getting the job at that price. Several distinct steps are involved in developing the strategy. The first four steps are concerned with preparing the data; the remaining steps are concerned with finding the right bid for the right job. The following seven steps are involved:

1. Tabulate competitors' bids on all jobs.
2. Summarize the tabulation for each major competitor.
3. Construct a probability curve for each major competitor.
4. Construct a probability curve for the typical competitor.
5. Identify the competitors involved on the particular job being considered.
6. Determine the probability of being low bidder on the job with any given job.

7. Compute the expected profit associated with each possible bid, and identify the optimum bid as the mark-up resulting in maximum expected profits.

6.5 Factors Affecting Bidding Strategy

In the previous section, the process involved in developing a competitive bidding strategy model were mentioned. Obviously, all the seven steps mentioned are only applicable if the general principles are understood and the necessary data for collection and analysing are available. In this section, it is tried to recognise all the important factors that affect the required bidding strategy model. The following lists all these factors:

1) Our mark-up:

This is one of the important factors that affect the bidding strategy models. Hence, it is worth defining the term mark-up. Many companies expressed the percentage mark-up on labour content. Some firms expressed it in terms of annual turnover. In any way, the mark-up usually includes all the costs towards on-site cost, head office, contribution towards the pensions and to cover all the risks that are involved. This is a factor that could be controlled by us. Replies to questionnaires revealed that one firm adopted a constant mark-up whereas another firm had a variable mark-up ranging between 1 and 16 percent.

2) Their mark-up:

This factor is uncontrollable by us. Based on the above, it would be unwise of us to assume that our competitors attitude to mark-up will be the same as ours. A variable mark-up for them would seem to be indicated but, perhaps, not within the extreme range of 1 and 16 percent. A range of 4 to 12 percent may be a compromise. This is a range that was confirmed by a number of firms during the interview with them. So the range of 4-12 percent seems to be acceptable.

3) Our Estimating Error:

This factor is uncontrollable by us to the extent that we can not eliminate it but it can be minimized. Estimating error includes the total minor errors in calculation and judgement, to which all estimators are prone, and which are likely to be equally positive or negative. In the previous chapter, a number of likely errors that could occur during the estimating processes were given. Practically, since nearly eighty percent of the job value is contained in only twenty percent of items (this fact is also indicated by a number of well-known contracting firms), then, it is possible to reduce the estimating error so long as the right decisions will be made. Depending on the size of the contract, a range of 5-10 percent estimating error is an acceptable figure in the real-world situation. Finally, it may be argued that computerised data handling systems will tend to reduce the range of this error, but may not eliminate it.

4) Their estimating error:

This is also uncontrollable by us. Based on the above arguments, a range of 5-10 percent estimating error is accepted for our competitors.

5) True cost ratio:

This is the ratio of our true cost to their true cost. It is uncontrollable by us to the extent that it is not predictable, unless the characteristics of all the jobs which are likely to come on the market in say, the next few years are known in advance. The true cost of a job to us, for example, may be considerably lower than the other likely competitors' cost because, in the case of a civil engineering contract, we may own a conveniently located quarry or tip, or we may have the sole rights to use a particular system of construction which offers clear advantages over other systems for this particular job.

6) Number of bidders:

This is again uncontrollable by us, however, the number of bidders for most government jobs (Department of Transport) is six and it does not exceed ten. Generally, for invited tenders on roads contracts the number of bidders lies probably within the range of 5 to 9 bidders (excluding us). This is again confirmed by some of the contracting firms during the interview between the researcher and them. However, it is important to mention that they also indicated a range of 2 to 4 bidders for a design and construct job. The identity of our competitors to us is also important. Although it is possible to find out about their identities, due to the fact that almost all of the contractors approach the same suppliers for materials and nearly the same sub-contractors.

7) Job values:

This factor is also uncontrollable by us. However, the upper and lower limits may be defined according to the size of the firm and its own policies. Obviously the size of the firm and its resources are important in evaluating the job value figures. Replies to questions reveals that the range of job values being taken is about 1-10 million pounds per year. Although, the bigger firms tend to have a job value of about 100m or more.

8) Number of jobs available per year:

This is again uncontrollable by us. The number of jobs available to bid for annually depends on external economic forces. This factor is related to the previous one because each firm or company has a target turnover. Depending on the turnover expected to be achieved by a particular firm, the number of contracts can be adjusted. Nevertheless, this cannot be controlled since different jobs offer different values.

It is important to recognise all these factors and to identify any sort of relationships between them. This is particularly useful in determining the dependence/independence of bidding factors. In chapter three the review of the literature, it has been shown that most of the researchers in bidding strategy have indicated that no correlation exists between the various factors listed above. It is also shown that in the previous chapter, based on the study of the bidding samples, there is no correlation between the various factors affecting the bidding strategy.

Therefore, in the bidding models to be described later, the uncontrollable variables are assumed to be independent random variables. This may be justified by the results of data analyses of chapter 5.

6.6 The Modified Friedman Bidding Model BID20

The Friedman simulation model that has been described in chapter four assumes that there is no estimating error involved. However, in the previous section it was further assumed that the estimating error, being one of the factors affecting the bidding strategy, is an independent random variable.

Now, an attempt was made here to incorporate the estimating error within the Friedman bidding model. It is assumed that there exists an estimating error and that it is randomly sampled from a uniform distribution. This model is called BID20.

The model decides the estimating error after the job is won. It is implicitly assumed that the distribution of bid/cost ratios includes some allowances for estimating error, etc., for all bidders and that any randomly sampled bid may equally likely involve a positive or negative estimating error.
The full listing of the program and a sample of output obtained from it are given in the Appendix (5). The following section describes the results obtained from this program.

6.6.1 Simulation Results

The Friedman simulation model has been run for 500 jobs. It is assumed that the estimating error is equal to 10%. Table (6.1) shows the results obtained from the programs for 10% estimating error and 500 job runs.

Now, with reference to Table (6.1), it can be seen that the optimum mark-up occurs at 9% with success ratio of 17.4 percent and the total values of jobs won at 88.3 million. Figure (6.1) shows the variation of profit against the mark-ups applied. Figure (6.2) illustrates the variation of job values against the different values of mark-ups in the range of 1-10 percent.

Further results can be obtained from Friedman simulation model which incorporated the estimating error.

As it was mentioned earlier, the total number of jobs to run is equal to 500. Now, by considering that exactly 50 jobs may be bid for each year, then the total duration of bidding for 500 jobs will be ten years. Tables (6.2) through to (6.6) present the values of jobs won, the profit and number of wins at the end of each year during ten year period for five different mark-ups. Figure (6.3) shows the variation of number of jobs won at the end of each year in 10 year period. Finally, Figures (6.4) and (6.5) show the variation of job values won and profits won at the end of each year in a ten year period for different values of mark-ups.

(BID 20)

Table (6.1) Results of Friedman Simulation Model for 10% estimating error.

PERCENTAGE MARK UP	NR OF JOBS WON	PERCENTAGE SUCCESS RATIO	TOTAL VALUE OF JOBS WON £	TOTAL PROFIT £
1	351	70.2	281,405,550	4,416,015
2	317	63.4	231,734,970	4,779,586
3	239	47.8	198,384,810	7,088,126
4	188	37.6	133,223,230	5,097,578
5	153	30.6	12,467,865	4,263,393
6	121	24.2	104,267,270	6,290,562
7	107	21.4	104,806,310	4,746,209
8	100	20	89,277,831	6,572,568
9	87	17.4	88,301,299	7,320,150
10	48	9.6	58,649,345	5,353,919

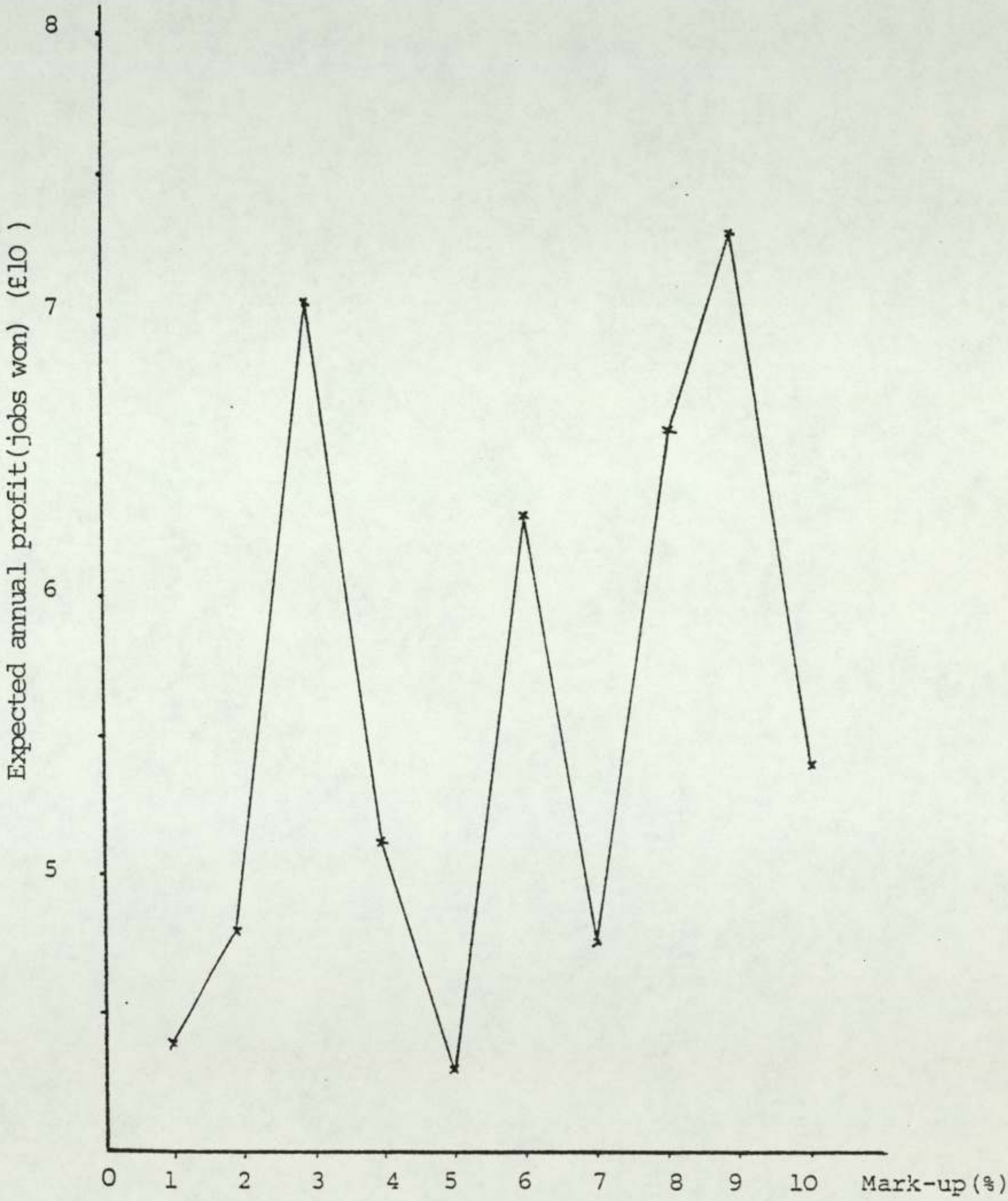
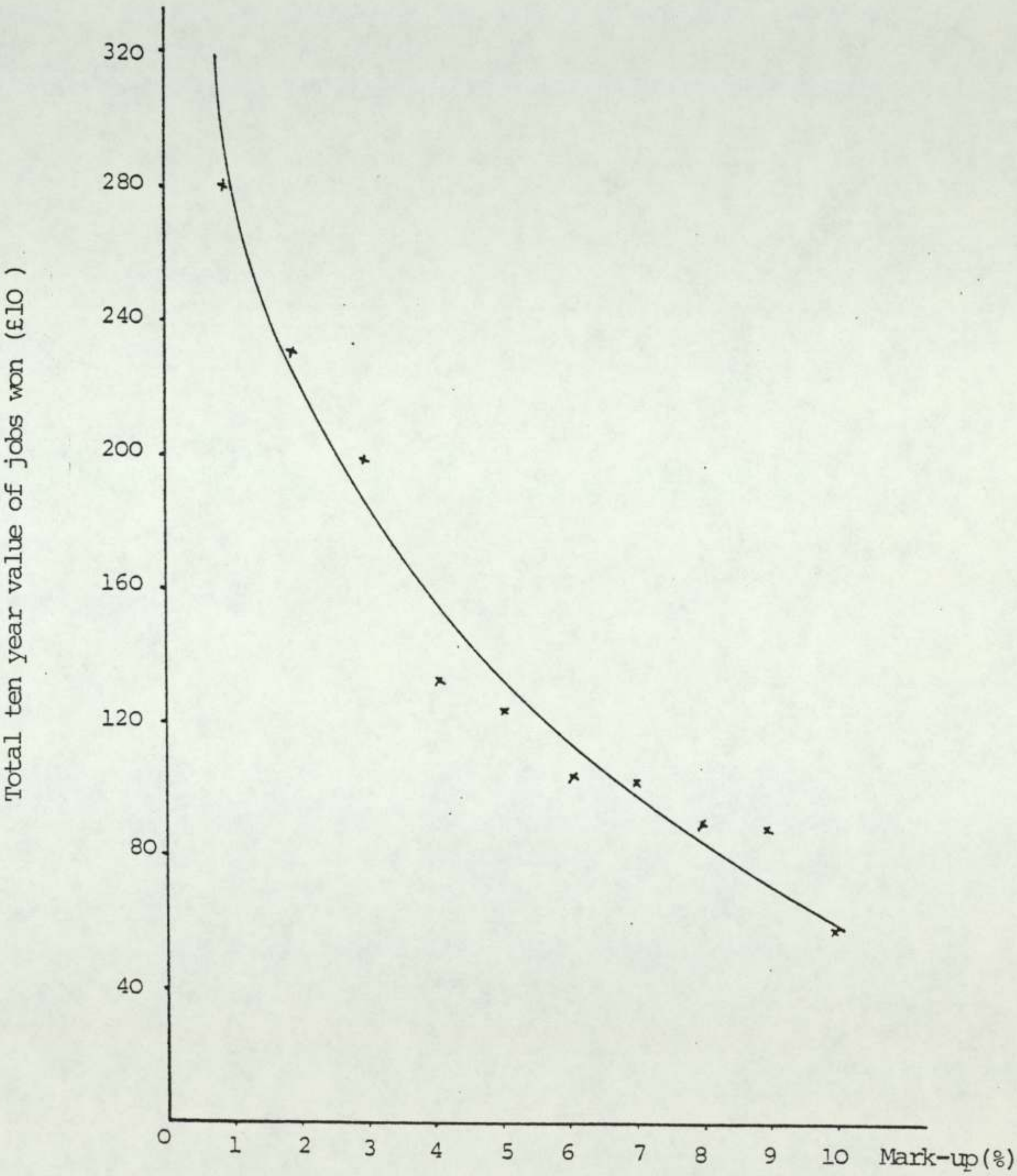


Figure (6.1) Variation of profit against mark-up for 10% estimating error (BID20)



Figure(6.2) Total ten year values against mark-up for 10% estimating error (BID20)

(BID 20)

Table (6.3) Simulation Results for 10 years Period

Mark-Up = 4%
Estimating Error = 10%

END OF YEAR	NR OF WINS	VALUE OF JOBS WON £	PROFIT £
1	10	16,822,421	766,504
2	16	6,855,530	337,347
3	22	18,730,092	25,623
4	19	10,388,637	407,376
5	17	11,745,808	848,239
6	23	13,302,132	588,625
7	21	13,981,120	1,058,209
8	19	11,338,400	239,460
9	20	8,365,920	263,182
10	21	21,693,170	558,010

Table (6.4) Simulation Results for 10 years Period

Mark-Up 6%
Estimating Error = 10%

END OF YEAR	NR OF WINS	VALUE OF JOBS WON £	PROFIT £
1	9	16,822,085	1097,863
2	7	3,779,065	317,165
3	15	16,787,336	173,920
4	11	6,837,738	498,607
5	11	9,504,202	926,308
6	14	10,822,009	615,443
7	13	11,496,784	1248,294
8	13	9,785,935	368,924
9	14	4,480,394	92,341
10	14	13,951,720	951,694

(BID 20)

Table (6.5) Simulation Results for 10 years Period

Mark-Up = 8%
Estimating Error = 10%

END OF YEAR	NR OF WINS	VALUE OF JOBS WON £	PROFIT £
1	5	13,103,101	823,782
2	5	1,384,971	122,680
3	11	13,813,467	364,352
4	10	6,175,343	599,943
5	9	9,170,434	1068,661
6	13	10,945,329	818,450
7	11	10,771,817	1386,071
8	13	9,970,576	553,564
9	11	4,386,995	164,904
10	12	9,555,798	710,155

Table (6.6) Simulation Results for 10 years Period

Mark-Up = 10%
Estimating Error = 10%

END OF YEAR	NO OF WINS	VALUE OF JOBS WON £	PROFIT £
1	3	13,259,384	1059,092
2	2	930,059	136,317
3	6	12,418,705	480,562
4	4	3,173,498	225,811
5	5	7,688,763	1215,462
6	5	3,441,889	395,813
7	7	4,429,543	475,371
8	3	3,298,790	514,932
9	6	2,385,811	169,867
10	7	7,622,903	680,688

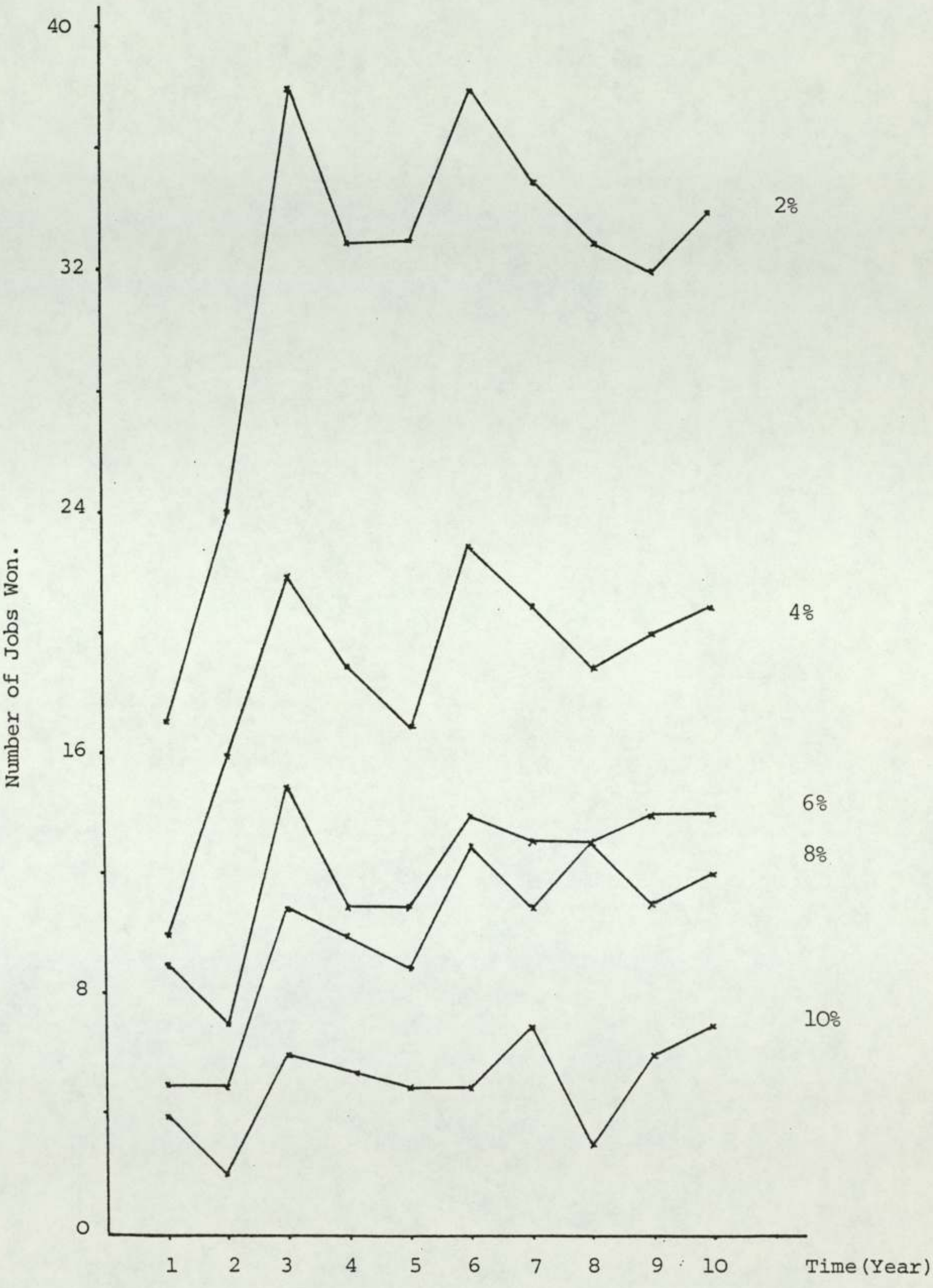


Figure (6.3) Variation of Number of jobs won in 10 years period for different mark-ups. (BID 20)

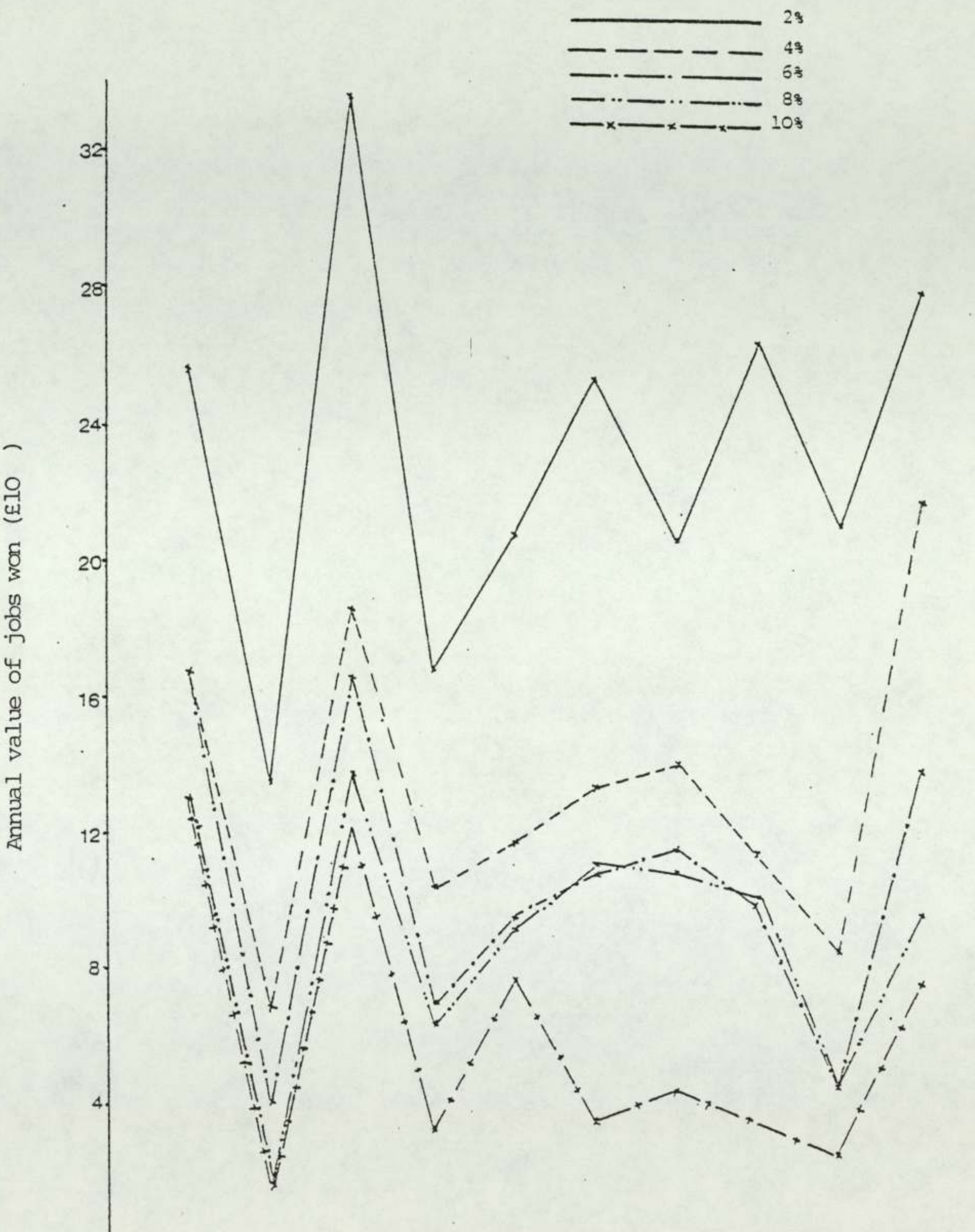


Figure (6.4) Variation of annual value of jobs won in 10 years period for different mark-ups (BID20)

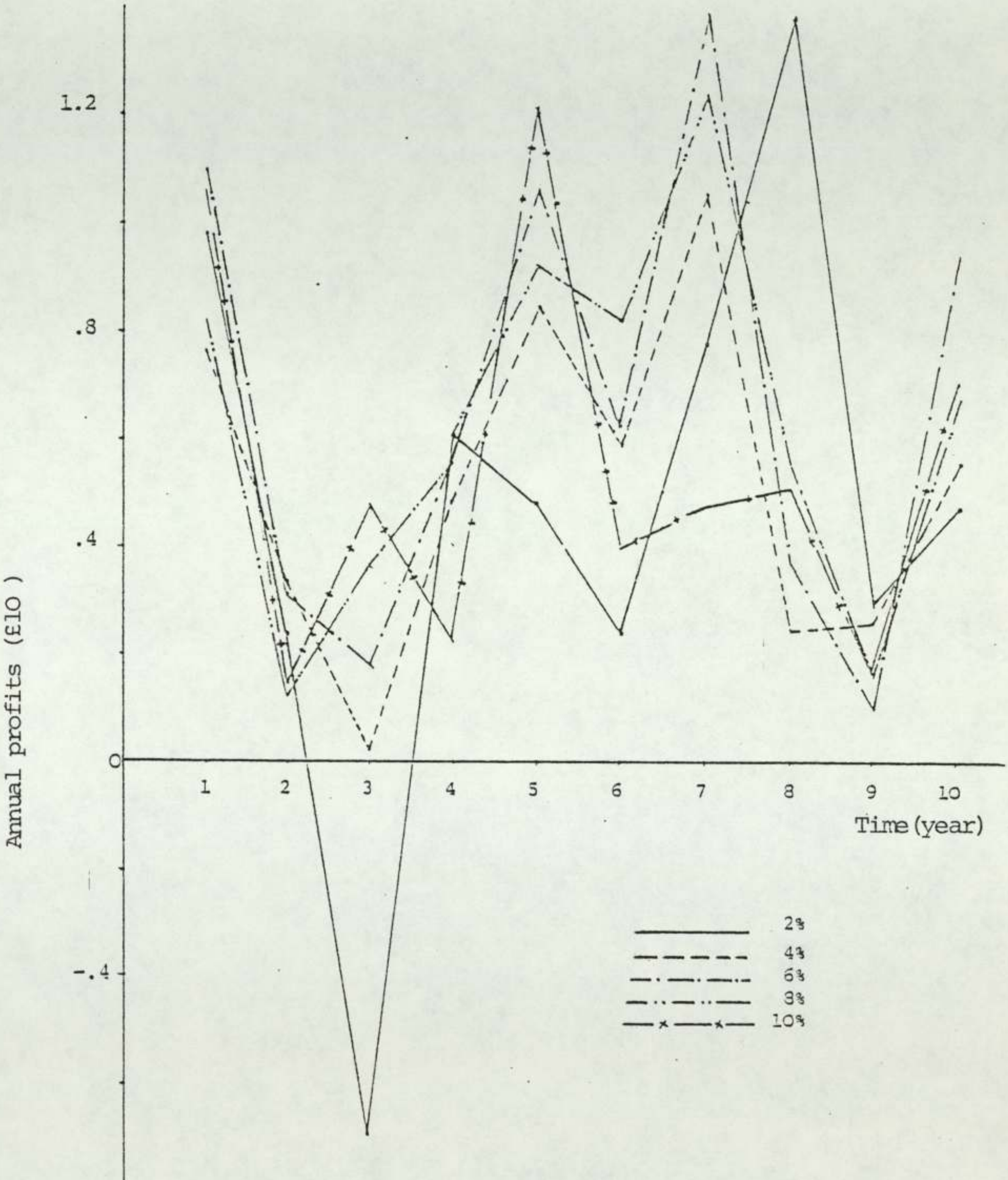
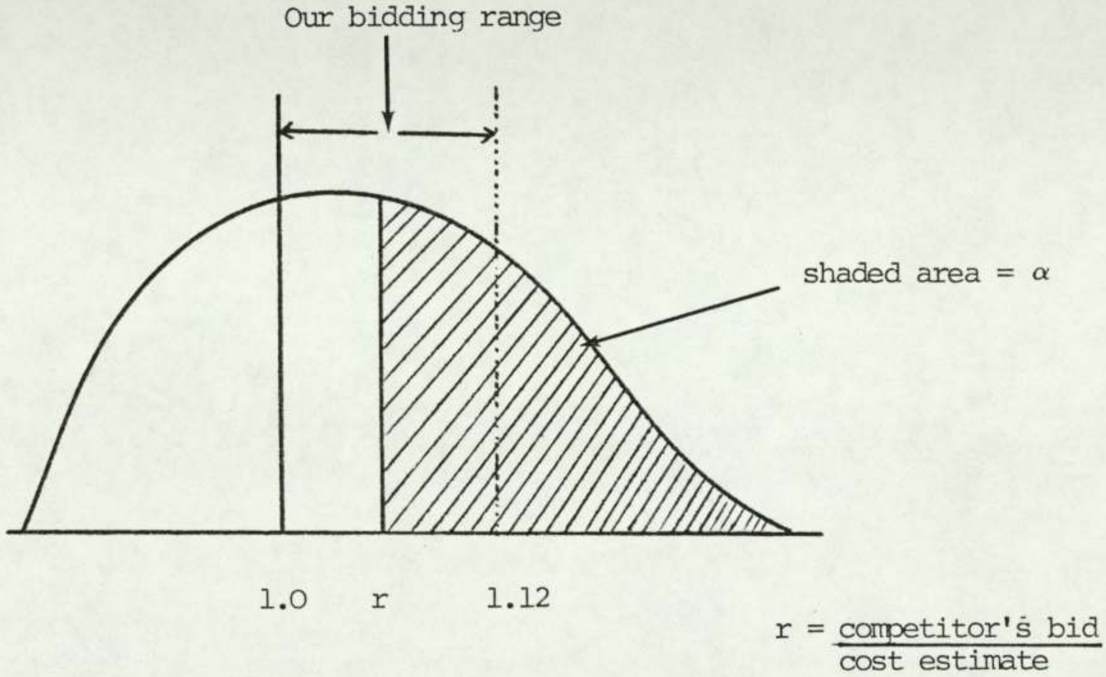


Figure (6.5) Annual profits in 10 years period for different mark-ups (BID20)

6.6.2 Validity of the Simulation Model BID20

The typical results obtained from the Friedman model which incorporates the estimating error has been shown in the previous section. However, the results obtained from this simulation model, are considered to be logically unsound for the following reasons. Consider the following bid/cost distribution for a typical competitor.



PDF of bid/cost ratio

Let C = our prime cost estimate for particular job (£),

A = true cost (£)

M = mark-up amount (£)

Now, for a particular job:-

$$\text{Our bid} = C + M$$

Let $r = \frac{C + M}{C} = 1 + M/C$

Probability of beating 1 competitor $= \alpha$

Probability of beating n competitor $= \alpha^n$

Therefore, the expected value is equal to:

$$\text{profit} * \text{probability of winning} = M * \alpha^{n}$$

However, this is not the true expected value since the mark-up (M) does not allow for an estimating error. Therefore, the true expected value is equal:

$$(M + C - A) * \alpha^{n}$$

Now, this is the basis of the simulation programme and, therefore, the following additional assumption will be made:

The data set which is used to construct f(r) includes all the random variables relating to both ´our´ and ´their´ bids. Based on this fact, it is assumed that it is possible for us to win with a large favourable estimating error (i.e. A = 90% * C). The above assumption seems to be in error in the cases of building contracts, where ´our´ true cost and ´their´ true cost are likely to differ by a small percentage and where ´their´ estimating error range is likely to be smaller than ´ours´.

For example, if the true cost of a particular job coming up for tender is £100,000 and ´our´ estimating error lies in the range of plus or minus 10% and ´theirs´ in the range of plus or minus 5%, and also assume that all bidders apply a 7% mark-up and our true cost = their true cost.

Now, the likely range of ´their´ cost estimate =

£100,000 plus or minus 5% = £95,000 -£105,000

the likely range of their bids =

(100,000 plus or minus 5%) * 1.07 = £101,650 - £<u>112350</u>

Similarly, the likely range of 'our' cost estimate =

£100,000 plus or minus 10% = £90,000 - £110,000

the likely range of our bids =

(100,000 plus or minus 10%) * 1.07 = £96,300 - £117,700

Thus, under the above conditions, we could not possibly win with a extreme negative estimating error. The only way it would be possible is if we reduced our mark-up to about 2%, i.e.

1.02 x 110000 = £112200

Having rejected the Friedman based model which incorporates the estimating error variable, it was then decided to apply further study to the "Estimating Error" model.

One drawback with the simple estimating error model is that the range of bid/cost ratios produced does not match those obtained in practice, although the range could be increased by extending the range of the estimating error probability density function by proposing a curtailed normal distribution, etc. Also, the range of bid/cost ratios further could be extended by proposing a PDF for mark-ups.

However, as a result of discussion with a number of estimators in the industry, it was decided that other factors, some of the most important of which have been mentioned earlier, affect the bid. One of the factors was the true cost.

Practically, the true cost of a job to one competitor is not likely to be the same as the true cost to another competitor for the same types of construction work.

It is therefore proposed to incorporate a "true cost ratio" factor within the estimating error model and to ′calibrate′ the model similarly by adjusting the range of the true cost-ratio probability density function to give a simulated range of bid/cost ratios which approximates to the observed data.

The following section explains the principle of this method. All random variables are assumed to follow uniform probability density functions, because their form can only be guessed at.

6.7 The Modified Estimating Error Model

In the previous section it was concluded that the simple Friedman model which incorporates the estimating error variable appears to be invalid. This is mainly due to the fact that the mark-up applied does not allow for any estimating error. Furthermore, the range of bid/cost ratio distribution produced by the simulation does not match those obtained in practice. Therefore, apart from the mark-up and estimating error variables, it is suggested that another random variable called "the true cost ratio" factor could affect the final outcome. This factor, as will be discussed later, could be used to adjust the range of the bid/cost ratio distribution such that this simulated range approximates to the observed data. Note that this model is partly "intuitive" and partly based on fact.

6.7.1 Example

The following assumptions will be made to explain this example:

1) Competitors´ mark-up is in range of 4-12% with a mean of 8%.

2) Estimating error (for us and them) is plus or minus 10% with a mean of zero.

3) True cost ratio factor: the range of this factor is not known. However, it is reasonable to assume a mean of one for this range.

It is important to mention that all these random variables are assumed to follow uniform probability density functions. It is also important to notice that the figures used for the first two variables have been obtained as a result of discussions with a number of well-known firms. Having made the above assumption, the typical distributions used for these variables are shown in Figure (6.6).

Now by using the three distributions shown in Figure (6.6), the following calculations will be performed for a particular job.

FOR OUR BID

Assume that our mark-up is fixed at 8% and that our estimate of the cost of performing the job is £100,000. Now we assume that RF (Random Fraction) to be used for our estimating error is 0.87. Hence, using Figure (6.6), the value of estimating error is:

$$\text{Error} = -10 + 0.87 \times 20 = +7.4\%$$

therefore, our true cost = 100,000 x (100 + 7.4/100) = £107,400.

$$\text{Our bid} = 100{,}000 \times 1.08 = £108{,}000$$

FOR THEIR BID

Here the sampling will be done for first competitor only. Assuming that RF to be used for competitor's mark-up is 0.25. Using Figure (6.6), the value of their mark-up is:

$$\text{Mak-up} = 4 + 0.25 \times 8 = 6\%$$

Similarly, the random fraction to be used for true cost ratio is assumed to be equal to 0.91 and RF for their estimating error is assumed to be 0.48. Hence, the values of true cost ratio and their estimating error are:

$$\text{True cost ratio} = 0.8 + 0.91 \times 0.4 = 1.164$$

$$\text{Their error} = -10 + 0.48 \times 20 = -0.04$$

Therefore, their true cost = our true cost x 1.164

$$= £107400 \times 1.164 = £125013$$

$$\text{their cost estimate} = £125013 \times \left(\frac{100}{.996}\right) = £125515$$

$$\text{their bid} = £125515 \times 1.06 = £133046$$

Now, using the above values, it is possible to determine the ratio of their bid to our cost estimate. This is equal to:

$$\text{Their bid/Our cost estimate} = \frac{133046}{100000} = 1.330$$

Similar attempts could be made in order to determine the extreme value of bid/cost ratio. For example, if our cost estimate is again equal to £100,000, then, for 10% estimating error our true cost is £110000. Now if our competitor's mark-up is 12%, the true cost ratio is 1.2 and their error is -10%, then, their true cost is equal to:

$$110000 \times 1.2 = £132000$$

their cost estimate = $132{,}000 \times \left(\frac{100}{100-10}\right) = £146{,}667$, and

$$\text{their bid} = 14556667 \times 1.12 = £164267$$

Therefore, the ratio of their bid to our estimated cost of a job is:

$$\frac{164267}{100000} = 1.64$$

On the other hand, by similar calculations it is possible to determine the lowest possible value of bid/cost ratio. This value is equal to 0.70. This means that the range of bid/cost ratio for this particular example will be 0.70 - 1.60.

It is mentioned before that by using the ′true cost ratio′ factor, it is possible to adjust the range of bid/cost ratio distribution. This has been demonstrated through the above examples.

6.7.2 Constructing a Bid/Cost Ratio Curve

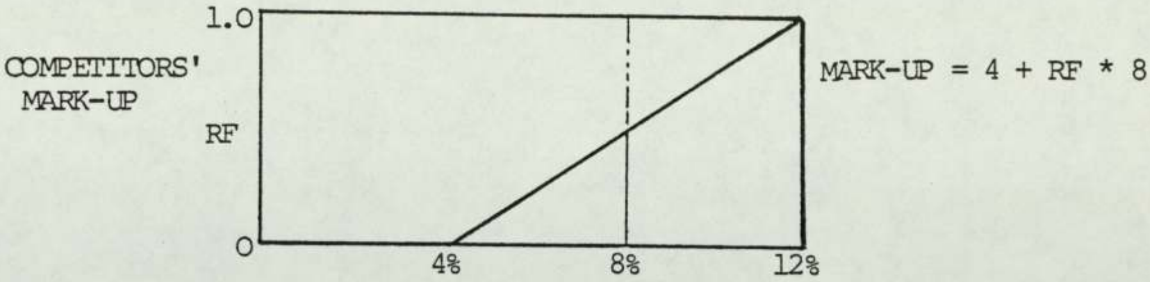
In the previous chapter the data belonging to three contracting firms have been analysed. It has been found that the range of bid/cost ratios is different for the different firms. For example, the range of bid/cost ratio for firm A was (0.7 - 1.6), whereas for firms B and C they were (0.9 - 1.4) and (0.5 - 1.8) respectively.

The range of values suggested that, apart from the mark-up and estimating error random variables, there is another major factor that may be contributing to this range. It is suggested in the previous section that this factor is ′true cost ratio′. The simple example which was mentioned earlier showed how this factor could affect the results. Now by using the three distributions shown in Figure (6.6), we can carry out the simulation for, say, 500 jobs. Having carried out the simulation it should then be possible to construct the bid/cost ratio curve and to compare this with an actual curve.

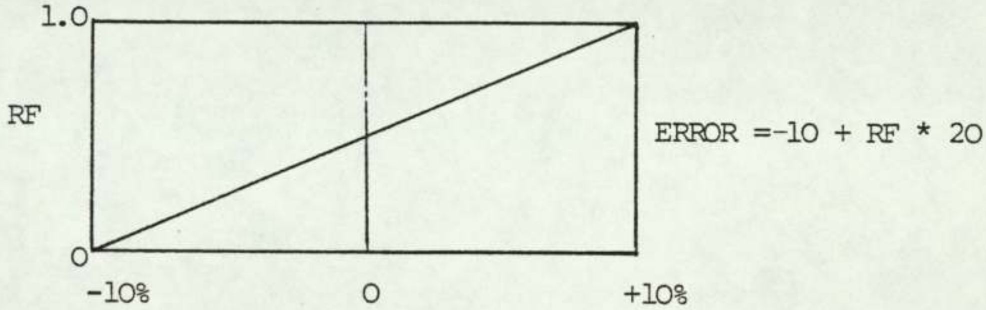
In order to get a good fit, or reasonable fit, the parameters of one or more of the basic distribution, shown in Figure (6.6), should be adjusted systematically. This then enables to produce a simulated range of bid/cost ratios to be produced which approximates to the observed data. Having emphasised the importance of the 'true cost ratio' factor, the two simulation models which incorporates these properties will be introduced in the next sections.

6.8 Modified Estimating Error Model BIDMOD9

In section (6.5) some of the important factors which affect the bidding strategy have been mentioned. Later, the Friedman simulation model, incorporating the estimating error, was mentioned. It was concluded that this model should be rejected due to some reasons which were explained in the previous section. It was then decided to introduce the 'true cost ratio' factor and an example has been given to show the affects of this factor on the results that could be obtained. Three distributions used for our competitors' mark-up, the estimating error (for us and our competitors), and true cost ratios have been shown. It was mentioned that by using these distributions it is possible to adjust the range of bid/cost ratios in order to obtain a reasonable fit to the bid/cost ratios that could be obtained in practice.



ESTIMATING ERROR (FOR US AND THEM)



TRUE COST-RATIO (THEIR TRUE COST/OUR TRUE COST)

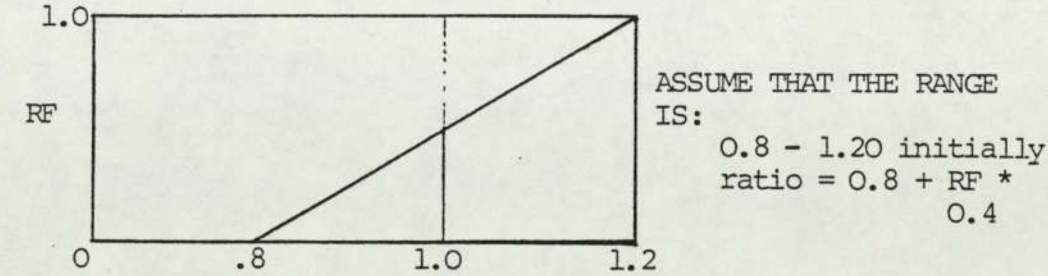


Fig. (6.6) Distributions describing the three random variables.

The computerised simulation model which will be described in the next section incorporates those factors affecting the bidding strategy and includes the properties of the previous section.

6.8.1 Example

Assumptions

1) Number of bidders randomly sampled from a discrete distribution in the range of 5-9 bidders which is a typical set of data for invited tenders. It was earlier emphasized that the range of 5-9 bidders which is assumed in this model has been confirmed after discussion with a number of contracting firms.

Figure (6.8) shows the typical distribution used for the number of bidders. It is important to mention that this distribution has been based upon the actual set of data taken from a contracting firm. The sets of data for number of bidders required to construct such a distribution could replace the distribution shown in Figure (6.8) for any contracting firm depending upon his own data set.

2) Job values randomly sampled from a log normal distribution for contract values in the range of £6K to £15000K.
Again the set of data being used to construct the job values distribution in this model approximate that taken from a contracting firm. It is possible to change the range of job values in the simulation programme according to the data set which can be obtained from any contracting firm. In other words, the job values range could be replaced once another firm decides to use the model and he can

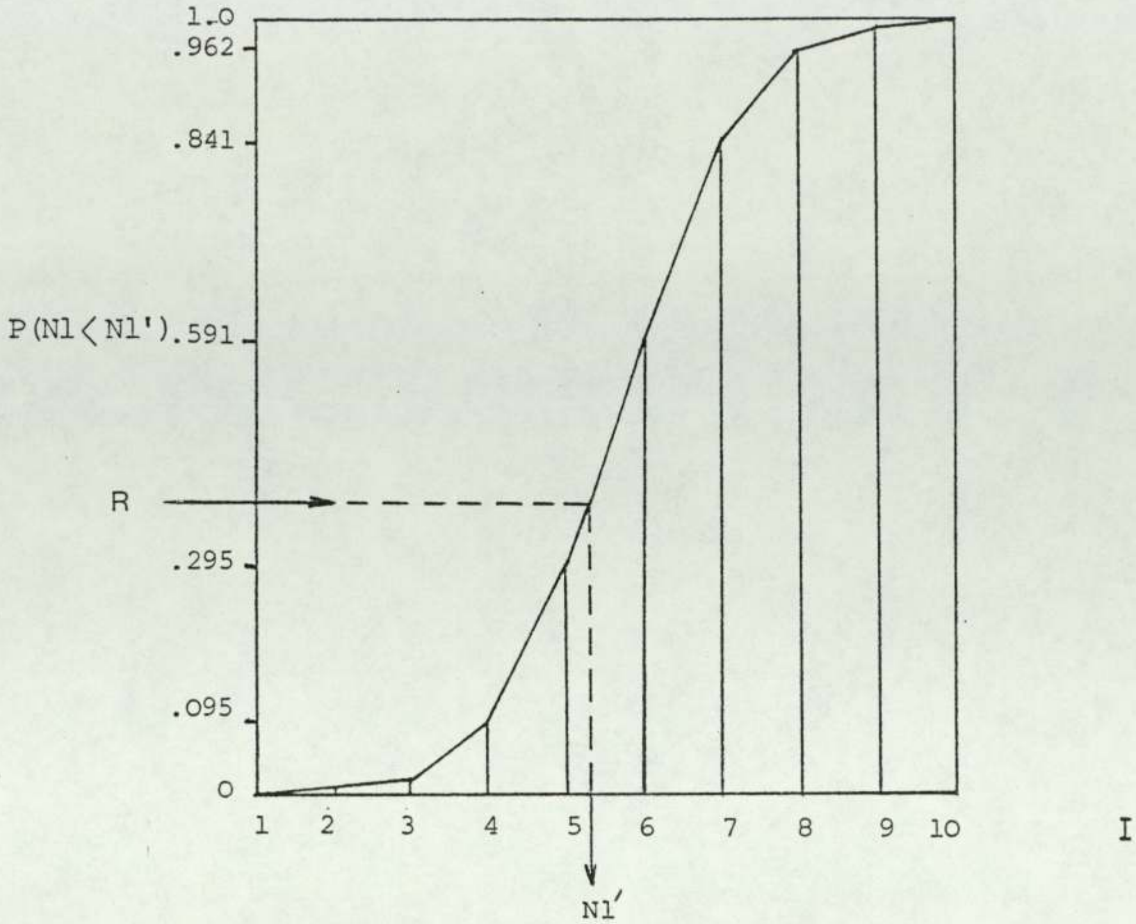


Figure (6.7) Distribution of Job Values.

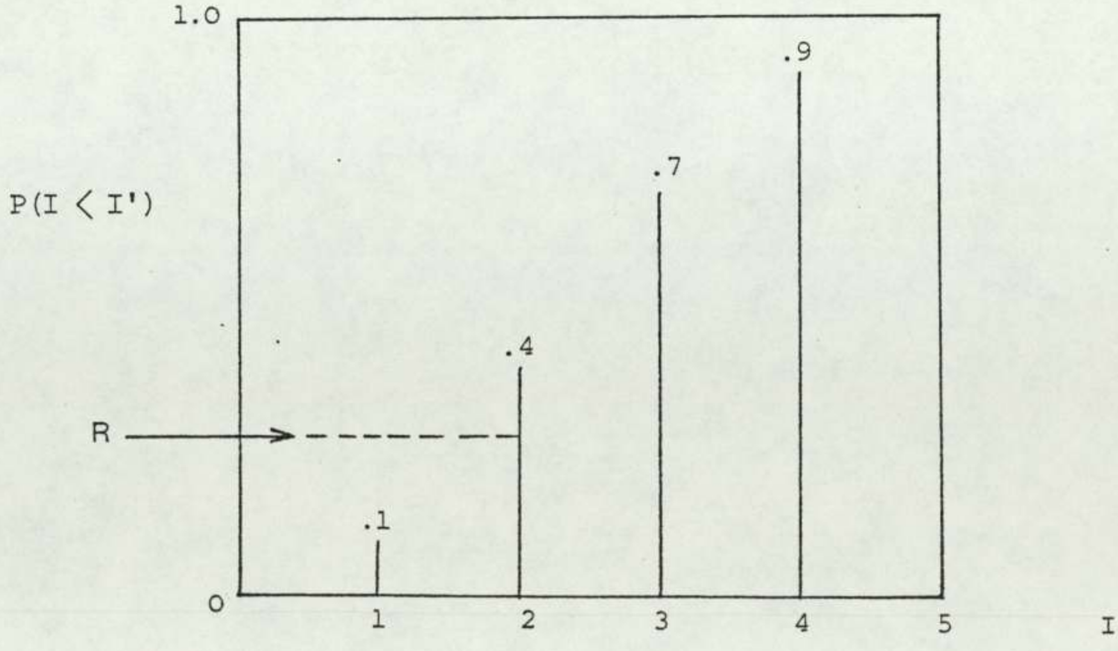


Figure (6.8) Distribution of Number of bidders.

simply substitute his own data set for this particular range. Figure (6.7) shows the distribution of job values as used in the model.

3) Estimating error randomly sampled from a uniform distribution. In this model the estimating error is assumned to vary, for all bidders, according to a uniform distribution whose mean is the true cost, to any particular bidder.
The type of distribution being used for our estimating error and our competitors´ estimating error is shown in Figure (6.9).

4) The value of our mark-up is fixed and inputted directly into the simulation model. In section 6.5 it was mentioned that this value could be controlled by us and the range of 1 to 16 percent has been suggested for our mark-up. In the simulation results, which will be discussed later, our mark-up values in the above range, have been used in order to demonstrate the usage of model.

5) It is assumed that our competitors´ mark-up varies uniformly over a defined area. As it was explained in the previous sections, a range of 4 to 12 percent mark-ups for our competitors may be a compromise. This range is again confirmed by a number of contracting firms during interviews with them.
The type of distribution used for our competitors´ mark-up is as shown in Figure (6.9).

6) This simulation model uses a range of true cost ratios which is assumed to vary according to a uniform distribution whose mean is one. It was earlier mentioned that the true cost ratio is uncontrollable by us to the extent that it is not predictable, unless the characteristics of all the jobs which are likely to come on the market

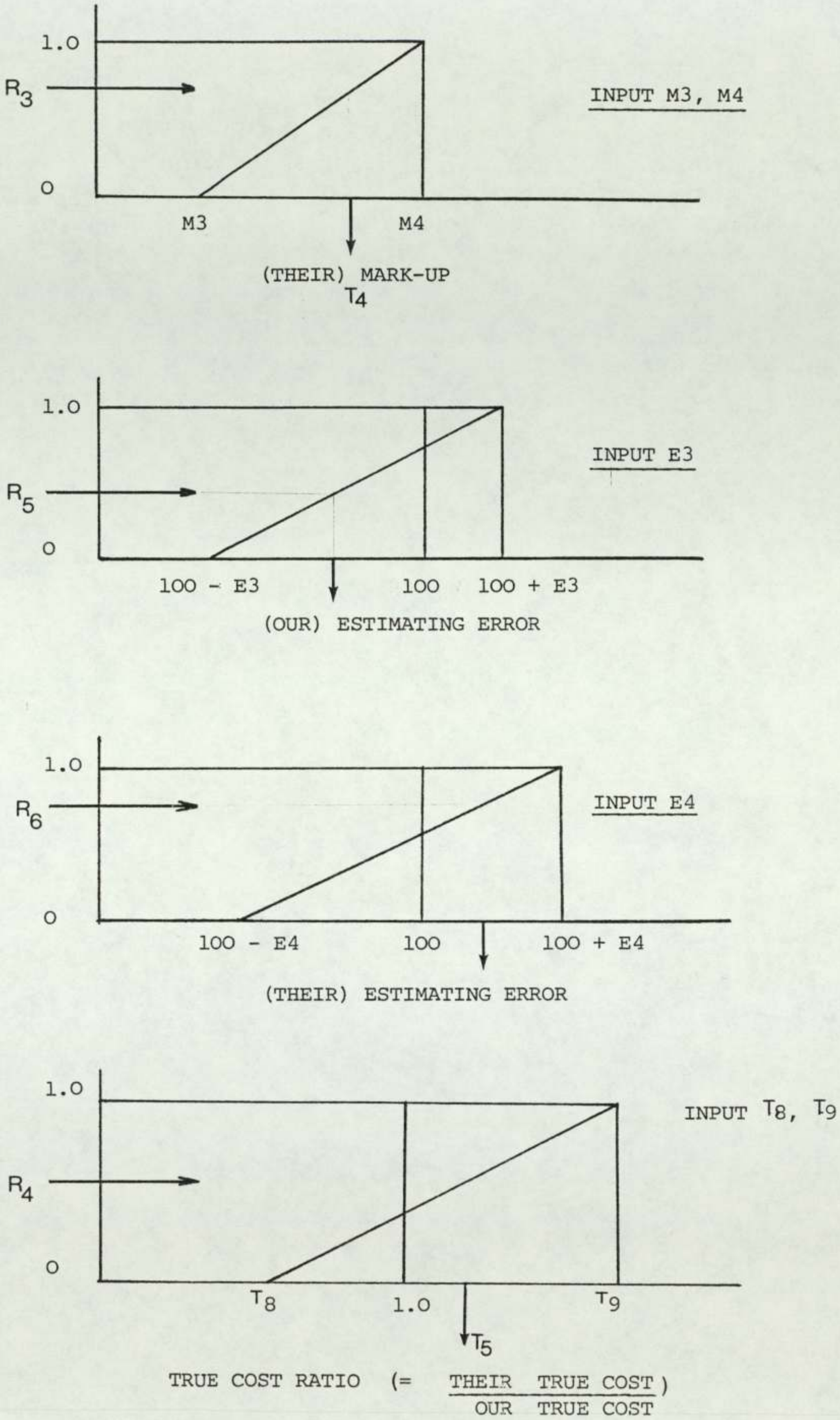


Figure (6.9) Distributions of our competitors' mark-up Our and Their estimating error and true cost ratio.

are known in advance. True cost ratio is intended to cover the many possibilities of advantage which any competitors may have over the other due to familiarity with local conditions, ownership of local tip or quarry, the rights to use a particular system of construction etc. The type of distribution used for true cost ratio (the ratio of 'their true cost' to 'our true cost') is assumed to follow the distribution that is shown in Figure (6.9).

Having made these assumptions this computerised simulation model can now be operated. The inputted information required for running the simulation program includes:

1. Total number of jobs to be simulated.
2. Number of jobs available to bid for per year.
3. Our percentage mark-up (fixed).
4. Their percentage mark-up (range).
5. Our estimating error (range).
6. Their estimating error (range).
7. True cost ratio (range).

The output information which could be obtained as a result of running the simulation programme is flexible and includes:

1. Details of each simulated job.
2. Details of each job which was won by us.
3. End of year summaries which includes number of wins, value of jobs won and profit which could be achieved.
4. The simulated bid/cost ratios are statistically analysed within the program . As a result of this the expected value (mean),

variance and distribution of frequencies of bid/cost ratios can be obtained and is outputted.

5. Finally, the end of simulation summaries is outputted which includes success ratio, total value of jobs won, and total profit.

In developing this simulation model, it is further assumed that in any simulated year, each job which is won is considered to be completed in that particular year and the profit is recorded for that year.

The fundamental components of BIDMOD9 include two sets of variables which are called 'Exogeneous Variables' and 'Endogenous Variables' and will be described below.

Exogeneous Variables

$V1_c$ = The value of the C^{th} job, C = 1,2 ..., C1

B_c = Number of bidders for Job C

$A1_c$ = Our estimated cost for Job C

$A2_c$ = Our bid for Job C

$A3_c$ = Our true cost for Job C

$T2_{B1,C}$ = Our competitors' bids $B1^{th}$ for Job C

Endogenous Variables

W = Total number of jobs won by us.

S - Total value of jobs won by us.

P = Total profit obtained from all jobs that have been won by us.

M9 = Mean of (Competitors' bid/our estimated cost) distribution.

D9 = Standard deviation of (competitors' bid/our estimated cost) distribution.

Having mentioned these variables, the listing of the simulation program and a sample of its output are given in Appendix (6).
In the following section, the simulation results of BIDMOD9 are presented and will be discussed.

6.8.2 Simulation Results of Bidding Model BIDMOD 9

Having made all the assumptions needed for developing BIDMOD9, the computerised simulation investigation will be conducted here to study the influence of the level of estimating accuracy and the mark-up policy on the results that could be obtained by using the concept of maximizing the expected profit. It is earlier emphasized that one of the most important objectives of bidding strategy is to maximise the expected profit that could be achieved as a result of applying the bidding strategy. A review of all the published works in the areas of bidding strategy which were explained in chapter three indicate that almost all of the researchers have adopted the objective of maximising the expected profit. It is also mentioned in the previous chapter that, due to the limited amount of information which was obtained from the three contracting firms, it was not possible to test most of the concepts of bidding strategy. Therefore, the simulation technique will be an ideal alternative to approach the bidding and test its concepts.
Here, the simulation model has been run for 500 jobs and it is assumed that the number of jobs to bid for each year is 50. The results of this simulation run are now presented in Tables (6.7), through (6.10). It is worth mentioning that all of these results have been obtained conditioned upon:

Table (6.7) Simulation Results of BIDMOD 9 where our estimating error and our competitors' estimating errors are 5% (True cost ratio .9 - 1.1)

OUR MARK-UP (%)	NO. OF WINS	SUCCESS RATIO (%)	VALUE OF JOBS WON (£)	PROFIT (£)	PERCENTAGE PROFIT
1	158	31.6	127943500	-2050804	-1.6
2	120	24	101872900	-729679	-0.72
3	95	19	72971751	6950	+0.01
4	74	14.8	52513105	571745	1.10
5	54	10.8	37295284	790142	2.16
6	40	8.0	30043995	868594	2.98
7	28	5.6	25542323	933711	3.79
8	21	4.2	22826410	1023170	4.69
9	12	2.4	14732589	798911	5.73
10	8	1.6	3209290	213147	7.11
11	6	1.2	2512373	180562	7.19
12	3	0.6	699869	45513	6.50

Table (6.8) Simulation results of BIDMOD 9 where our estimating error and our competitors' estimating errors are 10%
(True cost ratio .9 - 1.1)

OUR MARK-UP (%)	NO. JOBS WON	SUCCESS RATIO (%)	VALUE OF JOBS WON (£)	PROFIT (£)	PERCENTAGE PROFIT
2	125	25	111824280	-4433997	-3.97
3	100	20	88377656	-2711018	-3.07
4	93	18.6	83242659	-1898290	-2.28
5	77	15.4	73591080	-1104770	-1.50
6	67	13.4	54610679	- 337325	-0.62
7	54	10.8	48237591	- 85231	-0.18
8	40	8	38123892	333732	0.88
9	31	6.2	32680912	595815	1.82
10	26	5.2	30550973	785414	2.64
11	21	4.2	28571400	954612	3.46
12	14	2.8	24426221	931610	3.96
13	9	1.8	12872602	702955	5.78

Table (6.9) Simulation results of BIDMOD 9 where our estimating error is 5% and our competitors' estimating error is 10% (True cost ratio .9 - 1.1)

OUR MARK-UP (%)	NO. OF WINS	SUCCESS RATIO (%)	VALUE OF JOBS WON (£)	PROFIT (£)	PERCENTAGE PROFIT
1	111	22.2	94436754	-1275550	-1.35
2	89	17.8	86247958	- 256009	-0.30
3	75	15	58498159	308272	0.53
4	58	11.6	46879373	673445	1.46
5	48	9.6	39932941	852228	2.18
6	41	8.2	36850307	1031293	2.88
7	30	6.0	30660414	1044415	3.53
8	20	4.0	20558807	919499	4.68
9	14	2.8	15192047	839592	5.85
10	6	1.2	12148626	731472	6.02

Table (6.10) Simulation results of BIDMOD 9 where our estimating error is 10% and our competitors' estimating error is 5% (True cost ratio .9 - 1.1)

OUR MARK-UP (%)	NO. OF WINS	SUCCESS RATIO (%)	VALUE OF JOBS WON (£)	PROFIT (£)	PERCENTAGE PROFIT
2	176	35.2	135493380	-5555595	-4.10
3	148	29.6	120800860	-4058081	-3.36
4	125	25	113062770	-2912900	-2.58
5	104	20.8	96772312	-1740703	-1.80
6	80	16	74438774	- 975817	-1.31
7	64	12.8	60427147	- 275997	- .46
8	54	10.8	41425300	316395	-0.80
9	43	8.6	34747250	481152	1.40
10	32	6.4	25164524	706797	2.89
11	25	5.0	23296362	869045	3.87
12	20	4.0	22215749	1022741	4.83
13	9	1.8	8955444	434377	5.10

1) The range of our competitors' mark-ups is 4-12 percent

2) The estimating error for us and our competitors varies between five and ten percent, and

3) The range of true cost ratio is .9-1.1.

The relationship between the success ratio and the mark-up, whose determination is the central aim of all bidding models, can now be plotted for the various levels of estimation accuracy.
Figure (6.12) shows the relationship between the mark-up and the success ratio for different levels of estimation accuracy. It is assumed that the estimation error for us and our competitors varies between 5 and 10 percent. The results which are shown in Tables (6.7) through (6.10) have been obtained based upon 5% and 10% estimating accuracy for us and our competitors. Now, with reference to Figure (6.12), the success ratios, for different levels of estimation accuracy, varies between 40% and 0.6%. By comparing this range of values for success ratios with the one that was obtained from Friedman Simulation Model, it appeared that the range of success ratios for different values of our mark-up obtained from BIDMOD9 is much lower than Friedman Simulation Model. It will be seen later that the value of success ratios obtained from BIDMOD9 in fact lies between Friedman and Gates success ratios (see section 6.8.3).

Figure (6.13) illustrates the variation of mark-up versus percentage profit. As it can be seen, the break even mark-ups, in a situation where our estimating error remains at 5% and our competitors' estimating errors are 5% and 10%, are 3% and 2.3%.

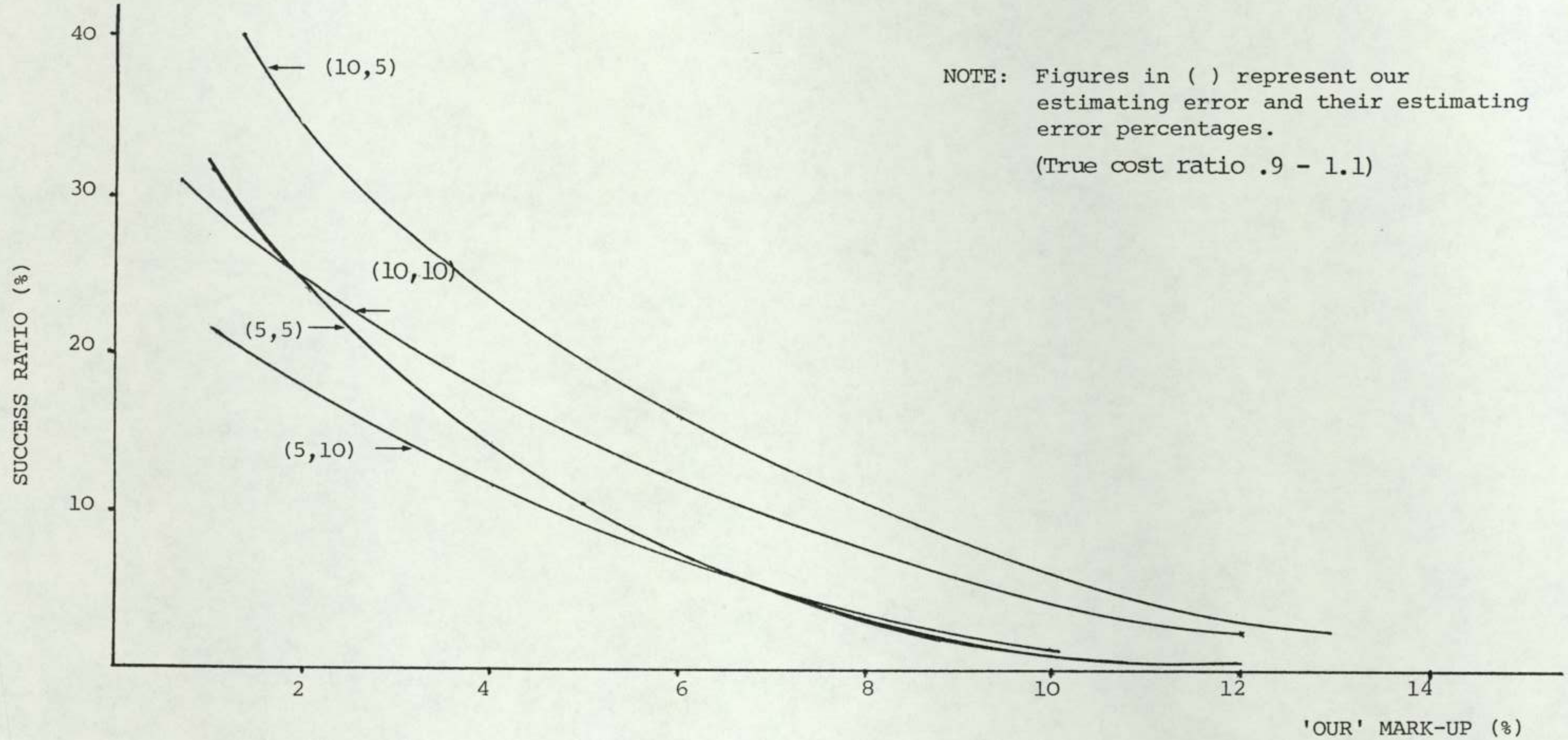
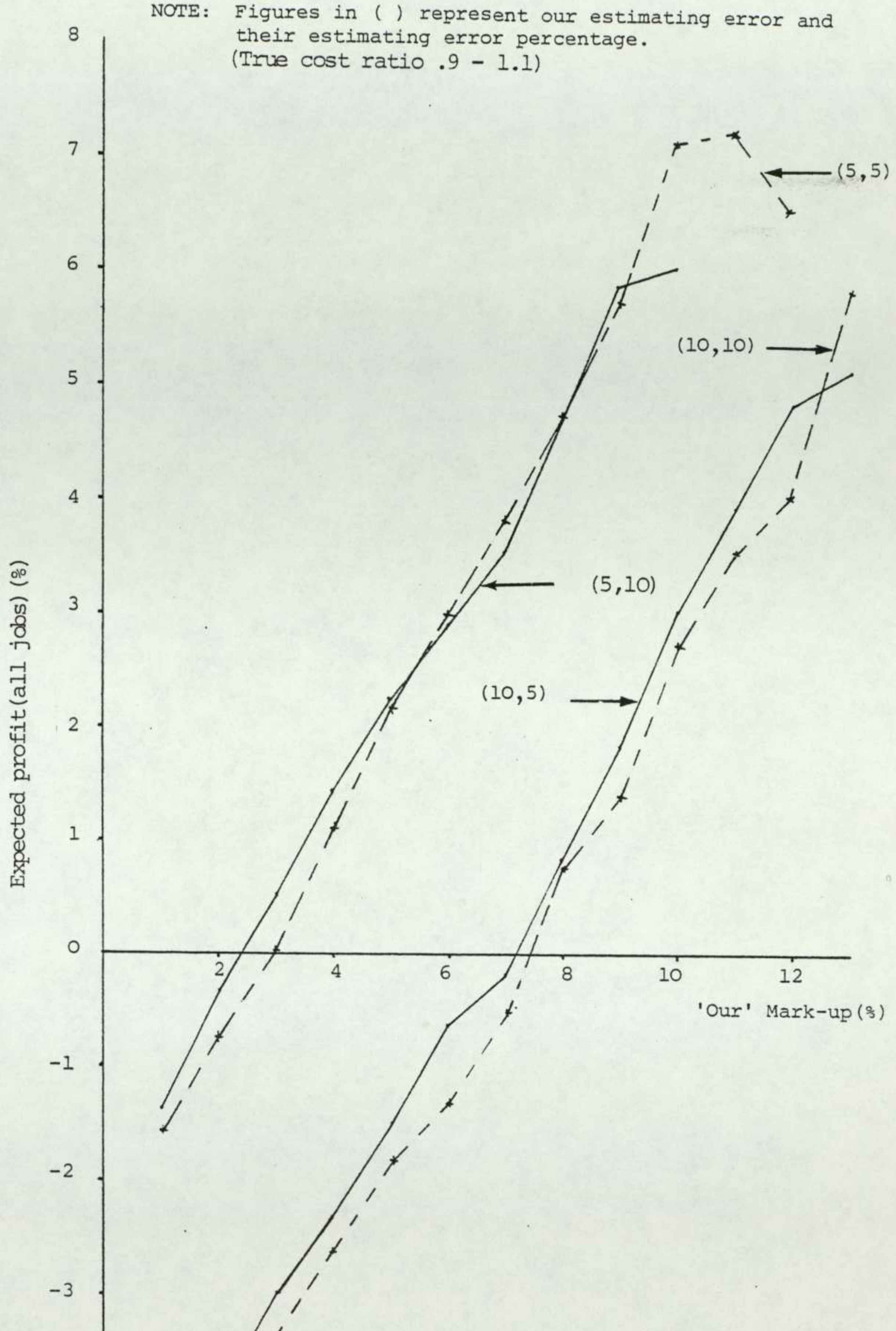


Figure (6.12) Variation of success ratio against mark-up for different levels of estimation accuracy. (BIDMOD 9)



Figure(6.13) Variation of expected profit(all jobs)(%) against mark-up for different levels of estimation accuracy (BIDMOD9)

In other words, by reducing our competitors' estimating error from 10% to 5%, the break even mark-up will be increased. Similarly, if our estimating error remains at 10%, by reducing our competitors' mark-ups from 10% to 5%, the break even mark-up will increase from 7.1% to 7.3%. It is further seen that if our competitors' estimating error remains constant, say at 10%, by increasing our estimating error from 5% to 10%, the break even mark-up will be increased by about 5%. Similarly, if our competitors' estimating error remains at 5%, by improving (reducing) our estimating error from 10% to 5%, the break even mark-up will be reduced about 4%. These observations about the break even mark-up could well match with all the concepts behind the break even mark-up. This is due to the fact that as the least bid is the winner, the contractor with the highest estimating error is generally awarded the contract and will end up with a profit less than the one he intended. Basically, the break even mark-up depends on two factors :

1) the level of estimation accuracy, and

2) the number of competitors.

As it was mentioned before, these factors were among those assumptions that have been made during the development of BIDMOD9 and the results of break-even mark-ups have illustrated the effects of these factors. The concept of break-even mark-up has been brought up by a number of researchers. Among those people were, Whittaker (37) and Fine (39), whose works were discussed in chapter three. It is important to mention that both Fine and Whittaker's estimation of the break even mark-up are suitable for models which consider the estimation accuracy as the major factor in determining the probability of winning.

Now, in order to study the effects of changes in estimating error on gross profit, the results of Tables (6.7) to (6.10) were used to draw Figures (6.14) and (6.15). With reference to these figures, it can be seen that if 'our' estimating procedures remain constant and 'their' estimating error is substantially reduced from 10% to 5%, for example, then assuming that we were bidding at optimum mark-up originally, an increase of 1% only is sufficient to maintain a profit levels at approximately the same level. However, a 5% improvement in our own estimating error from 10% to 5%, with no changes in their estimating error, would require a substantial reduction in our mark-up in order to maintain the same profit level, i.e. a reduction of 4%. The corollary is that: changes in ones own estimating practice which aim to improve (reduce) estimating error should proceed in carefully controlled stages in order that its effect on profit should be carefully monitored.

Figures (6.14) and (6.15) also indicated that the profit curves, because of low success ratios at an end, are likely to be distorted by the job-value distribution. The variations of profit which have been shown in the above figures also suggest that mark-up plus or minus 1% either side of optimum will reduce total profit by above 5% and beyond this range the profits drop dramatically. Finally, the variations of mark-ups versus the value of jobs won are shown in Figure (6.16) for different levels of estimating accuracy. With reference to Figure (6.16), it can be seen that, if 'our' competitors' estimating error remains constant, at say 5%, by improving (reducing) 'our' estimating error from 10% to 5% the cumulative value of jobs won will be dropped by about £34M when our mark-up is 2%. This is obviously true because

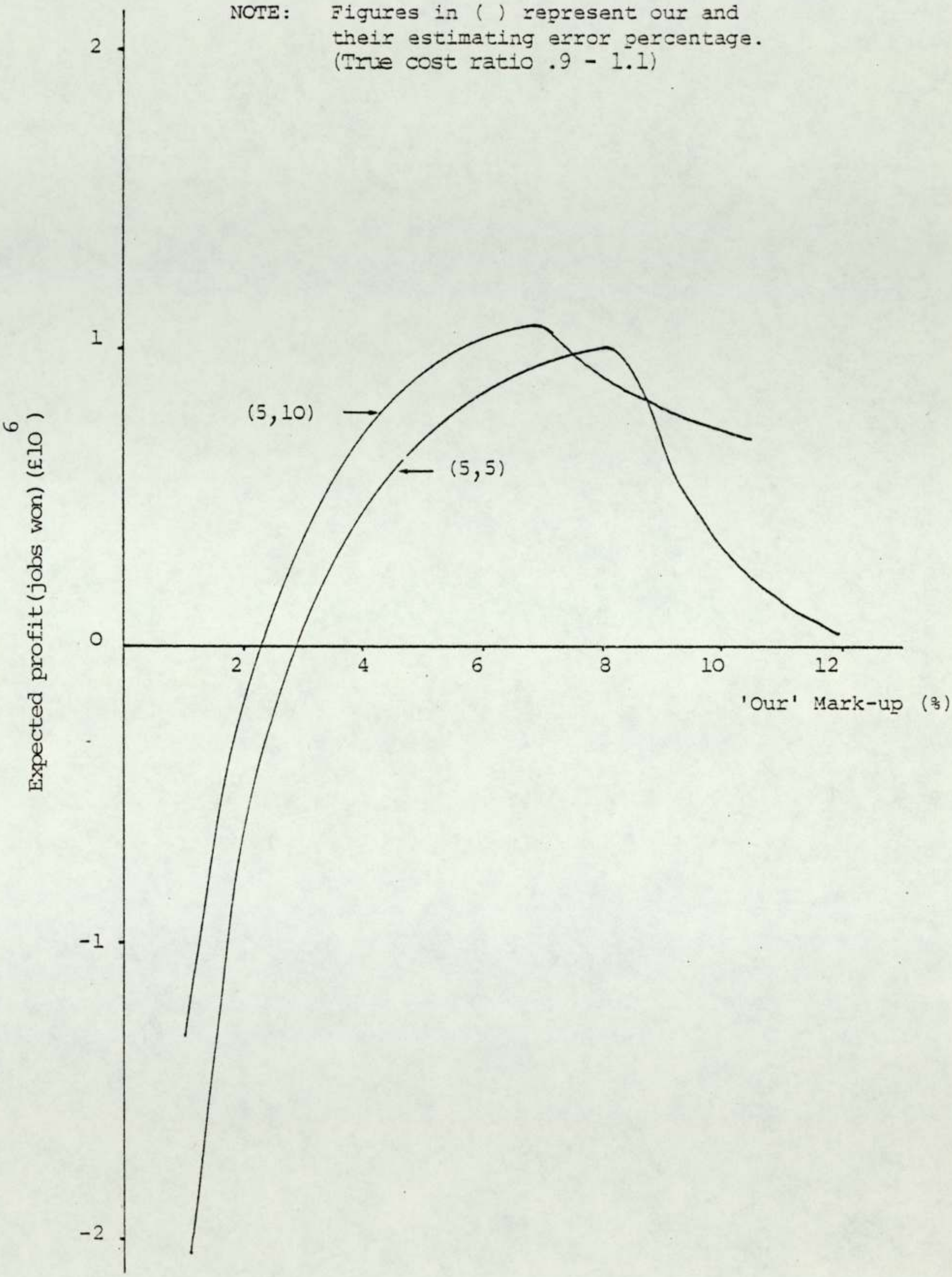


Figure (6.14) Variation of expected profit (jobs won) against mark-up for different levels of estimation accuracy (BIDMOD9)

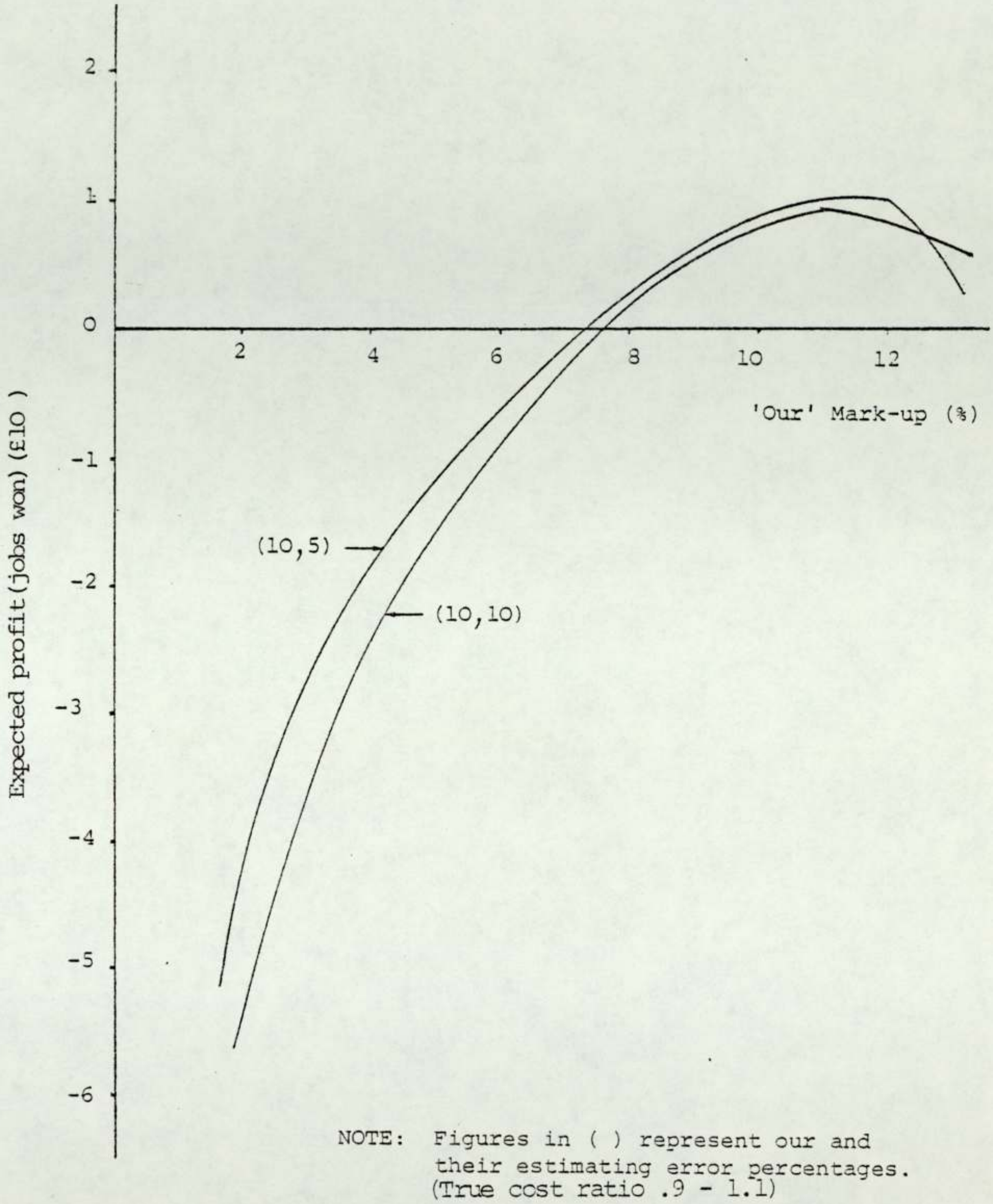


Figure (6.15) Variation of expected profit (jobs won) against mark-up for different levels of estimation accuracy (BIDMOD9)

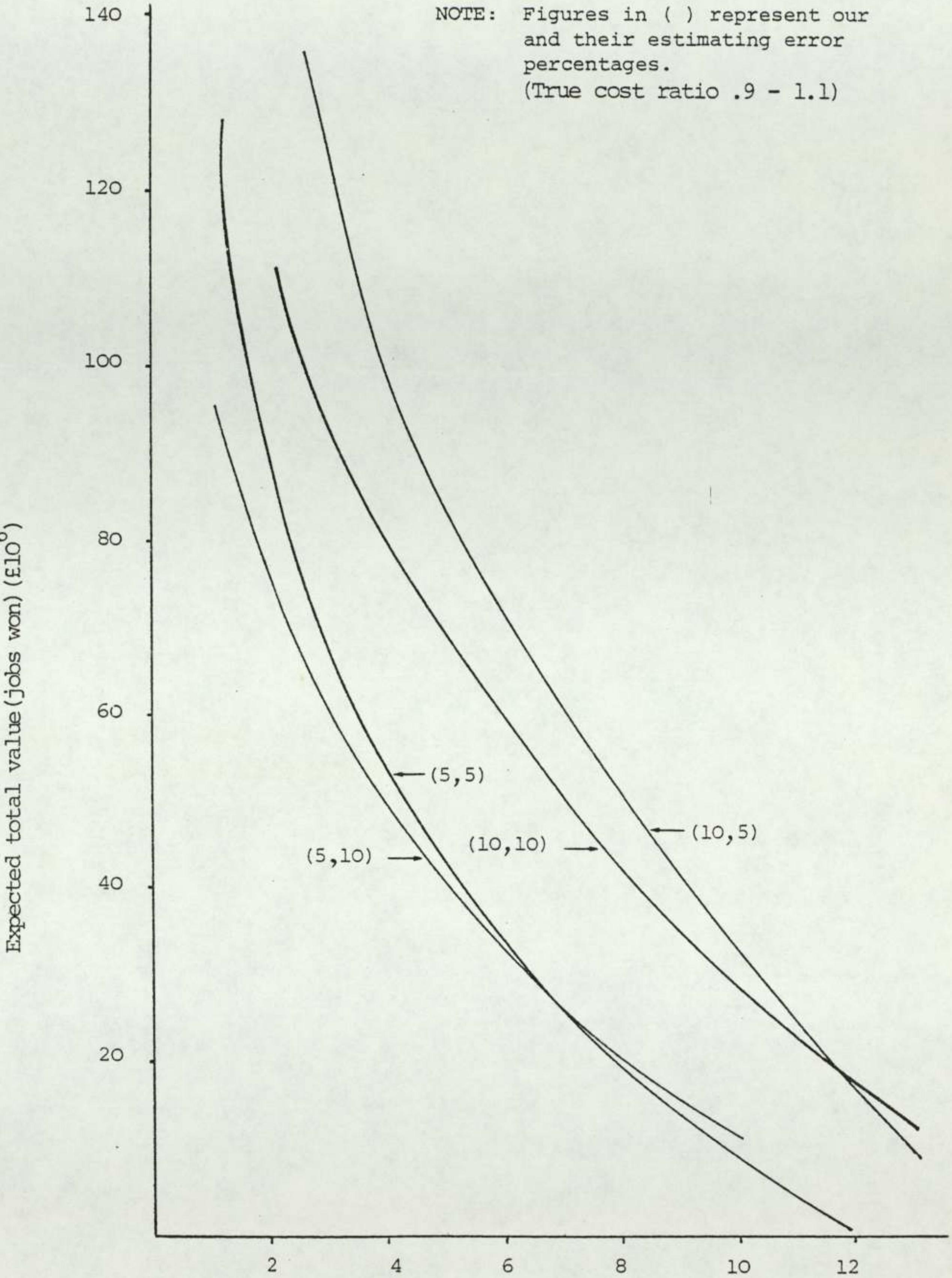


Figure (6.16) Variation of expected total values against mark-up for different levels of estimation accuracy (BIDMOD 9) of the fact that the higher our estimating error, the higher our chances are of winning more jobs, and consequently the bigger our success ratio. It is important to note that the results of cumulative values obtained from BIDMOD9 and being presented by Figure (6.16), support the results of success ratio which have been shown earlier in Figure (6.12). This is because the more jobs to be won, the higher the success ratio is and therefore the bigger is the cumulative value of jobs won.

As it was mentioned before, the results of BIDMOD9 which were presented in Table (6.7) to (6.10) apply to particular values of the true cost ratio in the range .9-1.1 and to 'our' competitors' mark-up range of 4% - 12%. Figure (6.12) to (6.16) showed these results for different levels of estimation accuracy. Now in order to illustrate the effect of true cost ratio on the results which could be obtained, the simulation model BIDMOD9 has been run for 500 jobs and it is assumed that all the assumptions which have been made before are to be applied except that the true cost ratio range is now .8-1.2. The results of these investigations, for different levels of estimation accuracy, are presented in Tables (6.11) through (6.14).

Again, the relationship between the success ratio and the mark-up can be obtained. Figure (6.17) shows such a relationship for different levels of estimation accuracy.

Now with reference to Figure (6.17), it can be seen that the value of the success ratios ranges between 11% and 0.6%. Comparing these results with the early results of BIDMOD9, where the true cost ratio range was .9 - 1.1, it is apparent that the values of success ratio

Table (6.11) Simulation results of BIDMOD 9 where our estimating and our competitors' estimating errors are 5% (True cost ratio 0.8 - 1.2)

OUR MARK-UP (%)	NO. OF WINS	SUCCESS RATIO (%)	VALUE OF JOBS WON (£)	PROFIT (£)	PERCENTAGE PROFIT
1	43	8.6	39350007	-241678	- .61
2	32	6.4	25719400	233942	.91
3	25	5	14698503	67022	.46
4	21	4.2	13682099	206593	1.51
5	16	3.2	11623837	239261	2.06
6	12	2.4	7084331	232061	3.28
7	10	2.0	6487438	278848	4.30
8	9	1.8	5964525	312566	5.24
9	8	1.6	5819753	367794	6.11
10	6	1.2	2208116	152393	6.90
11	5	1.0	1968549	148083	7.52

Table (6.12) Simulation results of BIDMOD 9 where our estimating and our competitors' estimating errors are 10%
(True cost ratio 0.8 - 1.2)

OUR MARK-UP (%)	NO. OF WINS	SUCCESS RATIO (%)	VALUE OF JOBS WON (£)	PROFIT (£)	PERCENTAGE PROFIT
3	47	9.4	32147657	-922692	-2.87
4	37	7.4	28533924	-699553	-2.14
5	33	6.6	26776560	-255881	- .96
6	26	5.2	24968701	30184	.12
7	23	4.6	24440384	234669	.96
8	17	3.4	14077367	224513	1.59
9	15	3	12407134	216746	1.75
10	13	2.6	9928478	278950	2.81
11	11	2.2	9620944	357735	3.72
12	8	1.6	8842338	405415	4.58
13	7	1.4	6520910	373538	5.73
14	5	1.0	1749314	127795	7.31

Table (6.13) Simulation results of BIDMOD 9 where our estimating error is 5% and our competitors' estimating error is 10% (True cost ratio 0.8 - 1.2)

OUR MARK-UP (%)	NO. OF WINS	SUCCESS RATIO (%)	VALUE OF JOBS WON (£)	PROFIT (£)	PERCENTAGE PROFIT
1	45	9	38597039	-215176	- .56
2	35	7	33554912	142564	.42
3	33	6.6	32117956	446904	1.39
4	26	5.2	24113654	283206	1.17
5	23	4.6	18785379	369005	2.20
6	16	3.2	17861981	715018	4.00
7	14	2.8	12437339	409227	3.92
8	9	1.8	11670011	625569	5.36
9	8	1.6	7806384	457992	5.87
10	5	1	7424465	475249	6.40
11	6	1.2	2228189	172466	7.74
12	3	.6	3829863	270143	7.05

Table (6.14) Simulation results of BIDMOD 9 where our estimating error is 10% and our competitors' estimating error is 5% (True cost ratio 0.8 - 1.2)

OUR MARK-UP (%)	NO. OF WINS	SUCCESS RATIO (%)	VALUE OF JOBS WON (£)	PROFIT (£)	PERCENTAGE PROFIT
2	52	10.4	43343941	-1662531	-3.84
3	42	8.4	28484345	- 676107	-2.37
4	34	6.8	26072931	- 324077	-1.24
5	31	6.2	21422068	71117	.33
6	24	4.8	20447834	288864	1.41
7	19	3.8	19155889	491234	2.56
8	17	3.4	16480473	538986	3.27
9	10	2	7461986	151578	2.02
10	8	1.6	7530445	219037	2.91
11	6	1.2	6969298	259633	3.73
12	5	1.0	6965337	319856	4.59
13	4	.8	6106418	246127	5.67

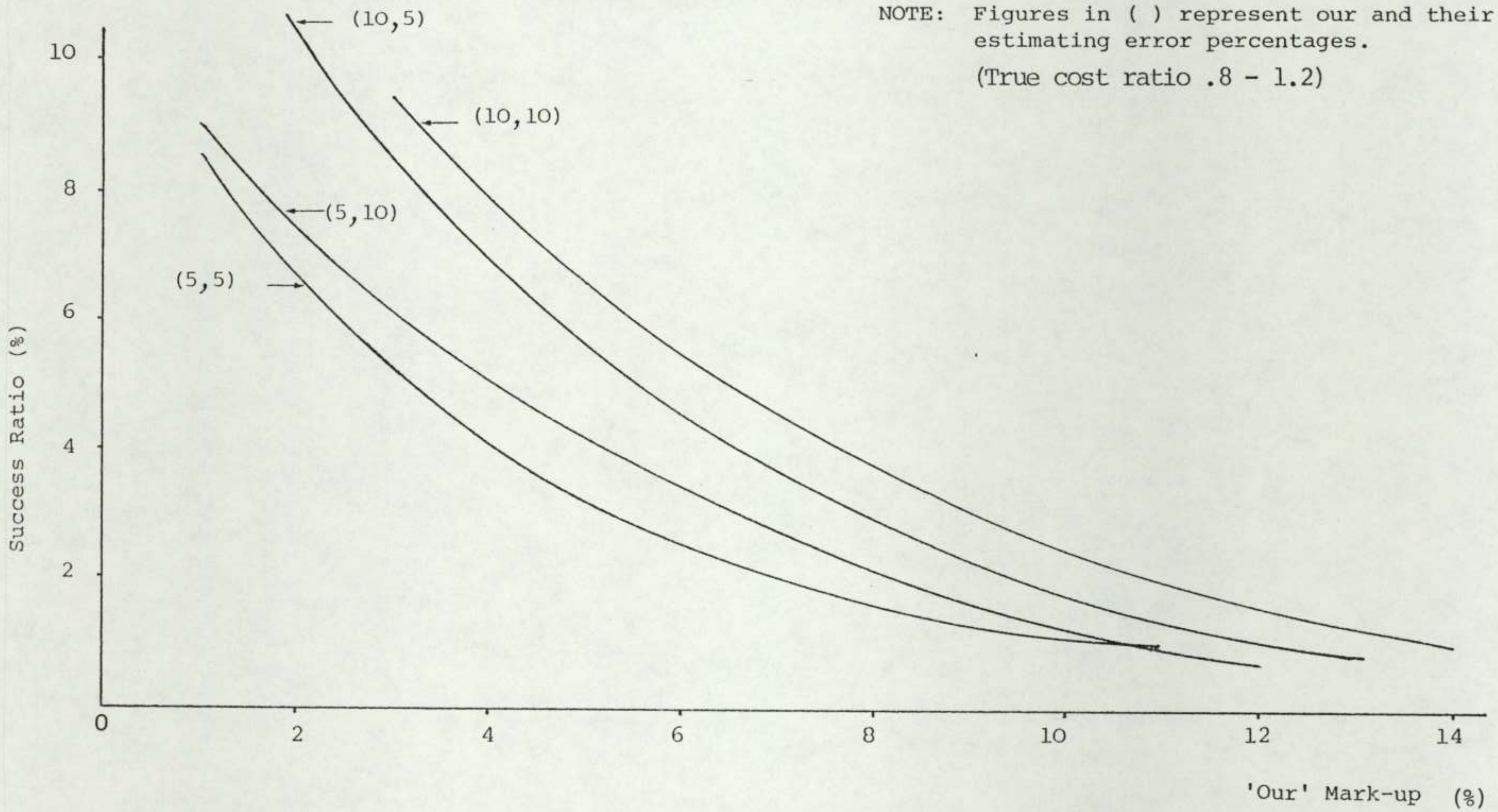


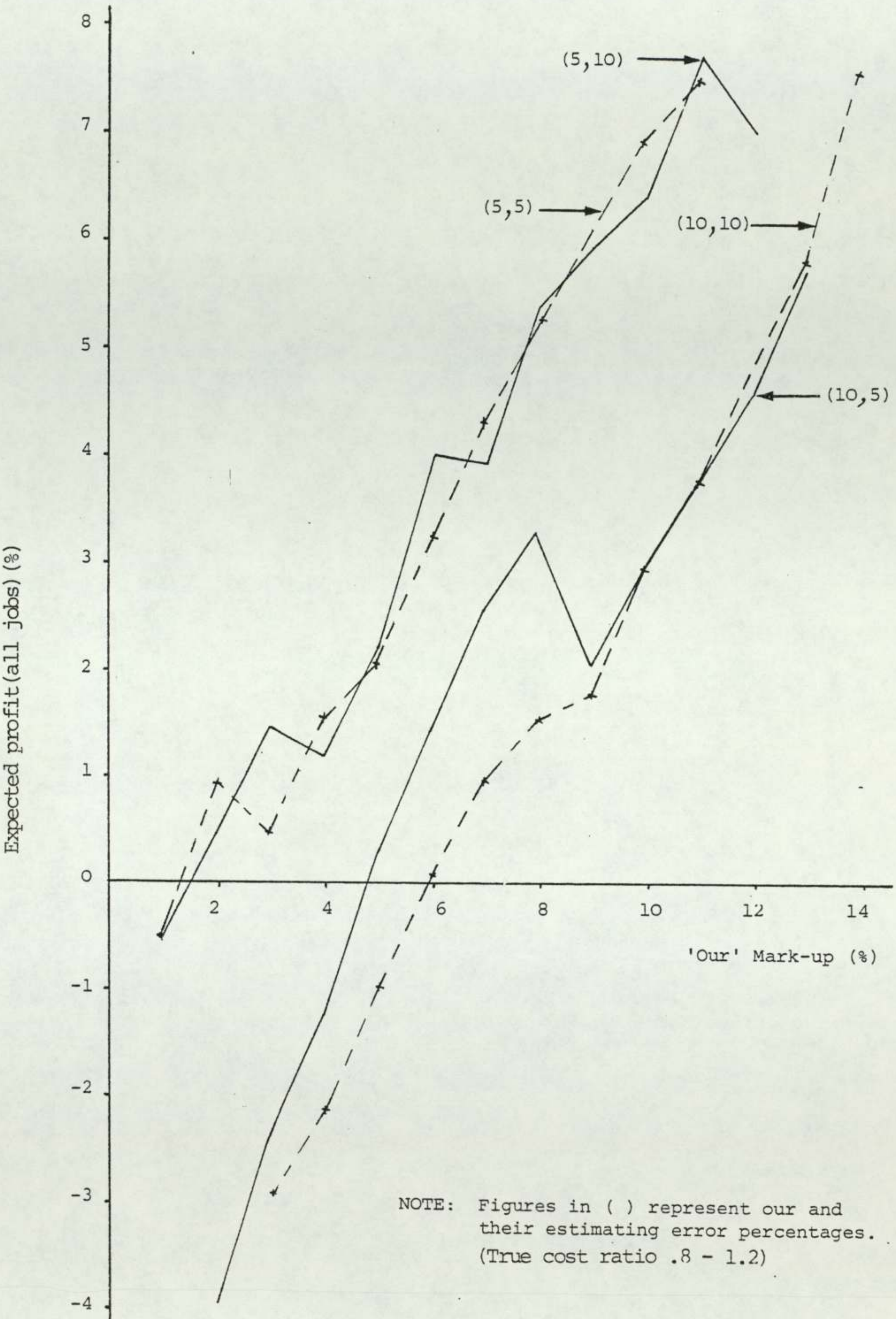
Figure (6.17) Variation of success ratios against mark-up for different levels of estimation accuracy. (BIDMOD 9) have been reduced as a result of increasing the range of true cost.

These observations indicate that an increase in the true cost ratio from .9-1.1 to .8-1.2 effectively reduces the break-even mark-up by about 2%, i.e., a smaller portion of the total number of jobs won is attributed to estimating error.

The variations of mark-ups versus the job values are also shown in Figure (6.21). Again, it can be seen that the cumulative value of jobs won, for different levels of estimation accuracy, is considerably lower than before. This indicates that under the same conditions the value of jobs won will be reduced as a result of increasing the range of true cost ratio from .9 - 1.1 to .8 - 1.2. This obviously confirms the reduction of success ratios since, the lower the success ratios, the lower the value of jobs won will be.

The relationship between the mark-up and the percentage profit can be obtained as before. This is shown by Figure (6.18) and from this figure it will be seen that if 'our' competitors' estimating error remains constant, say at 10%, by improving (reducing) our estimating error from 10% to 5%, the break even mark-up will be fall by about 4.6%.

Finally, Figures (6.19) and (6.20) demonstrate the effects of changes in estimating error on gross profit. From these figures it can be seen that, if 'our' estimating procedures remain constant and 'their' estimating error is substantially reduced from 10% to 5% it would require a substantial reduction in our mark-up in order to maintain the profit at nearly the same level. On the other hand, a 5% improvement in our estimating error from 10% to 5%, for example, with no changes in their estimating error will produce lower value of



Figure(6.18) Variation of expected profit(all jobs)(%) against mark-up for different levels of estimation accuracy (BIDMOD9)

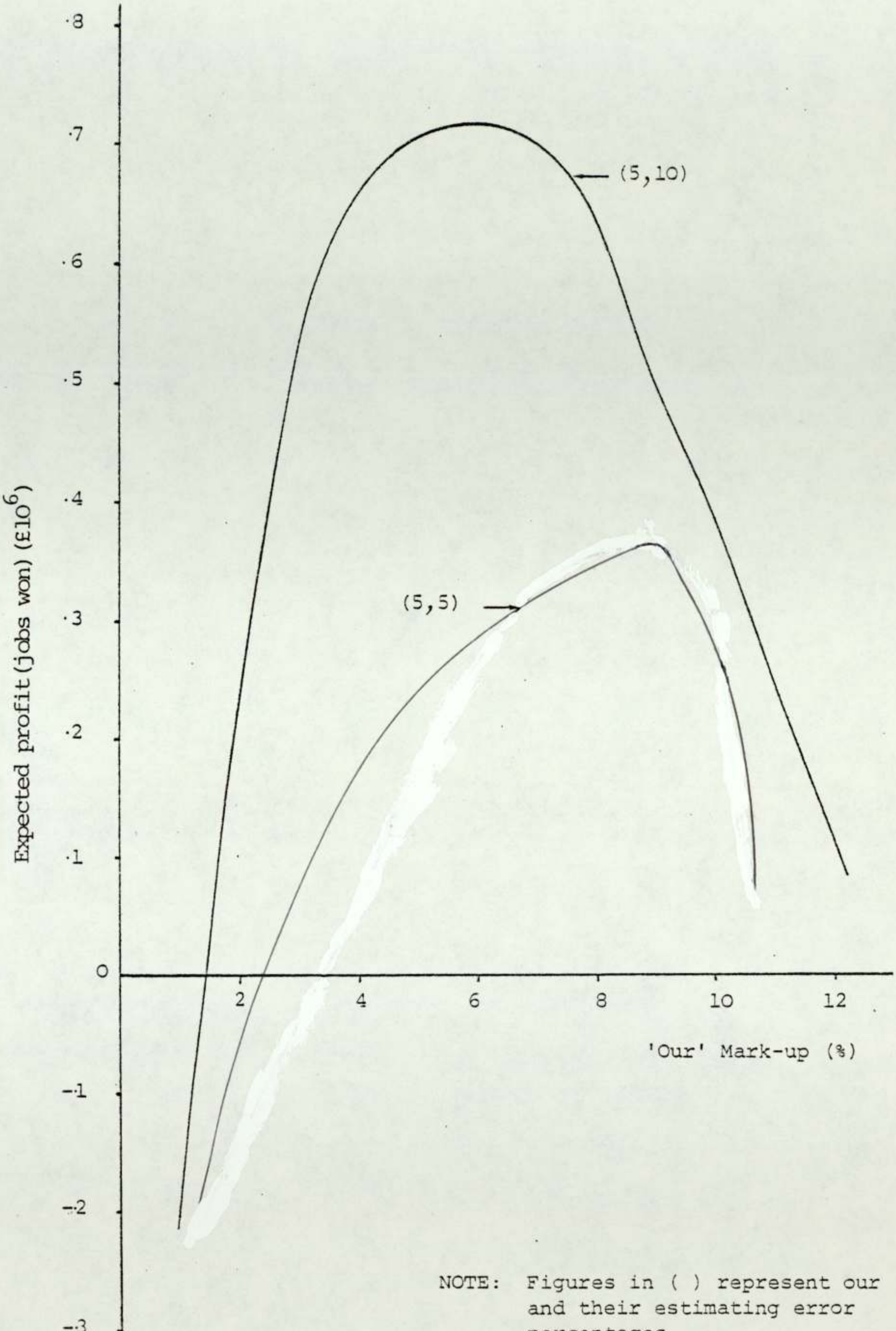
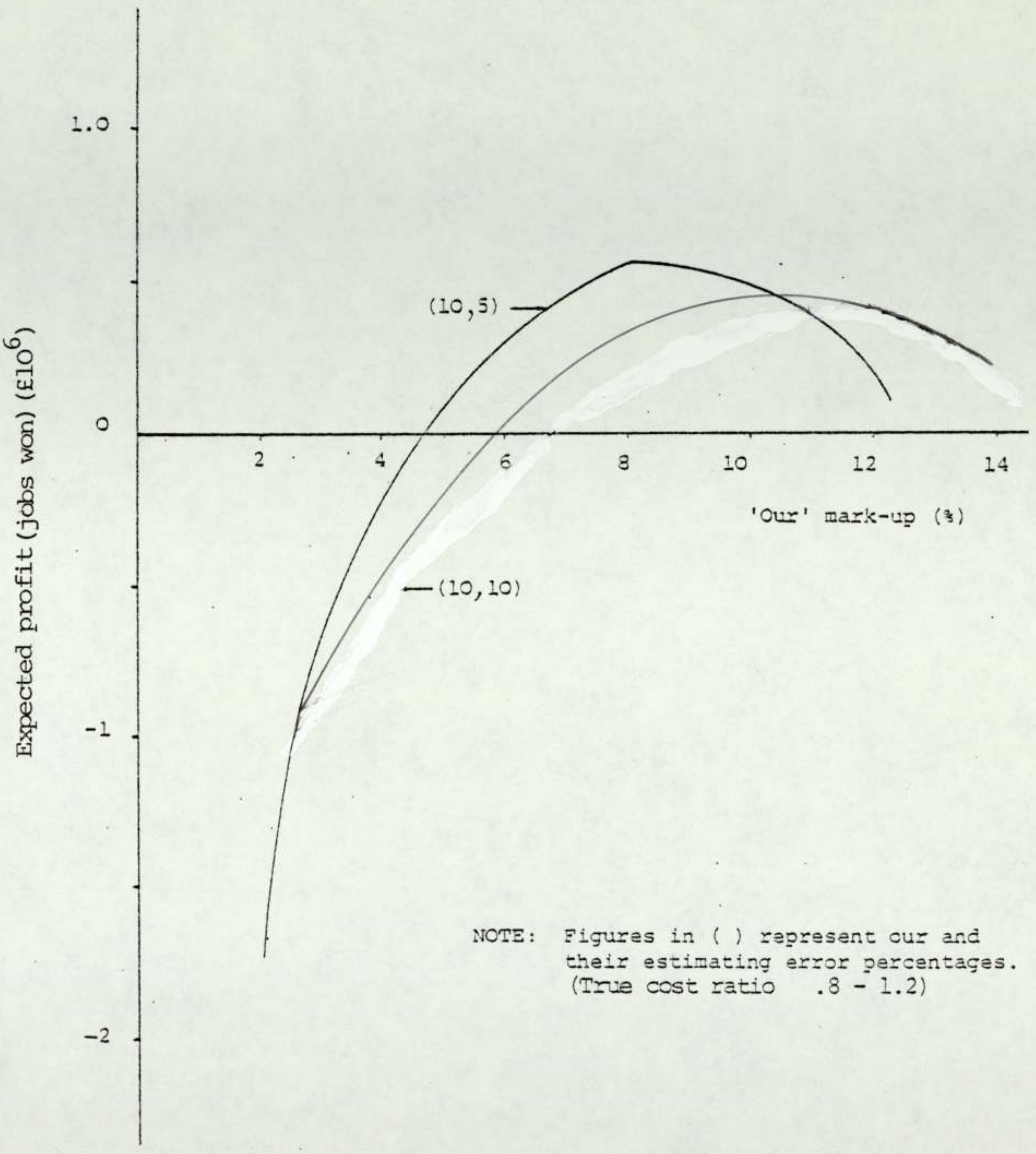
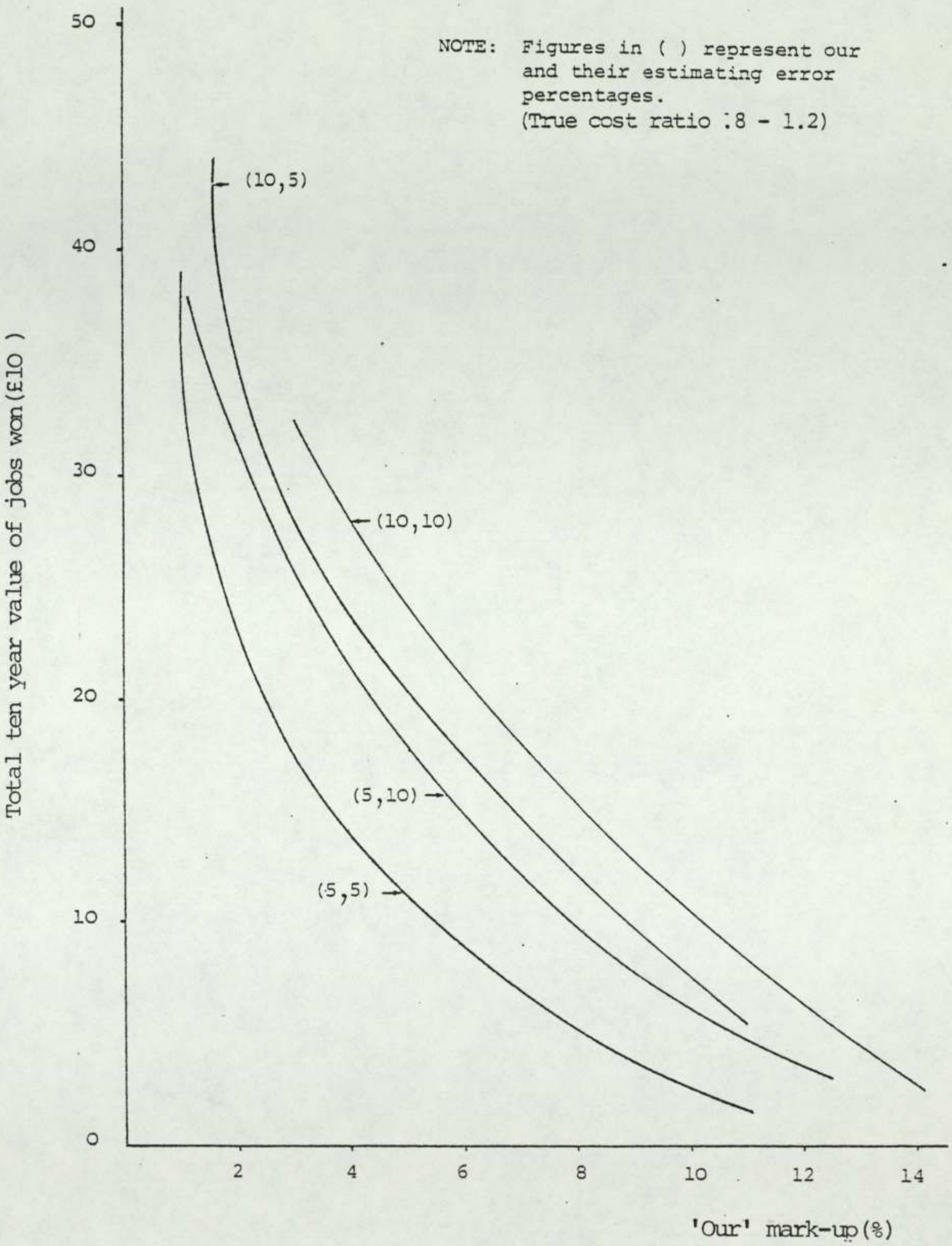


Figure (6.19) Expected profit (jobs won) against mark-up for different levels of estimation accuracy (BIDMOD9)



Figure(6.20) Expected profit(jobs won) agianst mark-up for different levels of estimation accuracy (BIDMOD9)



Figure(6.21) Total ten year job values against mark-up for different levels of estimation accuracy (BIDMOD9) profit when the mark-up is increased by 1% (assuming that we were bidding at optimum mark-up originally). These observations again indicate that any changes in ones own estimating practice should proceed in carefully controlled stages so that its effect on profit to be obtained can be carefully monitored.

Having discussed all of these important relationships from the cases when the range of true cost ratios are .9 - 1.1 and .8 - 1.2, in the next section the effect of this ratio on the distribution of bid/cost ratios that could be obtained through BIDMOD9 will be discussed.

6.8.3 The Effect of the True Cost Ratio on the Distribution of Bid/Cost Ratio

As it was mentioned before, one of the important feature of BIDMOD9 is that this simulation model produces simulated bid/cost ratios, which are statistically analysed within the program , and the frequencies of this distribution can be outputted.

It is also discussed that the use of ´true cost ratio´ factor enables us to adjust the model in a way that the simulated range of bid/cost ratio approximates to the observed data. In fact, as it was explained in section (6.6.4), it is possible to construct the bid/cost ratio curve and compare it with an actual one by using the three distributions shown in Figure (6.6). It is further mentioned that in order to get a reasonable fit the parameters of one or more of the basic distributions, being illustrated by Figure (6.6), should be adjusted systematically so that the simulated range of bid/cost ratio could be approximated to the observed data.

Although it may not be necessary to adjust all of the curves since the distribution of number of bidders is known fairly accurately. The range of mark-ups can also be determined fairly reliably. Fine suggested that estimating error is about ±10% although no particular distribution shape is suggested. Hence the most uncertainty rests on the true cost ratio range.

Having calibrated these important distributions within the BIDMOD9, an attempt is made to demonstrate the effect of true cost ratio on the distribution of bid/cost ratio in this section. In order to show this likely effect, BIDMOD9 has been run for 500 jobs. It is also assumed that the estimating errors for us and them remain at 10% and our optimum mark-ups are 10% and 12% for the cases where the true cost ratio ranges are .9 - 1.1 and .8 - 1.2 respectively. The distribution of simulated bid/cost ratios for these two cases can now be plotted. Figures (6.22) and (6.23) show these distributions. As it can be seen, the ranges of bid/cost ratio are .8 - 1.5 and .7 - 1.6 for true cost ratio ranges of .9 - 1.1 and .8 - 1.12 respectively.

Now, by refering to section of analysis of data in chapter five, the different range of bid/cost ratio obtained from actual data are shown. By comparing those distributions with the distribution of Figures (6.22) and (6.23), an apparent similarity can be observed. In other words, by adjusting the range of true cost ratio, it is possible to obtain a simulated bid/cost ratio range which can approximate to an actual one. Therefore, the observations obtained from Figure (6.22) and (6.23) indicate clearly the effect of true cost ratio on the bid/cost ratio distribution.

It was also mentioned before that the success ratios produced by

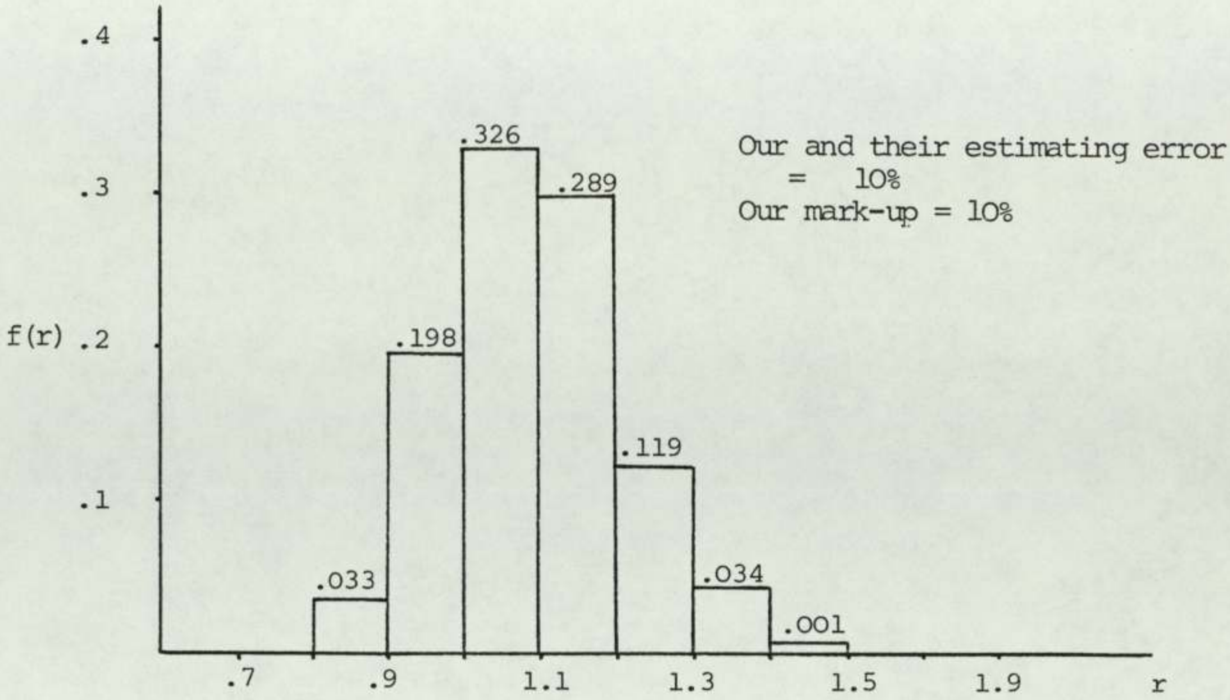


Figure (6.22) Distribution of bid/cost ratio for true cost ratio in range .9 - 1.1 (computer generated values)

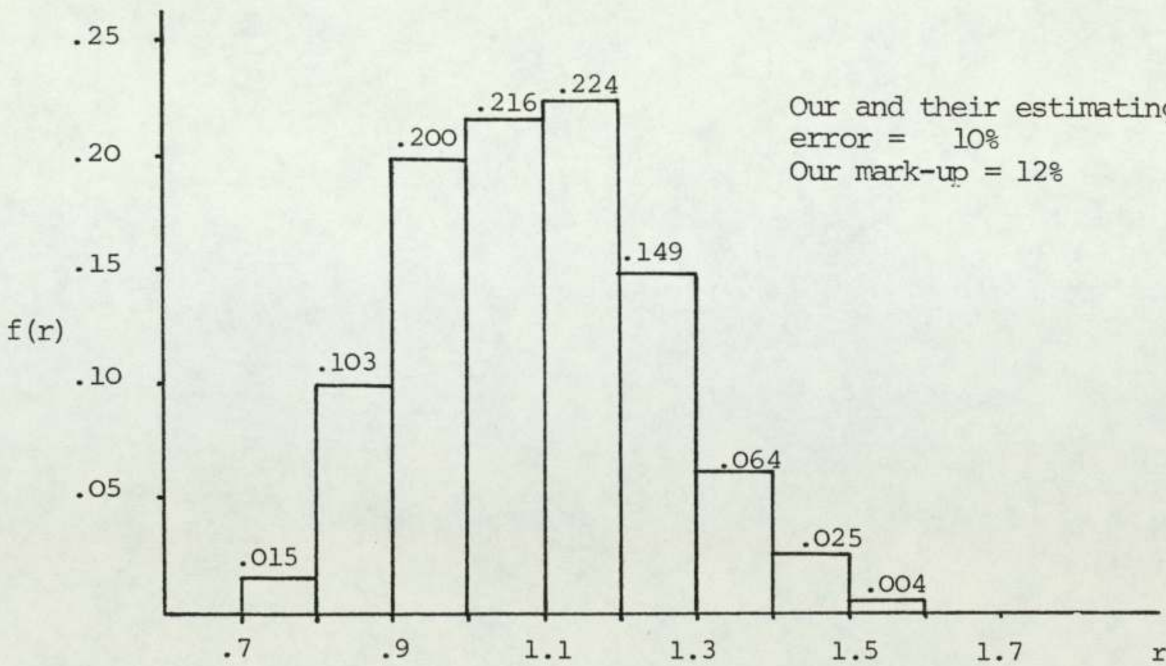


Figure (6.23) Distribution of bid/cost ratio for true cost ratio in range .8 - 1.2 (computer generated values) applying BIDMOD9 fall in between the Gates and Friedman success ratios. In order to demonstrate this, the distribution of bid/cost ratios, shown in Figure (6.22) will be used. In addition to this distribution, the distribution of number of bidders which has been used in developing the simulation models will also be used. Now, by using these two distributions and applying Friedman and Gates model, for calculation of success ratios, the comparison between the three success ratios can be made. The results of these three success ratios are presented in Table (6.15), Figure (6.24) illustrates the comparison between the success ratios for BIDMOD9, Gates Model and Friedman Model. As it can be seen from Figure (6.24), the results of success ratios for simulation model - BIDMOD9, lies between the Gates' results and the Friedman's results. Now with reference to appendix 1.1, firm A has only won two jobs having applied a 10% mark-up policy for every contract. This represent a success ratio of about 4.2%. By comparing this value and the value of success ratios obtained from Table (6.15) for 10% mark-up it can be seen that the BIDMOD9 indicates a reasonably good result for success ratios which could be obtained in real world situations and their values are not too high (Gates' Model) or too low (Friedman's Model).

Table (6.15) Results of Success Ratios for Three Different Bidding Models based on Figure (6.22) Our mark-up = 10%

Mark-Up (%)	Success Ratios for Friedman's Model (%)	Success Ratios for BIDMOD 9 (%)	Success Ratios for Gates' Model (%)
2	9.60	25.0	33.30
3	7.10	20.0	31.00
4	5.10	18.60	29.20
5	3.70	15.40	27.30
6	2.60	13.40	25.70
7	1.80	10.80	24.40
8	1.30	8.00	23.30
9	0.90	6.20	22.20
10	0.60	5.20	21.00
11	0.40	4.20	19.30
12	0.25	2.80	18.20

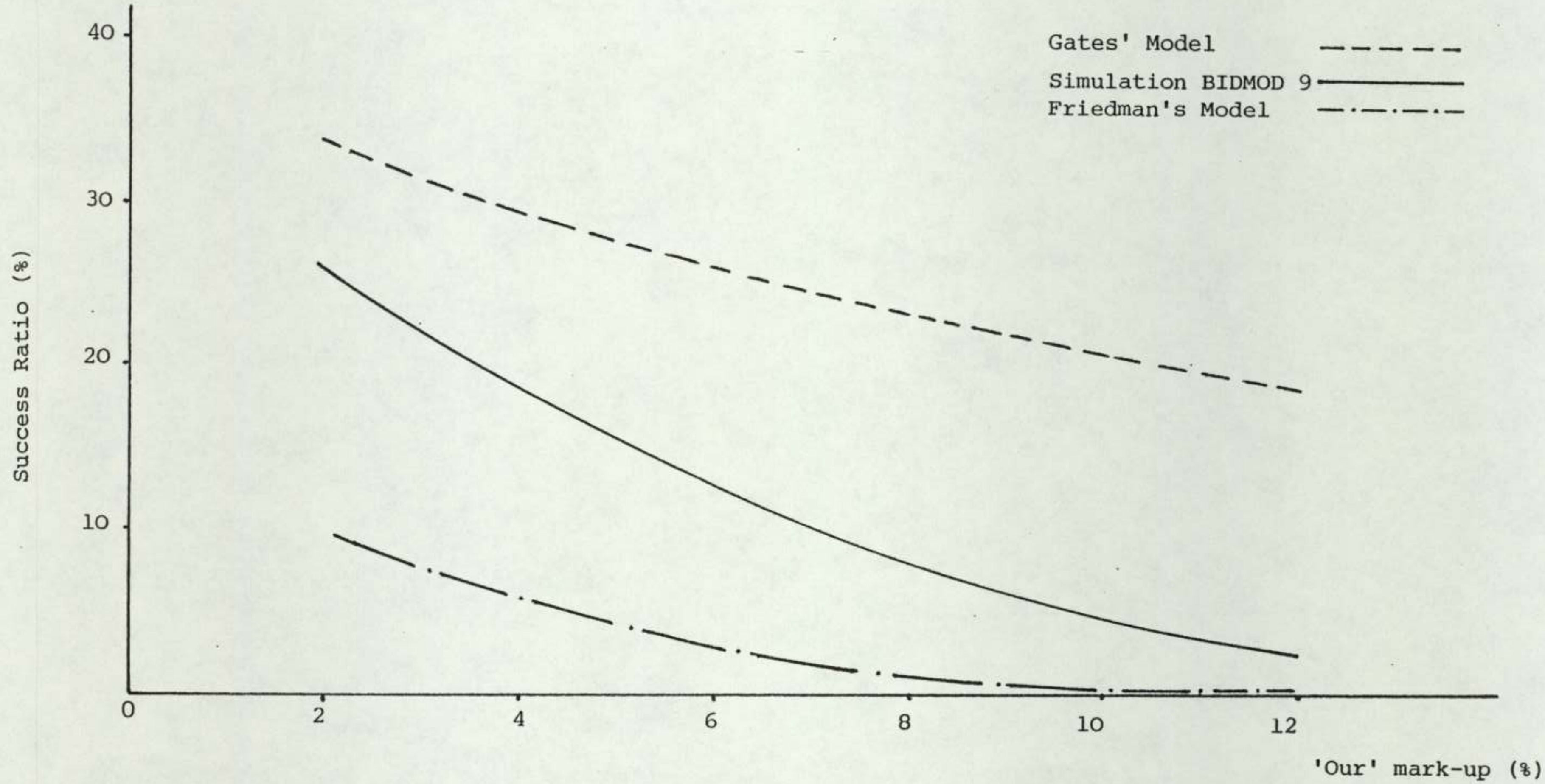


Figure (6.24) Variations of success ratio against mark-up for three different bidding models.

6.9 Simulation Bidding Model - BIDMOD11

This computerised bidding mnodel is a development of BIDMOD9 - which has been described in the previous section and incorporates a cash-flow sub-model which enables jobs of varying duration to be simulated. Most of the assumptions which have been made during the development of BIDMOD9 are applicable to this bidding model. However, it is worth mentioning these assumptions briefly at this stage.

This bidding model assumes that the estimating error (for us and for our competitors) varies, for all bidders, according to a uniform distribution whose mean is the true cost, to any particular bidder. The true cost is, also, assumed to vary from bidder to bidder. Competition is between us and a variable number of competitors. Our mark-up is fixed but our competitors' mark-up varies uniformly over a defined range. Job values are assumed to follow a lognormal distribution. Figures (6.7) and (6.8) illustrates the distributions of job values and number of bidders as they are used in the model. Distributions of our competitors' mark-ups, estimating error (for us and them), and true cost ratios are also shown in Figure (6.9).

Any number of years may be simulated, each year being sub-divided into quarters. The number of jobs available to bid for, in any quarter, is defined. For each job, our bid is compared with each bid of our competitors. If our bid is less than our competitors' bid, then, the job is considered to be won by us. As a result of this, the true cost and true profit are determined, also, the future cash-flow profile is computed. A job won in any particular quarter is assumed to be capable of starting in that quarter.

If a job value exceeds £5M in value then its duration is 2 years, otherwise its duration is one year. The individual job cash flows are aggregated.

In the development of BIDMOD9, it is assumed the particular sets of data for job values and the number of bidders that have been obtained from a contracting firm, are dedicated to the simulation model.

In addition to these dedicated data, the simulation model BIDMOD11 includes dedicated simulative "pay-in" and "pay-out" tables which, when applied to any job which is won, will produce a possible quarter-by-quarter cash-flow picture for that particular job and, add these cash-flows on to any existing cash-flow.

Figures (6.10) and (6.11) shows the cash-flow graphs for one year and two year contracts respectively.

The inputted information needed to run this simulation model is the same as for BIDMOD9. Similarly, the output information which could be obtained as a result of running this simulation program is also the same as for BIDMOD9, plus an additional cumulative quarterly cash-flows. The fundamental components of BIDMOD11 are:-

<u>Exogeneous Variables</u>

$V1_c$ = The value of the C^{th} job, C = 1,2, ... C1

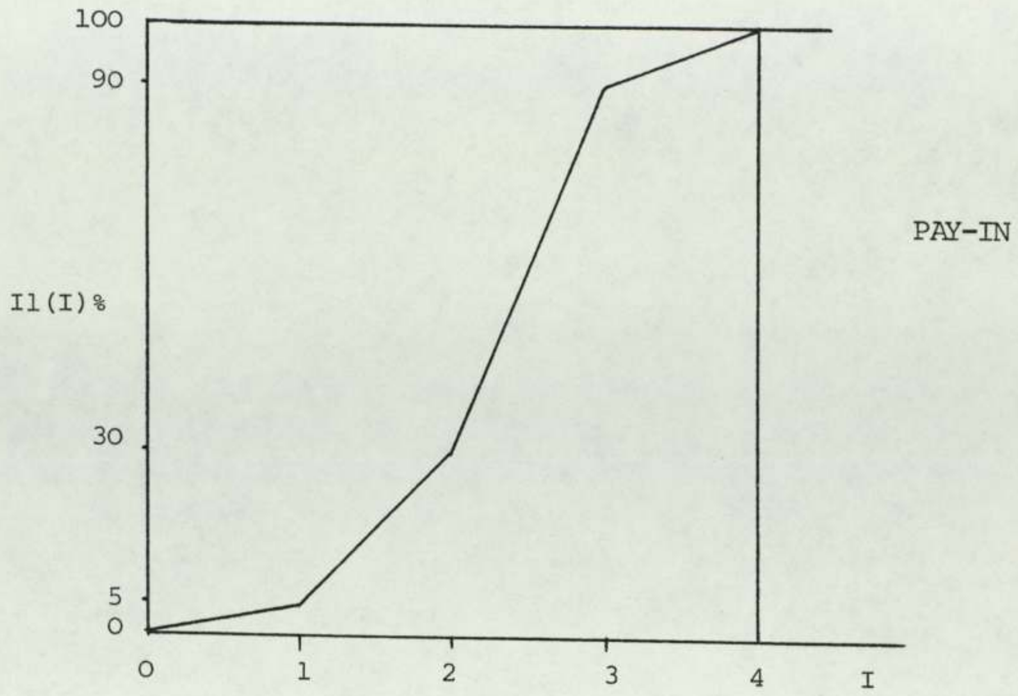
B_c = Number of bidders for Job C

$A1_c$ = Our estimated cost for Job C

$A2_c$ = Our bid for Job C

$A3_c$ = Our true cost for Job C

$T2_{B1,C}$ = Our competitors' bids $B1^{th}$ bid for Job C



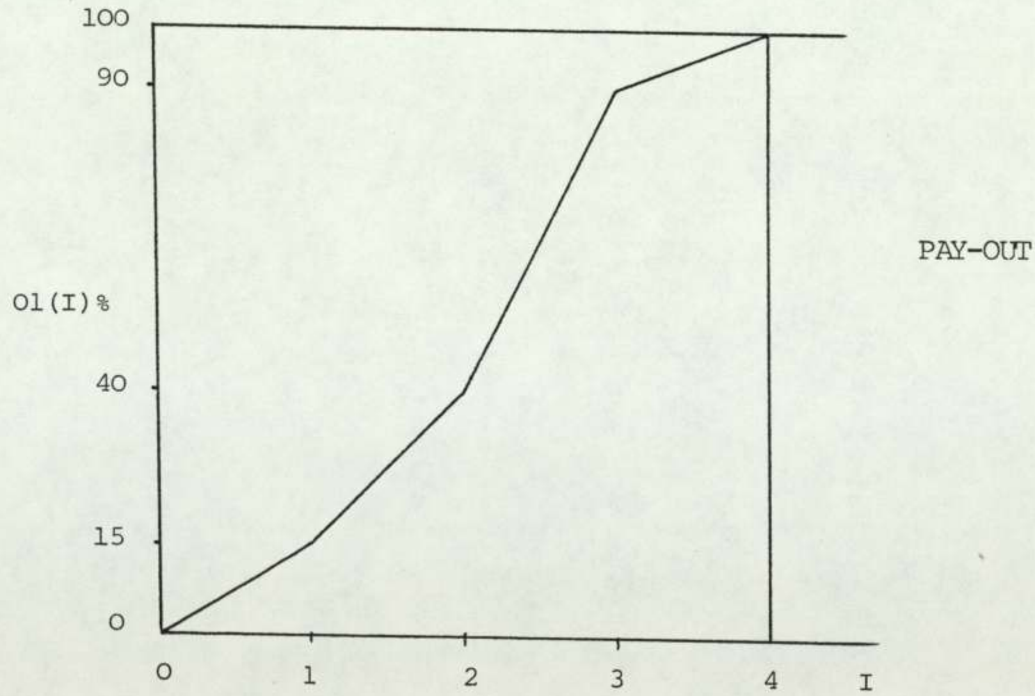
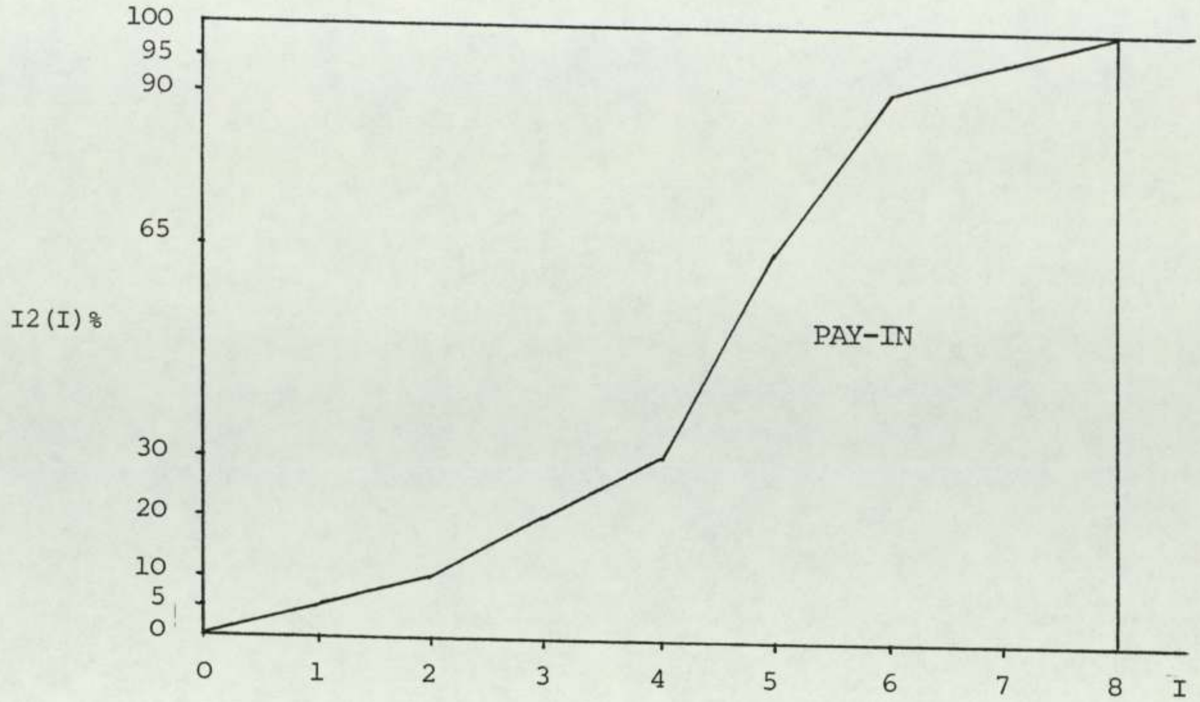


Figure (6.10) PAY-IN and PAY-OUT cash-flow graphs for 1 year contract.



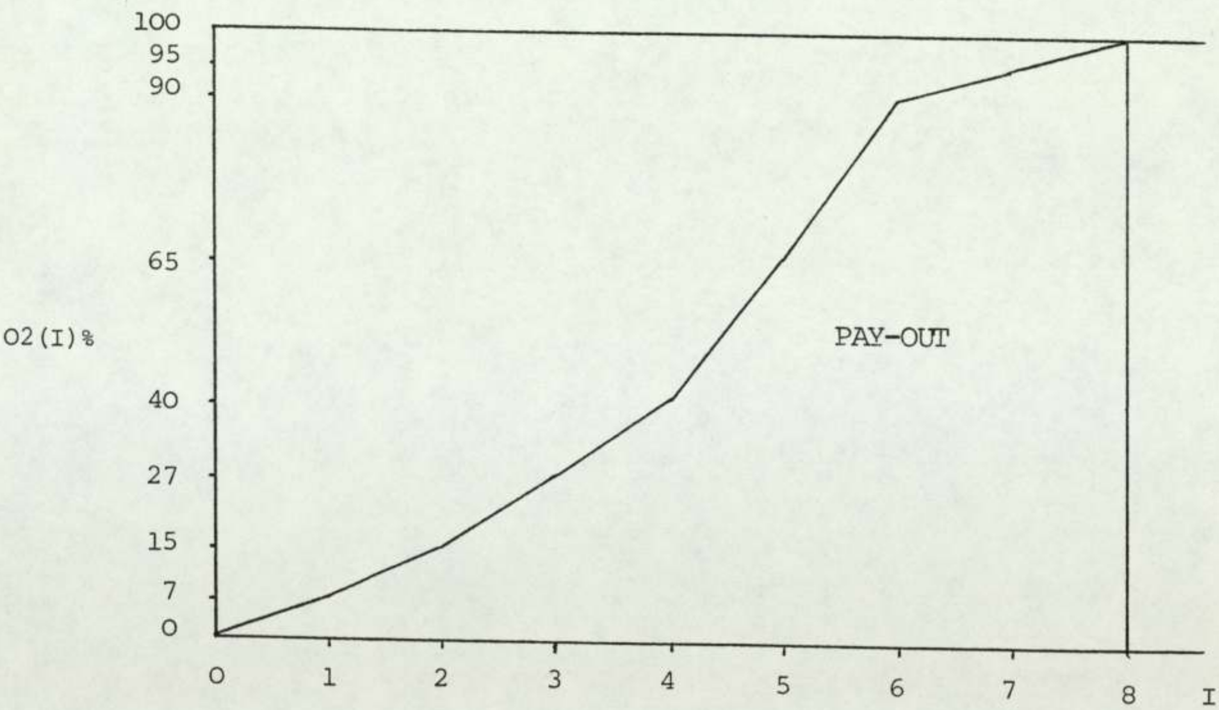


Figure (6.11) PAY-IN and PAY-OUT cash flow graphs for 2 years contract.

Endogeneous Variables

W = Total number of jobs won by us.

S = Total value of jobs won by us.

P = Total profit obtained from all jobs that have been won by us.

S9(I) = Quarterly cash-flow, I = 1,2,3, ... etc.

The full listing of the simulation program - BIDMOD11 and a sample of its output are presented in Appendix (7). In the following section, the results of cash-flows for a particular set of inputted information will be shown.

Note that the proposed cash flow graphs are purely hypothetical but assume that approximately one third of the total value of contract is associated with the middle third of the contract duration.

6.9.1 Simulation Results of Bidding Model - BIDMOD11

As it has been mentioned before, the computerised bidding model is a development of BIDMOD9 and incorporates a cash-flow sub-model which enables jobs of varying duration to be simulated. It was also mentioned that BIDMOD9 makes the simplifying assumptions.

1. All jobs on which successful bids have been made are completed in the same year that the bids are made.
2. The time lags for payments-in and payments-out are ignored.

Now, in order to study more carefully the possible effects of various strategies on cash-flows, BIDMOD11 could help the contractors to predict the cash-flow generated by jobs of varying duration, i.e. 1 or 2 years.

Most of the simulation results of BIDMOD11 are the same as BIDMOD9 which have been discussed in detail before and there is no need to explain them again here. However, in order to illustrate the important features of quarterly cash-flow results obtained from BIDMOD11, the simulation model has been run for a simulated period of 10 years. It is assumed that there are four quarters in each year and any job won in any particular quarter is assumed to be capable of starting in that quarter.
The number of jobs to bid for in each quarter is assumed to be 10 and hence the total number of jobs to bid for is 400.

It is further assumed that ´our´ estimating error is 5% and our competitors´ estimating error is 10% and the range of true cost ratios is .9 - 1.1. Following some simulation runs, it was found that the optimum mark-ups occur at 7%. Now, the results of this simulation run are presented in Table (6.16), with the results of quarterly cash-flow being shown in Table (6.16a). Figure (6.25) shows the cash-flow, plotted from data provided by Table (6.16a) for a contractor starting with zero cash and no job-in-progress at time zero. The model predicts that no jobs will be won in the first year. However, a relatively high value contract, worth 7.2m, and due to take two years to complete, is won in the first quarter of year two. This job, unfortunately generates high negative cash-flows during the first half of the contract.
From the end of year two onwards the situation improves, with good

Table (6.16) Simulation Results of BIDMOD 11 for 7% Mark-Up.
(Our estimating error = 5%
Their estimating error = 10%
True Cost Ratio .9 - 1.1)

END OF YEAR	NR OF WINS	VALUE OF JOBS WON £	PROFIT £
1	0	0	0
2	1	7194207	168706
3	3	968249	38484
4	2	724781	22077
5	4	1555512	72158
6	0	0	0
7	3	8893990	366477
8	2	936302	24997
9	2	823484	36724
10	3	258407	17690

Table (6.16a) Results of quarterly cash flow obtained from BIDMOD 11.
(Our estimating error = 5%
Their estimating error = 10%
True Cost Ratio .9 - 1.1)

Quarter No.	Cash-Flow (£)	Quarter No.	Cash-Flow (£)	Quarter No.	Cash-Flow (£)	Quarter No.	Cash-Flow (£)	Quarter No.	Cash-Flow (£)
1	0	11	169461	21	273481	31	560663	41	740535
2	0	12	132559	22	300662	32	579106	42	747046
3	0	13	132091	23	301428	33	690563	43	747318
4	0	14	199064	24	301428	34	625794	44	747318
5	-132074	15	153614	25	112380	35	624714	45	747318
6	-334404	16	157791	26	25534	36	714844	46	747318
7	-458043	17	211551	27	107843	37	724253	47	747318
8	-651937	18	143669	28	-8994	38	712258	48	747318
9	64965	19	137108	29	-177271	39	722877	49	747318
10	109695	20	220581	30	574238	40	738787	50	747318

overlapping of jobs which helps to smooth out the effects of early negative cash-flows on new jobs.

However, a situation has arisen, during year six, where no jobs are won, with the result that the two relatively high value contracts won in year seven have generated high early negative cash-flows. The cash-flow rapidly recovers during year eight and remains high from then on.

The Figure (6.2 5) shows a typical quarterly cash-flow where certain information is inputted into BIDMOD11. However, this simulation model, as was mentioned before, can be run for any number of years and any number of quarters in a year, with any number of jobs to bid for in that particular quarter. Although, the results of cash-flows will be different but the shape of cash-flow variation is the same as the one that has been shown in Figure (6.25).

Now, by using different random number streams, in the simulation, the BIDMOD11 can produce different cash-flow patterns, which should highlight the effects of the lack of continuity of overlapping of jobs on cash-flow.

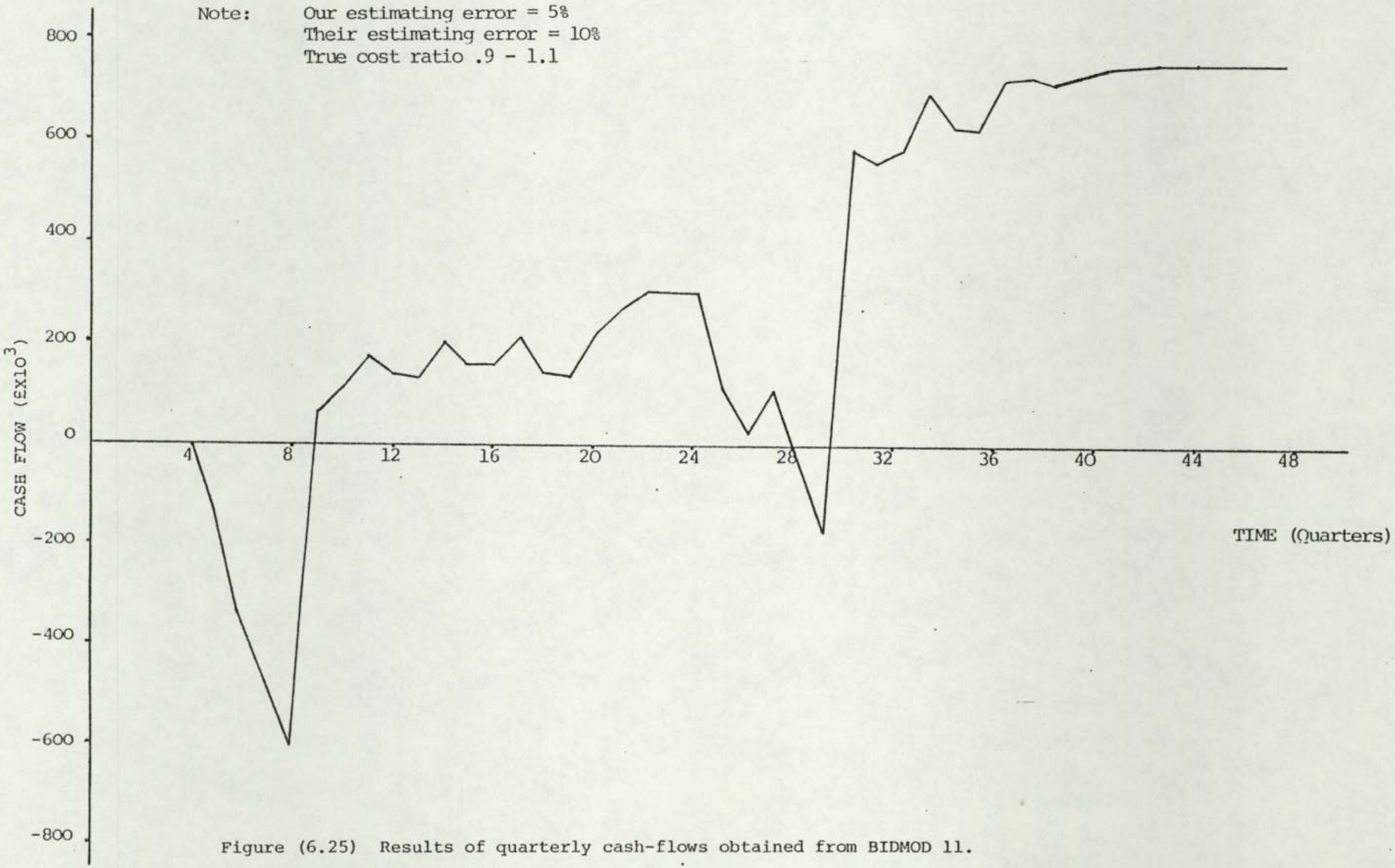


Figure (6.25) Results of quarterly cash-flows obtained from BIDMOD 11.

CHAPTER SEVEN

DISCUSSIONS AND CONCLUSIONS

7.1 Discussions

Competitive bidding is an intriguing, unique, and sometimes critical activity of management. In the construction industry competitive bidding is particularly important because the majority of private and public works are obtained by bidding against other contractors. Basically the bidding process consists of several competing contractors submitting closed bids to the client, mainly central and local government, who selects the bid most desirable to him. He will usually, and may be legally required to, accept the lowest possible bid. Obviously being able to produce low bids with an adequate profit margin is essential for the contractor's success.

When bidding a project, the contractor compiles the most accurate cost estimate possible of the work specified by bidding documents. He then adds a certain amount of mark-up (to cover overheads, profit and risk) to his cost estimate and produces his final bid amount. If he makes his mark-up too large, he may receive too few contracts to stay in business. Conversely, if he includes an inadequate mark-up he can win many contracts but may not make enough money to stay in business. The successful contractor must then employ a strategy that will enable him to avoid both extremes.

This is the strategy that has been employed by all researchers who developed their competitive bidding models. The various bidding models developed by different authors have been discussed in details in chapter three of this thesis. As it has been seen most of the bidding models are aimed at maximizing the expected value of the contractors profit. Although some of the models also included the objective of the contractor's work load .

The study of various bidding models and concepts of the theory of bidding strategy indicates the need for analysing large volume of correct bidding data in order to investigate the influence of various important parameters in the field of tendering strategy. During the course of this research several attempts were made to obtain sets of actual bidding data. However, due to the lack of cooperation from contractors who regard such information as a trade secret only three sets of data were obtained which are presentd in the Appendix (1).

The goodness of fit of known statistical distributions to the data sets was tested and showed a reasonable agreement in some cases while no fit was found in others.

The relation between the number of bidders and the job values, which is a subject of disagreement between different authors in the field of tendering strategy as disussed in chapter five, was investigated with the help of the three data sets. As it has been seen this investigation showed that there was no linear relationship between the number of bidders and the job values. This finding is in agreement with Gates's statement (32) while it is in disagreement with Friedman (20) and Park (25) findings.

A study of the effect of the job value on the coefficient of variation, the percentage spread, and the average standardised bid was also conducted. Here again the three available data sets were used to investigate the effect of the job value on the above parameters. This study showed that only for one set of data did a linear reletionship exist between the job value and the coefficient of variation while for the other two sets this relation does not exist. Similar investigation also showed that a linear relation exists between the job value and the percentage spread only for one set of data and with no relation for the other sets.
Generally it was concluded that the information available in the three sets of data indicate that the spread of bids, in the high job value market is less than that in the low job value one, which is thought to be due to better estimation and similar mark-up policies in the high risk region.

As expected, the analysis of the available data sets did not enable any firm conclusions to be drawn especiaaly in a field of controversy like that of tendering strategy. Even if more data were avaialable the reliability of such information remains in doubt as it may be expected that the contractor's site staff could manipulate their reports in order to hide any discrepancies. An example of this is sharing the time lost or money wasted on certain items among several other items which were efficiently executed.

Hence in order to approach competitive tendering in the construction industry in a systematic way, which is the main objective of this research , computer simulation technique was employed. This was done by assuming known statistical distributions , of the elements involved in tendering strategy models, and drawing samples from them.

The application of computerised simulation, for approaching the competitive tendering systematically, firstly was carried out through two simple models which were described in chapter four of this thesis. These two simple models were introduced in order to highlight the theory of tendering strategy. As it was explained in developing these models, a number of important assumptions have been made which corresponds to what has been said earlier, i.e., known statistical distributions were assumed for the important elements of the bidding models. Because the generation of random numbers is central to the application of simulation and the accuracy of the results depend on their true randomness,a subroutine with ten possible streams were used in these computerised simulation programs in order to produce satisfactory random numbers for the purpose of comparitive study.

The number of simulations required to arrive at a reasonable accuracy was found by comparing the simulation results of selected problems to those obtained analytically by order statistics. It was found that the number of simulation runs of 500 would be sufficient to perform the required analysis.

At later stage as it was seen in chapter six of this thesis, the modified Friedman and Estimating Error models were considerd. A number of factors affecting the tendering were introduced. These are : our mark-up, our competitors' mark-ups, our estimating error, our competitors' estimating errors, number of bidders, job values and the true cost ratio (the ratio of their true cost to our true cost) . Among these different variables only the applied mark-up can be controlled by the contractors and the other variables are uncontrollable by them.

The Friedman simulation model,which was developed in the early part of this research, did not take into account the estimating error factor. Hence to study the concepts of tendering as applied in the construction industry in more detail it was decided to incorporate the estimating error factor within the Friedman simulation model . In doing this it was further assumed that the distribution of estimating error follows a uniform distribution. Having done that, the simulation models was run for 500 jobs and their results are shown in chapter six. However, these results were later considered to be logically unsound for the reasons mentioned in that chapter. Having rejected this model, it was then decided to apply further investigations into the estimating error model.

As it has been mentioned, one drawback with the simple estimating error model is that the range of bid/cost ratios produced does not match with those obtained in practice. It is also found that the factor of true cost ratio also affects the tendering strategy. Hence it was decided to incorporate a "true cost ratio" factor within the estimating error model and to calibrate the model similarly by adjusting the range of the computer generated true cost ratio probability density function to give a simulated range of bid /cost ratios which approximate to the observed data. The worked example described in chapter six explains the principle of the method mentioned in the above. Then using the assumptions laid out in this example the two computerised simulation models were developed which take into account all the important factors affecting the tendering strategy.

It is worth mentioning that the assumptions which were used to develop the two simulation models (BIDMOD9 and BIDMOD11) have been based on a series of discussions between the reasearcher and a number of well known construction firms. These models assume that the number of bidders is randomly sampled from a discrete distribution in the range of 5-9 bidders which is typical for invited tenders. It is also assumed that the job values randomly sampled from a lognormal distribution for contract values in the range of 6000 pounds to 15 million pounds. The estimating error is also assumed to be sampled from a uniform distribution whose mean is the true cost to any particular tenderer . The competitors' mark-ups were assumed to vary uniformly over the range 4-12 percent . Finally these simulation models used a range of true cost ratios which were assumed to vary according a uniform distribution whose mean is one . Having incorporated all these assumptions into the simulation models, further investigations have been carried out to study the different aspects of tendering in the construction industry.

The models have been run for 500 jobs where every 50 jobs are expected to be completed in each year. Two cases were considerd. Firstly, it is assumed that the range of true cost ratio is (.9-1.1) .
Using this range the relationship between the success ratio and the mark-up, whose determination is the central aim of all bidding models, was investigated for various levels of estimation accuracy. It has

been found out the success ratios obtained from these simulation models, in fact, lies between the Gates's Model which produces a very high success rate and Friedman's Model which produces very low success rate.

The expected profit to be obtained by applying different mark-ups were studied for different levels of estimation accuracy. It has been found out that if our estimating error procedure remains constant and our competitors' estimating error is substantially reduced from 10% to 5%, for example, then assuming that we were bidding at optimum mark-up originally,an increase of 1%, only, is sufficient to maintain profit levels at approximately the same level. However, a 5% improvement in our own estimating error from 10% to 5%, with no changes in our competitors' estimating errors, would require a substantial reduction in our mark-up in order to maintain the same profit level. It is then concluded that changes in ones estimating error should proceed in carefully controlled stages in order that its effect on profit should be carefully monitored.

The variations of job values against the applied mark-ups were studied under different levels of estimation accuracy. The results of this study has been found to be in good agreement with those that obtained for the success ratios.

In the second case, it is assumed that the range of true cost ratio is (.8 - 1.2) . Under this assumption similar investigations were conducted to demonstrate the effects of applied mark-ups on the success ratios, the expected profit and the job values for different levels of estimation accuracy. It has generally been found out that the ranges of success ratios, the expected profits and the job values were reduced as a result of changing the range of true cost ratio . These general conclusions will clearly illustrate the importance of true cost ratio factor and its effects on the outcome of tendering process. In order to demonstrate the effect of true cost ratio factor on the distribution of bid/cost ratios, further study was conducted by using the simulation models where it is assumed that the estimating errors remain at 10% and the true cost ratio ranges are (.9 - 1.1) and (.8 - 1.2). It is found out that the distributions of simulated bid/cost ratios have the ranges of .8 - 1.5 and .7 - 1.6 when the true cost ratio ranges are .9 - 1.1 and .8 - 1.2 respectively. Comparing these distributions, with those that obtained when the three actual sets of data were used, apparent similarities can be observed. Hence, the general conclusion is that it could be possible to obtain a simulated bid/cost ratio range which can approximate to an actual one simply by adjusting the range of true cost ratio.

Finally, in order to study more carefully the possible effects of various strategies on cash-flows, the simulation model-BIDMOD11 was developed which could help the contractors to predict the cash-flows generated by jobs of varying duration,i.e., one or two years. One typical set of quarterly cash-flows which was obtained as a result of running BIDMOD11 has been presented in chapter six to demonstrate this study. It was concluded that by using different random number streams, in the simulation, the BIDMOD11 will produce different cash-flow patterns, which should highlight the effects of the lack of continuity of overlapping of the jobs on the cash-flows.

7.2 **Conclusions**

The method of competitive tendering, in which a number of contracting companies are invited to submit closed bids, is the one which is mostly used in awarding contracts and the lowest tenderer is usually the successful one.
This thesis has hopefully shown that the theory of competitive tendering strategy is extremely complex with numerous unpredictable variables. In order to approach competitive tendering in the construction industry systematically, which is the main objective if this thesis, two methods have been employed.

The first method is that of analysing actual bidding data by attempting to fit known statistical distributions to them. The three sets of data which obtained from contracting firms were used here and these data were analysed and applied to some aspects of the field of tendering strategy. However, the amount of bidding data was not enough to draw a general conclusion, as a general conclusion requires the analysis of a much larger volume of data .

As a result of the shortcomings of the first method an alternative method was employed. In this second method the computerised simulation technique was adopted. Here known statistical distributions, for the important elements involved in tenedering strategy, were assumed and by using number generation subroutines samples were drawn from them. The simulation models which were developed during the course of this research, then, have been employed in order to investigate the possible application of the various bidding parameters on success ratio, average net profit,etc.

The simulation results compare well with the theoretical published literature. A set of typical situations is arrived at, which can be used by a contractor to supplement, not replace, his subjective assessment of a particular bidding situation. Finally, this method can be developed further to examine other fields of competitive tendering which were untackled in this thesis.

7.3 Suggestion for further research

The study of the theory of competitive bidding strategy and the possible applications of the various bidding parameters has clearly shown that such a field of controversy like that of bidding is extremely complex with numerous unpredictable variables affecting the outcome of the bidding process.The work that has been carried out during the course of this study is not an isolated work but is part of the continuing study of competitive bidding problems initiated by Friedman in 1956. It is hoped that this research will stimulate still more exploration of the process of competitive bidding.

Although a lot of important situations were studied using the computerised simulation models and the influence of several relevant factors was tested there remains a great scope for further development and study. Some areas of possible further research will be suggested in the following:

(1) The continued implementation and testing of the models of this

thesis. One way of doing this is by comparing the simulation results with actual bidding data. The confidence in the simulation results can then be fully established when they compare well with actual bidding data. It is not certain, however, how such data can be made available but attempts must continue to do so.

(2) The investigation of the relation between the number of bidders and the job values which was conducted by using the avaiable data sets has shown that a linear reletion does not exist. It was also seen that some authors suggested a linear relation between the two parameters and some others stated that the relation is not linear with a third group inconclusive about the existence of this relation. Due to importance of this factor, further attempts could be made to see if a relationship exists in particular job value range or a special type of job.

(3) It was seen that one of the important assumption has been made in developing the simulation models in this thesis was that the range of true cost ratios follow a uniform distribution with mean of one. It is further emphasized that this factor affects the distribution of bid/cost ratios. Because of the importance of thisfactor, further study could be made in order to test the ranges of true cost ratio other than those which was investiagted in this reseach.

(4) A variable mark-up model could be developed where short term profits and/ or turnover are the aim(s). Here fore-knowledge of the likely number of bidders and the number of jobs remaining to bid for, may be used to adjust the mark-up as follows:

(i) Using the true cost ratio factor it is possible to adjust the bid/cost ratio distribution in order to develop a relationship between mark-up and the number of bidders for a range of success levels. Since the value of the next job is also known, the maximum likely loss and gain at these various mark-ups may also be evaluated. A decision rule based on utility theory may be developed for this situation.

(ii) Mark-ups may be adjusted according to the "need to win" which may be related to the shortfall between the annual cumulative value of jobs won and the optimum turnover, at any particular stage of the annual bidding process. For example, early successes may tempt the bidder to raise his mark-up on the remaining jobs available. On the other hand lack of success will tempt the bidder to lower his mark-up.

(5) Futher study could be made to investigate the possible effects of various strategies on cash flows. Here, as it has mentioned before using different number streams in the simulation it is possible to produce different cash flow patterns in order to demonstrate the effects of overlapping of the jobs on cash flow.

APPENDICES

APPENDIX 1

BIDDING DATA SETS

APPENDIX 1.1

FIRM A DATA SET (1968 - 1971)

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Compt. bids / Cost Est.
1	4		5879913			0.966
			6069464			0.996
		A	6696729	608793	6087936	
			8740694			1.436
2	6		3142189			0.869
			3530646			0.976
			3550441			0.982
			3717603			1.028
		A	3978280	361662	3616618	
			4552692			1.259
3	7		1379640			0.956
			1437529			0.996
			1480301			1.026
			1501344			1.042
		A	1587684	144335	1443349	
			1611572			1.117
			1615340			1.119
4	6		8892354			1.031
			9453821			1.084
		A	9594112	87192	871920	
			10346022			1.186
			10437083			1.197
			10521001			1.206
5	6		6942790			0.899
			7701606			0.997
		A	8496400	772400	7724000	
			8803060			1.140
			8900002			1.152
			9382239			1.215
6	6		3572925			0.888
			3900069			0.969
			4216232			1.048
			4252828			1.057
		A	4426138	402376	4023762	
			4523966			1.240

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Compt. bids / Cost Est.
7	6		3283858			0.969
			3581937			1.057
			3668264			1.082
		A	3728727	338975	3389752	
			3744651			1.105
			3915248			1.156
8	5		9918163			1.072
		A	10181753	925614	9256139	
			10416735			1.125
			10603000			1.146
			11414819			1.233
9	5		3098937			1.022
		A	3337039	303367	3033672	
			3779345			1.246
			3842488			1.267
			3966504			1.308
10	6		9760110			1.052
		A	10210122	928193	9281929	
			10220799			1.101
			10424448			1.123
			10472968			1.128
			11921362			1.284
11	6		2653798			1.040
		A	2805983	255089	2550894	
			2847445			1.116
			2853028			1.118
			3200147			1.255
			3264350			1.280
12	7		6727920			1.017
			6902772			1.044
			7248049			1.096
		A	7273864	661260	6612604	
			7338754			1.110
			7508054			1.135
			7804994			1.180

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Compt. bids / cost Est.
13	5		1648106			0.974
			1784481			1.055
			1795706			1.062
		A	1860402	169128	1691275	
			1912647			1.131
14	5		92688			0.788
			95157			0.809
			106718			0.908
			120263			1.023
		A	129347	11759	117588	
15	6		5852795			1.024
			5866900			1.026
			6165723			1.078
			6209478			1.086
		A	9290036	571822	5718215	
			7004430			1.225
16	6		1629851			1.000
			1707286			1.048
			1708483			1.049
			1787523			1.097
		A	1792472	162952	1629520	
			2293809			1.408
17	6		385249			0.965
		A	438988	39908	399080	
			443696			1.112
			505653			1.267
			515665			1.292
			525882			1.318
18	5		4538757			0.965
			4801104			1.021
			5159823			1.097
		A	5172316	470211	4702106	
			5307731			1.129

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Compt. bids / Cost Est.
19	5		5606			0.438
			9990			0.780
			12525			0.978
			13918			1.007
		A	14091	1281	12810	
20	7		8054614			0.977
			8534680			1.035
			8953647			1.086
		A	9072082	824735	8247347	
			9469862			1.148
			9741376			1.181
			9776689			1.185
21	7	A	1923745	174886	1748859	
			2025992			1.158
			2069571			1.183
			2096189			1.200
			2119168			1.212
			2284678			1.306
			2324655			1.329
22	6		5598383			0.983
			6262030			1.100
		A	6262760	569342	5693418	
			6331573			1.112
			6484996			1.139
			6948152			1.220
23	6		148803			0.814
			162325			0.888
			176054			0.964
			194021			1.062
		A	200981	18271	182710	
			222288			1.217

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Compt. bids / Cost Est.
24	6		1608918			0.947
			1721260			1.013
			1763077			1.038
			1826810			1.076
			1842471			1.085
		A	1868450	169859	1698591	
25	4		4437801			0.923
		A	4642603	422055	4220548	
			4704745			1.115
			6021738			1.427
26	6		10487060			0.923
			10908741			0.960
		A	12504013	1136729	11367285	
			12567168			1.106
			13381259			1.177
			15443850			1.359
27	5		454049			1.094
		A	456422	41493	414929	
			510582			1.231
			579669			1.397
			637367			1.536
28	7		278702			0.785
			289664			0.816
			302922			0.854
			305775			0.862
			315075			0.888
			315578			0.889
		A	390295	35481	354814	
29	5		1033551			0.896
			1103595			0.957
			1117995			0.970
		A	1268280	115298	1152982	
			1332244			1.156

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Compt. bids / Cost Est.
30	6		1979101			0.984
			2105423			1.047
			2122178			1.055
			2133244			1.061
		A	2211740	201067	2010673	
			2285203			1.137
31	7		431726			0.904
			474350			0.993
			503677			1.054
			507500			1.062
			510879			1.069
		A	525545	47777	477768	
			526758			1.103
32	5		561131			1.092
		A	567404	51583	515828	
			623301			1.208
			641952			1.245
			680059			1.318
33	6		155663			0.903
			157800			0.916
			158232			0.918
			160024			0.928
			168897			0.980
		A	189583	17235	172348	
34	6		7589020			0.861
			7947463			0.902
			8000371			0.908
			8548849			0.970
			9148925			1.038
		A	9695029	881366	8813663	
35	5		10124618			0.882
			10549654			0.919
			10663318			0.923
			10931316			0.953
		A	12621260	1147387	11473873	

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Compt. bids / Cost Est.
36	6		250052			0.842
		A	326780	29707	297073	
			340341			1.146
			371732			1.251
			389696			1.312
			401010			1.350
37	5		4390841			0.967
			4405901			0.970
			4808318			1.059
		A	4996166	454197	4541969	
			5095383			1.122
38	6		575404			0.964
			605607			1.015
		A	656515	59683	596832	
			708366			1.187
			725321			1.215
			748959			1.255
39	5		4259806			1.026
			4276202			1.030
		A	4567028	415184	4151844	
			4667175			1.124
			5247922			1.264
40	7		2174384			0.936
			2252771			0.970
			2255325			0.971
			2333749			1.004
			2443611			1.052
			2464971			1.061
		A	2555790	232345	2323445	
41	6		3575755			1.046
			3608510			1.056
			3681463			1.077
		A	3760533	341867	3418666	
			3932774			1.156
			4147900			1.213

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Compt. bids / Cost Est.
42	8		15826			0.583
			20705			0.763
			23001			0.848
			27777			1.024
		A	29852	2714	27138	
			30467			1.123
			31454			1.159
			33710			1.242
43	6	A	642814	58438	584376	
			694046			1.188
			739850			1.266
			756352			1.294
			769831			1.317
			945224			1.598
44	6		2080629			0.995
			2134051			1.020
			2218643			1.061
			2253064			1.077
		A	2300467	209133	2091334	
			2560285			1.224
45	7		3782825			1.043
		A	3988917	362629	3626288	
			4147656			1.144
			4178491			1.154
			4379336			1.208
			4413506			1.217
			4553482			1.256
46	6		1361029			0.938
			1455653			1.003
			1460319			1.006
			1574157			1.085
		A	1596366	145124	1451242	
			1948726			1.343
47	6		9721973			0.973
			9998494			1.001
			10255053			1.026
			10437998			1.045
		A	10992971	991361	9993610	
			11313685			1.132

APPENDIX 1.2

FIRM B DATA SET

Tender No.	No. of bidders	Tender figures (£)	Mark-up (£)	Cost estimate (£)	Compt. bids / Cost Est.
1	6	2540000			0.90
		2840000			1.01
		2870000			1.02
		B 2950000	140476	2809524	
		2980000			1.06
		3050000			1.09
2	6	2920000			1.05
		B 2930000	139533	2790467	
		2990000			1.07
		3110000			1.12
		3200000			1.15
		3510000			1.26
3	7	3340000			1.01
		3360000			1.01
		B 3480000	165714	3314286	
		3560000			1.07
		3630000			1.10
		3790000			1.14
		3920000			1.18
4	6	10290000			1.02
		10380000			1.02
		10610000			1.05
		B 10640000	506667	10133333	
		10670000			1.05
		10850000			1.07
5	6	23000000			1.01
		23160000			1.02
		B 23770000	1131905	22638095	
		24220000			1.07
		24500000			1.08
		26250000			1.16

Tender No.	No. of bidders	Tender figures (£)	Mark-up (£)	Cost estimate (£)	Compt. bids / Cost Est.
6	8	B 8990000	428095	8561905	
		9010000			1.07
		9160000			1.07
		9430000			1.10
		9970000			1.16
		10080000			1.18
		10430000			1.22
		11070000			1.30

APPENDIX 1.3

FIRM C DATA SET

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Compt. bids / Cost Est.
1	5		37536			0.561
			40362			0.603
			43445			0.650
			45476			0.680
		C	74902	8000	66902	
2	2		608682			0.988
		C	645180	35668	609512	
3	10	C	440869	15481	425388	
			457877			1.076
			480914			1.130
			486152			1.143
			491031			1.154
			496479			1.167
			521608			1.226
			539071			1.267
			541895			1.274
			597249			1.404
4	7		5017163			0.891
			5262099			0.934
			5504587			0.977
			5741968			1.020
		C	5849786	216850	5632936	
			5995652			1.064
			6349429			1.127
5	5	C	116597	10000	106597	
			118354			1.110
			126675			1.188
			132579			1.244
			133335			1.250
6	4		1023212			0.950
			1079787			1.002
		C	1092610	15000	1077610	
			1322039			1.277

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Copmt. bids / cost Est.
7	8		5544638			0.877
			6277917			0.993
		C	6675074	356000	6319074	
			11207071			1.774
			11254339			1.781
			11455085			1.813
			12377960			1.959
			12653625			2.002
8	7	C	209967	11797	198170	
			219465			1.108
			219741			1.109
			224123			1.131
			227261			1.147
			233008			1.176
			244354			1.233
9	7		10239606			0.926
			10680407			0.965
			10900573			0.985
		C	11262500	200000	11062500	
			11349921			1.026
			11374157			1.028
			11667519			1.055
10	7		89922			0.462
			108558			0.557
			109356			0.561
			109969			0.562
			130416			0.670
			131507			0.675
		C	216850	22000	194850	
11	5		249208			0.830
		C	321406	20400	301006	
			357352			1.187
			365118			1.213
			433414			1.440

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Copmt. bids / Cost Est.
12	6		88193			0.917
			90066			0.977
			94122			1.020
		C	103706	7500	92206	
			106456			1.155
			112380			1.220
13	6		113790			0.894
			116477			0.915
			128314			1.008
		C	147333	20000	127333	
			148076			1.163
			208716			1.640
14	6		451050			0.720
			524507			0.838
			535662			0.856
		C	663462	37699	625763	
			729765			1.167
			736562			1.177
15	5		1720174			1.017
			1752484			1.036
		C	1798928	107000	1691928	
			1955490			1.156
			2011426			1.189
16	5		195691			0.870
			202744			0.901
			212809			0.946
		C	237091	12084	225077	
			251139			1.116
17	8		2950039			1.033
		C	3000546	145421	2855125	
			3042619			1.066
			3185485			1.116
			3353701			1.175
			3474939			1.217
			3649202			1.280
			3773076			1.322

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Copmt. bids / Cost Est.
18	5	C	68868	6000	62868	
			71030			1.130
			75870			1.207
			88854			1.413
			104558			1.663
19	6	C	6866893	230000	6636893	
			7473782			1.126
			7603270			1.146
			7741660			1.166
			7991811			1.204
			8213620			1.238
20	13		104151			0.655
			108993			0.660
			113371			0.713
			116632			0.734
			117244			0.738
			119641			0.753
			122509			0.770
			122512			0.771
			132626			0.835
			140058			0.881
			145057			0.913
			168645			1.061
		C	172600	13700	158900	
21	6	C	102030	10000	92030	
			111309			1.210
			112372			1.221
			119958			1.303
			120811			1.313
			127154			1.382
22	8		160276			0.875
			166372			0.909
			176448			0.964
		C	193402	10312	183090	
			196319			1.073
			199604			1.090
			205562			1.123
			224714			1.277

Tender No.	No. of bidders	Tender figures (£)	Mark-up (£)	Cost estimate (£)	Compt. bids / Cost Est.
23	4	60500			1.017
		61443			1.033
		65681			1.104
		C 65796	6300	59496	
24	5	1268500			0.958
		1281129			0.967
		1378579			1.040
		1392700			1.051
		C 1395212	70467	1324745	
25	6	1148456			0.883
		1203100			0.925
		1264574			0.972
		1285871			0.989
		1308272			1.006
		C 1400768	100000	1300768	
26	6	139624			0.936
		148071			0.992
		C 154635	5400	149235	
		161177			1.080
		161990			1.085
		162653			1.090
27	4	1106567			0.999
		1108525			1.001
		C 1184446	77871	1106575	
		1292794			1.168
28	5	40921			0.908
		43098			0.956
		45771			1.016
		C 48569	3500	45069	
		48639			1.080

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Copmt. bids / Cost Est.
29	14		1898064			0.883
			1986531			0.925
			2017154			0.939
			2033405			0.946
			2054965			0.956
			2076961			0.967
			2159794			1.005
			2167292			1.009
			2209062			1.028
			2233157			1.039
		C	2248652	100000	2148652	
			2380029			1.108
			2668186			1.242
			2886609			1.344
30	5	C	3097689	175000	2922689	
			3261869			1.116
			3267619			1.118
			3410000			1.167
			3840944			1.314
31	8		7680910			1.012
			7745486			1.020
		C	7788910	200000	7588910	
			7972836			1.051
			8096221			1.067
			8404338			1.107
			8445533			1.113
			8621069			1.136
32	5		45531			1.079
		C	47200	5000	42200	
			57700			1.367
			59844			1.420
			94304			2.235
33	8	C	104643	7884	96759	
			115526			1.194
			121541			1.256
			124070			1.283
			134748			1.393
			144013			1.488
			152000			1.571
			186467			1.927

Tender No.	No. of bidders		Tender figures (£)	Mark-up (£)	Cost estimate (£)	Compt. bids / Cost Est.
34	7	C	4267600	237000	4030600	
			4513080			1.120
			4624706			1.147
			4717659			1.170
			4758845			1.181
			4890596			1.213
			4964468			1.231
35	8		501148			0.856
			524777			0.897
			531621			0.908
			558893			0.955
			573138			0.979
			576202			0.984
		C	611850	265000	585350	
			653078			1.116
36	7	C	194126	8610	185516	
			227545			1.227
			237282			1.279
			258654			1.394
			273013			1.472
			282429			1.522
			298575			1.609
37	3		192608			0.964
		C	214826	15000	199826	
			223174			1.117
38	3		1175670			1.084
		C	1204607	120460	1084147	
			1215536			1.121
39	5		90826			0.769
			92646			0.782
			124212			1.051
		C	131266	13126	118140	
			134766			1.141
40	7		953241			1.041
			981175			1.072
		C	997453	82000	915453	
			1014061			1.108
			1019969			1.114
			1032702			1.128
			1070189			1.169

APPENDIX 2

FRIEDMAN SIMPLE BIDDING MODEL

(BIDMOD2)

2.1 List of Computer Program.

```
1000 PRINT  "OUTPUT TO SCREEN TYPE 0; TO PRINTER TYPE 1",
1010 INPUT D
1020 PRINT £D,"**************************************************"
1030 PRINT £D,"*** SIMPLE FRIEDMAN MODEL -- PROG BIDMOD2        ***"
1040 PRINT £D,"*** This model samples competitors 'bids' from ***"
1050 PRINT £D,"*** the cdf of a fixed set of bid/cost ratios   ***"
1060 PRINT £D,"*** The number of competitors (ex A) is 5       ***"
1070 PRINT £D,"*** Output: A's success ratio for each 2.5%     ***"
1080 PRINT £D,"*** increment of A's mark-up in range 0-15%     ***"
1090 PRINT £D,"**************************************************"
1100 PRINT £D
1110 IF D=1 THEN 1120 ELSE LET A$="Y"\GOTO 1140
1120 PRINT "FOR JOB TABULATION TYPE Y ELSE TYPE N",
1130 INPUT A$
1140 PRINT "TYPE IN THE FOLLOWING INFORMATION"
1150 PRINT "TOTAL NR OF JOBS TO BE SIMULATED =",
1160 INPUT C
1170 PRINT "REF NR OF RANDOM NUMBER STREAM (1-10) =",
1180 INPUT Y
1190 PRINT £D,"NR OF JOBS SIMULATED FOR EACH INCREMENT OF A,S MARK-UP = ",C
1200 PRINT £D
1210 DATA 0.00,0.05,0.30,0.70,0.95,1.00\REM cdf of comp's bid/A's cost
1220 FOR I=1 TO 6
1230 READ X1(I)
1240 NEXT I
1250 B=5
1260 REM data input complete ***********************************
1270 REM start simulation
1280 PRINT £D
1290 PRINT £D,"RANDOM NUMBER STREAM = ",Y
1300 FOR M=0 TO 15 STEP 2.5
1310 PRINT £D
1320 PRINT £D,"A'S MARK-UP = ",M,"%"
1330 PRINT £D
1340 C1=0\W=0\N=1
1350 C1=C1+1
1360 IF C1>C THEN 1580
1370 A=1+M/100\REM A=A's bid
1380 IF A$="N" THEN 1400
1390 PRINT £D,%4I,C1,%6I,B,%8F3,A
1400 REM generate random set of competitor's bids
1410 REM check if A's bid is the low bid
1420 REM
1430 B1=0\W1=1
1440 B1=B1+1
1450 IF B1>B THEN 1520
1460 GOSUB 1680\REM generate random bid
1470 IF A$="N" THEN 1490
1480 PRINT £D,TAB(24),%12F2,X
1490 IF A<X THEN 1440
1500 W1=0
1510 GOTO 1440
1520 REM
1530 IF W1=0 THEN 1550
1540 W=W+W1
1550 REM
1560 GOTO 1350
1570 REM PRINT SUMMARY OF SIMULATION ***************************
1580 PRINT £D
1590 PRINT £D,"******* SUMMARY OF A'S BIDDING ****************"
1600 PRINT £D,"A'S MARK-UP =",M,"%"
1610 PRINT £D,"NR OF JOBS BID FOR =",C
```

```
1620 PRINT £D,"NR OF JOBS WON =",W
1630 PRINT £D,"SUCCESS RATIO =",W/C*100,"%"
1640 PRINT £D,"**********************************************"
1550 NEXT M
1660 STOP
1670 REM
1680 REM subroutine generates competitor's bid
1690 GOSUB 1750
1700 FOR I=2 TO 6
1710 IF R>X1(I) THEN 1740
1720 X=0.9+(I-2)*0.1+(R-X1(I-1))/(X1(1)-X1(I-1))*0.1
1730 RETURN
1740 NEXT I
1750 REM subroutine generates random fractions -- range 0 - 1
1760 IF N>1 THEN 1860
1770 N=2
1780 DATA 1023,657,1207,779,831
1790 DATA 1153,511,1317,923,473
1800 FOR Z=1 TO 10
1810 READ F1(Z)
1820 NEXT Z
1830 RESTORE 1780
1840 M1=2^18
1850 K1=509
1860 F2(Y)=F1(Y)
1870 F3=K1*F2(Y)
1880 F4=INT(F3/M1)
1890 F1(Y)=F3-F4*M1
1900 R=ABS(F1(Y)/M1)
1910 RETURN
1920 STOP
1930 END
```

2.2 A sample of program output

```
*************************************************
*** SIMPLE FRIEDMAN MODEL -- PROG BIDMOD2     ***
*** This model samples competitors 'bids' from ***
*** the cdf of a fixed set of bid/cost ratios ***
*** The number of competitors (ex A) is 5     ***
*** Output: A's success ratio for each 2.5%   ***
*** increment of A's mark-up in range 0-15%   ***
*************************************************

NR OF JOBS SIMULATED FOR EACH INCREMENT OF A,S MARK-UP =  5


RANDOM NUMBER STREAM =  9

A'S MARK-UP =  0%

   1      5   1.000
                                1.24
                                1.07
                                1.17
                                1.16
                                1.15
   2      5   1.000
                                1.03
                                1.18
                                1.07
                                1.04
                                1.34
   3      5   1.000
                                1.25
                                1.10
                                1.22
                                1.25
                                1.10
   4      5   1.000
                                1.25
                                1.11
                                1.13
                                1.13
                                1.36
   5      5   1.000
                                1.15
                                1.03
                                1.18
                                1.35
                                1.14

******* SUMMARY OF A'S BIDDING ****************
A'S MARK-UP = 0%
NR OF JOBS BID FOR = 5
NR OF JOBS WON = 5
SUCCESS RATIO = 100%
***********************************************
```

APPENDIX 3

THE ESTIMATING ERROR MODEL

(BIDMOD3)

3.1 List of computer program

```
1000 REM --- PROGRAM BIDMOD 3
1010 PRINT "OUTPUT TO SCREEN TYPE 0, TO PRINTER TYPE 1 ",\INPUT Z
1020 PRINT £Z\PRINT £Z
1030 PRINT £Z,"** BIDDING MODEL ----- PROG BIDMOD3                        **"
1040 PRINT £Z,"** EXAMPLE USING DEDICATED DATA FOR COMPETITORS  **"
1050 PRINT £Z,"** THERE ARE 5 COMPETITORS, ALL COMPETITORS HAVE **"
1060 PRINT £Z,"** A MARK-UP OF 10% AND AN ESTIMATING ERROR OF    **"
1070 PRINT £Z,"** 10%                                              **"
1076 PRINT £Z,"** A'S ESTIMATING ERROR VARIES 0,5,10 AND 15%     **"
1077 PRINT £Z,"** A'S MARK-UP VARIES 0-16% IN 2% INCREMENTS      **"
1080 PRINT "TYPE IN NUMBER OF JOBS TO BE SIMULATED ",\INPUT N1
1090 REM ******************************************** START SIMULATION
1100 DIM P(5,10),R(5,10),V(5,10)
1110 I=0\FOR E=0 TO 15 STEP 5\I=I+1\J=0\FOR M=0 TO 16 STEP 2\N=0\S=0\J=J+1
1120 FOR K=1 TO N1\A=(1-E/100)*(1+M/100)+RND(0)*(1+M/100)*E/50
1130 FOR L=1 TO 5\B=0.99+RND(0)*0.22\IF A>B THEN EXIT 1150\NEXT L
1140 N=N+1\S=S+A\REM --- A'S BID HAS BEEN SUCCESSFUL
1150 NEXT K
1160 IF N=0 THEN 1180
1170 R(I,J)=N/N1*100\P(I,J)=(S/N-1)*100\V(I,J)=P(I,J)*N/N1
1180 PRINT "ESTIMATING ERROR = ",E,"   MARK-UP = ",M\NEXT M\NEXT E
1190 REM ********************************************** END SIMULATION
1195 PRINT £Z\PRINT £Z," NUMBER OF JOBS SIMULATED = ",N1\PRINT £Z
1200 I=0\FOR E=0 TO 15 STEP 5\I=I+1
1210 PRINT £Z\PRINT £Z," A'S ESTIMATING ERROR = ",%4F1,E,"%"\PRINT £Z
1220 PRINT £Z,TAB(30),"A'S MARK-UP (%)"
1230 PRINT £Z,TAB(20),"      0      2      4      6      8     10     12     14     16"
1240 PRINT £Z
1250 PRINT £Z,"SUCCESS RATIO (%)",
1260 J=0\FOR M=0 TO 16 STEP 2\J=J+1\PRINT £Z,TAB(22+3*M),%4F1,R(I,J),\NEXT M
1270 PRINT £Z
1280 PRINT £Z,"AVERAGE PROFIT (%)",
1290 J=0\FOR M=0 TO 16 STEP 2\J=J+1\PRINT £Z,TAB(22+3*M),%4F1,P(I,J),\NEXT M
1300 PRINT £Z
1310 PRINT £Z,"EXPECTED VALUE (%)",
1320 J=0\FOR M=0 TO 16 STEP 2\J=J+1\PRINT £Z,TAB(22+3*M),%4F1,V(I,J),\NEXT M
1330 PRINT £Z\PRINT £Z
1340 NEXT E
1350 END
```

3.2 A sample of program output

```
** BIDDING MODEL ----- PROG BIDMOD 3                    **
** EXAMPLE USING DEDICATED DATA FOR COMPETITORS        **
** THERE ARE 5 COMPETITORS, ALL COMPETITORS HAVE       **
** A MARK-UP OF 10% AND AN ESTIMATING ERROR OF         **
** 10%                                                 **
** A'S ESTIMATING ERROR VARIES 0,5,10 AND 15%           **
** A'S MARK-UP VARIES 0-16% IN 2% INCREMENTS           **
```

NUMBER OF JOBS SIMULATED = 500

A'S ESTIMATING ERROR = .0%

	A'S MARK-UP (%)								
	0	2	4	6	8	10	12	14	16
SUCCESS RATIO (%)	81.4	46.0	26.6	18.4	7.2	3.8	1.8	.4	.0
AVERAGE PROFIT (%)	.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	.0
EXPECTED VALUE (%)	.0	.9	1.1	1.1	.6	.4	.2	.1	.0

A'S ESTIMATING ERROR = 5.0%

	A'S MARK-UP (%)								
	0	2	4	6	8	10	12	14	16
SUCCESS RATIO (%)	71.6	56.6	38.2	20.6	11.6	5.4	2.0	1.2	.4
AVERAGE PROFIT (%)	-1.2	.3	1.7	3.9	5.1	6.7	9.2	9.6	11.4
EXPECTED VALUE (%)	-.9	.2	.7	.8	.6	.4	.2	.1	.0

A'S ESTIMATING ERROR = 10.0%

	A'S MARK-UP (%)								
	0	2	4	6	8	10	12	14	16
SUCCESS RATIO (%)	66.8	54.0	43.8	33.2	22.8	15.0	10.0	5.2	2.2
AVERAGE PROFIT (%)	-3.5	-2.4	-1.2	-.5	.3	2.0	3.5	5.3	6.9
EXPECTED VALUE (%)	-2.4	-1.3	-.5	-.2	.1	.3	.4	.3	.2

A'S ESTIMATING ERROR = 15.0%

	A'S MARK-UP (%)								
	0	2	4	6	8	10	12	14	16
SUCCESS RATIO (%)	60.4	51.4	48.2	38.8	35.4	27.2	20.8	17.4	11.8
AVERAGE PROFIT (%)	-6.3	-4.6	-4.2	-3.0	-2.8	-.7	-.9	.8	1.9
EXPECTED VALUE (%)	-3.8	-2.3	-2.0	-1.2	-1.0	-.2	-.2	.1	.2

APPENDIX 4

COMPUTER PROGRAMS FOR CALCULATING MEAN, STANDARD DEVIATION, COEFFICIENT OF VARIATION AND PERCENTAGE SPREAD FOR THREE DATA SETS

```
4 REM THIS PROGRAMME IS CALLED BIDA20
5 DIM M1(60),N1(60),C1(60,10)
10 PRINT "FOR OUTPUT TO PRINTER TYPE 1"
20 PRINT "FOR OUTPUT TO SCREEN TYPE  0"
30 INPUT P
40 REM THIS PROGRAM   READ AND WRITE DATA FROM
50 REM DISC WHICH BELONGS TO DATA SET (A)
52 PRINT "TYPE IN NR OF JOBS",
53 INPUT N
54 PRINT "NR OF JOBS=",N
55 PRINT£P
60 OPEN£1,"DATA1,2"
80 FOR I=1 TO N
82 PRINT "JOB NR=",I
83 READ M1(I),N1(I)
84 WRITE£1,M1(I)
85 WRITE£1,N1(I)
86 PRINT " A'S BID=",M1(I)
87 PRINT "NR OF COMPETS=",N1(I)
100 FOR J=1 TO N1(I)
150 READ C1(I,J)
200 WRITE£1,C1(I,J)
250 PRINT "  COMPT  ",J,"'S BID=",C1(I,J)
300 NEXT J
400 NEXT I
620 CLOSE£1
700 PRINT "TYPE IN NR JOBS",
710 INPUT N
720 PRINT£P,"NR OF JOBS =",N
730 PRINT£P
800 OPEN£1,"DATA1,2"
910 FOR I=1 TO N
911 PRINT£P,"JOB NR=",I
915 READ£1,M1(I)\READ£1,N1(I)
916 PRINT£P,"A'S BID=",M1(I)
917 PRINT£P,"NR OF COMPTS=",N1(I)
920 FOR J=1 TO N1(I)
925 READ£1,C1(I,J)
962 PRINT£P,"  COMPT  ",J,"'S BID=",C1(I,J)
970 NEXT J
980 NEXT I
990 CLOSE£1
992 REM FOLLOWING DATA BELONG TO OUR BID AND NUMBER OF
994 REM COMPETITORS AND COMPETITORS'BIDS
996 DATA 6696,3,5879,6069,8740
998 DATA 3978,5,3142,3530,3550,3717,4552
1000 DATA 1587,6,1379,1437,1480,1501,1611,1615
1010 DATA 8496,5,6942,7701,8803,8900,9382
1020 DATA 9594,5,8992,9453,10346,10437,10521
1030 DATA 4426,5,3572,3900,4216,4252,4523
1040 DATA 3728,5,3283,3581,3668,3744,3915
1050 DATA 10181,4,9918,10416,10603,11414
1060 DATA 3337,4,3098,3779,3842,3966
1070 DATA 10210,5,9760,10220,10424,10472,11921
1080 DATA 2805,5,2653,2647,2853,3200,3264
1090 DATA 7273,6,6227,6902,7248,7338,7508,7804
1100 DATA 1860,4,1648,1784,1795,1912
1110 DATA 129,4,92,95,106,120
1120 DATA 6290,5,5852,5866,6165,6209,7004
1130 DATA 1792,5,1629,1707,1708,1787,2293
1140 DATA 438,5,385,443,505,515,525
1150 DATA 5172,4,4538,4801,5159,5307
```

```
1160 DATA 14,4,5,9,12,13
1170 DATA 9072,6,8054,8534,8953,9469,9741,9774
1180 DATA 1923,10,1932,2069,2015,2025,2096,2112,2119,2284,2324,2534
1190 DATA 6262,5,5598,6262,6331,6484,6948
1200 DATA 200,5,146,162,176,194,222
1210 DATA 1868,5,1608,1751,1763,1826,1842
1220 DATA 4642,3,4437,4704,6021
1230 DATA 12504,5,10487,10908,12567,13381,15443
1240 DATA 456,4,454,510,579,637
1250 DATA 390,6,278,289,302,305,315,315
1260 DATA 1268,4,1033,1103,1117,1332
1270 DATA 2211,5,1979,2105,2122,2133,2285
1280 DATA 525,6,431,474,503,507,510,526
1290 DATA 567,4,563,623,641,680
1300 DATA 189,5,155,157,158,160,168
1310 DATA 9695,5,7589,7947,8000,8548,9148
1320 DATA 12621,4,10124,10549,10663,10931
1330 DATA 326,5,250,340,371,389,401
1340 DATA 4996,4,4390,4405,4808,5095
1350 DATA 656,5,575,605,708,725,748
1360 DATA 4567,4,4259,4276,4667,5247
1370 DATA 2555,6,2174,2252,2255,2333,2443,2464
1390 DATA 3760,5,3575,3608,3681,3932,4147
1400 DATA 29,7,15,20,20,27,30,31,33
1410 DATA 642,5,694,739,756,769,945
1420 DATA 2300,5,2080,2134,2218,2253,2560
1430 DATA 3988,6,3782,4147,4148,4379,4413,4553
1440 DATA 1596,5,1361,1455,1460,1574,1948
1450 DATA 10992,5,9721,9998,10255,10437,11013
1500 END
```

```
4 REM THIS PROGRAMME IS CALLED BIDA21
5 DIM M1(60),N1(60),C1(60,10)
10 PRINT "FOR OUTPUT TO PRINTER TYPE 1"
20 PRINT "FOR OUTPUT TO SCREEN TYPE  0"
30 INPUT P
40 REM THIS PROGRAM WRREAD AND WRITE DATA FROM
50 REM DISC WHICH BELONGS TO DATA SET (B)
52 PRINT "TYPE IN NR OF JOBS",
53 INPUT N
54 PRINT "NR OF JOBS=",N
55 PRINT£P
60 OPEN£1,"DATA2,2"
80 FOR I=1 TO N
82 PRINT "JOB NR=",I
83 READ M1(I),N1(I)
84 WRITE£1,M1(I)
85 WRITE£1,N1(I)
86 PRINT " A'S BID=",M1(I)
87 PRINT "NR OF COMPETS=",N1(I)
100 FOR J=1 TO N1(I)
150 READ C1(I,J)
200 WRITE£1,C1(I,J)
250 PRINT "  COMPT  ",J,"'S BID=",C1(I,J)
300 NEXT J
400 NEXT I
620 CLOSE£1
700 PRINT "TYPE IN NR JOBS",
710 INPUT N
720 PRINT£P,"NR OF JOBS =",N
730 PRINT£P
800 OPEN£1,"DATA2,2"
910 FOR I=1 TO N
911 PRINT£P,"JOB NR=",I
915 READ£1,M1(I)\READ£1,N1(I)
916 PRINT£P,"A'S BID=",M1(I)
917 PRINT£P,"NR OF COMPTS=",N1(I)
920 FOR J=1 TO N1(I)
925 READ£1,C1(I,J)
962 PRINT£P,"  COMPT  ",J,"'S BID=",C1(I,J)
970 NEXT J
980 NEXT I
990 CLOSE£1
992 REM FOLLOWING DATA BELONG TO OUR BID AND NUMBER OF
994 REM COMPETITORS AND COMPETITORS'BIDS
1000 DATA 2950,5,2540,2840,2870,2980,3050
1100 DATA 2930,5,2920,2990,3110,3200,3510
1200 DATA 3480,6,3340,3360,3560,3630,3790,3920
1300 DATA 10640,5,10290,10380,10610,10670,10850
1400 DATA 23770,5,23000,23160,24220,24500,26250
1500 DATA 8990,7,9010,9160,9430,9970,10080,10430,11070
2000 END
```

```
4 REM THIS PROGRAMME IS CALLED BIDA22
5 DIM M1(60),N1(60),C1(60,20)
10 PRINT "FOR OUTPUT TO PRINTER TYPE 1"
20 PRINT "FOR OUTPUT TO SCREEN TYPE  0"
30 INPUT P
40 REM THIS PROGRAM WRREAD AND WRITE DATA FROM
50 REM DISC WHICH BELONGS TO DATA SET (C)
52 PRINT "TYPE IN NR OF JOBS",
53 INPUT N
54 PRINT "NR OF JOBS=",N
55 PRINT£P
60 OPEN£1,"DATA3,2"
80 FOR I=1 TO N
82 PRINT "JOB NR=",I
83 READ M1(I),N1(I)
84 WRITE£1,M1(I)
85 WRITE£1,N1(I)
86 PRINT " A'S BID=",M1(I)
87 PRINT "NR OF COMPETS=",N1(I)
100 FOR J=1 TO N1(I)
150 READ C1(I,J)
200 WRITE£1,C1(I,J)
250 PRINT "  COMPT  ",J,"'S BID=",C1(I,J)
300 NEXT J
400 NEXT I
620 CLOSE£1
700 PRINT "TYPE IN NR JOBS",
710 INPUT N
720 PRINT£P,"NR OF JOBS =",N
730 PRINT£P
800 OPEN£1,"DATA3,2"
910 FOR I=1 TO N
911 PRINT£P,"JOB NR=",I
915 READ£1,M1(I)\READ£1,N1(I)
916 PRINT£P,"A'S BID=",M1(I)
917 PRINT£P,"NR OF COMPTS=",N1(I)
920 FOR J=1 TO N1(I)
925 READ£1,C1(I,J)
962 PRINT£P,"  COMPT  ",J,"'S BID=",C1(I,J)
970 NEXT J
980 NEXT I
990 CLOSE£1
992 REM FOLLOWING DATA BELONG TO OUR BID AND NUMBER OF
994 REM COMPETITORS AND COMPETITORS'BIDS
1000 DATA 74902,4,37536,40362,43445,45476
1010 DATA 645180,1,608682
1020 DATA 440869,9,457877,480914,486152,491031,496479
1025 DATA 521608,539071,541895,597249
1030 DATA 5849786,6,5017163,5262099,5504587
1035 DATA 5741968,5995652,6349429
1040 DATA 116597,4,118354,126675,132579,133335
1050 DATA 1092610,3,1023212,1079787,1322039
1055 DATA 6675074,7,5544638,6277917,11207071
1060 DATA 11254339,11455085,12377960,12653625
1070 DATA 209967,6,219465,219741,224123,227261,233008,244354
1080 DATA 11262500,6,10239606,10680407,10900573
1085 DATA 11349921,11374157,11667519
1090 DATA 216850,6,89922,108558,109356,109969,130416,131507
1100 DATA 321406,4,249208,357352,365118,433414
1110 DATA 103706,5,88193,90066,94122,106456,112380
1120 DATA 147333,5,113790,116477,128314,148076,208716
1130 DATA 663462,5,451050,524507,535662,729765,736562
```

```
1140 DATA 1798928,4,1720174,1752484,1955490,2011426
1150 DATA 23709_,4,195691,202744,212809,251139
1160 DATA 3000546,7,2950039,3042619,3185485,3353701
1165 DATA 3474939,3649202,3773076
1170 DATA 68868,4,71030,75870,88854,104558
1180 DATA 172600,12,104151,108993,113371,116632,117244
1185 DATA 119641,122509,122512,132626,140058,145057,168645
1190 DATA 6866893,5,7473782,7603270,7741660,7991811,8213620
1200 DATA 102030,5,111309,112372,119958,120811,127154
1210 DATA 193402,7,160276,166372,176448,196319
1215 DATA 199604,205562,224714
1220 DATA 65796,3,60500,61443,65681
1230 DATA 1395212,4,1268500,1281129,1378579,1392700
1240 DATA 1400768,5,1148456,1203100,1264574,1285871,1400768
1250 DATA 154635,5,139624,148071,161177,161990,162653
1260 DATA 1184446,3,1106567,1108525,1292794
1270 DATA 48569,4,40921,43098,45771,48639
1280 DATA 2248652,13,1898064,1986531,2017154,2033405,2054965
1285 DATA 2076961,2159794,2167292,2209062,2233157
1286 DATA 2380029,2668186,2886609
1290 DATA 3097689,4,3261869,3267619,3410000,3840944
1300 DATA 7788910,7,7680910,7745486,7972836,8096221,8404338
1305 DATA 8445533,8621069
1310 DATA 47200,4,45531,57700,59844,94304
1320 DATA 104643,7,115526,121541,124070,134748,144013,152000,186467
1330 DATA 4267600,6,4513080,4624706,4717659
1335 DATA 4758845,4890596,4964468
1340 DATA 611850.7,50_148,524777,531621,558893,573138
1345 DATA 576202,653078
1350 DATA 194126,6,227545,237282,258654,273013,282429,298575
1360 DATA 214826,2,192608,223174
1370 DATA 1204607,2,1175670,1215536
1380 DATA 131266,4,90826,92646,124212,134766
1390 DATA 997453,6,953241,981175,1070189,1014061,1019969,1032702
1500 END
```

```
10 REM ****PROG BIDA11****
15 REM THIS PROGRAMME COMPUTES BID/COST RATIOS AND
16 REM PRODUCES TABLE OF STATISTICS FOR DATA SET (B)
20 PRINT "FOR OUTPUT TO SREEN TYPE 0  TO PRINTER TYPE 1"
30 INPUT P
100 DIM A(60),N(60),C(60,10),V2(60,10),C1(60)
110 DIM V3(60),V4(60),V5(60)
150 PRINT "TOTAL NR OF JOBS BID FOR=",
160 INPUT N
170 PRINT
180 PRINT£P,"NR OF JOBS BID FOR=",N
185 PRINT£P
190 S1=0
200 OPEN£1,"DATA5,2"
210 FOR I=1 TO N
215 PRINT£P,"------------------------------"
220 PRINT£P,"NEXT JOB NR=",I
230 READ£1,A(I)
240 PRINT£P,"A'S BID IN £K=",A(I)
242 READ£1,C1(I)
246 PRINT£P,"A'S COST ESTIMATE=",C1(I)
250 READ£1,N(I)
260 PRINT£P,"NR OF COMPETS'=",N(I)
265 PRINT£P
270 N3=N(I)
280 PRINT£P,"  LIST OF COMPETS' BIDS"
290 FOR J=1 TO N(I)
300 READ£1,C(I,J)
305 PRINT£P
310 PRINT£P,"  COMP ",J,"'S BID IN £K=",C(I,J)
330 B(J)=C(I,J)
340 NEXT J
345 GOSUB 1000
350 NEXT I
360 CLOSE£1
400 REM ***********************************
405 REM ****PRINT RESULTS****
410 PRINT£D,"***TABLE OF BID/COST RATIOS***"
420 PRINT£D
430 FOR I1=1 TO N
440 PRINT£D,"**JOB NR:",I1,
450 FOR J1=1 TO N(I1)
460 PRINT£D,%8F2,V2(I1,J1),
470 NEXT J1
480 PRINT£D
490 NEXT I1
500 PRINT£D
510 PRINT£D,"***TABLE OF BIDDING STATISTICS***"
520 PRINT£D
530 PRINT£D,"COEFF OF   MEAN BID/    SPREAD"
540 PRINT£D,"VARIATION  LOW BID%"
550 PRINT£D
560 FOR I1=1 TO N
570 PRINT£D,%6F2,V3(I1),%13F2,V4(I1),V5(I1)
580 NEXT I1
590 REM *** END OF MAIN PROG***
600 STOP
1000 REM ****SUBROUTINE****
1010 REM COMPUTES THE FOLLOWINGS
1020 REM BID/COST RATIOS
```

```
1030 REM COEFF OF VARIATION FOR EACH JOB
1040 REM MEAN BID/LOW BID%



1050 REM SPREAD
1060 REM
1100 S1=0
1110 FOR J2=1 TO N3
1120 S1=S1+B(J2)
1130 V2(I,J2)=B(J2)/C1(I)
1140 NEXT J2
1150 REM X1=MEAN BID
1170 X1=(S1+A(I))/(N3+1)
1175 PRINT£P
1180 PRINT£P,"MEAN BID=",X1
1190 PRINT£P
1200 S2=0
1210 FOR J2=1 TO N3
1220 S2=S2+(B(J2)-X1)^2
1230 NEXT J2
1250 S2=S2+(A(I)-X1)^2
1260 REM X2=STD DEVIATION OF BIDS
1270 X2=SQRT(S2/N3)
1280 PRINT£P,"STD DEVIATION OF BIDS=",X2
1285 PRINT£P,"------------------------------"
1290 PRINT£P
1310 REM V3(I)=COEFF OF VARIATION OF BIDS FOR JOB I
1320 V3(I)=X2/X1
1330 IF A(I)<B(1)  THEN 1500
1340 REM V4(I)=MEAN BID/LOW BID%
1350 V4(I)=X1/B(1)*100
1360 REM V5(I)=SPREAD
1370 V5(I)=(B(2)-B(1))/B(1)*100
1400 GOTO 2000
1500 V4(I)=X1/A(I)*100
1600 V5(I)=(B(1)-A(I))/A(I)*100
2000 RETURN
3000 END
```

TABLE OF BID/COST RATIOS

**JOB NR: 1	.97	1.00	1.44							
**JOB NR: 2	.87	.98	.98	1.03	1.26					
**JOB NR: 3	.96	1.00	1.03	1.04	1.12	1.12				
**JOB NR: 4	.90	1.00	1.14	1.15	1.21					
**JOB NR: 5	1.03	1.08	1.19	1.20	1.21					
**JOB NR: 6	.89	.97	1.05	1.06	1.12					
**JOB NR: 7	.97	1.06	1.08	1.10	1.16					
**JOB NR: 8	1.07	1.13	1.15	1.23						
**JOB NR: 9	1.02	1.25	1.27	1.31						
**JOB NR: 10	1.05	1.10	1.12	1.13	1.28					
**JOB NR: 11	1.04	1.04	1.12	1.25	1.28					
**JOB NR: 12	.94	1.04	1.10	1.11	1.14	1.18				
**JOB NR: 13	.98	1.06	1.06	1.13						
**JOB NR: 14	.79	.81	.91	1.03						
**JOB NR: 15	1.02	1.03	1.08	1.09	1.22					
**JOB NR: 16	1.00	1.05	1.05	1.10	1.41					
**JOB NR: 17	.97	1.11	1.27	1.29	1.32					
**JOB NR: 18	.97	1.02	1.10	1.13						
**JOB NR: 19	.42	.75	1.00	1.08						
**JOB NR: 20	.98	1.03	1.09	1.15	1.18	1.19				
**JOB NR: 21	1.11	1.18	1.15	1.16	1.20	1.21	1.21	1.31	1.33	1.45
**JOB NR: 22	.98	1.10	1.11	1.14	1.22					
**JOB NR: 23	.82	.90	.97	1.07	1.23					
**JOB NR: 24	.95	1.03	1.04	1.08	1.08					
**JOB NR: 25	1.05	1.11	1.43							
**JOB NR: 26	.92	.96	1.11	1.18	1.36					
**JOB NR: 27	1.10	1.23	1.40	1.54						
**JOB NR: 28	.79	.82	.85	.86	.89	.89				
**JOB NR: 29	.90	.96	.97	1.16						
**JOB NR: 30	.98	1.05	1.06	1.06	1.14					
**JOB NR: 31	.90	.99	1.05	1.06	1.07	1.10				
**JOB NR: 32	1.09	1.21	1.24	1.32						
**JOB NR: 33	.91	.92	.92	.94	.98					
**JOB NR: 34	.86	.90	.91	.97	1.04					
**JOB NR: 35	.88	.92	.93	.95						
**JOB NR: 36	.84	1.15	1.25	1.31	1.35					
**JOB NR: 37	.97	.97	1.06	1.12						
**JOB NR: 38	.96	1.02	1.19	1.22	1.26					
**JOB NR: 39	1.03	1.03	1.12	1.26						
**JOB NR: 40	.94	.97	.97	1.00	1.05	1.06				
**JOB NR: 41	1.05	1.06	1.08	1.15	1.21					
**JOB NR: 42	.58	.77	.77	1.04	1.15	1.19	1.27			
**JOB NR: 43	1.19	1.27	1.30	1.32	1.62					
**JOB NR: 44	1.00	1.02	1.06	1.08	1.22					
**JOB NR: 45	1.04	1.14	1.14	1.21	1.22	1.26				
**JOB NR: 46	.94	1.00	1.01	1.09	1.34					
**JOB NR: 47	.97	1.00	1.03	1.04	1.10					

BID/COST FREQUENCIES

NR BIDS= 233

NR IN RANGE -- .3 - .4 =	0
NR IN RANGE -- .4 - .5 =	1
NR IN RANGE -- .5 - .6 =	1
NR IN RANGE -- .6 - .7 =	0
NR IN RANGE -- .7 - .8 =	5
NR IN RANGE -- .8 - .9 =	15
NR IN RANGE -- .9 - 1.0 =	47
NR IN RANGE -- 1.0 - 1.1 =	67
NR IN RANGE -- 1.1 - 1.2 =	49
NR IN RANGE -- 1.2 - 1.3 =	31

NR IN RANGE -- 1.3 - 1.4 = 11
NR IN RANGE -- 1.4 - 1.5 = 4
NR IN RANGE -- 1.5 - 1.6 = 1
NR IN RANGE -- 1.6 - 1.7 = 1

(COMP BIDS/A'S EST COST) RATIO : MEAN = 1.08
STD DEV = .15

TABLE OF BIDDING STATISTICS

JOB NUM	COEFF OF VARIATION	MEAN BID/ LOW BID %	SPREAD %
1	.19	116.45	3.23
2	.13	119.16	12.35
3	.06	109.86	4.21
4	.11	120.57	10.93
5	.06	109.99	5.13
6	.09	116.13	9.18
7	.06	111.27	9.08
8	.05	105.93	5.02
9	.10	116.33	21.98
10	.07	107.59	4.71
11	.09	109.42	-.23
12	.07	115.38	10.84
13	.06	109.16	8.25
14	.14	117.39	3.26
15	.07	106.48	.24
16	.13	111.66	4.79
17	.12	121.56	15.06
18	.06	110.07	5.80
19	.30	200.00	80.00
20	.07	112.80	5.96
21	.09	110.76	.47
22	.07	112.79	11.86
23	.15	123.65	9.46
24	.05	110.45	8.89
25	.15	111.58	6.02
26	.14	119.65	4.01
27	.15	116.08	12.33
28	.12	112.59	3.96
29	.11	113.26	6.78
30	.05	108.08	6.37
31	.07	115.08	9.98
32	.08	109.06	10.66
33	.07	105.81	1.29
34	.09	111.83	4.72
35	.09	108.43	4.20
36	.16	138.40	36.00
37	.07	107.93	.34
38	.10	116.35	5.22
39	.09	108.08	.40
40	.06	108.23	3.59
41	.06	105.82	.92
42	.24	166.67	33.33
43	.13	117.91	8.10
44	.07	108.51	2.60
45	.06	111.08	9.65
46	.13	114.99	6.91
47	.05	107.01	2.85

TABLE OF BID/COST RATIOS

**JOB NR: 1	.90	1.01	1.02	1.06	1.09		
**JOB NR: 2	1.05	1.07	1.11	1.15	1.26		
**JOB NR: 3	1.01	1.01	1.07	1.10	1.14	1.18	
**JOB NR: 4	1.02	1.02	1.05	1.05	1.07		
**JOB NR: 5	1.02	1.02	1.07	1.08	1.16		
**JOB NR: 6	1.05	1.07	1.10	1.16	1.18	1.22	1.29

TABLE OF BIDDING STATISTICS

COEFF OF VARIATION	MEAN BID/ LOW BID%	SPREAD
.06	113.06	11.81
.07	106.51	2.40
.06	107.27	.60
.02	102.75	.87
.05	105.00	.70
.08	108.65	.22

TABLE OF BID/COST RATIOS

```
**JOB NR:  1    .55    .59    .64    .67
**JOB NR:  2  1.04
**JOB NR:  3  1.14   1.20   1.21   1.23   1.24   1.30   1.35   1.35   1.49
**JOB NR:  4    .94    .99   1.04   1.08   1.13   1.19
**JOB NR:  5  1.12   1.20   1.25   1.26
**JOB NR:  6  1.03   1.09   1.33
**JOB NR:  7    .91   1.03   1.85   1.85   1.89   2.04   2.09
**JOB NR:  8  1.15   1.15   1.17   1.19   1.22   1.28
**JOB NR:  9  1.00   1.04   1.06   1.11   1.11   1.14
**JOB NR: 10    .46    .55    .55    .56    .66    .67
**JOB NR: 11    .85   1.22   1.25   1.48
**JOB NR: 12    .94    .96   1.00   1.13   1.19
**JOB NR: 13    .85    .87    .96   1.11   1.56
**JOB NR: 14    .75    .87    .89   1.21   1.22
**JOB NR: 15  1.05   1.07   1.20   1.23
**JOB NR: 16    .91    .94    .99   1.17
**JOB NR: 17  1.08   1.12   1.17   1.23   1.27   1.34   1.38
**JOB NR: 18  1.13   1.21   1.42   1.67
**JOB NR: 19    .66    .69    .72    .74    .75    .76    .78    .78    .85    .89    .92
  1.07
**JOB NR: 20  1.20   1.22   1.24   1.28   1.32
**JOB NR: 21  1.20   1.21   1.29   1.30   1.37
**JOB NR: 22    .91    .95   1.00   1.12   1.14   1.17   1.28
**JOB NR: 23  1.01   1.03   1.10
**JOB NR: 24  1.00   1.01   1.09   1.10
**JOB NR: 25    .90    .94    .99   1.01   1.10
**JOB NR: 26    .99   1.05   1.15   1.15   1.16
**JOB NR: 27  1.03   1.03   1.20
**JOB NR: 28    .93    .98   1.04   1.10
**JOB NR: 29    .93    .97    .99    .99   1.01   1.02   1.06   1.06   1.08   1.09   1.16
  1.31  1.41
**JOB NR: 30  1.16   1.16   1.21   1.36
**JOB NR: 31  1.08   1.09   1.13   1.14   1.19   1.19   1.22
**JOB NR: 32  1.06   1.34   1.39   2.20
**JOB NR: 33  1.21   1.28   1.30   1.42   1.51   1.60   1.96
**JOB NR: 34  1.16   1.19   1.22   1.23   1.26   1.28
**JOB NR: 35    .90    .94    .96   1.00   1.03   1.04   1.17
**JOB NR: 36  1.29   1.34   1.47   1.55   1.60   1.69
**JOB NR: 37    .99   1.14
**JOB NR: 38  1.07   1.11
**JOB NR: 39    .76    .78   1.04   1.13
**JOB NR: 40  1.05   1.08   1.18   1.12   1.12   1.14
```

BID/COST FREQUENCIES

```
NR BIDS=  211
 NR IN RANGE --   .3 -   .4 =   0
 NR IN RANGE --   .4 -   .5 =   1
 NR IN RANGE --   .5 -   .6 =   5
 NR IN RANGE --   .6 -   .7 =   6
 NR IN RANGE --   .7 -   .8 =   9
 NR IN RANGE --   .8 -   .9 =   7
 NR IN RANGE --   .9 -  1.0 =  27
 NR IN RANGE --  1.0 -  1.1 =  42
```

```
NR IN RANGE -- 1.1 -  1.2 =  47
NR IN RANGE -- 1.2 -  1.3 =  32
NR IN RANGE -- 1.3 -  1.4 =  15
NR IN RANGE -- 1.4 -  1.5 =   6
NR IN RANGE -- 1.5 -  1.6 =   4
NR IN RANGE -- 1.6 -  1.7 =   3
```

```
(COMP BIDS/A'S EST COST) RATIO : MEAN      = 1.13
                                 STD DEV  =  .26
```

TABLE OF BIDDING STATISTICS

JOB NUM	COEFF OF VARIATION	MEAN BID/ LOW BID %	SPREAD %
1	.31	128.79	7.53
2	.04	103.00	-93.37
3	.09	114.62	3.86
4	.08	113.10	4.88
5	.06	107.64	1.51
6	.12	110.38	5.53
7	.31	174.60	13.23
8	.05	107.36	4.52
9	.04	108.09	4.30
10	.33	142.44	20.72
11	.19	138.56	43.40
12	.10	112.43	2.12
13	.24	126.36	2.36
14	.20	134.54	16.29
15	.07	107.41	1.88
16	.11	112.37	3.60
17	.09	111.99	3.14
18	.18	118.83	3.14
19	.17	124.38	4.65
20	.06	111.38	8.84
21	.08	113.30	9.09
22	.11	118.76	3.80
23	.04	104.72	1.56
24	.05	105.89	1.00
25	.08	111.80	4.76
26	.06	110.79	6.05
27	.07	106.01	.18
28	.07	110.94	5.32
29	.12	116.73	4.66
30	.08	108.97	5.30
31	.04	105.38	.84
32	.32	133.79	26.73
33	.19	129.37	10.40
34	.05	109.59	5.75
35	.09	113.01	4.71
36	.14	130.37	17.22
37	.08	109.13	15.87
38	.02	101.95	3.39
39	.19	126.33	2.00
40	.04	105.94	2.93

APPENDIX 5

FRIEDMAN BIDDING MODEL- BID20

5.1 List of Computer Program

```
10 PRINT  "OUTPUT TO SCREEN TYPE 0; TO PRINTER TYPE 1",
20 INPUT D
30 PRINT £D,"*********************************************"
40 PRINT £D,"** SIMULATION OF FRIEDMAN'S BIDDING MODELBID20 **"
50 PRINT £D,"** INCLUDING JOB VALUES AND ESTIMATING ERROR    **"
60 PRINT £D,"** FIXED MARK-UP MODEL                          **"
70 PRINT £D,"*********************************************"
80 PRINT £D,
90 PRINT "FOR END OF YEAR SUMMARY ONLY TYPE Y ELSE TYPE N ",
100 INPUT B$
110 PRINT "FOR JOB TABULATION TYPE Y ELSE TYPE N ",
120 INPUT A$
130 PRINT "SIMULATION OF FRIEDMAN BIDDING MODEL"
140 PRINT "TYPE IN THE FOLLOWING INFORMATION"
150 PRINT "TOTAL NR OF JOBS TO BE SIMULATED =",
160 INPUT C
170 PRINT "NR OF JOBS AVAILABLE PER YEAR =',
180 INPUT N4
190 PRINT "RANGE OF MARK UPS, HIGHEST FIRST AND STEP SIZE % "
200 PRINT "HIGHEST MARK-UP =",
210 INPUT M1
220 PRINT "LOWEST MARK-UP =",
230 INPUT M2
240 PRINT "STEP IN MARK-UP = ",
250 INPUT M3
260 PRINT    "FIRM A'S PERCENTAGE ESTIMATING ERROR =",
270 INPUT E
280 PRINT £D,"JOB VALUE DATA"
290 DATA 0.000,0.002,0.019,0.095
300 DATA 0.295,0.591,0.841,0.962
310 DATA 0.994,1.000
320 FOR I=1 TO 10
330 READ V(I)
340 PRINT £D,%7F2,V(I),
350 NEXT I
360 PRINT £D," "
370 PRINT £D,"NR OF BIDDERS DATA"
380 DATA 0.1,0.4,0.7,0.9,1.0
390 FOR I=1 TO 5
400 READ B(I)
410 PRINT £D,%7F2,B(I),
420 NEXT I
430 PRINT £D," "
440 PRINT £D,"BID/COST DATA"
450 DATA 0.00,0.05,0.30,0.70,0.95,1.00
460 FOR I=1 TO 6
470 READ X1(I)
480 PRINT £D,%7F2,X1(I),
490 NEXT I
500 PRINT £D," "
510 REM DATA INPUT COMPLETE *********************************
520 REM START SIMULATION
530 R1=0\ REM R1= RUN NR
540 FOR M=M1 TO M2 STEP -M3\R1=R1+1\N=1
550 PRINT £D,"****************************************"
560 PRINT £D,"SIMULATION RUN NR ",R1," FOR % MARK-UP ",M
570 PRINT £D,"****************************************"
580 A=1+M/100\ REM A=A'S BID/COST RATIO
590 C1=0\S=0\P=0\W=0
600 W2=0\S2=0\P2=0
610 Y1=1
620 C1=C1+1
```

```
630 IF C1>C THEN 1150
640 GOSUB 1270\ REM GEN RDM JOB VALUE V1 IN £K
650 A1=V1/1.15\ REM A1=A'S ESTIMATED COST IN £K
660 GOSUB 1570\ REM GEN RDM ESTIMATING ERROR E1
670 A3=A1*E1  \ REM A3=A'S ACTUAL COST IN £K
680 GOSUB 1390\ REM GEN RDM NR OF BIDS B
690 A2=A1*A   \ REM A2=A'S BID IN £K
700 IF A$="N" THEN 720
710 PRINT £D,%4I,C1,%12F0,1000*A2,%6I,B
720 REM   GEN RDM SET OF COMPETITORS BIDS
730 REM   CHECK IF A'S BID IS THE LOW BID
740 REM
750 B1=0\W1=1
760 B1=B1+1
770 IF B1>B THEN 840
780 GOSUB 1480\ REM GEN RDM COMPETITOR'S BID/COST RATIO X "
790 IF A$="N" THEN 810
800 PRINT £D,TAB(24),%12F0,1000*(X/1.15)*V1
810 IF A<X THEN 760
820 W1=0
830 GOTO 760
840 REM   IF A'S BID IS NOT THE
850 REM   WINNING BID THEN
860 REM   CONSIDER NEXT JOB
870 IF W1=0 THEN 1010
880 W=W+W1\S=S+A2
890 REM   COMPUTE PROFIT P1
900 P1=A2-A3\P=P+P1
910 IF B$="Y" THEN 1000
920 REM PRINT DETAILS OF WINNING BID **************************
930 PRINT £D," "
940 PRINT £D,"JOB NR =",C1
950 PRINT £D,"A'S MARK-UP =",M,"%"
960 PRINT £D,"A'S BID = £",INT(1000*A2)
970 PRINT £D,"A'S ESTIMATED COST = £",INT(1000*A1)
980 PRINT £D,"A'S ACTUAL COST = £",INT(1000*A3)
990 PRINT £D,"A'S PROFIT = £",INT(1000*A2-1000*A3)
1000 PRINT £D," "
1010 IF C1= INT(N4*Y1) THEN 1020 ELSE 620
1020 W3=W-W2\S3=INT(1000*S-S2)\P3=INT(1000*P-P2)
1030 PRINT £D," "
1040 PRINT £D,"******* END OF YEAR ",Y1
1050 PRINT £D,"        NR OF WINS =",W3
1060 PRINT £D,"        VALUE OF JOBS WON = £",S3
1070 PRINT £D,"        PROFIT = £",P3
1080 IF W3=0 THEN 1100
1090 PRINT £D,"        ACTUAL % PROFIT = ",%5F2,P3/(S3-P3)*100
1100 PRINT £D," "
1110 W2=W\S2=1000*S\P2=1000*P
1120 Y1=Y1+1
1130 GOTO 620
1140 REM PRINT SUMMARY OF SIMULATION **************************
1150 PRINT £D," "
1160 PRINT £D,"******* SUMMARY OF A'S BIDDING ****************"
1170 PRINT £D,"NR OF JOBS BID FOR =",C
1180 PRINT £D,"NR OF JOBS WON =",W
1190 PRINT £D,"SUCCESS RATIO =",W/C*100,"%"
1200 PRINT £D,"TOTAL VALUE OF JOBS WON = £",INT(1000*S)
1210 PRINT £D,"TOTAL PROFIT = £",INT(1000*P)
1220 PRINT £D,"**********************************************"
1230 PRINT £D," "
1240 PRINT £D," "
1250 NEXT M
```

```
1260 STOP
1270 REM   SUBROUTINE GENERATES JOB VALUES
1280 Y=1
1290 GOSUB 1620
1300 FOR I=1 TO 10
1310 REM
1320 IF R>V(I)  THEN 1380
1330 N1=(I-1)+(R-V(I-1))/(V(I)-V(I-1))
1340 REM   V1=BASIC JOB VALUE IN THOUSANDS OF POUNDS
1350 REM   BASED ON THE MEAN BID/COST RATIO OF 1.15
1360 V1=EXP(N1)
1370 RETURN
1380 NEXT I
1390 REM   SUBROUTINE GENERATES NR OF BIDDERS
1400 Y=2
1410 GOSUB 1620
1420 FOR I=1 TO 5
1430 REM
1440 IF R>B(I) THEN 1470
1450 B=4+I
1460 RETURN
1470 NEXT I
1480 REM   SUBROUTINE GENERATES BID/COST RATIOS
1490 Y=3
1500 GOSUB 1620
1510 FOR I=2 TO 6
1520 REM
1530 IF R>X1(I) THEN 1560
1540 X=0.9+(I-2)*0.1+(R-X1(I-1))/(X1(I)-X1(I-1))*0.1
1550 RETURN
1560 NEXT I
1570 REM   SUBROUTINE GENERATES ESTIMATING ERROR
1580 Y=4
1590 GOSUB 1620
1600 E1=(1-E/100)+2*E/100*R
1610 RETURN
1620 REM   SUBROUTINE GENERATES RANDOM FRACTIONS
1630 REM
1640 IF N>1 THEN 1750
1650 N=2
1660 RESTORE 1670
1670 DATA 1023,657,1207,779,831
1680 DATA 1153,511,1317,923,473
1690 FOR Z=1 TO 10
1700 READ F1(Z)
1710 PRINT "F1(Z)= ",F1(Z)
1720 NEXT Z
1730 M1=2^18
1740 K1=509
1750 F2(Y)=F1(Y)
1760 F3=K1*F2(Y)
1770 F4=INT(F3/M1)
1780 F1(Y)=F3-F4*M1
1790 R=ABS(F1(Y)/M1)
1800 RETURN
1810 STOP
1820 END
```

5.2 A Sample of Program Output

```
**************************************************
** SIMULATION OF FRIEDMAN'S BIDDING MODEL       **
** INCLUDING JOB VALUES AND ESTIMATING ERROR    **
** FIXED MARK-UP MODEL                          **
**************************************************
JOB VALUE DATA
   .00    .00    .02    .10    .30    .59    .84    .96    .99   1.00
NR OF BIDDERS DATA
   .10    .40    .70    .90   1.00
BID/COST DATA
   .00    .05    .30    .70    .95   1.00
******************************************
SIMULATION RUN NR  1 FOR % MARK-UP  2
******************************************
   1    5657018.     6
                         6161171.
                         7092144.
                         6414178.
                         6826610.
                         6519380.
                         6235542.

   2      25698.     6
                           26695.
                           27023.
                           31454.
                           34744.
                           30057.
                           25355.
   3     995778.     7
                         1136390.
                          984021.
                         1141113.
                         1256672.
                         1076836.
                         1237238.
                         1329558.
   4     277103.     7
                          299056.
                          301840.
                          288582.
                          323848.
                          281426.
                          282218.
                          343344.

   5     134638.     5
                          152423.
                          137081.
                          150207.
                          177586.
                          134510.

******* END OF YEAR  1
        NR OF WINS = 2
        VALUE OF JOBS WON = £ 5934121
        PROFIT = £ 78832
        ACTUAL % PROFIT =  1.35

   6     313662.     9
                          366569.
                          315211.
                          339082.
```

```
                                      316458.
                                      351160.
                                      312298.
                                      332937.
                                      365908.
                                      372970.
   7    3714363.     8
                                     4343165.
                                     4084286.
                                     4320383.
                                     4323328.
                                     3999067.
                                     4084953.
                                     3411959.
                                     4101734.
   8      79707.     7
                                       87926.
                                      101475.
                                       94258.
                                       82867.
                                       87009.
                                       78695.
                                       88117.
   9      41888.     7
                                       53038.
                                       49826.
                                       44022.
                                       38703.
                                       50980.
                                       56499.
                                       51532.
  10     660300.     6
                                      655762.
                                      879289.
                                      725502.
                                      825120.
                                      695263.
                                      765003.

******* END OF YEAR  2
        NR OF WINS = 0
        VALUE OF JOBS WON = £ 0
        PROFIT = £ 0

******* SUMMARY OF A'S BIDDING *****************
NR OF JOBS BID FOR = 10
NR OF JOBS WON = 2
SUCCESS RATIO = 20%
TOTAL VALUE OF JOBS WON = £ 5934121
TOTAL PROFIT = £ 78832
************************************************

****************************************
SIMULATION RUN NR  2 FOR % MARK-UP  1
****************************************
   1    5601558.     6
                                     6161171.
                                     7092144.
```

```
                              6414178.
                              6826610.
                              6519380.



                              6235542.

  2     25446.      6
                                26695.
                                27023.
                                31454.
                                34744.
                                30057.
                                25355.
  3    986016.      7
                              1136390.
                               984021.
                              1141113.
                              1256672.
                              1076836.
                              1237238.
                              1329558.
  4    274387.      7
                               299056.
                               301840.
                               288582.
                               323848.
                               281426.
                               282218.
                               343344.

  5    133318.      5
                               152423.
                               137081.
                               150207.
                               177586.
                               134510.

******* END OF YEAR  1
        NR OF WINS = 3
        VALUE OF JOBS WON = £ 6009261
        PROFIT = £ 24584
        ACTUAL % PROFIT =    .41

  6    310587.      9
                               366569.
                               315211.
                               339082.
                               316458.
                               351160.
                               312298.
                               332937.
                               365908.
                               372970.

  7   3677948.      8
                              4343165.
                              4084286.
                              4320383.
                              4323328.
                              3999067.
```

```
                                     4084953.
                                     3411959.
                                     4101734.
   8       78926.        7
                                       87926.
                                      101475.




                                       94258.
                                       82867.
                                       87009.
                                       78695.
                                       88117.
   9       41477.        7
                                       53038.
                                       49826.
                                       44022.
                                       38703.
                                       50980.
                                       56499.
                                       51532.
  10      653827.        6
                                      655762.
                                      879289.
                                      725502.
                                      825120.
                                      695263.
                                      765003.

******* END OF YEAR  2
        NR OF WINS = 2
        VALUE OF JOBS WON = £ 964413
        PROFIT = £ -59
        ACTUAL % PROFIT =  -.01

******* SUMMARY OF A'S BIDDING *****************
NR OF JOBS BID FOR = 10
NR OF JOBS WON = 5
SUCCESS RATIO = 50%
TOTAL VALUE OF JOBS WON = £ 6973675
TOTAL PROFIT = £ 24526
************************************************
```

APPENDIX 6

SIMULATION BIDDING MODEL - BIDMOD9

6.1 List of Computer Program

```
10 PRINT  "OUTPUT TO SCREEN TYPE 0; TO PRINTER TYPE 1",
20 INPUT D
30 PRINT £D,"***************************************************"
40 PRINT £D,"** BIDDING MODEL: BIDMOD9                        **"
50 PRINT £D,"** INCLUDES RANDOM SAMPLING FROM THE FOLLOWING   **"
60 PRINT £D,"** DISTRIBUTIONS:                                **"
70 PRINT £D,"**     NUMBER OF BIDDERS: FIXED RANGE 5-9        **"
80 PRINT £D,"**     JOB VALUES: FIXED RANGE £6K-£15M (APPROX) **"
90 PRINT £D,"**     ESTIMATING ERROR: INPUTTED RANGE          **"
100 PRINT £D,"**     THEIR MARK-UP: INPuTTED RANGE             **"
110 PRINT £D,"**     RATIO OF 'THEIR TRUE COST' TO 'OUR TRUE   **"
120 PRINT £D,"**     COST': INPUTTED RANGE                     **"
130 PRINT £D,"** ALL INPUTTED PARAMETERS RELATE TO UNIFORM     **"
140 PRINT £D,"** DISTRIBUTIONS                                 **"
150 PRINT £D,"***************************************************"
160 PRINT £D
170 PRINT "FOR JOB TABULATION TYPE Y ELSE TYPE N ",
180 INPUT A$\D1=0\IF A$="N" THEN LET D1=0
190 PRINT "SIMULATION OF BIDDING MODEL: BIDMOD9"
200 PRINT "TYPE IN THE FOLLOWING INFORMATION"
210 PRINT "TOTAL NR OF JOBS TO BE SIMULATED =",\ INPUT C
220 PRINT £D,"TOTAL NR OF JOBS SIMULATED = ",C
230 PRINT "NR OF JOBS AVAILABLE PER YEAR =",\ INPUT N4
240 PRINT £D,"NR OF JOBS AVAILABLE PER YR = ",N4
250 PRINT "FIRM A'S PERCENTAGE MARK-UP = ",\ INPUT M
260 PRINT £D,"FIRM A'S PERCENTAGE MARK-UP = ",M
270 PRINT "THEIR RANGE OF PERCENTAGE MARK-UPS:"
280 PRINT "     MINIMUM = ",\ INPUT M3
290 PRINT "     MAXIMUM = ",\ INPUT M4
300 PRINT £D,"THEIR RANGE OF PERCENTAGE MARK-UPS: ",
310 PRINT £D,M3," - ",M4
320 PRINT "FIRM A'S ESTIMATING ERROR = ",\ INPUT E3
330 PRINT £D,"FIRM A'S ESTIMATING ERROR = ",E3
340 PRINT "THEIR ESTIMATING ERROR = ",\ INPUT E4
350 PRINT £D,"THEIR ESTIMATING ERROR = ",E4
360 PRINT "RANGE OF TRUE COST RATIOS:"
370 PRINT "     MINIMUM = ", \ INPUT T8
380 PRINT "     MAXIMUM = ",\ INPUT T9
390 PRINT £D,"RANGE OF TRUE COST RATIOS: ",T8," - ",T9
395 PRINT£D\PRINT£D\PRINT£D
400 N=1
410 PRINT £D,"JOB VALUE DATA"
420 DATA 0.000,0.002,0.019,0.095
430 DATA 0.295,0.591,0.841,0.962
440 DATA 0.994,1.000
450 FOR I=1 TO 10
460 READ V(I)
470 PRINT £D,%7F3,V(I),
480 NEXT I
490 PRINT £D
500 PRINT £D,"NR OF BIDDERS DATA"
510 DATA 0.1,0.4,0.7,0.9,1.0
520 FOR I=1 TO 5
530 READ B(I)
540 PRINT £D,%7F2,B(I),
550 NEXT I
560 PRINT £D\PRINT £D
570 REM    DATA INPUT COMPLETE ********************************
580 REM    START SIMULATION    ********************************
590 DIM R9(C*9),G(16,2)
600 C1=0\S=0\P=0\W=0\I9=0
610 W2=0\S2=0\P2=0
```

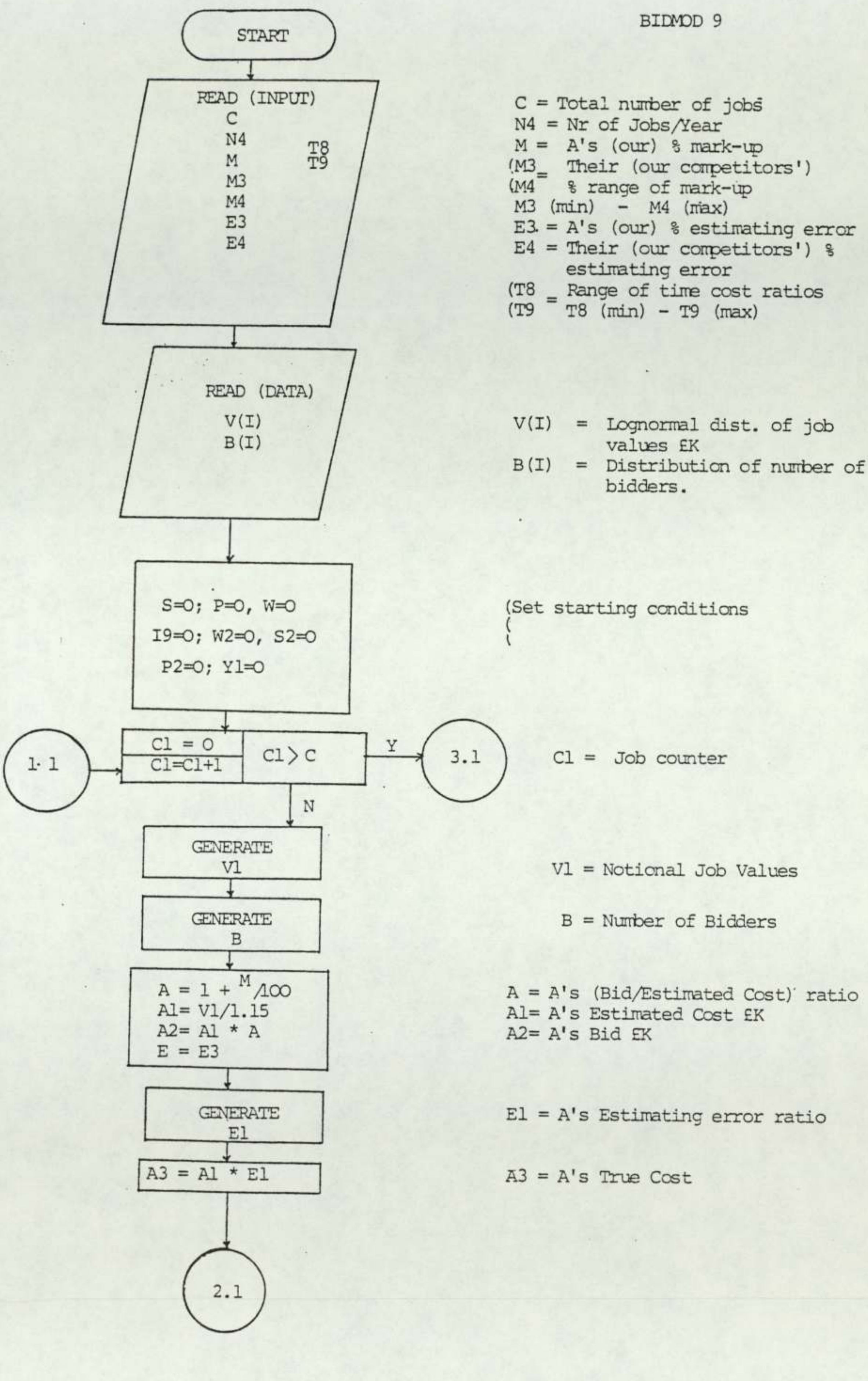
```
620 Y1=1
630 C1=C1+1
640 IF C1>C THEN 1250
650 REM   GEN RDM JOB VALUE V1
660 GOSUB 1530
670 REM   GEN RDM NR OF BIDS B
680 GOSUB 1650
690 REM COMPUTE FIRM A'S BID/(ESTIMATED COST) RATIO
700 A=1+M/100
710 REM   A1=A'S ESTIMATED COST--EXCL ERROR IN £1000'S
720 REM   A2=A'S BID IN £1000'S
730 A1=V1/1.15\A2=A1*A\E=E3
740 GOSUB 1910 \ REM GEN RDM SAMPLE OF EST ERROR
750 A3=A1*E1 \ REM A3=A'S TRUE COST
770 PRINT £D1,%4I,C1,%12F0,1000*A2,1000*A1,1000*A3,%6I,B
780 REM   GEN RDM SET OF COMPETITORS BIDS
790 REM   CHECK IF A'S BID IS THE LOW BID
810 B1=0\W1=1\ REM  ASSUME, INITIALLY, THAT FIRM A WINS
820 B1=B1+1
830 IF B1>B THEN 930
840 I9=I9+1
850 REM   GEN RDM COMPETITOR'S BID
860 GOSUB 1740
870 R9(I9)=T2/A1
880 IF A$="N" THEN LET D1=0
890 PRINT £D1,TAB(48),%12F0,1000*T2,%12F4,R9(I9)
900 IF A2<T2 THEN 820 \ REM A'S BID < THEIR BID
910 W1=0 \ REM  A IS UNDERBID AND LOSES THIS JOB
920 GOTO 820
930 REM
950 IF W1=0 THEN 1100
960 W=W+W1\S=S+A2
970 REM   COMPUTE PROFIT P1
980 REM   ALLOWING FOR ESTIMATING ERROR E1
990 P1=A2-A3\P=P+P1
1000 REM    PRINT DETAILS OF WINNING BID ***********************
1010 PRINT £D
1020 PRINT £D,"JOB NR =",C1
1030 PRINT £D,"A'S BID = £",INT(1000*A2)
1040 PRINT £D,"A'S ESTIMATED COST = £",INT(1000*A1)
1050 PRINT £D,"A'S ACTUAL COST = £",INT(1000*A3)
1060 PRINT £D,"A'S PROFIT = £",INT(1000*A2-1000*A3)
1070 PRINT £D,"A'S PROFIT % = ",%5F2,(A2-A3)/A3*100
1080 PRINT £D
1090 REM    ************************************************
1100 IF C1= INT(N4*Y1) THEN 1110 ELSE 630
1110 W3=W-W2\S3=INT(1000*S-S2)\P3=INT(1000*P-P2)
1120 PRINT £D," "
1130 PRINT £D,"******* END OF YEAR ",Y1
1140 PRINT £D,"         NR OF WINS =",W3
1150 PRINT £D,"         VALUE OF JOBS WON = £",S3
1160 PRINT £D,"         PROFIT = £",P3
1170 IF P3=0 THEN 1200
1180 PRINT £D,"         ACTUAL % PROFIT = ",%5F2,P3/(S3-P3)*100
1190 GOTO 1210
1200 PRINT £D,"         ACTUAL % PROFIT = ",%5F2,P3
1210 PRINT £D," "
1220 W2=W\S2=1000*S\P2=1000*P
1230 Y1=Y1+1
1240 GOTO 630
1250 REM    SIMULATION COMPLETE *******************************
1260 REM   COMPUTE MEAN (M9) AND STD DEV (D9) OF
1270 REM   (COMP BID/A'S EST COST) RATIOS
```

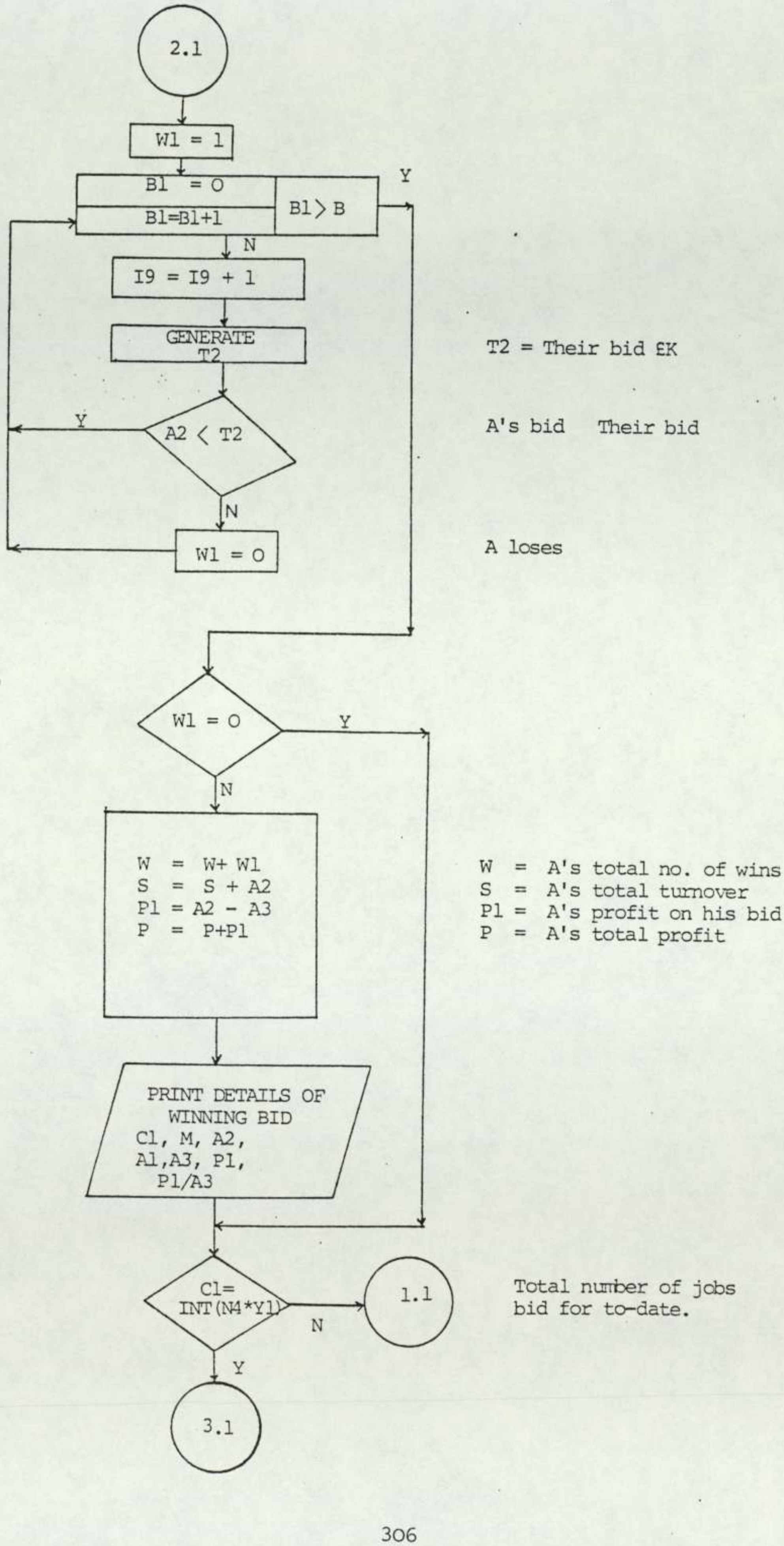
```
1280 R8=0\FOR I=1 TO I9\R8=R8+R9(I)\NEXT I\M9=R8/I9
1290 S9=0\FOR I=1 TO I9\S9=S9+(M9-R9(I))^2\NEXT I
1300 D9=SQRT(S9/I9)
1302 REM    COMPUTE BID/COST FREQUENCIES AT 0.1 INTERVALS
1304 PRINT £D,"BID/COST FREQUENCIES"\PRINT £D
1310 FOR I=1 TO 12\G(I,1)=0\FOR J=1 TO I9\G(I,2)=(I+5)*0.1
1320 IF R9(J)>(I+5)*0.1 AND R9(J)<=(I+6)*0.1 THEN 1330 ELSE 1340
1330 G(I,1)=G(I,1)+1
1340 NEXT J
1350 PRINT £D,"NR IN RANGE - ",G(I,2)," - ",G(I,2)+0.1," = ",G(I,1)
1360 NEXT I
1370 REM     PRINT SUMMARY OF SIMULATION ************************
1380 PRINT £D
1390 PRINT £D,"******* SUMMARY OF A'S BIDDING ****************"
1400 PRINT £D,"NR OF JOBS BID FOR =",C
1410 PRINT £D,"NR OF JOBS WON =",W
1420 PRINT £D,"SUCCESS RATIO =",W/C*100,"%"
1430 PRINT £D,"TOTAL VALUE OF JOBS WON = £",INT(1000*S)
1440 PRINT £D,"TOTAL PROFIT = £",INT(1000*P)
1450 IF P=0 THEN 1480
1460 PRINT £D,"PERCENTAGE PROFIT = ",%5F2,P/(S-P)*100
1470 GOTO 1490
1480 PRINT £D,"PERCENTAGE PROFIT = ",%5F2,P
1490 PRINT £D,"(COMP BID/A'S EST COST) RATIO: MEAN    = ",%5F2,M9
1500 PRINT £D,"                             : STD DEV = ",%5F2,D9
1510 PRINT £D,"**********************************************"
1520 STOP
1530 REM    SUBROUTINE GENERATES JOB VALUES
1540 Y=1
1550 GOSUB 1960
1560 FOR I=1 TO 10
1570 REM
1580 IF R>V(I)  THEN 1640
1590 N1=(I-1)+(R-V(I-1))/(V(I)-V(I-1))
1600 REM    V1=BASIC JOB VALUE IN THOUSANDS OF POUNDS
1610 REM    BASED ON THE MEAN BID/COST RATIO OF 1.15
1620 V1=EXP(N1)
1630 RETURN
1640 NEXT I
1650 REM    SUBROUTINE GENERATES NR OF BIDDERS
1660 Y=2
1670 GOSUB 1960
1680 FOR I=1 TO 5
1690 REM
1700 IF R>B(I) THEN 1730
1710 B=4+I
1720 RETURN
1730 NEXT I
1740 REM  SUBROUTINE GENERATES RANDOM SAMPLE OF THEIR BID
1750 REM T1= THEIR COST ESTIMATE
1760 REM T2= THEIR BID
1770 REM T3= THEIR TRUE COST
1780 REM T4= THEIR MARK-UP
1790 REM T5= THEIR TRUE COST RATIO
1810 Y=3\ GOSUB 1960
1820 T4=M3+R*(M4-M3)
1830 Y=4\ GOSUB 1960
1840 T5=T8+R*(T9-T8)
1850 T3=A3*T5
1860 E=E4
```

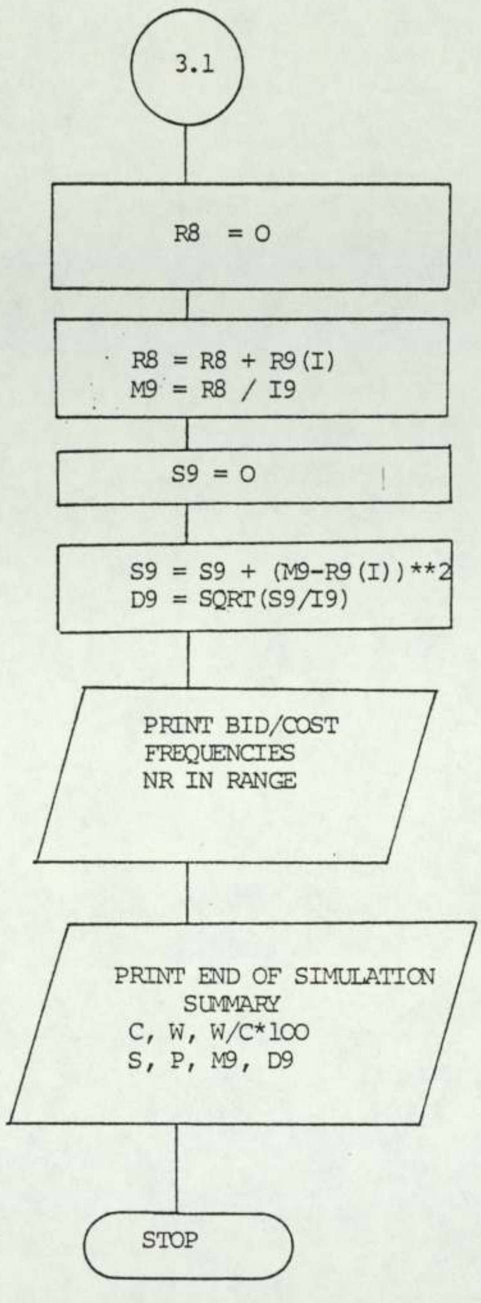
```
1870 GOSUB 1910
1880 T1=T3*E1
1890 T2=T1*(1+T4/100)
```

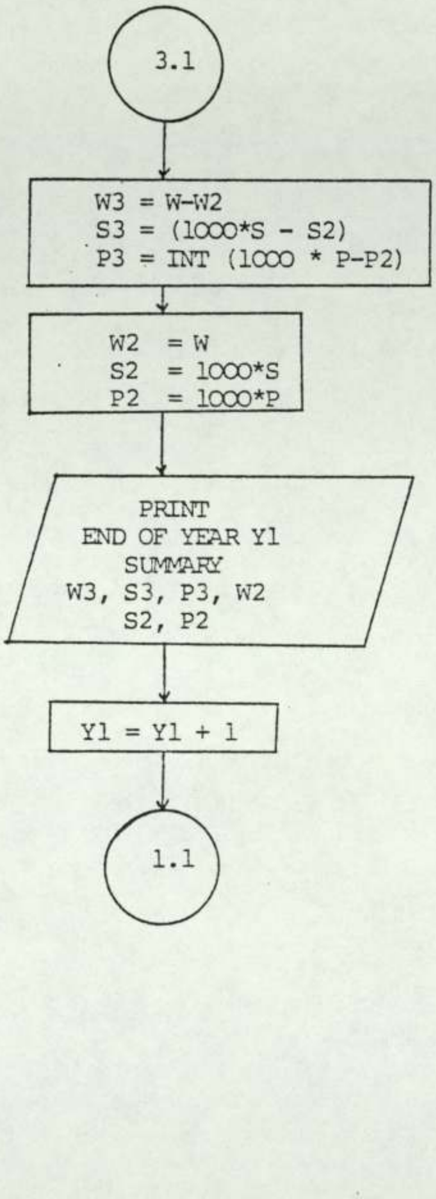
```
1900 RETURN
1910 REM   SUBROUTINE GENERATES ESTIMATING ERROR
1920 Y=6
1930 GOSUB 1960
1940 E1=(1-E/100)+2*E/100*R
1950 RETURN
1960 REM   SUBROUTINE GENERATES RANDOM FRACTIONS
1970 REM
1980 IF N>1 THEN 2070
1990 N=2
2000 DATA 1023,657,1207,779,831
2010 DATA 1153,511,1317,923,473
2020 FOR Z=1 TO 10
2030 READ F1(Z)
2040 NEXT Z
2050 M1=2^18
2060 K1=509
2070 F2(Y)=F1(Y)
2080 F3=K1*F2(Y)
2090 F4=INT(F3/M1)
2100 F1(Y)=F3-F4*M1
2110 R=ABS(F1(Y)/M1)
2120 RETURN
2130 STOP
2140 END
```

6.2 Program flow-chart




2.1
W1 = 1
B1 = O
B1=B1+1
B1 > B
Y
N
I9 = I9 + 1
GENERATE T2
T2 = Their bid £K
A2 < T2
A's bid Their bid
W1 = O
A loses
W1 = O
W = W+ W1
S = S + A2
P1 = A2 - A3
P = P+P1
W = A's total no. of wins
S = A's total turnover
P1 = A's profit on his bid
P = A's total profit
PRINT DETAILS OF WINNING BID
C1, M, A2, A1,A3, P1, P1/A3
C1= INT(N4*Y1)
1.1
Total number of jobs bid for to-date.
3.1


3.1
R8 = O
R8 = R8 + R9(I)
M9 = R8 / I9
S9 = O
S9 = S9 + (M9-R9(I))**2
D9 = SQRT(S9/I9)
PRINT BID/COST
FREQUENCIES
NR IN RANGE
PRINT END OF SIMULATION
SUMMARY
C, W, W/C*100
S, P, M9, D9
STOP
END OF SIMULATION

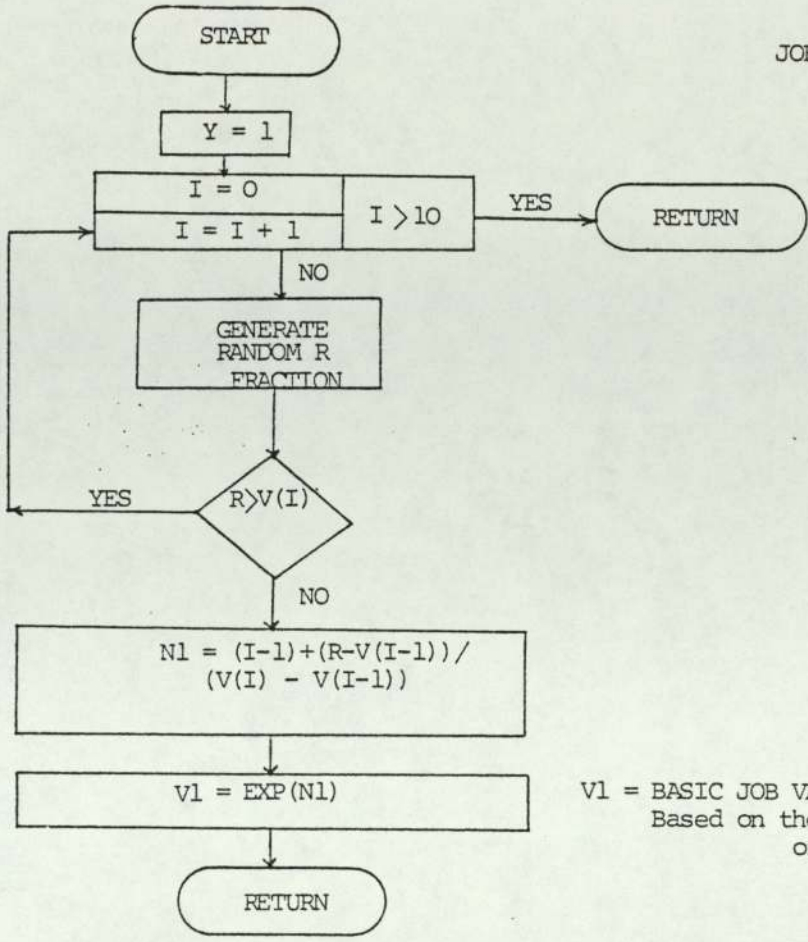


W3 = A's number of wins in year Y1.
S3 = A's turnover in year Y1.
P3 = A's actual profit in year Y1.

W2 = A's number of wins total end Y1.
S2 = A's turnover total end Y1
P2 = A's actual profit total end Y1.

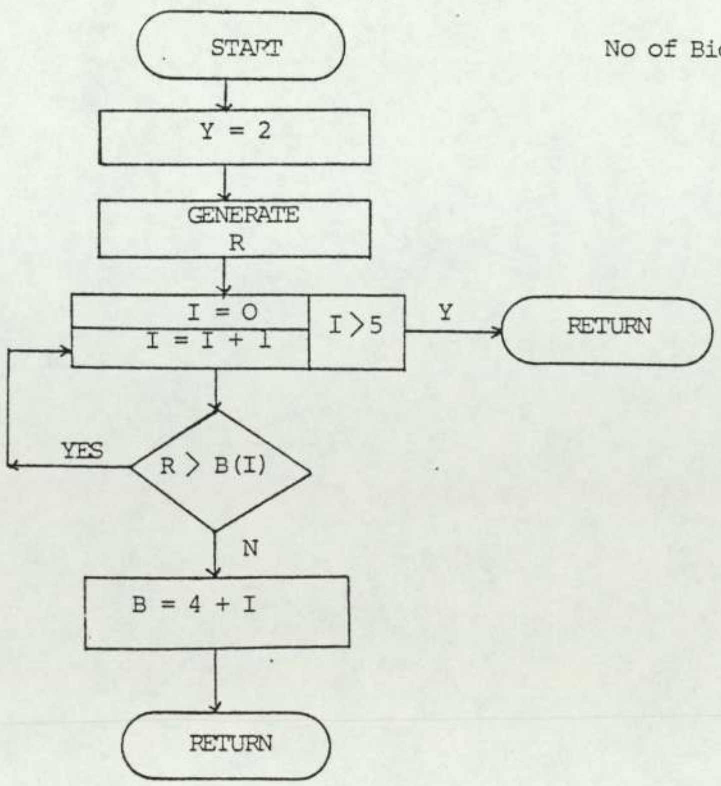
BIDMOD9

JOB VALUE SUB-ROUTINE

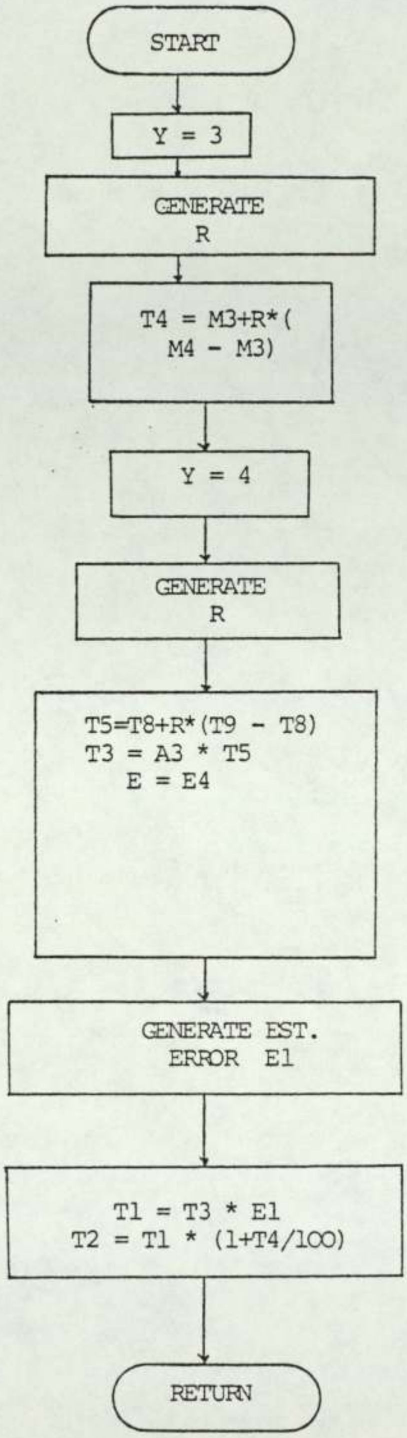


V1 = BASIC JOB VALUES
Based on the mean bid/cost ratio of 1.15

No of Bidders Sub-Routine



SUB-ROUTINE GENERATE RANDOM SAMPLE OF THEIR BID



T4 = Their Mark-Up

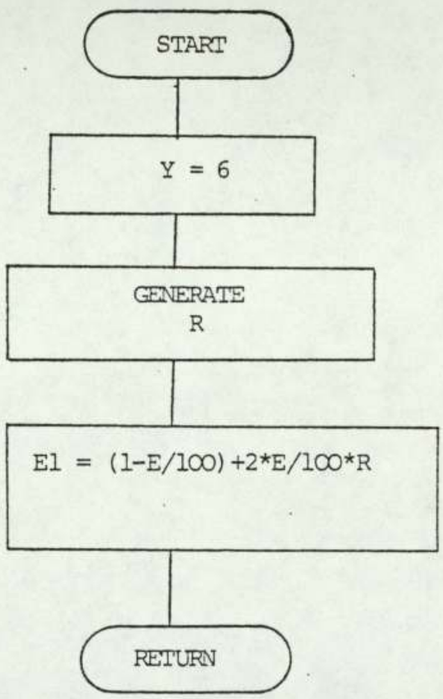
T5 = Their True Cost Ratio

T3 = Their True Cost

T1 = Their Cost Est

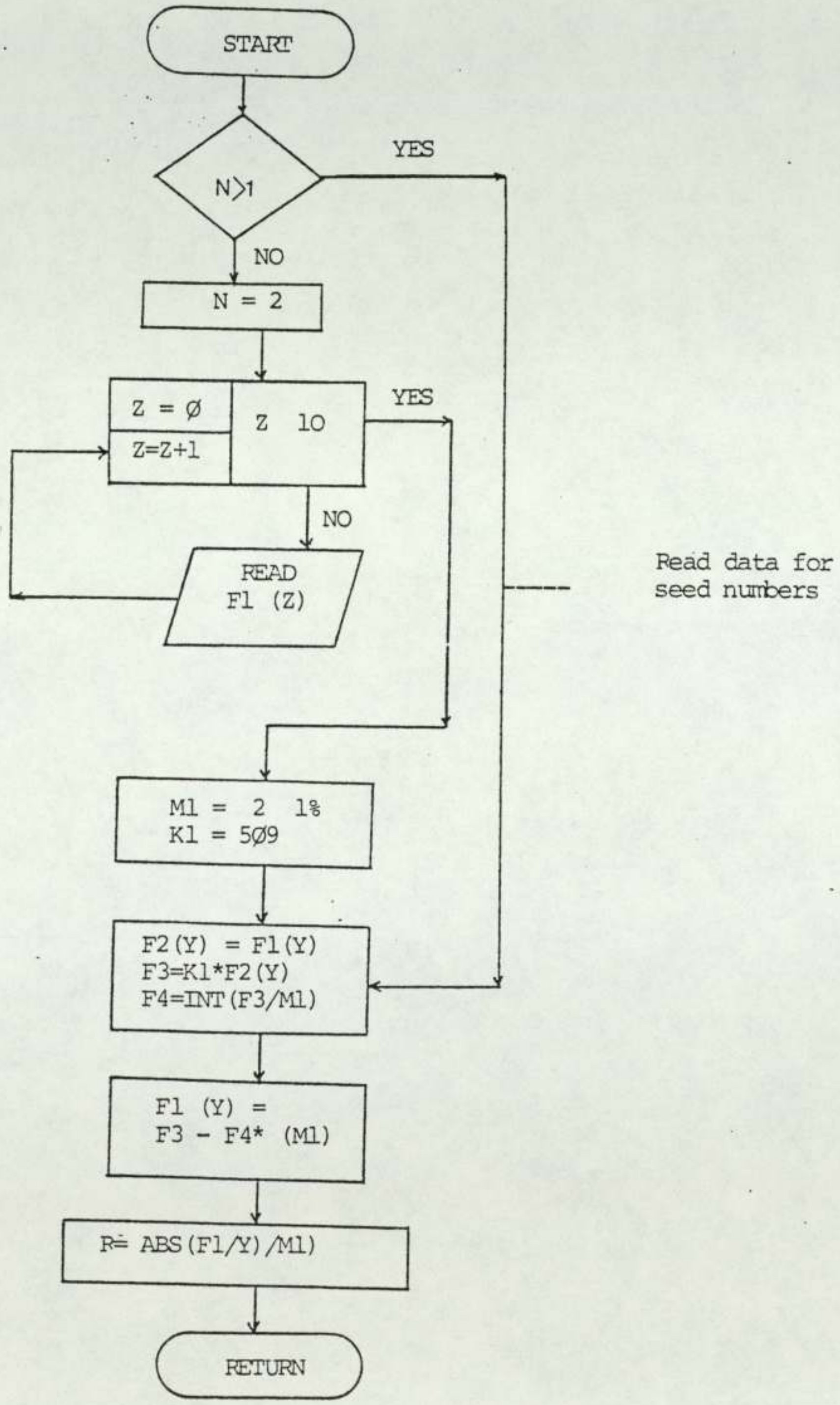
T2 = Their Bid

SUB-ROUTINE GEN.
EST. ERROR



BIDMOD 9

SUB-ROUTINE GENERATES RANDOM FRACTIONS 1Ø STREAMS



6.3 A sample of program output

```
**********************************************
** BIDDING MODEL: BIDMOD9                   **
** INCLUDES RANDOM SAMPLING FROM THE FOLLOWING **
** DISTRIBUTIONS:                           **
**    NUMBER OF BIDDERS: FIXED RANGE 5-9    **
**    JOB VALUES: FIXED RANGE £6K-£15M (APPROX) **
**    ESTIMATING ERROR: INPUTTED RANGE      **
**    THEIR MARK-UP: INPuTTED RANGE         **
**    RATIO OF 'THEIR TRUE COST' TO 'OUR TRUE **
**    COST': INPUTTED RANGE                 **
** ALL INPUTTED PARAMETERS RELATE TO UNIFORM **
** DISTRIBUTIONS                            **
**********************************************

TOTAL NR OF JOBS SIMULATED =  10
NR OF JOBS AVAILABLE PER YR =  5
FIRM A'S PERCENTAGE MARK-UP =  5
THEIR RANGE OF PERCENTAGE MARK-UPS:   4 -  12
FIRM A'S ESTIMATING ERROR =  5
THEIR ESTIMATING ERROR =  5
RANGE OF TRUE COST RATIOS:  .9 -  1.1


JOB VALUE DATA
   .000   .002   .019   .095   .295   .591   .841   .962   .994  1.000
NR OF BIDDERS DATA
   .10    .40    .70    .90   1.00




   1   5823401.    5546097.    5401209.     6
                                                   5796331.      1.0451
                                                   6601863.      1.1904
                                                   6200869.      1.1181
                                                   6775322.      1.2216
                                                   5967839.      1.0760
                                                   5205183.       .9385
   2     26454.      25194.      25740.     6
                                                     26877.      1.0668
                                                     27885.      1.1068
                                                     26717.      1.0605
                                                     30402.      1.2067
                                                     31934.      1.2675
                                                     24827.       .9854
   3   1025066.     976253.     940514.     7
                                                   1005746.      1.0302
                                                    925038.       .9475
                                                    978946.      1.0028
                                                    996399.      1.0206
                                                    947697.       .9707
                                                    967997.       .9915
                                                   1135448.      1.1631
   4    285253.     271670.     276024.     7
                                                    264813.       .9748
                                                    317202.      1.1676
                                                    278161.      1.0239
                                                    298856.      1.1001
                                                    309283.      1.1384
```

```
                                                    318753.      1.1733
                                                    314897.      1.1591
   5    138598.     131998.     127687.    5
                                                    130639.       .9897
                                                    127250.       .9640
                                                    123566.       .9361
                                                    139323.      1.0555
                                                    143457.      1.0868

******* END OF YEAR  1
        NR OF WINS = 0
        VALUE OF JOBS WON = £ 0
        PROFIT = £ 0
        ACTUAL % PROFIT =    .00

   6    322887.     307512.     298540.    9
                                                    347292.      1.1294
                                                    273317.       .8888
                                                    321946.      1.0469
                                                    309384.      1.0061
                                                    334335.      1.0872
                                                    302636.       .9841
                                                    326570.      1.0620
                                                    321878.      1.0467
                                                    293135.       .9532
   7   3823609.    3641533.    3471408.    8
                                                   3947348.      1.0840
                                                   3436524.       .9437
                                                   4180714.      1.1481
                                                   4086793.      1.1223
                                                   4176666.      1.1470
                                                   3876433.      1.0645
                                                   3245115.       .8911
                                                   3861159.      1.0603
   8     82052.      78144.      79702.    7




                                                     96880.      1.2398
                                                    101679.      1.3012
                                                     95728.      1.2250
                                                     83367.      1.0668
                                                     87433.      1.1189
                                                     76989.       .9852
                                                     86608.      1.1083
   9     43120.      41067.      40870.    7
                                                     43672.      1.0634
                                                     45631.      1.1112
                                                     46355.      1.1288
                                                     48202.      1.1738
                                                     49467.      1.2045
                                                     44670.      1.0877
                                                     44059.      1.0729

 JOB NR = 9
 A'S BID = £ 43119
 A'S ESTIMATED COST = £ 41066
 A'S ACTUAL COST = £ 40869
 A'S PROFIT = £ 2250
 A'S PROFIT % =  5.51

  10    679721.     647353.     662940.    6
                                                    661166.      1.0213
```

```
                                                     721804.        1.1150
                                                     763618.        1.1796
                                                     644191.         .9951
                                                     697485.        1.0774
                                                     794739.        1.2277

******* END OF YEAR  2
        NR OF WINS = 1
        VALUE OF JOBS WON = £ 43119
        PROFIT = £ 2250
        ACTUAL % PROFIT =  5.51

BID/COST FREQUENCIES

NR IN RANGE -  .6 -  .7 =  0
NR IN RANGE -  .7 -  .8 =  0
NR IN RANGE -  .8 -  .9 =  2
NR IN RANGE -  .9 -  1 =  14
NR IN RANGE -  1 -  1.1 =  24
NR IN RANGE -  1.1 -  1.2 =  20
NR IN RANGE -  1.2 -  1.3 =  7
NR IN RANGE -  1.3 -  1.4 =  1
NR IN RANGE -  1.4 -  1.5 =  0
NR IN RANGE -  1.5 -  1.6 =  0
NR IN RANGE -  1.6 -  1.7 =  0
NR IN RANGE -  1.7 -  1.8 =  0

******* SUMMARY OF A'S BIDDING *****************
NR OF JOBS BID FOR = 10
NR OF JOBS WON = 1
SUCCESS RATIO = 10%
TOTAL VALUE OF JOBS WON = £ 43119
TOTAL PROFIT = £ 2250
PERCENTAGE PROFIT =  5.51
(COMP BID/A'S EST COST) RATIO: MEAN     =  1.08
                             : STD DEV =   .09
**********************************************
```

APPENDIX 7

SIMULATION BIDDING MODEL - BIDMOD11

7.1 List of computer program

```
10 PRINT  "OUTPUT TO SCREEN TYPE 0; TO PRINTER TYPE 1",
20 INPUT D
30 PRINT £D,"****************************************************"
40 PRINT £D,"** BIDDING MODEL: BIDMOD11                        **"
50 PRINT £D,"** INCLUDES RANDOM SAMPLING FROM THE FOLLOWING    **"
60 PRINT £D,"** DISTRIBUTIONS:                                 **"
70 PRINT £D,"**    NUMBER OF BIDDERS: FIXED RANGE 5-9          **"
80 PRINT £D,"**    JOB VALUES: FIXED RANGE £6K-£15M (APPROX)   **"
90 PRINT £D,"**    ESTIMATING ERROR                            **"
100 PRINT £D,"**    THEIR MARK-UP                              **"
110 PRINT £D,"**    RATIO 'THEIR TRUE COST/ OUR TRUE COST'     **"
130 PRINT £D,"** ALL INPUTTED PARAMETERS RELATE TO UNIFORM     **"
140 PRINT £D,"** DISTRIBUTIONS                                 **"
141 PRINT £D,"** INPUT: NR OF JOBS BID FOR PER QUARTER         **"
142 PRINT £D,"**        NR OF YEARS SIMULATED                  **"
143 PRINT £D,"**        FIRM A'S (OUR) MARK-UP                 **"
144 PRINT £D,"**        COMPET'S (THEIR) RANGE OF MARK-UPS     **"
145 PRINT £D,"**        FIRM A'S ESTIMATING ERROR              **"
146 PRINT £D,"**        COMPET'S ESTIMATING ERROR              **"
147 PRINT £D,"**        RANGE OF TRUE COST RATIOS              **"
148 PRINT £D,"** OUTPUT:DETAILS OF ALL BIDS FOR EACH JOB       **"
149 PRINT £D,"**        END OF YEAR SUMMARY                    **"
150 PRINT £D,"**        END OF SIMULATION SUMMARY INCLUDING-   **"
151 PRINT £D,"**            SUCCESS RATIO                      **"
152 PRINT £D,"**            TOTAL VALUE OF JOBS WON            **"
153 PRINT £D,"**            TOTAL PROFIT                       **"
154 PRINT £D,"**            QUARTERLY CASH FLOWS               **"
159 PRINT £D,"***************************************************"
160 PRINT £D,
170 PRINT "FOR JOB TABULATION TYPE Y ELSE TYPE N ",
180 INPUT A$
190 PRINT "SIMULATION OF BIDDING MODEL: BIDMOD9"
200 PRINT "TYPE IN THE FOLLOWING INFORMATION"
210 PRINT "NR OF JOBS BID FOR PER QTR = ",\ INPUT N9
212 PRINT "NR OF YEARS SIMULATED = ",\ INPUT Y9
214 C=4*N9*Y9\ N4=4*N9
240 PRINT £D,"NR OF JOBS BID FOR PER YEAR = ",N4
242 PRINT £D,"NR OF YEARS SIMULATED = ",Y9
244 PRINT £D,"TOTAL NR OF JOBS SIMULATED = ",C
250 PRINT "FIRM A'S PERCENTAGE MARK-UP = ",\ INPUT M
260 PRINT £D,"FIRM A'S PERCENTAGE MARK-UP = ",M
270 PRINT "THEIR RANGE OF PERCENTAGE MARK-UPS:"
280 PRINT "     MINIMUM = ",\ INPUT M3
290 PRINT "     MAXIMUM = ",\ INPUT M4
300 PRINT £D,"THEIR RANGE OF PERCENTAGE MARK-UPS: ",
310 PRINT £D,M3," - ",M4
320 PRINT "FIRM A'S ESTIMATING ERROR = ",\ INPUT E3
330 PRINT £D,"FIRM A'S ESTIMATING ERROR = ",E3
340 PRINT "THEIR ESTIMATING ERROR = ",\ INPUT E4
350 PRINT £D,"THEIR ESTIMATING ERROR = ",E4
360 PRINT "RANGE OF TRUE COST RATIOS:"
370 PRINT "     MINIMUM = ", \ INPUT T8
380 PRINT "     MAXIMUM = ",\ INPUT T9
390 PRINT £D,"RANGE OF TRUE COST RATIOS: ',T8," - ",T9
400 N=1
410 PRINT £D,"JOB VALUE DATA"
420 DATA 0.000,0.002,0.019,0.095
430 DATA 0.295,0.591,0.841,0.962
440 DATA 0.994,1.000
450 FOR I=1 TO 10
460 READ V(I)
```

```
470 PRINT £D,%7F3,V(I),
480 NEXT I
```

```
490 PRINT£D\PRINT£D\PRINT£D
500 PRINT £D,"NR OF BIDDERS DATA"
510 DATA 0.1,0.4,0.7,0.9,1.0
520 FOR I=1 TO 5
530 READ B(I)
540 PRINT £D,%7F2,B(I),
550 NEXT I
560 PRINT £D\PRINT£D\PRINT£D
561 PRINT £D,"1 YR CONTRACT, PAY-IN %"
562 DATA 5,30,90,100
563 FOR I=1 TO 4\ READ I1(I)
564 PRINT £D,%5I,I1(I),\ NEXT I
565 PRINT £D\PRINT£D\PRINT£D
566 PRINT £D,"1 YR CONTRACT, PAY-OUT %"
567 DATA 15,40,90,100
568 FOR I=1 TO 4\ READ O1(I)
569 PRINT £D,%5I,O1(I),\ NEXT I
570 PRINT £D\PRINT£D\PRINT£D
571 PRINT £D,"2 YR CONTRACT, PAY-IN %"
572 DATA 5,10,20,30,65,90,95,100
573 FOR I=1 TO 8\ READ I2(I)
574 PRINT £D,%5I,I2(I),\ NEXT I
575 PRINT £D\PRINT£D\PRINT£D
576 PRINT £D,"2 YR CONTRACT, PAY-OUT %"
577 DATA 7,15,27,40,65,90,95,100
578 FOR I=1 TO 8\ READ O2(I)
579 PRINT £D,%5I,O2(I),\ NEXT I
580 PRINT £D\PRINT£D\PRINT£D
586 REM DATA INPUT COMPLETE ***********************************
588 REM START SIMULATION **************************************
589 DIM S9(50)
590 C1=0\S=0\P=0\W=0
600 W2=0\S2=0\P2=0
610 Y1=1
620 C1=C1+1
630 IF C1>C THEN 1260
640 REM   GEN RDM JOB VALUE V1
650 GOSUB 1390
660 REM   GEN RDM NR OF BIDS B
670 GOSUB 1510
680 REM COMPUTE FIRM A'S BID/(ESTIMATED COST) RATIO
690 A=1+M/100
700 REM   A1=A'S ESTIMATED COST--EXCL ERROR IN £1000'S
710 REM   A2=A'S BID IN £1000'S
720 A1=V1/1.15\A2=A1*A\E=E3
730 GOSUB 1770 \ REM GEN RDM SAMPLE OF EST ERROR
740 A3=A1*E1 \ REM A3=A'S TRUE COST
750 IF A$="N" THEN 770
760 PRINT £D,%4I,C1,%12F0,1000*A2,%6I,B
770 REM   GEN RDM SET OF COMPETITORS BIDS
780 REM   CHECK IF A'S BID IS THE LOW BID
790 REM
800 B1=0\W1=1\ REM  ASSUME, INITIALLY, THAT FIRM A WINS
810 B1=B1+1
820 IF B1>B THEN 900
830 REM   GEN RDM BID
840 GOSUB 1600
850 IF A$="N" THEN 870
```

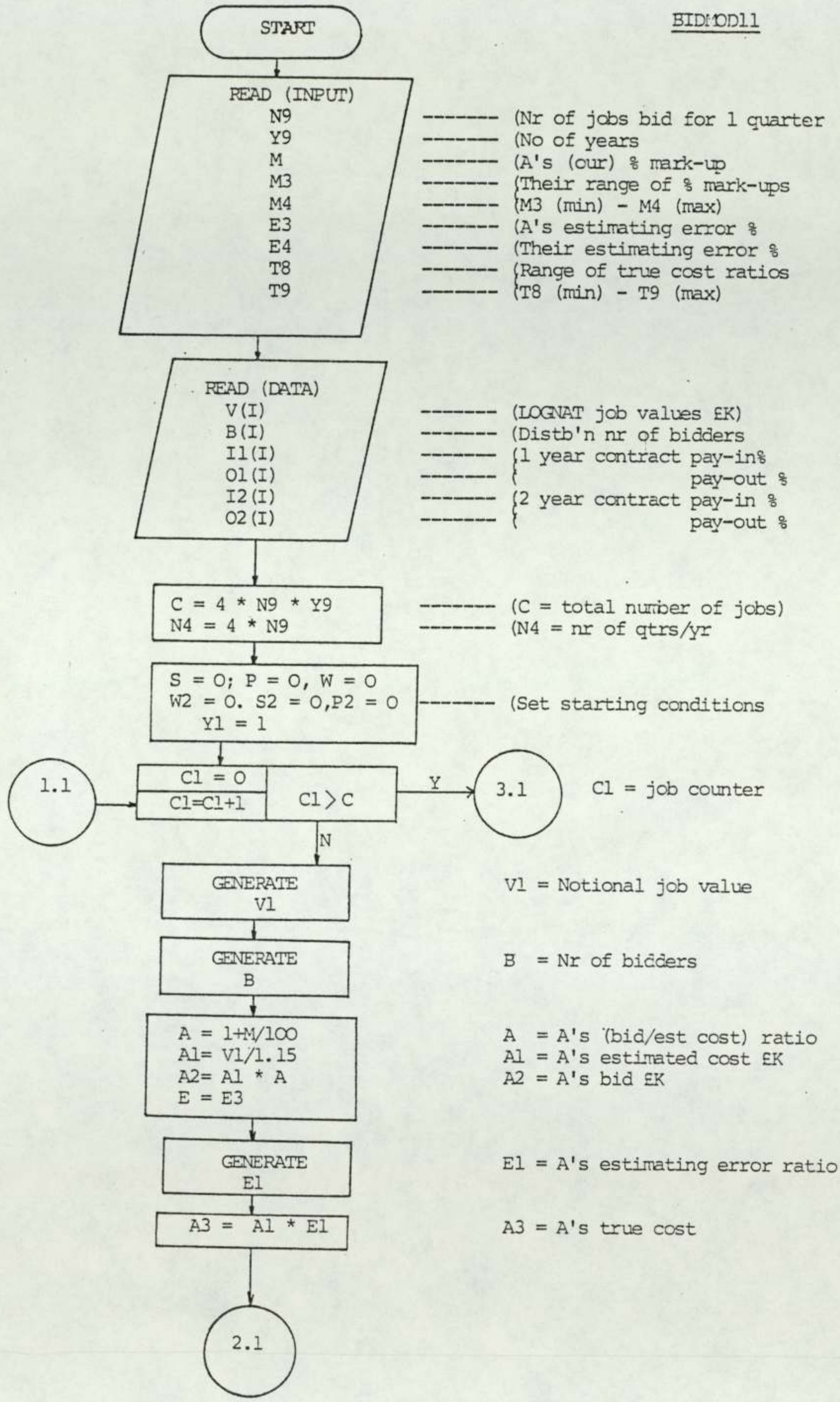
```
860 PRINT £D,TAB(24),%12F0,1000*T2
870 IF A2<T2 THEN 810 \ REM A'S BID < THEIR BID
880 W1=0 \ REM  A IS UNDERBID AND LOSES THIS JOB
890 GOTO 810
900 REM   IF A'S BID IS NOT THE
910 REM   WINNING BID THEN
920 REM   CONSIDER NEXT JOB
930 IF W1=0 THEN 1100
940 W=W+W1\S=S+A2
950 REM   COMPUTE PROFIT P1
960 REM   ALLOWING FOR ESTIMATING ERROR E1
970 P1=A2-A3\P=P+P1
971 Q=1+INT((C1-1)/N9)
973 GOSUB 2050\ REM COMPUTE CASH FLOWS
980 REM PRINT DETAILS OF WINNING BID **************************
990 PRINT £D," "
1000 PRINT £D,"JOB NR = ",C1,"  QTR NR = ",Q
1010 PRINT £D,"A'S MARK-UP =",M,"%"
1020 PRINT £D,"A'S BID = £",INT(1000*A2)
1030 PRINT £D,"A'S ESTIMATED COST = £",INT(1000*A1)
1040 PRINT £D,"A'S ACTUAL COST = £",INT(1000*A3)
1050 PRINT £D,"A'S PROFIT = £",INT(1000*A2-1000*A3)
1060 PRINT £D,"CUM NR OF WINS =",W
1070 PRINT £D,"CUM VAL OF JOBS WON = £",INT(1000*S)
1080 PRINT £D,"CUM PROFIT = £",INT(1000*P)
1090 PRINT £D," "
1100 IF C1= INT(N4*Y1) THEN 1110 ELSE 620
1110 W3=W-W2\S3=INT(1000*S-S2)\P3=INT(1000*P-P2)
1120 PRINT £D," "
1130 PRINT £D,"******* END OF YEAR ",Y1
1140 PRINT £D,"          NR OF WINS =",W3
1150 PRINT £D,"          VALUE OF JOBS WON = £",S3
1160 PRINT £D,"          PROFIT = £",P3
1170 IF P3=0 THEN 1200
1180 PRINT £D,"          ACTUAL % PROFIT = ",%5F2,P3/S3*100
1190 GOTO 1210
1200 PRINT £D,"          ACTUAL % PROFIT = ",%5F2,P3
1210 PRINT £D," "
1220 W2=W\S2=1000*S\P2=1000*P
1230 Y1=Y1+1
1240 GOTO 620
1250 REM PRINT SUMMARY OF SIMULATION ***************************
1260 PRINT £D," "
1270 PRINT £D,"******* SUMMARY OF A'S BIDDING ****************"
1280 PRINT £D,"NR OF JOBS BID FOR =",C
1290 PRINT £D,"NR OF JOBS WON =",W
1300 PRINT £D,"SUCCESS RATIO =",W/C*100,"%"
1310 PRINT £D,"TOTAL VALUE OF JOBS WON = £",INT(1000*S)
1320 PRINT £D,"TOTAL PROFIT = £",INT(1000*P)
1330 IF P=0 THEN 1360
1340 PRINT £D,"PERCENTAGE PROFIT = ",%5F2,P/S*10C
1350 GOTO 1370
1360 PRINT £D,"PERCENTAGE PROFIT = ",%5F2,P
1370 PRINT £D,"*********************************************"
1372 PRINT £D,"******* A'S QUARTERLY CASH FLOWS ***************"
1373 PRINT £D,"  QTR NR   CASH FLOW"
1374 FOR I=1 TO 4*Y9+10
1375 PRINT £D,%10I,I,%10F1,S9(I)*1000\ NEXT I
1376 PRINT £D,"*********************************************"
1380 STOP
```

```
1390 REM   SUBROUTINE GENERATES JOB VALUES
1400 Y=1
1410 GOSUB 1820
1420 FOR I=1 TO 10
1430 REM
1440 IF R>V(I)  THEN 1500
1450 N1=(I-1)+(R-V(I-1))/(V(I)-V(I-1))
1460 REM   V1=BASIC JOB VALUE IN THOUSANDS OF POUNDS
1470 REM   BASED ON THE MEAN BID/COST RATIO OF 1.15
1480 V1=EXP(N1)
1490 RETURN
1500 NEXT I
1510 REM   SUBROUTINE GENERATES NR OF BIDDERS
1520 Y=2
1530 GOSUB 1820
1540 FOR I=1 TO 5
1550 REM
1560 IF R>B(I) THEN 1590
1570 B=4+I
1580 RETURN
1590 NEXT I
1600 REM  SUBROUTINE GENERATES RANDOM SAMPLE OF THEIR BID
1610 REM T1= THEIR COST ESTIMATE
1620 REM T2= THEIR BID
1630 REM T3= THEIR TRUE COST
1640 REM T4= THEIR MARK-UP
1650 REM T5= THEIR TRUE COST RATIO
1670 Y=3\ GOSUB 1820
1680 T4=M3+R*(M4-M3)
1690 Y=4\ GOSUB 1820
1700 T5=T8+R*(T9-T8)
1710 T3=A3*T5
1720 E=E4
1730 GOSUB 1770
1740 T1=T3*E1
1750 T2=T1*(1+T4/100)
1760 RETURN
1770 REM   SUBROUTINE GENERATES ESTIMATING ERROR
1780 Y=6
1790 GOSUB 1820
1800 E1=(1-E/100)+2*E/100*R
1810 RETURN
1820 REM   SUBROUTINE GENERATES RANDOM FRACTIONS
1830 REM
1840 IF N>1 THEN 1930
1850 N=2
1860 DATA 1023,657,1207,779,831
1870 DATA 1153,511,1317,923,473
1880 FOR Z=1 TO 10
1890 READ F1(Z)
1900 NEXT Z
1910 M1=2^18
1920 K1=509
1930 F2(Y)=F1(Y)
1940 F3=K1*F2(Y)
1950 F4=INT(F3/M1)
1960 F1(Y)=F3-F4*M1
1970 R=ABS(F1(Y)/M1)
1980 RETURN
1990 STOP
```

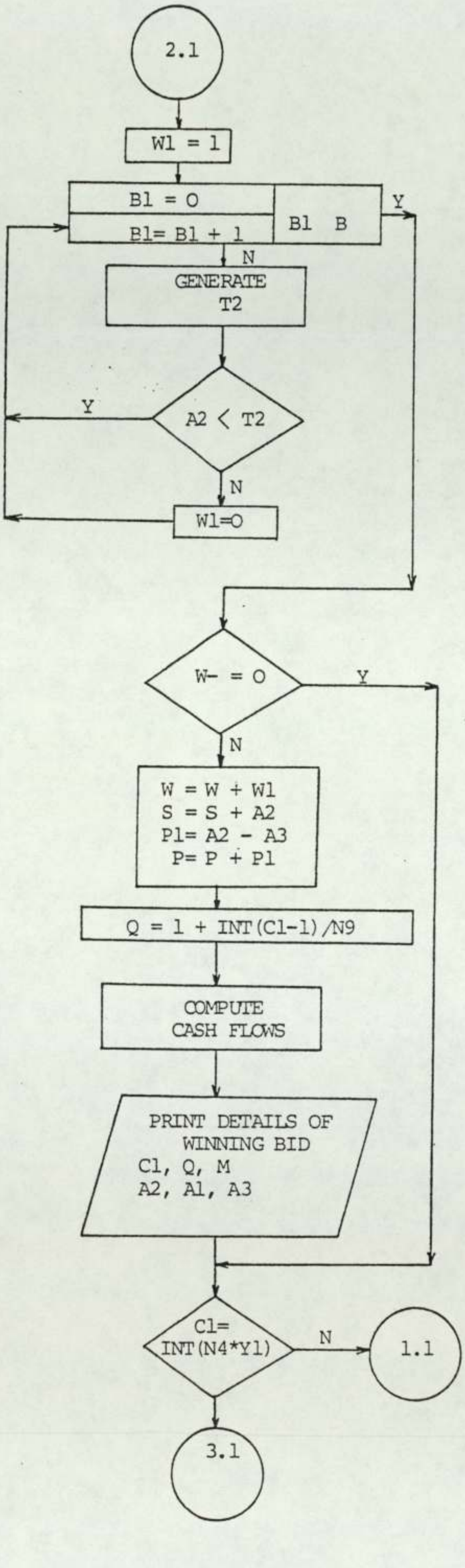
```
2000 END
2050 REM    SUBROUTINE FOR CASH FLOWS
2054 PRINT £D,"Q= ",Q,"  A2= ",%10F2,A2,"  A3= ",%10F2,A3
2060 IF A2>5000 THEN 2100
2061 REM 1 YR CONTRACT
2070 FOR I=1 TO 4
2080 S9(Q+I-1)=S9(Q+I-1)+A2*I1(I)/100-A3*O1(I)/100
2082 PRINT     " S9(",Q+I-1,")= ",S9(Q+I-1)
2083 NEXT I
2090 FOR J=Q+4 TO Y9*4+10\ S9(J)=S9(J)+A2-A3
2091 PRINT     "        S9(",J,")= ",S9(J)
```

```
2092 NEXT J
2098 RETURN
2100 REM 2 YR CONTRACT
2110 FOR I=1 TO 8
2112 S9(Q+I-1)=S9(Q+I-1)+A2*I2(I)/100-A3*O2(I)/100
2120 PRINT     " S9(",Q+I-1,")= ",S9(Q+I-1)
2121 NEXT I
2122 FOR J=Q+8 TO Y9*4+10\ S9(J)=S9(J)+A2-A3
2123 PRINT     "        S9(",J,")= ",S9(J)
2124 NEXT J
2125 RETURN
2200 END
```

7.2 Program flow-charts



BIDMOD11



T2 = Their bid £K

A's Bid Their Bid

A loses

A loses?

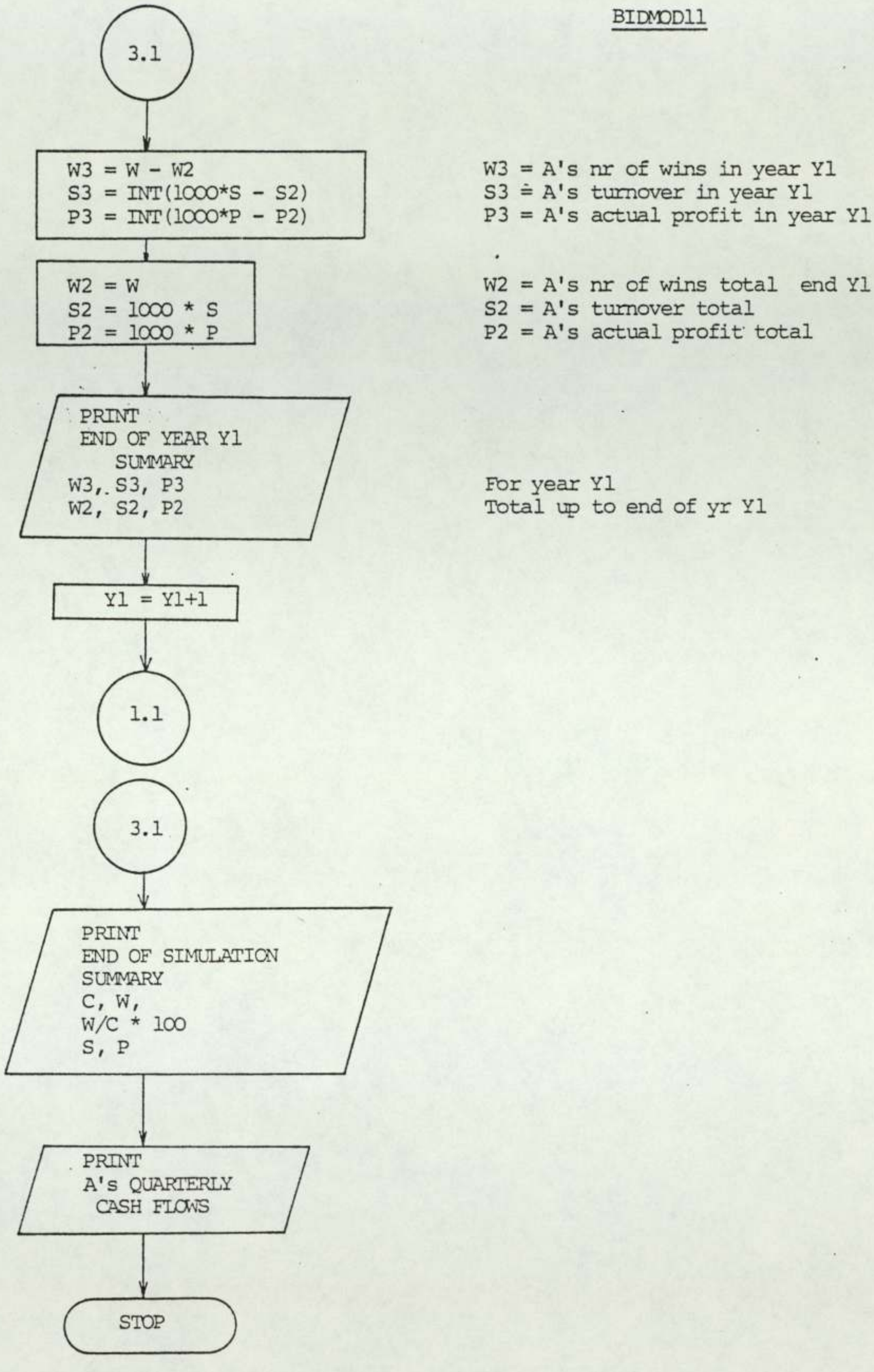
W = A's total nr of wins
S = A's total turnover
P1= A's profit on this bid
P = A's total profit

Q = Quarter number

Sub-routine - see sheet 4

C1 = Total nr of jobs bid for to-date

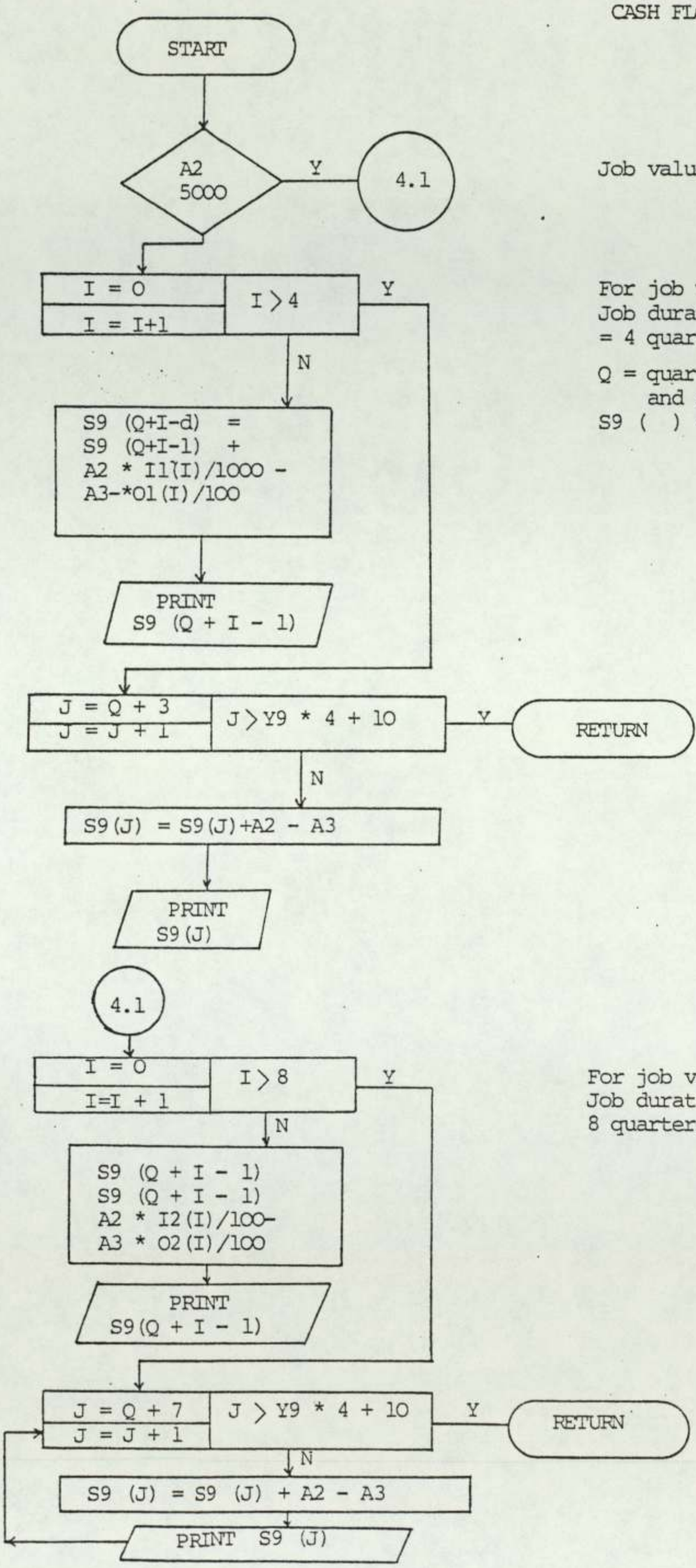
BIDMOD11



END OF SIMULATION

BIDMOD11

CASH FLOW SUB-ROUTINE



Job value (A2) £5000K

For job values £5M
Job duration = 1 yr
= 4 quarters

Q = quarter when job was
and starts

S9 ( ) = cumulative net
cash flow for a
particular qtr.

For job values £5M
Job duration = 2 yr =
8 quarters.

7.3 A sample of program output

```
*************************************************
** BIDDING MODEL: BIDMOD11                     **
** INCLUDES RANDOM SAMPLING FROM THE FOLLOWING **
** DISTRIBUTIONS:                              **
**    NUMBER OF BIDDERS: FIXED RANGE 5-9       **
**    JOB VALUES: FIXED RANGE £6K-£15M (APPROX) **
**    ESTIMATING ERROR                         **
**    THEIR MARK-UP                            **
**    RATIO 'THEIR TRUE COST/ OUR TRUE COST'   **
** ALL INPUTTED PARAMETERS RELATE TO UNIFORM   **



** DISTRIBUTIONS                               **
** INPUT: NR OF JOBS BID FOR PER QUARTER       **
**        NR OF YEARS SIMULATED                **
**        FIRM A'S (OUR) MARK-UP               **
**        COMPET'S (THEIR) RANGE OF MARK-UPS   **
**        FIRM A'S ESTIMATING ERROR            **
**        COMPET'S ESTIMATING ERROR            **
**        RANGE OF TRUE COST RATIOS            **
** OUTPUT:DETAILS OF ALL BIDS FOR EACH JOB     **
**        END OF YEAR SUMMARY                  **
**        END OF SIMULATION SUMMARY INCLUDING- **
**            SUCCESS RATIO                    **
**            TOTAL VALUE OF JOBS WON          **
**            TOTAL PROFIT                     **
**            QUARTERLY CASH FLOWS             **
*************************************************
NR OF JOBS BID FOR PER YEAR =  8
NR OF YEARS SIMULATED =  2
TOTAL NR OF JOBS SIMULATED =  16
FIRM A'S PERCENTAGE MARK-UP =  5
THEIR RANGE OF PERCENTAGE MARK-UPS:  4 -  12
FIRM A'S ESTIMATING ERROR =  5
THEIR ESTIMATING ERROR =  5
RANGE OF TRUE COST RATIOS:  .9 -  1.1
JOB VALUE DATA
   .000   .002   .019   .095   .295   .591   .841   .962   .994  1.000


NR OF BIDDERS DATA
    .10    .40    .70    .90   1.00


1 YR CONTRACT, PAY-IN %
    5   30   90  100


1 YR CONTRACT, PAY-OUT %
   15   40   90  100


2 YR CONTRACT, PAY-IN %
    5   10   20   30   65   90   95  100


2 YR CONTRACT, PAY-OUT %
    7   15   27   40   65   90   95  100
```

1	5823401.	6	
			5796331.
			6601863.
			6200869.
			6775322.
			5967839.
			5205183.
2	26454.	6	
			26877.
			27885.
			26717.
			30402.
			31934.
			24827.
3	1025066.	7	
			1005746.
			925038.
			978946.
			996399.
			947697.
			967997.
			1135448.
4	285253.	7	
			264813.
			317202.
			278161.
			298856.
			309283.
			318753.
			314897.
5	138598.	5	
			130639.
			127250.
			123566.
			139323.
			143457.
6	322887.	9	
			347292.
			273317.
			321946.
			309384.
			334335.
			302636.
			326570.
			321878.
			293135.
7	3823609.	8	
			3947348.
			3436524.
			4180714.
			4086793.
			4176666.
			3876433.
			3245115.
			3861159.
8	82052.	7	
			96880.
			101679.

```
                                    95728.
                                    83367.
                                    87433.
                                    76989.
                                    86608.

******* END OF YEAR  1
        NR OF WINS = 0
        VALUE OF JOBS WON = £ 0
        PROFIT = £ 0
        ACTUAL % PROFIT =    .00

   9      43120.      7
                                    43672.
                                    45631.
                                    46355.
                                    48202.
                                    49467.
                                    44670.
                                    44059.




Q=  5  A2=      43.12  A3=      40.87

JOB NR =  9  QTR NR =  5
A'S MARK-UP = 5%
A'S BID = £ 43119
A'S ESTIMATED COST = £ 41066
A'S ACTUAL COST = £ 40869
A'S PROFIT = £ 2250
CUM NR OF WINS = 1
CUM VAL OF JOBS WON = £ 43119
CUM PROFIT = £ 2250

  10     679721.      6
                                   661166.
                                   721804.
                                   763618.
                                   644191.
                                   697485.
                                   794739.
  11     782067.      7
                                   779033.
                                   832812.
                                   839252.
                                   735642.
                                   678973.
                                   790797.
                                   773046.
  12     425696.      8
                                   450553.
                                   384251.
                                   440995.
                                   421482.
                                   427389.
                                   436118.
                                   449271.
                                   401555.
  13      98772.      8
                                   113348.
                                    88309.
                                    88395.
```

```
                                    104902.
                                    104691.
                                    116793.
                                     98262.
                                    114359.
  14     2978239.      7
                                   2713349.
                                   3204424.
                                   3044468.
                                   2757040.
                                   3512847.
                                   3262971.
                                   2982719.
  15       57887.      8
                                     52606.
                                     61167.
                                     63051.
                                     64464.
                                     52727.
                                     63172.
                                     61339.
                                     62204.
  16      343855.      7




                                    366150.
                                    363109.
                                    328588.
                                    421247.
                                    331171.
                                    365839.
                                    358509.

******* END OF YEAR  2
        NR OF WINS = 1
        VALUE OF JOBS WON = £ 43119
        PROFIT = £ 2250
        ACTUAL % PROFIT =  5.22


******* SUMMARY OF A'S BIDDING *****************
NR OF JOBS BID FOR = 16
NR OF JOBS WON = 1
SUCCESS RATIO = 6.25%
TOTAL VALUE OF JOBS WON = £ 43119
TOTAL PROFIT = £ 2250
PERCENTAGE PROFIT =  5.22
************************************************
******* A'S QUARTERLY CASH FLOWS ***************
  QTR NR   CASH FLOW
       1          .0
       2          .0
       3          .0
       4          .0
       5     -3974.4
       6     -3411.9
       7      2025.3
       8      2250.3
       9      2250.3
      10      2250.3
      11      2250.3
      12      2250.3
```

13	2250.3
14	2250.3
15	2250.3
16	2250.3
17	2250.3
18	2250.3

****

APPENDIX 8

INVITATION LETTER AND LIST OF QUESTIONS

THE UNIVERSITY
OF ASTON
IN BIRMINGHAM

Gosta Green, Birmingham B4 7ET/Tel: 021.359 3611 Ex 4378

Department of Civil Engineering

8.1 Invitation letter to co-operate on Research Programme

Our ref: Civil/AAS/JPS

Dear Sir

I am a research student in the Department of Civil Engineering, at Aston University in Birmingham, and I am seeking some assistance on the practical aspects of my studies.

My research is concerned with tendering processes and tendering strategy and I summarise on the attached sheet the theoretical aspect of my work.

I am not asking for data (although this would certainly be gratefully accepted) but some help in formulating a systematic approach to tendering.

I am aware of the fact that much of the research work on bidding strategy (mainly from the USA) has no practical application in a rapidly changing environment, but I hope that my model may be of use for training/education purposes, e.g. management games. I am very willing to visit your offices to discuss this matter further and/or receive your valued comments however brief.

Yours faithfully

Ali Akbar SHARIFI

Telex 336997

Summary of my research on tendering

One of the aims of my research is to develop a computerised model which may be used to measure the sensitivity of predicted project cash-flows to certain controllable factors such as mark-up, payment-out lags, marketing policy, etc., and to certain uncontrollable factors such as number of jobs available to bid for, estimating error (partically controllable?) number (and identity?) of competitors.

The model, as it stands at the present, is a very crude one and assumes that the mark-up is fixed (at about 8%), that the number of jobs available to bid for each year is fixed (at 50), that all the jobs are of the same category with random job values in the range of £5k to £15M, that the number of competitors lies in the range of 5 to 9 and that bidding opportunities are randomly distributed throughout the year. One variant of the model attempts to set an optimum (or target) annual turnover, to which overheads are related, and that jobs of high value, which would cause the turnover limit to be exceeded, could be rejected.

8.2 List of questions asked during the interviews

1. What factors control the turnover?
2. Is the turnover one of the objectives of the firm for maximising the profit (depending on the market conditions)?
3. How do you define the term 'mark-up' and what do you include in the mark-up?
4. How do you allow for risk and in what way do you measure it?
5. How do you assess the optimum mark-up policy?
6. What is the range of estimating error?
7. Do you have any idea about the number and identity of your competitors?
8. Do you consider the usage of a fixed 'mark-up' policy?
9. What processes are involved in estimating?
10. What method would you use in selecting a contractor?
11. Is the lowest bid always the winning bid?
12. What is your policy regarding subletting/subcontracting?
13. What is the relation between the contract cost and contract duration?
14. Do you consider a fixed number of jobs to bid for in any calendar year?
15. What is your target turnover?
16. How much computer facilities do you use and in what way do you employ the micro computers?
17. How is the desired turnover calculated; is it linked to overheads in any consistent way?
18. What is the range of your mark-ups?

REFERENCES

1 Beishon, J. and P. , Geoff, eds. "System Behaviour", London : Harper and Row Ltd, 1972

2 Kast, F. E. and Rosenzwig, J. E. " The modern view : A system approach in system behaviour ", second edition , London : Harper and Row Ltd. , 1976

3 Checkland, P. B. " Towards a system - based methodology for real world problem solving in system behaviour " , London : Harper and Row Ltd , 1976

4 Jenkins , G. M. " The system approach in system behaviour " , London: Harper and Row Ltd , 1976

5 Churchman , G. W. " The system approach " , London : Dell publishing Co. Inc. , 1968

6 Ackoff, R. L. " Towards a system of systems concepts in system behaviour " , London : Harper and Row Ltd. , 1976

7 DeNeufville, R. and Stafford, J. H. " System analysis for engineers and managers ", New York : MacGraw - Hill Inc. , 1971

8 Naylor, T. H., Balintfy, J. L., Burdick, D. S. and Chu, K. " computer simulation technique ", J. Wiley and Son Inc., New York, London, Sydney, 1966

9 Moser, C. A. and Kalton, G. "Survey methods in social investigation", Heineman education books, 1958

10 Drake , J.D. " Interviewing for managers: sizing up people", American management association, 1972

11 MacMillen , W. " Statistical methods for social workers", The university of chicago press, 1963

12 Colclough, J. R. " the construction industry of Great Britain ", Butterworth and Co. Ltd. , 1965

13 Hillebrant, P.M." Economic theory and the construction industry", The Macmillan press limited, 1977

14 Thompson, P. " Organization and economics of construction " , MacGraw Hill book company (U.K.) Ltd. , 1981

15 " Civil Engineering Procedure " , the Institute of Civil Engineering, third edition, 1979

16 Milne, J.A. " Tendering and estimating procedures", George Godwin Limited, 1980

17 Deatherage , G.E. " Construction company organization and management", New-York: Macgraw Hill, 1964

18 "The public client and the construction industries", the report of the building and civil engineering economic development committees'joint working party, 1975

19 "Guidance on tendering for civil engineering contracts" , The Institution of Civil engineers, 1983

20 Friedman, L. "A competitive bidding strategy", Operational Research, 1956, Vol. 4, pp 104-112.

21 Friedman, L. "Competitive bidding strategies", Doctoral Dissertation, 1957, Case Institute of Technology.

22 Benjamin, N.B.H. " Competitive bidding for building construction contracts ", Ph.D. Thesis, May 1969, Stanford University

23 Benjamin, N.B.H. " Competitive bidding: The probability of winning ", Journal of the construction Division, ASCE, Sept 1972, pp 313-330

24 Park, W.R. "The strategy of contracting for profit", Edgewood Cliffs, N.J.: Prentice-Hall, Inc, 1966.

25 Park, W.R. "Bidders and job size determine your optimum markup", Engineering News-Record, June, 1968, pp 122-123.

26 Park, W.R. "How to bid to get both job and profit", Engineering News-Record, April, 1962, pp 38-39.

27 Park, W.R. "Lets have less bidding for bigger profits", Engineering News-Record, Feb. 1963, pp 41.

28 Broemser, G. M. " Competitive bidding in the construction industry ", Ph.D. dissertation, Stanford University, 1968

29 Howard, R.A. "Information value theory", IEEE transactions on system science and Cybernetics, August, 1966, pp 22-26.

30 Howard, R.A. "Value of information lotteries", IEEE tansactions on system science and Cybernetics, June, 1967, pp 54-60.

31 Gates , M. " Statistical and economical analysis of a bidding trend ", Journal of the construction Division, Nov. 1960, pp13-35

32 Gates , M. " Bidding strategies and probabilities ", Journal of the construction Division, ASCE, Nov. 1971, pp 277-303

33 Gates , M. " A monte carlo experiment ", Journal of the construction Division, ASCE, Dec. 1976, pp 669-680

34 Casey, B.J. and Shaffer, L.R. " An evaluation of some competitive bidding strategy models for contractors ", Construction research series No. 4, University of Illionis, 1964

35 Christenson , C. " Strategic aspect of competitive bidding for corporate securities ", Harward University, 1965

36 Clough, R.H. and Morin, T.L. "OPBID: Competitive bidding strategy model", Journal of the Construction division, ASCE, July 1969, pp 85-106.

37 Whittaker, J.D. " A study of competitive bidding with particular reference to the construction industry ",Ph.D. Thesis, 1970, City University

38 Maines, P.W. and Curtis, F.J. " Closed competitive bidding ", OMEGA, Journal of the management science, 1973

39 Fine , B. " Economics of construction: Tendering strategy ", Building , Oct. 1974, pp 115-121

40 Fine , B. " Reports of the Costain O.R. Group ", 1968-1974

41 Grinyer, P.H. and Whittaker, J.D. "Managerial judgement in a competitive bidding model", Operational Research Quarterly, 1973, pp 181-191.

42 Hanssman , F. and Rivett, B.H.P. " Competitive bidding ", Operational Research Quarterly, 1959, pp 49-55

43 Statham , W. and Sargent, M. " Determining an optimum bid ", Building, 1969, Vol. 216, No. 6573

44 Rickwood, A.K. " An investigation into the tenability of bidding behaviour theory and techniques ", M.Sc.Project report, 1972, Laughborough University

45 MacCaffer, R. " contractor's bidding behaviour and tender price pridiction ", Ph.D. Thesis, 1976, Loughborough University

46 Barnes, N.M.L. and Lau, K.T. " Bidding strategies and company performance in process plant contracting " , Third international cost engineering symposium, London, Oct. 1974

47 Russel, J.I.T. and Mercer, A. " Recurrent competitive bidding ", Operational Research Quarterly, 1969, Vol. 20, pp 209-221

48 Vickrey , W. " Counterspeculation, auctions and competitive sealed tenedrs ", Journal of Finance, Vol. 16, 1961, pp 8-37

49 Wilson, R.B. " comprtitive bidding with asymmetric information ", Management Science, 1967, pp 816-820

50 Griesmer, J.H., Levitan, R.E. and Shubik, M. " Toward a study of bidding processecs: Games with unknown costs ", Naval Research Logestics Quarterly, 1967, pp 415-473

51 Stark, R.M. " Unbabalnced bidding models - theory ", Journal of the construction Division, ASCE, Oct. 1968, pp 197

52 Stark, R.M. " Competitive bidding: A comprehensive bibliography", Operational Research Quarterly, Vol. 27, 1979, pp 364-390

53 Rosenshine, M. "Bidding Models: Resolution of a controversy",

Journal of the Construction Division, ASCE, March, 1972, pp 141-148.

54 Dixie, J.M. " Bidding models - the final resolution of a controversy ", Journal of the construction Division, ASCE, Sept. 1974, pp 265-271

55 Fuerst, M.J. "Bidding models: Truths and comments", Journal of the Construction Division, March 1976, pp 169-177.

56 Fuerst, M.J. "Theory for competitive bidding", Journal of the Construction Division, March 1977, pp 139-152.

57 Fuerst, M.J. "Competitive bidding: Theory of practice", M.Sc. Thesis, August 1975, Illinois University.

58 Benjamin, N.B.H. and Meader,C.M. " Comparison of Friedman and Gates bidding models ", Journal of the construction Division, ASCE, March 1979 , pp 25-40

59 Pim, J.C. "Competitive tendering and bidding strategy, Part 1: Collecting data and evaluating strategies", National Builder, Nov. 1974, pp 541-545.

60 Pim, J.C. "Part 2: New strategies for old", Feb. 1975, pp 56-57, 94-95.

61 Pim, J.C. "Part 3: Balancing profits and risks", Oct. 1975, pp 361-365.

62 Pim, J.C. "Part 4: Deal with chance on scientific basis", pp 68-70, 109-111.

63 MacCaffer, R. and Pettitt, A.N. " Bidding behaviour in project management ", The project manager, Vol. 1, Sept. 1976, pp 5-8

64 Harris, R.B. and Wade, R.L. " LOMARK: A bidding strategy ", Journal of the construction Division, March 1976, pp 197-211

65 Shaffer, L.R. and Micheau, T.W. " Bidding with competitive strategy models ", Journal of the construction Division, ASCE, March 1971, pp 113-126

66 Spooner, J.E. "Probabilistic estimating", Journal of Construction Division, ASCE, March 1974, pp 65.

67 Edelman, F. "The art and science of competitive bidding", Harvard Business Review, July-August, 1965.

68 Willenbrock, J.H. "Utility function determination for bidding models", Journal of the Construction Division, ASCE, Vol. 88, July 1973, pp 133.

69 Dean, B.V. "Contract award and bidding strategies", IRE Transactions on Engineering Management, Vol. 12, 1965, pp 53-59.

70 Carr, R.I. " General bidding model", Journal of the construction Division, ASCE, Dec. 1982, pp 639-650

71 Carr, R.I. " Impact of number of bidders on competition ", Journal of the construction Division, ASCE, 1982, PP 61-73

72 Ringwald, R.C. " Bid mark-up calculation by Crew-day method ", Journal of the construction Division, ASCE, Dec. 1982, pp 520-530

73 Turner, J.W.H. " Construction management ", 1963, C.R. Book Ltd

74 Wood, J.F. " Cnstruction management and design ", The macmillan press Ltd. , 1975

75 Chatfield, C. " Statistics for technology ", Chapman and Hall, 1975

76 Mayer, P.L. " Introductory probability and statistical applications ", Addison-Wesely, London, 1965

77 Mode, E.B. " Elements of probability and statistics ", Prentice Hall , 1966