CONTRACTORS' BIDDING BEHAVIOUR AND
TENDER PRICE PREDICTION

R. McCaffer

ERRATA

PAGE 212, 17th line

The coefficient of 'n' should be -0.196 not +0.196

PAGE 213, 3rd line

The coefficient of 'n' should be -0.196 not +0.196

This correction records the polynomials as used in the calculations and so no results are affected.

Page 104, 21st line

The expression for autocorrelation coefficients

should be

$$r_k = \frac{\sum_{i=1}^{n-k} (x_{(i+k)} - \bar{x})(x_i - \bar{x})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

Page 310, 6th line

z_i is $\phi\left[\frac{y_i - \bar{y}}{s}\right]$

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Variable print quality

DISTORTED PAGES IN ORIGINAL

Page 187 16th line should read

.... the designers under-estimate.......

and the last line should read

.... the designers under-estimate.......

Page 189 Table 6.2

To be consistent with the captions used to describe the value of the means the signs should be reversed.

Appendix R

The residuals presented are (Designers estimate - Mean bid)
and (Designers estimate - lowest bid)

CONTRACTORS' BIDDING BEHAVIOUR AND TENDER PRICE PREDICTION

BY

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SUMMARY

Data collected and work undertaken

Data relating to the bids for 384 roads contracts and 190 buildings contracts and a library of individual unit prices were obtained.

A statistical analysis of the distribution of bids and the behaviour patterns of individual contractors were undertaken examining both buildings and roads contracts.

A computer based system was developed which simulates tenders by selecting the required unit prices from the price library, correcting these prices for inflation, analysing the variability of the prices and predicting the likely mean and standard deviation of the tender prices. The accuracy of these predictions was tested against tenders that did not form any part of the price library's data base. The number of such tenders available was limited to 15.

CONCLUSIONS

The normality or near normality of the distribution of bids for buildings and roads contracts is established. This allows the relationship between mean and lowest bids to be defined using normal order statistics. It also permits the application of outlier tests to be used in identifying unrealistically low bids.

The average mean standardised bids of contractors have a strong negative correlation with the contractor's success ratio. This allows contractors to predict success ratios of others using their mean - standardised bids. The data required for this is not limited to the competitions in which the contractor himself enters.

Contractors have different behaviour patterns, some with disproportionate numbers of high or low bids and others behave randomly. These behaviour features correlate well with the average mean - standardised bids.

Graphs of the cumulative sum of (bid-mean bid)/mean bid are useful in identifying contractors who are seeking work and those who are not. These can be used to identify serious rivals for particular contracts.

Contractors have different sensitivity of success ratio to changes in bid value thus indicating different market judgements.

Contractors also have different trends within their standardised bids to contract value. This only affects success ratios in extreme cases.

Designers have accuracies of standard deviations of 16.63% and 20.14% for predicting the lowest bid of buildings and roads contracts respectively. Price models based on multiple regression analysis produce similar accuracies for comparable construction works.

Contd/...

The tender price prediction system developed, based on a library of unit prices and inflation indices achieved a standard deviation of 8.30% in predicting the mean bid and 11.08% in predicting the lowest bid for roads contracts. This could be improved with more data in the price library but nevertheless is a substantial improvement on the results achieved by designer's estimating.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

Figure S.2 Multiple regression model

$$Cost = a + B_1 \text{ (Total area of single units)} + B_2 \text{ (No. of storeys)}$$

Figure S.3 In this case cost does not vary linearly with quantity

Figure S.4 By transforming quantity to(quantity) a linear relationship with cost could be obtained

ACKNOWLEDGEMENTS

In preparing a thesis members of staff are not accorded the privilege of a supervisor. For this reason I am more than usually grateful to those who gave me their supervision, advice and guidance.

In particular I am thankful to

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The late Mr. P. De Vigne who made the arrangements for me to have access to the data.

1.0 INTRODUCTION, OBJECTIVES AND MAIN FINDINGS

1.1 INTRODUCTION

Competitive bidding is still the most common basis of awarding contracts to contractors in the construction industry. The competitive bidding process and its implications have been the subject of academic study and of many papers in learned journals since 1956. 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 contracts. However the effect and impact on the industry of this effort is difficult to detect. This is not a new observation and has been the starting point of some of the more recent attempts to improve the situation.

The reasons for the apparent lack of practical application of existing theories and recommended approaches are not difficult to determine. The main reason is the lack of a consensus amongst the experts. A review of the literature reveals that the first 10 to 15 years of discussion on bidding strategy was dominated by a debate between Friedman(1) who was the first to propose a 'model' for predicting the probability of a contractor winning a contract and Gates(2) who argued that Friedman was wrong. Gates proposed his own solution which produced estimates of the probability of winning that differed from Friedman's estimates.

During this period the major contribution of others were attempts to resolve this conflict. In the post Friedman-Gates argument era several different approaches emerged but they either failed to gain support or met with damaging criticism.

Another reason put forward for the lack of practical applications of statistical approaches to bidding is that it is unnecessary and existing intuitive practices are adequate. However there is substantial evidence that the existing bidding processes are little more than random. The low profit/turnover ratios achieved and the high bankruptcy rates experienced by the construction and in the U.K. the obsession with claims can also be, at least, partially attributed to the methods of awarding contracts. It can therefore be contended that existing approaches to bidding are inadequate and more rational approaches are needed.

The questions remaining are what has the investigations to date revealed and what are the major drawbacks remaining that make the use of existing bidding theories impractical?

The main historical effort has 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 maximise expected profits. Also the minimisation of the difference between the winning bid and the second lowest has been attempted; again as a means of improving profit margins. Almost all of the approaches involve the collection of competitors' bids each time the individual contractor entered a bidding competition. Since all the approaches were 'statistical' and dependent on reasonable sample sizes and most contractors bid for a relatively small number of contracts meeting different competitors these approaches foundered. In order to break with this type of approach Whittaker(3) proposed a distribution of all possible bids belonging to building contracts. If the mean of this distribution was estimated with fairly high accuracy the Whittaker distribution could be used to predict the probability of any specific bid being the winning bid. The criticisms of Whittaker's approach were aimed at the method of analysis used to produce the distribution and on the estimating of the mean bid which was left to 'managerial judgement'. However the Whittaker approach remains interesting in that it attempted to produce a method which was not heavily dependent on each contractor collecting large amounts of data. Finally the work of Mercer & Russell[4] made the point that contractors prices (i.e. bids) will change with time relative to other contractors. This has been largely ignored by subsequent work on the grounds that to monitor price changes requires a substantial amount of data which is usually unavailable and it is likely to be impossible in construction type contracts where there is little similarity between one contract and the next. The value of comparing bids is further questioned when the inaccuracy of contractors estimating is considered.

1.2 OBJECTIVES

To summarise the major weaknesses of the historical work in 'bidding strategy', which were taken as the objectives of this research, are:

(i) that the data base available to contractor's from their own competitions is too narrow for most statistical approaches and therefore if statistical approaches are to be used the data base must be broadened to include data other than the contractor's own competitions;

(ii) that a more rigorous analysis of bidding data is needed in order to support the distribution of all possible bids approach put forward by Whittaker;

(iii) that a method is needed, other than managerial judgement, for estimating the likely tender price;

(iv) that the differences in bidding behaviour of different contractors and the changes that take place in this bidding behaviour with time should be accounted for in any explanatory or predictive models of bidding behaviour.

1.3 Work Undertaken

The analysis which attempts to answer some of these points was made possible by obtaining the bids relating to 190 buildings contracts and to 384 roads contracts involving some 400 contractors. This enabled the distribution of bids to be analysed taking account of the contract type, the contract value and the number of bidders. As the individual contractors were identifiable a study of the individual bidding behaviour of each contractor was also possible. Further data relating to the individual unit prices which were collected to form a price library were used as input to a tender price prediction system. All the data relate to the Belgian construction industry and not to the U.K. construction industry.

The investigations required the development of over 50 different computer programs. The listings of these programs are not reproduced in this document but a brief description of the main programs is given in appendix U.

1.4 MAIN FINDINGS

As a result of this work the following main conclusions were drawn.

Distribution of Bids

(1) Normal distributions are appropriate when describing the distribution of bids for buildings. Although less conclusive evidence is presented the same assumption is practical for roads contracts.

(2) Different types of contract (i.e. Roads and Buildings) have significantly different variances.

(3) There is little correlation between the number of bidders and the variance of the distribution of bids. That is the variance does not alter systematically as the number of bidders increases.

(4) There is little correlation between the value of the contracts and variance of the distribution of bids. That is the variance does not alter systematically as the value of the contracts increases.

(5) The distribution of bids grouped by the number of bidders is more useful than an overall distribution when studying the relationship of the lowest bid with the mean bid.

(6) Using the assumption of normality for the distribution of bids tests for 'outliers' can be used to exclude unrealistically low bids.

Contractors Bidding Behaviour

(1) There are differences between the average bids of contractors which can be shown to be significantly different. There is a strong negative correlation between these average bids and the contractors' success ratio(bids won/bids submitted).

(2) There are different behaviour patterns with different contractors, some have a predominant number of high or low bids whereas some others behave randomly.

(3) Different contractors show different sensitivities in their success ratio(number of bids won/number of bids submitted) to changes in their bids*. This indicates differing skills in market judgement.

(4) Simulation of contracts using historical bids is unhelpful in predicting the winning bidder.

(5) By monitoring the effect of contractor's bids relative to the mean bid in a cumulative manner a pattern emerges which indicates whether the contractor is currently seeking work or not. This method is successful in indicating the serious competitors. It also widens the data base available to contractors beyond the contracts for which they bid and is consistent with the claims of Mercer & Russell that relative prices change with time.

Tender Price Prediction

(1) The attempts at predicting tender prices is currently undertaken by the designers of the contract works. The accuracy of these designers is a standard deviation of 16.63% for buildings contracts and 20.14% for roads contracts. For building works in particular there is strong evidence that as the number of competitors increases not only does the value of the lowest bid decrease, as would be expected assuming the designer takes no account of the number of bidders, but the value of the mean bid also decreases. This is taken to indicate that as competition increases there is evidence of price reduction.

(2) A tender price prediction system based on a library of unit prices which could be continually topped up with new unit prices for the same items from recent contracts produces tender price estimates which have an accuracy of a standard deviation of 8.68% when predicting the mean of a set of bids for roads contracts. This compares favourably with the 20.03%

accuracy achieved by the designers. Using the relationship between the mean and lowest bids the estimates of mean bid can be converted into an estimate of lowest bid. The accuracy achieved by estimating the lowest bid is a standard deviation of 11.09%. Again this is a substantial improvement on the 20.14% achieved by the designers.

Note

As stated in page 4 all the data used relate to the Belgian construction industry and not to the U.K. construction industry.

The Belgian contractors were tendering under special conditions (described in reference 26) and the bids that they were offering were subject to possible additions based on a process of comparison and averaging of the various bids. It is likely, therefore, that the contractor's expectations and attitudes would be different from those of a U.K. contractor tendering under U.K. conditions. Also data are available to the Belgian contractors in respect of other contractor's bids and therefore the possibility of examining the bidding behaviour of competitors is much greater than in the U.K. At the end of section 8.0, the conclusions, some comments are made on the limitations of the application of the findings of this work.

2.0 BRIEF HISTORICAL REVIEW

The study of the competitive 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".[(1)] 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 esimate being a "scientifically" prepared estimate of the cost to the contractor in performing the work involved in the contract. The accuracy that contractors' achieve in their estimating will be discussed in detail later as it is a major variable influencing the outcome of these bidding competitions. 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 (his bid)/(our cost estimate). From these ratios he produced a cumulative frequency distribution as in figure 2.1.

This established the concept of a continuation of mark ups from mark ups which give a 100% chance of winning to mark ups which produce no chance of winning, assuming that the competitor's behaviour is unchanged. The probability of beating competitor A, $P_{(M)} = P_{(A)}$, for any specific mark up was extended to cover several competitors in the following model

$$P_{(M)} = P_{(A)} \times P_{(B)} \times P_{(C)} \text{ etc.}$$

To deal with the case of unknown competitors the suggestion was that regardless of who the competitors were the collected data would be aggregated into one 'typical' frequency distribution which would give the probability of beating a 'typical' competitor for any specific mark up (M).

$$P_{(M)} = P_{(T)}$$

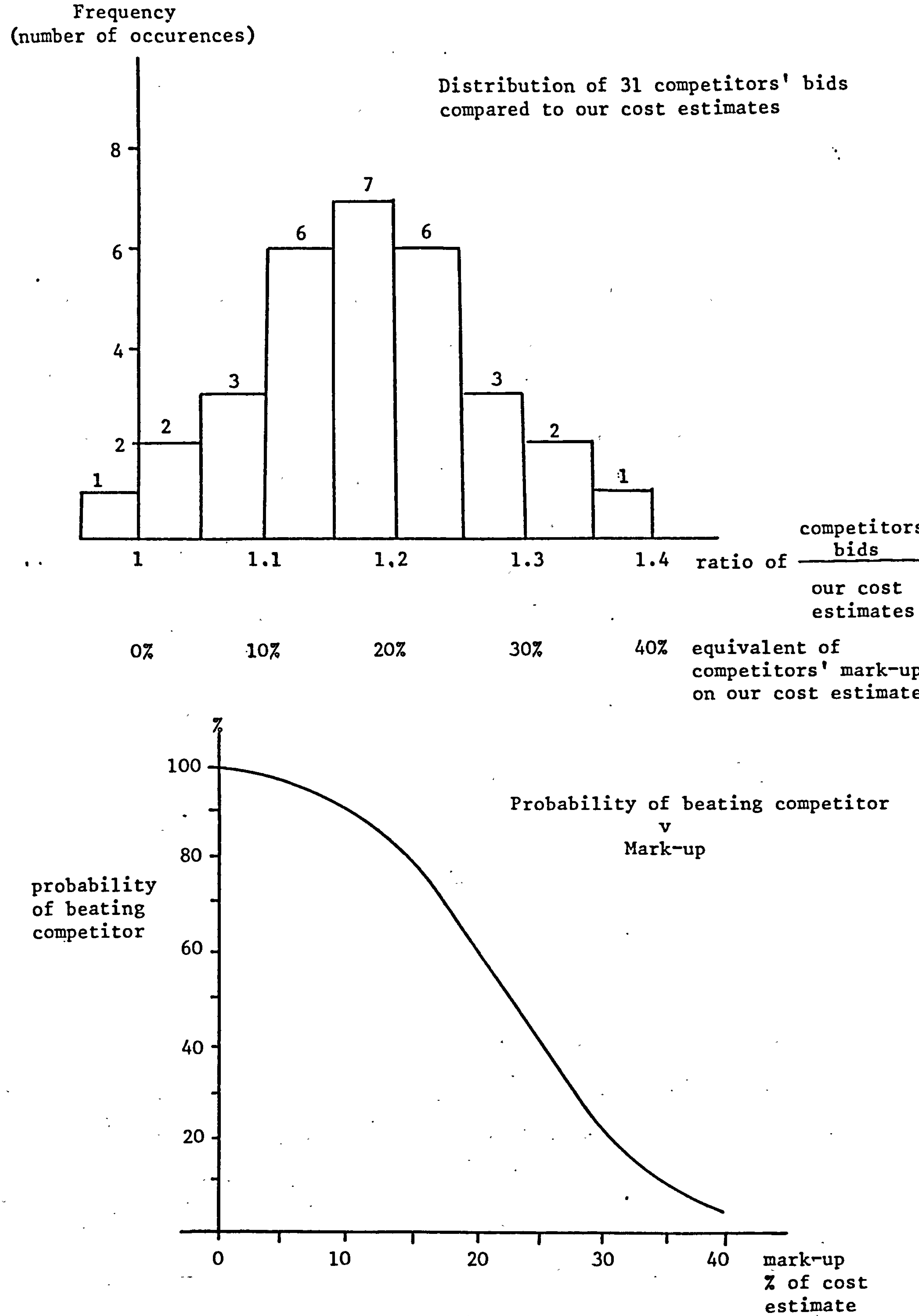


Figure 2.1 Probability of beating a competitor v mark-up

This was extended to the general case of several unknown competitors in the model

$$P_{(M)} = P_{(T)}^{\,n}$$

where n is the number of unknown competitors.

Several people developed from this starting point, the more notable being Park[5], Statham & Sargeant[6], Gates[2], Morin & Clough[8], Stark[8], Rosenshine[9] and Fine[10].

Gates[2] 1967, being the more important of these at the time clearly challenged the validity of Friedman's model mainly on the basis that Friedman was assuming the collected data was independent and the probabilities of each contractor winning as calculated by Friedman did not usually add up to one. The alternative he put forward was again based on the same frequency distributions but the method of calculating the probability of winning for a given mark up (M) was given by

$$P_{(M)} = \frac{1}{\dfrac{(1-P_{(A)})}{P_{(A)}} + \dfrac{(1-P_{(B)})}{P_{(B)}} + \ldots + \dfrac{(1-P_{(n)})}{P_{(n)}} + 1}$$

and for the typical case using an aggregated frequency distribution

$$P_{(M)} = \frac{1}{\dfrac{n(1-P_{(T)})}{P_{(T)}} + 1}$$

The probabilities sum to one when the probability of one competitor beating another is 0.5. Gates and Friedman succeeded in stimulating an academic debate which unfortunatley resulted in a substantial effort being made in resolving their argument.

Park[5a, 5b] accepted Friedman's approach and published a book in 1966 and a paper in 1968. He emphasised in particular the effect of the number of bidders and of job size in the determination of an 'optimum mark up'. This optimum mark is easily calculated from Friedman probabilities and is based on the expected profit, for example with a mark up of say 10%

and the probability of winning of 50% the expected profit is 5%. If a range of mark ups is calculated in this way then the 'optimum' emerges as the mark up which produces the largest 'expected profit'. However this approach does not seem to have captured the imagination of the construction industry who view it with incredulity. The approach of determining an optimum mark up was supported in the U.K. by Statham & Sargeant[6] who also attempted to determine the optimum mark up, if the subsequent literature is examined it seems that they were no more successful than Park in having their ideas adopted. The lack of support for these approaches can be identified as the fundamental question of validity which hangs over Friedman and the insensitivity of the optimum mark up to specific market conditions.

Theoretical justification was put forward for Gates by Baumgarten, Benjamin and Gates[11] as part of their discussion on Morin and Clough's[8] OPBID model. However the academic world seemed unconvinced and one attempted resolution of the controversy by Rosenshine[9] in 1972 by argued that Friedman and Gates calculated probabilities were in fact representing different situations and that Gates' probability was independent of the contractors bid and thus independent of the mark up.

As previously noted the differences in the two models rests on the assumptions as to whether the Friedman distributions of competitors are statistically independent of each other. Fine[10] and Rickwood[12] have attributed the variability of a contractor's bid to estimating variability and mark up variability. The estimating variability they attribute to estimating errors which in their view are mainly random and therefore the cost estimate is a random variable. Rickwood[12] 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. In the practical situation where both the estimates and the mark ups are variables neither Friedman nor Gates are correct. Fine[10] in general agreed with this conclusion. Rickwood[12] proposed, but never tested, a weighted average of Friedman and Gates, the weightings representing the contribution to the total variability of the estimating variability and the mark up variability.

Fine[10] had earlier attempted to circumnavigate the problem of calculating probabilities by declaring that the only competitor one was trying to beat was the lowest. 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 from different distributions. The drawback admitted by Fine himself was that the distribution required a substantial amount of data before it became 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 stabilise the distribution. The length of time required would cast doubt on the value of the early data.

Grinyer and Whittaker[13] had a different approach which was an imaginative break with the previous, almost 'traditional' approaches but left a number of significant questions unanswered. Whittaker collected data relating to 57 buildings contracts and derived a distribution which represented the distribution of all bids. This distribution which he showed to be more or less uniform was used to predict the probability of any specific bid being the winning bid provided the mean bid could be estimated to within + 1%, - 3.5%. The questions that were raised were

(1) Is the use of a uniform distribution accurate and adequate?

(2) Can contractors estimate mean bids to within +1%, -3.5%, to which a supplementary question could be asked - if they can, what more aid do they need?

Both points were raised by Curtis and Maine[14] both of whom had acted as assistants to Fine. They alleged that the statistical analysis used by Whittaker to derive his distribution was invalid. For each set of bids belonging to one contract Whittaker divided each bid by the mean bid. He then amalgamated all these 'mean standardised bids' from all his 57 contracts into one set of data irrespective of the individual sample size of each contract. From this set of data he fitted a distribution and validated it by a Chi-squared test. The point in this method which was criticised by Curtis and Maine was the amalgamation of the data irrespective of sample size. They demonstrated their case by simulations. This same point has also been criticised by statisticians and therefore the criticism must be accepted.

On the second point Curtis and Maine also demonstrated by simulation how sensitive Whittaker probabilities are to changes in the estimate of mean bid.

Grinyer and Whittaker's[15] reply was to quote their successful application where they claim that a bidding performance of a company could have been improved in 60% of cases using the 'Whittaker' model.

Curtis and Maine[16] also produced a conditional probability model as did Dixie[17] in an attempt to clarify the Friedman-Gates situation. Curtis and Maine[16], however, observed that there are many variables not taken into account by these probabilistic approaches and are cautionary about placing too much reliance upon them.

An important contribution made by Whittaker[5] and also supported and further explained by Fine[10] was to describe the potential effects of estimating inaccuracy. 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 "true cost". Given that competitive bidding selects the lowest bid then the winning bid is nearly always on the low side of true cost. Grinyer & Whittaker's[13] observation was 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 ± 0.35% about a mean. Thus the controlling variable was the estimate and in turn the estimating inaccuracy. From this followed the concept of 'break even mark up' which states that if a contractor wishes to break even in the long term he must add a mark up greater than zero. This mark up, known as the break even mark up, compensates for the effect of always selectingthe lowest bid and therefore the one that is usually based on an estimate that is less than the true cost. The amount of the break even mark up is a function of the number of competitors and the level of estimating accuracy. Figure A.2 in appendix A shows this relationship. Appendix A, "Is there an economic case for more accurate estimating" by McCaffer[18] describes the effect of varying the assumed estimating accuracy and consequentiallygives a measure of the benefits to be gained in improving estimating accuracies. Conversely it also demonstrates the inherent dangers in becoming slack and complacent in producing estimates. Appendix A is a reprint of a paper originally presented at an Estimating Conference held in September 1973 at Loughborough University of Technology sponsored by Construction News. The conference proceedings[19] are published but the technical addendum in Appendix A has not previously been published.

Barnes and Lau[20] 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% at best to a coefficient of variation of 18.4% at worst. Barnes and Lau also concluded that this inaccuracy made it impossible to obtain feedback from real bidding situations as to the effect of different pricing policies. Some of the observations of Fine[10] on the subject of estimating accuracy were recorded by Hackemer[21], these largely consolidated the observations of Whittaker[3].

A major contribution to bidding strategy not yet discussed is that by Mercer and Russell[4]. Mercer and Russell in studying gravel supply contracts demonstrated that contractor's relative prices changed with time, that is the lowest priced contractor did not remain the lowest priced contractor for all time. The sense of what they stated was irrefutable but Whittaker[3] while acknowledging that contractors relative prices would change with time conceded that he was unable to take account of this because of the amounts of data required. The other major difficulty in following Mercer and Russell's work is that each contract in the construction industry is virtually unique, except in a few cases where work is repetitive. It is thus much more difficult to detect different pricing policies when the product is so variable. Nevertheless Mercer and Russell's observations are fact and should be taken into account.

This brief review of the historical work on bidding strategy led to the starting point which were taken as the research objectives as stated in page 3.

3.0 DATA

3.1 Source and Nature of bidding data

The data used in this work were taken from records of a continental contractors' association. These records were kept on pre-printed proformas on which were entered, by hand, the data relevant to a specific contract. Each form referred to one contract only and contained the following information:

1) geographical location;
2) description of work;
3) client;
4) bidding opening date;
5) a reference number;
6) any remarks;
7) a file number;
8) category and class of contractor;
9) cost estimate by designer;
10) data of closing bids;
11) contractors' identity (these were given numbers so that names could not be identified);
12) the bid of each contractor;
13) arithmetic mean;
14) file number of previous bids.

Items 1) to 7) are self explanatory, Item 8) refers to the country's own classification system whereby some contractors are limited to certain ranges of work by type of work and by value fo contract; this item of information was not particularly helpful and in many cases was missing.

Item 9) was not present in all cases but existed in a sufficient number to test the accuracy of the designer in predicting the lowest tender value.

Item 10) is self explanatory.

Item 11) - a code number was given to contractors with a view to preserving the ability to identify bids belonging to the same contractor whilst maintaining confidentiality.

Item 12) was the bid submitted by each contractor and item 13) was the mean of all the bids submitted for the contract. Item 14) referred to any contracts that had been withheld previously and 're-tendered.

Some 600 forms were obtained, 190 referring to buildings contracts, 384 referring to roads contracts and 16 referring to bridge contracts.

3.2 Organisation and handling of bidding data

The data contained on the forms described in 3.1 were transferred to coding sheets (see Appendix B) in a pre-determined format and punched on cards. A purpose written computer program read these cards, performed some error checks and transferred the data to magnetic tapes. All future programs accessed the magnetic tapes.

The number of forms available made the coding a formidable and tediously long task.

3.3 Price Library Data - source and nature

A private company of cost consultants had formed the framework of a 'price library'. The price library was made up of standard item numbers and the prices entered against these item numbers were taken from contractors' bills of quantities. The bills of quantities are very different from those used in the U.K. and a large job may only contain some 100 - 150 items compared with the 1000 to 1500 items that may appear in a U.K. bill. The price library was divided into two geographical regions, each region contained three sections divided by work type and each section was divided into time periods.

The useable data in this price library were held on magnetic tape in a summarised form. This summarised form contained the following data for each item in each contract analysed.

1) The item number
2) An identifier which indicated whether the item was "quantity measured" or "lump sum measured".
3) The units of quantity measured items, e.g. M3 or M2 etc.
4) The quantity of the item.
5) The unit price of one contractor or median of the price submitted by the contractors tendering for the contract.
6) The total price, the product of 4) and 5).
7) The percentage contribution of the item to the total contract value, the total contract value measure as the sum of all the prices appearing in 6).
8) The cumulative percentage of the sum of this item and all other items with a larger contribution to the contract value.
9) The position of the item in rank order of items in the contract. Items being ranked largest to smallest in terms of contribution to the contract value.
10) The number of items in the bill of quantities.
11) The item reference number in the bill of quantities.
12) A code number which includes the contract number.

A magnetic tape of these summaries based on 171 contracts was made available for this study.

The items which were missing and judged to be important were the date of the contract and the number of prices from which the median was taken. Both these items of information were made available separately, but not on magnetic tape. The data on the magnetic tape and this information made available separately were correlated via the contract number, which was unique.

3.4 Organisation and handling of price library data

The data contained on the magnetic tape were produced by a Burrough's computer. This tape was copied and modified to render the tape useable on an I.C.L. computer. This task involved the use of computer centre library tape handling routines. The other data was punched on cards and added to the copied tape. This modified tape file was used in the tender price prediction system described in section 7.0.

4.0 DISTRIBUTION OF BIDS

The Data and reasons for Analysis

The data consisted of bids made for 574 contracts for public works between 1971 and 1974. The prices of the submitted bids varied from less than 1 million units of currency to more than 30 million units of currency and were known to the nearest 1 unit, that is continuous to six significant figures. The contracts were of two types, roadworks and building works. 190 contracts related to buildings and 384 related to roadworks. For each contract at least two companies submitted bids and the largest number of competing companies for a particular contract was 18. Thus the data consisted of 574 samples of differing size, location and spread.

The reason that led to undertaking a rigorous analysis of the distribution of these bids was basically a lack of sufficient and supported evidence as to how these bids would behave. A review of the literature reveals:

i) Whittaker's[3] analysis to establish a distribution of bids was invalid (see 14); his number of samples was much smaller than the data available and his bids related to only one contract type;

ii) Beeston[23] alleged that distributions of bids,or prices as he called them, were lopsided (skew) but did not in the available document produce his analysis and went on, in the same document, to assume normality. Beeston pointed out that his assumption of normality did not lead to errors;

iii) Emond[24] based his work on the assumption of normality but again did not support it with published evidence;

iv) Alexander[25] again assumed normality but did not support it with any analytical evidence.

To summarise, there is Whittaker's almost uniform distribution, Beeston's skewed distribution and Emond and Alexander assuming normal distributions but not producing any supporting evidence.

It was considered essential, therefore, to undertake an analysis of the available data to establish the distribution of the bids in order

a) that the feasibility of a Whittaker type prediction model could be fully explored,

b) to determine if there is any difference between different types of contracts or contracts of different value or of contracts with different numbers of bidders,

c) to establish if there was any reasonable theoretical support for the price adjustments based on differences between mean and lowest bids as employed in Belgian tendering systems (see ref. 26). The theoretical investigation of this aspect relates to the method of calculating the price adjustment. The issue of whether such price adjustments are valid is not considered here.

d) to determine if statistical tests could be employed to identify unrealistically low bids.

The analysis of the distribution of bids was undertaken as follows.

4.1 Calculation of basic parameters.

4.2 Variability of the basic parameters.with contract type, contract size and number of bidders.

4.3 Tests for uniformity and normality.

4.4 Relationship between mean and lowest bid.

4.5 Tests for outliers.

The Reasons for choosing these statistics

i) Basic distribution parameters

The basic parameters used to describe a distribution are mean, variance, skewness and kurtosis. The last three being functions of the 2nd, 3rd and 4th moments of a distribution. While variance measures dispersion, skewness and kurtosis together will indicate the type of distribution to which the samples belong.

ii) Variability of the parameters with contract type, contract size and number of bidders

This was a study of the identifiable factors that may have influenced the distribution of bids.

iii) Tests for uniformity and normality

The test for uniformity was undertaken to either support or refute the suggestion of uniformity made by Whittaker [3]. The basic distribution parameters suggested normality. The test for uniformity chosen was the Studentized Range as described by Pearson and Hartley[30] and in appendix D. This test was chosen because it was known to be a powerful test of uniformity against normality.

The test for normality used was the Anderson-Darling test as described by Pearson and Hartley [32] and in appendix E. This test was chosen because it was known to be a powerful test for normality as reported by Stephens[33] in his comparison of Anderson-Darling with other statistics. The Studentized Range is only powerful as a test for uniformity against normality but is not a powerful test for normality. The need for powerful tests is that the data are many small samples.

iv) Relationship between mean and lowest bids

Previous tests indicated normality or near normality. This calculation would demonstrate if the assumption of normality could be used to predict the lowest bid from the mean bid. If this was possible the assumption of normality would be further confirmed and the relationship could be used in the tender price prediction system described in section 7.0. This prediction system would use the argument that the mean bid is less variable and therefore predictable with higher accuracy. The established relationship between the mean and lowest bid could in turn be used to predict the lowest bid.

v) Test for Outliers

As with item iv) this calculation was used to determine if the assumption of normality could be used to determine if the lowest bid lay in the lower 10% tail of the distribution of possible bids.. If 10% of the lowest bids did lie in the lower 10% tail then again the assumption of normality would be confirmed. Also the statistical mechanism for identifying such low bids would be established.

4.1 Calculation of the Basic Parameters

The data relating to 384 roads contracts and 190 buildings contracts and 16 bridges contracts were analysed as described below.

For each type of contract each set of bids (a set is the bids belonging to one contract) was treated as follows.

1) The bids for each set were standardised by dividing by the mean of the set.

2) Using the raw and standardised bids the mean, variance, third moment, fourth moment, skewness and kurtosis were calculated. Appendix C gives the method of calculation. It should be noted that in these calculations a correction for small samples was made, as described in appendix C.

3) For sets of bids with the same number of bidders the average of each of the above statistics was calculated.

4) For each contract type the weighted average of the above statistics was calculated, the weighting being the number of bidders multiplied by the number of contracts with that number of bidders.
The resultant statistics were taken to be the statistics which describe the parent distribution to which all bids of the same contract type belong.

By calculating the statistics for each set of bids and taking the average for sets with the same number of bidders and then taking the weighted average for all bids the criticisms of Whittaker's method of calculation are avoided. The criticism of Whittaker by Curtis and Maine[14] was that all the bids were amalgamated irrespective of sample size and then the statistics calculated from

Footnote

The standardisation of bids against the mean bid for the contract is a method of scaling the absolute bids. The eventual method adopted was to scale the bids before statistical calculations; this was chosen in preference to scaling the statistics obtained by calculation. The reason for the adopted method was on the grounds that the statistics so obtained were more easily compared with the work of others (e.g. Whittaker) and that the standardized data lends itself more easily to further statistical tests such as t-tests and ANOVA. The use of non-standardized data to calculate basic parameters is possible and was explored early in the investigation.

The use of the words 'raw data' in item 2 above was intended to refer to the use of the raw data to calculate means and the standardised data to calculate the other parameters.

this combined set of data.

Table 4.1 shows the weighted average of the key statistics as described previously. The individual statistics for each 'n' bidder is represented in figures 4.2, 4.3, 4.4 and 4.5.

TABLE 4.1 Summary of hypothetical distributions describing the distribution of all possible standardised bids

Type of contract	Degrees of freedom	Variance	Skewness	Kurtosis
Buildings	1114	0.0042217	0.517685	3.08209
Bridges	108	0.005735	-0.012364	3.64213
Roads	1721	0.007038	0.21029	3.199704

(Note: Degrees of freedom = (nx no. of contracts with 'n' bidders) - Total number of contracts

n = No. of bidders

Degrees of freedom give a relative weight to the calculated parameters, the calculations are based on contracts with 3 or more bidders.)

The observations to be made are that the skewness was relatively small and that the kurtosis is near to 3.0. If skewness is zero and kurtosis was 3.0 then it could be assumed that the samples were being drawn from normal distributions, see ref. (27) page 460. This is sufficient for the time being to assume that the parent distribution is normal or near normal. Further tests are reported in section 4.3.

4.2 Variability of basic parameters with contract type, contract size and number of bidders

Contract type

Significance tests (F-test at 10% level of significance as described in ref. 28) show that the variance of the bids for buildings, bridges and roads given in table 4.1 are significantly different from each other. Therefore these contracts must be treated separately and it is not appropriate to treat them as if they belonged to one data set.

<u>Contract size</u>

The data were separated into the same size ranges as used by the organisation supplying the data. The reason why the data supplying organisation categorised the contracts according to contract value was that the price adjustments made to winning bids which are controlled by the difference between the lowest bid and the mean bid are limited according to the contract value. Reference 26, pages 156 to 201, explains this and figure 4.1 shows the diagram used to calculate the adjustments and the limitations imposed by the contract value.

Table 4.2 shows the results for each contract value range calculated in a manner as described in section 4.1.

TABLE 4.2 Variance of bids within different contract value ranges

Contract Value Range	Variances of overall distribution of bids			Degrees of Freedom		
Units of Currency	Buildings	Bridges	Roads	Buildings	Bridges	Roads
<6m	0.006684	0.008942	0.006742	31	9	786
6m - 15m	0.00372	0.01318	0.008681	330	20	510
15m - 30m	0.004908	0.00287369	0.004952	459	18	310
>30m	0.00346	0.0036919	0.008059	294	61	115

(Degrees of freedom = (n x number of contracts with 'n' bidders)- total number of contracts

n = number of bidders)

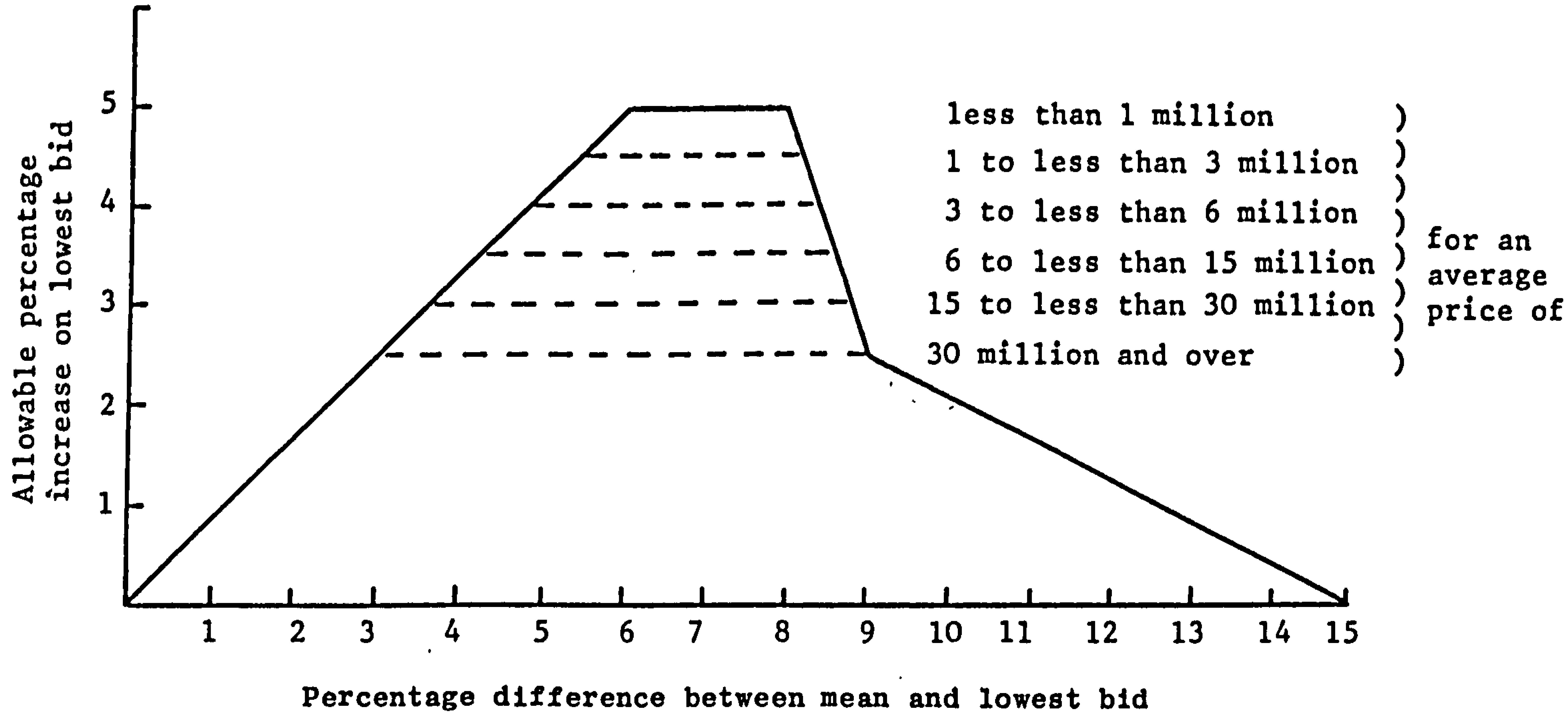


Figure 4.1 Adjustment of prices in Belgian Tendering System

Although some of these variances are significantly different as calculated by the F-test at 10% level of significance there is no systematic change of variance with increasing contract value. The conclusion drawn is that there is no clear trend between variance of bids and contract value and no basis exists for differentiating between contracts of different value. This conclusion means that contracts of the same type can be treated together irrespective of the value. This calls into question the logic behind limiting the price adjustments as the value increases (see reference 26 and figure 4.1), although it is understood that the main reason is to limit the absolute value of the price adjustments.

Number of Bidders

Having criticised Whittaker for amalgamating all his data irrespective of the sample size, that is the number of bidders, it was considered important to fully explore the effect of number of bidders on the calculated statistics. The results of this investigation are presented in graphical form in figures 4.2 and 4.3 for buildings contracts and figures 4.4 and 4.5 for roads contracts. The number of contracts contained in the bridges sample was considered too small to be of interest and no further investigation of bridges contracts was made.

The conclusions relating to the graphs produced are given on each graph.

The preliminary conclusion that the bids are samples from normal distributions made in section 4.1 was based on the near zero skewness and a kurtosis of 3.0. Re-examining these variables, skewness and kurtosis, for each 'n' bidder for both buildings and roads contracts leaves this preliminary conclusion intact. The reasons

Contd on page 31/...

BUILDING CONTRACTS

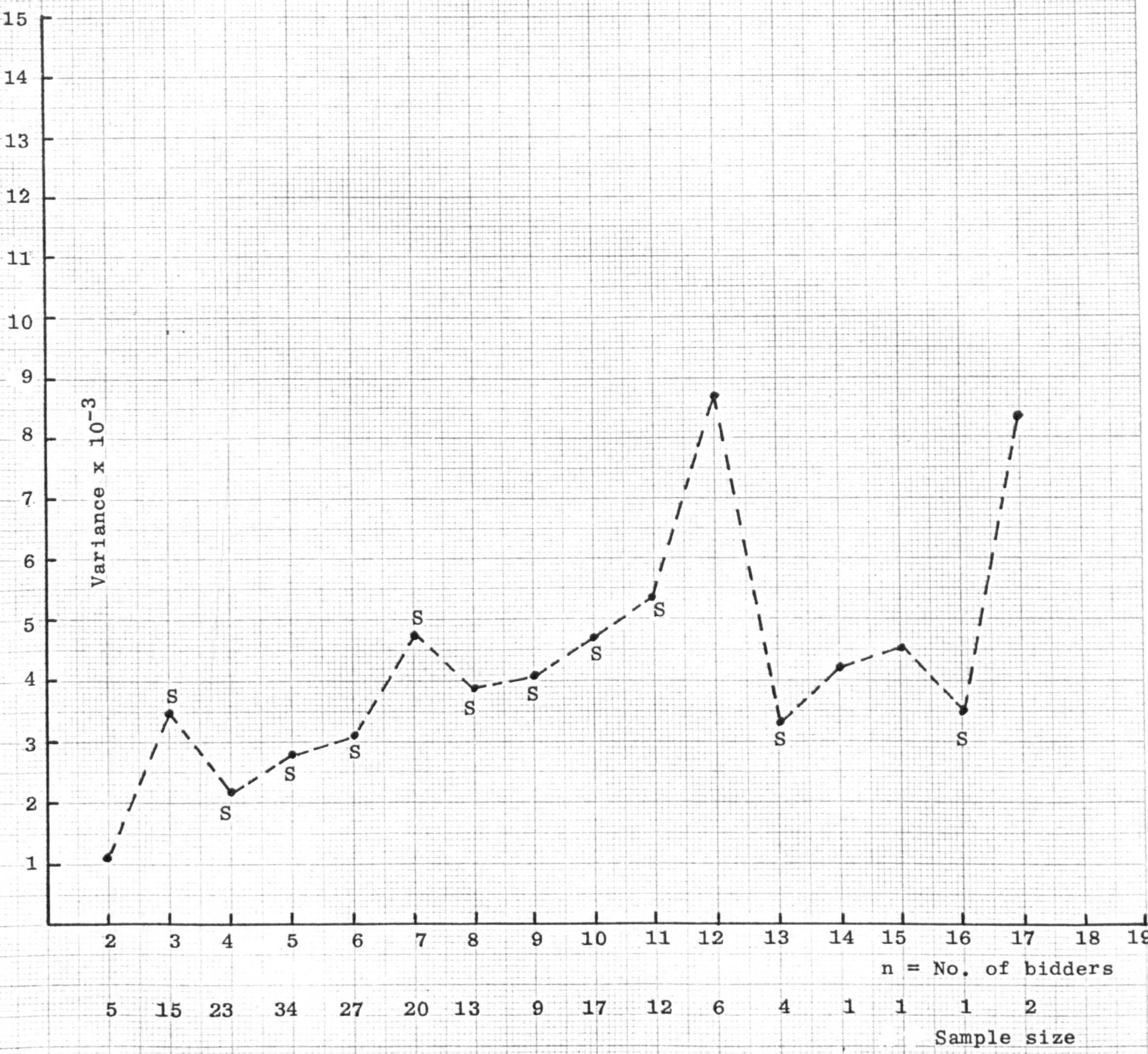


Figure 4.2 A plot of variance against number of bidders for Building Contracts. The S indicates that the variance is significantly different from the previous variance (i.e. for n - 1 bidders)

Conclusion: If any trend exists it is that variance increases as n increases.

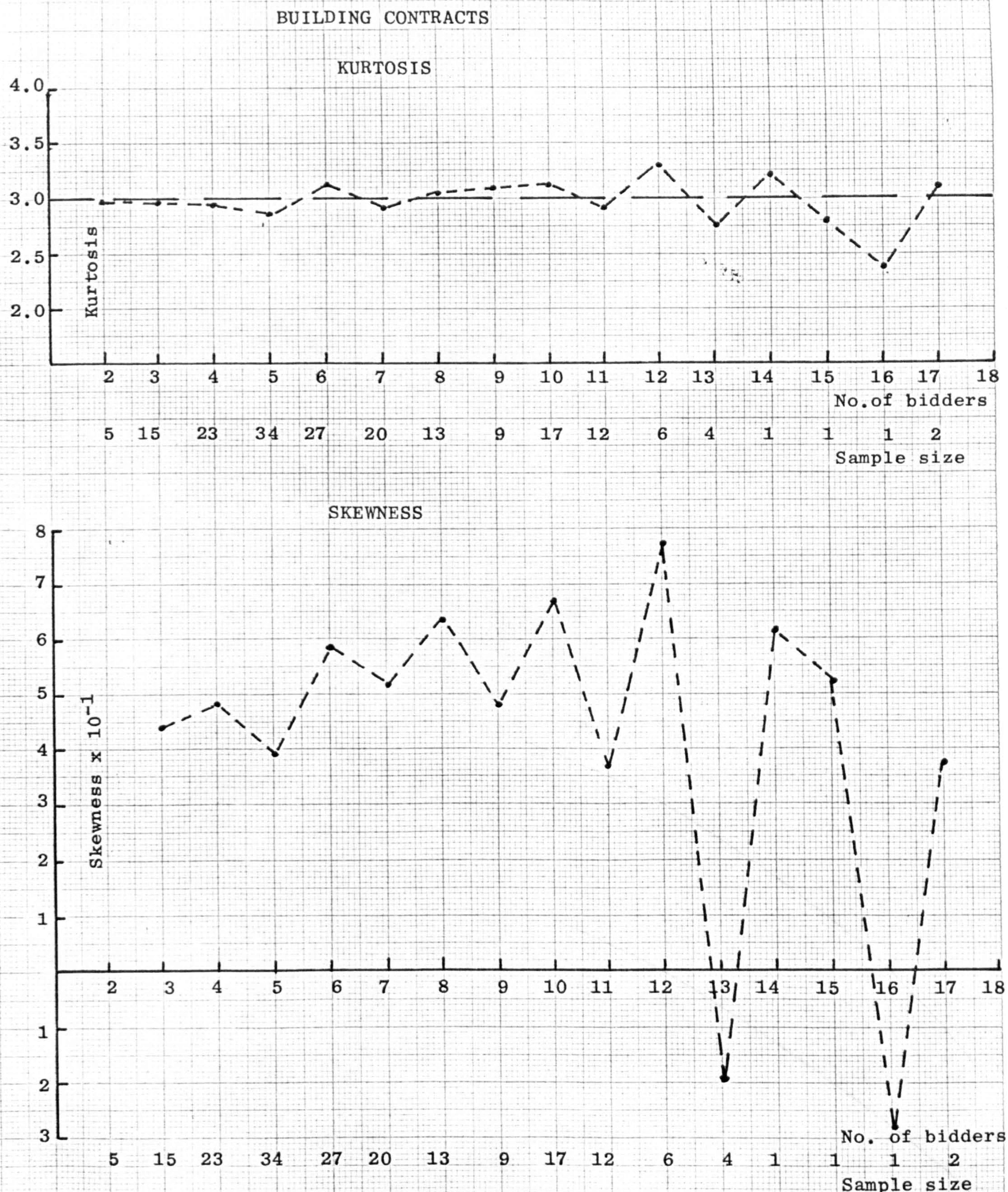


Figure 4.3 A plot of kurtosis and skewness against number of bidders for Building Contracts

Conclusion: Neither the kurtosis nor the skewness show any clear correlation with the number of bidders.

ROADS CONTRACTS

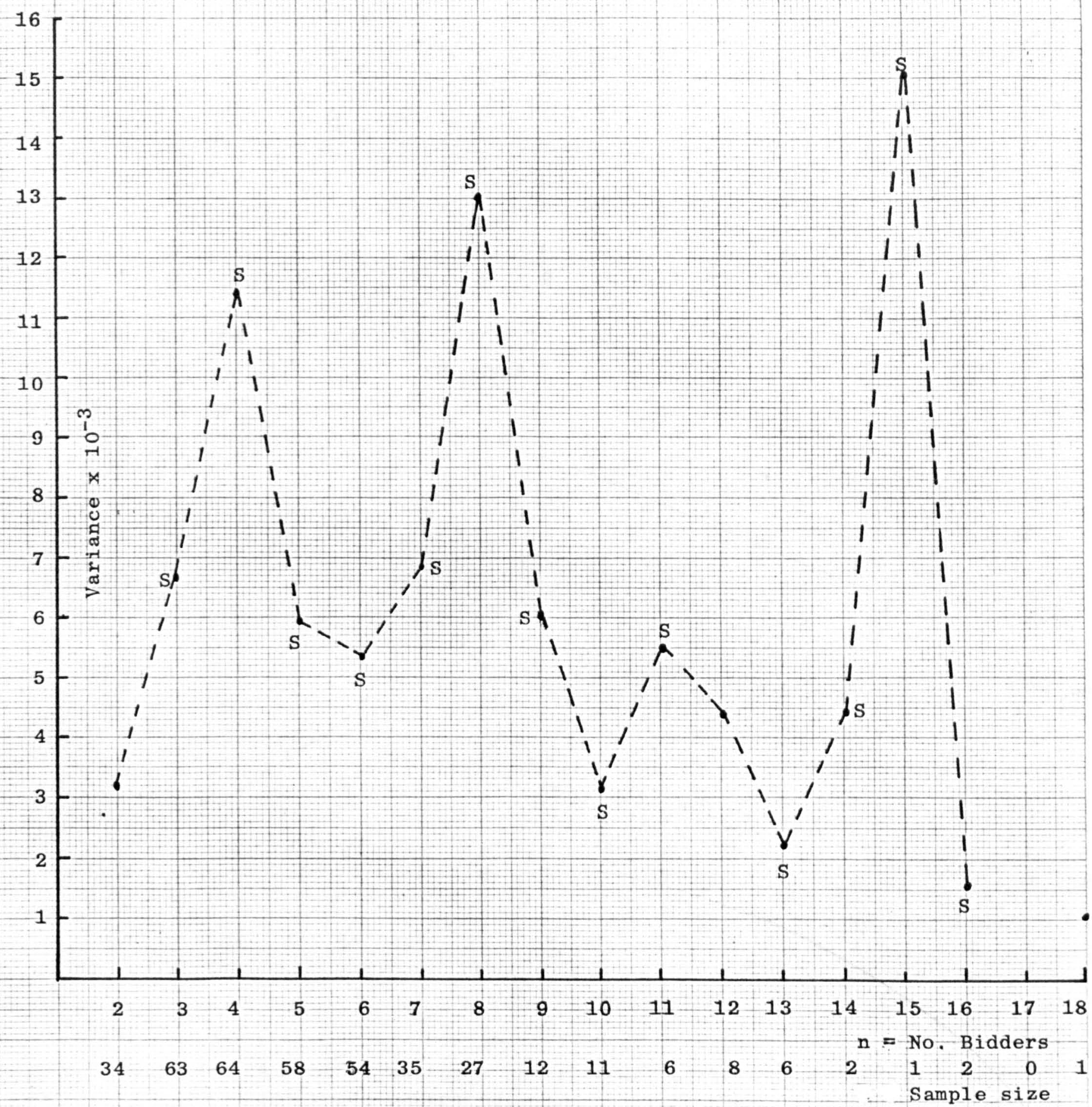
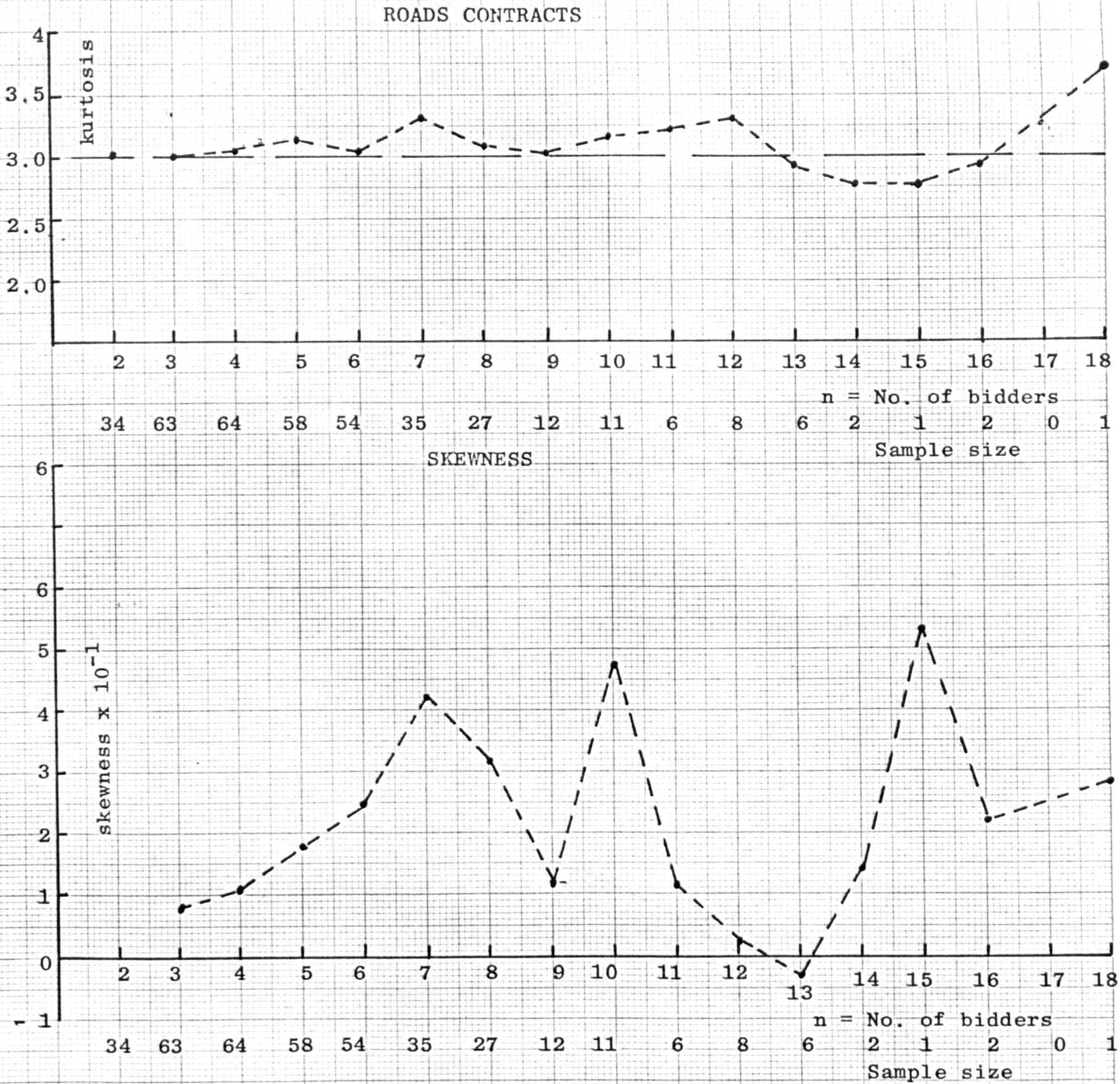


Figure 4.4 A plot of variance against number of bidders for roads contracts. The S indicates that the variance is statistically significantly different from the previous variance (i.e. the adjacent variance for n - 1 bidders)

Conclusion: If any trend exists it is that variance slightly decreases with increasing n.



Graph 4.5 A plot of kurtosis and skewness against number of bidders for roads contracts.

Conclusion: Neither the kurtosis nor the skewness show any clear trend with the number of bidders.

for this are that by inspection the kurtosis is near 3.0 for all values of 'n' for both buildings and roads. The skewness although predominantly positive is not in every case significantly different from zero according to the following measure adapted from Kendall and Stuart[38] significance test for skewness.

$$\text{Standard error of skewness} = \sqrt{\frac{6}{n} \times \frac{1}{S}}$$

where n is the number of bidders and S is the number of contracts with 'n' bidders. Thus the skewness is not significantly different from zero if it lies within two standard errors of zero.

For buildings contracts this test for significance shows that contracts with 6, 7, 8, 10 and 11 bidders have skewnesses that are just greater than 2 standard errors different from zero. Thus contracts with 2, 3, 4, 5, 9, 12, 13, 14, 15, 16 and 17 have skewnesses that are not significantly different.

For roads contracts only contracts with 7 bidders have a skewness of more than 2 standard errors difference from zero. Contracts with 10 bidders are almost 2 standard errors different from zero. All others are well within the band of two standard errors.

Plotting the values for skewness and kurtosis in the figure on page 460, reference 27 showing areas for different types of distributions calculated by Pearson also indicates that the values lie near to the normal point. The question as to whether an overall distribution representing all bids or whether individual distributions for each 'n' bidders should be used in any calculations or Whittaker type distribution is discussed in section 4.4.

At this point the provisional conclusion is that the samples belong to normal distributions. The conclusion of Whittaker that the distribution is near uniform is provisionally rejected for the data analysed because the kurtosis is higher than the 1.8 expected for uniform distributions.

4.3 Tests for Uniformity and Normality

Although the statistics of skewness and kurtosis taken together are accepted as being reasonably good indicators of distribution 'shape' it was decided to undertake further and more powerful tests. The reason for this decision was that the data represents many small samples not a large sample. Most statistical tests are not as sensitive when used for small samples and therefore further reinforcement of the provisional conclusion of normality not uniformity was thought to be necessary. The tests chosen for this supporting evidence were

a) Studentized range to check for uniformity

and b) Anderson-Darling to test for normality.

a) Test for Uniformity

The studentized range is described in reference (30) and in appendix D.

The test for normality against uniformity is to determine if there exists a large number of samples with small values of W , the studentized range. Table 4.3 shows the number of samples in the lower 10% of the distribution of W assuming normality (percentage points taken from Table 29c Pearson and Hartley.[30]). Table 4.3 shows that 16 significantly low values were found for buildings contracts compared with the 18.5 expected for normal distributions from 185 samples of buildings contracts and 30 significantly low values were found for the 350 roads contracts when 35 were expected for normal distributions. This was taken to indicate that there was not a disproportionate number of small values of W and therefore these samples do not behave as samples from a uniform distribution.

To test for uniformity against normality Pettitt[31] produced an empirical distribution of W assuming uniformity and calculated the upper 10 per cent points of the W statistic, the studentized range. Table 4.4 shows the expected number of samples with significantly large values of W based on an empirical distribution. The number of 47 from table 4.4 for buildings contracts is to be compared with the 21 found as in table 4.3. The 57 from table 4.4 for roads contracts is to be compared with the 32 found as in table 4.3. It was concluded that it is highly unlikely that these samples belong to a uniform distribution and that the test results are compatible with those of normal distributions.

b) Test for Normality

The evidence as to the distribution of the bids for roads and buildings as represented by our data is

1) skewness and kurtosis indicating normality

and 2) studentized range tests being compatible with the assumption of normality.

The decision to undertake a further test was simply that the power of the studentized range in testing for longtailed, skewed or normal distributions is poor except in testing for normality against uniformity. Therefore a powerful test for normality was needed to produce convincing evidence that these data represent samples from normal distributions.

The statistics test for normality is known as the Anderson-Darling statistic (A^2). The method of calculating A^2 is given in appendix E and in Pearson and Hartley.[32] A description of the comparison of A^2 with other statistics is given by Stephens.[33] The A^2 statistic was calculated for each contract by number of bidders and by percentage points. The percentage points of the A^2 distribution were taken from Pettitt[34] Large values for the A^2 statistic would be taken to indicate non-normality. Table 4.5 for buildings contracts and table 4.6 for roads contracts shows the A^2 statistics grouped by number of bidders and by percentage points (in 5% groups). The total of A^2 values in each 10% group are shown in the histograms in figures 4.6 and 4.7. The test for normality is that the distribution of A^2 values should be the same as the distribution of the A^2 values for a normal distribution. That is uniformly distributed A^2 values with an equal number of entries in each grouping. To test how our distribution of A^2 values compared with the expected distribution for normal distributions the Chi-squared test (χ^2) was used. Because in some cases insufficient entries appeared in the 5% groups for a χ^2 test, 10%, 15% and 20% groupings were used. The χ^2 test is described in appendix F which also gives the calculations leading to the summary in table 4.7

TABLE 4.3

Number of samples with studentized range significant at the lower 10 per cent or upper 10 per cent value, * for normal samples

SAMPLE SIZE	BUILDINGS			ROADS		
	NOS OF SAMPLES	NOS SIGNIFICANT AT		NOS OF SAMPLES	NOS SIGNIFICANT AT	
		LOWER	UPPER		LOWER	UPPER
3	15	1	4	63	6	7
4	23	2	1	64	4	5
5	34	1	1	58	3	4
6	27	2	7	54	9	4
7	20	3	1	35	2	2
8	13	2	2	27	3	4
9	9	0	1	12	0	0
10	17	2	2	11	1	0
11	12	0	1	6	0	1
12	6	2	1	8	1	3
13	4	0	0	6	0	1
14	1	0	0	2	0	0
15	1	0	0	1	1	0
16	1	1	0	2	0	0
17	2	0	0	-	-	-
18	-	-	-	1	0	1
TOTAL	185	16	21	350	30	32

* Percentage values obtained from Pearson and Hartley.[30]

TABLE 4.4

Empirical upper 10 per cent points of the studentized range for uniform samples and the number of samples with significant values of the statistic.

		BUILDINGS		ROADS	
SAMPLE SIZE	UPPER 10 PER CENT POINT	NOS OF SAMPLES	NOS SIGNIFICANT	NOS OF SAMPLES	NOS SIGNIFICANT
3	1.997	15	4	63	7
4	2.394	23	1	64	5
5	2.666	34	5	58	4
6	2.861	27	7	54	9
7	3.026	20	6	35	8
8	3.317	13	3	27	9
9	3.204	9	3	12	1
10	3.292	17	6	11	3
11	3.336	12	6	6	3
12	3.374	6	3	8	3
13	3.450	4	0	6	3
14	3.480	1	1	2	1
15	3.480	1	0	1	0
16	3.440	1	0	2	1
17	3.500	2	2	-	-
18	3.510	-	-	1	0
TOTAL		185	47	350	57

TABLE 4.5 Buildings Contracts: The Probability Integral Transformation of the A^2 Statistic.

PERCENTAGE POINTS	NO. OF BIDDERS 4	5	6	7	8	9	10	11	12	13	14	15	16	17	TOTAL	
0 – 5%	2	6	1	1	0	1	0	1	0	0	0	0	0	0	12)	)19
5% – 10%	1	1	1	1	1	0	0	0	0	1	0	0	0	1	7)	
10% – 15%	0	1	0	0	1	0	2	0	0	1	0	0	0	0	5)	)16
15% – 20%	2	3	2	0	1	1	0	1	0	1	0	0	0	0	11)	
20% – 25%	0	1	0	0	0	0	1	1	0	0	0	0	0	0	3)	)10
25% – 30%	0	3	1	1	0	1	0	1	0	0	0	0	0	0	7)	
30% – 35%	1	3	2	1	0	1	1	1	0	1	0	0	0	0	11)	)23
35% – 40%	1	3	3	2	0	0	1	1	0	0	1	0	0	0	12)	
40% – 45%	1	0	1	2	0	0	0	3	1	0	0	0	0	0	8)	)15
45% – 50%	0	2	0	1	0	2	1	1	0	0	0	0	0	0	7)	
50% – 55%	2	2	0	1	0	1	1	0	0	0	0	1	0	0	8)	)15
55% – 60%	3	0	2	1	0	0	1	0	0	0	0	0	0	0	7)	
60% – 65%	1	0	1	0	0	0	0	0	0	0	0	0	0	1	3)	)12
65% – 70%	0	2	4	0	1	0	1	1	0	0	0	0	0	0	9)	
70% – 75%	3	0	0	5	1	0	0	1	1	0	0	0	0	0	11)	)18
75% – 80%	1	2	1	1	1	0	1	0	0	0	0	0	0	0	7)	
80% – 85%	1	2	2	1	3	0	2	1	1	0	0	0	1	0	14)	)22
85% – 90%	1	1	1	1	1	1	2	0	0	0	0	0	0	0	8)	
90% – 95%	3	1	1	0	3	0	1	0	0	0	0	0	0	0	9)	)20
95% – 100%	0	0	4	1	0	1	2	0	3	0	0	0	0	0	11)	

TABLE 4.6 Roads Contracts ; The Probability Integral Transformation of the A^2 Statistic.

PERCENTAGE POINTS	NO. OF BIDDERS 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	TOTAL	
0 – 5%	4	3	3	5	1	1	0	0	0	0	1	0	0	0	0	18)	)33
5% – 10%	2	2	4	1	2	2	2	0	0	0	0	0	0	0	0	15)	
10% – 15%	5	3	1	0	2	0	0	0	2	1	0	0	1	0	0	15)	)22
15% – 20%	2	0	1	2	0	0	1	0	0	1	0	0	0	0	0	7)	
20% – 25%	1	2	4	1	1	0	0	0	0	0	1	0	1	0	0	11)	)21
25% – 30%	4	3	0	2	0	1	0	0	0	0	0	0	0	0	0	10)	
30% – 35%	2	4	4	0	1	0	1	2	0	0	0	0	0	0	0	14)	)25
35% – 40%	1	5	2	2	1	0	0	0	0	0	0	0	0	0	0	11)	
40% – 45%	2	1	3	1	2	0	1	1	0	0	0	0	0	0	0	11)	)22
45% – 50%	3	3	3	1	0	0	0	0	0	1	0	0	0	0	0	11)	
50% – 55%	3	3	3	1	2	1	0	0	0	0	0	0	0	0	0	13)	)24
55% – 60%	5	2	1	1	1	0	0	1	0	0	0	0	0	0	0	11)	
60% – 65%	4	0	1	1	2	1	0	0	0	0	0	0	0	0	0	9)	)18
65% – 70%	3	0	4	0	1	0	0	1	0	0	0	0	0	0	0	9)	
70% – 75%	2	6	2	0	3	0	2	0	1	0	0	0	0	0	0	16)	)26
75% – 80%	0	4	1	2	0	1	0	0	0	0	0	1	0	0	1	10)	
80% – 85%	3	5	3	1	1	2	0	0	2	1	0	0	0	0	0	18)	)39
85% – 90%	4	3	5	3	3	0	2	0	0	1	0	0	0	0	0	21)	
90% – 95%	7	1	4	4	2	1	0	1	3	0	0	0	0	0	0	23)	)57
95% – 100%	7	8	5	7	2	2	2	0	0	1	0	0	0	0	0	34)	

TABLE 4.7 Summary of χ^2 results comparing observed distribution of A^2 statistics with the expected distribution for normal samples for both roads and buildings contracts.

BUILDINGS CONTRACTS	χ^2 value	Degrees of Freedom	Position in parent χ^2 distribution
10% groups	9.29	9	58%
15% groups	3.28	5	34%
20% groups	2.88	4	42%
ROADS CONTRACTS			
10% groups	42.93	9	99.9%
15% groups	9.11	5	90%
20% groups	33.71	4	99.9%

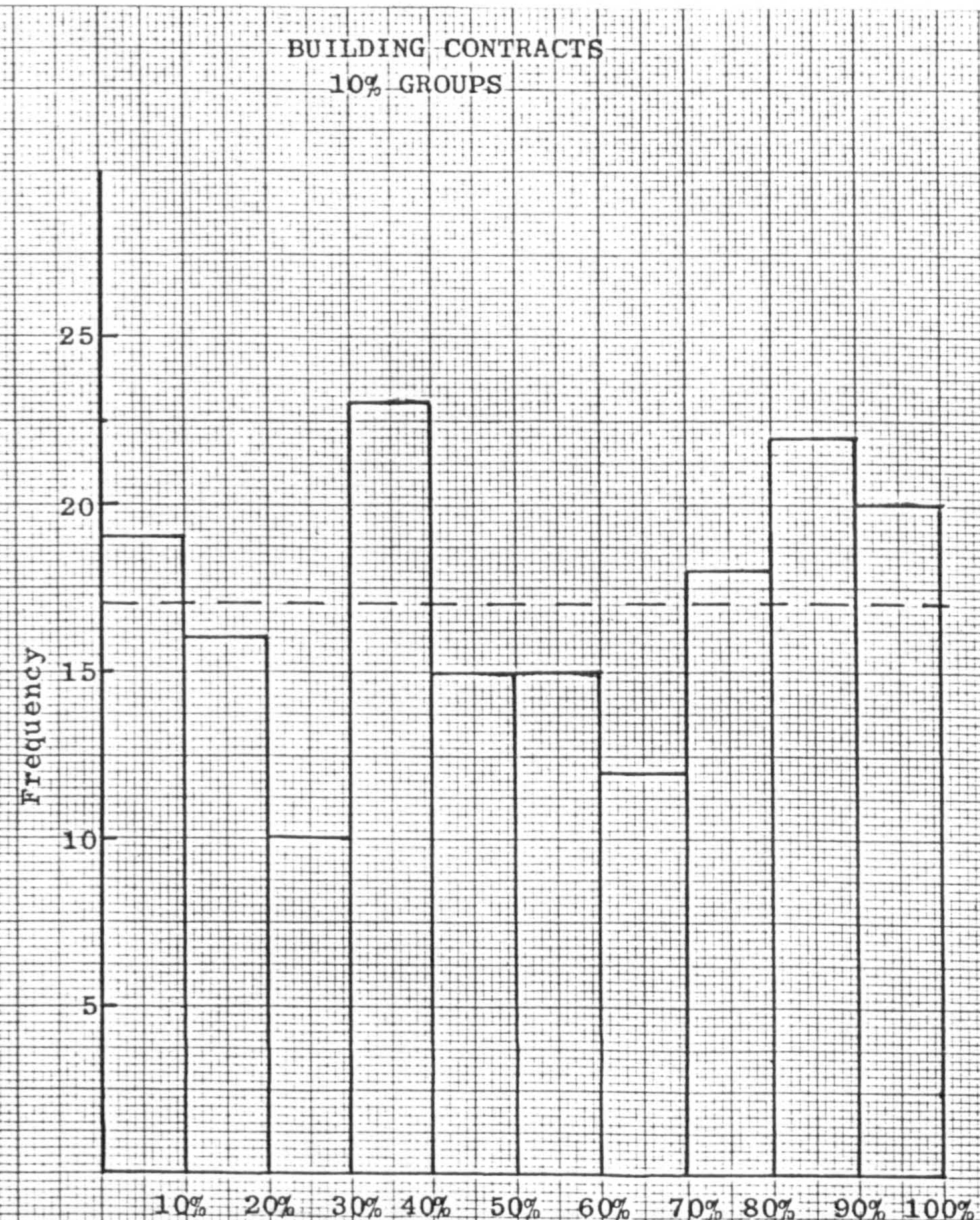


Figure 4.6 Buildings Contracts : The Probability Integral Transformation of the A^2 Statistics

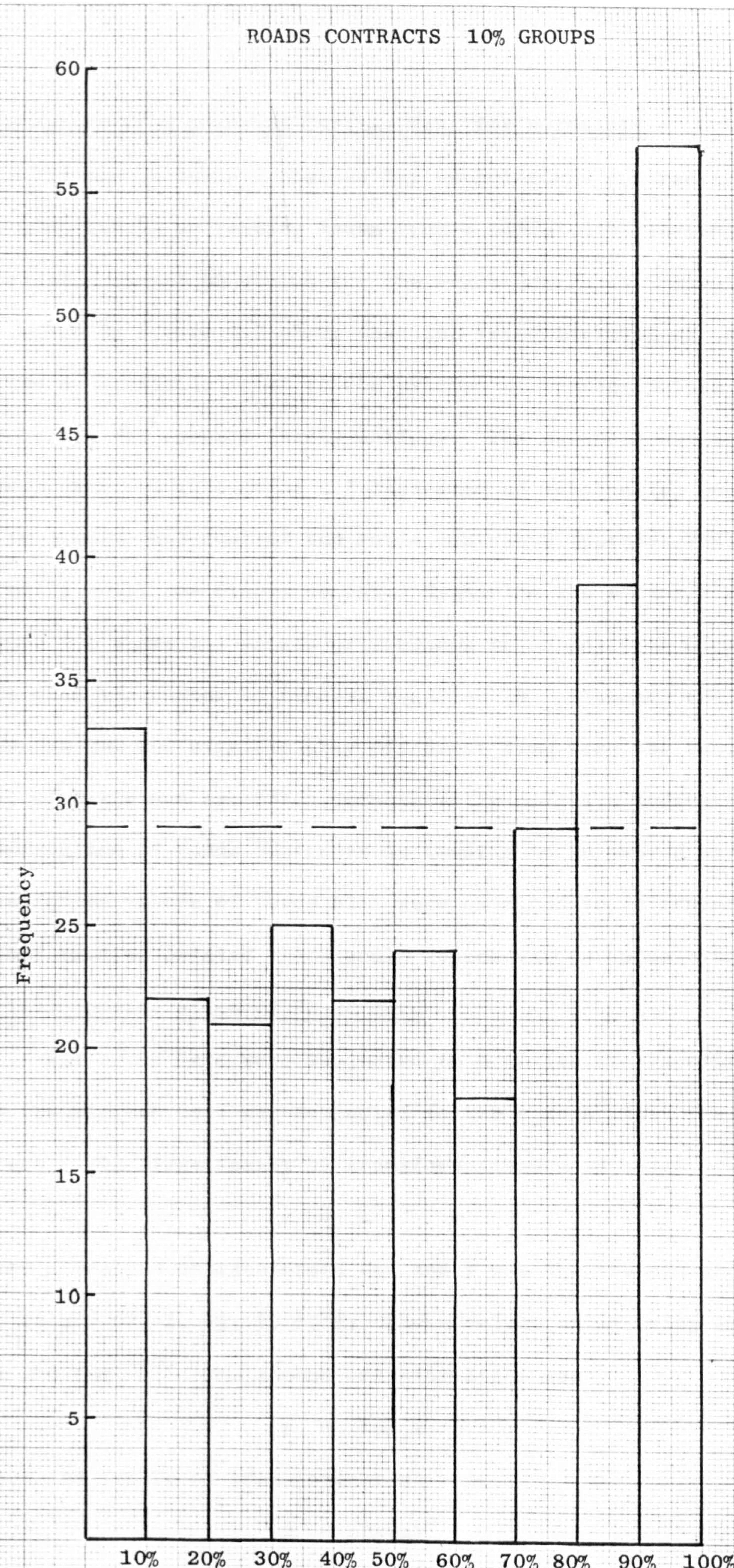


Figure 4.7 Roads Contracts : The Probability Integral Transformation of the A^2 Statistics

Conclusions from Anderson-Darling Test for Normality

It can be assumed that as far as buildings contracts are concerned the bids behave as samples drawn from a normal distribution. The same conclusion cannot be stated for the roads contracts. Examining the histogram in figure 4.7 shows that the irregularities of the distribution of the A^2 statistic occur at the extreme percentage points and that over the middle 75% appears fairly uniform. The skewness and the kurtosis values examined in section 4.2 indicated no substantial non-normality. It is likely that most of the roads contracts (perhaps 75%) behave normally while the others do not. Examining the skewness statistics figure 4.5 shows all values of skewness to be positive except for the case when the number of bidders equalled 13. Although the values of skewness are not significantly different from zero the fact that they are, with the one exception, consistently positive indicates that the distribution of roads contracts is tending to be skewed to the right. Transformed values of roads bids were examined to determine if a simple transformation existed which would reduce the roads data to normality.

Further consideration of Roads data

The roads data were subjected to a series of transformations and the transformed data was subjected to the same A^2 test for normality as before. The first family of transformations used were

$$y = x^{\lambda}$$

where x was the untransformed bid and y was the transformed bid and λ had values of -1, $-\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{3}{4}$. These values of λ being suggested by Box and Cox.[35] The second transformation was

$$y = \log x.$$

The third family of transformations were

$$y = (x+a)^{b}$$

with b taking values of 0.2 to 1.0 in steps of 0.2 and 'a' taking values of -0.6 to +1.0 in steps of 0.2.

The fourth family of transformations were

$$y = (x+c)$$

with c taking values of -0.6 to +1.0 in steps of 0.2.

None of these transformations reduced the data to normality nor did any trend emerge that indicated that a transformation might be found that could reduce the roads data to normality. It was concluded that no simple transformation would reduce the roads data to normality. Accepting that the roads data are not normally distributed, that previous tests indicate near normality and that what little skewness exists is to the right (i.e. positive) it was considered that the lower tail of the distribution which controls the value of the lowest (usually winning) bid may behave similarly to a normal distribution. Therefore examination of the lowest bid in relationship to the mean bid was undertaken to determine if normal order statistics could be used to predict the relationship between mean and lowest bid which in turn could imply whether the lower tail of the distribution behaved as a normal distribution. This assumes that the skewness is small enough not to affect the value of the mean bid to any great extent.

4.4. Relationship between Mean and Lowest Bid

The reasons for examining the relationship between the mean and lowest bids were

i) to determine if normal order statistics can predict this relationship, thus implying in the case of roads contracts that the lower tail behaves as normal distributions.

ii) to examine the observed and expected relationship between mean and lowest bid in comparison with the calculated price adjustments based on this relationship described in section 4.2 and in (26).

Figures 4.8 and 4.9 show for buildings and roads respectively

- the observed average difference between mean and lowest bids for each 'n' bidders.

- the expected average difference using the overall standard deviation of 6.49% for buildings and 8.38% for roads and assuming normality
- the expected average difference using the calculated standard deviation for each group of 'n' bidders.

The expected average differences are based on the tabulated normal order statistics (30).

Tables 4.8 and 4.9 list the standard deviations and the calculated average differences on which figures 4.8 and 4.9 are based.

The observation made was that in both buildings and roads data the expected average differences based on both the overall standard deviations and the standard deviation of individual groups of 'n' bidders over estimated the actual observed average differences. The possibility of a systematic error in the programs used to calculate these values was examined and discounted. The possibility of the method of calculating standard deviations causing some over-estimation of the standard deviation was considered. Appendix C explains the method of calculation of variance and the standard deviation was taken as the square root of the variance which gives a biased estimate of standard deviation. David[36] describes a method of calculating standard deviation put forward by Downton[37] which places less importance on extreme values and is unbiased. Downton's method of calculating standard deviations is given in appendix G.

The standard deviations calculated according to Downton's method are given in tables 4.8 and 4.9. Figures 4.10 and 4.11 compare, as before,

- the observed average difference between mean bid and lowest bid for each 'n' bidders,
- the expected average difference using the overall standard deviation of 5.93% for buildings and 6.52% for roads calculated by Downton's method again assuming normality,

- the expected average difference using the Downton calculated standard deviation for each group of 'n' bidders.

The improvement in the prediction of the average difference between mean and lowest bids is clear when figure 4.10 is compared with figure 4.8 and figure 4.11 is compared with figure 4.9.

The conclusion was that in predicting the difference between mean and lowest bid the use of the standard deviation as calculated by Downton produced the better result, the use of the standard deviation for the individual group of 'n' bidders was better than using the overall standard deviation, as to be expected.

Some comments on the uses previously made of the relationship between mean and lowest bids

As Whittaker's approach was based on the relationship between an estimated mean and the lowest bid figures 4.10 and 4.11 show the accuracy achievable using a known mean to predict the lowest bid, further deterioration of this accuracy can be expected when an estimated mean is used. The accuracy of estimating the mean bid is considered in sections 6.0 and 7.0. Reference (26) and figure 4.1, section 4.2, describe the method of calculating allowances to be added to the lowest bid. This allowance is intended to compensate for the lowest contractor having an unrealistically low price. Again the philosophy of such compensations ~~are~~ not discussed here but the effect of the method of calculating is. Essentially the rules described in reference (26) takes the mean bid as a 'fair' bid and compensate the lowest bid by an amount which is calculated within the limitations shown on figure 4.1 which is reproduced from reference (26). It was noted that the limitations do not make any adjustment that includes the number of bidders. For example, from figure 4.1 the total limit of allowed compensation decreases after the difference between the mean and lowest bid reaches 8%. The reasoning given that there is no intention to compensate contractors who present foolishly low bids. However from figure 4.10 it is seen that for building contractors for contracts with 8 or more bidders the average observed and average expected difference between mean and lowest bidders is greater than 8%. Similarly from figure 4.11 for roads contracts the average observed and expected difference between mean and lowest bids is more than 8% for 6 or more bidders. The average observed differences from figures 4.10 and 4.11 are superimposed on figure 4.1 as shown in figures 4.12 and 4.13. If a system of compensation is based on the difference between mean and lowest bids it should be adjustable to take account of the number of bidders.

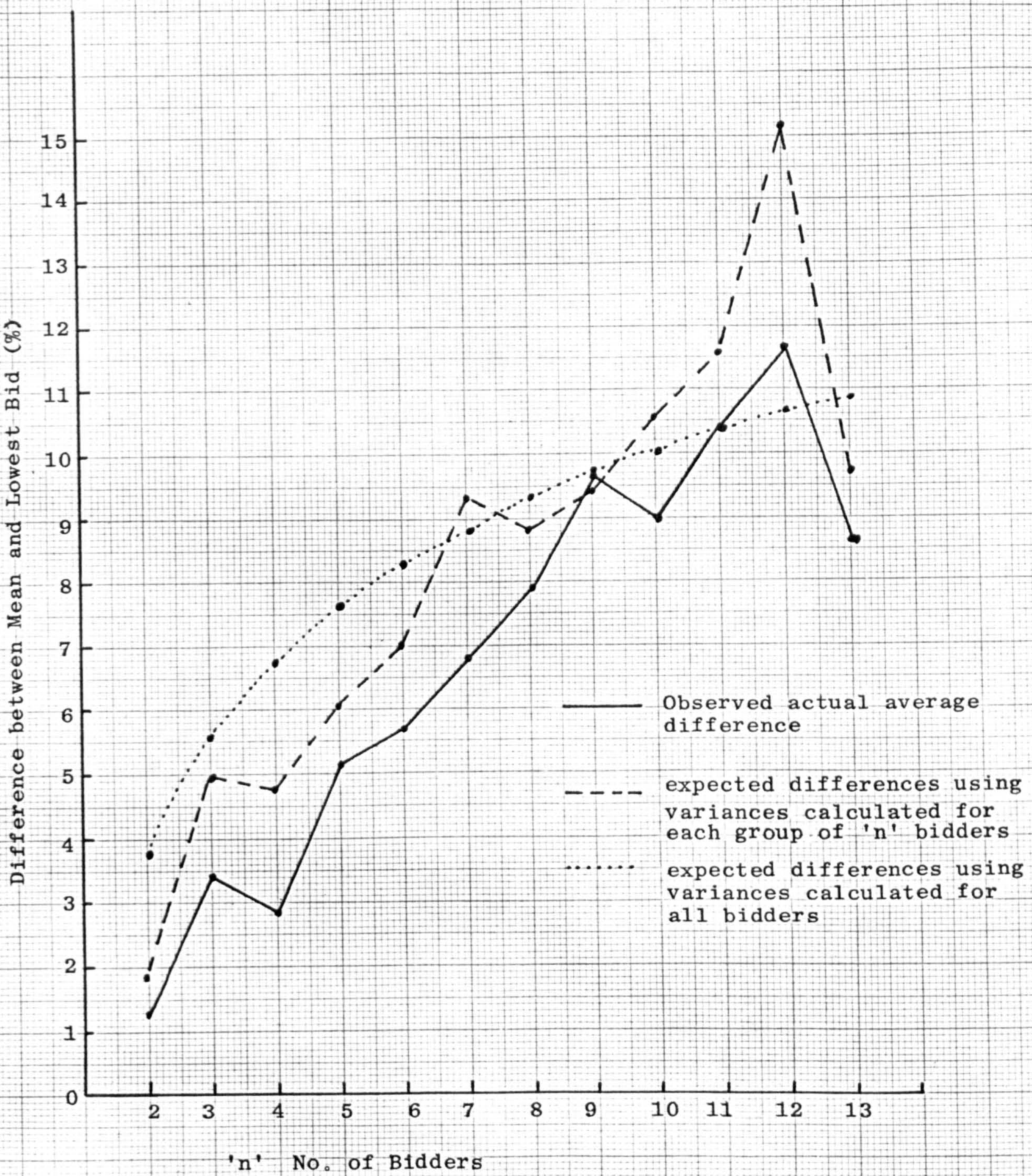


Figure 4.8 The average differences between mean and lowest bids for each 'n' compared with the expected differences obtained by the calculated variances of (i) the overall distribution and (ii) the distribution of each group of bids with the same 'n'.

Note: This graph is to be compared to Figure 4.10

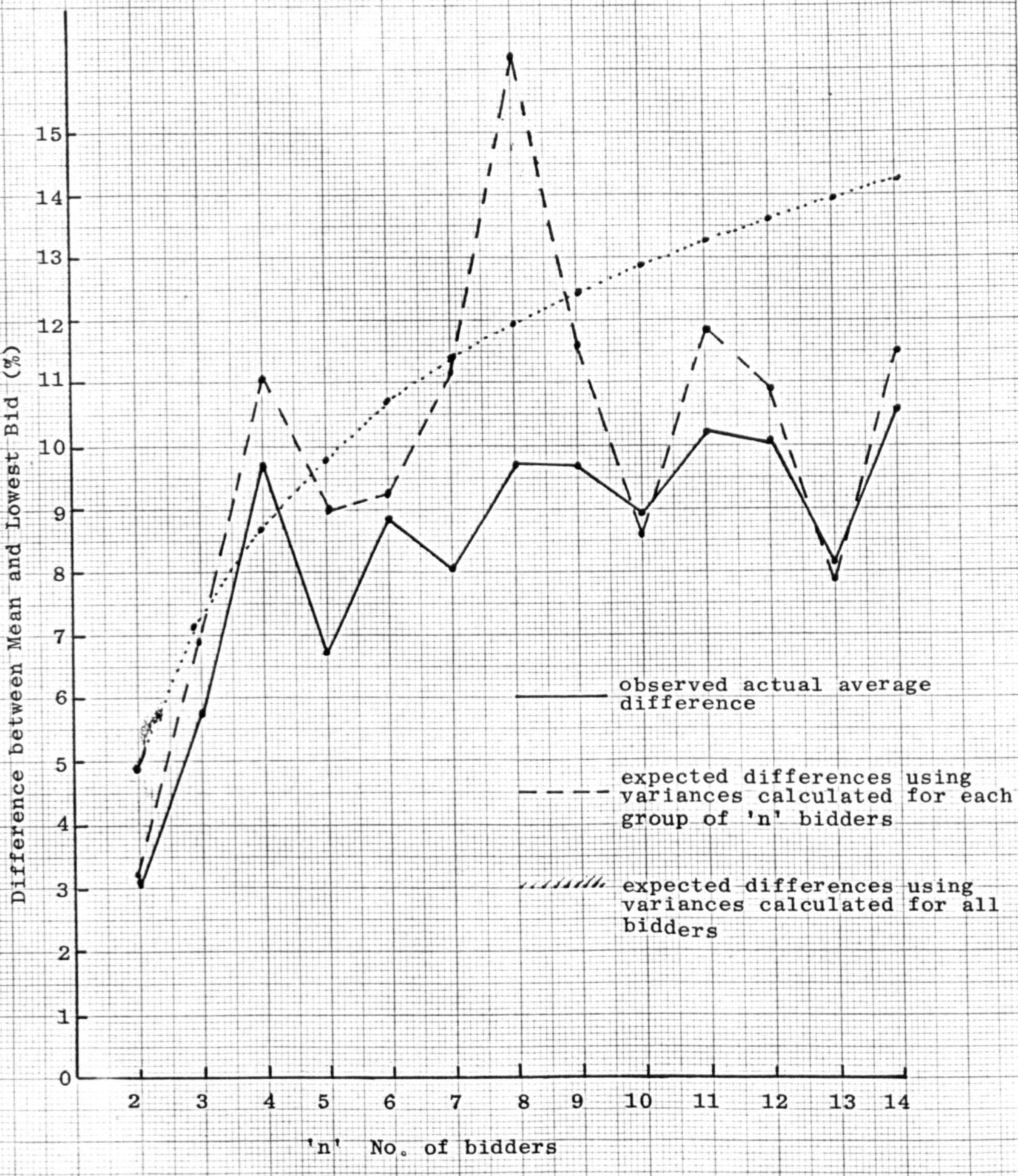


Figure 4.9 The average differences between mean and lowest bids for each 'n' compared with the expected differences obtained by the calculated variances of (i) the overall distribution and (ii) distribution of each group of bids with the same 'n'.

Note: This graph is to be compared to graph 4.11

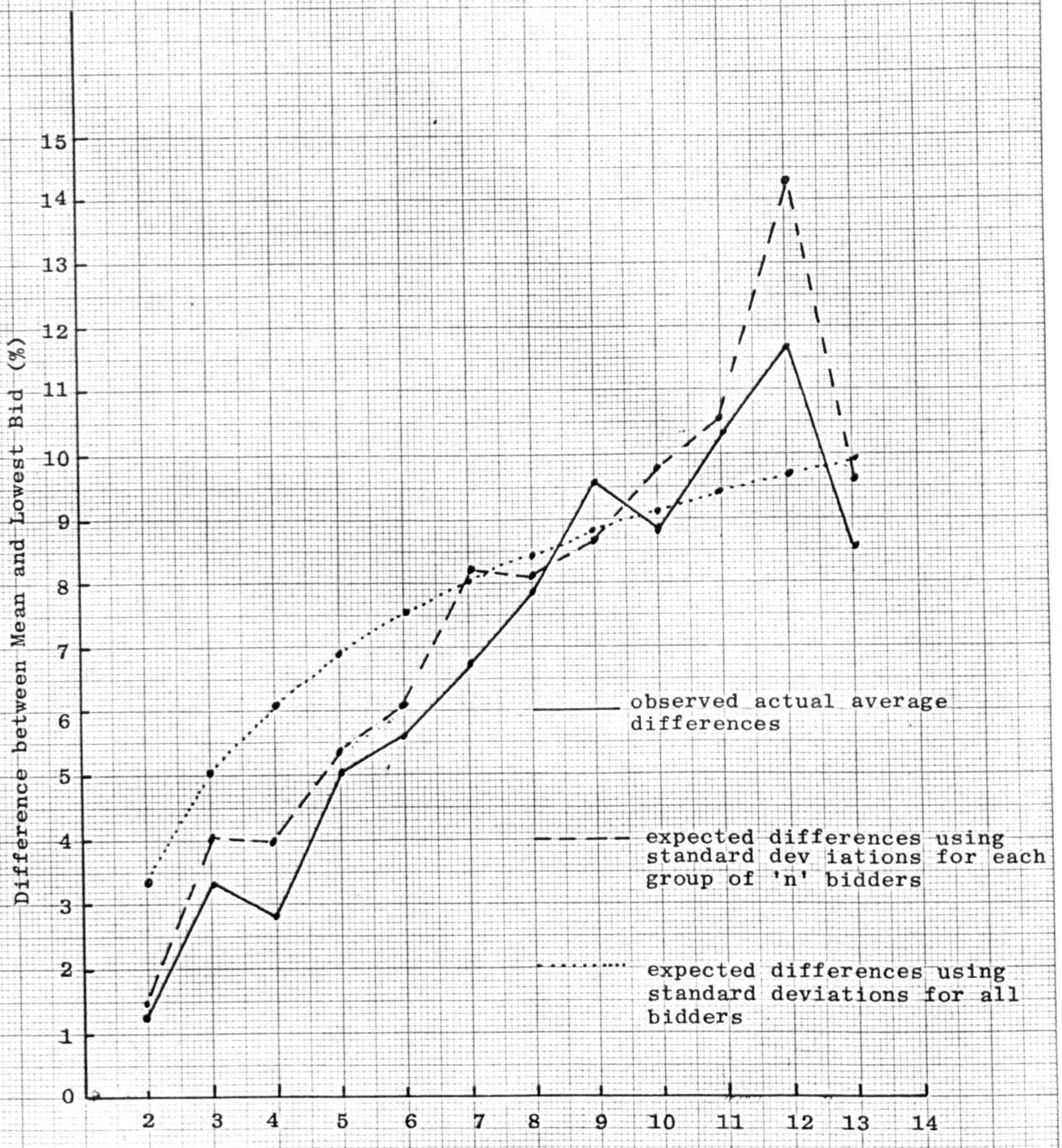


Figure 4.10 The average differences between mean and lowest bids for each 'n' compared with the expected differences obtained by the calculated standard deviations using Downton's method of (i) the overall distribution of bids and (ii) the distribution of each group of bids with the same n.

Note: This graph should be compared with Figure 4.8 and the improvement of the expected values as a predictor of actual values noted.

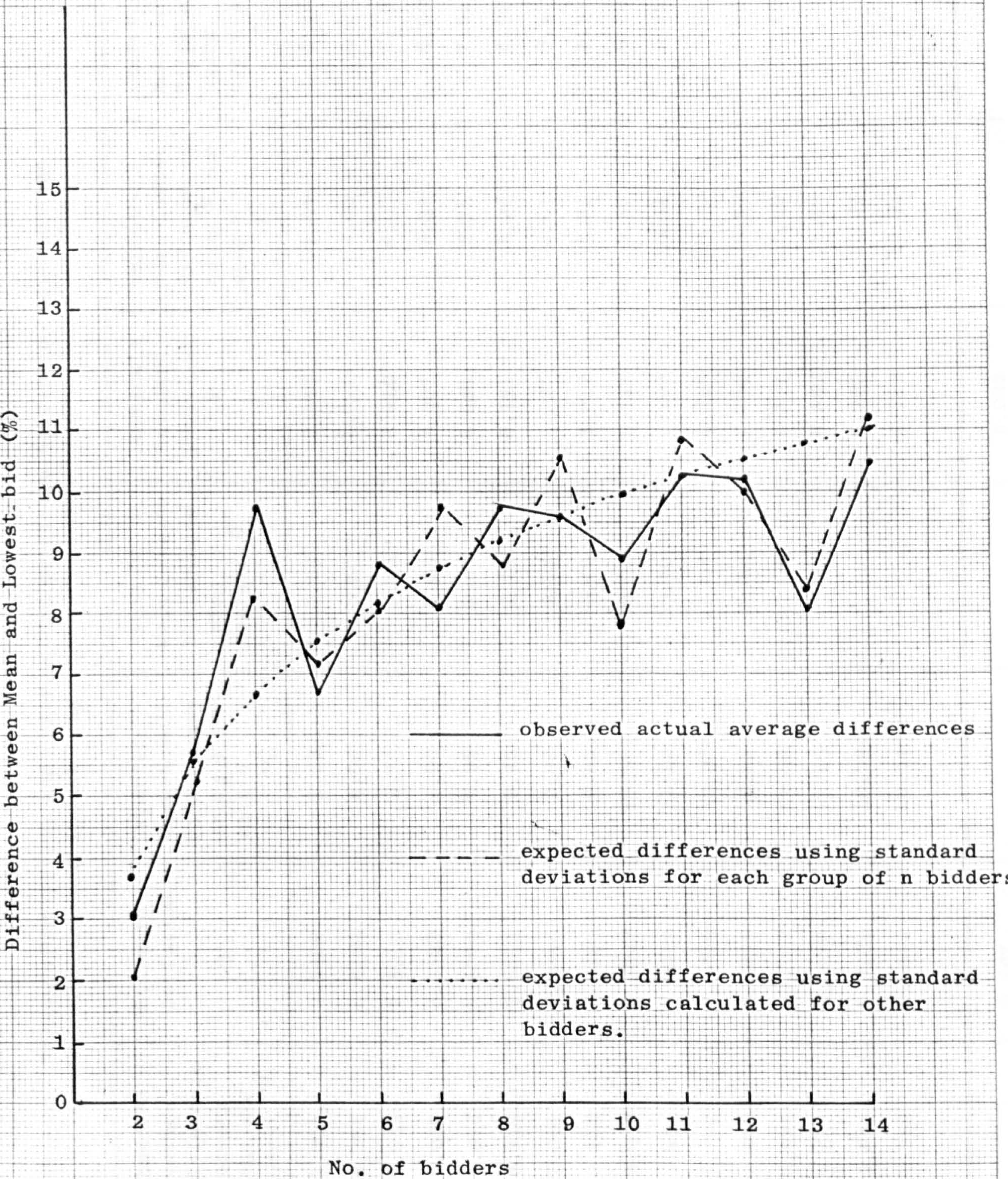


Figure 4.11 The average differences between mean and lowest bids for each 'n' compared with the expected differences obtained by the calculated standard deviations using Downton's method of (i) the overall distribution of bids and (ii) the distribution of each group of bids with the same 'n'.

Note: This graph should be compared with Figure 4.9 and the improvement in the estimated values as a predictor of actual values noted.

TABLE 4.8 Building Contracts : Standard Deviations and observed and predicted difference between mean and lowest bids

No. of Bidders	Sample Size	Observed Average Difference between mean and lowest %	Standard Deviation σ %	Expected Mean-Lowest Differences using σ for each N %	Expected Mean-Lowest Differences using overall σ %	Downton's Standard Deviation $\hat{\sigma}$ %	Expected Mean-Lowest Differences using $\hat{\sigma}$ for each N %	Expected Mean-Lowest Differences using overall $\hat{\sigma}$ %
2	5	1.253	3.2469	1.83	3.66	2.586	1.46	3.35
3	15	3.386	5.8784	5.08	5.50	4.778	4.04	5.02
4	23	2.843	4.6016	4.74	6.69	3.916	4.03	6.10
5	34	5.039	5.2328	6.09	3.56	4.595	5.34	6.90
6	27	5.674	5.5079	6.98	8.23	4.861	6.16	7.52
7	20	6,818	6.9136	9.35	8.78	6.121	8.28	8.02
8	13	7.901	6.2345	8.88	9.25	5.627	8.01	8.45
9	9	9.675	6.3396	9.41	9.65	5.917	8.79	8.81
10	17	8,899	6.8543	10.55	10.00	6.413	9.87	9.13
11	12	10.400	7.3069	11.59	10.30	6.690	10.61	9.41
12	6	11.786	9.3449	15.22	10.58	8.829	14.38	9.66
13	4	8.570	5.8010	9.68	10.84	5.756	9.60	9.89
14	1	9.934	6.5113	11.09	11.06	6.577	11.20	10.10
15	1	13.067	6.7086	11.65		6.867	11.92	
16	1	9.856	5.9908	10.58		6.206	10.96	
17	2	17.273	9.1654	16.44		8.754	15.93	
18								
OVERALL	190		6.497			5.932		

TABLE 4.9 Roads Contracts ; Standard Deviations and observed and predicted differences between mean and lowest bids

No. of Bidders N	Sample Size	Observed Average Difference between mean and lowest %	Standard Deviation σ %	Expected Mean-Lowest Differences using σ for each N %	Expected Mean-Lowest Differences using overall σ %	Downton's Standard Deviation $\tilde{\sigma}$ %	Expected Mean-Lowest Differences using $\tilde{\sigma}$ for each N %	Expected Mean-Lowest Differences using overall $\tilde{\sigma}$ %
2	34	3.014	5.622	3.17	4.73	3.683	2.08	3.68
3	63	5.72	8.161	6.90	7.10	6.252	5.29	5.52
4	64	9.701	10.671	10.98	8.63	8.050	8.28	6.72
5	58	6.695	7.737	9.00	9.76	6.158	7.16	7.59
6	54	8.856	7.295	9.24	10.63	6.334	8.03	8.27
7	35	8.025	8.274	11.19	11.34	7.253	9.81	8.83
8	27	9.725	11.409	16.25	11.95	6.199	8.83	9.30
9	12	9.663	7.805	11.59	12.46	7.159	10.63	9.69
10	11	8.969	5.592	8.61	12.89	5.026	7.74	10.05
11	6	10.26	7.463	11.84	13.30	6.911	10.96	10.35
12	8	10.22	6.694	10.90	13.67	6.220	10.13	10.63
13	6	8.067	4.722	7.88	13.99	4.416	7.37	10.89
14	2	10.60	6.754	11.50	14.29	6.663	11.35	11.12
15	1		12.313	21.38		12.578	21.84	
16	2		4.080	7.21		4.116	7.27	
17								
18	1		3.442	6.26		3.328	5.97	
OVERALL	384		8.389			6.5275		

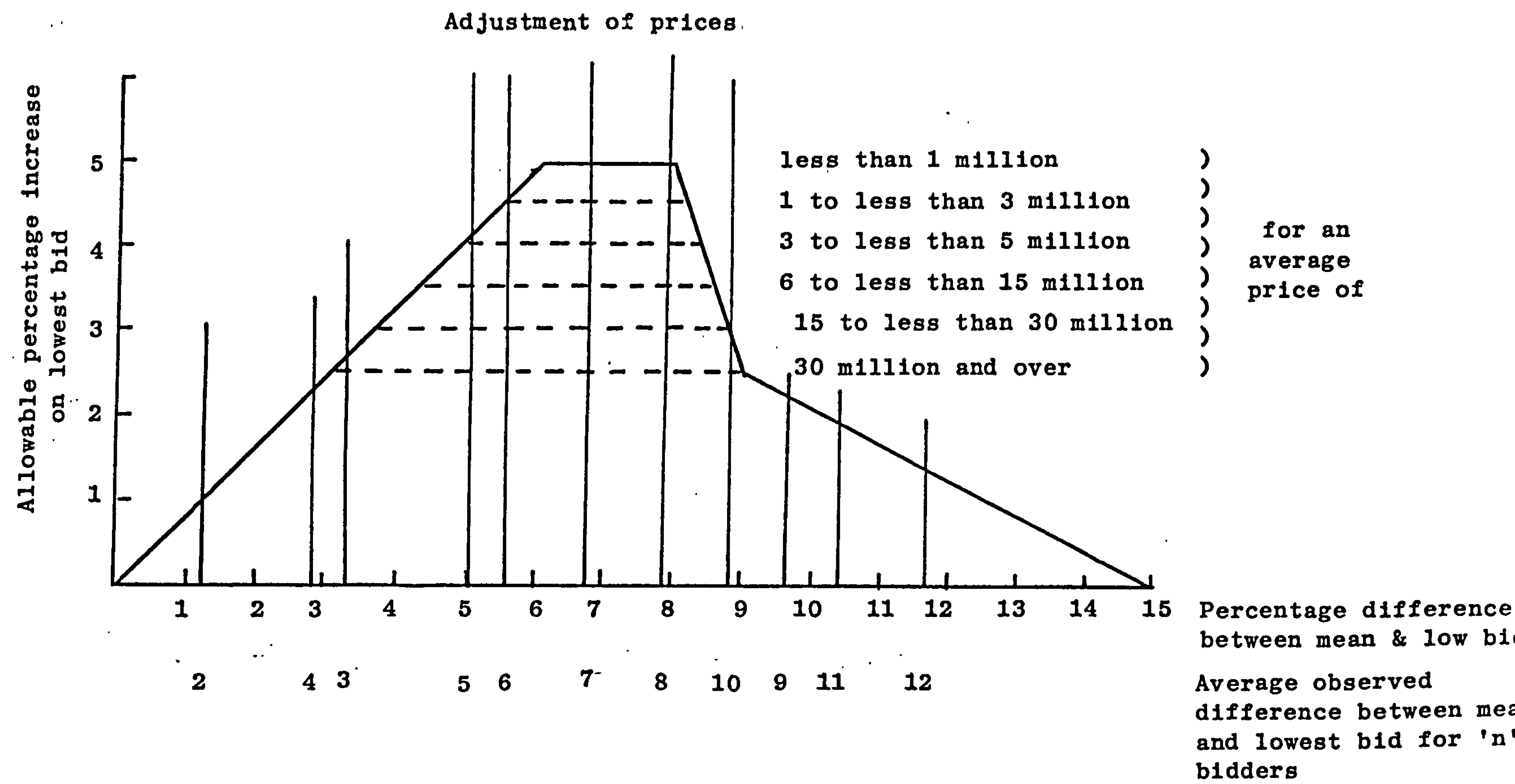


Figure 4.12 Building contracts - the average observed difference between mean and lowest bid superimposed on Figure 4.1.

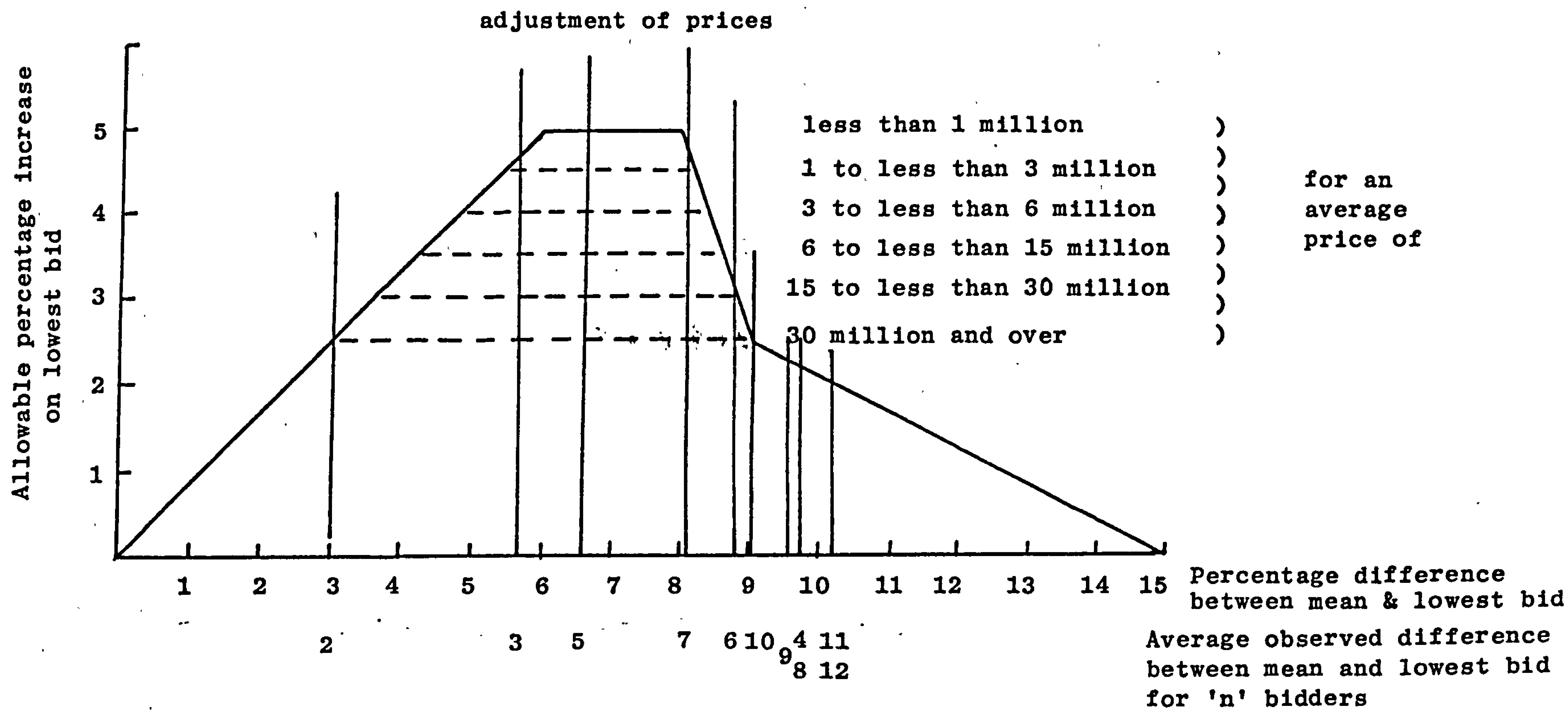


Figure 4.13 Roads Contracts - the average observed difference between mean and lowest bid superimposed on figure 4.1.

4.5 Tests for Low Bids

As already noted in section 2.0 there is evidence that the controlling variable in determining the lowest bidder is the accuracy of estimating. That is it is very likely that the lowest bidder is the lowest by underestimating the cost of executing the contract. A contract won as a result of the contractor seriously underestimating the cost of the work involved is likely to lead to a difficult contract which in the U.K. would almost certainly lead to substantial claims and the arguments that accompany such claims.

In the U.K. system the industry's professional advisors would welcome more numerical guidance in identifying unrealistically low bids. While any evidence of methods of identifying unrealistically low bids resulting from analysis of this data cannot be directly transferred to U.K. bids it will at least illustrate whether methods exist and if they are likely to be practical.

The investigation undertaken was:

a) finding methods of identifying low bids;

b) determining the number of low bids identified.

a) Identifying Low Bids or Outliers

So far it has been established that the bids are normally distributed in the case of buildings and are near normal in the case of roads. The variance of this overall distribution for buildings and roads has been calculated and the variance for bids for each group of 'n' bidders has been calculated again for both buildings and roads.

Grubbs, as reported by David[36] developed a statistic for identifying outliers in normal distributions. This statistic is

$$G = \frac{\bar{x} - x_{(1)}}{S}$$

where $\bar{x}$ is the mean bid, $\bar{x} = \sum_{i=1}^{n} x_i/n$ and $x_{(1)}$ is the lowest bid and

S is the standard deviation, $S = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n}}$

Grubbs[39] tabulated the significance points of the statistic G. Thus it is possible to identify the contracts whose lowest bid gives a value of G significant at say the 10% level.

The value of G was calculated for each contract for both buildings and roads with three or more bidders, using the standard deviation (square root of the variance) for the overall distribution of bids and using the standard deviation for the distribution of each group of 'n' bidders.

The results of these calculations are given in full in appendix H, in tables H.1 and H.2 for buildings and roads respectively. Each contract whose G value is significant at the 10% level is marked with an asterisk. Thus the asterisk identifies the contract whose lowest bid is, according to Grubbs' statistic, an outlier or in our terms potentially an unrealistically low bid.

The observations taken from these tables are

		Buildings Contracts	Roads Contracts
i)	total number of contracts tested	190	384
ii)	number of contracts identified with lowest bid significantly low at 10% level using overall distribution	21	29
iii)	number of contracts identified with lowest bid significantly low at 10% level using distribution group by number of bidders	20	32
iv)	number of contracts where ii) and iii) both identify the lowest bid as being significantly low at 10% level.	15	24

There are 26 buildings contracts and 37 roads contracts with an outlier identified by either method ii) or iii).

Considering that the significance level of 10% was used the number of outliers identified out of a total of 190 for buildings and a total of 384 for roads is consistent with the assumption of normality.

Although there is no positive proof that the bids identified as unrealistically low are so in fact this method is put forward for consideration with other methods of appraising low bids.

4.6 Comparison with Grinyer and Whittaker's findings

Grinyer and Whittaker's work described in (3) and (13) produced a distribution for Y, the bid of any company. This distribution was based on 57 buildings contracts taking no account of the number of bidders. The distribution is given by equation 2 of (13) and is

$$y = (0.97449 + 0.1352319F_Y(y) - 0.005555/F_Y(y))$$

where F_Y is the cumulative distribution and is the "average bid".

This distribution is skewed to the left and bounded above because $F_Y(y) = 1$ for all values of $y \geqslant 1.10412$, that is no bid is expected to be greater than 10% more than the average.

The cumulative frequency distribution on which Grinyer and Whittaker based their case has a very similar shape to the cumulative frequency curve of a normal distribution. Without demonstrating that it is normal but by making this assumption the standard deviation of the Grinyer and Whittaker distribution can be calculated. If mean is taken as 1 then two standard deviations lie between 0.841345 and 1 - 0.841345 from tabulated values of a normal distribution. Thus to find the same two points on the Grinyer and Whittaker distribution $F_Y(y_1)$ must equal 0.841345 and $F_Y(y_2)$ must equal 1 - 0.841345.

Substituting in the given expression gives

$$y_1 = 1.08162$$

and $y_2 = 0.96086$.

Thus the standard deviation of Grinyer and Whittaker's distribution is (1.08162 - 0.96086)/2 = 0.0604. This 6.04% is a remarkable agreement with the 6.49% calculated by the methods given in appendix C and 5.93% calculated by Downton's method. The agreement is remarkable because data used in each case was taken from different countries.

Preamble to section 5.0 Contractor's Bidding Behaviour

The statistical calculations and tests undertaken and reported in this section are

a) The average mean-standardised bid of each contractor.

b) Tests for significant differences on a), the t-test.

c) Correlations between a) and success ratios.

d) Binomial tests for randomness to determine if contractors displayed disproportionate numbers of low or high bids or were random.

e) Simulations to investigate if the distributions of individual contractors' bids could be used to predict winning contractors.

f) A series of time based tests, namely

i) Wald Wolfowitz test for runs

ii) Time series analysis

iii) Autocorrelation coefficients

and iv) Cusum graphs.

The reasons for choosing these statistical calculations were

a) The average mean-standardized bid for each contractor was calculated to determine if these were different or if all contractors tended towards the same mean.

b) Having established that the average mean standardised bids for each contractor varied it was necessary to determine if these different 'averages' were significantly different or merely different due to differing sample sizes. The test chosen was the t-test as described in appendix I. The t-test assumes the distribution of $\bar{x}$ to be normal and although this was not demonstrated to be the case the t-test is robust against non-normality particularly with increasing sample size. As the sample size increases the distribution of $\bar{x}$

tends towards normality. Thus the t-test is valid for the larger sample sizes but less valid for the smaller sample sizes. However the results of the t-test investigation will be further examined using other tests. The binomial test for randomness would either support or refute the findings of the t-tests. (Sample sizes of contractor's bids were up to 98).

c) The average mean-standardized bid was compared with the contractor's success ratio to determine if the average mean standardized bid could be used as a predictor of success ratio.

d) Having found significantly different average mean standardized bids and having found that these had a strong negative correlation with success ratio it was considered necessary to determine if contractors with low 'averages' had a disproportionate number of low bids and vice versa for those with high averages. The contractors' bidding histories were subjected to the binomial test for randomness described by Conover[40] and in appendix J.

e) It was now established that contractors had significantly different average mean standardized bids that strongly negatively correlated with success ratio and were well supported by the randomness test. Thus there existed for each contractor an individual distribution of bids. Therefore it may have been possible to use these individual distributions to predict winning contractors. Simulation using the individual contractor's distributions were undertaken. If this simulation had succeeded the use of time based models and the analyses needed to find them would have been unnecessary.

f) Because the simulation referred to in e) failed a series of time based analyses were undertaken. The first of these was a simple test for runs, the Wald Wolfowitz runs test described by Conover[40] and in appendix K. Because this was unsatisfactory two further and more sophisticated tests were attempted namely the time series analysis and autocorrelation coefficients. The time series analysis used was a standard Box-Jenkins routine described in reference 41. The autocorrelation coefficients are described by Kendall and Stuart[42].

As neither of these time based models improved on the information already derived mainly from the mean standardized bids a method was sought that produced a comparison of the contractors performance relative to the mean bid and to time. The method was called the CUSUM graphs and is described in appendix M.

5.0 CONTRACTOR'S BIDDING BEHAVIOUR

A criticism put forward in section 1.0 was that the previous efforts at interpreting competitor's behaviour were largely based on comparisons with the contractor's own cost estimate and therefore restricted to the contractor's own competitions and that this usually led to inadequate data for any statistical approach. What was needed therefore was methods of interpreting competitor's behaviour that included data from competitions other than those that the contractor entered and so widen the data base. This section examines some of these methods.

Another criticism made in section 1.0 was that the work of Mercer and Russell[4] had not been followed. Mercer & Russell had stated that they had observed in studying gravel supply contracts the changing of contractors prices relative to each other. It has been the accepted view that to include this obvious truth in any explanatory or predictive models relating to general contracting would be too difficult.

This section reports the attempts to answer these two criticisms.

5.1 The Average Mean Standardised Bid and Introduction to tests used to determine contractor's bidding behaviour

The basic difficulty in comparing a competitor's bids from one contract with his bids for another contract is simply that contracts in the construction industry are not standard. The price for gravel supply for example can be reduced to a unit price which is comparable between contracts. Since all contractors bidding for the same contract do so on the same documents, i.e. drawings and specifications, their bids for that contract are comparable, they are bidding on the same basis. To compare bids between contracts a method of standardising the bids must be found. The most obvious and simple method is to standardise the bids for one contract against the mean for that contract. Thus by making the mean 1.0 bids can be compared. However the major and seemingly insuperable objection to standardising the bids against the mean is that the mean itself is a variable. Thus to use a variable quantity to standardise bids invalidates the concept of standardised bids. Accepting this and having no other effective method of standardisation the approach adopted was to determine what information could be obtained from comparing bids standardised against the mean bid. To do this the mean standardised bids (i.e. bid/mean bid) for each contract were calculated. Bidding histories of the type shown in figure 5.1 were created for all contractors. Figure 5.1 shows the bidding history for four sample contractors. These histories were plotted on the line printer as shown for each contractor and displayed the mean standardised bid, a transformed position and the difference between the contractor's bid and the winning bid or the second lowest bid. The transformed position is explained in section 5.3.

In addition, to the bid history plots as shown in figure 5.1 the same information was reproduced in tabular form as shown in table 5.1 for the same sample contractors.

In addition for each contractor the average of his standardised bids was calculated for all the bids submitted by that contractor in the data. The average mean standardised bid for contractors for both buildings and roads contracts are tabulated in tables 5.2 and 5.3. For buildings the average standardised bid ranged from .8765 to 1.0915 and for roads contracts from .88714 to 1.2217.

It seemed at this point that there were differences in these average standardised bids that were due to more than just variability in the standardisor, the mean. For this reason the average of standardised bids were subjected to t-tests to determine of there were significant differences between them and then compared with the contractor's achieved success ratio (number of winning bids/number of bids submitted) to determine if any correlation existed.

The bidding histories as expressed by the standardised bids were also subjected to a series of tests to determine if the behaviour represented by these bidding histories was entirely random or if any patterns existed that could be identified. The tests used were:

i) visual inspection;

ii) binomial test for randomness;

iii) Wald-Wolfowitz test for runs;

iv) time series analysis;

v) autocorrelation coefficients;

vi) graph of cumulative sum of (bid-mean bid)/mean bid drawn against date ordered contract numbers.

Item i) is naturally limited and items iv) and v) proved unhelpful. Useful information was gained by all other tests. The remainder of this section describes the t-test for significant differences between average mean standardised bids, the correlation of average mean standardised bid and success ratio and the above tests particularly ii), iii) and vi). In addition to the above other exercises were undertaken as follows:

vii) an attempt at an analysis of variance for two factors, one factor being the contractor and the other the contracts. This was an attempt to measure the variability due to contractors and the variability that appeared to be due to the contracts themselves which could be taken as the measure of random error that existed. The results of this test are reported and are inconclusive;

viii) the simulation of bids to determine the winning bidder based on a data bank of standardised bids. The results are reported;

ix) a study of the sensitivity of the contractor's success rate to changes in his bid values;

x) a study of the contractors' standardised bids in relation to contract value.

5.2 <u>t-test on the Contractor's Average Mean Standardised Bid</u>

The average mean standardised bid for each contractor shown in tables 5.2 and 5.3 range from 0.87 to 1.09 for buildings contracts and from 0.88 to 1.22 for roads contracts. The number of contracts submitted by each contractor ranges from 2 to 78 for buildings contracts and from 2 to 96 for roads contracts. To test if these differences were significant the standard student t-test was used. The t-test is described in appendix I and by Lamb.[28] Each contractor's average mean standardised bid was tested at 10% level of significance for significant differences with <u>all</u> other contractors' average mean standardised bids. The results are displayed in the form of a matrix which display whether differences between contractors' average mean standardised bids are significantly different or not. The contractors in the matrix are ranked in ascending order of average mean standardised bids. Figure 5.2 gives the t-test results for building contractors and figure 5.3 gives them for roads contractors.

In both buildings and roads contracts there are groups of contractors at the upper and lower end of the range of 'average bids' that are significantly different from those in the centre and the other end. There are also groups of contractors in the centre of the range of average bids that are not significantly different from each other.

This implies that contractors do not display a behaviour which is common to all, that is they cannot be regarded as homogeneous.

Taking this conclusion that there were identifiable differences in contractors 'average bids' the remaining question was did this indicate different success ratios (number of contracts won/number of bids submitted). Columns 3 and 4 of tables 5.4 and 5.5 for buildings and roads show the average mean standardised bid and the success ratio of the contractors whose reference number is given in column 1. For building contracts, with the exception of contractor number 106 there is a clear negative correlation between 'average mean standardised bid' and 'success ratio'. Therefore, although theoretical objections can be raised to using the average mean standardised bid it appears to be a good indication of success ratios.

To place a statistical measure on this negative correlation the Spearman rho or Spearman's rank correlation coefficient was calculated as described by Conover[40], that is

$$\text{Spearman's rho} = \frac{1 - 6(\Sigma D^2)}{n(n^2 - 1)}$$

where D is the difference in the rank position of, in this case, average mean standardised bid and success ratio. Both ranked in ascending order. n is the number of items of data.

Spearman's rho for buildings contracts was -0.71. This supports the conclusion of the strong negative correlation. The same conclusion can be drawn for roads contracts, in fact the Spearman's rho was the same as that for buildings contracts, that is -0.71.

Figure 5.1 Sample Bidding Histories plotted for two building contractors and two roads contractors

Ref. No.	-	Contract reference number
NBIDS	-	The Number of bidders
Transformed position	-	The position of the contractor in the rank order of submitted bids transformed as 2P-n-1. P is the position of the bid in ascending numerical order, n is the number of bidders.
Standardised Bid	-	The contractors bid divided by the mean bid
Deficit	-	The percentage difference between the contractors bid and the winning bid or the second lowest bid when the contractor wins

Building Contractors	122 and 142
Roads Contractors	301 and 171

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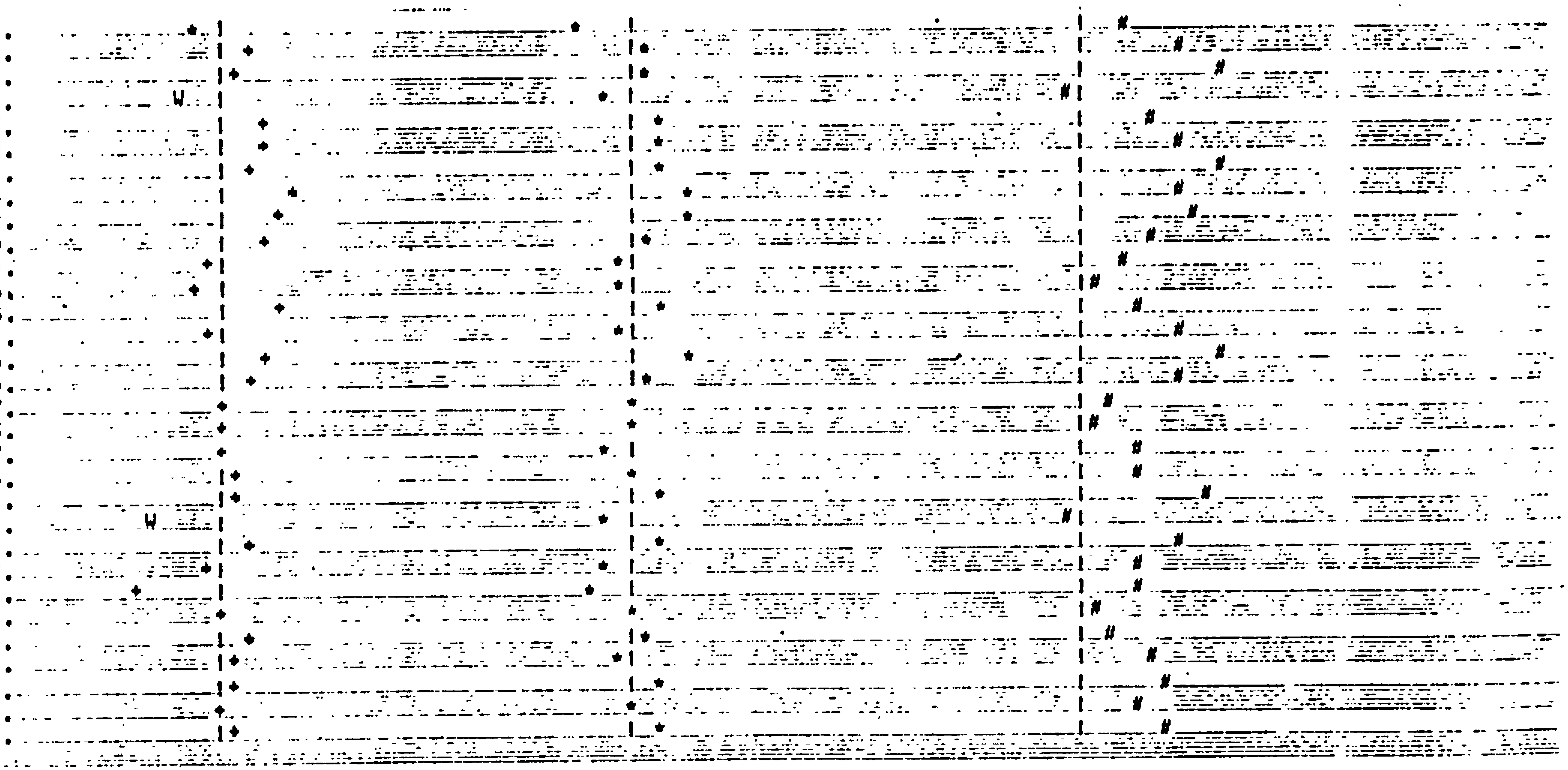
CONTRACTOR NO. 122. FREQUENCY = 78.

	REF. NO.	NBIDS	TRANSFORMED POSITION (-10, 0, +10)	STANDARDISED BID (%) (80, 90, 100, 110, 120)	DEFICIT (%) (-20, -10, 0, +10, +20)
1	3.	11.			
2	5.	2.			
3	11.	12.			
4	12.	8.			
5	14.	10.			
6	19.	13.			
7	20.	6.			
8	21.	6.			
9	24.	10.			
10	35.	6.			
11	42.	6.			
12	46.	7.			
13	48.	11.			
14	53.	6.			
15	54.	8.			
16	55.	5.			
17	56.	4.			
19	60.	7.			
20	61.	4.			
21	66.	7.			
22	75.	6.			
23	76.	5.			
24	80.	10.			
25	89.	11.			
26	92.	10.			
27	93.	4.			
28	95.	9.			
29	97.	10.			
30	101.	4.			
31	105.	10.			
32	108.	7.			
33	109.	8.			
34	110.	6.			
35	111.	10.			
36	114.	6.			
37	122	15.			
38	125.	14.			
39	133.	12.			
40	142.	11.			
41	143.	9.			
42	147.	7.			
43	150.	10.			
44	152.	10.			
45	153.	9.			
46	158.	12.			
47	164.	8.			

Contd/....

48	165.	6.
49	173.	11.
50	174.	11.
51	176.	6.
52	178.	7.
53	183.	10.
54	187.	9.
55	188.	13.
56	189.	12.
57	190.	10.
58	200.	5.
59	211.	6.
60	216.	8.
61	218.	11.
62	219.	6.
63	227.	6.
64	230.	7.
65	231.	3.
66	232.	7.
67	237.	8.
68	238.	5.
69	239.	10.
70	241.	9.
71	242.	7.
72	243.	17.
73	245.	3.
74	246.	4.
75	248.	8.
76	250.	9.
77	252.	5.
78	254.	4.

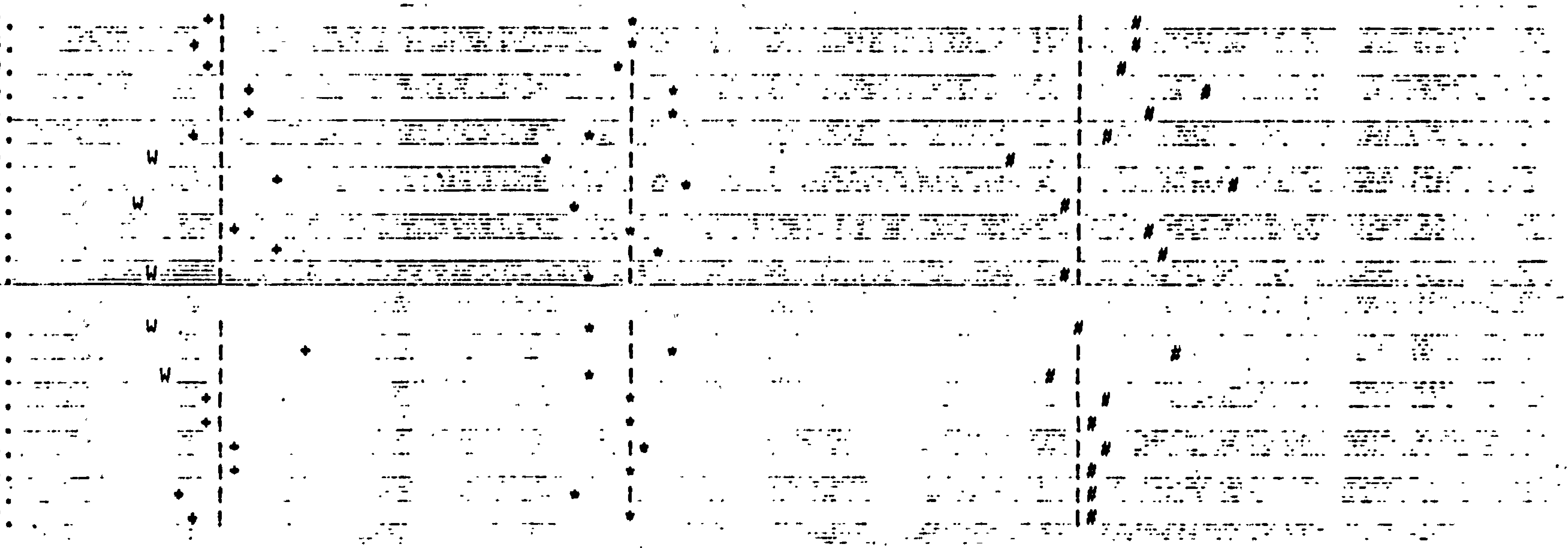


CONTRACTOR NO. 142. FREQUENCY = 66.

	REF. NO.	NBIDS
1	2.	12.
2	3.	11.
3	4.	5.
4	11.	12.
5	12.	6.
6	13.	5.
7	14.	10.
8	18.	7.
9	24.	10.
10	35.	6.
11	40.	3.
12	48.	11.
13	54.	6.
14	57.	10.
15	67.	7.
16	71.	5.
17	75.	6.
18	80.	10.
19	93.	4.
20	94.	4.
21	95.	9.
22	102.	7.
23	103.	6.
24	105.	10.
25	108.	7.
26	111.	10.
27	112.	11.
28	113.	6.
29	116.	7.
30	121.	3.
31	122.	15.
32	123.	5.
33	124.	10.
34	125.	14.
35	126.	7.
36	127.	17.
37	130.	13.
38	136.	3.
39	141.	13.
40	142.	11.
41	144.	4.
42	145.	6.
43	148.	5.
44	150.	10.
45	152.	10.

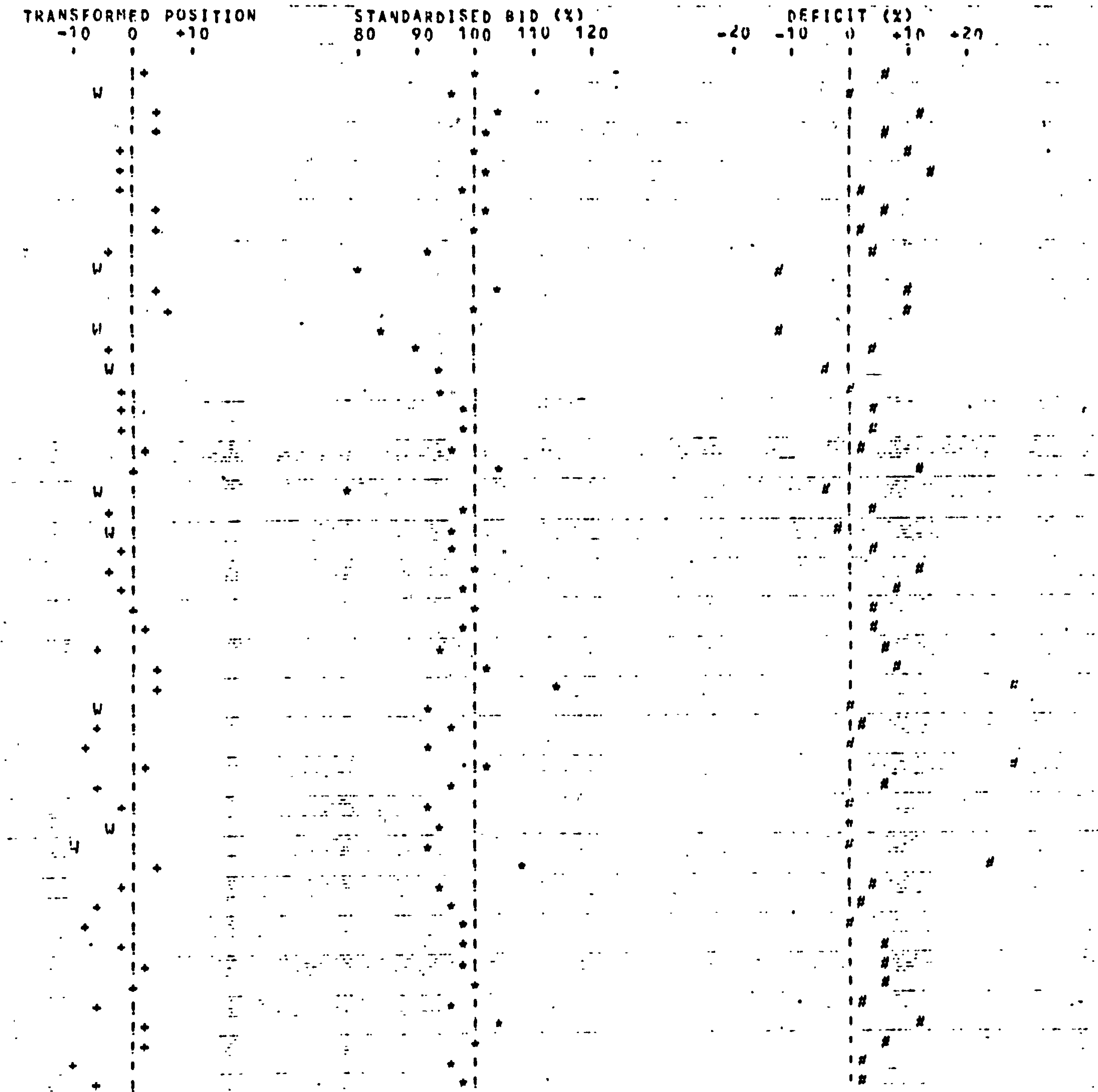
Contd/...

46	153.	9.
47	159.	8.
48	160.	10.
49	165.	6.
50	180.	5.
51	182.	11.
52	183.	10.
53	187.	9.
54	188.	13.
55	189.	12.
56	192.	9.
57	209.	10.
58	210.	11.
59	215.	16.
60	216.	8.
61	230.	7.
62	239.	10.
63	245.	3.
64	246.	4.
65	250.	9.
66	253.	7.



CONTRACTOR NO. 301. FREQUENCY = 96.

	REF. NO.	NBIDS
1	19.	6.
2	27.	7.
3	35.	6.
4	37.	7.
5	59.	7.
6	89.	7.
7	113.	5.
8	114.	6.
9	115.	5.
10	149.	7.
11	152.	7.
12	172.	4.
13	177.	12.
14	181.	6.
15	182.	7.
16	188.	4.
17	192.	4.
18	199.	11.
19	203.	4.
20	205.	6.
21	213.	3.
22	220.	6.
23	225.	8.
24	229.	4.
25	234.	8.
26	238.	12.
27	250.	6.
28	259.	3.
29	278.	6.
30	286.	10.
31	290.	9.
32	331.	7.
33	332.	7.
34	347.	9.
35	353.	11.
36	356.	11.
37	379.	10.
38	423.	4.
39	481.	4.
40	482.	11.
41	492.	4.
42	493.	5.
43	499.	8.
44	505.	10.
45	508.	6.
46	511.	8.
47	512.	11.
48	530.	9.
49	531.	5.
50	533.	9.
51	603.	16.
52	604.	13.



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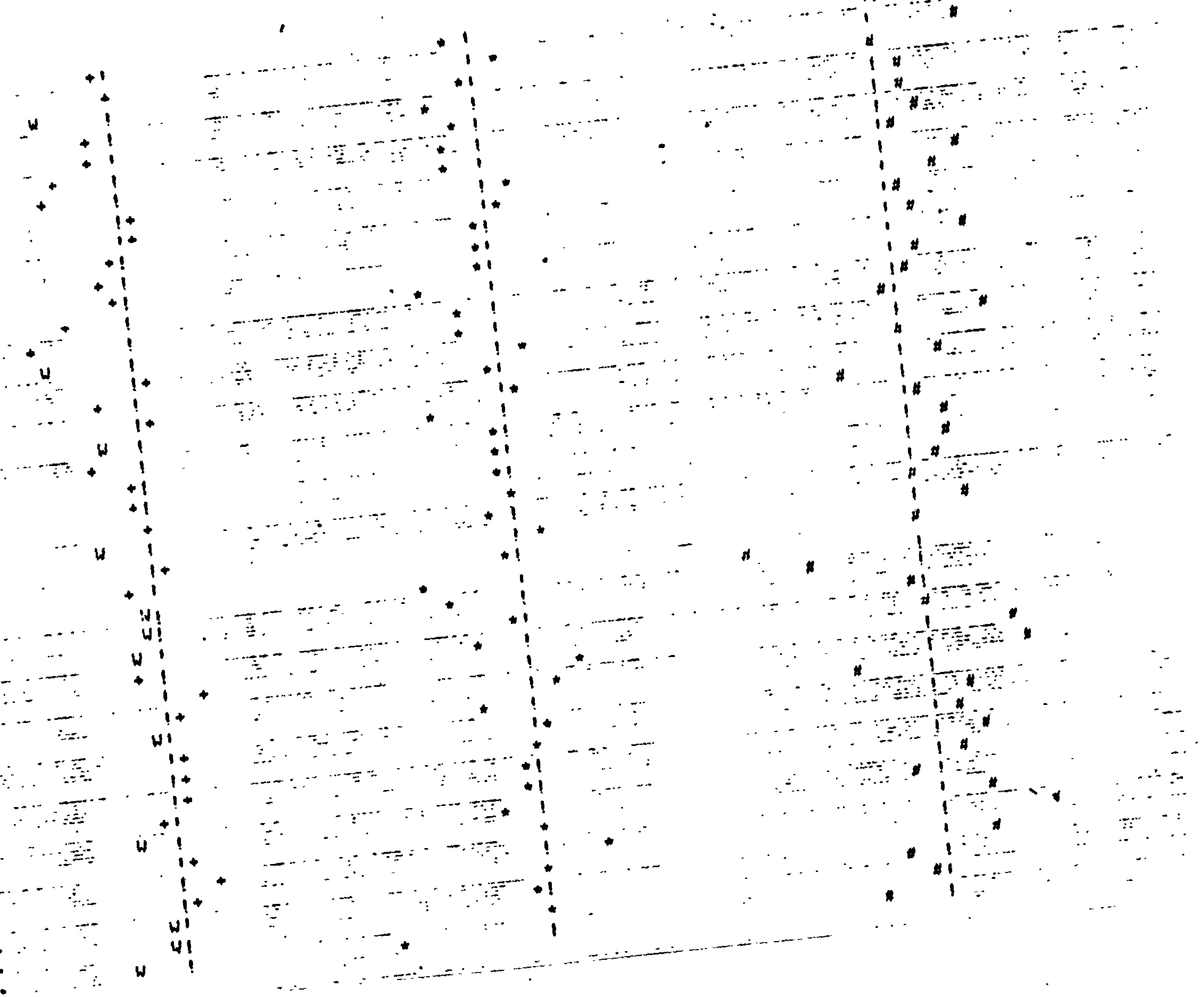
53	608.	8.
54	609.	7.
55	610.	13.
56	618.	9.
57	626.	7.
58	633.	13.
59	637.	16.
60	644.	4.
61	654.	9.
62	657.	5.
63	662.	10.
64	665.	14.
65	666.	15.
66	667.	18.
67	668.	14.
68	673.	12.
69	674.	10.
70	680.	7.
71	694.	6.
72	698.	12.
73	721.	6.
74	772.	7.
75	778.	5.
76	793.	8.
77	842.	2.
78	1000.	10
79	1020.	2.
80	1136.	3.
81	1147.	4.
82	1240.	7.
83	1283.	9.
84	1318.	7.
85	1448.	3.
86	1456.	5.
87	1497.	7.
88	1520.	5.
89	1528.	7.
90	1529.	6.
91	1553.	8.
92	1558.	6.
93	1599.	5.
94	1611.	2.
95	1625.	2.
96	1679.	9.



CONTRACTOR NO. 171. FREQUENCY = 95.

	REF. NO.	NBIDS
1	55.	6.
2	56.	4.
3	66.	6.
4	79.	8.
5	81.	6.
6	89.	7.
7	90.	5.
8	92.	3.
9	94.	8.
10	99.	5.
11	105.	3.
12	107.	7.
13	112.	4.
14	113.	5.
15	114.	6.
16	115.	5.
17	121.	4.
18	149.	7.
19	169.	3.
20	177.	12.
21	178.	7.
22	182.	7.
23	192.	4.
24	196.	3.
25	199.	11.
26	219.	6.
27	225.	8.
28	229.	4.
29	250.	6.
30	253.	3.
31	256.	4.
32	273.	4.
33	290.	9.
34	301.	5.
35	304.	7.

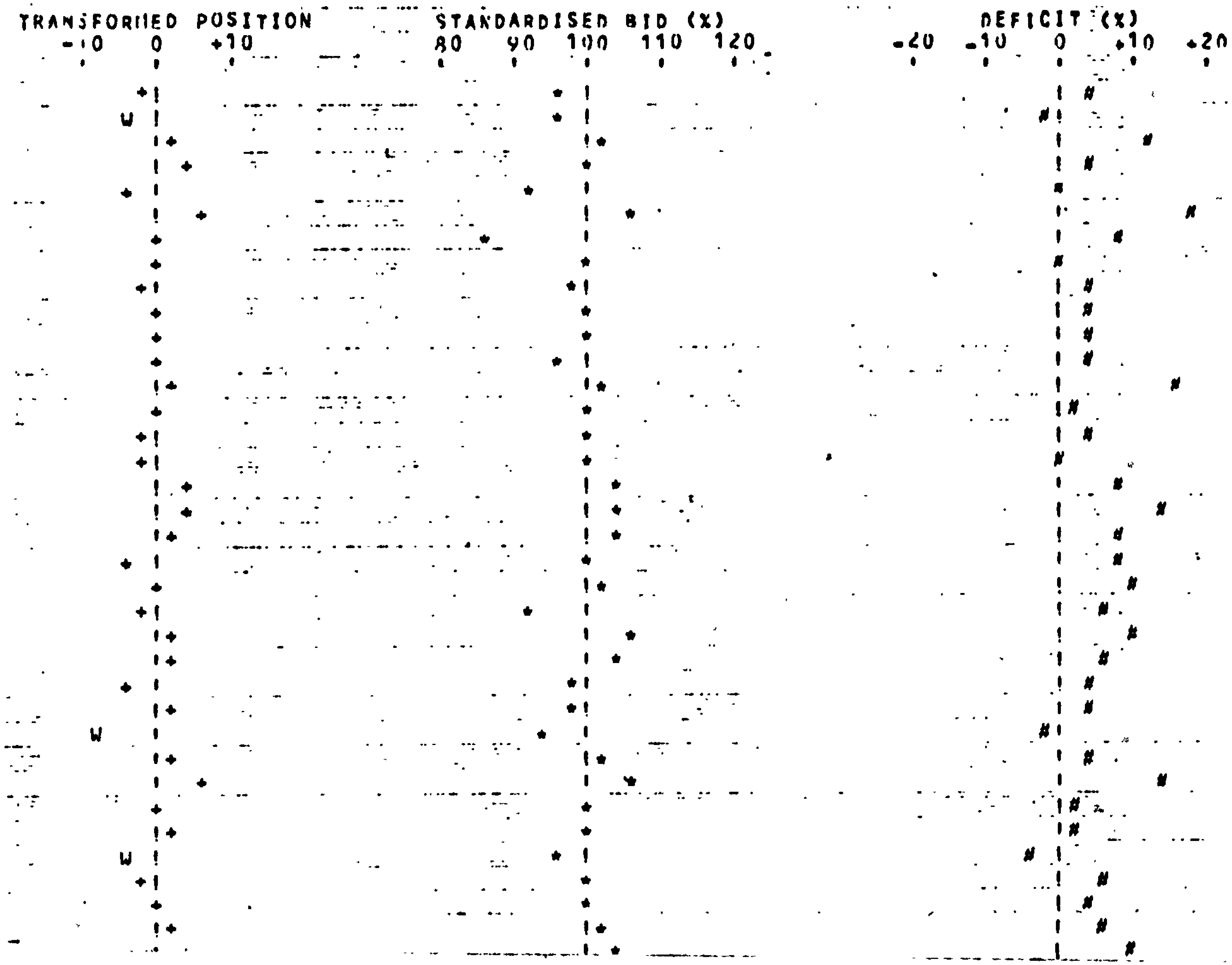


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TABLE 5.1 Sample Bidding Histories for two building contractors and two roads contracts

Ref. No.	-	Contract Reference number
Date	-	Date of Bid Submission
Mean Bid	-	Mean of all bids submitted for the contract in absolute terms
Bid	-	The absolute value of the contractors bid
Position	-	The positon of the contractors bid in the ascending order of submitted bids
NBIDS	-	The number of bids submitted
Transformed position	-	Position transformed as 2P - n - 1 where P is position and n is the number of bidders
Standardised Bid	-	The contractor's bid divided by the mean bid
Deficit	-	The percentage difference between the contractor's bid and the winning bid or the second lowest when the contractor wins

Buildings contracts	-	122 and 142
Roads contracts	-	301 and 171

CONTRACTOR NO. 122 FREQUENCY = 78.

REF. NO.		DATE	MEAN BID	BID	POSITION	NBIDS	TRANSFORMED POSITION	STANDARDISED BID	DEFICIT
1	3,	7.- 1.-70,	38529336.	41140000.	11.	11.	10.	1.06775783	0.1466456
2	5,	16.- 1.-70,	23189841.	24000000.	2.	2.	1.	1.03493594	0.0675135
3	11,	15.- 2.-70,	29281949.	27553000.	5.	12.	-3.	0.94095513	0.0685424
4	12,	24.- 2.-70,	9782047.	9698000.	5.	8.	1.	0.99140806	0.0308436
5	14,	4.- 3.-70,	29219964.	27180000.	2.	10.	-7.	0.93018530	0.0809416
6	19,	26.- 3.-70,	42323504.	39850000.	3.	13.	-8.	0.94155720	0.0287861
7	20,	25.- 3.-70,	17704570.	17200000.	4.	6.	1.	0.97150059	0.0252558
8	21,	25.- 3.-70,	16716907.	16100000.	3.	6.	-1.	0.96309679	0.0217391
9	24,	13.- 4.-70,	8827652.	8542500.	4.	10.	-3.	0.96769787	0.0488657
10	35,	10.- 5.-70,	30873039.	29830000.	2.	6.	-3.	0.96621520	0.0151037
11	42,	17.- 7.-70,	16164855.	15800000.	3.	6.	-1.	0.97743043	0.0313291
12	46,	18.- 3.-70,	118719591.	118293512.	4.	7.	0.	0.99641104	0.0524670
13	48,	25.- 8.-70,	8826140.	9019248.	9.	11.	6.	1.02187913	0.0602321
14	53,	22.- 9.-70,	68119306.	67125205.	2.	6.	-3.	0.98540645	0.0169897
15	54,	28.- 9.-70,	26851789.	25578770.	WINNER	8.	-7.	0.95259160	-0.0173666
16	55,	1.-10.-70,	54597000.	55500000.	6.	6.	5.	1.01653937	0.0360360
17	56,	2.-10.-70,	24971309.	25200000.	3.	4.	1.	1.00915816	0.0339044
18	57,	15.-10.-70,	32478758.	33800000.	8.	10.	5.	1.04068015	0.1390533
19	60,	23.-10.-70,	82985450.	87200000.	5.	7.	2.	1.05078662	0.1515828
20	61,	27.-10.-70,	43204673.	43500000.	3.	4.	1.	1.00683086	0.0259569
21	66,	13.-11.-70,	14163959.	14500000.	6.	7.	4.	1.02372506	0.0689655
22	75,	7.-12.-70,	15209939.	14300000.	2.	6.	-5.	0.94017468	0.0340119
23	76,	10.-12.-70,	27836800.	27847000.	4.	5.	2.	1.00036642	0.0519625
24	80,	18.- 1.-71,	50498970.	54700000.	10.	10.	9.	1.08319041	0.1522924
25	89,	24.- 2.-71,	10139261.	10409808.	8.	11.	4.	1.02668310	0.0907357
26	92,	24.- 2.-71,	21145579.	20756371.	4.	10.	-3.	0.98159388	0.1362779
27	93,	5.- 3.-71,	14409254.	14800000.	4.	4.	3.	1.02711769	0.0850891
28	95,	15.- 3.-71,	66688148.	57000000.	WINNER	9.	-8.	0.85472459	-0.0368421
29	97,	17.- 3.-71,	7775907.	8200000.	8.	10.	5.	1.05453939	0.1536139
30	101,	23.- 3.-71,	43204873.	43500000.	3.	4.	1.	1.00683086	0.0259569
31	105,	1.- 4.-71,	16523920.	16709000.	6.	10.	1.	1.01107836	0.1040756
32	105,	9.- 4.-71,	16730584.	18924922.	7.	7.	6.	1.13115727	0.1927370
33	109,	13.- 4.-71,	43284564.	44640000.	7.	8.	5.	1.03131452	0.0733780
34	110,	22.- 4.-71,	54605366.	55550000.	6.	6.	5.	1.01729925	0.0369037
35	111,	30.- 4.-71,	39436526.	41940000.	7.	10.	3.	1.06348110	0.1945116
36	116,	17.- 5.-71,	25259117.	25240826.	4.	6.	1.	0.99927585	0.0151734
37	122,	24.- 6.-71,	18823135.	19970000.	13.	15.	10.	1.06092846	0.1805996
38	125,	30.- 6.-71,	20623755.	20992398.	9.	14.	3.	1.01787469	0.1151609
39	133,	24.- 6.-71,	25865641.	28300000.	10.	12.	7.	1.09411555	0.1684635
40	142,	9.- 9.-71,	19151651.	18842000.	4.	11.	-4.	0.98383163	0.0796326
41	145,	13.- 9.-71,	129596976.	132000000.	7.	9.	4.	1.01854229	0.0911258
42	147,	14.-10.-71,	13173225.	14000000.	6.	7.	4.	1.06276178	0.3263440
43	150,	8.-11.-71,	9683769.	9395000.	4.	10.	-3.	0.97018012	0.1317722
44	152,	25.-11.-71,	11259102.	10930000.	5.	10.	-1.	0.97077014	0.0584181
45	155,	26.-11.-71,	62602792.	65760000.	8.	9.	6.	1.05043239	0.1278893
46	158,	1.-12.-71,	16211420.	17150000.	11.	12.	9.	1.05789622	0.2576608
47	164,	10.- 1.-72,	5616547.	5730000.	5.	8.	1.	1.02019975	0.2019358
48	165,	11.- 1.-72,	47675025.	43860000.	2.	6.	-3.	0.91997855	0.0587715
49	173,	17.- 2.-72,	18641539.	18980000.	8.	11.	4.	1.01815629	0.1348817
50	174,	17.- 2.-72,	22683589.	22980000.	7.	11.	2.	1.01285289	0.1997440
51	176,	29.- 2.-72,	6505226.	6228256.	WINNER	6.	-5.	0.95742344	-0.0153725

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52	178,	6.- 3.-72,	73730105.	76940000.	7.	7.	6.	1.04353575	0.0906646
53	183,	23.- 3.-72,	6279016.	6494000.	8.	10.	5.	1.03423849	0.1478457
54	187,	10.- 4.-72,	16754090.	17520000.	7.	9.	4.	1.04571484	0.1986936
55	183,	20.- 4.-72,	7263833.	7800000.	12.	13.	10.	1.07381328	0.1397436
56	189,	12.- 4.-72,	11821050.	12740000.	10.	12.	7.	1.07773567	0.1629054
57	190,	20.- 4.-72,	24354772.	24880000.	8.	10.	5.	1.02156572	0.1079390
58	200,	6.- 9.-72,	13790393.	13425000.	2.	5.	-2.	0.97335876	0.0534608
59	211,	21.- 9.-72,	18240833.	17800000.	2.	6.	-3.	0.97583261	0.0264607
60	215,	18.-10.-72,	6644434.	6900000.	8.	8.	7.	1.03846325	0.0865399
61	215,	12.-10.-72,	28911061.	28416000.	5.	11.	-2.	0.98287643	0.1393416
62	219,	25.-10.-72,	39782414.	42642000.	6.	6.	5.	1.07188064	0.1915403
63	227,	29.-11.-72,	10307675.	10550000.	5.	6.	3.	1.02350921	0.1355450
64	230,	11.-12.-72,	40177775.	40116434.	4.	7.	0.	0.99847325	0.0332142
65	231,	8.- 3.-72,	24190553.	24180000.	2.	3.	0.	0.99957283	0.0189826
66	232,	22.-12.-72,	19930693.	19132500.	4.	7.	0.	0.95754938	0.0839671
67	237,	28.-12.-72,	20783162.	20900000.	5.	8.	1.	1.00562174	0.0808414
68	235,	28.-12.-72,	129251401.	134185000.	4.	5.	2.	1.03817057	0.1790475
69	239,	29.-12.-72,	18597540.	17980000.	WINNER	10.	-9.	0.96679453	-0.0117019
70	241,	25.- 1.-73,	85825262.	89400000.	7.	9.	4.	1.04165136	0.1391187
71	242,	8.- 1.-73,	12926428.	12468000.	3.	7.	-2.	0.96453561	0.0762314
72	243,	8.- 2.-73,	39955982.	37706000.	3.	17.	-12.	0.94368848	0.0718270
73	245,	22.- 2.-73,	10339895.	10416097.	2.	3.	0.	1.00736974	0.0289069
74	245,	2.- 3.-73,	23462669.	23978000.	4.	4.	3.	1.02196385	0.0430946
75	248,	3.- 3.-73,	33898875.	32970000.	5.	8.	1.	0.97259866	0.0973429
76	250,	5.- 4.-73,	13754960.	14200000.	6.	9.	2.	1.03235485	0.1285915
77	252,	19.- 4.-73,	25917689.	25900000.	3.	5.	0.	0.99931750	0.0849421
78	255,	9.- 5.-73,	16081750.	16750000.	3.	4.	1.	1.04155331	0.1136119
MEANS :				30931190.			1.308	1.00840078	0.0923973
STANDARD DEVIATIONS :				26962396.			4.554	0.04543270	0.0679143
MEDIANS :				21986199.			1.0	1.01196562	0.0824544

CONTRACTOR NO. 142. FREQUENCY = 66.

	REF. NO.	DATE	MEAN BID	BID	POSITION	NBIDS	TRANSFORMED POSITION	STANDARDISED BID	DEFICIT
1	2,	15.-12.-69,	19733493,	19150412,	3,	12,	-7,	0,97045224	0,0060608
2	5,	7.- 1.-70,	38529336,	39068813,	6,	11,	0,	1,01400173	0,1014060
3	6,	8.- 1.-70,	22109616,	22912408,	4,	5,	2,	1,03630962	0,1081497
4	11,	15.- 2.-70,	29281949,	25664452,	WINNER	12,	-11,	0,87645983	-0,0147194
5	12,	24.- 2.-70,	9782047,	9546512,	2,	8,	-5,	0,97592173	0,0154646
6	13,	3.- 3.-70,	44796686,	44612320,	2,	5,	-2,	0,99588439	0,0080420
7	14,	4.- 3.-70,	29219984,	28412608,	4,	10,	-3,	0,97236904	0,1208126
8	18,	25.- 3.-70,	13865145,	13460000,	2,	7,	-4,	0,97077960	0,0666793
9	24,	13.- 4.-70,	8827652,	8532628,	3,	10,	-5,	0,96657956	0,0477652
10	35,	10.- 6.-70,	30873039,	30312428,	3,	6,	-1,	0,98184139	0,0307785
11	40,	10.- 7.-70,	11307284,	11698612,	3,	3,	2,	1,03460852	0,0971793
12	45,	25.- 8.-70,	8826140,	8671677,	3,	11,	-6,	0,98249940	0,0225651
13	54,	28.- 9.-70,	26651769,	26612400,	5,	8,	1,	0,99853383	0,0460097
14	57,	15.-10.-70,	32478758,	31373721,	3,	10,	-5,	0,96597661	0,0724721
15	65,	13.-11.-70,	14163959,	14500000,	5,	7,	2,	1,02372506	0,0689655
16	71,	1.-12.-70,	16691279,	17876549,	5,	5,	4,	1,07101132	0,1154892
17	75,	7.-12.-70,	15209939,	13813630,	WINNER	6,	-5,	0,90819756	-0,0352094
18	80,	18.- 1.-71,	50498970,	48287154,	3,	10,	-5,	0,95620077	0,0397114
19	95,	5.- 3.-71,	14409254,	14540535,	2,	4,	-1,	1,00909698	0,0687503
20	96,	4.- 3.-71,	7737014,	7178549,	WINNER	4,	-3,	0,92781899	-0,0437817
21	97,	15.- 3.-71,	66688148,	74212680,	7,	9,	4,	1,11283163	0,2319372
22	102,	24.- 3.-71,	13865145,	13460000,	2,	7,	-4,	0,97077960	0,0666793
23	103,	29.- 3.-71,	14351377,	13820000,	2,	6,	-3,	0,96297379	0,0292863
24	105,	1.- 4.-71,	16525920,	15960412,	4,	10,	-3,	0,96578055	0,0620543
25	108,	9.- 4.-71,	16730584,	16945531,	5,	7,	2,	1,01284753	0,0984414
26	111,	30.- 4.-71,	39436526,	37180210,	5,	10,	-1,	0,94278614	0,0913934
27	112,	6.- 5.-71,	8198412,	7815535,	3,	11,	-6,	0,95329866	0,0370791
28	113,	6.- 5.-71,	20114601,	19853170,	2,	6,	-3,	0,98700290	0,0521082
29	116,	3.- 6.-71,	7047533,	7429608,	6,	7,	4,	1,05421399	0,1317592
30	121,	21.- 6.-71,	34894496,	35500000,	3,	3,	2,	1,01735241	0,0293432
31	122,	24.- 6.-71,	18823135,	19507805,	11,	15,	6,	1,03637364	0,1611857
32	123,	24.- 6.-71,	33499136,	35400000,	5,	5,	4,	1,05674367	0,0981589
33	124,	29.- 6.-71,	6037101,	6214368,	8,	10,	5,	1,02936287	0,1647738
34	123,	30.- 6.-71,	20623755,	20212408,	6,	14,	-3,	0,98005471	0,0810152
35	125,	8.- 7.-71,	37963110,	39618424,	6,	7,	4,	1,04360323	0,0927676
36	127,	8.- 7.-71,	16680538,	17753988,	13,	17,	8,	1,06435347	0,2684519
37	130,	12.- 3.-71,	6565621,	6734867,	9,	13,	4,	1,02577768	0,1215843
38	136,	31.- 8.-71,	33854230,	33647690,	2,	3,	0,	0,99389914	0,0127108
39	141,	9.- 9.-71,	9461463,	9780924,	10,	13,	6,	1,03376176	0,1120471
40	142,	9.- 9.-71,	19151651,	17341562,	WINNER	11,	-10,	0,90548653	-0,0441966
41	144,	17.- 9.-71,	14166965,	14687401,	4,	4,	3,	1,03673442	0,0832684
42	145,	21.- 9.-71,	17017927,	16507000,	3,	6,	-1,	0,96997714	0,0158587
43	148,	0.- 0.- 0,	3845000,	3888400,	4,	5,	2,	1,01128739	0,0867709
44	150,	8.-11.-71,	9683769,	9254300,	3,	10,	-5,	0,95565066	0,1185719
45	152,	25.-11.-71,	11259102,	10678445,	4,	10,	-3,	0,94842777	0,0362370
46	153,	26.-11.-71,	62602792,	62674833,	4,	9,	-2,	1,00115077	0,0849597
47	157,	13.-12.-71,	41993609,	42145065,	3,	8,	-3,	1,00355901	0,0892950

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48	160,	10,-12,-71,	9711707.	9472454,	5,	10,	-1,	0,97536452	0,0625966
49	165,	11,- 1,-72,	47675025,	50875000,	5,	6,	3,	1,06712058	0,1885547
50	180,	9,- 3,-72,	14564726,	15590248,	5,	5,	4,	1,05667953	0,0969652
51	162,	20,- 3,-72,	21652792,	20513000,	4,	11,	-4,	0,93815152	0,0302871
52	163,	23,- 3,-72,	6279016,	5533890,	WINNER	10,	-9,	0,88153077	-0,0925345
53	167,	10,- 4,-72,	16754990,	17990000,	9,	9,	8,	1,07376769	0,2196282
54	168,	20,- 4,-72,	7263053,	6710000,	WINNER	13,	-12,	0,92375476	-0,0247392
55	169,	12,- 4,-72,	11821080,	11854165,	7,	12,	1,	1,00279878	0,1003512
56	192,	25,- 4,-72,	38126469,	39670000,	9,	9,	8,	1,04048449	0,1210258
57	209,	20,- 9,-72,	5908651,	5549158,	WINNER	10,	-9,	0,93915811	-0,0169121
58	210,	20,- 9,-72,	8420458,	7972472,	WINNER	11,	-10,	0,94679794	-0,0085439
59	215,	17,-10,-72,	25878609,	27375000,	14,	16,	11,	1,05782346	0,1478336
60	216,	18,-10,-72,	6644454,	6302875,	WINNER	8,	-7,	0,94859479	-0,0471412
61	230,	11,-12,-72,	40177775,	40084620,	3,	7,	-2,	0,99768142	0,0324469
62	237,	29,-12,-72,	18597540,	18530000,	5,	10,	-1,	0,99636834	0,0296816
63	245,	22,- 2,-73,	10339695,	10488587,	3,	3,	2,	1,01438045	0,0356184
64	246,	2,- 3,-73,	23462669,	23636000,	3,	4,	1,	1,00738750	0,0292487
65	250,	5,- 4,-73,	13754960,	12740000,	2,	9,	-6,	0,92621132	0,0287284
66	255,	19,- 4,-73,	20110971,	19980000,	2,	7,	-4,	0,99348756	0,0127227
		MEANS :		21138120,			-1,091	0,99244974	0,0651811
		STANDARD DEVIATIONS :		14626021,			5,007	0,04862250	0,0677911
		MEDIANS :		17143546,			-1,0	0,99489176	0,0646380

CONTRACTOR NO. 301. FREQUENCY = 96.

	REP. NO.	DATE	MEAN BID	BID	POSITION	NBIDS	TRANSFORMED POSITION	STANDARDISED BID	DEFICIT
1	19.	30.-11.-67.	10502976.	10475000.	4.	6.	1.	0.99733637	0.0684420
2	27.	13.-12.-67.	13745104.	13317349.	WINNER	7.	-6.	0.96887947	-0.0013271
3	35.	21.-12.-67.	12504209.	13028394.	5.	6.	3.	1.04192066	0.1125909
4	37.	21.-12.-67.	14814222.	15035200.	6.	7.	4.	1.01491663	0.0686489
5	59.	8.- 2.-68.	6669660.	6699020.	3.	7.	-2.	1.00440207	0.0941362
6	89.	21.- 3.-68.	7794184.	7875200.	3.	7.	-2.	1.01039438	0.1399068
7	113.	16.- 4.-68.	29105864.	28732150.	2.	5.	-2.	0.98716017	0.0166020
8	114.	18.- 4.-68.	6287013.	6430616.	5.	6.	3.	1.02284121	0.0638533
9	115.	18.- 4.-68.	2789278.	2812400.	5.	5.	4.	1.00828953	0.0203918
10	149.	9.- 5.-68.	6381369.	5872334.	2.	7.	-4.	0.92023113	0.0465610
11	152.	0.- 0.- 0.	18578624.	14802655.	WINNER	7.	-6.	0.79675733	-0.1166916
12	172.	0.- 0.- 0.	10860816.	11250000.	4.	4.	3.	1.03583377	0.0901195
13	177.	11.- 6.-68.	19707608.	19904384.	9.	12.	5.	1.00997454	0.0929496
14	181.	13.- 6.-68.	41098556.	34304311.	WINNER	6.	-5.	0.83468816	-0.1146412
15	182.	13.- 6.-68.	3412377.	3093300.	2.	7.	-4.	0.90649417	0.0399735
16	188.	0.- 0.- 0.	1782627.	1692960.	WINNER	4.	-3.	0.94969965	-0.0455752
17	192.	0.- 0.- 0.	945775.	895450.	2.	4.	-1.	0.94678967	0.0060863
18	199.	27.- 6.-68.	4650978.	4546000.	5.	11.	-2.	0.97742880	0.0348847
19	203.	29.- 6.-68.	5054442.	4995312.	2.	4.	-1.	0.98830143	0.0330944
20	205.	5.- 7.-68.	4181634.	3979000.	4.	6.	1.	0.95154183	0.0217203
21	213.	11.- 7.-68.	2619725.	2724405.	2.	3.	0.	1.03995839	0.1153298
22	220.	0.- 0.- 0.	4228699.	3325700.	WINNER	6.	-5.	0.78645938	-0.0464510
23	223.	0.- 0.- 0.	21624907.	21200000.	3.	8.	-3.	0.98035104	0.0375825
24	229.	0.- 0.- 0.	21422190.	20777000.	WINNER	4.	-3.	0.96988216	-0.0167493
25	234.	22.- 8.-68.	36692757.	35210000.	4.	8.	-1.	0.95958993	0.0340585
26	238.	29.- 8.-68.	8222564.	8157705.	5.	12.	-3.	0.99213620	0.1275652
27	250.	0.- 0.- 0.	7898587.	7808340.	3.	6.	-1.	0.98857422	0.0736302
28	259.	19.- 9.-68.	2423006.	2401585.	2.	3.	0.	0.99115919	0.0448183
29	278.	0.- 0.- 0.	5713117.	5650000.	4.	6.	1.	0.98895218	0.0410513
30	286.	22.-10.-68.	11406029.	10807000.	3.	10.	-5.	0.94748135	0.0634898
31	290.	18.- 9.-68.	5754768.	5895600.	7.	9.	4.	1.02447219	0.0707858
32	331.	28.-11.-68.	20513502.	23300000.	6.	7.	4.	1.13583724	0.2738197
33	332.	0.- 0.- 0.	67961255.	62000612.	WINNER	7.	-6.	0.91238209	-0.0079570
34	347.	20.-12.-68.	30160552.	28827000.	2.	9.	-6.	0.95579187	0.0147268
35	353.	23.-12.-68.	17446200.	15943000.	2.	11.	-8.	0.91383797	0.0081540
36	356.	0.- 0.- 0.	17873187.	18303000.	7.	11.	2.	1.02404790	0.2749262
37	379.	0.- 0.- 0.	16399449.	15800000.	3.	10.	-5.	0.96344698	0.0614000
38	423.	13.- 5.-69.	23689701.	21729000.	2.	4.	-1.	0.91723404	0.0024614
39	481.	18.- 1.-67.	9102121.	8539545.	WINNER	4.	-3.	0.93819282	-0.0015833
40	482.	12.- 5.-69.	9552636.	8799900.	WINNER	11.	-10.	0.92120122	-0.0088603
41	492.	29.- 5.-69.	4514384.	4850000.	4.	4.	3.	1.07434376	0.2359227
42	493.	0.- 0.- 0.	1709505.	1595600.	2.	5.	-2.	0.93336938	0.0334044
43	499.	5.- 6.-69.	7198022.	6920420.	2.	8.	-5.	0.96143350	0.0117999
44	505.	12.- 6.-69.	10522148.	10300000.	2.	10.	-7.	0.97888756	0.0098344
45	508.	17.- 6.-69.	5052365.	4979563.	3.	6.	-1.	0.98559058	0.0540736
46	511.	0.- 0.- 0.	9455225.	9354512.	5.	8.	1.	0.98932730	0.0591882
47	512.	26.- 6.-69.	11467862.	11450000.	6.	11.	0.	0.99844241	0.0510917
48	530.	8.- 7.-69.	9149356.	8866900.	2.	9.	-6.	0.96912833	0.0126354
49	531.	0.- 0.- 0.	9519775.	9850600.	4.	5.	2.	1.03475139	0.1168051
50	533.	10.- 7.-69.	10720185.	10800600.	6.	9.	2.	1.00750123	0.0617952
51	603.	2.-10.-69.	7782855.	7509560.	4.	16.	-9.	0.96488750	0.0199729

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52	004,	2,-10,-69,	32436285,	31821000,	4.	13,	-6,	0,98104946	0,0236192
53	008,	0,- 0,- 0,	3160227,	3052320,	4.	8,	-1,	0,96585471	0,0171411
54	009,	13,-10,-69,	35186441,	36375000,	4.	7,	0,	1,03377890	0,1370771
55	010,	13,-10,-69,	24055457,	23448000,	WINNER	13,	-12,	0,97470793	-0,0073354
56	018,	16,-10,-69,	3724236,	3456900,	3.	9,	-4,	0,92821714	0,0393162
57	026,	0,- 0,- 0,	7325062,	7046600,	2.	7,	-4,	0,96185372	0,0317880
58	033,	31,-10,-69,	20370298,	19336000,	2.	13,	-10,	0,94922518	0,0597158
59	037,	0,- 0,- 0,	20367643,	19280000,	3.	16,	-11,	0,94659945	0,0214730
60	044,	22,-11,-69,	2007945,	2096800,	3.	4,	1,	1,04425158	0,1129431
61	054,	11,-12,-69,	5923252,	6040000,	6.	9,	2,	1,01971016	0,0894040
62	057,	13,-12,-69,	2773796,	2725000,	2.	5,	-2,	0,98240822	0,0102752
63	062,	0,- 0,- 0,	19239994,	19022000,	4.	10,	-3,	0,98866974	0,0425949
64	063,	0,- 0,- 0,	27785465,	27367255,	7.	14,	-1,	0,98494788	0,1285199
65	066,	22,-12,-69,	44308145,	38750000,	3.	15,	-10,	0,87455704	0,0322581
66	067,	27,-12,-69,	14992631,	14178000,	2.	18,	-15,	0,94566460	0,0177035
67	068,	22,-12,-69,	29815934,	27750000,	WINNER	14,	-13,	0,93071042	-0,0163604
68	073,	29,-12,-69,	20023931,	20689521,	7.	12,	1,	1,03323972	0,1399681
69	074,	29,-12,-69,	6535554,	6425257,	3.	10,	-5,	0,98315054	0,0096287
70	080,	30,-12,-69,	2224976,	2250500,	5.	7,	2,	1,01138183	0,0674048
71	094,	0,- 0,- 0,	59424555,	52750000,	WINNER	6,	-5,	0,88768350	-0,1041896
72	098,	29,- 1,-70,	19064404,	18789000,	3.	12,	-7,	0,98555401	0,0297328
73	721,	5,- 5,-70,	5484465,	5350421,	3.	6,	-1,	0,97555966	0,0684707
74	772,	0,- 0,- 0,	34064498,	33678163,	3.	7,	-2,	0,98865873	0,0697830
75	776,	0,- 0,- 0,	5071956,	5075000,	3.	5,	0,	1,00099018	0,0345691
76	793,	15,- 2,-70,	7097552,	6855000,	WINNER	8,	-7,	0,96582593	-0,0036470
77	842,	21,- 5,-70,	21629150,	22440000,	2.	2,	1,	1,03748969	0,0722700
78	1000,	18,-11,-70,	49878272,	48940000,	4.	10,	-3,	0,98118877	0,0099351
79	1020,	19,-12,-70,	12363000,	10445000,	WINNER	2,	-1,	0,84485966	-0,3672571
80	1136,	17,- 6,-71,	30064901,	26721000,	WINNER	3,	-2,	0,88877725	-0,1809533
81	1147,	27,- 6,-71,	8335397,	8138710,	WINNER	4,	-3,	0,97640334	-0,0173848
82	1240,	4,-11,-71,	17867127,	16402000,	2.	7,	-4,	0,91799873	0,0010365
83	1283,	17,- 1,-72,	1169063,	1252192,	8.	9,	6,	1,07110768	0,1337830
84	1318,	0,- 0,- 0,	4289428,	4453230,	5.	7,	2,	1,03818741	0,1668582
85	1445,	18,- 8,-72,	11461453,	10436500,	WINNER	3,	-2,	0,91057390	-0,1114889
86	1456,	23,- 3,-72,	6423927,	6495000,	4.	5,	2,	1,01106379	0,0646651
87	1497,	19,-10,-72,	3923050,	3900000,	5.	7,	2,	0,99412443	0,0475218
88	1520,	23,-11,-72,	34444009,	33447000,	4.	5,	2,	0,97105421	0,0881095
89	1528,	30,-11,-72,	5973327,	5874495,	3.	7,	-2,	0,98345445	0,0474075
90	1529,	30,-11,-72,	13603901,	12759000,	WINNER	6,	-5,	0,93789276	-0,0378527
91	1533,	9,- 1,-73,	3761000,	3752900,	5.	8,	1,	0,99784618	0,0804977
92	1536,	18,- 1,-73,	590184,	649800,	6.	6,	5,	1,10101319	0,1705140
93	1599,	0,- 0,- 0,	8556744,	8639000,	4.	5,	2,	1,00961303	0,0803167
94	1611,	5,- 4,-73,	11580762,	11283500,	WINNER	2,	-1,	0,97433135	-0,0526898
95	1625,	4,- 4,-73,	7827157,	7752034,	WINNER	2,	-1,	0,99040226	-0,0193815
96	1679,	18,- 4,-73,	18402618,	13953000,	WINNER	9,	-8,	0,75820735	-0,0910199
		MEANS :		13674650,			-2,156	0,97252471	0,0378874
		STANDARD DEVIATIONS :		12071799,			4,258	0,05994818	0,0844673
		MEDIANS :		9602456,			-2,0	0,98111912	0,0362336

CONTRACTOR NO. 171. FREQUENCY = 95.

	REF. NO.	DATE	MEAN BID	BID	POSITION	NBIDS	TRANSFORMED POSITION	STANDARDISED BID	DEFICIT
1	55.	21.-12.-67.	12504209.	12122655.	3.	6.	-1.	0.96948433	0.0462870
2	56.	0.- 0.- 0.	4727715.	4507550.	WINNER	4.	-3.	0.95338869	-0.0251168
3	66.	0.- 0.- 0.	773471.	785500.	4.	6.	1.	1.01296579	0.1148909
4	79.	7.- 3.-68.	4301549.	4294608.	6.	8.	3.	0.99843270	0.0450176
5	81.	7.- 3.-68.	1939516.	1834708.	2.	6.	-3.	0.92228075	0.0032468
6	89.	21.- 3.-68.	7794184.	8225418.	7.	7.	6.	1.05532763	0.1765274
7	90.	0.- 0.- 0.	5985095.	5187595.	3.	5.	0.	0.86671914	0.0835574
8	92.	0.- 0.- 0.	2344044.	2343382.	2.	3.	0.	0.99971758	0.0057933
9	96.	28.- 3.-68.	7323434.	7240000.	4.	8.	-1.	0.98860721	0.0313398
10	99.	0.- 0.- 0.	2828194.	2855853.	3.	5.	0.	1.00376869	0.0313405
11	105.	0.- 0.- 0.	5525446.	5519620.	2.	3.	0.	0.99824735	0.0300095
12	107.	11.- 4.-68.	2707975.	2607810.	4.	7.	0.	0.96301106	0.0354182
13	112.	12.- 4.-68.	2323639.	2386500.	3.	4.	1.	1.02696664	0.1522441
14	113.	16.- 4.-68.	29105864.	28876077.	3.	5.	0.	0.99210512	0.0215035
15	114.	18.- 4.-68.	6287013.	6270000.	3.	6.	-1.	0.99729395	0.0398724
16	115.	18.- 4.-68.	2789278.	2777825.	2.	5.	-2.	0.99589385	0.0081989
17	121.	23.- 4.-68.	5188273.	5388259.	4.	4.	3.	1.03854582	0.0884492
18	149.	9.- 5.-68.	6381569.	6586525.	6.	7.	4.	1.03214928	0.1499445
19	169.	30.- 5.-68.	918747.	964000.	3.	3.	2.	1.04925551	0.0890124
20	177.	11.- 6.-68.	19707808.	19664218.	5.	12.	-3.	0.99778820	0.0818714
21	175.	0.- 0.- 0.	2565732.	2610905.	4.	7.	0.	1.01760634	0.1075891
22	184.	13.- 6.-68.	3412377.	3144970.	3.	7.	-2.	0.92163611	0.0557462
23	192.	0.- 0.- 0.	945775.	998500.	3.	4.	1.	1.05574793	0.1086630
24	195.	0.- 0.- 0.	5132943.	5311018.	3.	3.	2.	1.03469251	0.0680578
25	199.	27.- 6.-68.	4650978.	4526693.	4.	11.	-4.	0.97327763	0.0307684
26	219.	14.- 7.-68.	5595471.	5488829.	4.	6.	1.	0.98094140	0.0440784
27	225.	0.- 0.- 0.	21624907.	20405250.	WINNER	8.	-7.	0.94350695	-0.0107287
28	229.	0.- 0.- 0.	21422190.	21686760.	3.	4.	1.	1.01235028	0.0419500
29	253.	0.- 0.- 0.	7898587.	8318000.	6.	6.	5.	1.05309968	0.1303907
30	255.	28.-10.-68.	6841527.	6821495.	2.	3.	0.	0.99710110	0.0152518
31	256.	18.- 9.-68.	5808801.	5783483.	3.	4.	1.	0.99564144	0.0196207
32	275.	0.- 0.- 0.	6502757.	6291850.	WINNER	4.	-3.	0.96756649	-0.0355110
33	290.	18.- 9.-68.	5754768.	5783483.	4.	9.	-2.	1.00498974	0.0527724
34	301.	4.-11.-68.	2877589.	2877744.	3.	5.	0.	1.00012331	0.0305250
35	304.	4.-11.-68.	2735734.	2767252.	5.	7.	2.	1.01152075	0.0671421
36	305.	5.-11.-68.	2263268.	2337000.	5.	6.	3.	1.03257790	0.0968763
37	320.	0.- 0.- 0.	2964881.	2820000.	2.	3.	0.	0.95113440	0.0304823
38	331.	28.-11.-68.	20513502.	19215557.	3.	7.	-2.	0.93662879	0.1193709
39	341.	19.-12.-68.	713286.	724691.	2.	3.	0.	1.01598890	0.0476382
40	347.	20.-12.-68.	30160332.	30092906.	6.	9.	2.	0.99776442	0.0561739
41	355.	23.-12.-68.	17446200.	16351460.	3.	11.	-6.	0.93725052	0.0329304
42	356.	0.- 0.- 0.	17873187.	17500850.	4.	11.	-4.	0.97916783	0.2416925
43	369.	0.- 0.- 0.	7039551.	7015740.	6.	10.	1.	0.99662040	0.0622232
44	379.	0.- 0.- 0.	16399449.	16558520.	7.	10.	3.	1.00968756	0.1043850

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45	391,	13,- 5,-69,	2716843,	2725000,	4,	5,	2,	1,00300231	0,0264103
46	422,	31,- 5,-69,	1824532,	1858930,	3,	4,	1,	1,01885277	0,0473014
47	457,	24,- 4,-69,	7782194,	7735450,	2,	6,	-3,	0,99399340	0,0027729
48	482,	12,- 5,-69,	9552636,	9445500,	4,	11,	-4,	0,98876372	0,0683303
49	492,	29,- 5,-69,	4514584,	4785000,	3,	4,	1,	1,05994534	0,2255434
50	505,	17,- 6,-69,	10522148,	10917500,	9,	10,	7,	1,03755429	0,0658216
51	511,	0,- 0,- 0,	9455225,	10567940,	8,	8,	7,	1,11768258	0,1672316
52	512,	26,- 6,-69,	11467862,	11129700,	3,	11,	-6,	0,97051218	0,0237832
53	513,	0,- 0,- 0,	4427610,	4549599,	3,	3,	2,	1,02755196	0,0475578
54	525,	3,- 7,-69,	11809535,	11564570,	2,	7,	-4,	0,97924008	0,0215636
55	530,	8,- 7,-69,	9149356,	9254485,	7,	9,	4,	1,01149033	0,0539870
56	531,	0,- 0,- 0,	9519775,	10016367,	3,	5,	4,	1,05216430	0,1314216
57	534,	0,- 0,- 0,	10579635,	10492000,	2,	4,	-1,	0,99171659	0,0038124
58	538,	2,- 8,-69,	1126009,	1187769,	3,	3,	2,	1,05484827	0,1387214
59	550,	0,- 0,- 0,	10933552,	11218585,	5,	6,	3,	1,02606959	0,0890117
60	575,	11,- 9,-69,	16282833,	15250000,	WINNER	9,	-8,	0,93656921	-0,0033443
61	576,	13,- 9,-69,	5042199,	4967791,	2,	5,	-2,	0,98524302	0,0645339
62	598,	2,-10,-69,	1105000,	1187000,	2,	2,	1,	1,07420814	0,1381634
63	599,	2,-10,-69,	7440169,	7310000,	3,	8,	-3,	0,98250460	0,0075239
64	603,	2,-10,-69,	7782835,	7418376,	2,	16,	-13,	0,95317146	0,0079268
65	604,	2,-10,-69,	32436285,	31294672,	2,	15,	-10,	0,96480445	0,0071792
66	626,	0,- 0,- 0,	7326062,	7238800,	3,	7,	-2,	0,98808883	0,0574953
67	630,	30,-10,-69,	5370000,	5163000,	WINNER	3,	-2,	0,96145251	-0,0259539
68	633,	31,-10,-69,	20370298,	20049640,	8,	13,	-2,	0,98425854	0,0931840
69	634,	31,-10,-69,	16129075,	14998000,	WINNER	10,	-9,	0,92987355	-0,0041339
70	637,	0,- 0,- 0,	20367645,	20720000,	10,	16,	3,	1,01729983	0,0894788
71	651,	10,-12,-69,	1290226,	1326866,	5,	6,	3,	1,02859826	0,1588261
72	653,	11,-12,-69,	1586032,	1516130,	WINNER	4,	-5,	0,95592619	-0,0421270
73	654,	11,-12,-69,	5923252,	5724151,	2,	9,	-6,	0,96658658	0,0391588
74	655,	11,-12,-69,	6126362,	6250000,	3,	4,	1,	1,02018122	0,0631280
75	661,	18,-12,-69,	1733278,	1751690,	4,	5,	2,	1,01062265	0,0437806
76	662,	0,- 0,- 0,	19239994,	19492500,	7,	10,	3,	1,01312921	0,0657090
77	675,	29,-12,-69,	20023951,	19800775,	5,	12,	-3,	0,98885553	0,1013661
78	696,	29,- 1,-70,	19064404,	18230350,	WINNER	12,	-11,	0,95625071	-0,0120486
79	701,	5,- 2,-70,	499000,	488000,	WINNER	2,	-1,	0,97795591	-0,0450820
80	721,	5,- 5,-70,	5484463,	5495578,	5,	6,	3,	1,00199014	0,0930426
81	772,	0,- 0,- 0,	34064498,	31733555,	2,	7,	-4,	0,93157267	0,0127800
82	793,	15,- 2,-70,	7097552,	7097485,	4,	8,	-1,	0,99999052	0,0341649
83	808,	24,- 4,-70,	11022050,	10756000,	WINNER	3,	-2,	0,97586202	-0,0189801
84	842,	21,- 5,-70,	21629130,	20818261,	WINNER	2,	-1,	0,96251031	-0,0778998
85	852,	28,- 5,-70,	5358156,	5420960,	3,	3,	2,	1,01172126	0,0287824
86	861,	0,- 0,- 0,	21157156,	21094000,	4,	6,	1,	0,99701490	0,0353870
87	1001,	20,-11,-70,	21746667,	20700000,	WINNER	3,	-2,	0,95187002	-0,0647343
88	1143,	24,- 6,-71,	3761173,	3735570,	2,	3,	0,	0,99313955	0,0488225
89	1240,	4,-11,-71,	17867127,	21435554,	7,	7,	6,	1,19970904	0,2356086
90	1253,	9,-12,-71,	1268665,	1232545,	3,	7,	-2,	0,97153044	0,0729174
91	1280,	19,- 1,-72,	8308667,	8219290,	3,	6,	-1,	0,98924286	0,0935957
92	1303,	13,- 4,-72,	14621882,	16710420,	6,	6,	5,	1,14283650	0,1846910
93	1413,	0,- 0,- 0,	3674070,	3780000,	4,	5,	2,	1,02883184	0,0767196
94	1446,	10,- 8,-72,	3462538,	3910000,	4,	4,	3,	1,12922940	0,1912120
95	1543,	21,-12,-72,	4543527,	4641143,	5,	5,	4,	1,02148468	0,0715748
		MEANS :		9032133,			-0,337	1,00027027	0,0596128
		STANDARD DEVIATIONS :		7694030,			3,735	0,04759840	0,0630177
		MEDIANS :		6270000,			0,0	0,99729395	0,0476382

TABLE 5.2 Average Mean Standardised Bids for Building Contractors with two or more bids

Contractor No.	No. of bids submitted	Average Bid
170	2	0.876512
146	2	0.909258
186	2	0.919241
174	2	0.933417;
116	4	0.943063
115	45	0.954028
107	10	0.962650
179	4	0.963443
124	2	0.965789
185	10	0.968492
143	8	0.971472
106	30	0.971835
105	16	0.973022
196	2	0.974124
194	5	0.974687
113	32	0.978017
154	8	0.979968
117	18	0.980374
191	14	0.982698
176	6	0.982687
131	46	0.983252
103	63	0.984768
150	10	0.985322
144	9	0.986909
198	2	0.987642
123	7	0.989128
125	21	0.990908
136	27	0.991042
112	8	0.991265
153	22	0.991323
142	66	0.992450
104	10	0.993329
141	5	0.993742

TABLE 5.2 (Contd)

Contractor No.	No. of Bids Submitted	Average Bid
183	7	0.994920
189	2	0.996450
133	65	0.997082
149	39	0.997963
111	27	0.998090
100	36	0.998606
132	4	0.998693
126	15	0.999911
172	3	1.000785
155	3	1.001196
178	7	1.001399
160	41	1.001434
152	5	1.001515
180	4	1.001999
130	17	1.003128
119	2	1.003861
140	25	1.004752
110	6	1.005325
102	21	1.005754
101	23	1.006123
145	15	1.006714
122	78	1.008401
197	16	1.009194
151	26	1.011002
134	7	1.011810
156	6	1.012141
139	8	1.015245
120	17	1.016426
184	6	1.016604
137	15	1.016656
128	22	1.018439
127	15	1.022221
159	43	1.031066
158	8	1.031505

TABLE 5.2. (Contd)

Contractor No.	No. of Bids Submitted	Average Bid
129	2	1.032266
157	29	1.033448
177	4	1.033729
135	33	1.037237
118	12	1.040766
192	8	1.050696
138	21	1.050750
109	6	1.059080
148	2	1.067450
199	2	1.084124
164	3	1.091550

TABLE 5.3 Average Mean - Standardised Bids for Roads Contractors

Contractor No.	No. of Bids Submitted	Average Bid
386	2	0.887141
320	3	0.891869
434	3	0.905457
351	2	0.926352
329	3	0.931346
319	3	0.940864
417	4	0.956074
425	3	0.957605
335	24	0.964564
410	10	0.966080
355	26	0.966225
416	13	0.967576
388	8	0.967885
337	29	0.968720
412	4	0.969214
369	9	0.969359
313	33	0.969395
427	18	0.970996
384	4	0.971521
334	4	0.972406
301	96	0.972525
395	3	0.972797
387	6	0.973788
379	7	0.973827
406	17	0.975444
392	5	0.975665
390	48	0.975982
336	10	0.978468
118	65	0.978630
399	5	0.982651
315	28	0.983461
310	9	0.983828
435	2	0.984317
371	2	0.984404

TABLE 5.3 (Contd)

Contractor No.	No. of Bids Submitted	Average Bid
321	14	0.984691
382	31	0.986805
307	17	0.988074
400	16	0.988334
407	20	0.990815
370	46	0.990826
403	8	0.991165
311	62	0.992168
366	4	0.992499
340	5	0.992584
363	5	0.992717
342	4	0.993476
302	9	0.993901
344	68	0.994061
303	41	0.994757
312	47	0.996098
385	2	0.996164
391	29	0.996175
345	46	0.996798
306	58	0.997509
402	33	0.998387
305	4	0.998806
348	40	0.999102
171	95	1.000270
398	15	1.000316
338	14	1.000506
383	50	1.001581
432	62	1.001738
433	2	1.002646
168	26	1.004593
401	3	1.005945
415	7	1.006306
393	13	1.007237
300	25	1.007344
309	75	1.007358
405	5	1.008234

TABLE 5.3 (Contd)

Contractor No.	No. of bids Submitted	Average Bid
314	86	1.009731
318	58	1.014543
350	2	1.014947
322	8	1.015157
404	7	1.015274
409	14	1.016479
343	27	1.019952
418	8	1.020262
411	9	1.023078
422	2	1.023208
376	5	1.023532
122	22	1.024134
353	21	1.025124
360	19	1.025206
361	2	1.025660
357	2	1.029719
326	35	1.033484
414	4	1.036500
324	53	1.036904
426	4	1.037046
352	20	1.037376
339	12	1.039784
394	2	1.041592
431	2	1.042773
327	23	1.043006
323	5	1.046633
419	3	1.047743
354	3	1.053102
396	6	1.053959
356	2	1.061247
377	18	1.066255
380	8	1.079111
408	3	1.127051
397	2	1.221711

Figure 5.2   t-test results for Building Contractors

The chart is in the form of a matrix with the contractors reference numbers reading from left to right and top to bottom, in ascending order of their mean bid.

The matrix is completed above the 45^{o} line only. Below the 45^{o} line is a mirror image. The entries in the matrix are either a star (*) or a blank. The star means that there is a significant difference between the two contractor's mean bids at the 10% level. A blank means that no significant difference was found.

As the contractors are ranked in ascending order of mean bids the pattern of significant differences shows that contractors near the top and bottom are significantly different from each other and those at the centre. The contractors at the centre show no significant differences.

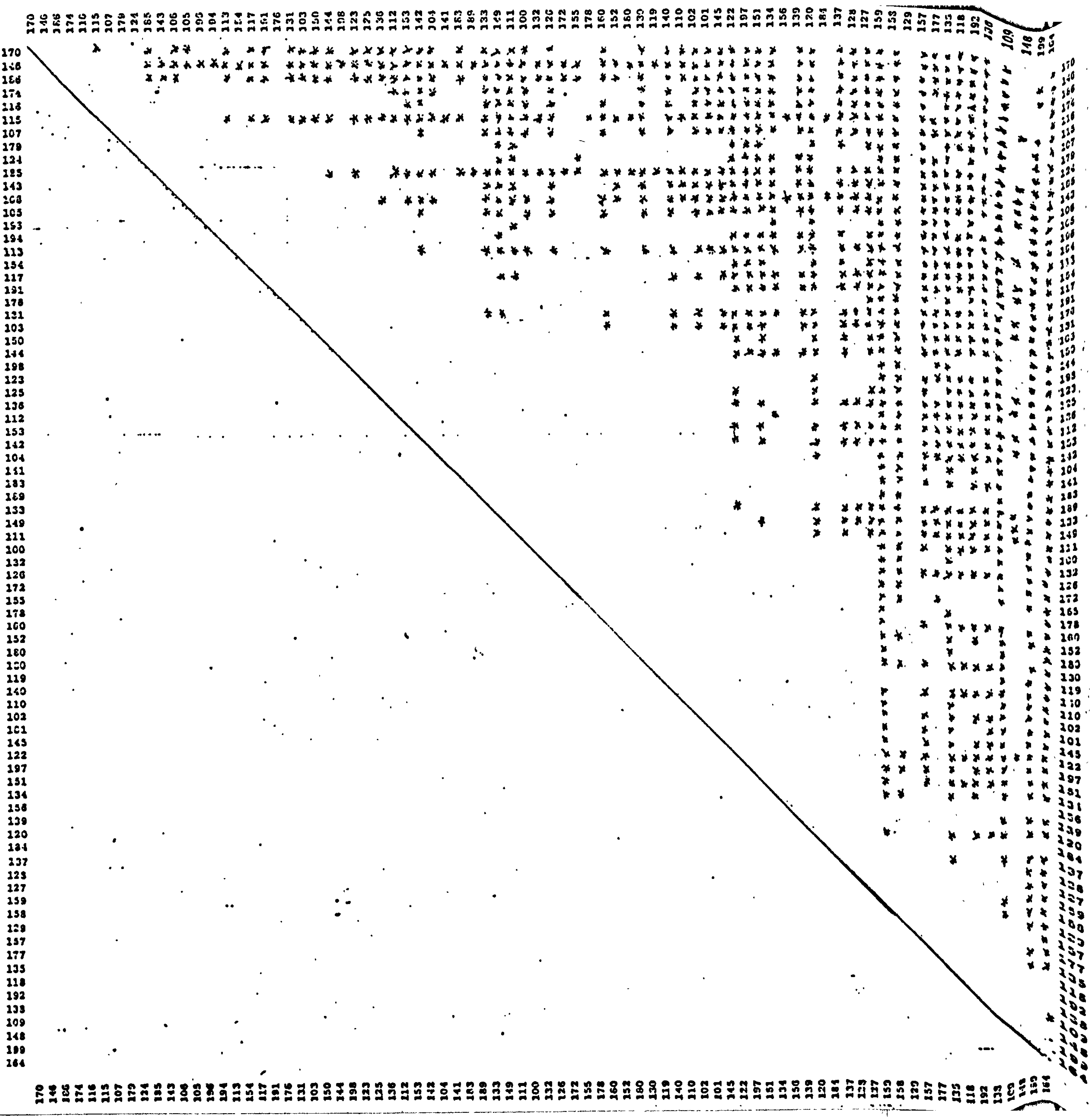


Figure 5.3 t-test results for Roads Contractors

The chart is in the form of a matrix with the contractors reference numbers reading from left to right and top to bottom, in ascending order of their mean bid.

The matrix is completed above the 45^{o} line only. Below the 45^{o} line is a mirror image. The entries in the matrix are either a star (*) or a blank. The star means that there is a significant difference between the two contractor's mean bids at the 10% level. A blank means that no significiant difference was found.

As the contractors are ranked in ascending order of mean bids the pattern of significant differences shows that contractors near the top and bottom are significantly different from each other and those at the centre. The contractors at the centre show no significant differences.

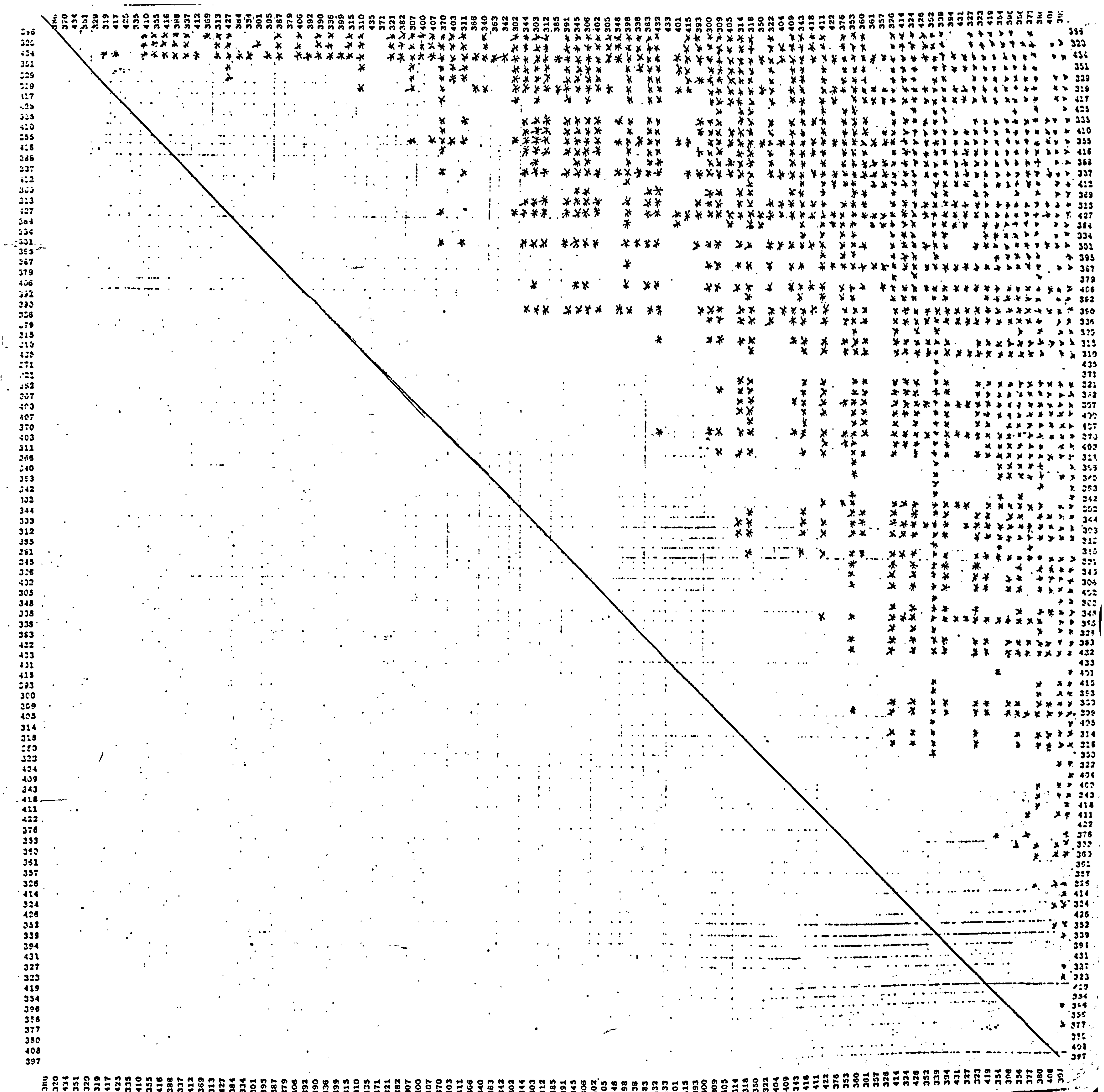


TABLE 5.4 Building Contractors, Success Ratio and average mean standardised bids

Company Number	Frequency	Average Mean Standardised Bids	Success Ratio (%)
115	45	0.95403	44.44
106	30	0.97184	6.67
113	32	0.97802	25.00
131	46	0.98325	21.74
103	63	0.98477	20.64
125	21	0.99091	23.81
136	27	0.99104	14.82
153	22	0.99132	22.73
142	66	0.99245	13.64
133	65	0.99708	16.92
149	39	0.99796	17.95
111	27	0.99809	11.11
100	36	0.99861	16.67
160	41	1.00143	24.39
140	25	1.00475	20.00
102	21	1.00575	4.76
101	23	1.00612	8.70
122	78	1.00840	5.13
151	26	1.01100	7.69
128	22	1.01844	4.55
159	43	1.03107	4.65
157	29	1.03345	6.90
135	33	1.03724	0.00
138	21	1.05075	9.52

TABLE 5.5 Roads Contractors, Success Ratios and average mean standardised bids

Company Number	Frequency	Average mean Standardised Bids	Success Ratio (%)
335	24	0.9646	29.17
355	26	0.9662	42.31
337	29	0.9687	24.14
313	33	0.9694	30.30
301	96	0.9725	21.88
390	48	0.9760	41.67
118	65	0.9786	23.08
315	28	0.9835	17.86
382	31	0.9868	16.13
370	46	0.9908	13.04
311	62	0.9922	25.81
344	68	0.9941	16.18
303	41	0.9948	24.39
312	47	0.9961	21.28
391	29	0.9962	0.00
345	46	0.9968	23.91
306	58	0.9975	20.69
402	33	0.9984	18.18
348	40	0.9991	17.50
171	95	1.0003	12.63
383	50	1.0016	14.00
432	62	1.0017	12.90
168	26	1.0046	19.23
300	25	1.0073	24.00
309	75	1.0074	10.67
314	86	1.0097	12.79
318	58	1.0145	17.24
343	27	1.0200	14.82
326	35	1.0335	8.57
324	53	1.0369	9.43
327	23	1.0430	8.70

5.3 Testing Contractor's Bidding Histories for Randomness and Runs

Bidding histories of the type represented by figure 5.1 in section 5.1 were produced for all contractors. The conclusion implied from section 5.2 was that there seemed to be identifiable differences between the 'average mean standardised bid' which negatively correlated with success ratio (Spearmans rho - 0.71). The test now was to determine if the behaviour patterns represented by the bidding histories were entirely random or whether perceptible changes could be identified within these behaviour patterns. This was an effort to consolidate the findings of section 5.2 and to examine the data for evidence of the observations made by Mercer and Russell[21] that the prices offered by contractors changed with time relative to each other.

The method of analysis adopted was a preliminary manual calculation which tested for random or non-random behaviour in the bids submitted by each contractor. Random behaviour would tend to have the same proportion of high or low bids. Also the bidding pattern was tested to determine whether there were 'runs', i.e. groups of bids of the same type, for example low bids or high bids, occurring together. When understood these tests were included in a computer program (see Appendix V) which was then used to test all contractors.

5.3.1 Preliminary analysis

The preliminary analysis undertaken was to determine if these contractors bids appear as a random or non-random sequence of numbers, that equal proportions of high or low bids or disproportionate numbers of either high or low bids. If the sequence is random then no account needs to be taken of time when considering a contractor's performance and data that are several years old may be as valid as new data. If the sequence is non-random then the patterns of behaviour must be identified.

The preliminary investigation was to;

(i) select only a few contractors bidding histories for investigation;

(ii) classify the contractor's bid as being H-high, L-low or O-neutral according to the position of the bid relative to other bids. For example if a contractor was 1 or 2 out of 5 bids he would be classified as low. If he was 4 or 5 he would be classified as high and 3 would be neutral;

(iii) test these sequences of H's, L's and O's for randomness on the assumption that a random sequence would produce as many H's as L's. The test used was the binomial test and is described in appendix J and by Conover[40];

(iv) test these sequences for 'runs'. A run is a sequence of adjacent bids having the same classification (i.e. H or L). The test used was the Wald-Wolfowitz runs test and is described in appendix K and by Conover.[40]

Examples of the calculations for these preliminary tests are given in appendix L. A summary of the results of these preliminary tests is given in tables 5.6 and 5.7 for buildings and roads contractors respectively. The observation made was that some contractors had random behaviour patterns and some had not. Only two of the contractors tested displayed a disproportionate number of runs. There seemed to emerge at least three types of behaviour patterns, for example

Contractor 301 displayed a non-random pattern of behaviour and had a high number of 'Low' bids.

Contractor 306 displayed a random pattern of behaviour.

Contractor 309 displayed a non-random pattern of behaviour and had a large number of 'High' bids.

The runs test did not identify a non-random set of runs for Contractor 309 but visual inspection of appendix L shows three distinct phases, viz.

(i) the first 12 bids are predominantly low

(ii) the next 29 bids are random

and (iii) the remaining bids are predominantly high.

This is taken as an indication that contractors do alter their bidding behaviour with time. This point is further examined in section 5.4.

TABLE 5.6 Summary of preliminary tests for Randomness for Building Contractors

Contractor	Randomness test	Runs test
122	N.R.	R
133	R	N.R
103	R	R
142	N.R.	R
115	N.R.	N.R.
131	R	R
159	N.R.	R
160	R	R
149	R	R

N.R. = Not Random

R = Random

TABLE 5.7 Summary of preliminary tests for Randomness and Runs for Roads Contractors.

Contractor	Randomness test	Runs test
301	N.R.	R
306	R	R
311	R	R
314	R	R
324	N.R.	R
344	R	R
432	R	R
309	N.R.	R
318	N.R.	R
383	R	R
390	N.R.	R

N.R. = Not Random

R = Random

5.3.2 Extended Analysis

The binomial test for randomness and the Wald-Wolfowitz test for runs were incorporated into a computer program. The computerised binomial test for randomness was the same as described in appendix J, except that the bids were classified either as above or below the mean. The test for randomness was conducted for all contractors who submitted bids for 20 or more contracts. The computerised Wald-Wolfowitz test for runs was as described in appendix K except that the bids were classified as being above or below the mean. The test for runs was conducted for all contractors who submitted bids for 20 or more contracts.

The binomial and Wald-Wolfowitz tests were repeated on what was called the transformed position of the bids as displayed in figure 5.1. The transformed position was calculated as

$$2P - n - 1$$

where P is the position of the bid in the ascending numerical order of bids for a contract, i.e. 1 for lowest, 2 for second lowest, etc. and n is the number of bidders for that contract. Thus low bids have a negative transformed position, high bids a positive transformed position and middle bids have 0. The use of the transformed position removed any theoretical objections that surrounded the use of the mean bid. Thus good correlation between the results obtained from using the transformed position and from using mean bid would help confirm or refute the usefulness of the mean bid as a relative measure of a contractor's bid.

The results of these tests are summarised in columns 5 to 8 of tables 5.8 and 5.9 for buildings and roads contracts respectively. The explanations of the entries are:

Tables 5.8 and 5.9 Summary of Bid Frequency, Mean Bid Success Ratio, Binomial test results and Runs test results for the major contractors for buildings and roads contracts

N.B. Frequencies : The No. of bids submitted by that contractor

Mean Bid : The Mean of the contractors standardised bid

Success Ratio: (No. of bids won/No. submitted as a %)

Binomial test based on either the standardised bid or the transformed position

Low : a disproportionate number of low bids

High : " " " high "

R : Random

Runs test based on either standardised bids or the transformed position

R : random, i.e. no runs

Blank : insufficient data for computerised version of test

Trend : too few runs in evidence

Variable : too many runs in evidence.

It should be noted that 1) there is a strong negative correlation between mean bid and success ratio and 2) the binomial test correlates well with hit rate.

The slight differences between tables 5.6 and 5.8 and between tables 5.7 and 5.9 is due entirely to the different method of classifying the bids before analysis.

TABLE 5.8 Building Contractors - Summary of tests for Randomness and Runs

Company Number	Frequency	Average Mean Standardised Bids	Success Ratio (%)	Binomial Test		Runs Test	
				Std.Bid	Trans.Pos.	Std.Bid	Trans.Pos
115	45	0.95403	44.44	Low	Low	R	R
106	30	0.97184	6.67	Low	Low		
113	32	0.97802	25.00	Low	R		
131	46	0.98325	21.74	R	Low	R	R
103	63	0.98477	20.64	R	R	R	R
125	21	0.99091	23.81	R	R		
136	27	0.99104	14.82	R	Low		
153	22	0.99132	22.73	R	R		
142	66	0.99245	13.64	R	Low	R	R
133	65	0.99708	16.92	R	R	R	R
149	39	0.99796	17.95	R	R		R
111	27	0.99809	11.11	R	R		
100	36	0.99861	16.67	R	R		R
160	41	1.00143	24.39	R	Low	R	R
140	25	1.00475	20.00	R	R		
102	21	1.00575	4.76	R	R		
101	23	1.00612	8.70	R	R		
122	78	1.00840	5.13	R	High	R	R
151	26	1.01100	7.69	R	R		
128	22	1.01844	4.55	R	R		
159	43	1.03107	4.65	High	High	R	R
157	29	1.03345	6.90	High	High		
135	33	1.03724	0.00	High	High		
138	21	1.05075	9.52	High	High		

TABLE 5.9 Roads Contractors- Summary of Tests for Randomness and Runs

Company Number	Frequency	Average Mean Standardised Bids	Success Ratio (%)	Binomial Test		Runs Test	
				Std.Bid	Trans.Pos.	Std.Bid	Trans.Pos
335	24	0.9646	29.17	Low	Low		
355	26	0.9662	42.31	Low	Low		
337	29	0.9687	24.14	Low	Low		
313	33	0.9694	30.30	Low	Low		
301	96	0.9725	21.88	Low	Low	R	R
390	48	0.9760	41.67	Low	Low	Trend	R
118	65	0.9786	23.08	Low	Low	R	R
315	28	0.9835	17.86	Low	Low		
382	31	0.9868	16.13	Low	Low		
370	46	0.9908	13.04	R	R	R	R
311	62	0.9922	25.81	R	R	R	R
344	68	0.9941	16.18	R	R	R	R
303	41	0.9948	24.39	R	R	R	TREND
312	47	0.9961	21.28	R	R	R	R
391	29	0.9962	0.00	R	R		
345	46	0.9968	23.91	R	R	R	R
306	58	0.9975	20.69	R	R	R	R
402	33	0.9984	18.18	R	R		
348	40	0.9991	17.50	R	R	R	TREND
171	95	1.0003	12.63	R	R	R	R
383	50	1.0016	14.00	R	R	R	R
432	62	1.0017	12.90	R	R	R	R
168	26	1.0046	19.23	R	R		
300	25	1.0073	24.00	R	R		
309	75	1.0074	10.67	R	R	R	R
314	86	1.0097	12.79	R	R	R	R
318	58	1.0145	17.24	R	R	R	R
343	27	1.0200	14.82	R	R		
326	35	1.0335	8.57	High	High		
324	53	1.0369	9.43	R	R	TREND	
327	23	1.0430	8.70	High	High		

CONCLUSIONS

The conclusions drawn from these results are that the 'average mean standardised bid' negatively correlates with the success ratio, Spearman's rho -0.71. The randomness test based either on the standardised bid (i.e. compared to mean) or on transformed position also correlates well with success rate and average mean standardised bids. That is the non-random and 'low' contractors have a high success rate, the non-random and 'high' contractors have a low success rate. This further reinforces the conclusions from section 5.2 and adds weight to the interpretation that can be placed on average mean standardised bids.

The runs tests are inconclusive but visual inspection shows that there are periods when contractors are predominantly 'low' or 'high'. Therefore it was considered that the sensitivity of the test used was suspect. This led to the investigation described in section 5.4.

5.4 TESTING FOR MOVEMENT IN THE RELATIVE BID PRICES OF INDIVIDUAL CONTRACTORS

As previously noted Mercer and Russell[21] made the observation that the relative prices (bids) offered by contractors changed with time. The analyses described in sections 5.1, 5.2 and 5.3 confirm that overall differences exist between contractors. The runs test performed in section 5.4 was not sensitive enough to identify relative price shifts. Visual inspection of the bidding history graphs of which figure 5.1 is an example indicated that these price shifts did exist and that there were periods when the same contractor was a low bidder and periods when he was a high bidder. Therefore a method of identifying these price shifts was required. As already indicated the tests used were:

iv) time series analysis;

v) auto correlation coefficient;

and vi) graphs of (bid-mean bid)/mean bid.

iv) Time series analysis

The time series analysis was based on I.C.L's standard Box-Jenkins routine F4SBJF as described in I.C.L. Statistical Procedures 1900 Series.[41] Time series was attempted for both buildings and roads contractors using as the time dependent variable either the standardised bid (bid/mean bid) or the 'deficit' that is the percentage difference between the contractor's bid and the winning bid or between the contractor's bid and the second lowest, when that contractor's bid was the winning bid.

Table 5.10 presents a typical example of the output. Interpreting this output it is seen that the estimate of standardised is no more accurate than a sample taken from the distributions defined by the analyses reported in section 4.0

For contractor 122, the estimated model is

$$z_{t+1} - .87\, z_t - .13\, z_{t-1} = r_t$$

(where $\bar{z}_t$ is the mean standardised bid and r_t is the residual at the t^{th} time) giving an estimate for time $t_o + 1$,

$$\bar{z}_{t_o+1} = .87\ \bar{z}_{t_o} + .13\ \bar{z}_{t_o-1}.$$

For the last known contract on 9/5/73 this gives an estimate for the next as 1.036 with a confidence interval of 1.036 ± .112 , 0.112 being the 95% limit that is scaledup from the 0.0663 given in table 5.10, based on two standard deviations, which is nearly as wide as 1.00 ± 2 x (.06) from table 4.1 using the model distribution described in section 4.0. Thus there is very little improvement in using this method over the universal model distribution for predicting bids. Similar comments hold for contractor 301.

The method of analysis used here assumes that bids occur at equally spaced times. This assumption is obviously violated for these data, but whether a more sophisticated model would lead to more promising results is questionable.

v) Auto correlation Coefficients

Auto correlation coefficients between the standardised bids and also between the 'deficit' (difference between contractors bid and winning bid, or second lowest bid). The auto-correlation coefficient calculated was

$$r_k = \frac{\sum_{i=1}^{k} (x_{(i+k)} - \bar{x})\ (x - \bar{x})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

where n is the total number of bids submitted by the contractor date ordered $i = 1, n$ thus

x_i is the i^{th} standardised bid or the i^{th} deficit.

$x_{(i+k)}$ is the $(i+k)^{th}$ bid

k was varied from 1 to 10.

$\bar{x}$ was the contractors average standardised bid when calculating autocorrelation coefficients or standardised bids or the average 'deficit' when calculating auto-correlation coefficients for 'deficits'.

Described in Kendall and Stuart[42] this calculation should show whether there is any correlation between the $x_{(i+k)}$th standardised bid or deficit and the x_ith, x_{1+i}, x_{i+2}, x_{i+3} ....x_{i+9} th standardised bid or deficit.

To judge whether the autocorrelation coefficients are significant the standard error is calculated as $\frac{1}{\sqrt{n}}$ and the autocorrelation coefficient is taken as significant if its absolute value is greater than $2 \times \frac{1}{\sqrt{n}}$. Table 5.11 gives typical examples of the autocorrelation coefficient for standardised bids and the observation made was that the coefficients were not significant. The values of s, where $s = \sum_{k=1}^{10} r_k^2$ and n.s were calculated for use with statistical tables for testing significance. As the values of the autocorrelation coefficients were so small these values were not used.

Therefore autocorrelation coefficients cannot be used to predict future standardised bids. The same conclusion was made for 'deficit'. The reason for using 'deficit' was that this value was not dependent on the mean as a standardisor.

TABLE 5.10 Sample Output from Time Series Analysis

Building Contractor	122
Roads Contractor	301

CONTRACTOR NO. 122

NO. OF BIDS FOUND FOR THIS CONTRACTOR = 78

05/05/75 21/41/56 ICL 1900 BOX-JENKINS FORECASTING

ESTIMATED PARAMETERS :-

AUTOREGRESSIVE UNIT PARAMETERS -0.12558

75.0% PROBABILITY LIMITS FOR FORECASTS

LEAD TIME	LIMIT
1	0.0663
2	0.0881
3	0.1061
4	0.1214
5	0.1349
6	0.1472
7	0.1586
8	0.1692
9	0.1792
10	0.1886
11	0.1976
12	0.2062
13	0.2145
14	0.2224
15	0.2301
16	0.2375
17	0.2447
18	0.2517
19	0.2585
20	0.2652
21	0.2716
22	0.2780
23	0.2841
24	0.2902

Contd/....

CHI-SQUARE DIAGNOSTIC CHECK

AUTOCORRELATIONS OF THE RESIDUALS

LAGS 1- 10	-0.1101	-0.0988	0.0808	-0.1275	0.0302	0.0405	-0.0223	0.0663	-0.0845	0.0458
LAGS 11- 20	0.0029	0.0033	-0.0072	-0.0376	0.0554	-0.0121	0.0172	0.0453	-0.0884	0.0255

CHI-SQUARE VALUE = 5.9957 WITH 19 DEGREES OF FREEDOM

PROBABILITY OF GREATER CHI-SQUARE VALUE = 99.777 PER CENT

Contd/....

05/05/75 21/41/59 ICL 1900 BOX-JENKINS FORECASTING

PERIODOGRAM DIAGNOSTIC CHECK

FREQUENCY		NORMALIZED INTEGRATED PERIODOGRAM		
NO.	VALUE	LOWER BOUND	VALUE	UPPER BOUND
1	0.0128	-0.1729	0.0184	0.2242
2	0.0256	-0.1473	0.0354	0.2498
3	0.0385	-0.1216	0.0552	0.2755
4	0.0513	-0.0960	0.0681	0.3011
5	0.0641	-0.0703	0.0903	0.3267
6	0.0769	-0.0447	0.1103	0.3524
7	0.0897	-0.0191	0.1251	0.3780
8	0.1026	0.0066	0.1465	0.4037
9	0.1154	0.0322	0.1714	0.4293
10	0.1282	0.0579	0.1960	0.4549
11	0.1410	0.0835	0.2200	0.4806
12	0.1538	0.1092	0.2284	0.5062
13	0.1667	0.1348	0.2753	0.5319
14	0.1795	0.1604	0.3213	0.5575
15	0.1923	0.1861	0.3342	0.5832
16	0.2051	0.2117	0.3634	0.6088
17	0.2179	0.2374	0.3831	0.6344
18	0.2308	0.2630	0.3978	0.6601
19	0.2436	0.2886	0.4199	0.6857
20	0.2564	0.3143	0.4366	0.7114
21	0.2692	0.3399	0.4787	0.7370
22	0.2821	0.3656	0.4798	0.7626
23	0.2949	0.3912	0.5247	0.7883
24	0.3077	0.4168	0.5446	0.8139
25	0.3205	0.4425	0.5935	0.8396
26	0.3333	0.4681	0.6175	0.8652
27	0.3462	0.4938	0.6933	0.8908
28	0.3590	0.5194	0.7603	0.9165
29	0.3718	0.5451	0.7662	0.9421
30	0.3846	0.5707	0.8075	0.9678
31	0.3974	0.5963	0.8690	0.9934
32	0.4103	0.6220	0.8790	1.0191
33	0.4231	0.6476	0.9137	1.0447
34	0.4359	0.6733	0.9203	1.0703
35	0.4487	0.6989	0.9322	1.0960
36	0.4615	0.7245	0.9490	1.1216
37	0.4744	0.7502	0.9690	1.1473
38	0.4872	0.7758	0.9775	1.1729
39	0.5000	0.8015	0.9969	1.1985

NO. WITHIN BOUNDARIES = 39 OR 100.000 PER CENT

NO. OUTSIDE BOUNDARIES = 0 OR 0.000 PER CENT

Contd/....

IUNTDIF = 1

IPERDIF = 0

LEAD TIME 1, FORECAST 1.036249

LEAD TIME 2, FORECAST 1.036832

LEAD TIME 3, FORECAST 1.036841

LEAD TIME 4, FORECAST 0.000000

LEAD TIME 5, FORECAST 0.000000

REF. NO.	DATE	MEAN BID	BID	RESIDUAL(%)
3.	7.- 1.-70.	38529336.	1.067758	88.8429
5.	16.- 1.-70.	23189841.	1.034936	0.0000
11.	15.- 2.-70.	29281949.	0.940955	-9.8103
12.	24.- 2.-70.	9782047.	0.991408	3.8651
14.	4.- 3.-70.	29219984.	0.930185	-5.4867
19.	26.- 3.-70.	42323504.	0.941557	0.3683
20.	25.- 3.-70.	17704570.	0.971501	5.1371
21.	25.- 3.-70.	16716907.	0.963097	-0.4643
24.	13.- 4.-70.	8827652.	0.967698	0.3546
35.	10.- 6.-70.	30873039.	0.966215	-0.0905
42.	17.- 7.-70.	16164833.	0.977430	1.1029
46.	18.- 8.-70.	118719591.	0.996411	2.0389
48.	25.- 8.-70.	8826140.	1.021879	2.7852
53.	22.- 9.-70.	68119308.	0.985406	-3.3274
54.	28.- 9.-70.	26851769.	0.952592	-3.7395
55.	1.-10.-70.	54597000.	1.016539	5.9827
56.	9.-10.-70.	24971309.	1.009158	0.0650
57.	15.-10.-70.	32478758.	1.040680	3.0595
60.	23.-10.-70.	82985450.	1.050787	1.4065
61.	27.-10.-70.	43204873.	1.006831	-4.2687
66.	13.-11.-70.	14163959.	1.023725	1.1374
75.	7.-12.-70.	15209939.	0.940175	-8.1429
76.	10.-12.-70.	27836800.	1.000366	4.9699
80.	18.- 1.-71.	50498970.	1.083190	9.0383
89.	24.- 2.-71.	10139261.	1.026683	-4.6106
92.	26.- 2.-71.	21145579.	0.981594	-5.2186
93.	5.- 3.-71.	14409254.	1.027118	3.9861
95.	15.- 3.-71.	66688148.	0.854725	-16.6676
97.	17.- 3.-71.	7775907.	1.054539	17.8165
101.	23.- 3.-71.	43204873.	1.006831	-2.2615
105.	1.- 4.-71.	16525920.	1.011078	-0.1744
108.	9.- 4.-71.	16730584.	1.131157	12.0612
109.	13.- 4.-71.	43284564.	1.031315	-6.4763
110.	22.- 4.-71.	54605368.	1.017299	-2.6554
111.	30.- 4.-71.	39436526.	1.063481	4.4422
114.	17.- 5.-71.	25259117.	0.999276	-5.8406
122.	24.- 6.-71.	18823135.	1.060928	5.3590
125.	30.- 6.-71.	40623755.	1.017875	-3.5311
133.	26.- 8.-71.	25865641.	1.094116	7.0834
142.	9.- 9.-71.	19151651.	0.983032	-10.0709
143.	13.- 9.-71.	129596976.	1.018542	2.0861
147.	14.-10.-71.	13173225.	1.062762	4.8579
150.	8.-11.-71.	9683769.	0.970180	-8.7028
152.	25.-11.-71.	11259102.	0.970770	-1.1057
153.	26.-11.-71.	62602792.	1.050432	7.0736
158.	1.-12.-71.	16211420.	1.057896	1.7468
164.	10.- 1.-72.	5616547.	1.020200	-3.6759
165.	11.- 1.-72.	47675025.	0.919979	-10.4955
173.	17.- 2.-72.	18641539.	1.018156	8.5592
174.	17.- 2.-72.	22688389.	1.012853	0.7026
176.	29.- 2.-72.	6505226.	0.957423	-5.6095
178.	6.- 3.-72.	73730105.	1.043536	7.9151
183.	23.- 3.-72.	6279016.	1.034238	0.1517
187.	10.- 4.-72.	16754090.	1.045715	1.0309
188.	20.- 4.-72.	7263833.	1.073813	2.9540
189.	12.- 4.-72.	11821080.	1.077736	0.7451
190.	20.- 4.-72.	24354772.	1.021566	-5.5677
200.	6.- 9.-72.	13790393.	0.973359	-5.5261
211.	21.- 9.-72.	18240833.	0.975833	-0.3580
216.	18.-10.-72.	6044434.	1.038463	6.2941
218.	19.-10.-72.	28911061.	0.982876	-4.7722
219.	25.-10.-72.	39782414.	1.071881	8.2023
227.	29.-11.-72.	10307675.	1.023509	-3.7194
230.	11.-12.-72.	40177775.	0.998473	-3.1111
231.	8.- 3.-72.	24190333.	0.999573	-0.2045
232.	22.-12.-72.	19980693.	0.957549	-4.1885
237.	28.-12.-72.	20783162.	1.005622	4.2795
238.	28.-12.-72.	129251401.	1.038171	3.8586
239.	29.-12.-72.	18597540.	0.968795	-6.7288
241.	25.- 1.-73.	85825262.	1.041651	6.5893
242.	8.- 1.-73.	12926428.	0.964536	-6.7715
243.	8.- 2.-73.	39955982.	0.943688	-3.0552
245.	22.- 2.-73.	10339895.	1.007370	6.1063
246.	2.- 3.-73.	23462669.	1.021964	2.2591
248.	3.- 3.-73.	33898875.	0.972599	-4.7532
250.	5.- 4.-73.	13754960.	1.032355	5.3557
252.	19.- 4.-73.	25917689.	0.999318	-2.5553
254.	9.- 5.-73.	16081750.	1.041553	3.5087

CONTRACTOR NO. 301
=================

NO. OF BIDS FOUND FOR THIS CONTRACTOR = 96

07/05/75 17/10/21 ICL 1900 BOX-JENKINS FORECASTING

ESTIMATED PARAMETERS :-

AUTOREGRESSIVE UNIT PARAMETERS -0.31660

75.0% PROBABILITY LIMITS FOR FORECASTS

LEAD TIME	LIMIT
1	0.1382
2	0.1673
3	0.1993
4	0.2248
5	0.2482
6	0.2694
7	0.2891
8	0.3076
9	0.3250
10	0.3415
11	0.3573
12	0.3724
13	0.3869
14	0.4008
15	0.4144
16	0.4274
17	0.4401
18	0.4525
19	0.4645
20	0.4762
21	0.4876
22	0.4988
23	0.5097
24	0.5204

Contd/....

07/05/75 17/10/24 ICL 1900 BOX-JENKINS FORECASTING PAGE 2

CHI-SQUARE DIAGNOSTIC CHECK

AUTOCORRELATIONS OF THE RESIDUALS

LAGS 1- 10	-0.1884	-0.1200	-0.0361	-0.0468	-0.2526	0.3190	-0.0407	-0.0150	0.1033	-0.0894
LAGS 11- 20	-0.0200	0.0488	-0.0041	-0.0646	0.0180	-0.0558	0.1328	-0.0217	-0.0180	0.0316

CHI-SQUARE VALUE = 26.1221 WITH 19 DEGREES OF FREEDOM

PROBABILITY OF GREATER CHI-SQUARE VALUE = 12.646 PER CENT

Contd/....

07/05/75 17/10/24 ICL 1900 BOX-JENKINS FORECASTING

PERIODOGRAM DIAGNOSTIC CHECK

FREQUENCY		NORMALIZED INTEGRATED PERIODOGRAM		
NO.	VALUE	LOWER BOUND	VALUE	UPPER BOUND
1	0.0103	-0.1560	0.0027	0.1973
2	0.0206	-0.1354	0.0046	0.2179
3	0.0309	-0.1148	0.0058	0.2385
4	0.0412	-0.0942	0.0079	0.2591
5	0.0515	-0.0736	0.0088	0.2797
6	0.0619	-0.0529	0.0097	0.3004
7	0.0722	-0.0323	0.0142	0.3210
8	0.0825	-0.0117	0.0176	0.3416
9	0.0928	0.0089	0.0208	0.3622
10	0.1031	0.0295	0.0282	0.3828
11	0.1134	0.0502	0.0356	0.4035
12	0.1237	0.0708	0.0567	0.4241
13	0.1340	0.0914	0.1036	0.4447
14	0.1443	0.1120	0.1206	0.4653
15	0.1546	0.1326	0.1365	0.4859
16	0.1649	0.1532	0.1802	0.5065
17	0.1753	0.1739	0.2256	0.5272
18	0.1856	0.1945	0.2461	0.5478
19	0.1959	0.2151	0.2652	0.5684
20	0.2062	0.2357	0.2709	0.5890
21	0.2165	0.2563	0.2917	0.6096
22	0.2268	0.2770	0.2930	0.6303
23	0.2371	0.2976	0.3077	0.6509
24	0.2474	0.3182	0.3404	0.6715
25	0.2577	0.3388	0.3454	0.6921
26	0.2680	0.3594	0.3456	0.7127
27	0.2784	0.3801	0.3532	0.7334
28	0.2887	0.4007	0.3694	0.7540
29	0.2990	0.4213	0.4151	0.7746
30	0.3093	0.4419	0.4525	0.7952
31	0.3196	0.4625	0.4961	0.8158
32	0.3299	0.4831	0.5241	0.8364
33	0.3402	0.5038	0.5750	0.8571
34	0.3505	0.5244	0.6994	0.8777
35	0.3608	0.5450	0.7219	0.8983
36	0.3711	0.5656	0.7260	0.9189
37	0.3814	0.5862	0.7328	0.9395
38	0.3918	0.6069	0.7423	0.9602
39	0.4021	0.6275	0.7447	0.9808
40	0.4124	0.6481	0.7468	1.0014
41	0.4227	0.6687	0.7496	1.0220
42	0.4330	0.6893	0.7598	1.0426
43	0.4433	0.7099	0.7772	1.0632
44	0.4536	0.7306	0.7984	1.0839
45	0.4639	0.7512	0.8556	1.1045
46	0.4742	0.7718	0.8943	1.1251
47	0.4845	0.7924	0.9578	1.1457
48	0.4948	0.8130	0.9897	1.1663

NO. WITHIN BOUNDARIES = 41 OR 85.417 PER CENT

NO. OUTSIDE BOUNDARIES = 7 OR 14.583 PER CENT

Contd/....

IUNTDIF = 1

IPERDIF = 0

LEAD TIME 1, FORECAST 0.851721

LEAD TIME 2, FORECAST 0.815815

LEAD TIME 3, FORECAST 0.814221

LEAD TIME 4, FORECAST 0.000000

LEAD TIME 5, FORECAST 0.000000

REF. NO.	DATE	MEAN BID	BIn	RESIDUAL(%)
19.	30.-11.-67.	10502976.	0.997336	75.9453
27.	15.-12.-67.	15745104.	0.968879	0.0000
35.	21.-12.-67.	12504209.	1.041921	6.4032
37.	21.-12.-67.	14814222.	1.014917	-0.3879
59.	8.- 2.-68.	6669660.	1.004402	-1.9064
85.	14.- 3.-68.	7060401.	0.266436	-74.1295
89.	21.- 3.-68.	7794184.	1.010394	51.0315
113.	16.- 4.-68.	29105864.	0.987160	21.2306
114.	18.- 4.-68.	6287013.	1.022841	2.8325
115.	18.- 4.-68.	2789278.	1.008290	-0.3255
149.	9.- 5.-68.	6381369.	0.920231	-9.2666
152.	0.- 0.- 0.	18578624.	0.796757	-15.1353
172.	0.- 0.- 0.	10860816.	1.035834	19.9984
177.	11.- 6.-68.	19707808.	1.009975	4.9833
181.	13.- 6.-68.	41098356.	0.834688	-18.3474
182.	13.- 6.-68.	3412377.	0.906494	1.6310
188.	0.- 0.- 0.	1782627.	0.949700	6.5940
192.	0.- 0.- 0.	945775.	0.946790	1.0769
199.	27.- 6.-68.	4650978.	0.977429	2.9718
203.	29.- 6.-68.	5054442.	0.988301	2.0573
205.	5.- 7.-68.	4181654.	0.951542	-3.3317
213.	11.- 7.-68.	2619725.	1.039958	7.6778
220.	0.- 0.- 0.	4228699.	0.786459	-22.5506
225.	0.- 0.- 0.	21624907.	0.980351	11.3653
229.	0.- 0.- 0.	21422190.	0.969882	5.0918
234.	22.- 8.-68.	36692757.	0.959590	-1.3607
238.	29.- 8.-68.	8222364.	0.992136	2.9288
250.	0.- 0.- 0.	7898587.	0.988574	0.6742
259.	19.- 9.-68.	2423006.	0.991159	0.1457
278.	0.- 0.- 0.	5713117.	0.988952	-0.1389
286.	22.-10.-68.	11406029.	0.947481	-4.2170
290.	18.- 9.-68.	5754768.	1.024472	6.3861
331.	28.-11.-68.	20513502.	1.135837	13.5741
332.	0.- 0.- 0.	67961233.	0.912382	-18.8197
347.	20.-12.-68.	50160332.	0.955792	-2.7337
353.	23.-12.-68.	17446260.	0.913838	-2.8210
356.	0.- 0.- 0.	17873167.	1.024048	9.6927
379.	0.- 0.- 0.	16599449.	0.963447	-2.5708
423.	13.- 5.-69.	23689701.	0.917234	-6.3329
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
482.	12.- 5.-69.	9552556.	0.921201	-1.0356
492.	29.- 5.-69.	4514564.	1.074344	14.7763
493.	0.- 0.- 0.	1709505.	0.933369	-9.2489
499.	5.- 6.-69.	7193022.	0.961434	-1.6569
505.	12.- 6.-69.	10522148.	0.978888	2.6339
508.	17.- 6.-69.	5052365.	0.985591	1.2229
511.	0.- 0.- 0.	9455225.	0.989327	0.5859
512.	26.- 6.-69.	11467862.	0.998442	1.0298
530.	8.- 7.-69.	9149356.	0.969128	-2.6428
531.	0.- 0.- 0.	9519775.	1.034751	5.6342
533.	10.- 7.-69.	10720185.	1.007501	-0.6474
603.	2.-10.-69.	7782855.	0.964887	-5.1241
604.	2.-10.-69.	32436285.	0.981049	0.2670
608.	0.- 0.- 0.	5160227.	0.965855	-1.0078
609.	13.-10.-69.	35186441.	1.033779	6.3113
610.	13.-10.-69.	24054437.	0.974708	-3.7566
618.	16.-10.-69.	3724256.	0.928217	-6.5193
626.	0.- 0.- 0.	7326062.	0.961854	1.8917
633.	31.-10.-69.	20370298.	0.949225	-0.1979
637.	0.- 0.- 0.	20367643.	0.946599	-0.6624
644.	22.-11.-69.	2007945.	1.044252	9.6821
654.	11.-12.-69.	5923252.	1.019710	0.6376
657.	13.-12.-69.	2773796.	0.982408	-4.5072
662.	0.- 0.- 0.	19239994.	0.988670	-0.5548
665.	0.- 0.- 0.	27785463.	0.984948	-0.1739
666.	22.-12.-69.	44308145.	0.874557	-11.1569
667.	22.-12.-69.	14992631.	0.945665	3.6157
668.	22.-12.-69.	29815934.	0.930710	0.7559
673.	29.-12.-69.	20023951.	1.033240	9.7795
674.	29.-12.-69.	6535354.	0.983151	-1.7628
680.	30.-12.-69.	2224976.	1.011382	1.2373
694.	0.- 0.- 0.	59424333.	0.887683	-11.4760
698.	29.- 1.-70.	19064404.	0.985554	5.8707
721.	5.- 5.-70.	5484463.	0.975560	2.0992
772.	0.- 0.- 0.	34064498.	0.988659	0.9935
778.	0.- 0.- 0.	3071958.	1.000990	1.6479
793.	15.- 2.-70.	7097552.	0.965826	-3.1260
842.	21.- 5.-70.	21629130.	1.037490	6.0531
1000.	18.-11.-70.	49878272.	0.981189	-3.3612
1020.	10.-12.-70.	12563000.	0.844860	-15.4154
1136.	17.- 6.-71.	30064901.	0.888777	0.0755
1147.	27.- 6.-71.	8335397.	0.976403	10.1531
1240.	4.-11.-71.	17867127.	0.917099	-3.0462
1283.	17.- 1.-72.	1169063.	1.071108	13.4418
1318.	0.- 0.- 0.	4289428.	1.038187	1.5555
1448.	18.- 8.-72.	11461453.	0.910574	-13.8036
1456.	23.- 8.-72.	6423927.	1.011064	6.0087
1497.	19.-10.-72.	3923050.	0.994124	1.4876
1520.	23.-11.-72.	34444009.	0.971054	-2.8433
1528.	30.-11.-72.	5973327.	0.983454	0.5096
1529.	30.-11.-72.	13603901.	0.937893	-4.1636
1553.	9.- 1.-73.	3761000.	0.997846	4.5528
1558.	13.- 1.-73.	590184.	1.101013	12.2148
1559.	0.- 0.- 0.	8556744.	1.009613	-5.8737
1611.	5.- 4.-73.	11580762.	0.974331	-6.4219
1625.	4.- 4.-73.	7827157.	0.990402	0.4901
1679.	13.- 4.-73.	18402618.	0.758207	-22.7107

TABLE 5.11 Sample Output from Autocorrelation Analysis

Building Contractors	142, 131, 133, 115, 103 and 159
Roads Contractors	301, 309, 171, 344 314 and 118

CONTRACTOR 142

K	R(K)
1	-0.169526
2	-0.101317
3	0.153788
4	-0.034178
5	-0.043817
6	0.132910
7	-0.084541
8	0.024356
9	-0.110969
10	0.087666

S = 0.11115264
N = 66
S * N = 7.3360744
STD. ERR. = 0.12309149

CONTRACTOR 131

K	R(K)
1	-0.076930
2	0.304716
3	-0.065687
4	0.329874
5	-0.043847
6	0.192326
7	-0.139813
8	0.128734
9	-0.014837
10	0.081615

S = 0.29381469
N = 46
S * N = 13.5154760
STD. ERR. = 0.14744196

CONTRACTOR 133

K	R(K)
1	0.247200
2	0.180923
3	0.093292
4	-0.097896
5	-0.225792
6	-0.256152
7	-0.154102
8	-0.107226
9	-0.010432
10	0.009771

S = 0.26417291
N = 65
S * N = 17.1712394
STD. ERR. = 0.12403473

CONTRACTOR 115

K	R(K)
1	0.186498
2	-0.048780
3	0.075550
4	-0.222376
5	-0.165972
6	-0.158549
7	-0.007127
8	0.058030
9	0.034333
10	0.012440

S = 0.14975618
N = 45
S * N = 6.7390283
STD. ERR. = 0.14907120

CONTRACTOR 103

K	R(K)
1	-0.023127
2	0.033943
3	-0.085657
4	0.034972
5	0.048538
6	-0.134286
7	0.174057
8	-0.264352
9	-0.022845
10	-0.019060

S = 0.13169885
N = 63
S * N = 8.2970275
STD. ERR. = 0.12598816

CONTRACTOR 159

K	R(K)
1	0.203627
2	-0.099515
3	-0.177739
4	0.109163
5	0.252784
6	-0.095081
7	-0.144248
8	-0.105854
9	0.050018
10	0.023521

S = 0.20288328
N = 43
S * N = 8.7239809
STD. ERR. = 0.15249857

CONTRACTOR 301

K	R(K)
1	-0.003909
2	-0.095332
3	-0.015312
4	-0.096227
5	0.011767
6	0.018624
7	-0.118734
8	0.076968
9	0.073972
10	-0.245776

S = 0.10498255
N = 96
S * N = 10.0783248
STD. ERR. = 0.10206207

CONTRACTOR 171

K	R(K)
1	-0.013253
2	0.036028
3	0.190955
4	0.065815
5	0.181236
6	0.052461
7	-0.010357
8	-0.134746
9	-0.031277
10	-0.082477

S = 0.10391736
N = 95
S * N = 9.8716720
STD. ERR. = 0.10259784

CONTRACTOR 316

K	R(K)
1	-0.006924
2	-0.117670
3	0.159804
4	-0.181112
5	0.022979
6	0.067689
7	-0.291394
8	0.182096
9	0.058115
10	-0.177438

S = 0.22884335
N = 86
S * N = 19.6805278
STD. ERR. = 0.10783277

CONTRACTOR 309

K	R(K)
1	0.201374
2	0.301364
3	0.202795
4	0.116241
5	0.096072
6	0.190858
7	0.131673
8	0.122337
9	0.146412
10	0.231345

S = 0.33892670
N = 75
S * N = 25.4195029
STD. ERR. = 0.11547005

CONTRACTOR 344

K	R(K)
1	-0.027976
2	-0.234950
3	0.014736
4	-0.077342
5	0.046981
6	0.056919
7	0.037875
8	-0.043865
9	-0.025394
10	0.027067

S = 0.07161910
N = 68
S * N = 4.8700987
STD. ERR. = 0.12126781

CONTRACTOR 118

K	R(K)
1	-0.061132
2	0.023137
3	-0.122093
4	-0.070257
5	0.024718
6	0.015163
7	0.105789
8	-0.076447
9	-0.147488
10	0.106276

S = 0.07503880
N = 65
S * N = 4.8775220
STD. ERR. = 0.12403473

vi) Graphs of $\sum$(Bid-Mean Bid)/(Mean Bid)

Notwithstanding the results of investigations iv) and v) of this section the view that there were behaviour patterns within the contractor's bidding histories that could be seen by inspection should be identifiable in a more positive way. To achieve this a computer program (see appendix V) was produced which displayed the individual contractor's bidding behaviour in a different form. This form was

$$\sum \text{(Bid - Mean Bid)/Mean Bid}$$

or $$\sum_{i=1}^{n} (x_i - 1.0)$$

where x_i is the ith mean standardised bid submitted by the contractor and n is the total number of bids, the contractors bids being in date order. The value of $\sum_{i=1}^{n} (x_i - 1.0)$ was given the name CUSUM value

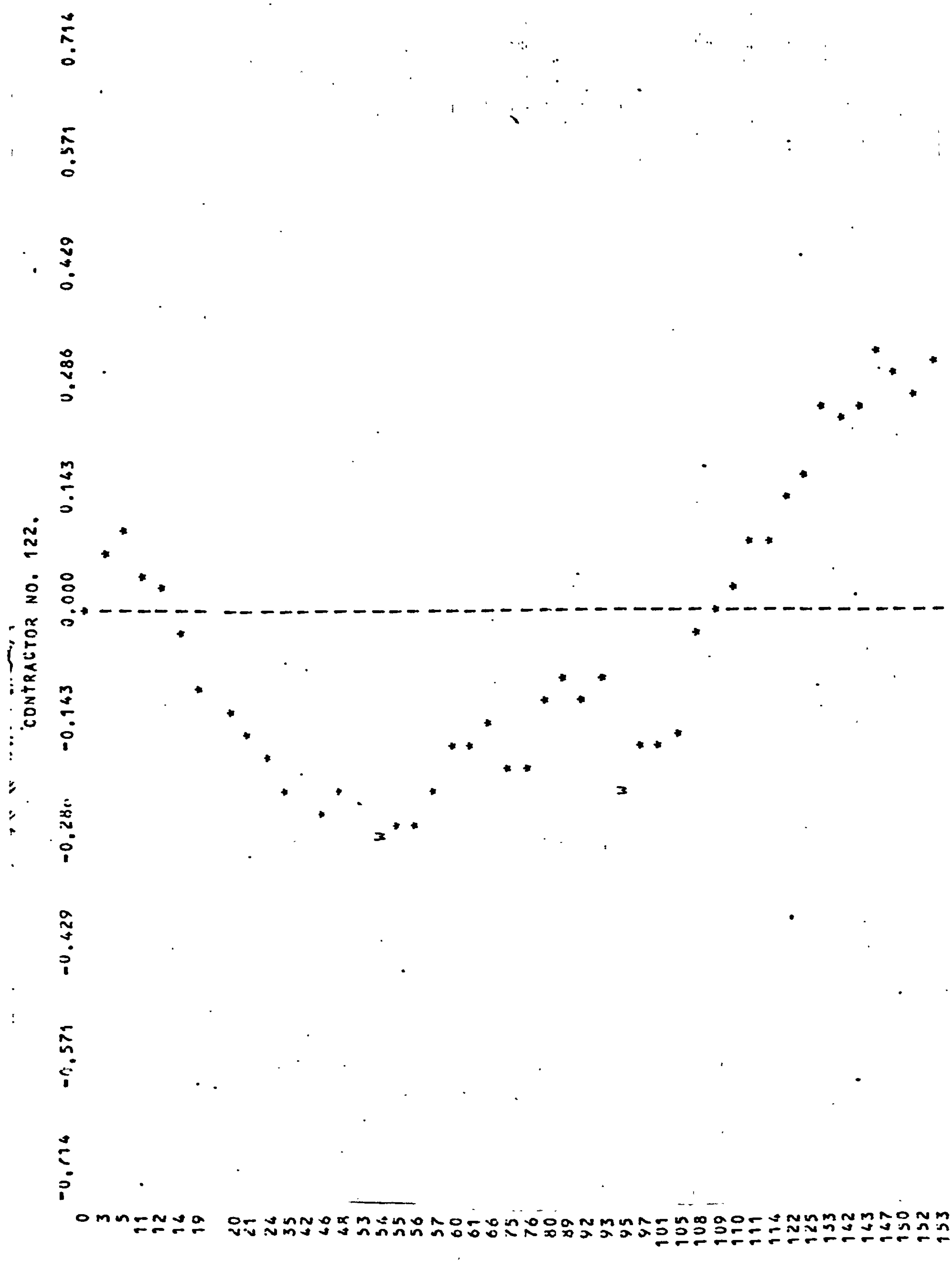
and calculated for each value of n for each contractor in turn. If a contractor bids below the mean bid then $(x_i - 1.0)$ will be negative. Thus if the contractor consistently bids below the mean the CUSUM value will drift away from the zero line in a negative direction. Conversely if a contractor bids above the mean then $(x_i - 1.0)$ will be positive. Thus if a contractor starts to bid above the mean after a number of bids below the mean the CUSUM value will reverse direction and drift in a positive direction. Appendix M illustrates how the CUSUM values were calculated. Figures 5.4 and 5.3 give examples of CUSUM plots for 6 sample contractors.

Visual inspection of these CUSUM graphs shows that in general a winning bid comes after a negative drift in the graph and a contractor who appears less anxious to win in that he is recording no wins has a positive drift in his graph. Thus, visually, these graphs present the previous observations in a more explicit way. Table 5.12 gives the percentage number times a winning bid was preceded at least a given number of decrements in the CUSUM value. A decrement in the CUSUM value is a falling step in the graph between successive bids.

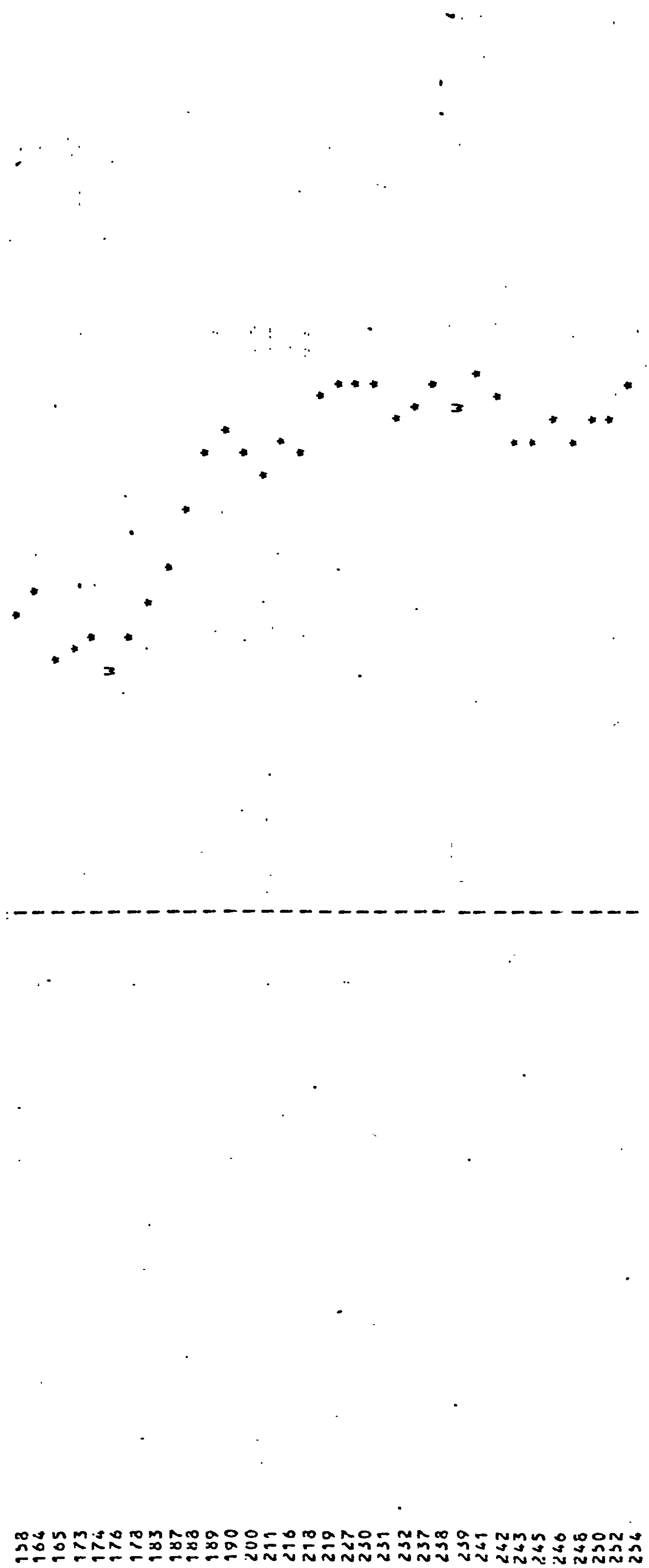
FIGURE 5.4 Sample of CUSUM plots for Building Contractors

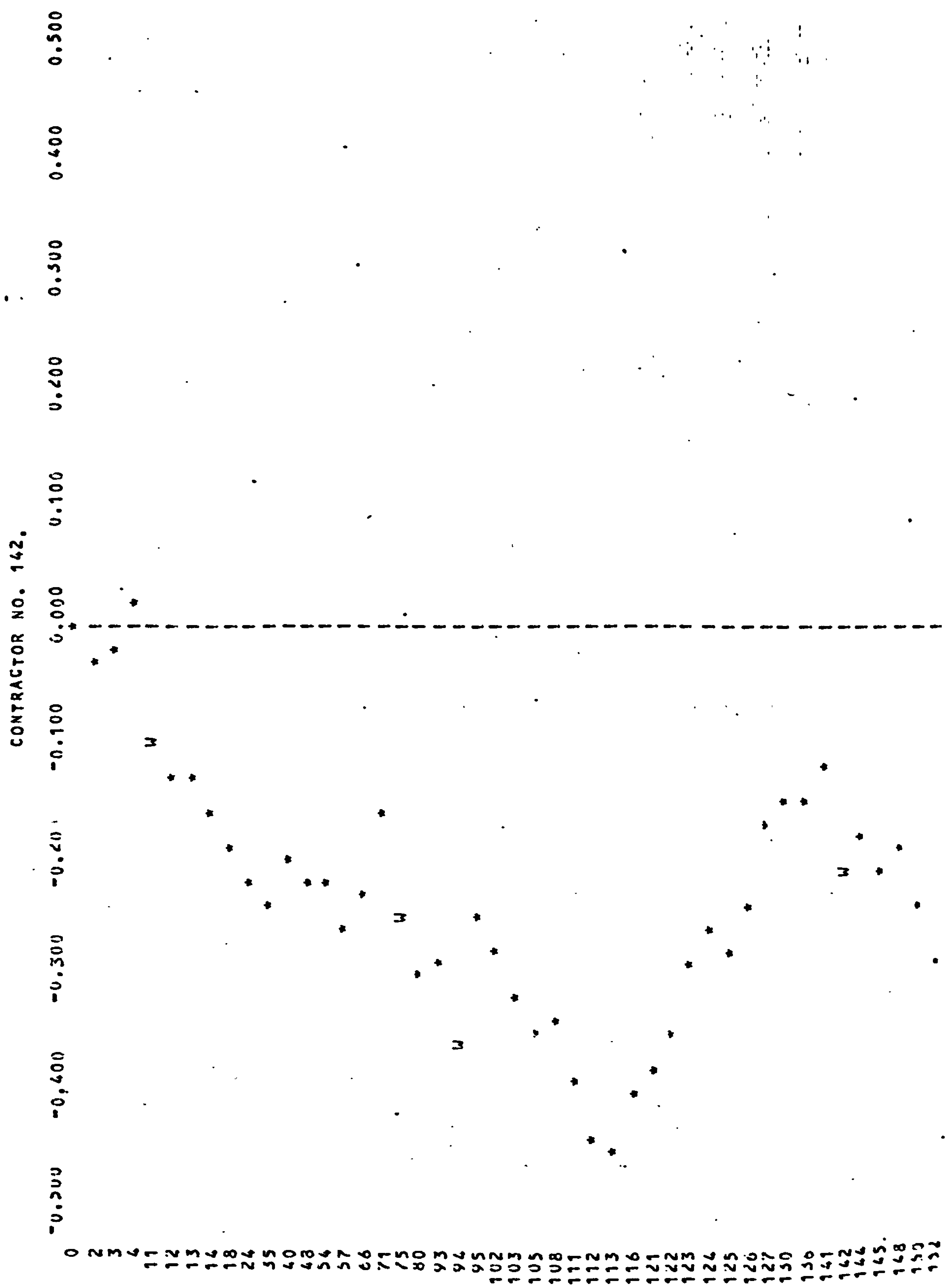
N.B. The Scale across the page is the CUSUM value
the scale down the page is the contract
reference numbers in date order

Building Contractors 122, 142, 133.

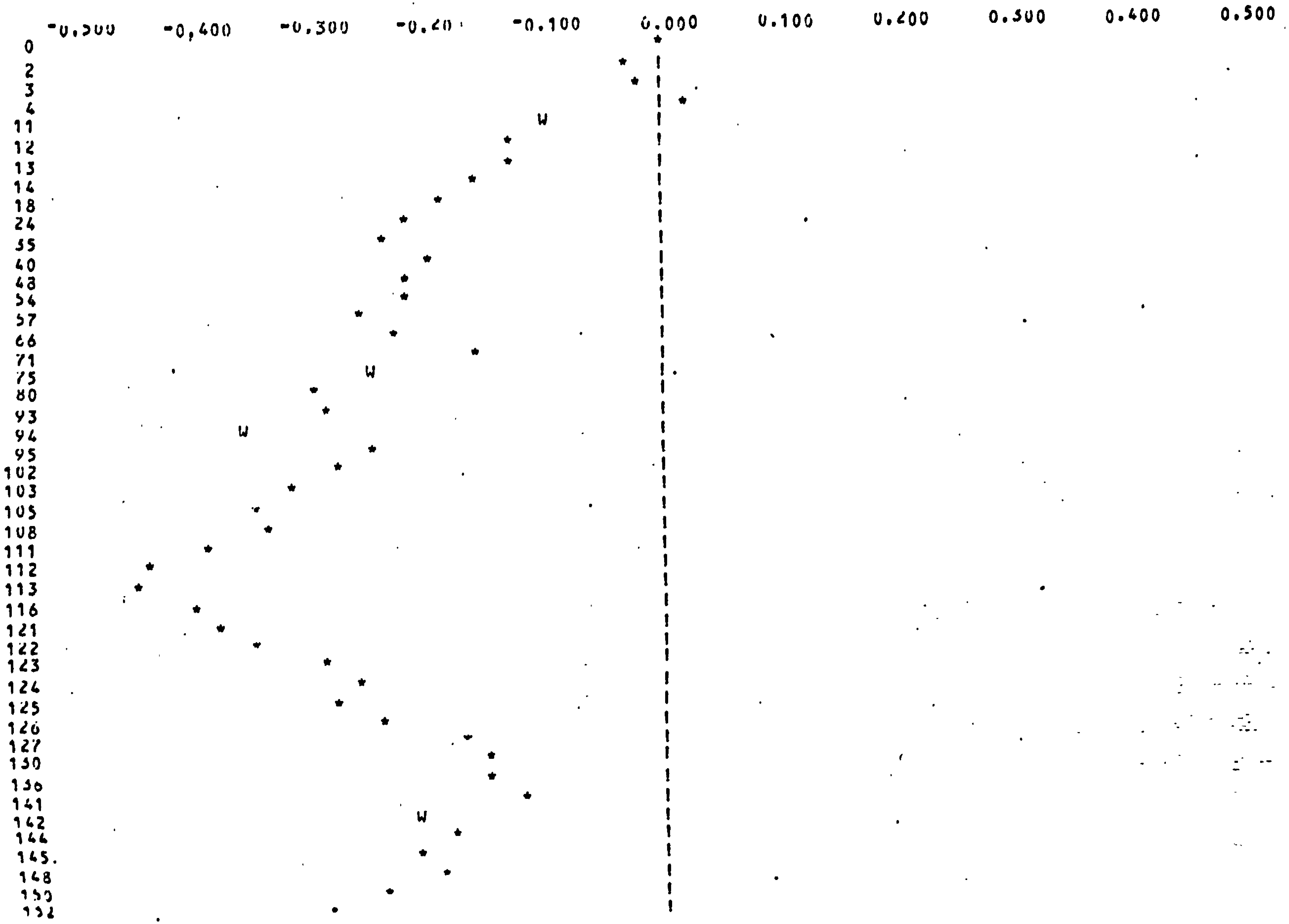

CONTRACTOR NO. 122.
-0.714
-0.571
-0.429
-0.286
-0.143
0.000
0.143
0.286
0.429
0.571
0.714
0 3 5 11 12 14 19 20 21 24 35 42 46 48 53 54 55 56 57 60 61 66 75 76 80 89 92 93 95 97 101 105 108 109 110 111 114 122 125 133 142 143 147 150 152 153

Contd/...

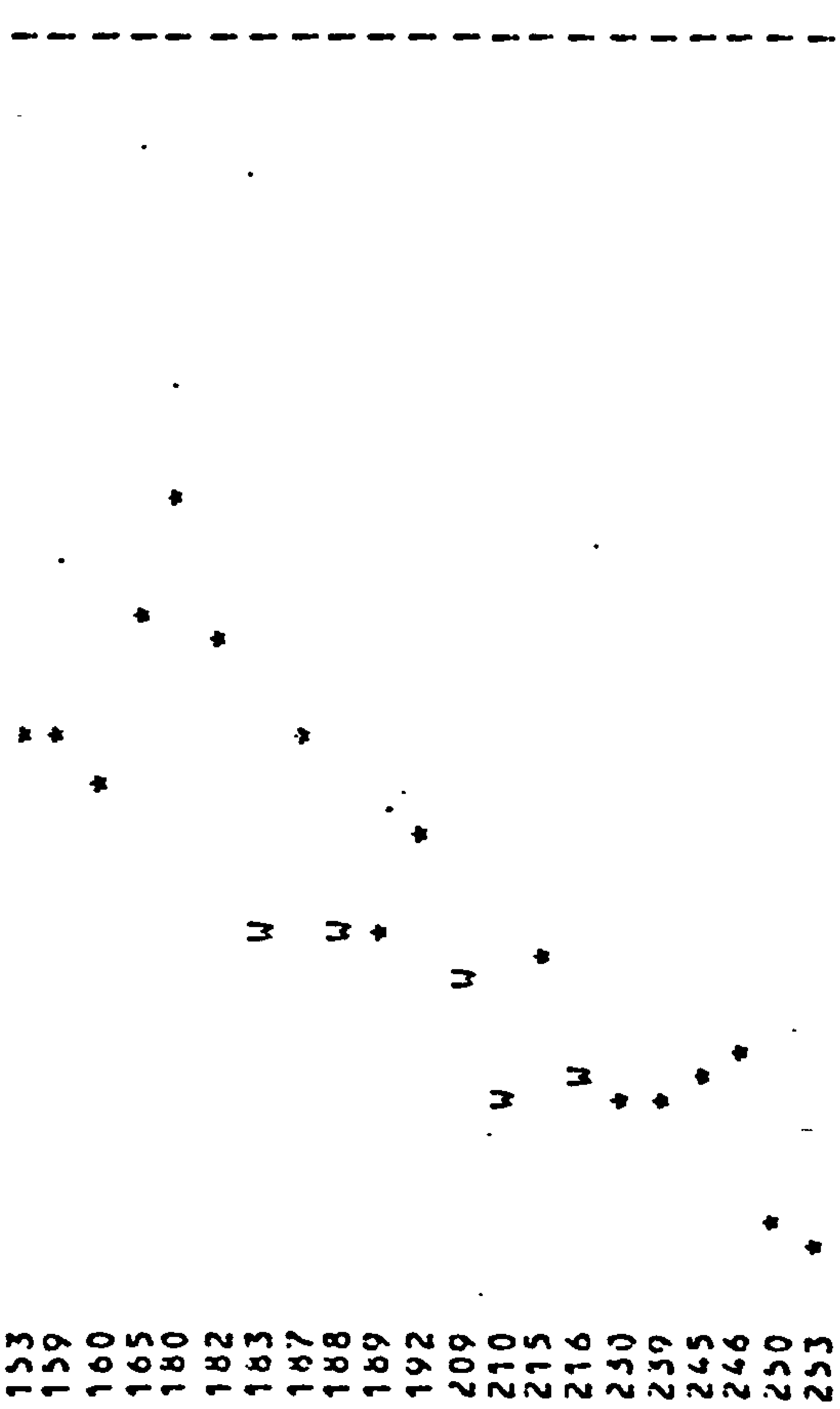

158 164 165 173 174 176 178 183 187 188 189 190 200 211 216 218 219 227 230 231 232 237 238 239 241 242 243 245 246 248 250 252 254


CONTRACTOR NO. 142.
-0.500 -0.400 -0.300 -0.200 -0.100 0.000 0.100 0.200 0.300 0.400 0.500
0 2 3 4 11 12 13 14 18 24 35 40 48 54 57 66 71 75 80 93 94 95 102 103 105 108 111 112 113 116 121 122 123 124 125 126 127 130 136 141 142 144 145 148 150 152

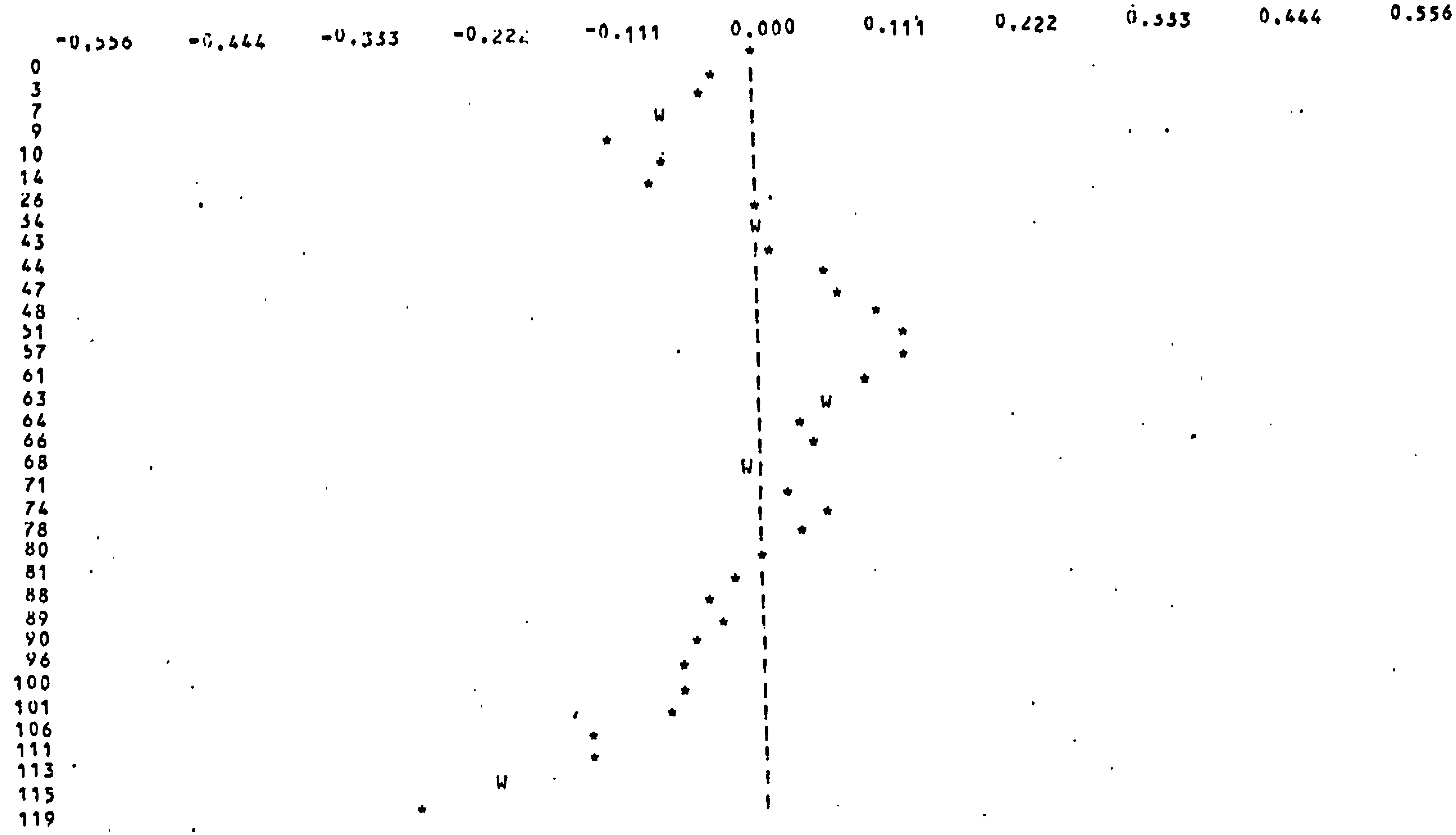
CONTRACTOR NO. 142.



Contd/....


153 159 160 165 180 182 183 187 188 189 192 209 210 215 216 230 239 245 246 250 253

CONTRACTOR NO. 133.



Contd/...

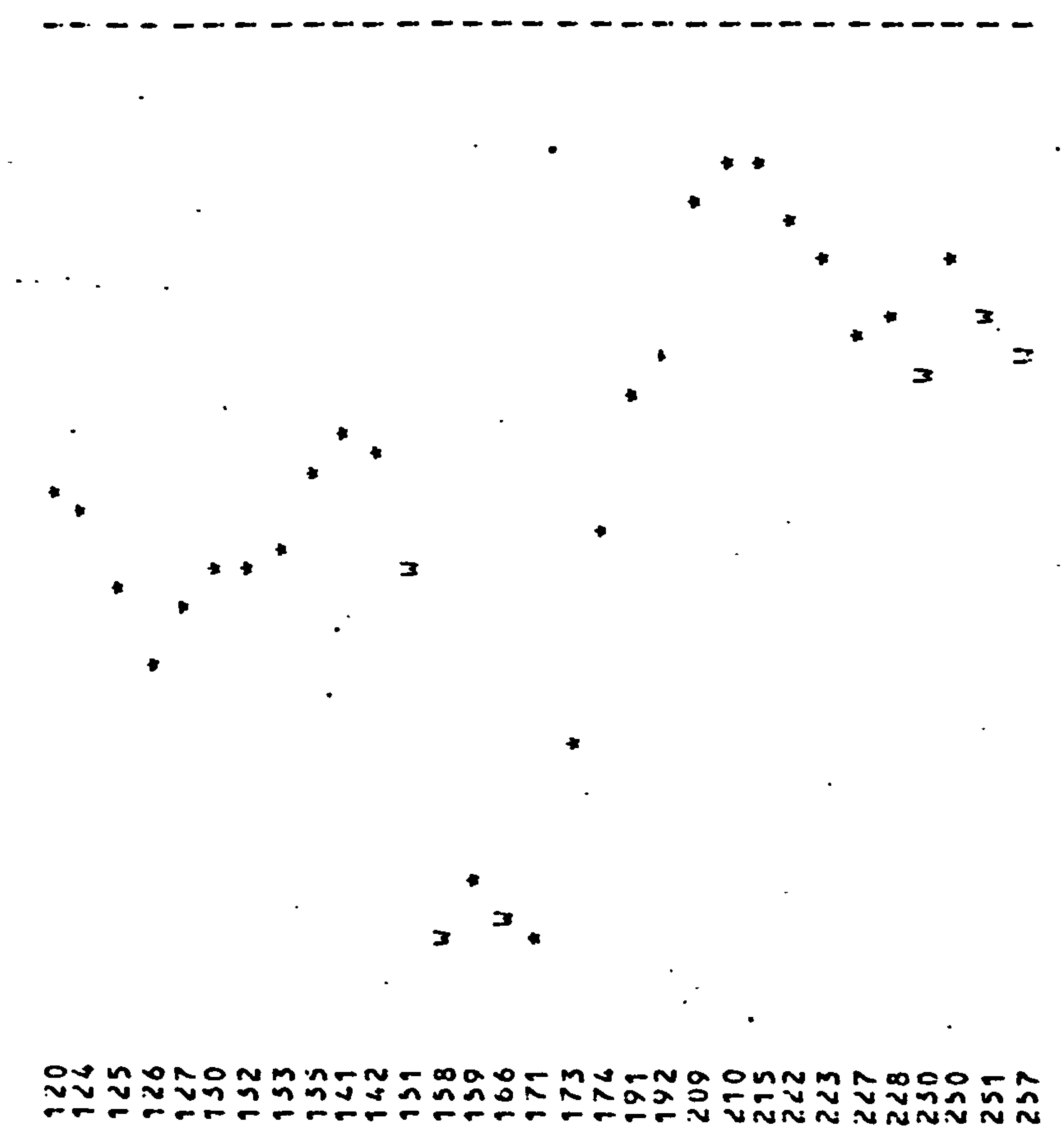
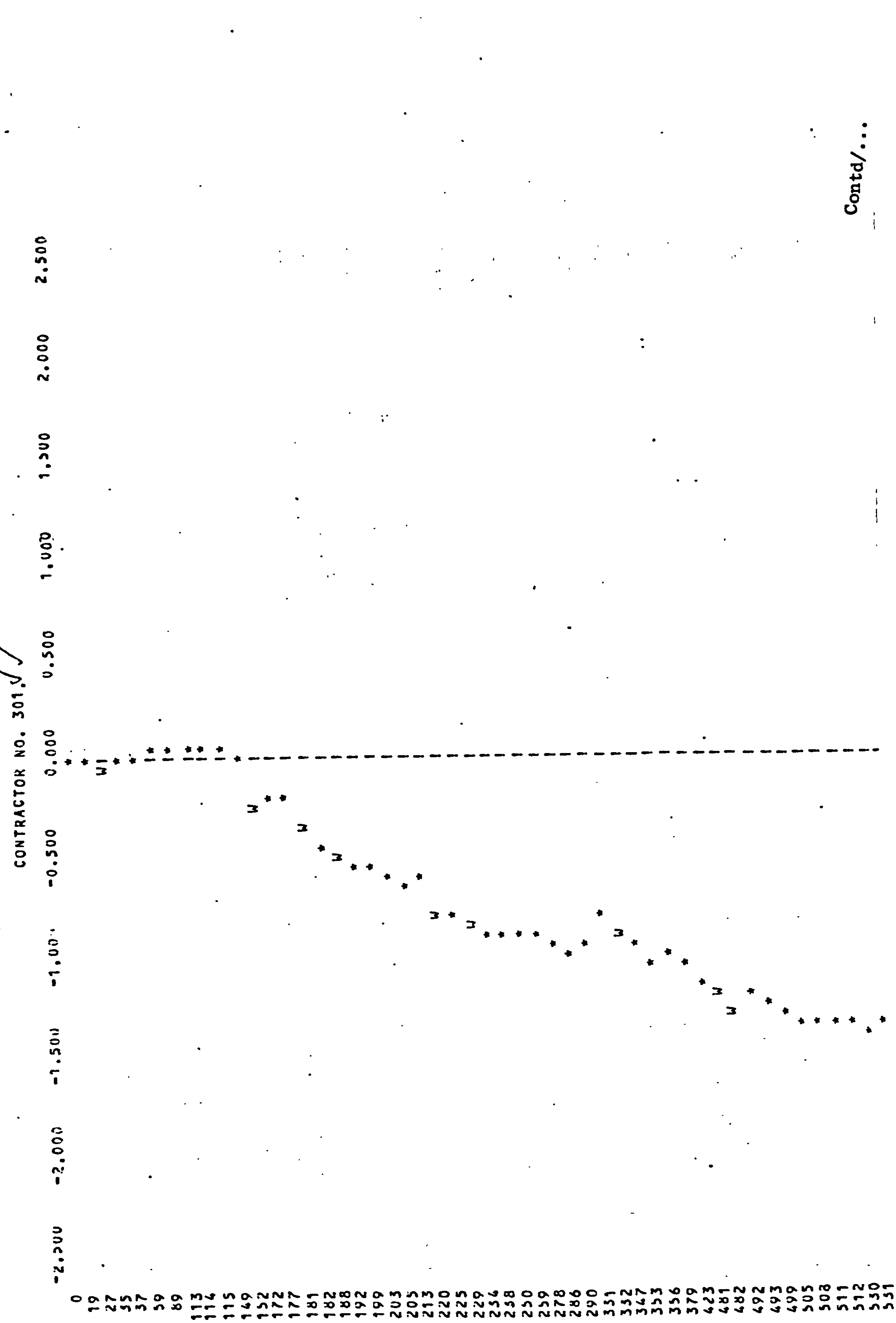
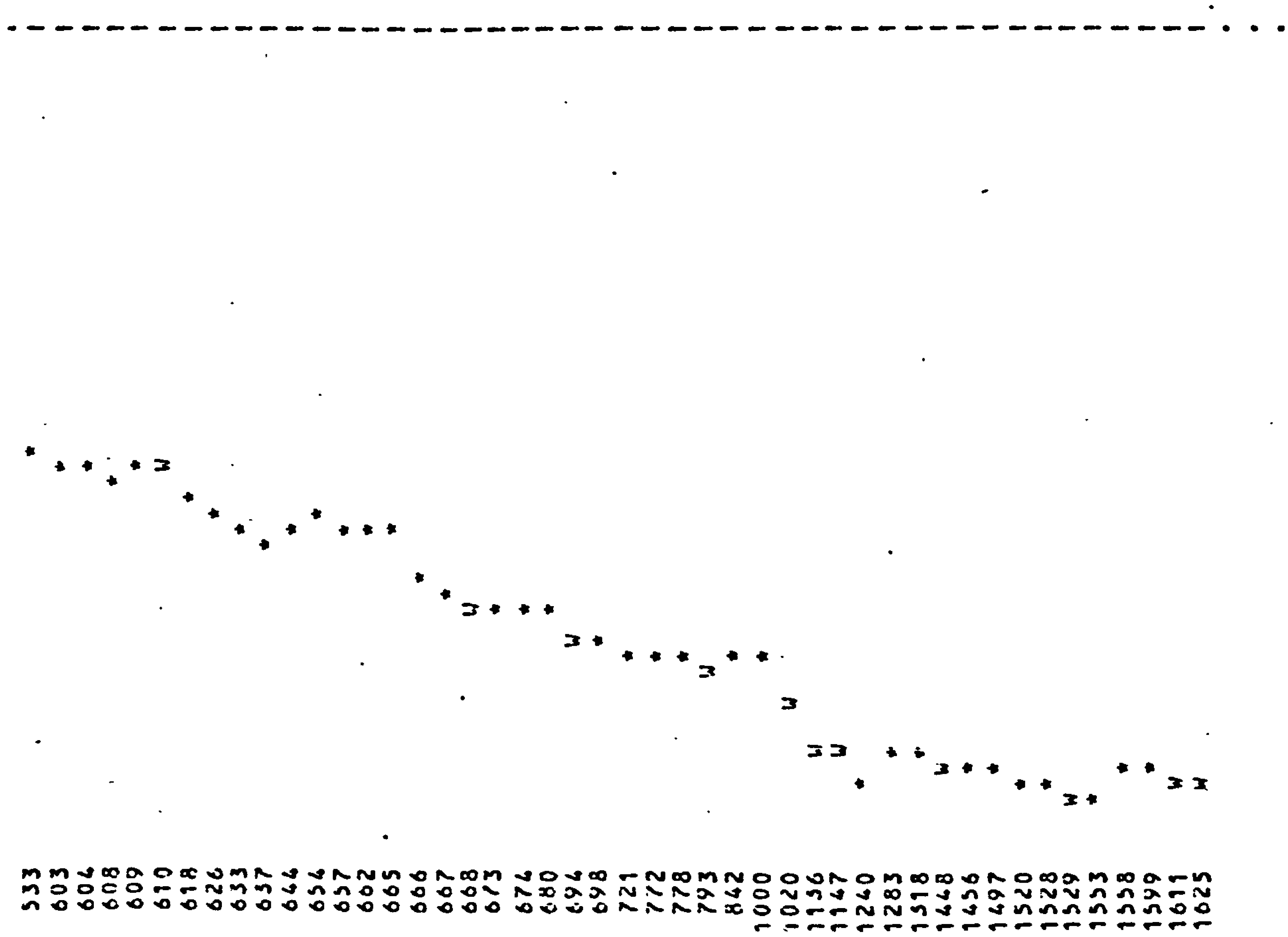

120
124
125
126
127
130
132
133
135
141
142
151
158
159
166
171
173
174
191
192
209
210
215
222
223
227
228
230
250
251
257

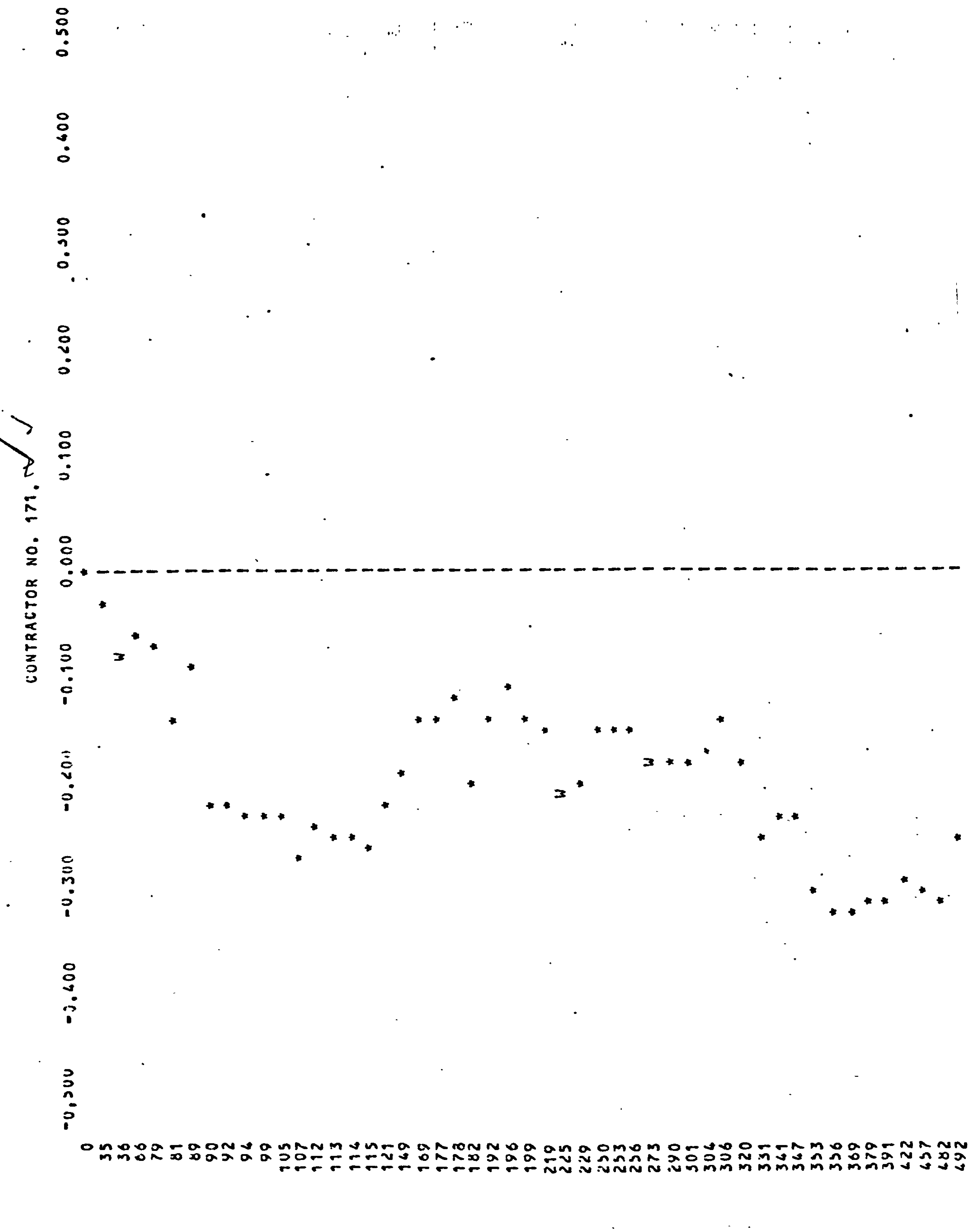
FIGURE 5.5 Sample of CUSUM plots for Roads Contractors

Roads Contractors 301, 171, 314

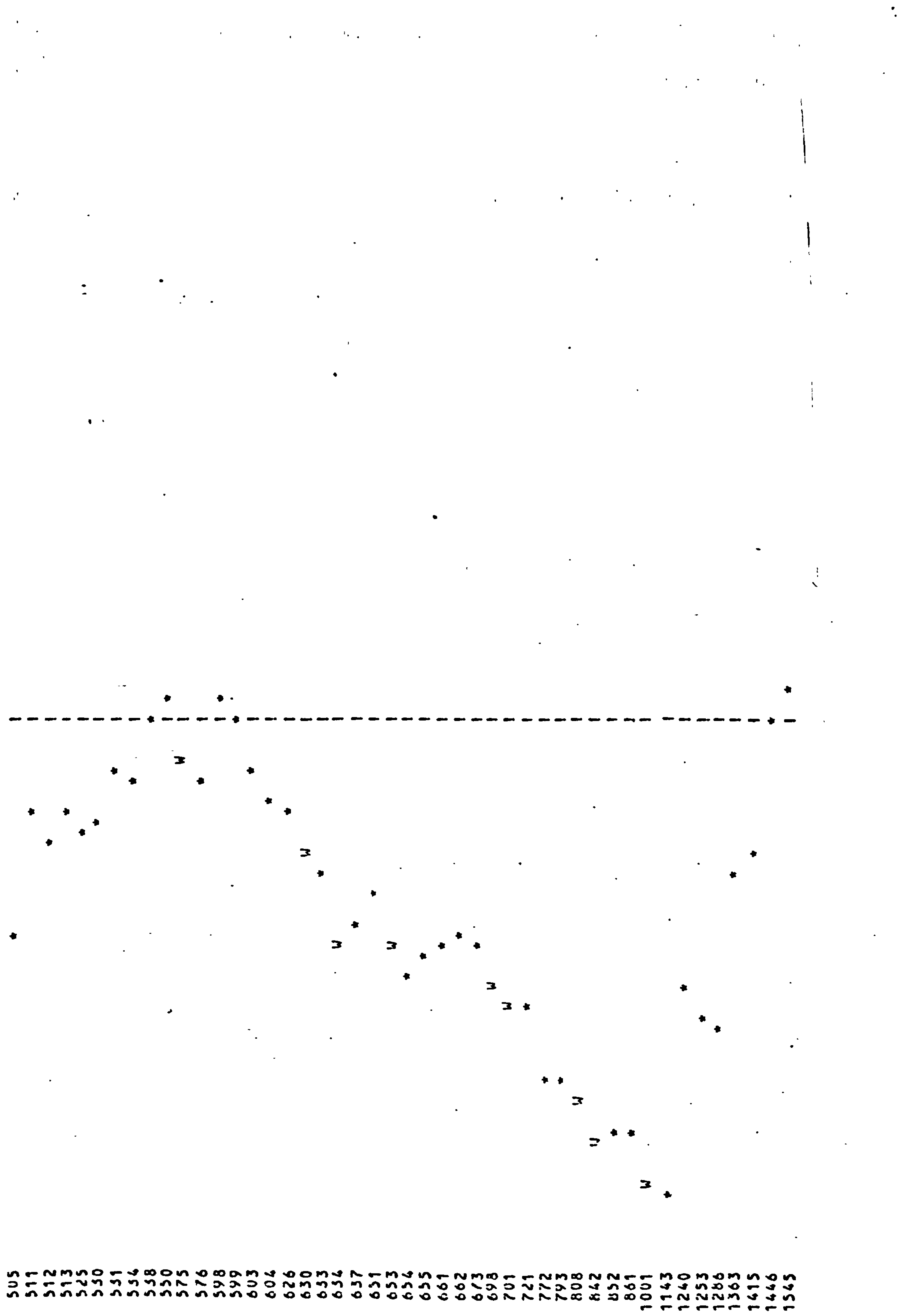

CONTRACTOR NO. 301
-2.500
-2.000
-1.500
-1.000
-0.500
0.000
0.500
1.000
1.500
2.000
2.500
0
19
27
35
37
59
89
113
114
115
149
152
172
177
181
182
188
192
199
203
205
213
220
225
229
234
238
250
259
278
286
290
331
332
347
353
356
379
423
481
482
492
493
499
505
508
511
512
530
531

Contd/...

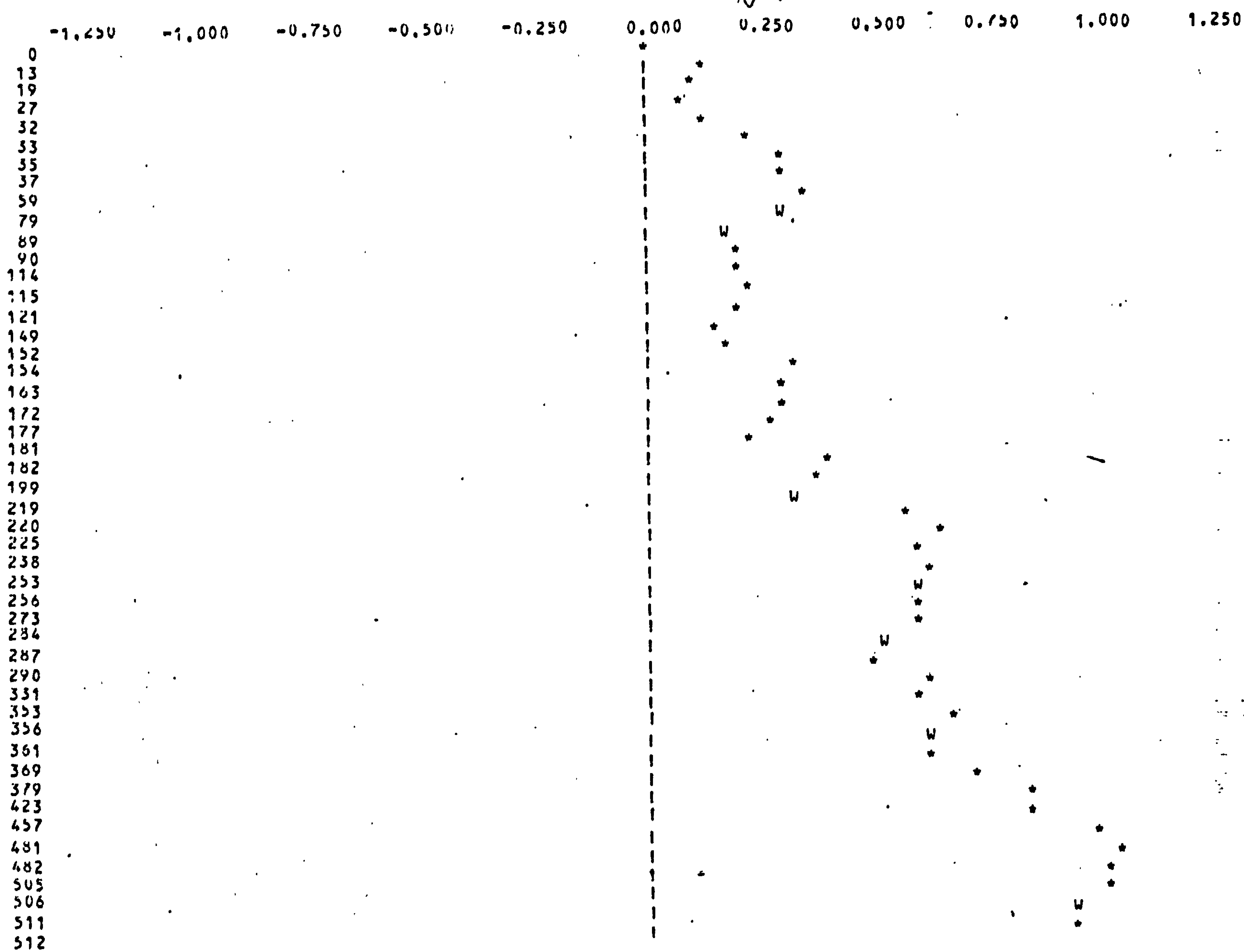

533 603 604 608 609 610 618 626 633 637 644 654 657 662 665 666 667 668 673 674 680 694 698 721 772 778 793 842 1000 1020 1136 1147 1240 1283 1318 1448 1456 1497 1520 1528 1529 1553 1558 1599 1611 1625


CONTRACTOR NO. 171.
-0.500
-0.400
-0.300
-0.200
-0.100
0.000
0.100
0.200
0.300
0.400
0.500
0 35 36 66 79 81 89 90 92 94 99 105 107 112 113 114 115 121 149 169 177 178 182 192 196 199 219 225 229 250 253 256 273 290 301 304 306 320 331 341 347 353 356 369 379 391 422 457 482 492

Contd/...


505
511
512
513
525
530
531
534
538
550
575
576
598
599
603
604
626
630
633
634
637
651
653
654
655
661
662
673
698
701
721
772
793
808
842
852
861
1001
1143
1240
1253
1286
1363
1415
1446
1545

CONTRACTOR NO. 314.



Contd/...

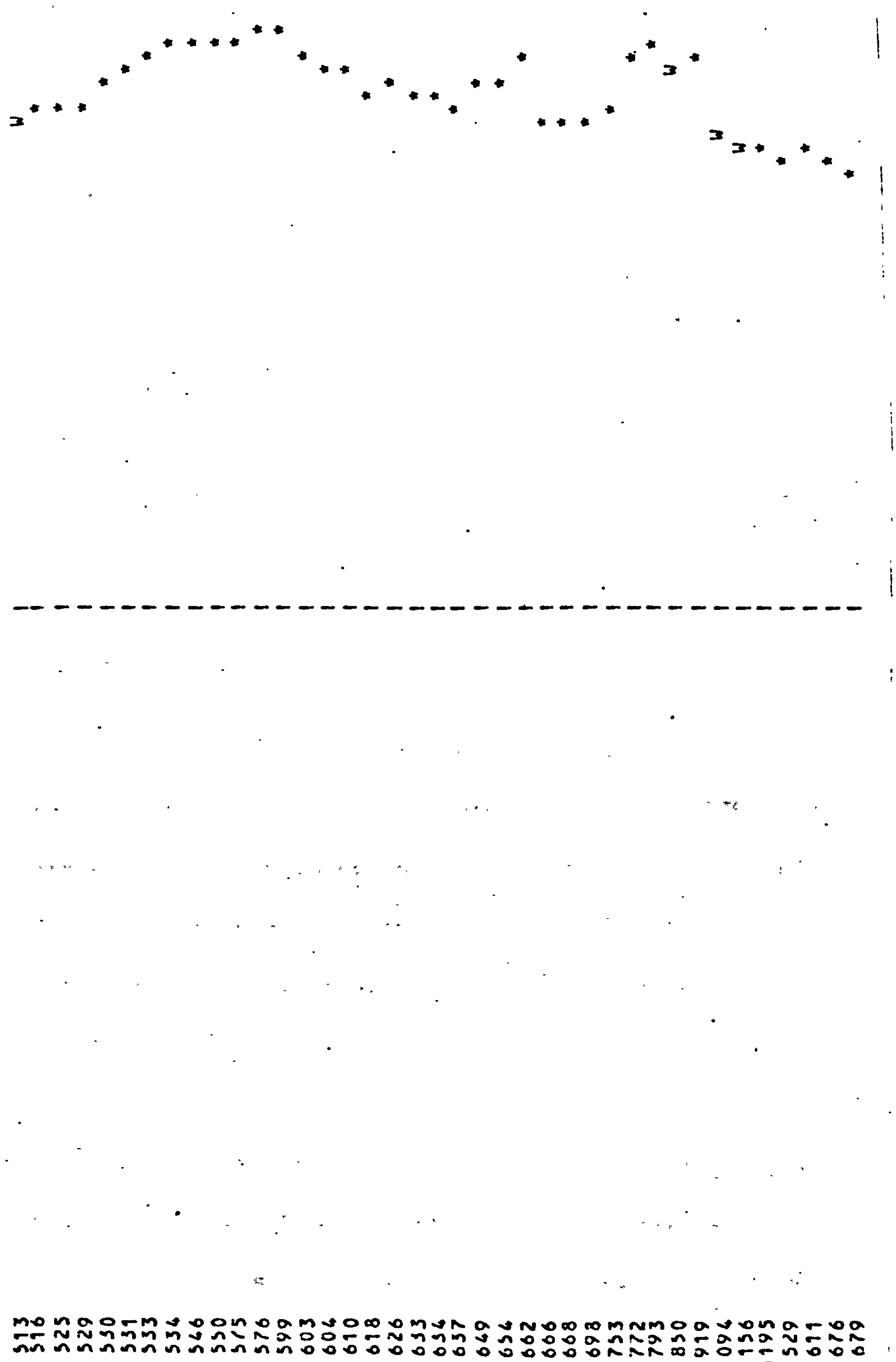

513
516
525
529
530
531
533
534
546
550
575
576
599
603
604
610
618
626
633
634
637
649
654
662
666
668
698
753
772
793
850
919
1094
1156
1195
1529
1611
1676
1679

TABLE 5.12 Winning Bids preceded by 2, 3, 4 or 5 decrements in a contractor's CUSUM value

	Percentage of the total number of winning bids preceded by at least 'M' decrements in the contractor's CUSUM value	Minimum number of decrements in CUSUM 'M'
Building Contracts	84.24%	2
	74.84%	3
	69.72%	4
	65.41%	5
Roads Contracts	85.59%	2
	77.64%	3
	72.61%	4
	69.04%	5

The figures for both the buildings and roads contracts given in table 5.12 are very similar. The important point to note is that only 15% of contracts were won by contractors who were previously displaying a rising CUSUM graph, the remaining 85% were won by contractors with a falling CUSUM graph. These graphs thus present in a very clear way a contractor who is being competitive and seeking work (a falling graph) or being non-competitive and not seeking work (a rising graph).

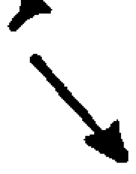
To turn the information contained in table 5.12 around and say how many times is 2 decrements followed by a win and how many times is 3 decrements followed by a win does not, as would be expected, produce a very powerful predictive tool. Table 5.13 summarises this calculation.

TABLE 5.13 Predicting winning bids from a known number of decrements in the CUSUM value

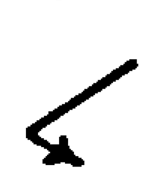
	Percentage number of times that a that a winning bid followed 'M' decrements in CUSUM. The percentage is a percentage of the total number of times 'M' decrements occurred	Number of decrements 'M'
Building Contracts	16.6%	2
	19.0%	3
	20.5%	4
	18.7%	5
Roads Contracts	20.2%	2
	20.9%	3
	22.2%	4
	21.5%	5

The CUSUM analysis was extended by classifying the observed behaviour of each contractor immediately prior to his submitting his next bid. The classification of behaviour was as follows:

(i)  a steady decline in the value of CUSUM;

(ii)  a steady increase in the value of CUSUM;

(iii)  a change downwards in the value of CUSUM;

(iv)  a change upwards in the value of CUSUM;

(v)  a decline in the value of CUSUM, when the last contract had been won;

(vi)  a change downwards in the value of CUSUM, when the last contract had been won.

The direction of the arrow represents the movement of the CUSUM graph as it is printed by the line printer, see figures 5.4 and 5.5, that is bids in date order CUSUM negative to the left and positive to the right. The method of obtaining the behaviour classification is illustrated in appendix N.

A list of bidders for each contract in the data was produced. The contractors for each contract were listed in the order of the position of their bid for that contract. For example the lowest bid was number 1, the second lowest number 2 and so on. For each contract in turn the behaviour of each contractor bidding for the contract immediately prior to the contract in question was classified. The classification was recorded so that for each contract a record was obtained thus

Contract No.	Bidders			
	A	B	C	D
601	↙	↓	↘	↘↙

The contracts were grouped according to the number of bidders, i.e. all those with 5 bidders were grouped together and all those with 6 bidders were grouped together and so on. For each group of contracts examined a table was compiled showing the number of times a type of behaviour was recorded and the rank position of the bid subsequently submitted. Table 5.14 below is an example.

TABLE 5.14 Classified Bidding Behaviour for Buildings Contracts with 5 bidders

Previous behaviour	Rank position of subsequent bid				
	1	2	3	4	5
↙	9	8	5	4	1
↘	4	6	7	4	15
↘↙	3	3	4	2	-
↙↘	9	5	3	5	7
↓	3	1	2	5	3
↘↙ W	2	1	2	2	-
↙ W	2	5	3	3	3

Similar tables were produced for buildings contracts with 6, 7, and 8 bidders and for roads contracts with 5, 6, 7 and 8 bidders. These tables are tables nos. 5.15 and 5.16. Visual inspection shows that previous behaviour classified as ↙, a negative drift of CUSUM value, appears more often in the lower positions of the ranked bids, i.e. positions 1 and 2: Previous behaviour classified as ↘ , a positive drift of CUSUM value, appears more often in the higher positions of the ranked bids. Although this is not absolutely consistent, as buildings contracts for six bidders illustrates. A test for trend in this classified behaviour was undertaken, that is the trend for ↙ to the lower position significant. The test for trend used is described in Conover[40] and in appendix O.

The results of this test for trend for buildings contracts with 5, 6, 7 and 8 bidders and roads contracts with 5, 6, 7 and 8 bidders are given in tables 5.15 and 5.16.

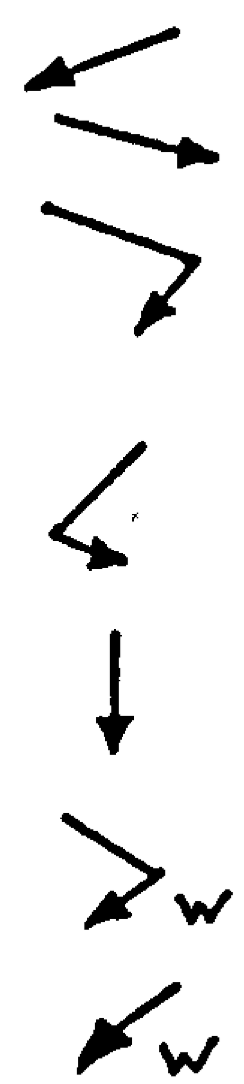
CONCLUSIONS

The trend analysis in general supports the visual inspection in both buildings and roads contracts except for 6 bidder roads contracts. Also although the calculated trend produces, with this exception, the hoped for indications that negative drifts in CUSUM led to wins and positive drifts did not, the test value calculated was not always significant. The likely explanation is that not all the bids submitted by these contractors are represented in the data. For example, bids for private sector contracts are not represented and this is likely to have a distorting effect. Notwithstanding the lack of strong statistical proof, the general conclusion that negative CUSUM drifts lead to wins and positive CUSUM drifts do not is considered valid.

TABLE 5.15

BUILDING CONTRACTS : 5 Bidders

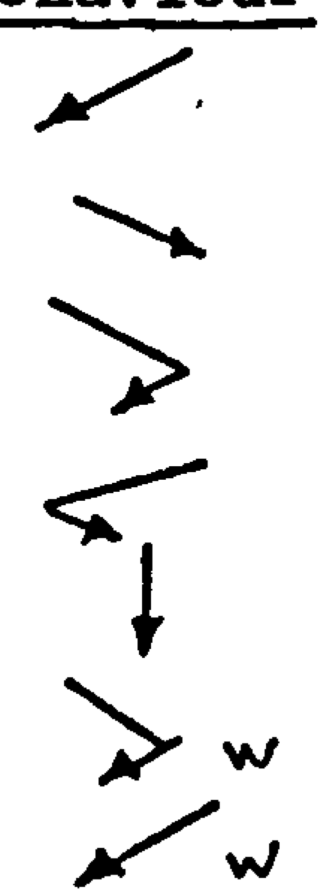
Classified Behaviour and Trend Analysis



Behaviour	Position 1	2	3	4	5	N	N/5	D (= max $\sum(N_j-N/5)$)	
	9	8	5	4	1	27	5.4	6.2	*
	4	6	7	4	15	36	7.2	-7.8	*
	3	3	4	2	-	12	2.4	no analysis	
	9	5	3	5	7	29	5.8	2.4	
	3	1	2	5	3	14	2.8	no analysis	
	2	1	2	2	-	7	1.4	"	
	2	5	3	3	3	16	3.2	"	

BUILDING CONTRACTS : 6 Bidders

Classified Behaviour and Trend Analysis



Behaviour	Position 1	2	3	4	5	6	N	N/6	D (= max $\sum(N_j-N/6)$)	
	5	7	5	8	4	4	33	5.5	3.0	
	4	6	1	2	4	5	23	3.8	2.4	
	3	4	3	4	-	3	17	2.8	no analysis	
	1	1	6	4	4	5	21	3.5	-5.0	*
	4	-	4	2	5	1	16	2.7	no analysis	
	2	-	3	2	1	2	10	1.7	"	
	4	3	2	-	2	2	13	2.2	"	

* Significant at 10% level

TABLE 5.15 (Contd)

BUILDING CONTRACTS : 7 Bidders

Classified Behaviour and Trend Analysis

Behaviour	Position 1	2	3	4	5	6	7	N	N/7	D (= max $\sum(N_j - N/7)$)
↙	3	3	2	6	5	1	1	21	3.0	4.0
↘	3	4	4	3	9	6	8	36	5.1	-6.4 *
↘↙	1	3	2	2	-	3	-	11	1.6	no analysis
↙↘	4	2	2	1	1	3	2	15	2.1	"
↓	3	2	2	5	1	2	2	17	2.4	"
↘↙ w	1	1	2	-	-	-	2	6	0.9	"
↙ w	4	-	1	1	2	3	2	13	1.9	"

BUILDING CONTRACTS : 8 Bidders

Classified Behaviour and Trend Analysis

Behaviour	Position 1	2	3	4	5	6	7	8	N	N/8	D (= max $\sum(N_j - N/8)$)
↙	3	2	4	1	1	2	2	2	17	2.1	no analysis
↘	2	-	2	2	5	4	4	3	22	2.8	-5.0 *
↘↙	2	2	1	1	1	1	-	-	8	1.0	no analysis
↙↘	2	-	3	1	1	1	-	3	11	1.4	"
↓	-	2	-	1	1	-	3	-	7	0.9	"
↘↙ w	0	1	-	-	1	1	-	-	3	0.4	"
↙ w	3	2	-	-	1	-	1	1	8	1.0	"

* Significant at 10% level

TABLE 5.16

ROADS CONTRACTS : 5 Bidders

Classified Behaviour and Trend Analysis

Behaviour	Position 1	2	3	4	5	N	N/5	D (=max $\sum(N_j - N/5)$)	
↙	12	7	4	9	5	37	7.4	4.6	
↘	7	5	8	7	11	38	7.6	-3.4	
<	11	8	15	11	10	53	10.6	2.6	
>	5	8	10	11	10	44	8.8	-4.6	
↙ w	5	5	7	6	7	30	6.0	-7.0	*
↓	5	11	7	6	7	36	7.2	-2.2	

ROADS CONTRACTS : 6 Bidders

Classified Behaviour and Trend Analysis

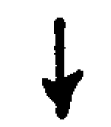
Behaviour	Position 1	2	3	4	5	6	N	N/6	D (= max (N - N/6))	
↙	4	6	6	5	5	5	31	5.2	-1.2	
↘	6	12	7	7	6	11	49	8.2	-3.0	
<	8	8	7	8	10	10	51	8.5	-3.0	
>	15	9	13	14	8	7	66	11.0	7.0	*
↙ w	1	3	4	5	6	6	25	4.2	-4.6	
↓	13	4	7	5	6	6	41	6.8	6.2	*

* Significant at 10% level

TABLE 5.16 (Contd)

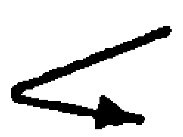
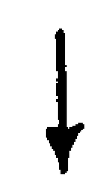
ROADS CONTRACTS : 7 Bidders

Classified Behaviour and Trend Analysis

Behaviour	Position 1	2	3	4	5	6	7	N	N/7	D (= max $\sum(N_j - N/7)$)	
	4	5	5	4	3	2	3	26	3.7	2.9	
	6	4	5	4	9	5	10	43	6.1	-5.4	*
	3	6	6	8	3	7	1	34	4.9	3.6	
	8	7	8	6	4	6	3	42	6.0	5.0	*
	1	3	1	1	3	1	1	11	1.6	no analysis	
	4	4	4	6	8	4	6	36	5.1	-3.3	

ROADS CONTRACTS : 8 Bidders

Classified Behaviour and Trend Analysis

Behaviour	Position 1	2	3	4	5	6	7	8	N	N/8	D (= max $\sum(N_j - N/8)$)	
	8	8	5	7	3	1	2	-	34	4.25	11.0	*
	3	4	5	-	5	5	6	10	38	4.75	- 7.0	*
	2	5	5	4	2	5	5	6	34	4.25	- 3.3	
	2	4	4	4	3	4	3	2	26	3.25	1.5	
	4	1	4	2	2	2	3	-	18	2.25	no analysis	
	4	1	2	7	5	2	2	1	24	3.0	4.0	

* Significant at 10% level

5.5 APPORTIONING THE VARIABILITY IN BIDS BETWEEN THE CONTRACTORS AND THE CONTRACTS

Sections 5.1 to 5.4 deal with interpreting the behaviour of individual contractors, that is the competitors of a specific company. This section and the next one, 5.6, deal with some other issues. Section 5.1 observed differences in the average standardised bid of contractors and using 't-tests' demonstrated that there were some that were significantly different from others at 10% level of significance. Whittaker[3] and others such as Fine[10] and Rickwood[12], as reported in section 2.0, argued that at least two major categories of variability were present in bids. One being variability due to contractors,made up of differences in 'true costs' (as a result of differing efficiences) and differences in applied mark-up the amount added by the contractor to his cost estimate. The other category of variability was that due to 'random estimating errors'. Whittaker[3] produced evidence that the variability due to differences in mark-ups was very small, viz. within $\pm$ 0.35% of a mean of 6.8%[13]. A similar result has been obtained in extensive simulations using a computer based simulation or game developed in Loughborough University of Technology's Department of Civil Engineering by McCaffer[44] and reproduced in Appendix P, and participants being either students or construction company executives. In these simulations each participant acts as a company competing for work in a competitive market created by the other participants. The variables the participant is trying to control are his turnover, his overhead recovery and his cash flow. The consistent outcome that supports Whittaker's findings on mark-up are that after an initial period of high variability at the start of these simulations the range of applied mark-ups settles to a very narrow range of between $\pm$ 0.5% and $\pm$ 1% of the mean mark-up. The explanation attached to this behaviour is that competitive pressures drive the applied mark-ups down until a value of mark-up is reached whereby the pressures from the calculations of likely achieved mark-up and knowledge of the risks involved in taking the contract at a lower price balance the downward competitive pressures. In the simulations when this equilibrium is reached applied mark-ups stabilize and the range is very narrow.

Thus if the variability in bids due to mark-up is dimissed as being negligible then the variability in bids is accounted for in the two other categories, differences in contractors' cost estimates due to differences in efficiency and random errors. No quantitative evidence has been found to place a measure of variability due to contractors efficiencies. It could be argued that in a competitive market the efficiencies would tend to the same level as the inefficient would go out of business leaving all the pressures on the next most inefficient who would either raise his efficiency to competitive levels or go out of business. If this is the case, the variability in bids as measured by the variances found in section 4.0 are due solely to random errors and the variance of bids reflects only contractor's estimating accuracy. Since this is speculative an investigation using analysis of variance was undertaken to determine if the variability of bids could be apportioned to contractors and to contracts. The first possibly representing variability due to differences in mark-ups and efficiency, the second possibly representing random errors. The dangers in this analysis were acknowledged to be the lack of confidence that could be placed on the results, particularly if the result was inconclusive and that residual variances were dominant. The likelihood of an inconclusive result was increased by the need to create a matrix of 'contracts by contractors' with entries in the elements of the matrix being the mean standardised bids. As previously discussed in section 5.1 using the mean bid as a standardisor introduces variability which in this analysis will have an obscuring effect. Also when a matrix of 'contracts by contractors' was created, the need to have a matrix that had as few missing entries as possible meant that the contractors who were included were those who met most often. These contractors tended to belong to the central group of Figures 5,3 and 5.4 and had average mean standardised bids that were not significantly different from each other.

Analysis

The method of measuring variances due to two factors was analysis of variance (known as ANOVA) as described by Snedecor and Cochran[45] and in Appendix Q. The method required a matrix of data, (i.e. 'contractors v contracts') with entries of the contractor's bids for the contract standardised against the mean bid for the contract. As the complete matrix of all contractors v all contracts was very sparse with a large number of missing entries the matrix was reduced to the contractors we met most often and the contracts on which they met. Even this did not produce a complete matrix with a value for every element and the missing entries were estimated as recommended by Snedecor and Cochran[45] and described in appendix Q.

A second similar matrix was created with entries being log (to base e) of the actual bids. The ANOVA was executed on both matrices.

Table 5.17 shows the matrix of data for buildings contracts with entries being standardised bids. Table 5.18 shows the matrix for buildings contracts with entries being the logarithm (to base e) of the actual bid value. Tables 5.19 and 5.20 show the matrices for roads contracts with entries being standardised bids and logarithm (to base e) of actual bid respectively.

Results.

The results of these analyses on both buildings and roads contracts for both standardised bids and ^{L}n bids are given in tables 5.21, 5.22, 5.23 and 5.24 as follows.

Table 5.21 Mean standardised bids for buildings contracts

Table 5.22 Log to base e of actual bids for buildings contracts

Table 5.23 Mean standardised bids for roads contracts

Table 5.24 Log to base e of actual bids for roads contracts.

Table 5.17 Buildings Contracts mean standardised bids.

Estimates in gaps " "

		Contractors					
		103	113	122	131	136	160
Contracts	111	0.911560	1.005490	1.063480	0.856620	"0.979374"	0.933510
	3	1.026980	0.971270	1.067760	1.015090	0.971470	"0.973410"
	80	0.918230	0.959390	1.083190	1.023840	"1.021404"	"0.959058"
	92	0.998140	0.984700	0.981590	0.963330	"0.980358"	0.847820
	125	"0.965622"	1.007950	1.017870	1.025710	0.921270	"0.956096"
	190	"0.988742"	0.998840	1.021570	0.914980	1.190730	0.955480
	241	"1.009878"	1.117970	1.041650	0.973990	1.002040	1.051630
	53	0.986740	1.033370	0.985410	"0.983950"	1.020240	1.005580

Table 5.18 Buildings Contracts Logarithims (to base e) of Actual Bids

Estimates in gaps " "

		Contractors					
		103	113	122	131	136	160
Contracts	111	17.397605	17.439207	17.551751	17.335444	"17.503871"	17.421396
	3	17.493553	17.437783	17.532491	17.481909	17.437983	"17.499345"
	80	17.652155	17.696005	17.817374	17.761026	"17.806431"	"17.754242"
	92	16.865078	16.863598	16.848364	16.829580	"16.896487"	16.701660
	125	"16.853880"	16.849875	16.859671	16.867340	16.759950	"16.856810"
	190	"17.039981"	17.007082	17.029575	16.919385	17.182806	16.962699
	241	"18.323164"	18.379338	18.308631	18.241471	18.269858	18.318167
	53	18.023418	18.069595	18.022070	"17.924178"	18.056810	18.042339

Table 5.19 Roads Contracts Mean Standardised Bids

Estimates in gaps " "

	Contractors					
	301	306	311	314	324	432
Contracts 19	0.997300	"1.044331"	1.087630	0.968760	1.002300	1.121510
199	0.977430	1.039700	0.94330	0.992580	"1.013603"	0.959840
379	0.963450	"1.032597"	1.030370	1.112870	1.098210	0.913930
482	0.921200	0.997110	"0.944293"	1.035840	0.991870	0.929360
603	0.964890	1.002210	"0.998487"	0.953410	1.042290	0.983550
604	0.981050	0.994260	0.979310	0.982620	1.048700	0.989230
610	0.974710	"1.003930"	1.002890	1.010810	0.999730	0.987360

Table 5.20 Roads Contracts Logarithims (to base e) of Actual Bids

Estimates in gaps " "

	Contractors					
	301	306	311	314	324	432
Contracts 19	16.164502	"15.965760"	16.093605	16.135430	16.169471	16.281847
199	15.329758	15.391524	15.294251	15.345136	"15.507492"	15.311604
379	16.675520	"16.430208"	16.642679	16.719701	16.706438	16.522755
482	15.990251	16.069430	16.148621	16.107545	16.064167	15.999072
603	15.831687	15.869634	"15.998676"	15.819718	15.908855	15.850843
604	17.275656	17.289029	"17.273879"	17.277258	17.342342	17.283962
610	16.970296	"16.787706"	16.998603	17.006661	16.995646	16.983190

ANOVA results tables

Table 5.21 Buildings Contracts, Mean Standardised Bids

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F. Ratio
Companies	5	3.2783E-02	6.5566E-03	1.642
Contracts	7	2.7645E-02	3.9492E-03	0.989
Residuals	26	1.0380E-01	3.9922E-03	
TOTAL	38	1.6422E-01		

Table 5.22 Buildings Contracts, logarithms of Actual Bids

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Companies	5	3.2376E-02	6.4753E-03	1.335
Contracts	7	1.2496E+01	1.7851	368.147**
Residuals	26	1.2122E-01	4.8489E-03	
TOTAL	38	1.2649E+01		

Table 5.23 Roads Contracts, Mean Standardised Bids

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Companies	5	1.6676E-02	3.3353E-03	1.457
Contracts	6	1.6804E-02	2.8006E-03	1.224
Residuals	24	5.4923E-02	2.2885E-03	
TOTAL	35	8.8403E-02		

Table 5.24 Roads Contracts, logarithms of Actual bids

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Companies	5	6.5103E-02	1.3021E-02	2.039
Contracts	6	1.5842E+01	2.6404	413.425**
Residuals	24	1.5328E-01	6.3865E-03	
TOTAL	35	1.6061E+01		

Conclusions to ANOVA Exercise

The results obtained are inconclusive.

From table 5.21 for buildings contracts it can be seen that there is no significant difference between companies' (contractors') variance, contracts variance and residual variance. Thus it appears that either no differences exist or the randomising effect of the mean bid obscures the results. From table 5.22 for buildings contracts it can be seen that there is no significant difference between companies' variance and residual variance but there is a significant difference between the contracts variance and the residual variance. This is obviously to be expected since the contracts are of different values.

From table 5.23 for roads contracts it can be seen that there is no significant difference between the companies variance, the contracts variance and the residual variance.

From table 5.24 for roads contracts it can be shown that companies' variance is significantly different from the residual variance at the 10% level. The contracts variance,as for buildings and for the same reason, is significantly different from the residual variance. This implies that there is variability in the roads contracts that is attributable to contractors, i.e. differences due to mark-up and/or efficiency.

The general lack of measurable differences is thought to be due to the selection of contractors who meet most often and this resulted in contractors who had similar average mean standardised bids.

However, it is gratifying that the 'F ratio' for companies variance is of similar order when calculated from mean standardised bids or from logs of bids. That is 1.642 from table 5.21 and 1.335 from table 5.22 for buildings is of the same order. Similarly 1.457 from table 5.23 and 2.039 from table 5.24 is again of the same order. This is taken to indicate that the process of standardising bids against the mean does not introduce wild distortions and that there is little effect from mean standardising bids. This acts as reassurance for previous conclusion from section 4.0.

5.6 Using Simulation to Predict Winning Bidders

This investigation was undertaken to determine if simulation based on mean standardised bids would be useful in predicting winning bidders. To enable simulation exercises to be undertaken the data was organised in the following way for each contractor.

(1) The mean standardised bids were collected into one set from which random samples could be selected.

(2) The mean standardised bids were grouped by 'n' the number of bidders. That is all bids submitted by the contractor in question for contracts with the same number of bidders were grouped together. Again these data sets were created so that random samples could be selected.

A computer simulation was undertaken for each contract as follows.

(3) The bidders competing for the contract were identified, say A, B, C and D.

(4) A mean standardised bid was selected at random from A's data set containing all A's mean standardised bids. This was taken to be

A's bid for the simulated contract. Similarly bids were selected for B, C and D from their data sets of all their bids. The lowest bid of A, B, C and D for this simulated contract was taken as the winner and this was recorded against the winning company. The simulation was completed 5000 times and the number of wins recorded against each company. The output from the program as shown in table 5.25 shows the companies listed in the order of their original bids for the real contract with the number and percentage of simulated wins shown.

(5) The exercise was repeated but this time the randomly selected bids were taken from the data set grouped by 'n' as described in 2). Again the output as shown in table 5.26 was companies in order of their original bids with the number and percentage of simulated wins shown.

Results

The full results are not presented but table 5.25 shows a sample of simulated building contracts using the total data sets. Table 5.26 shows a sample of simulated buildings contracts using the data sets grouped by 'n' bidders. The results for roads contracts were similar.

Conclusions

Inspection of the results showed that this method of simulation was not particularly helpful in predicting the winning contractor. For example the second contract shown in table 5.25 shows both the actual winning bidder and the bidder who came last as having probabilities of winning of 27%. The third contract in table 5.25 shows the actual winner as having a probability of winning of only 8% while the bidder who came last is shown as having a probability of winning of 35%. This was regarded as an important finding as it demonstrates that the data cannot be collected together in this way without regard to time. It is taken as evidence that a time based approach such as the CUSUM graphs is more appropriate.

Table 5.25 Samples of Simulations for Buildings contracts using all available data (not grouped by 'n').

TYPE D

NBID 6
COYS 115 183 151 122 128 164
REPT 5000

	COMPANY	WINS	WINS(%)
1	115	980	19,600
2	183	2396	47,920
3	151	852	17,040
4	122	772	15,440
5	128	0	0,000
6	164	0	0,000
	TOTAL	5000	100,000

TYPE D

NBID 6
COYS 149 122 142 126 106 160
REPT 5000

	COMPANY	WINS	WINS(%)
1	149	1384	27,680
2	122	771	15,420
3	142	1229	24,580
4	126	209	4,180
5	106	40	0,800
6	160	1367	27,340
	TOTAL	5000	100,000

Contd/....

TYPE D

NBID 6
COYS 136 101 127 131 113 122

	COMPANY	WINS	WINS(%)
1	136	436	8,720
2	101	83	1,660
3	127	50	1.000
4	131	1699	33,980
5	113	972	19,440
6	122	1760	35,200
	TOTAL	5000	100,000

TYPE D

NBID 6
COYS 160 149 153 140 133 103
REPT 5000

	COMPANY	WINS	WINS(%)
1	160	1615	32,300
2	149	1089	21,780
3	153	338	6,760
4	140	1191	23,820
5	133	702	14,040
6	103	65	1,300
	TOTAL	5000	100,000

TYPE D

NBID 6
COYS 160 142 117 103 157 155
REPT 5000

	COMPANY	WINS	WINS(%)
1	160	1599	31,980
2	142	1899	37,980
3	117	767	15,340
4	103	404	8,080
5	157	298	5,960
6	155	33	0,660
	TOTAL	5000	100,000

Table 5.26 Samples of simulations for 5 Buildings Contracts using data grouped by 'n'

TYPE D
NBID 6
COYS 113 183 151 122 128 164
REPT 5000

	COMPANY	WINS	WINS(%)
1	113	1359	27.180
2	183	1064	21.280
3	151	1205	24.100
4	122	467	9.340
5	128	905	18.100
6	164	0	0.000
	TOTAL	5000	100.000

TYPE D
NBID 6
COYS 149 122 142 126 106 160
REPT 5000

	COMPANY	WINS	WINS(%)
1	149	464	9.280
2	122	441	8.820
3	142	959	19.180
4	126	530	10.600
5	106	1544	30.880
6	160	1062	21.240
	TOTAL	5000	100.000

Contd/....

```
TYPE D
NBID     6
COYS    136   101   127   131   113   122
REPT   5000

    COMPANY    WINS    WINS(%)

1     136      1085     21,700
2     101       594     11,880
3     127       579     11,580
4     131      1091     21,820
5     113      1207     24,140
6     122       444      8,880

       TOTAL   5000    100,000
```

```
TYPE D
NBID     6
COYS    160   149   155   140   153   103
REPT   5000

    COMPANY    WINS    WINS(%)

1     160       905     18,100
2     149       398      7,960
3     155      1030     20,600
4     140       767     15,340
5     153       570     11,400
6     103      1330     26,600

       TOTAL   5000    100,000
```

```
TYPE D
NBID     6
COYS    160   142   117   103   157   135

REPT   5000

    COMPANY    WINS    WINS(%)

1     160      1005     20,100
2     142       937     18,740
3     117      1291     25,820
4     103      1430     28,600
5     157       204      4,080
6     135       133      2,660

       TOTAL   5000    100,000
```

Sections 5.1 to 5.4 dealt with interpreting competitor's behaviour. Sections 5.5 and 5.6 dealt with wider topics relating sources of variability and predicting winners. The following two sections, 5.7 and 5.8, deal with appraising a contractor's own behaviour.

5.7 Sensitivity of Success Rate to changes in Bid value

Amongst the advice that emerges from studying the effect of random errors, as discussed in section 2.0, is simply to increase mark-ups and compensate for this by bidding for more contracts. This advice is inadequate, firstly from the view that the construction market is finite and there may be no scope for increasing the number of contracts bid. Also the sensitivity of success rate to changes in mark-up should be examined and it is this exercise that is described in this section. Tables 5.4 and 5.5 in section 5.2 show contractors' average mean standardised bids and the contractors' success ratio. The exercise undertaken was to vary all the contractors bids by a known percentage and to calculate his new success ratio. The contractor's bids were reduced in steps of 1% until the contractor won all the contracts, that is had a success ratio of 100%. The contractor's bids were also increased in steps of 1% until the contractor won no contracts at all. The graph of success ratio versus change in bid value was plotted. Figures 5.6 and 5.7 are typical examples of these graphs for buildings and roads contracts respectively.

The first observation was that these graphs were different for each contractor.

Figure 5.6 Sample of Success Rate y Changes in Mark-up for Building Contractors

Mark-up - The percentage change to all the bids of the contractor. (N.B. This is a slight misuse of the term but acts as a convenient shorthand)

No. of Wins - The absolute number of wins

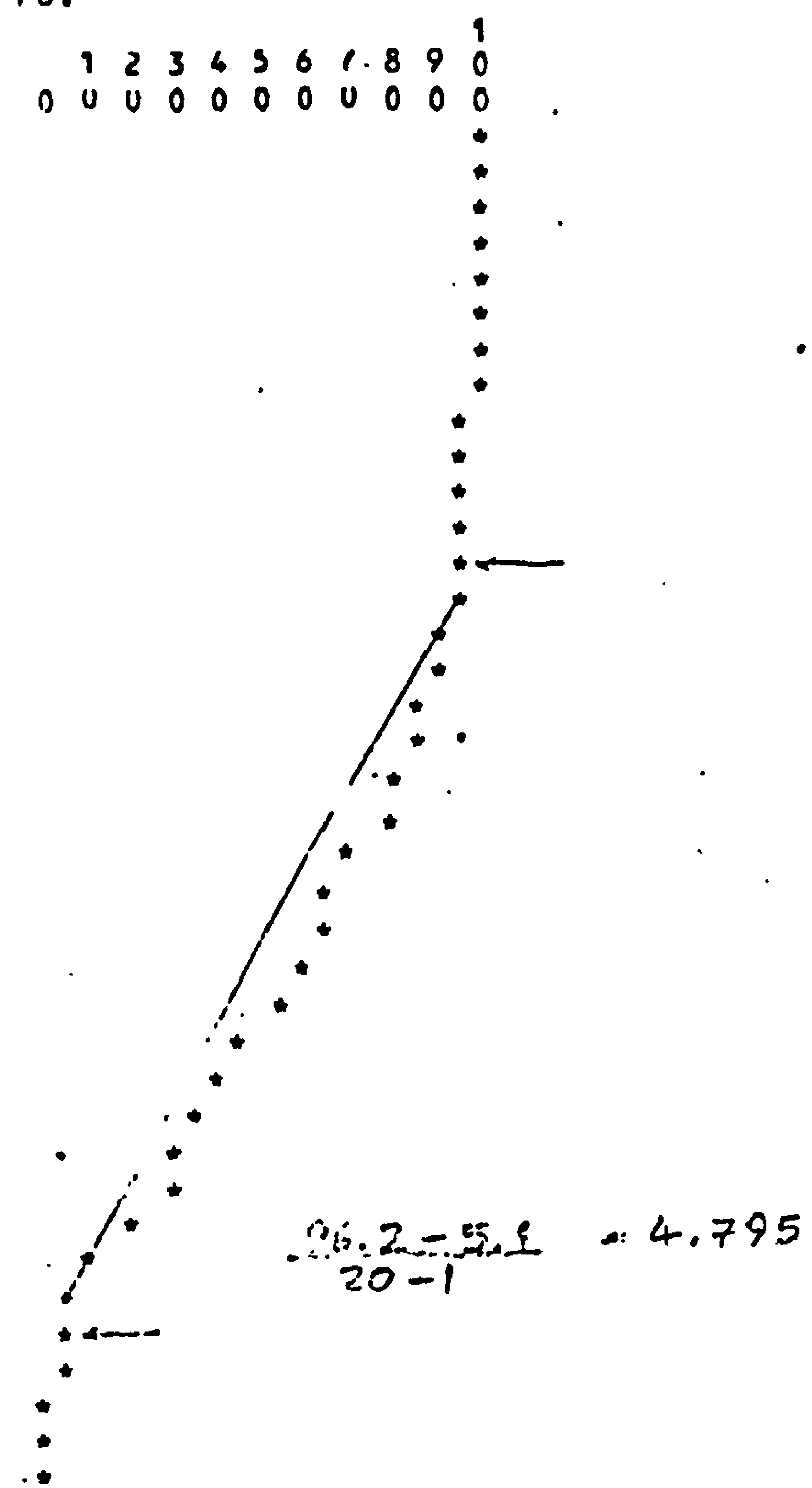
Percentage Wins - The number of wins as a percentage of the number of submitted bids (i.e. Success rate or ratio)

N.B. The scale across the page is the percentage wins

Building Contractors 122 and 142

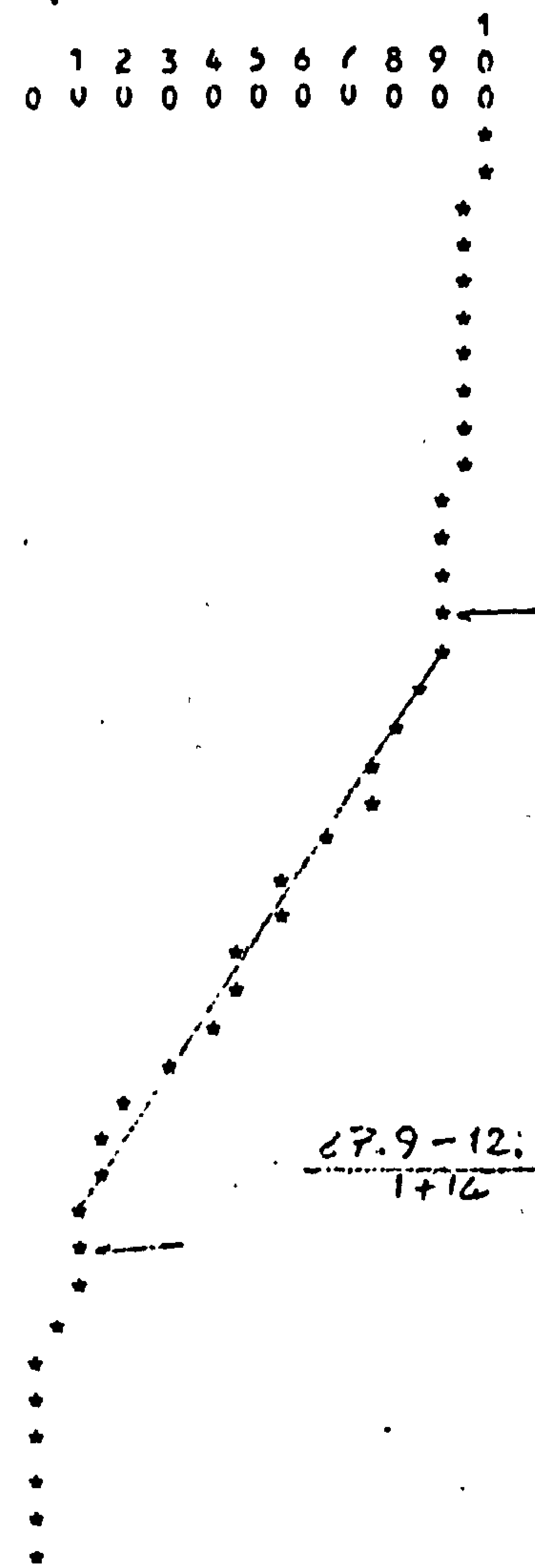
CONTRACTOR 122, FREQUENCY 78.

MARKUP (%)	NO. OF WINS	PERCENTAGE WINS
-33.0	78	100.0
-32.0	77	98.7
-31.0	77	98.7
-30.0	77	98.7
-29.0	77	98.7
-28.0	77	98.7
-27.0	77	98.7
-26.0	77	98.7
-25.0	76	97.4
-24.0	76	97.4
-23.0	76	97.4
-22.0	76	97.4
-21.0	76	97.4
-20.0	75	96.2
-19.0	70	89.7
-18.0	69	88.5
-17.0	68	87.2
-16.0	66	84.6
-15.0	63	80.8
-14.0	61	78.2
-13.0	53	67.9
-12.0	51	65.4
-11.0	49	62.8
-10.0	47	60.3
-9.0	43	55.1
-8.0	37	47.4
-7.0	33	42.3
-6.0	29	37.2
-5.0	24	30.8
-4.0	22	28.2
-3.0	15	19.2
-2.0	8	10.3
-1.0	4	5.1
0.0	4	5.1
1.0	4	5.1
2.0	1	1.3
3.0	1	1.3
4.0	0	0.0



CONTRACTOR 142, FREQUENCY 66,

MARKUP (X)	NO. OF WINS	PERCENTAGE WINS
-28.0	66	100.0
-27.0	65	98.5
-26.0	64	97.0
-25.0	64	97.0
-24.0	64	97.0
-23.0	63	95.5
-22.0	63	95.5
-21.0	62	93.9
-20.0	62	93.9
-19.0	62	93.9
-18.0	61	92.4
-17.0	61	92.4
-16.0	59	89.4
-15.0	59	89.4
-14.0	58	87.9
-13.0	57	86.4
-12.0	54	81.8
-11.0	51	77.3
-10.0	48	72.7
-9.0	42	63.6
-8.0	37	56.1
-7.0	36	54.5
-6.0	30	45.5
-5.0	29	43.9
-4.0	27	40.9
-3.0	20	30.3
-2.0	13	19.7
-1.0	10	15.2
0.0	9	13.6
1.0	8	12.1
2.0	6	9.1
3.0	5	7.6
4.0	4	6.1
5.0	1	1.5
6.0	1	1.5
7.0	1	1.5
8.0	1	1.5
9.0	1	1.5
10.0	0	0.0



$$\frac{87.9-12.1}{1+14} = 5.053$$

Figure 5.7 Sample of Success Rate v Changes in Mark-up for Roads Contractors

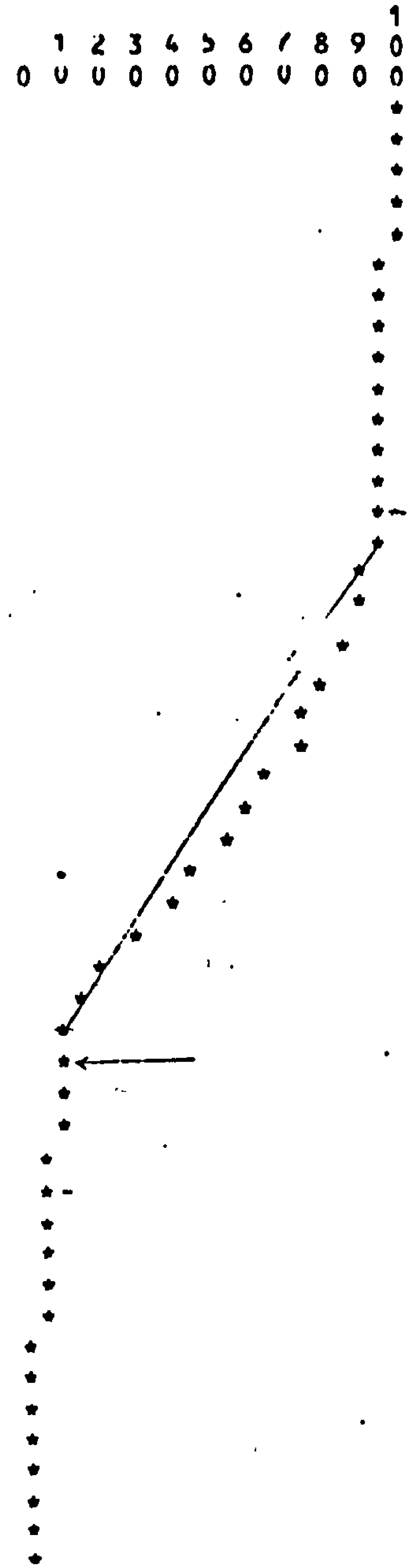
Mark-up	-	The percentage change to all the bids of the contractor. (N.B. This is a slight misuse of the term but acts as a convenient shorthand)
No. of Wins	-	The absolute number of wins
Percentage Wins	-	The number of wins as a percentage of the number of submitted bids (i.e. success rate or ratio)

N.B. The scale across the page is the percentage wins

Roads Contractors 301 and 171

CONTRACTOR 301, FREQUENCY 96.

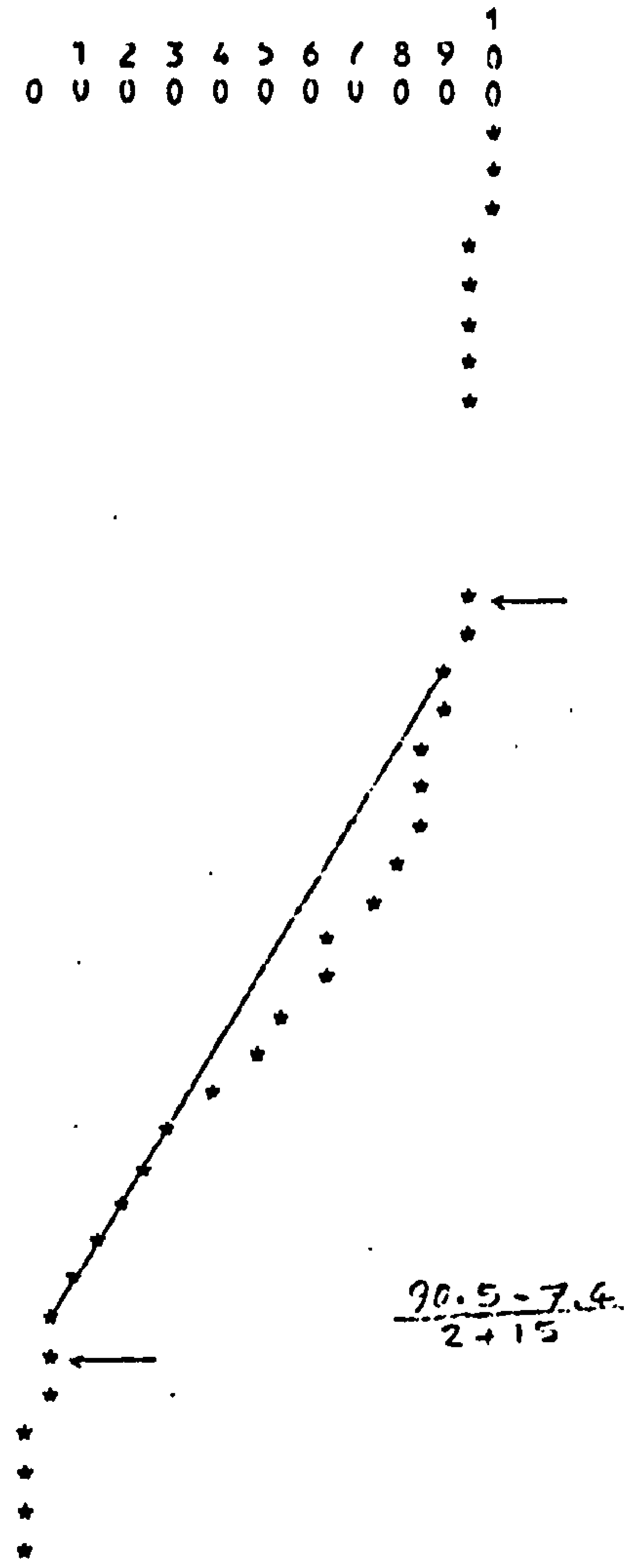
MARKUP (%)	NO. OF WINS	PERCENTAGE WINS
-28.0	96	100.0
-27.0	94	97.9
-26.0	94	97.9
-25.0	94	97.9
-24.0	94	97.9
-23.0	93	96.9
-22.0	93	96.9
-21.0	93	96.9
-20.0	93	96.9
-19.0	93	96.9
-18.0	93	96.9
-17.0	91	94.8
-16.0	90	93.8
-15.0	90	93.8
-14.0	90	93.8
-13.0	87	90.6
-12.0	85	88.5
-11.0	81	84.4
-10.0	80	83.3
-9.0	77	80.2
-8.0	73	76.0
-7.0	71	74.0
-6.0	61	63.5
-5.0	57	59.4
-4.0	51	53.1
-3.0	41	42.7
-2.0	36	37.5
-1.0	28	29.2
0.0	21	21.9
1.0	15	15.6
2.0	11	11.5
3.0	11	11.5
4.0	10	10.4
5.0	8	8.3
6.0	7	7.3
7.0	7	7.3
8.0	7	7.3
9.0	7	7.3
10.0	6	6.3
11.0	5	5.2
12.0	2	2.1
13.0	2	2.1
14.0	2	2.1
15.0	2	2.1
16.0	2	2.1
17.0	2	2.1
18.0	2	2.1
19.0	1	1.0



$\frac{93.8 - 11.5}{2 + 14} = 5.144$

CONTRACTOR 171, FREQUENCY 95.

MARKUP (%)	NO. OF WINS	PERCENTAGE WINS
-25.0	95	100.0
-24.0	94	98.9
-23.0	93	97.9
-22.0	92	96.8
-21.0	92	96.8
-20.0	92	96.8
-19.0	91	95.8
-18.0	90	94.7
-17.0	89	93.7
-16.0	88	92.6
-15.0	86	90.5
-14.0	85	89.5
-13.0	81	85.3
-12.0	81	85.3
-11.0	79	83.2
-10.0	75	78.9
-9.0	71	74.7
-8.0	64	67.4
-7.0	61	64.2
-6.0	53	55.8
-5.0	49	51.6
-4.0	40	42.1
-3.0	28	29.5
-2.0	23	24.2
-1.0	20	21.1
0.0	12	12.6
1.0	10	10.5
2.0	7	7.4
3.0	5	5.3
4.0	4	4.2
5.0	2	2.1
6.0	2	2.1
7.0	1	1.1
8.0	0	0.0



$$\frac{90.5-7.4}{2+15} = 4.888$$

The general shape of the graphs was a long flat insensitive section, see 1 in figure 5.8, a steep gradient, see 2 in figure 5.8 and finally another long flat section, see 3 in figure 5.8.

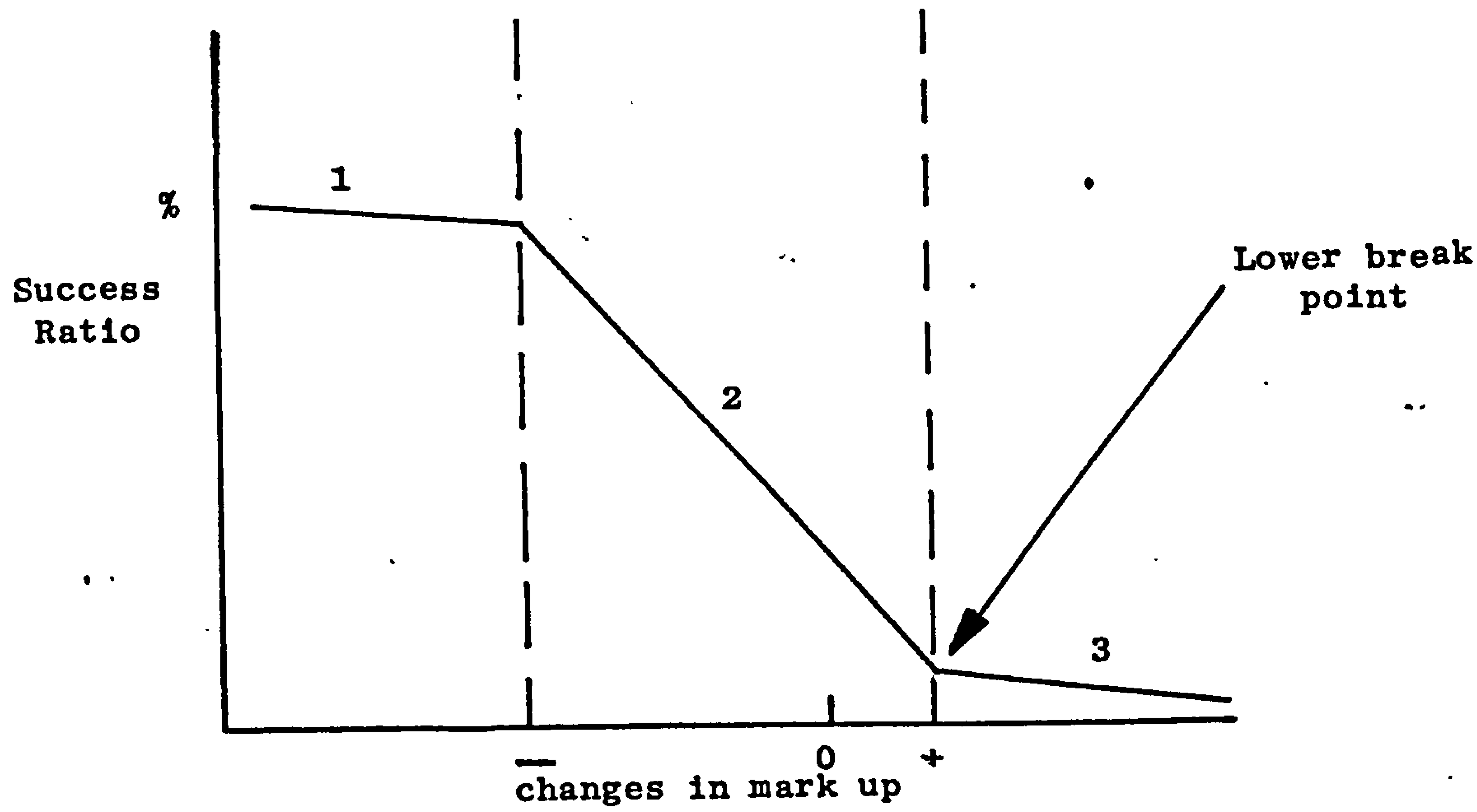


Figure 5.8 General shape of the curve of success ratio v changes in mark up

These graphs were given a numerical representation by identifying the lower break point in terms of the success rate at that point and the percentage change in bids. The middle section, section 2 in figure 5.8, was represented by a gradient.

Table 5.27 and table 5.28 show the lower break point and the gradient for building contractors and roads contractors respectively. The interesting aspect to note is the differences in gradient and lower break point. This is taken to suggest different market judgements. These graphs and/or the numerical representations provide guidance to a contractor as to the value of changes in his pricing policy to produce improvements in his success ratio. The results presented here have a relationship with the average mean standardised bid as shown in tables 5.4 and 5.5. In table 5.5 Contractor 122 has an average bid of 1.008 to give him the same success ratio as Contractor 115. Table 5.4 suggests an average bid of 0.954 is needed. This is a reduction of 5.4%. Figure 5.6 indicates that a drop of 7% - 8% would be needed to give a success ratio of 44%.

Table 5.27 Building Contractors : Numerical representation of changes in bid value v success rate graphs

Company	Gradient of middle section	*Mark-up of lower point	Success Rate	Company	Gradient of middle section	*Mark-up of lower point	Success Rate
122	4.795	-1	5.1	153	6.2	-4	27.3
142	5.053	1	12.1	102	5.358	-9	33.3
133	6.46	2	4.6	125	4.2	2	14.3
103	5.443	4	7.9	138	3.569	-4	14.3
131	4.589	1	15.2	117	5.985	5	0.0
115	4.916	6	4.4	120	5.15	0	0.0
159	6.05	-1	2.3	130	6.418	-6	23.5
160	5.156	-2	26.8	105	9.375	3	0.0
149	4.989	2	5.1	197	7.143	-1	6.3
100	5.556	-1	16.7	126	6.25	-1	0.0
135	4.711	-1	0.0	127	5.556	-6	20.0
113	5.8	3	6.3	137	6.667	-9	26.7
106	8.333	0	6.7	145	4.442	-6	40.0
157	7.886	-8	31.0	191	7.15	-4	35.7
111	5.144	2	0.0	118	6.95	-8	25.0
136	7.0	-1	14.8	104	10.0	2	0.0
151	5.133	-2	11.5	107	10.0	-2	10.0
140	5.6	-6	40.0	150	6.667	-5	40.0
101	5.433	0	8.7	185	11.667	2	20.0
128	5.153	0	4.5				

* Mark up is used as a shorthand to mean percentage change to bid value

Table 5.28 Roads Contractors : Numerical Representation of changes in bid value v success rate graphs

Company	Gradient of middle section	* Mark-up	Success Rate of lower point	Company	Gradient of middle section	* Mark-up	Success Rate of lower point
301	5.144	2.0	11.5	343	4.095	-1	14.8
171	4.888	2.0	7.4	168	7.7	-2	19.2
314	5.12	2.0	5.8	355	5.45	1	26.9
309	5.438	2.0	4.0	300	5.6	2	4.0
344	4.7	3.0	7.4	335	5.094	5	8.3
118	5.747	4	1.5	327	7.457	-2	8.7
311	5.242	3	11.3	122	4.925	-2	9.1
432	4.376	4	1.6	353	5.041	0	0.0
306	5.914	4	1.7	352	9.286	-10	25.0
318	4.395	4	0.0	407	8.125	2	10.0
324	3.691	2	3.8	360	5.262	2	0.0
383	4.814	4	2.0	377	5.187	-5	0.0
390	6.417	4	6.3	427	5.985	4	0.0
312	4.82	4	6.4	307	6.47	2	5.9
345	5.271	-3	37.0	406	7.844	3	17.6
370	8.15	-2	17.4	400	6.693	0	6.3
303	5.483	2	17.1	398	6.667	0	26.7
348	4.583	3	10.0	321	6.43	-1	21.4
326	5.492	-2	8.6	338	7.133	3	14.3
313	5.853	6	6.1	409	7.933	3	0.0
402	7.786	2	6.1	191	8.967	2	7.7
382	5.993	5	0.0	393	9.613	-1	7.7

* Mark up is used as a shorthand to mean percentage change to bid value.

Table 5.28 (Contd)

Company	Gradient of middle section	Mark-up of lower point	Success Rate of lower point	Company	Gradient of middle section	Mark-up of lower point	Success Rate of lower point
337	6.9	3	6.9	416	7.689	0	7.7
391	9.857	0	0.0	339	8.343	-5	8.3
315	5.658	3	0.0	336	12.5	0	20.0
				410	8.571	-3	30.0

5.8 The Relationship of Contractor's Standardised Bids with Contract Value

Reasons for Investigation

Section 5.1 has already shown a strong negative correlation between a contractor's average mean standardised bid and success ratio. CUSUM graphs monitor the change of contractors' bids relative to the mean with respect to time. It is also possible that the contractors' bids relative to the mean bid also change with contract value. The question asked is does any underlying trend exist that increases (or decreases) a contractor's bid relative to the mean as the value of the contract increases, as has been suggested by Pim[46]? This information was regarded as important to the contracting company to know about its own bids and thus highlight any unwitting tendency that may or may not be in accordance with the company's aims. It is also valuable as a guide to the behaviour of competitiors. Whereas CUSUM indicated movement in competitor's keenness to win contracts with respect to time, any trend found in the competitor's competitiveness with respect to contract value would augment the information produced by CUSUM.

Method

To test whether any trend existed when the bids for each contractor were ranked in ascending order of contract value. The contract value was defined as the mean bid for the contract. Previously CUSUM graphs and tests for runs used bids ranked in date order. Plots of the contractor's mean standardised bids ranked in order of contract value were produced as shown in figures 5.9 and 5.10 for buildings and roads contracts respectively. To these plots of mean standardised bids a straight line was fitted (see appendix V for description of computer program) using a simple regression model (a least squares fit) $y \doteqdot c + B.T$ where c is a constant term and B is the gradient of the trend line. 'T' was a transformed contract value. If x_i was the contract value, i.e. the mean of the bids for the i^{th} contract then

$$T = \frac{2x_i - (x_{max} + x_{min})}{(x_{max} - x_{min})}$$

where x_{max} is the largest contract value and x_{min} is the smallest contract value. The reason for using this transformation is that the standardised bids range approximately from 0.9 to 1.1 and the contract values range from 0.5 million to over 100 million and to fit a straight line to the untransformed contract values would have produced coefficients that would be so small as to be unusable. The transformation given reduces the contract values from these large numbers to ones which lie in the range -1 to +1. The trend line thus produced needs to be interpreted in terms of the maximum and minimum contract values used in the calculations.

Results

The results of these curve fitting exercises are partly presented in figures 5.8 and 5.9 which show the mean standardised bid both numerically and plotted and also the contract value. These figures also show the constant term 'c' and the coefficient 'B'. The goodness of fit of the straight line (that is sum of squares of residuals/degrees of freedom) is also given. Tables 5.29 and 5.30 summarise these for all contractors with more than 20 bids in the data. Included in the tables, but not in figures 5.8 and 5.9, is the standard error of residuals, that is the square root of the goodness of fit.

Conclusions

Mean standardised bids do show trends with contract value.

The goodness of fit of the straight lines to mean standardised bids is poor. This does not undermine the information contained as the straight line is not put forward as a predictive model of a particular mean standardised bid at a particular value. The straight line is simply testing whether there is any tendency within mean standardised bids to either increase or decrease with increasing contract value. This trend information is useful for a contracting company to have about the company's own behaviour and that of competitor's behaviour.

A simple check to determine how much a trend in the standardised bid affected a contractor's success in winning contracts was undertaken for contractor number 113 having the greatest positive coefficient and 111 having the greatest negative coefficient for buildings contracts. The same check was undertaken for 122, 313 and 300 with large positive coefficients and for 353, 348 and 382 having large negative coefficients for the roads contracts. This simple test is shown in figures 5.8 and 5.9 where the winning contracts are marked 'W'. To summarise the results:

Buildings Contracts

Contractor No. 113 has a positive coefficient, therefore average mean standardised bid increases with contract value. Figure 5.8 shows the 'wins' tend towards the lower contract values.

Contractor No. 111 has a negative coefficient, therefore average mean standardised bid decreases with increasing contract value. Figure 5.8 shows two of three wins in the upper ranges of contract value and one win placed centrally.

Roads Contracts

Contractor No. 313 has the largest positive coefficient but the ten wins are very uniformly distributed in the range of contract values as shown in figure 5.9.

Contractor No. 122 has a positive coefficient but the two wins are placed central and low in the range of contract value as shown in figure 5.9.

Contractor No. 300 has a positive coefficient and again the wins are uniformly distributed in the range of contract values as shown in figure 5.9.

Contract No. 353 has the largest negative coefficient but has no wins.

Contractor No. 348 has a negative coefficient and 5 of the 7 wins are in the lower half of the contracts ranked by value as shown in figure 5.9.

Contractor No. 382 has a negative coefficient but the wins are placed in the upper ranges of the contracts as ranked by value, as shown in figure 5.9.

Thus the evidence is that while there are identifiable underlying trends in contractors mean standardised bids these trends seem only to have an observable effect on the pattern of wins in the extreme cases where the coefficient is substantial. It seems unlikely therefore that much benefit would be derived by linking this type of analysis automatically with the CUSUM graphs.

Table 5.29 Buildings Contractors

Trend lines with contract value y = c + B.T where T is the transformed contract value

$$T_i = \frac{2x_i - (x_{max} + x_{min})}{(x_{max} - x_{min})}$$, x_i being the contract value

Contractor	Number of bids submitted	Constant Term (c)	Coefficient (B)	Goodness of fit	Standard Error of Residuals	Smallest contract value	Largest contract value
122	78	1.009066	0.00126	0.002091	0.0457	5,616,547	129,596,976
142	66	1.003854	0.030940	0.002225	0.0472	3,845,000	66,688,148
133	65	0.996952	-0.000608	0.002530	0.0503	5,908,651	60,170,200
103	63	0.987816	0.006478	0.003465	0.0589	3,845,000	140,517,887
131	46	0.981830	-0.003736	0.003157	0.0561	6,505,226	140,517,887
115	45	0.965528	0.019648	0.003870	0.0622	5,581,458	129,596,976
159	43	1.030744	-0.001161	0.001362	0.0369	6,505,226	73,730,105
160	41	1.009350	0.013532	0.005140	0.0717	3,845,000	129,596,976
149	39	0.997656	-0.002683	0.001194	0.0346	6,279,016	50,224,912
100	36	1.006959	0.041049	0.004290	0.0655	4,279,666	43,877,390
135	33	1.035580	-0.002676	0.002384	0.0488	5,616,547	118,719,561
113	32	0.987773	0.056258	0.002342	0.0484	5,616,547	85,825,262
106	30	0.971954	0.000527	0.001753	0.0419	3,845,000	45,185,818
157	29	1.041110	0.042255	0.002740	0.0523	6,505,226	41,993,609
111	27	0.992585	-0.10864	0.001150	0.0339	5,908,651	87,736,872
136	27	0.995140	0.008593	0.003927	0.0627	8,198,412	129,596,976
151	26	1.018892	0.019805	0.001971	0.0444	5,581,458	46,829,664
140	25	0.996061	-0.014390	0.003883	0.0623	6,565,621	129,596,976

Table 5.29 (Contd)

Contractor	Number of bids submitted	Constant Term (c)	Coefficient (B)	Goodness of fit	Standard Error of Residuals	Smallest contract value	Largest contract value
101	23	1.005798	-0.001870	0.008835	0.0940	10,139,261	85,825,262
128	22	1.001677	-0.047180	0.005687	0.0754	7,448,961	82,985,430
153	22	1.002070	0.018847	0.002525	0.0502	7,737,014	140,517,887
102	21	1.004948	-0.002327	0.004405	0.0669	5,581,458	66,688,148
125	21	0.992366	-0.033026	0.003932	0.0627	5,581,458	25,917,689
138	21	1.657896	0.024356	0.009490	0.0979	5,581,458	46,829,664

TABLE 5.30 Roads Contractors

Trend lines with contract value $y = c + B.T_i$ where T is the transformed contract value

$$T_i = \frac{2x_i - (x\max + x\min)}{(x\max - x\min)}$$ where x_i is the contract value

Contractor	Number of bids submitted	Constant Term (c)	Coefficient (B)	Goodness of fit	Standard Error of Residuals	Smallest Contract value	Largest contract value
301	96	0.946824	-0.044326	0.003342	0.0578	590,184	67,961,233
171	95	0.991782	-0.018202	0.002219	0.0471	499,000	34,064,498
314	86	1.003365	-0.015222	0.004103	0.0641	2,592,900	44,308,145
309	75	1.000424	-0.016993	0.003444	0.0587	471,183	20,370,298
344	68	0.988924	-0.007440	0.003611	0.0601	562,682	44,308,145
118	65	0.960349	-0.032823	0.001387	0.0372	1,290,226	67,961,233
311	62	0.971735	-0.025830	0.004788	0.0692	542,468	67,961,233
432	62	0.999501	-0.003831	0.003254	0.0570	625,300	35,186,441
306	58	0.985041	-0.021597	0.003111	0.0558	499,000	32,436,285
318	58	1.027260	0.023160	0.004013	0.0633	550,714	22,530,830
324	53	1.037215	0.000647	0.006478	0.0805	3,110,720	67,961,233
383	50	0.999321	-0.00383	0.003967	0.0630	593,267	35,954,886
390	48	0.985350	0.018991	0.003557	0.0596	387,428	17,267,900
312	47	0.979855	-0.025333	0.003555	0.0596	542,468	19,707,808
345	46	0.996048	-0.001345	0.003717	0.0610	625,300	21,624,907

Table 5.30 (Contd)

Contractor	Number of bids submitted	Constant Term (c)	Coefficient (β)	Goodness of fit	Standard Error of Residuals	Smallest contract value	Largest contract value
370	46	0.989987	-0.001293	0.002391	0.0489	387,428	28,426,761
303	41	1.010336	0.024232	0.002459	0.0496	590,184	21,157,156
348	40	0.966344	-0.047297	0.007965	0.0892	471,183	22,530,830
326	35	1.027464	-0.021334	0.005266	0.0726	4,660,197	59,424,333
313	33	0.971391	0.004983	0.002688	0.0518	542,468	34,444,009
402	33	1.007296	0.020866	0.004786	0.0692	625,300	10,933,552
382	31	0.97079	-0.033981	0.005412	0.0736	1,992,984	49,878,272
337	29	0.970385	0.005142	0.003404	0.0583	650,411	11,467,862
391	29	0.995456	-0.002190	0.003463	0.0588	471,183	19,465,779
315	28	0.957042	-0.037385	0.004321	0.0657	5,713,117	173,233,518
343	27	1.000200	-0.034184	0.004139	0.0643	918,747	67,961,233
168	26	1.003358	-0.003166	0.002606	0.0510	1,992,984	49,878,272
355	26	0.972759	0.01555	0.002178	0.0467	945,775	29,105,864
300	25	1.023656	0.033753	0.002954	0.0544	590,184	24,056,437
335	24	0.968341	0.007439	0.008998	0.0949	649,549	8,222,364
327	23	1.028886	-0.025707	0.013130	0.1146	1,989,316	37,397,691
122	22	1.032597	0.045884	0.011270	0.1062	4,301,349	51,605,596
353	21	1.0022996	-0.07695	0.001500	0.0387	2,118,511	59,424,333
352	20	1,035200	-0.007397	0.001542	0.0303	2,118,511	59,424,333

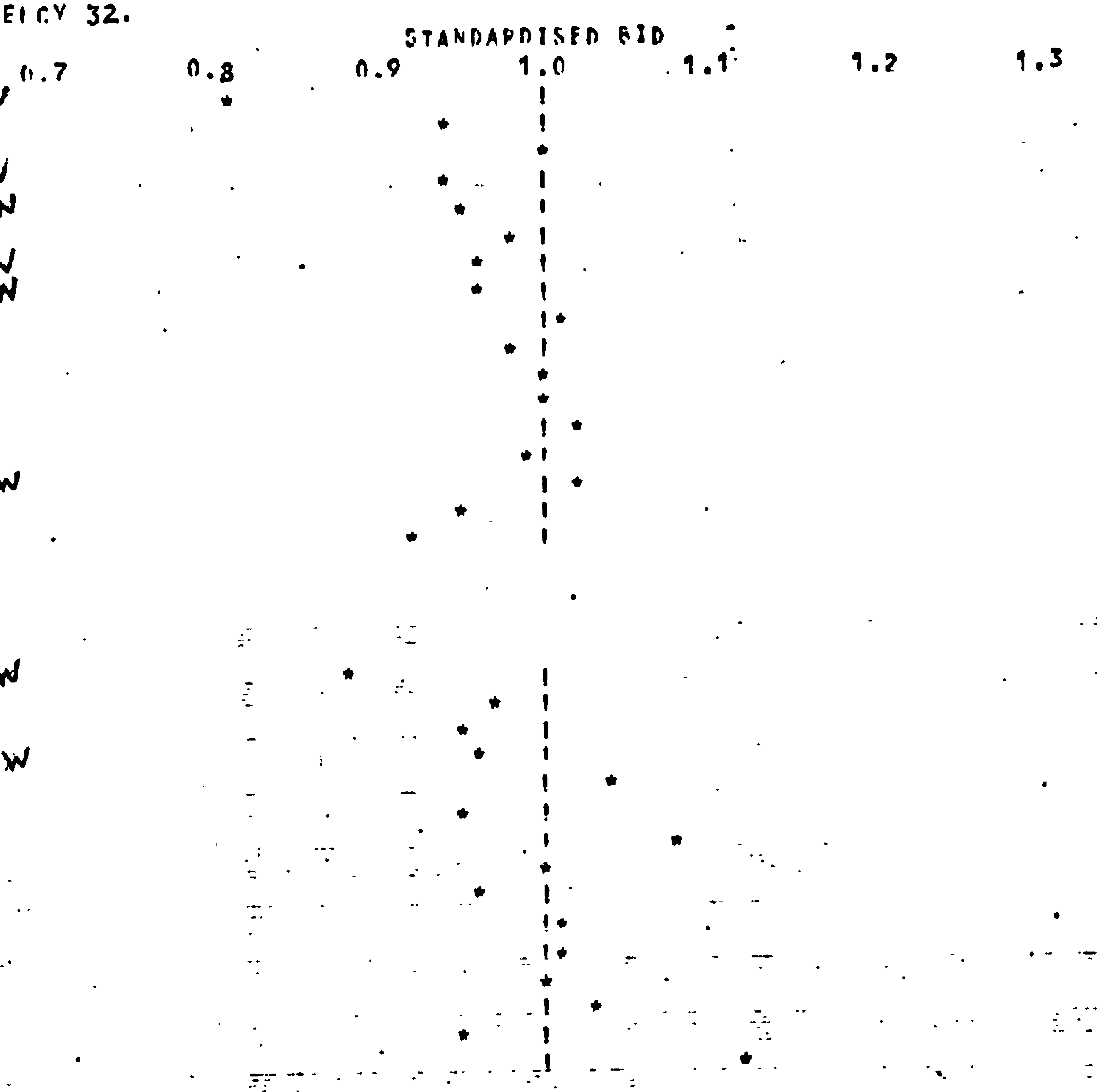
Figure 5.9 Samples of Standardised bids v Contract value with trend line statistics for Buildings Contractors

x	-	number of contract, marked in order of contract value
contract	-	Contract reference number
mean bid	-	The mean of all bids submitted for the contract
standardised bid	-	The contractor's bid divided by the mean bid

Building Contractors 113 and 111.

CONTRACTOR 113. FREQUENCY 32.

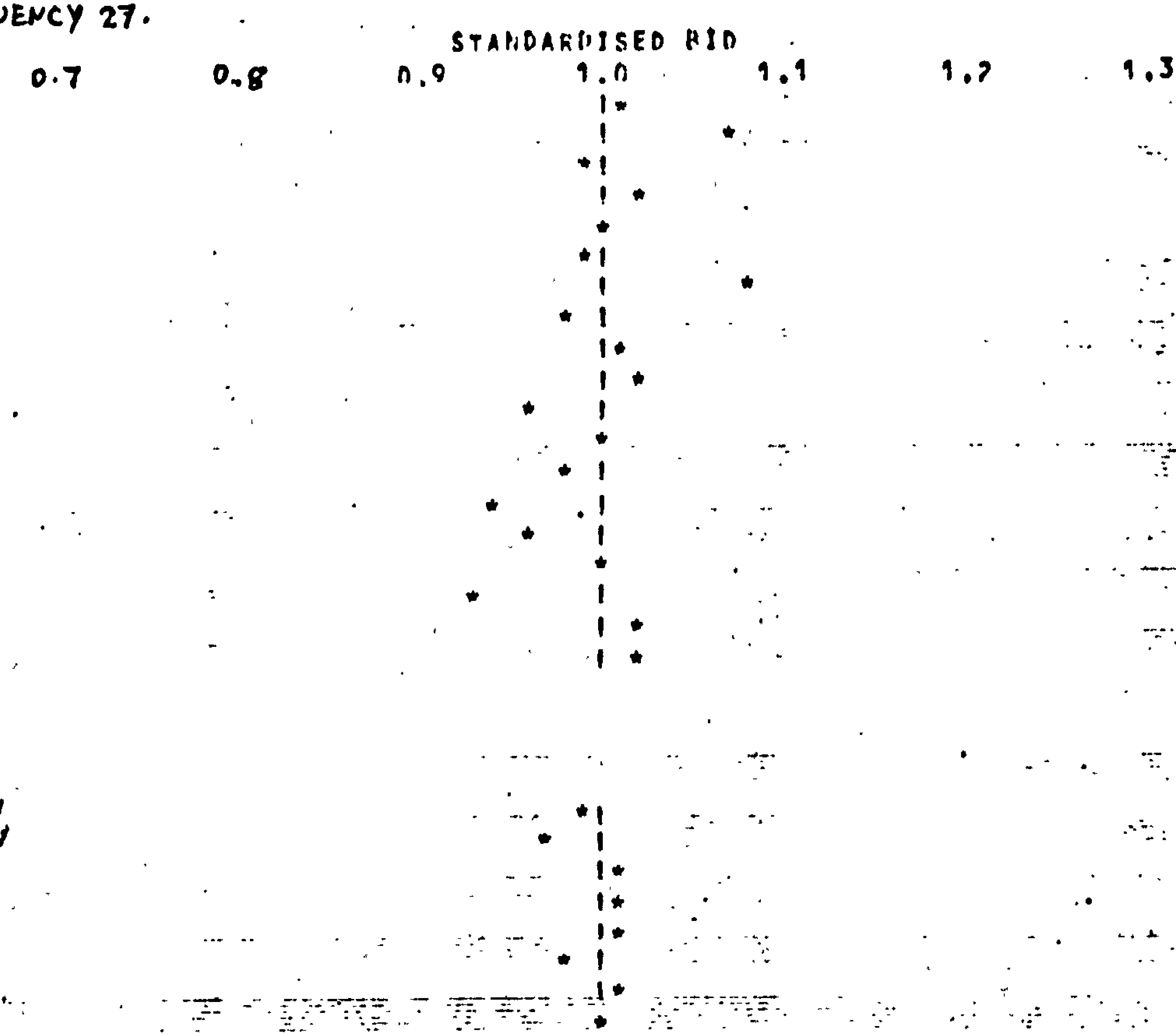
X	CONTRACT	MEAN BID	STD. BID	
1	164.	5616547.	0.814185	W
2	152.	11259102.	0.936964	
3	189.	11821080.	0.998207	
4	21.	16716987.	0.942160	W
5	20.	17704570.	0.948908	W
6	155.	17831189.	0.982745	
7	86.	19067801.	0.956251	W
8	167.	19067801.	0.956251	W
9	125.	20623765.	1.007952	
10	92.	21145579.	0.984698	
11	182.	21652792.	1.001352	
12	190.	24354772.	0.998844	
13	114.	25259117.	1.018246	
14	27.	25550088.	0.986018	
15	156.	27769028.	1.015520	W
16	76.	27836800.	0.948386	
17	11.	29281949.	0.918550	
18	248.	33898875.	0.877923	W
19	3.	38528336.	0.971273	
20	118.	39436526.	0.950783	
21	109.	43284564.	0.955639	W
22	194.	43877390.	1.036404	
23	29.	45816045.	0.947594	
24	165.	47675025.	1.075900	
25	8.	48793513.	0.997059	
26	80.	50498970.	0.959389	
27	56.	54597000.	1.005641	
28	110.	54605368.	1.005487	
29	251	60170200.	0.995509	
30	53.	68119308.	1.033369	
31	60.	82985450.	0.950675	
32	241.	85825262.	1.117969	



LINE FITTED BY E02ABF:
CONSTANT TERM = 0.987773
COEFF. OF X = 0.056258
GOODNESS OF FIT = 0.002542

CONTRACTOR ***. FREQUENCY 27.

X	CONTRACT	MEAN BID	STD. BID	
1	209.	5908651.	1.010273	
2	33.	6486063.	1.073070	
3	130.	6565621.	0.989436	
4	210.	8420458	1.017336	
5	30	13133200.	1.001279	
6	10.	13165871.	0.989832	
7	223.	14712698.	1.082201	
8	47.	15177506.	0.980928	
9	64.	15334799.	1.010643	
10	107.	15720750.	1.017254	
11	32.	16321615.	0.956660	
12	127.	16680538.	1.001167	
13	207.	16970854.	0.982744	
14	134.	18946219.	0.940188	W
15	85.	19515201.	0.957408	
16	63.	19714964.	1.001777	
17	232.	19980693.	0.925443	
18	253.	20110971.	1.016858	
19	237.	20783162.	1.024146	
20	68.	23943194.	0.985666	W
21	100.	24329141.	0.972907	W
22	135.	25973312.	1.014272	
23	14.	29219984.	1.010028	
24	222.	36049635.	1.009192	
25	219.	39782414.	0.978045	
26	243.	39955982.	1.008660	
27	131.	87736872.	0.995021	



LINE FITTED BY E02ABF
CONSTANT TERM = 0.992585
COEFF. OF X. = -0.010864
GOODNESS OF FIT = 0.001150

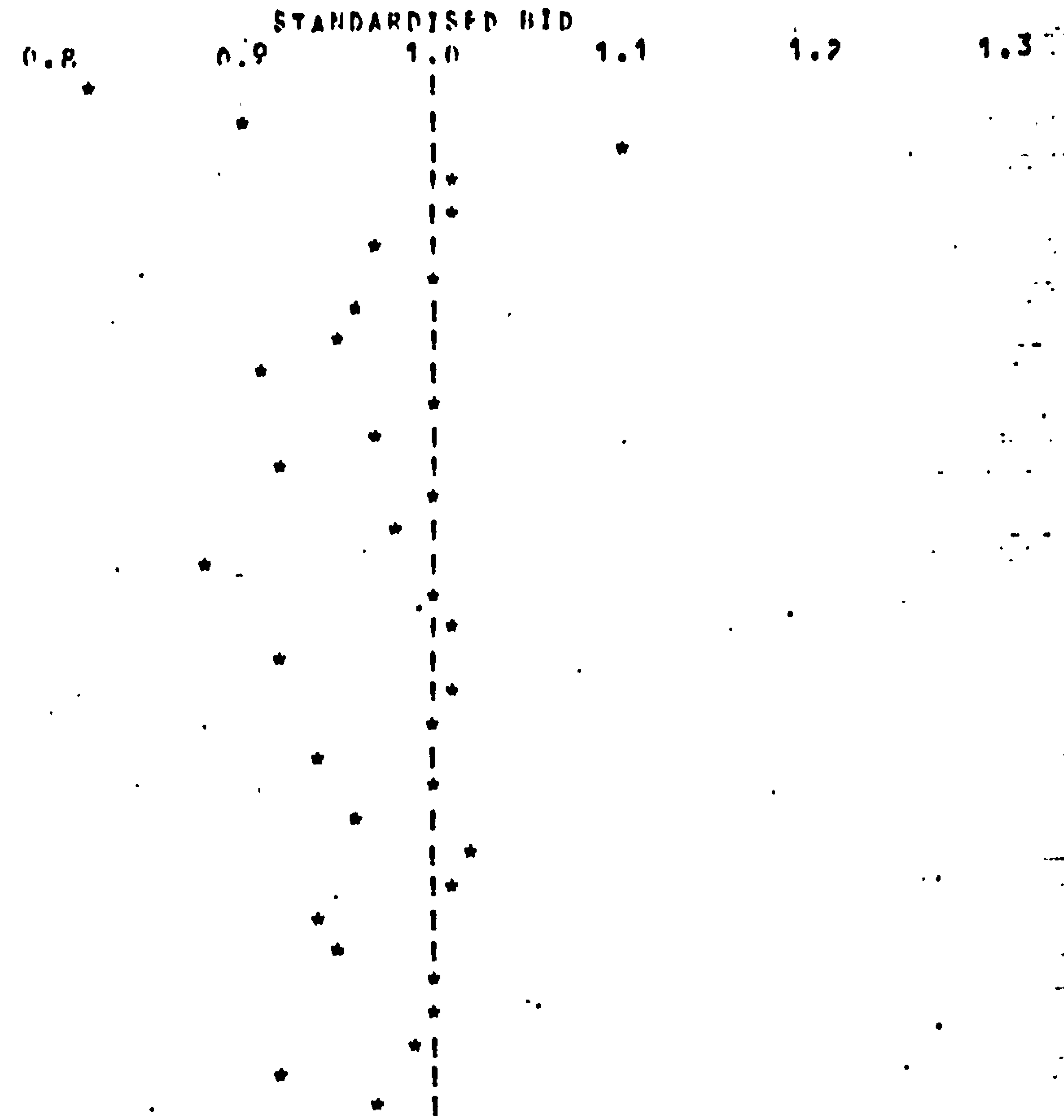
Figure 5.10 Samples of Standardised bids v Contract value with trend line statistics for Roads Contractors

x	-	Number of contract ranked in order of contract value
Contract	-	Contract reference number
mean bid	-	The mean of all bids submitted for the contract
standardised bid	-	The contractor's bid divided by the mean bid

Roads Contractors 313, 122, 300, 363, 348, 382

CONTRACTOR 313. FREQUENCY 33.

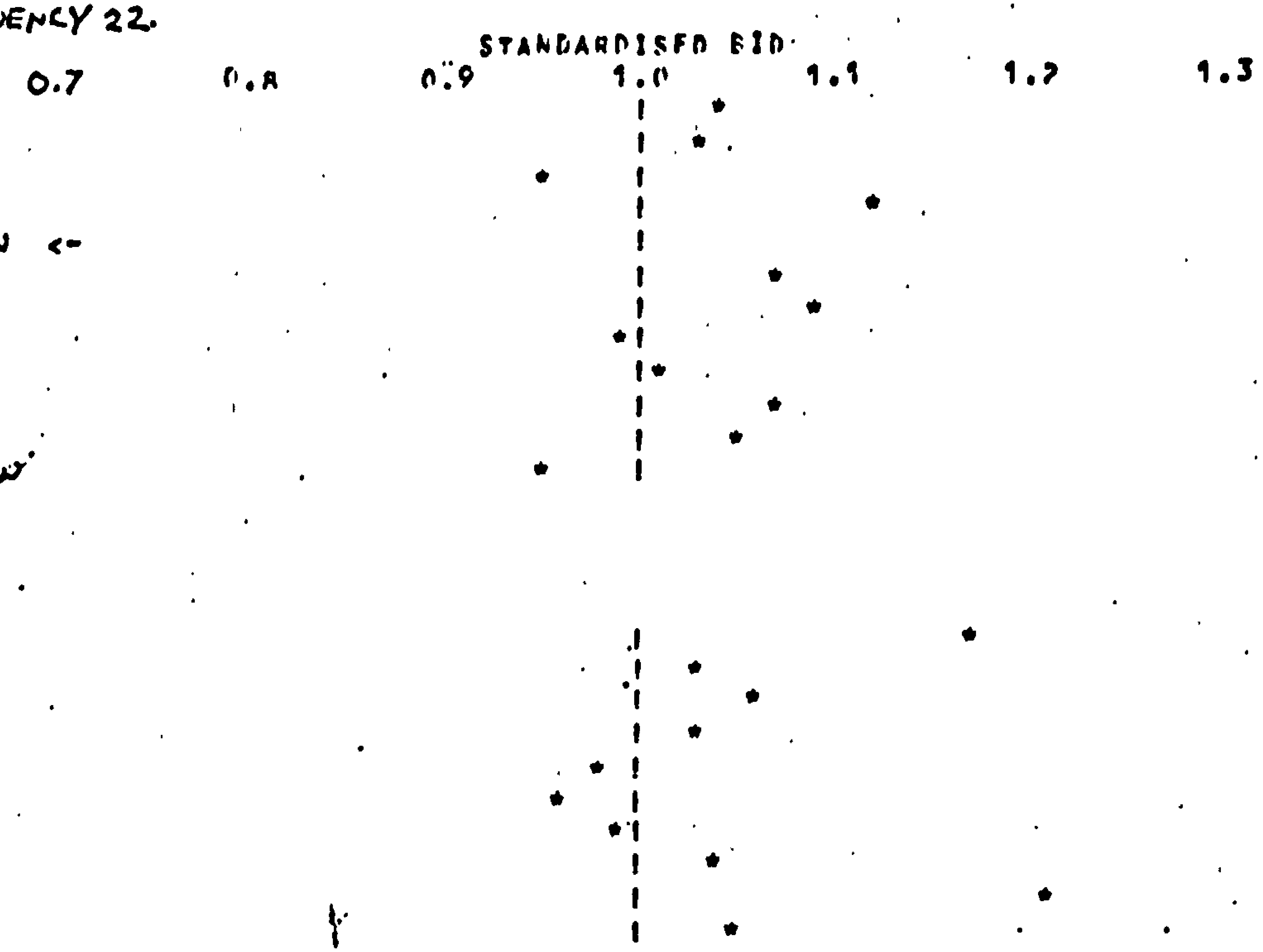
X	CONTRACT	MEAN BID	STD. BID	
1	475.	543468.	0.822866	W
2	66.	773471.	0.896585	W
3	160.	1310883.	1.096500	
4	306.	2263268.	1.009540	
5	92.	2344044.	1.006357	
6	301.	2877389.	0.969595	W
7	1420.	3369822.	1.003387	
8	1415.	3674070.	0.957087	
9	1297.	3923050.	0.946882	W
10	1318.	4269428.	0.911547	
11	1545.	4543527.	1.004184	
12	284.	4820455.	0.970611	
13	549.	5272901.	0.921184	
14	256.	5808801.	0.995128	
15	114.	6287013.	0.975542	
16	149.	6381369.	0.877384	W
17	369.	7039531.	1.002859	
18	603.	7782835.	1.012203	
19	250.	7898587.	0.915785	W
20	530.	9149356.	1.006576	
21	533.	10720185.	0.998341	
22	172.	10860816.	0.942485	W
23	550.	10933552.	1.002483	
24	525.	11809535.	0.958124	W
25	575.	14282833.	1.016905	
26	379.	16399449.	1.008288	
27	529.	16683572.	0.936939	W
28	353.	17446200.	0.948807	
29	698.	19064404.	0.998195	
30	177.	19707808.	1.001903	
31	604.	32436285.	0.988474	
32	772.	34064498.	0.919667	W
33	1520.	34444009.	0.965834	



LINE FITTED BY E02ABF:
CONSTANT TERM = 0.971391
COEFF. OF X = 0.004983
GOODNESS OF FIT = 0.002688

CONTRACTOR 122. FREQUENCY 22.

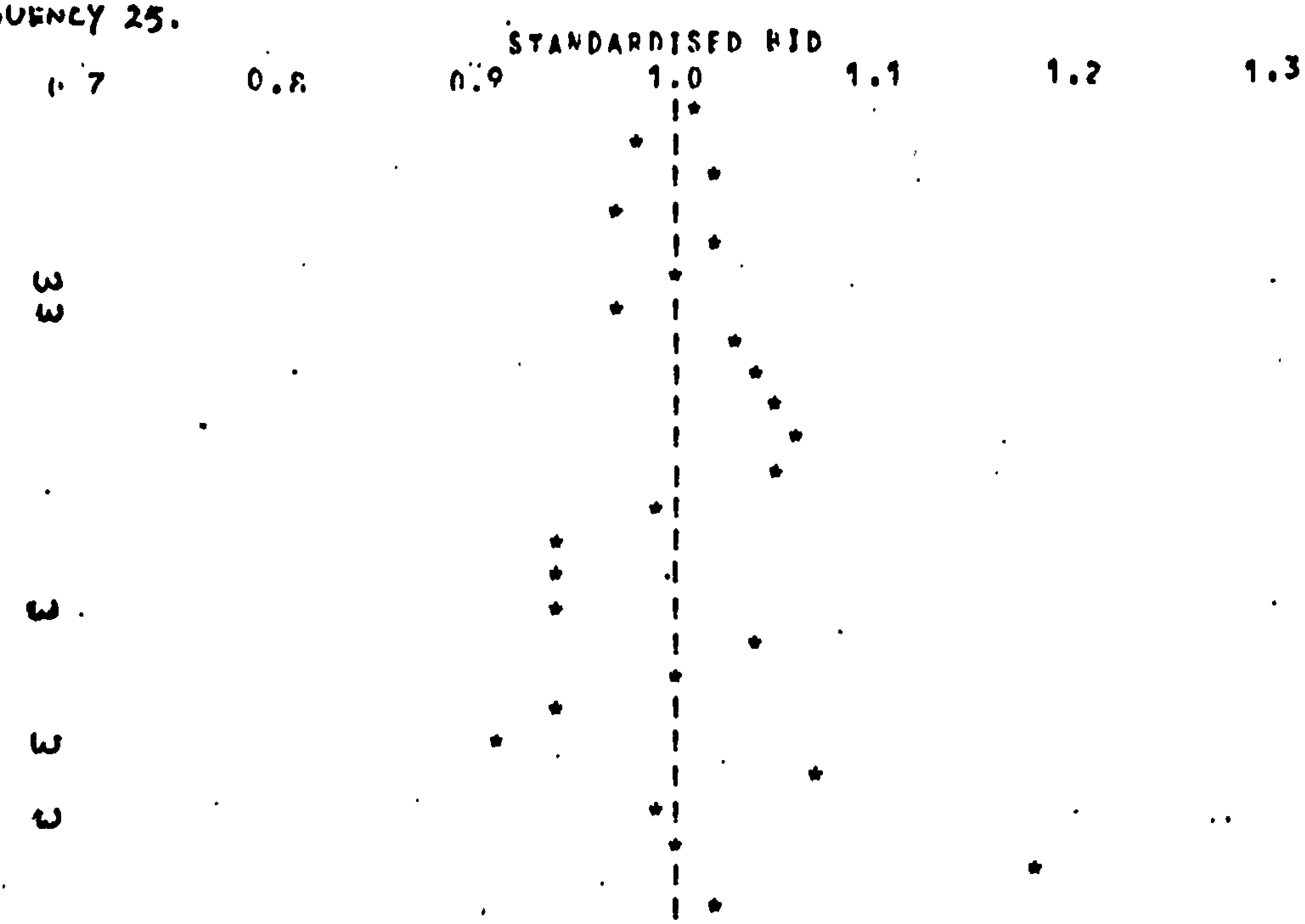
X	CONTRACT	MEAN BID	STD. BID	
1	79.	4301349.	1.044465	
2	273.	6502757.	1.027757	
3	287.	8190540.	0.954755	
4	527.	8204610.	1.121521	
5	154.	8939785.	0.648517	W <-
6	281.	13305785.	1.067205	
7	27.	13745104.	1.085099	
8	634.	16129075.	0.990757	
9	575.	16282833.	1.007190	
10	192.	16560105.	1.070041	
11	153.	16905305.	1.052924	
12	973.	17774024.	0.950408	W
13	152.	16578624.	1.170942	
14	177.	19707808.	1.029541	
15	673.	20023931.	1.058753	
16	948.	28426761.	1.030719	
17	668.	29815934.	0.977195	
18	347.	30160337.	0.961196	
19	234.	36692757.	0.985481	
20	181.	41093350.	1.035677	
21	666.	44308145.	1.209034	
22	554.	51605596.	1.052211	



LINE FITTED BY E02ABF:
CONSTANT TERM = 1.032597
COEFF. OF X = 0.045884
GOODNESS OF FIT = 0.011270

CONTRACTOR 300. FREQUENCY 25.

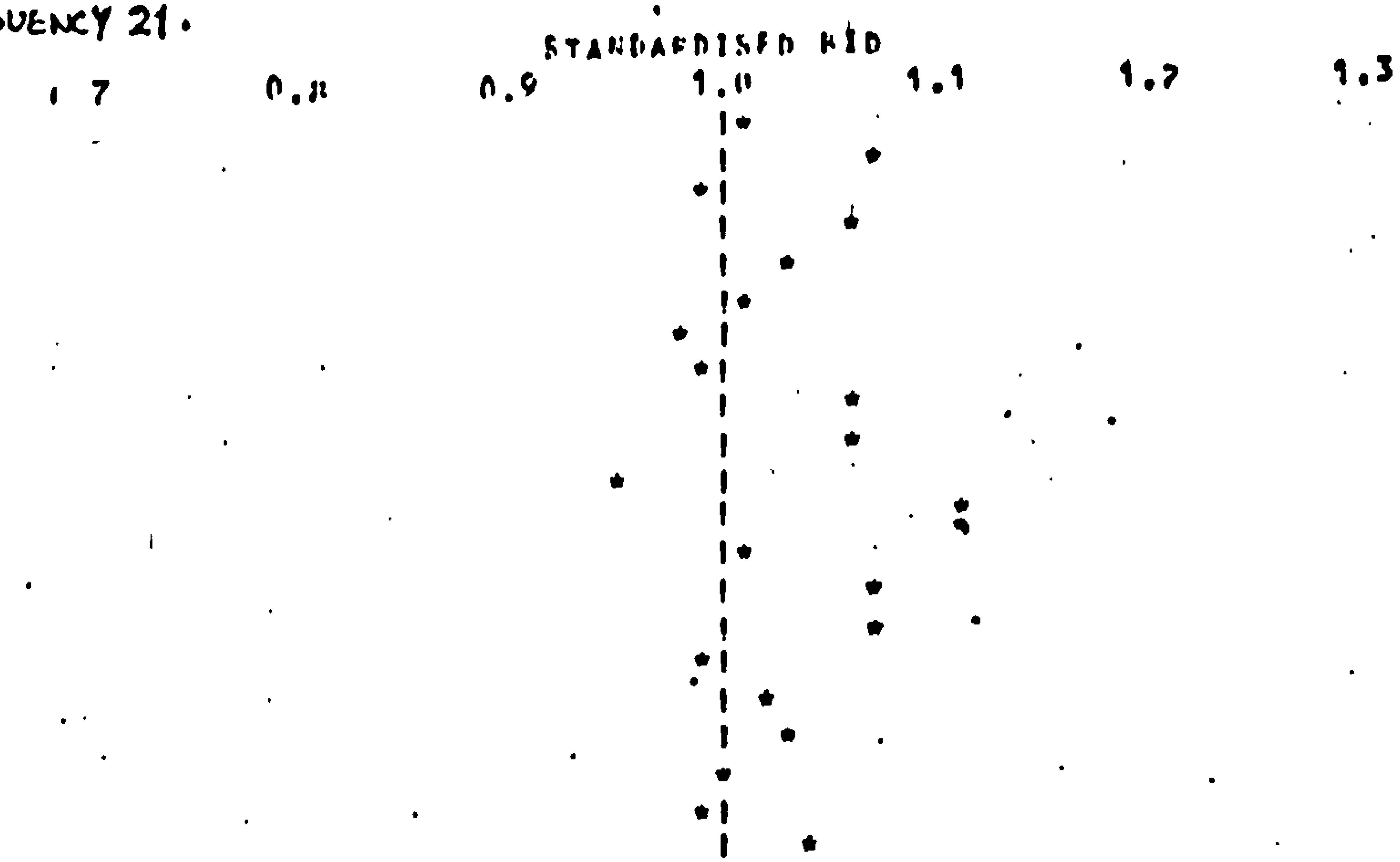
X	CONTRACT	MEAN BID	STD. BID
1	1558.	590184.	1.007395
2	714.	711603.	0.983195
3	854.	1124235.	1.022918
4	1253.	1268663.	0.973468
5	661.	1733278.	1.016571
6	1148.	2498112.	0.998354
7	657.	2778796.	0.972314
8	444.	2894587.	1.031186
9	182.	3412377.	1.040330
10	1553.	3761000.	1.046377
11	1143.	3761173.	1.062208
12	1554.	3778026.	1.053462
13	1417.	3923050.	0.993105
14	205.	4181634.	0.939346
15	556.	5476408.	0.941858
16	1528.	5973327.	0.936831
17	328.	7084789.	1.044491
18	1286.	8308667.	1.004579
19	511.	9455225.	0.939173
20	531.	9519775.	0.913887
21	482.	9552636.	1.072547
22	1153.	10046500.	0.993381
23	534.	10579635.	0.997199
24	1676.	19503000.	1.177050
25	610.	24056437.	1.021889



LINE FITTED BY E02ABF:
CONSTANT TERM = 1.023656
COEFF. OF X = 0.033753
GOODNESS OF FIT = 0.002954

CONTRACTOR 353. FREQUENCY 21.

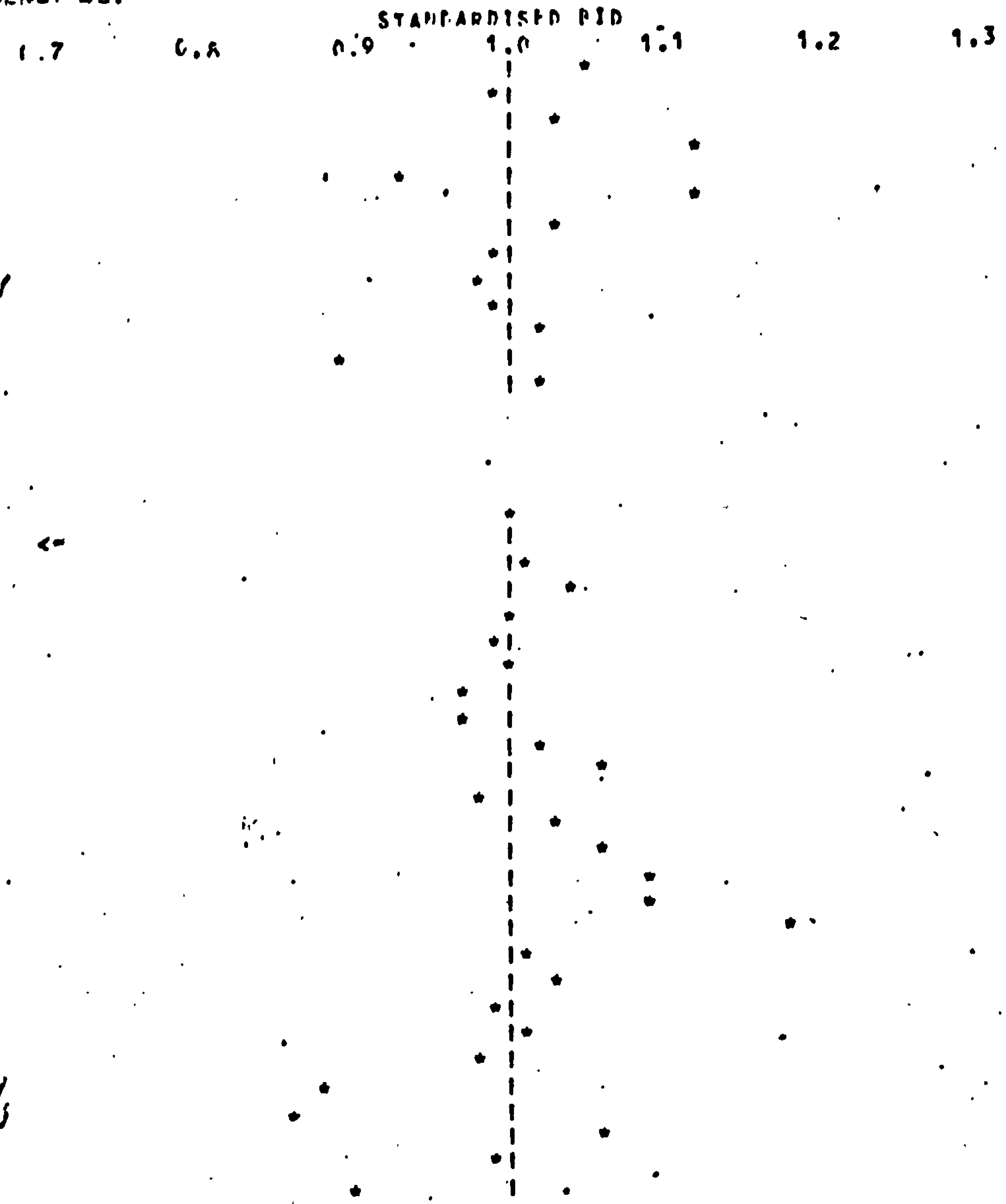
X	CONTRACT	MEAN BID	STD. BID
1	1208.	2118511.	1.008016
2	1169.	6873938.	1.066347
3	638.	8766607.	0.996084
4	681.	12737538.	1.060844
5	555.	13101268.	1.026610
6	1117.	13566491.	1.009016
7	1174.	14153762.	0.982459
8	667.	14992631.	0.990487
9	686.	15146347.	1.059522
10	634.	16129075.	1.055237
11	649.	18098129.	0.950374
12	1679.	18402618.	1.167451
13	698.	19064404.	1.006063
14	637.	20367643.	1.067723
15	633.	20370298.	1.065866
16	665.	27785463.	0.992005
17	998.	28426761.	1.017351
18	668.	29815934.	1.033005
19	666.	44306145.	0.997559
20	1000.	49678272.	0.994862
21	694.	59424333.	1.039078



LINE FITTED BY E02ABF:
CONSTANT TERM = 1.022997
COEFF. OF X = -0.007695
GOODNESS OF FIT = 0.001500

CONTRACTOR 341.   FREQUENCY 40.

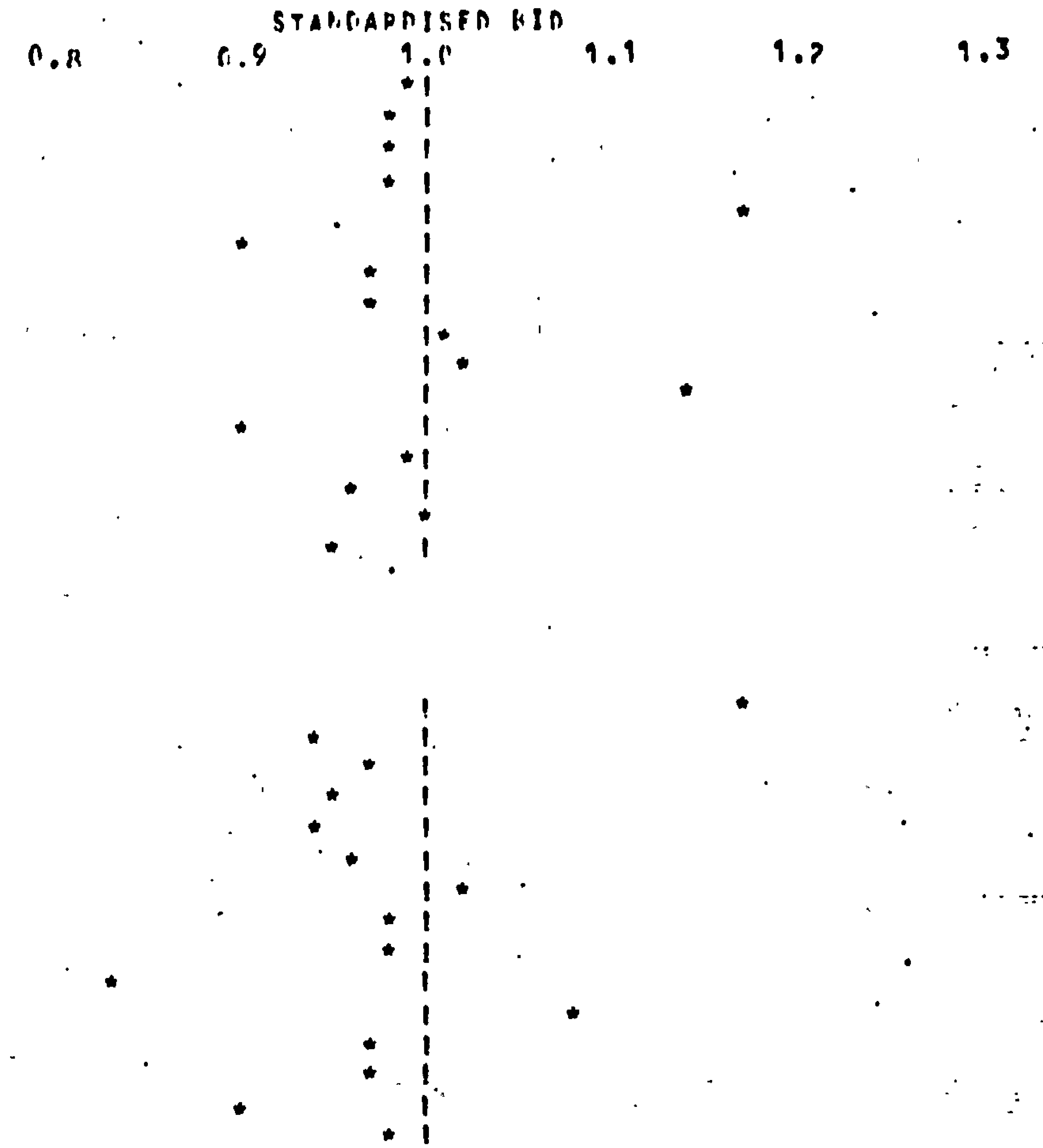
X	CONTRACT	MEAN BID	STD. BID	
1	248.	471183.	1.052489	
2	354.	551621.	0.992330	
3	706.	562682.	1.028197	
4	219.	586343.	1.124704	
5	1464.	612428.	0.933988	W
6	1785.	625835.	1.115150	
7	732.	652677.	1.032977	
8	734.	667555.	0.991890	
9	1467.	835460.	0.978700	W
10	58.	853029.	0.993665	
11	705.	960810.	1.021274	
12	491.	1149782.	0.890689	
13	737.	1265325.	1.017557	
14	865.	1617817.	0.997023	
15	736.	2095610.	0.608147	W <-
16	1564.	2171355.	1.006975	
17	642.	2587032.	1.036461	
18	887.	2606575.	1.002081	
19	781.	2767020.	0.987344	W
20	771.	2913635.	1.002459	
21	641.	2916873.	0.967557	
22	614.	2917038.	0.967502	
23	261.	3029297.	1.018864	
24	262.	3108311.	1.055894	
25	620.	3267659.	0.978463	
26	338.	3286684.	1.034476	
27	760.	3289112.	1.059435	
28	362.	3368523.	1.091390	
29	382.	3465323.	1.086243	
30	618.	3724236.	1.181040	
31	815.	3797757.	1.010465	
32	624.	3851590.	1.030452	
33	764.	4267124.	0.992612	
34	1382.	4424960.	1.011538	
35	643.	6036390.	0.976126	
36	172.	6416314.	0.878928	W
37	1486.	6784527.	0.874172	W
38	1169.	6873938.	1.058345	
39	361.	15080259.	0.988448	
40	588.	22530830.	0.899084	



LINE FITTED BY E02ABF:
CONSTANT TERM = 0.966344
COEFF. OF X = -0.047597
GOODNESS OF FIT = 0.007965

CONTRACTOR 38. FREQUENCY 31.

X	CONTRACT	MEAN BID	STD. BID	
1	1009.	1992984.	0.993570	
2	261.	3029297.	0.975002	
3	262.	3108311.	0.981614	
4	260.	3289112.	0.984766	
5	102.	4055527.	1.173092	
6	1102.	4817603.	0.904833	
7	1087.	5394689.	0.967367	
8	1087.	5394689.	0.967307	
9	1024.	5592840.	1.005303	
10	263.	6145859.	1.024502	
11	370.	7347216.	1.144515	
12	1195.	7502655.	0.899580	
13	527.	8204610.	0.989776	
14	638.	8766602.	0.964516	W
15	380.	10975817.	0.999857	
16	509.	11160436.	0.954724	
17	166.	12555797.	1.174237	
18	1117.	13565491.	0.939369	W
19	1124.	14153262.	0.973737	W
20	686.	15148346.	0.952475	
21	385.	16067273.	0.944093	W
22	192.	16560105.	0.963686	
23	770.	16658580.	1.023497	
24	153.	16905305.	0.978537	
25	186.	17267900.	0.980779	
26	1679.	18402618.	0.827219	
27	897.	19465779.	1.081385	
28	1116.	22951592.	0.968190	
29	998.	28426761.	0.970916	
30	275.	35954886.	0.903994	W
31	1000.	49878272.	0.978900	



LINE FITTED BY E02ABF:
CONSTANT TERM = 0.970790
COEFF. OF X = -0.033981
GOODNESS OF FIT = 0.005412

6.0 THE ACCURACY OF DESIGNERS AND OTHERS IN ESTIMATING TENDER PRICES

6.1 Reasons for Investigation and Analysis of Designers' Estimating

Reason

The designers and/or professional advisors to the clients of the construction industry are required to produce estimates of the cost to the client of proposed construction work. The client uses these estimates in preparing budgets and in assessing the economic feasibility of any proposed scheme. The client's cost is made up of several items, a major one being the monies paid to the contractor, that is the contractor's price. The designer or professional advisor is therefore required to produce estimates of the contractor's price. It is not always clear precisely what the designer or professional advisor is estimating, for example it could be the tender price or the final account. The difference generally being the amounts settled by claims. In the data there were designers' estimates and these were understood to be estimates of the tender price.

Contractors produce estimates of their cost of executing a contract and add a mark-up to produce a tender price. In many companies the 'cost' estimate is based on rates that already have a mark-up included, therefore the two stage process of cost estimate, then mark-up is reduced to one stage. This is understood to be the case with the majority of contractors whose bids are represented in the data. The contractor would be interested in an 'accurate' estimate of the tender price as a check for his own figures and as a means of calculating his chances of winning given his particular tender price. Whittaker[3] and Grinyer and Whittaker[13] based their approach to estimating probabilities of winning on an estimate of the mean tender price. The accuracy of estimating the mean bid required by Grinyer and Whittaker is +1% to -3.5%[13]. However, Curtis and Maines[14] on commenting on Grinyer and Whittaker's work stated "It is impossible to forecast the mean bid for a contract to the required accuracy". Thus the situation is that contractors would like to know accurate estimates of either mean or lowest tender prices or bids and another group, the designers, are producing estimates. The accuracy of these designers' estimates needs to be established for three reasons. One is to quantify the reliability of such estimates and the second is as a basis for comparing the accuracy of alternative estimating procedures. The third reason is to produce correction factors should the designer's estimating show any bias with respect to contract value and/or number of bidders.

The objective of this exercise was thus to evaluate the independently produced designers' estimates as a predictor of either the mean or the lowest bid. In addition the accuracy of a purely numerical approach, namely the use of regression analysis, is also examined.

Analysis

The analysis was undertaken for both buildings contracts and roads contracts and these were analysed separately.

In the data there were 132 buildings contracts and 168 roads contracts which had designers' estimates. For each contract which had a designer's estimate the ratios of

M = (mean bid/designer's estimate) x 100%

and L = (lowest bid/designer's estimate) x 100%

were calculated. The mean of M and L were calculated as

$$\bar{M} = \sum_{i=1}^{n} \frac{Mi}{n} \quad \text{or} \quad \bar{L} = \sum_{i=1}^{n} \frac{Li}{n}$$

where n is the number of contracts. The standard deviation of M and L were calculated as

$$\text{S.D of M} = \sqrt{\sum_{i=1}^{n} \frac{(Mi-\bar{M})^2}{n-1}}$$

and

$$\text{S.D of M} = \sqrt{\sum_{i=1}^{n} \frac{(Mi-\bar{M})^2}{n-1}}$$

The results of these calculations were as shown in table 6.1.

Table 6.1 Mean and Standard deviation of bids/Designers' estimates for Buildings and Roads Contracts

		Buildings Contracts	Roads Contracts
M	Mean of (Mean Bid/Designer's Estimate) x 100%	112.64%	108.20%
	Standard Deviation of Mean Bid/Designer's Estimate)x 100%	14.27%	19.15%
L	Mean of (Lowest Bid/Designer's Estimate) x 100%	105.17%	101.45%
	Standard Deviation of (Lowest bid/Designer's Estimate) x 100%	13.805%	18.632%
	Number of Contracts	132	168

For buildings contracts the designers over-estimate both the mean and lowest bid by 12.69% and 5.17% respectively but this could be removed by correction factors. The more interesting figures are the standard deviations of 14.27% and 13.805% which are measuring the spread of the designers' estimates about the mean and lowest bid after correcting for over-estimating, and therefore is a measure of the accuracy of the designers' estimate.

For roads contracts the designers over-estimate both the mean and lowest bid by 8.20% and 1.45% respectively. The standard deviations, or measure of accuracy for roads contracts, is much higher at 19.15% and 18.632% for mean and lowest bids respectively. Section 4.1 reported the higher variability in the bids for roads contracts and here again they are shown to be much more variable. The ratio of the variances of buildings to roads contracts given in section 4 is 0.599 (i.e. $\frac{0.0042717}{0.007038}$ from table 4.1). The ratio of variances of designers' estimating accuracy mean bids for buildings and roads contracts is 0.555 (i.e. $\frac{(0.1427)^2}{(0.1915)^2}$ from table 6.1) and for lowest bids is 0.548 (i.e. $\frac{(0.13805)^2}{(0.18632)^2}$ from table 6.1). Thus in the distribution of bids the buildings contracts show 0.599 of the variance of the roads contracts. In the designers estimating the building contracts show either 0.555 (for mean bids) or 0.548 (for lowest bid) of the variance of the roads estimates. For mean bids the ratio of designers' estimate variance/bid variance is 4.82 (i.e. $\frac{(0.1427)^2}{0.0042217}$ from tables 4.1 and 6.1) for buildings and 5.21 (i.e. $\frac{(0.1915)^2}{0.007038}$ from tables 6.1 and 4.1) for roads contracts. These figures indicate that there is much more variability in the designers' estimates than in the bids themselves. The figures also indicate that the increase in variability from bids to designers' estimates is greater for roads contracts than for buildings contracts. However figures given in table 6.1 for standard deviations of either (mean or lowest bid/designer's estimate) are a standard by which any improved estimating accuracies can be compared. The figures given in table 6.1 indicate that the estimates are not accurate enough for purposes of computing the probability of winning with a particular bid as suggested by Whittaker.

Other than the ratio of $\left(\frac{\text{Actual}}{\text{Predicted}}\right)$ the alternative method of expressing the designers' accuracy is to calculate the residuals and the standard deviation of the residuals. The residuals used in this exercise were for both buildings and roads contracts

(lowest bid - Designer's estimate)

and (mean bid - Designer's estimate).

Both of these were expressed as percentages of either the lowest or mean bid where appropriate or of the designer's estimate. The full results showing residuals in absolute and percentage terms are shown in appendix R in table R.1 for buildings contracts and table R.2 for roads contracts. Table 6.2 below summarises these results.

Table 6.2 Mean and Standard Deviation of Residuals (Bid - Designer's Estimate) for Buildings and Roads Contracts

Residuals (%)	Buildings Contracts		Roads Contracts	
	Mean	Standard Deviation	Mean	Standard Deviation
(Low Bid-Designer's Estimate)/ Low Bid	- 2.44%	16.48%	2.59%	22.20%
(Mean Bid-Designer's Estimate)/ Mean Bid	- 9.51%	12.60%	-4.35%	18.98%
(Low Bid-Designer's Estimate)/ Designer's Estimate	- 5.16%	16.63%	-1.44%	20.14%
(Mean Bid-Designer's Estimate)/ Designer's Estimate	-12.63%	16.08%	-8.19%	20.03%

Again this alternative way of presenting the measure of accuracy produces the same conclusions. The accuracy of designers in estimating the lowest bid of buildings contracts is above 16%, the accuracy of predicting mean bids depending on how it is calculated ranges from 12.60% to 16.08%. The accuracy of designers in estimating the lowest bids of roads contracts is, depending on the method of taking percentages, 20.14%

to 22.20% and for mean bids is 18.98% to 20.03%. Again the importance of these measures is as a basis for comparison with any proposed alternative method of producing estimates.

6.2 Correlation between designers' estimates and a) number of bidders and b) contract values

a) Number of Bidders

The designers' estimates were examined for possible correlations with the number of bidders, that is do designers'estimates change systematically with increasing number of bidders.

As before buildings and roads contracts were treated separately.

The analysis undertaken was as follows.

1) The contracts for which designers'estimates were known were grouped by 'n' where n was the number of bidders.

2) For each 'n' the mean of (mean bid/designer's estimate) and of (lowest bid/designer's estimate) was calculated for the group of contracts with the same number of bidders. Other statistics calculated were standard deviation, skewness and kurtosis. (Appendix C shows the calculations for these statics, no corrections for small samples were used).

The results of these calculations are shown in tables 6.3 and 6.4 for buildings and roads contracts respectively.

3) The mean of (mean bid/designer's estimate) and (lowest bid/designer's estimate) for each group of contracts with the same number of bidders were plotted against 'n' the number of bidders. Figure 6.1 is the plot for buildings contracts and figure 6.2 is the plot for roads contracts.

Figure 6.1 The Lowest Bid/designers' estimate and mean bid/designers' plotted against 'n' the number of bidders.

Table 6.3 Buildings Contracts : Statistics of(mean bid/designer's estimate)and (lowest bid/designer's estimate)

STATS OF LOWEST/DESIGN

N	SAMPLE SIZE	MEAN	VARIANCE	STANDARD DEVIATION	SKEWNESS	KURTOSIS
2	5	120.71	3.910	1.9774	-0.2777	
3	8	110.99	30.655	5.5367	-0.0303	4.3081
4	21	109.24	61.554	7.8456	-0.0169	3.1990
5	25	114.55	331.642	18.2110	0.0192	10.5076
6	19	109.35	145.182	12.0491	0.0193	5.6217
7	13	108.59	417.887	20.4423	0.0116	7.9831
8	8	100.64	193.232	13.9008	-0.0292	10.7164
9	5	101.53	52.106	7.2184	-0.0484	8.5104
10	12	96.29	265.846	16.3048	0.0187	6.5947
11	10	91.34	129.166	11.3651	0.0206	3.8984
12	4	92.40	220.911	14.8631	0.0016	7.5522
13	2	70.57	0.612	0.7826		
14	1	81.29				
15	1	106.34				
16	0					
17	2	67.17	117.635	10.8460		
18	0					

STATS OF MEAN/DESIGN

N	SAMPLE SIZE	MEAN	VARIANCE	STANDARD DEVIATION	SKEWNESS	KURTOSIS
2	5	122.70	0.220	0.4685	4.0890	
3	8	116.84	37.101	6.0911	0.0572	4.7668
4	21	114.00	56.724	7.5315	-0.0216	3.2291
5	25	120.64	455.837	21.3503	0.0165	13.0661
6	19	115.83	131.036	11.4471	0.0176	4.4241
7	13	116.40	400.160	20.0040	0.0125	7.5627
8	8	109.52	117.375	10.8340	-0.0416	10.1535
9	5	109.80	53.824	7.3365	-0.0362	9.1065
10	12	106.91	277.632	16.6623	0.0174	7.0737
11	10	100.81	133.559	11.5568	0.0160	3.0404
12	4	109.14	210.785	14.5184	-0.0232	16.5462
13	2	77.60	3.529	1.8784		
14	1	90.26				
15	1	122.32				
16	0					
17	2	80.93	40.724	6.3815		
18	0					

Table 6.3 Buildings Contracts : Statistics of(mean bid/designer's estimate)and (lowest bid/designer's estimate)

STATS OF LOWEST/DESIGN

N	SAMPLE SIZE	MEAN	VARIANCE	STANDARD DEVIATION	SKEWNESS	KURTOSIS
2	5	120.71	3.910	1.9774	-0.2777	
3	8	110.99	30.655	5.5367	-0.0303	4.3081
4	21	109.24	61.554	7.8456	-0.0169	3.1990
5	25	114.55	331.642	18.2110	0.0192	10.5076
6	19	109.35	145.182	12.0491	0.0193	5.6217
7	15	108.59	417.887	20.4423	0.0116	7.9831
8	8	100.64	193.232	13.9008	-0.0292	10.7164
9	5	101.53	52.106	7.2184	-0.0484	8.5104
10	12	96.29	265.846	16.3048	0.0187	6.5947
11	10	91.34	129.166	11.3651	0.0206	3.8984
12	4	92.40	220.911	14.8631	0.0016	7.5522
13	2	70.57	0.612	0.7826		
14	1	81.29				
15	1	106.34				
16	0					
17	2	67.17	117.635	10.8460		
18	0					

STATS OF MEAN/DESIGN

N	SAMPLE SIZE	MEAN	VARIANCE	STANDARD DEVIATION	SKEWNESS	KURTOSIS
2	5	122.70	0.220	0.4685	4.0890	
3	8	116.84	37.101	6.0911	0.0572	4.7668
4	21	114.00	56.724	7.5315	0.0216	3.2291
5	25	120.64	455.837	21.3503	0.0165	13.0661
6	19	115.83	131.036	11.4471	0.0176	4.4241
7	15	116.40	400.160	20.0040	0.0125	7.5627
8	8	109.52	117.375	10.8340	-0.0416	10.1535
9	5	109.80	53.824	7.3365	-0.0362	9.1065
10	12	106.91	277.632	16.6623	0.0174	7.0737
11	10	100.81	133.559	11.5568	0.0160	3.0404
12	4	109.14	210.785	14.5184	-0.0232	16.5462
13	2	77.60	3.529	1.8784		
14	1	90.26				
15	1	122.32				
16	0					
17	2	80.93	40.724	6.3815		
18	0					

Figure 6.2 The Lowest Bid/designers' estimate and mean bid/designers' estimate plotted against 'n' the number of bidders.

Table 6.4 Roads Contracts : Statistics of (mean bid/designer's estimate) and (lowest bid/designer's estimate)

STATS OF LOWEST/DESIGN

N	SAMPLE SIZE	MEAN	VARIANCE	STANDARD DEVIATION	SKEWNESS	KURTOSIS
2	15	122.28	639.480	25.2879	-0.0033	3.9431
3	26	111.97	552.250	23.5000	0.0071	5.0537
4	36	97.16	227.280	15.0758	0.0137	4.0404
5	30	100.60	341.235	18.4725	0.0056	3.3092
6	25	92.70	378.927	19.4660	-0.0053	7.3670
7	15	98.39	106.371	10.3136	0.0170	2.9440
8	13	93.99	213.063	14.5967	0.0085	4.0828
9	3	96.11	502.070	22.4069	0.0093	
10	4	92.92	83.059	9.1137	-0.0088	7.8692
11	1	83.68				
12	2	107.90	101.135	10.0566		
13	1	102.00				
14	1	87.48				
15	0					
16	0					
17	0					
18	0					

STATS OF MEAN/DESIGN

N	SAMPLE SIZE	MEAN	VARIANCE	STANDARD DEVIATION	SKEWNESS	KURTOSIS
2	15	124.88	743.486	27.2669	-0.0015	3.8448
3	26	117.06	538.742	23.2108	-0.0076	5.2088
4	36	105.65	250.243	15.8191	0.0174	4.7397
5	30	107.72	352.276	18.7690	0.0072	3.5552
6	25	99.55	371.306	19.2693	-0.0054	8.1262
7	15	106.97	186.836	13.6688	0.0166	3.5915
8	15	100.89	201.009	14.1777	0.0140	5.1335
9	3	103.84	588.220	24.2533	0.0103	
10	4	100.17	36.263	6.0219	-0.0585	12.9319
11	1	88.71				
12	2	117.06	143.952	11.9980		
13	1	104.65				
14	1	93.99				
15	0					
16	0					
17	0					
18	0					

Buildings Contracts

Inspection of figure 6.1, the plot of the mean of (mean bid/designer's estimate) and mean of (lowest bid/designer's estimate) against the number of bidders, shows a strong negative correlation. The measure of correlation used was Spearman's rho described in section 4.0 and was found to be - 0.97 for (low bid/designer's estimate) v number of bidders and - 0.83 for (mean bid/designer's estimate) v number of bidders. Both these values indicate very strong negative correlation. That is as the number of bidders increases the value of both the mean of (mean bid/designer's estimate) and mean of (lowest bid/designer's estimate) decreases. From previous knowledge of the effect of the number of bidders and from establishing that the designer's estimate was produced without knowing the number of bidders the expected form of this plot was as shown in figure 6.3.

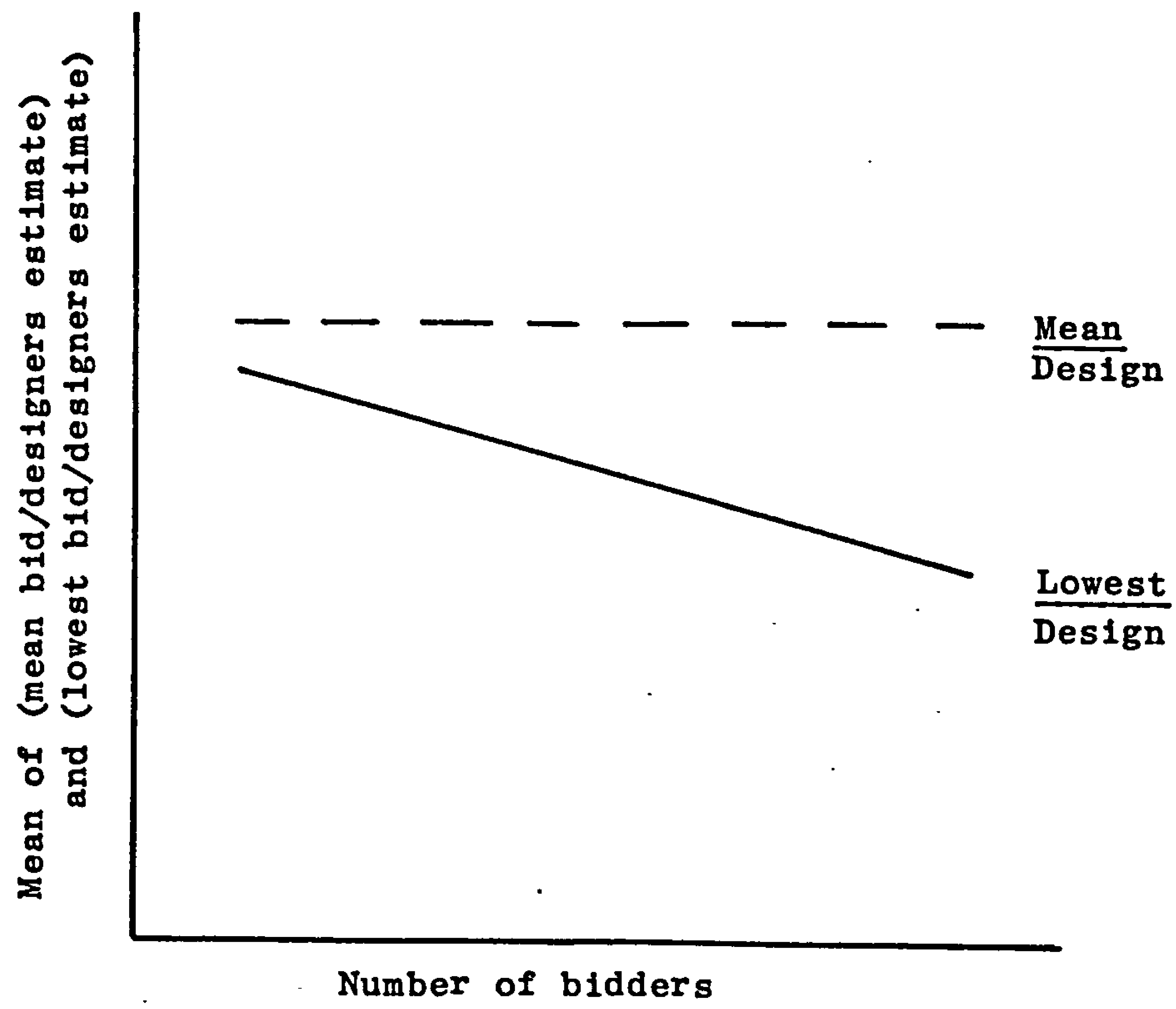


Figure 6.3 Expected form of mean bid/designer's estimate and low bid/designer's estimate plotted against the number of bidders.

The form shown in figure 6.3 is a negative correlation with the mean of (lowest bid/designer's estimate) since the designer's estimate is independent of the number of bidders and, as indicated in section 4.4, as the number of bidders increases the lowest bidder tends to decrease. Therefore the negative correlation with the mean of (lowest bid/designer's estimate) was expected. However the negative correlation with the mean of (mean bid/designer's estimate) was not expected. The number of bidders has theoretically no depressing effect on the mean bid. The explanation of the observed negative correlation with the mean of (mean bid/designer's estimate) can only be surmised as a general depression in tender prices caused by the increase in competition resulting from the increase in the number of bidders. Thus there exists two possible mechanisms that depress tender prices with increasing number of bidders. One is that the greater the number of bidders the lower in the distribution of bids is the lowest bid and the other is that the mean of the distribution of bids is reduced.

Roads Contracts

Inspection of figure 6.2, the plot of the mean of (mean bid/designer's estimate) and mean of (lowest bid/designer's estimate) against the number of bidders, shows a less clearly defined correlation than was found for buildings contracts. However if figure 6.2 is examined for up to eight bidders a negative correlation with number of bidders for both mean of (mean bid/designer's estimate) and mean of (lowest bid/designer's estimate) is observed. Greater than eight bidders there is some confusion but the sample sizes are small, that is the number of contracts with nine or more bidders is small. For example there are only three contracts with nine bidders and four with ten bidders and one for eleven bidders. Thus it is argued that the plot in figure 6.2 for nine or more bidders can be ignored. This leaves substantially the same conclusions as were made for the buildings contracts. That is that both mean of (lowest bid/designer's estimate) and mean of (mean bid/designer's estimate) have a negative correlation with the number of bidders. The Spearman rho values calculated for all bidders up to 14 is - 0.48 for (lowest bid/designer's estimate) v number of bidders and - 0.51 for (mean bid/designer's estimate) v number of bidders. The same values calculated for up to eight bidders becomes -0.86 and - 0.75. The negative correlation with mean of (lowest bid/designer's estimate) was expected and is consistent with previous findings for the mean of (lowest bid/designer's estimate). The negative correlation between the number of bidders and mean of (mean bid/designer's estimate) could be taken to indicate depression of tender prices caused by increased competition as a direct result of the increase in the number of bidders.

b) Contract Value

The designers' estimates were examined for possible correlations with the contract value, that is do designers estimates change systematically with increasing contract value.

As before buildings and roads contracts were examined separately.

As correlations had been identified with the number of bidders the examination for possible correlations with the contract value was undertaken with contracts grouped by 'n' the number of bidders. The analysis was as follows.

1) The contracts for which designers estimates were known were grouped by 'n' the number of bidders.

2) Within each group of contracts with the same number of bidders the contracts were ranked in ascending order of contract value. Contract value being taken as the mean bid.

3) For each group of contracts the (mean bid/designer's estimate) and (lowest bid/designer's estimate) were calculated and listed in the rank order of contract value. These ratios were examined for correlations with contract value by calculating Spearman's rho.

Table 6.5 for buildings contracts and table 6.6 for roads contracts show the contracts grouped by the number of bidders and for each group the lowest bid, the (lowest bid/designer's estimate), the mean bid and the (mean bid/designer's estimate). The tables also summarise the calculated Spearman rho values. These results are presented ranked in the order of contract value. Inspection of tables 6.5 and 6.6 show that no strong correlations (either positive or negative) between either (mean bid/designer's estimate)or (lowest bid/designer's estimate) and contract value exist.

Examination of the values of Spearman's rho values in tables 6.5 and 6.6 show that some groups of 'n' bidders have slight positive correlations and some have slight negative correlations. In only a few cases are these correlations significant at the 10% level. It can therefore be safely concluded that there is no consistent pattern of correlation between the accuracy of designers estimates and contract value.

Table 6.5 Buildings Contracts

The lowest bid/designer's estimate and mean bid/designer's estime grouped by 'n' and ranked in order of contract value

No correlation between size and accuracy of designer's estimate is observed

NBIDS = 2

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
16074697.	120.981	16269861.	122.450
21710799.	122.545	21854367.	123.242
29718905.	118.617	30069872.	122.412

NBIDS = 3

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
10561749.	114.804	11307284.	122.907
10561749.	103.582	11152788.	109.378
22205000.	110.077	23621601.	117.099
29205952.	110.580	30141604.	114.123
29205962.	114.932	30141668.	118.614
31270000.	119.386	33440000.	127.671
33220000.	111.156	33654250.	113.279
46486745.	103.368	50224912.	111.680

NBIDS = 4

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
7178549.	105.341	7737014.	113.536
12134734.	95.595	13770703.	108.483
12272709.	96.347	12669832.	101.035
13464404.	96.037	14166985.	101.048
13540682.	112.780	14409254.	120.014
14949907.	108.031	15534799.	110.815
15876016.	115.883	16477463.	120.273
16598500.	103.028	17282399.	107.273
16939031.	101.977	17831189.	107.545
17800000.	112.997	18545874.	117.732
18343123.	124.525	19094112.	129.623
22944076.	107.500	23462669.	109.927
23600000.	118.623	23943194.	120.348
24345608.	113.547	24971309.	116.466
26500000.	106.604	27100000.	109.018
26600000.	107.006	27125000.	109.118
42370874.	120.510	43204873.	122.882
42370874.	111.834	43204873.	114.035
44399620.	109.564	46211434.	114.035
60742749.	111.522	62702913.	115.121
81610000.	114.839	89511167.	125.957

NBIDS = 5

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
8796000.	117.906	9687335.	129.854
8845496.	118.570	9629925.	129.085
12705396.	112.424	13790393.	122.024
12989000.	117.422	13133200.	118.726
13897930.	99.129	14564726.	103.885
14275000.	100.175	15179506.	106.523
14518792.	126.038	14984305.	130.079
15812000.	108.752	16691279.	114.800
18233604.	113.295	19067801.	118.479
18233604.	98.188	19067801.	102.681
21537322.	111.853	22073322.	114.637
22948824.	115.903	24177539.	122.109
23670000.	108.401	24329141.	111.420
25021956.	122.424	25550082.	125.008
26400000.	96.305	27836800.	101.546
31925174.	103.749	33499156	108.866
35455000.	94.002	36401163.	96.510
35895000.	109.846	36745852.	112.450
39059302.	180.046	43877390.	202.255
43088553.	131.583	45816045.	139.912
44253546.	138.359	44796666.	140.058
45500000.	110.261	48793513.	118.242
133200000.	100.103	140517867.	105.603

NBIDS = 6

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
6228256.	98.996	6505226.	103.398
7665000.	115.684	8346115.	125.964
12580000.	114.364	13165871.	119.690
13415265.	112.503	14351377.	120.353
15130272.	110.446	16650553.	121.537
16245220.	106.785	17017927.	111.864
16958968.	103.333	17574569.	107.084
18667542.	106.664	19714964.	112.648
18818656.	117.617	20114601.	125.716
24857656.	104.445	25259117.	106.131
26501839.	98.821	27769028.	104.534
29379456.	102.785	30873039.	108.010
29547030.	109.620	32468167.	120.458
41282280.	96.803	47675025.	111.793
43635665.	107.677	45185818.	111.501
53500000.	141.278	54597000.	144.175
57956000.	84.731	64275590.	93.970
65984760.	122.194	68119308.	126.147
85605000.	122.862	87736872.	125.922

NBIDS = 7

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
6233810.	102.595	6625182.	109.036
6450089.	94.243	7047533.	102.963
6500000.	71.981	7448961.	82.490
10865435.	162.108	11286512.	168.390
14925927.	103.890	16321615.	113.604
15277389.	94.407	16730564.	103.587
17748254.	108.969	18743368.	115.078
20905000.	118.104	22339630.	126.209
35943116.	117.291	37963110.	125.882
38784000.	113.073	40177775.	117.156
69964268.	101.123	75730105.	106.566
73981982.	118.287	82985430.	132.682
112087001.	105.591	118719591.	111.839

NBIDS = 8

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
4495000.	67.965	5581458.	84.392
9398879.	101.599	9782047.	105.741
15783425.	105.177	16970854.	113.090
17813000.	107.757	18946219.	114.612
18331000.	104.823	19515201.	111.595
29760604.	98.073	33898875.	111.710
38379902.	106.755	41993609.	116.806
41364405.	112.941	43284564.	118.183

NBIDS = 9

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
12374000.	107.059	13754960.	119.007
13000000.	90.508	14212698.	98.951
…	…	…	…
23304465.	108.785	24046361.	112.248
34868906.	101.706	38126469.	111.208
119971400.	99.605	129596976.	107.596

NBIDS = 10

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
5190405.	94.393	6037101.	109.791
5533890.	91.043	6279016.	103.502
5549158.	107.046	5908651.	113.981
6879511.	85.871	9711707.	95.919
10291490.	82.828	11259102.	90.615
17927736.	98.145	21145579.	115.762
17980000.	112.209	18597540.	116.062
22194477.	99.027	24354772.	108.666
24980006.	86.442	29219984.	101.114
33710106.	81.220	36049635.	86.842
33782184.	80.373	39436526.	95.825
40369605.	136.860	50498970.	149.048

NBIDS = 11

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
7525742.	91.992	8198412.	100.214
7972472.	83.070	8420458.	87.738
8476000.	112.015	8826140.	116.642
9465267.	96.326	10139261.	103.185
17341562.	78.332	19151651.	86.508
19698560.	88.781	21652792.	97.590
21586152.	78.069	25973312.	93.936
24450470.	95.156	28911061.	112.465
35107000.	83.637	38529336.	91.790
42082317.	106.029	46829664.	117.990

NBIDS = 12

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
10664585.	79.389	11821080.	87.998
13950000.	79.696	19733493.	112.737
23532485.	104.520	25865641.	114.883
25664452.	106.008	29281949.	120.950

NBIDS = 13

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
5916013.	71.120	6565621.	78.929
8685000.	70.013	9461488.	76.272

NBIDS = 14

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
18574895.	81.293	20623755.	90.260

BUILDINGS CONTRACTS

Number of Bidders	Number of Contracts	Low bid/designer's estimate Spearman's rho	Mean bid/designer's estimate Spearman's rho
3	8	-0.45	-0.59
4	21	+0.47*	+0.32
5	23	-0.12	-0.06
6	19	+0.08	+0.33
7	13	+0.43	+0.38
8	8	+0.62	+0.81*
10	12	-0.20	+0.05
11	10	+0.01	+0.20

Spearman's rho calculated as $1 - \frac{6\sum D_i^2}{n(n^2-1)}$

where D_i is the difference in the rank order of the contract value and the Low or Mean Bid/designer's estimate. n is the number of contracts.

* Indicates significant correlation at 10% level two sided test, Conover[40].

Table 6.6 Roads Contracts

The Lowest Bid/Designer's estimate and Mean Bid/designer's estimate grouped by 'n' and ranked in size of contract order.

No correlation between size and accuracy of designer's estimate is observed.

NBIDS = 2

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
381250.	114.387	387428.	116.238
617265.	68.169	618392.	68.293
640824.	134.910	650411.	136.929
903800.	154.067	953913.	162.609
903800.	154.067	953913.	162.609
1072015.	107.341	1077550.	107.895
1098470.	109.462	1124235.	112.029
1525083.	102.891	1542630.	104.075

2494000.	121.659	2498112.	121.859
2943950.	99.141	2967700.	99.941
3109560.	142.969	3116967.	143.309
4799558.	107.852	4911542.	110.373
6659439.	126.533	6854719.	130.243
8620849.	164.892	8890424.	170.048
9980000.	125.856	10046500.	126.695

NBIDS = 3

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
446379.	68.458	542468.	85.195
536223.	103.265	550714.	106.055
546272.	111.489	551621.	112.581
707030.	100.814	713461.	101.751
737463.	101.493	760832.	104.709
769947.	128.139	786234.	130.850
870095.	65.798	908008.	68.665
878192.	113.518	918747.	118.761
899000.	98.454	923910.	101.182
1024098.	109.864	1149782.	123.347
1351210.	94.237	1386747.	96.715
1520000.	91.236	1603803.	96.267
1590000.	111.009	1617817.	112.951
1763000.	125.455	1794107.	127.669
1796000.	131.049	1864275.	136.031
1862660.	109.360	1892353.	111.103
1916565.	103.979	2302494.	124.917
2112780.	111.243	2152260.	113.322
2329806.	130.862	2344044.	131.662
2398731.	99.581	2441379.	101.352
3324920.	113.626	3797757.	122.420
3940012.	105.541	4482926.	120.084
4333230.	155.933	4427610.	159.329
4949562.	175.745	5132943.	182.257
6717455.	144.699	6841327.	147.367
10756000.	106.316	11022050.	108.946

NBIDS = 4

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
516834.	85.309	562662.	92.876
566210.	86.651	625835.	95.776
599726.	83.470	625300.	87.030
697019.	86.879	713485.	88.931
717181.	93.329	743352.	96.734
774679.	88.293	826023.	94.144
976359.	81.281	1111207.	92.507
1053388.	91.793	1102606.	96.082
1209352.	102.557	1284075.	108.893
1274439.	64.477	2095610.	106.022
1356240.	105.588	1382476.	107.631
1692960.	102.862	1782627.	108.310
1771000.	99.661	1824532.	102.674
2023000.	88.225	2323639.	101.336
2030678.	90.530	2119080.	94.471
2150875.	99.079	2294198.	105.681
2272479.	97.079	2592900.	110.767
2670000.	102.976	2894587.	111.638
2704000.	116.384	2842851.	122.359
3093535.	117.235	3177287.	120.409
3113570.	88.574	3435412.	97.730
3122450.	96.929	3267659.	101.436
3180250.	137.288	3491355.	150.718
3256790.	74.419	3499370.	79.962
3298000.	108.630	4426000.	145.784
3417808.	111.551	3502944.	114.330
3484666.	122.870	3742730.	131.970
3850000.	93.121	4074255.	98.545
4122461.	90.584	5147359.	113.104
4829995.	89.163	5054442.	93.311
4911672.	101.332	5188273.	107.039
5670007.	129.532	5808801.	132.702
5676000.	82.707	6096465.	88.834
6138710.	109.380	8555397.	112.025
10236156.	92.000	10660816.	97.614
21675517.	86.154	23689701.	94.160

NBIDS = 5

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
457000.	122.172	471185.	125.964
555000.	112.389	580343.	117.521
586334.	100.927	649549.	111.809
638507.	77.532	692042.	84.059
742120.	93.829	791627.	100.089
900330.	106.611	952221.	112.756
1076000.	111.856	1153257.	119.887
1120000.	139.122	1186000.	147.320
1125000.	139.743	1211272.	150.459
1197216.	76.401	1310883.	83.655
1542300.	96.394	1709505.	106.844
1675000.	112.904	1733278.	116.833
1789200.	85.434	1880830.	89.810
1944662.	61.238	2171355.	68.376
1993224.	102.747	2086260.	107.543
2494580.	89.934	3069244.	110.652
2697000.	100.149	2773796.	103.000
2749882.	118.709	2828194.	122.090
2789901.	95.020	2877389.	98.000
2804373.	80.399	3045262.	87.306
2968700.	102.453	3071958.	106.017
3086051.	102.066	3368191.	111.397
3770928.	84.161	4159866.	92.396
4647200.	95.537	5042199.	103.657
5202000.	90.446	5394689.	93.796
5202000.	90.446	5394689.	93.796
5371000.	118.893	5701649.	126.212
5863000.	75.509	6784527.	87.377
6768032.	111.687	7084789.	116.915
9904000.	123.402	10926763.	136.146

NBIDS = 6

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
539000.	86.795	590184.	95.037
693483.	86.685	773471.	96.684
851504.	90.233	900451.	97.715
886500.	92.751	927620.	97.075
903897.	87.024	960810.	92.503
929520.	99.752	996896.	106.983
1116125.	95.112	1290226.	109.949
1250464.	40.613	1366658.	44.386
1828751.	84.039	1989316.	91.417
2110600.	98.520	2263268.	105.647
2420000.	96.010	2587032.	102.636
2732000.	97.988	2767020.	99.244
2770500.	145.243	2917038.	152.926
2872887.	105.876	2913835.	107.385
3037142.	54.525	3825024.	68.221
3204408.	95.071	3405112.	101.026
3245156.	93.025	3465323.	99.336
3892575.	94.392	4181634.	101.402
4710500.	83.965	5052305.	90.062
4984074.	99.596	5484463.	109.595
5246890.	97.366	5595471.	103.835
5418060.	87.663	5713117.	92.436
8279699.	119.889	8572715.	124.132

NBIDS = 7

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
631103,	91.883	662555.	96.462
813422,	95.753	853029.	100.415
2120000,	87.299	2284323.	94.065
2330000,	99.124	2565752.	109.152
2581453,	95.563	2735734.	101.274
2933769,	96.170	3266684.	107.758
3275000,	84.427	3388523.	87.353
3989600,	112.515	4267124.	120.342
4352000,	85.042	4985384.	97.419
11315000,	108.485	11809535.	113.227
13317349,	98.009	13745104.	101.157
16920000,	109.015	20513502.	132.168
31388822,	115.799	35186441.	129.809

NBIDS = 8

LOWEST BID	LOWEST/DESIGN(%)	MEAN BID	MEAN/DESIGN(%)
739471,	85.830	783660.	90.959
1196266,	89.280	1265325.	94.433
1500717,	94.484	1606176.	101.123
1825720,	96.946	1974066.	104.824
1847910,	77.536	2118511.	88.890
2830000,	94.951	3029297.	101.638
3000000,	103.842	3160227.	109.388
3188290,	95.539	3289112.	98.560
3450800,	69.765	3761000.	76.037
4101275,	109.575	4301349.	114.921
6227909,	76.878	7211954.	89.025
8800647,	123.501	9455225.	132.686
16892000,	103.709	17774024.	109.120

ROADS CONTRACTS

Summary of correlations between contract value and (Low bid/designer's estimate) and (mean bid/designer's estimate)

Number of Bidders	Number of Contracts	Low bid/designer's estimate Spearman's rho	Mean bid/designer's estimate Spearman's rho
3	26	+0.51*	+0.63*
4	36	+0.26	+0.34
5	30	-0.09	-0.14
6	23	+0.41*	+0.29
7	13	+0.57*	+0.36
8	13	+0.36	+0.36

Spearman's rho calculated as $1 - \frac{6\sum D_i^2}{n(n^2-1)}$

where D_i is the difference in the rank order of the contract value and the low or mean bid/designer's estimate. n is the number of contracts.

* Indicates significant correlation at 10% level two sided test, Conover[40]

6.3 Calculation of correction factors using the designers' estimate correlation with the number of bidders

Section 6.1 established that there was a negative correlation between the ratio of mean of (mean bid/designer's estimate) and mean of (lowest bid/designer's estimate) and number of bidders. Section 6.2 established that there was little or no correlation between the ratios (mean bid/designer's estimate) and (lowest bid/designer's estimate) and contract value. Thus the calculation of correction factors to compensate for identified correlations could only take account of the number of bidders.

The simplest correction factor would be to adjust the means of (lowest bid/designer's estimate) and (mean bid/designer's estimate) by simple subtraction or addition until they were 100%. This would not affect the standard deviations which would remain as reported in section 6.1. A more general approach is to fit curves to the graphs shown in figures 6.1 and 6.2. To use these curves to calculate correction factors and to apply these correction factors to the designers' estimates according to the number of bidders involved. It is expected that this will lead to a deterioration in the standard deviations since any curve will not fit the data exactly and the resultant correction factor will reflect the residual errors in the curve fit. Also since the curve-fitting exercise is based on the means of (low or mean bid/designer's estimate) the correction factor will not reduce the existing dispersion. Therefore the resultant residuals will reflect the original residuals plus the error introduced by the curve fitting exercise.

Figures 6.1 and 6.2 for buildings and roads contracts respectively show the correlations with the number of bidders. To calculate the correction factors polynomials were fitted to these graphs taking account of the weighting of each point. The weighting of each data point was taken as the number of contracts included in the calculation of the means for that number of bidders (i.e. the sample size). The fitting routine was taken from the N.A.G. I.C.L. 1900 Library and was E02ABF[47] of that library. This routine was incorporated into a computer program which calculated the best fitting polynomial. The best fitting polynomial for buildings contracts was found to be of order one, that is a straight line. The best fitting polynomial for roads contracts was found to be of order three. These polynomials were, for buildings contracts,

(mean bid/designer's estimate)

$$= 1.273 - 0.02134\,n$$

(lowest bid/designer's estimate)

$$= 1.252 - 0.029\,n,$$

for roads contracts

(mean bid/designer's estimate)

$$= 1.558 + 0.196n + 0.0228n^2 - 0.00084n^3$$

(lowest bid/designer's estimate)

$$= 1.608 - 0.249n + 0.0297n^2 - 0.0011n^3$$

where 'n' is the number of bidders.

The designers' estimates were then multiplied by a correction factor calculated as follows.

For buildings contracts

Correction factor for designers' estimating

mean bids : $1.0/(1.273 - 0.02134n)$

Correction factor for designers' estimating

lowest bids : $1.0/(1.252 - 0.029n)$

For roads contracts

Correction factor for designers' estimating

mean bids : $1.0/(1.558 + 0.196n + 0.0228n^2 - 0.00084n^3)$

Correction factor for designers' estimating

lowest bids : $1.0/(1.608 - 0.249n + 0.0297n^2 - 0.011n^3)$

Again 'n' is the number of bidders.

Using these correction factors the corrected designers' estimates were calculated and compared to the mean bid and the lowest bid. The standard deviation of the residuals (i.e. (mean bid - corrected designer's estimate) and (lowest bid - corrected designer's estimate) were calculated and are shown in table 6.7. The full list of residuals are not given.

Table 6.7 Standard Deviations of residuals of (mean bid - corrected designers' estimates) and of (lowest bid - corrected designers' estimates)

Residuals (%)	Buildings Contracts Standard Deviation	Roads Contracts Standard Deviation
(Low bid - corrected designer's estimate)/low bid	24.42%	25.37%
(mean bid - corrected designer's estimate)/mean bid	15.22%	19.65%
(low bid - corrected designer's estimate)/corrected designer's estimate	23.25%	26.20%
(mean bid - corrected designer's estimate)/corrected designer's estimate	21.86%	26.06%

These residuals are calculated on the same basis as those shown in table 6.2 and are therefore directly comparable.

The conclusion that can be taken from this is that the general correction factor leads to a substantial deterioration in the standard deviation of the residuals. Thus if correction factors are to be devised they should be based on simple subtractions or additions to adjust the means of (low or mean bid/designer's estimate).

6.4 Estimating based on Regression Analysis

Analysis

As sections 6.1 to 6.3 established the accuracy of designers' estimating this section establishes the accuracy of using regression based cost models. Estimating based on such a statistical technique has the appeal of condensing historical records into a usable form. A description of the technique of multiple linear regression analysis is given by Draper and Smith[48]. A simplified description of the technique and of its use as a cost modelling tool is given by McCaffer[49]. An extract from this paper giving the simplified explanation is given in appendix S.

The important points to take from this explanation are the method of appraising the models accuracy and the deterioration of this accuracy when the model is used with data that does not belong to its own data base, as is the case in normal use. The model's accuracy is assessed by examining the residuals by drawing residual scatter diagrams or by calculating the coefficient of variation (c.v), i.e.

$$\text{c.v.} = \frac{\text{standard deviation of residuals}}{\text{mean cost of all schemes}} \times 100\%$$

This c.v. can be compared to the standard deviations of the residuals as calculated in sections 6.1 and 6.3. The c.v's shown in the following examples are calculated for the cases included in the models own data base. Thus it is a measure of how well the model fits the data. Experience from these models and elsewhere has indicated that the c.v. will increase by 25% to 50% when applied to data outwith its own data base. Thus a model with a c.v. of 10% will deteriorate to 15% to 20% when used on other similar cases.

The following examples were originally described in "Some Examples of the Use of Regression Analysis as an Estimating Tool" by McCaffer[49] and the following is an extract.

"Examples of Cost Models .

Examples of eight regression based cost models developed at Loughborough are given. The models are not described in full but their accuracy is given either in terms of the coefficient of variation or as scatter diagram of residuals.

Reinforced Concrete Frames

1) An exploratory study by J.S. Buchanan[53] produced a cost model for reinforced concrete frames in buildings. The model contained variables such as gross floor area, average load, shortest span, longest span, number of floors, height between floors, slab concrete thickness and number of lifts.

The residuals shown in figure 6.4 demonstrate that the model is more accurate for medium and high cost schemes rather than low cost schemes.

2) Services in Buildings

P.R. Gould[54] produced a cost model for heating, ventilating and air conditioning services in buildings. The variables included functions which described the heat and air flow through the building, the heat source and distance which it has to be ducted and shape variables.

The residuals are shown in figure 6.5 and demonstrate higher accuracies at higher costs.

As a result of this further extensive work was undertaken as part of a research contract for H.M.Treasury. The results are not available for publication.

3) School Buildings

B.F. Moyles[55] produced a cost model for system built school buildings and included variable such as floor areas, area of external and internal walls, number of rooms and functional units, area of corridors, storey height and number of sanitary fittings.

The residuals shown in figure 6.6 demonstrate high accuracy.

4) Houses

R.H. Neale[56] produced a cost model for houses built by a private contractor for private sale. The model included such variables as floor area, area of roof and of garage, number of storeys, slope of site, unit cost of external finishes and cost of sanitary fittings, area and volume of kitchen units, site densities, regional factors, number of doors, area of walls, number of angles on plan, construction date and duration of development and type of central heating. The residuals shown in figure 6.7 show that only two cases fell outside the ± 10% band.

5) Homes for Old People

M.J. Baker[57] produced a cost model for residential apartment schemes for old people. His model included such variables as the area of single units, double units, triple units, common rooms, Warden's flat, laundry, access corridors, number of lifts and garages and duration of contract. The model had a coefficient of variation of 9.16% and the residuals are shown in figure 6.8. Baker adjusted his basic cost data for regional variations, contract size and date before conducting his analysis.

6) Passenger Lifts

J.D. Blackhall[58] produced a cost model for passenger lifts in office buildings. The model's variables included the contract date, the dimensions of the car, the number of landings, the length of travel, the operating speed, and variables referring to the type of control system and the location of the installation. The coefficient of variation was 20.9%.

7) Electrical Services in Buildings

Blackhall[58] also produced a cost model for electrical services in office buildings. The model's variables included number of distribution boards, fused load, number of active ways, number of socket and other outlets, voltage, contract date and differentiation whether the building was for commercial or domestic use. The coefficient of variation was 20.0% and the residuals plotted in figure 6.9 again show better accuracies for more costly schemes.

Blackhall also had the opportunity of comparing the accuracy of his model with the accuracy of traditional estimating. Blackhall calculated the accuracy of the traditionally produced estimates in a way that could be directly compared with the models coefficient of variation. The result was

Traditional estimates	34%
Models c.v.	20%

Even allowing for a deterioration in the model's performance when applied to data outwith its own data base, which will leave the model with a c.v. of 25% - 30% the model is still more accurate than traditional methods. Also, and perhaps more important, the time taken by the user of the model is much less than the traditional estimator.

Although the coefficient of variation of this model is high the performance of traditional estimating is also poor. In a highly variable situation neither can hope to be very accurate.

8) Motorway Drainage

D. Coates[59] produced an estimating model for a contractor's unit rate for laying motorway drainage using porous pipes, Hepline pipes and asbestos pipes. The three models, one for each pipe type, contained the variables, internal diameter, average depths and the cost of the pipe.

The coefficients of variation were, for porous pipes 12.8%, for Hepline 9.2% and for asbestos pipes 6.9%.

NOTE: Figures 6.4 to 6.9 are scatter diagrams of residuals for six different regression based cost models. If the model predicted the cost exactly all points would lie on a 45^{o} line through the origin. However, since the model does not predict the actual costs exactly the error shows as the distance between the plotted point and the 45^{o} line.

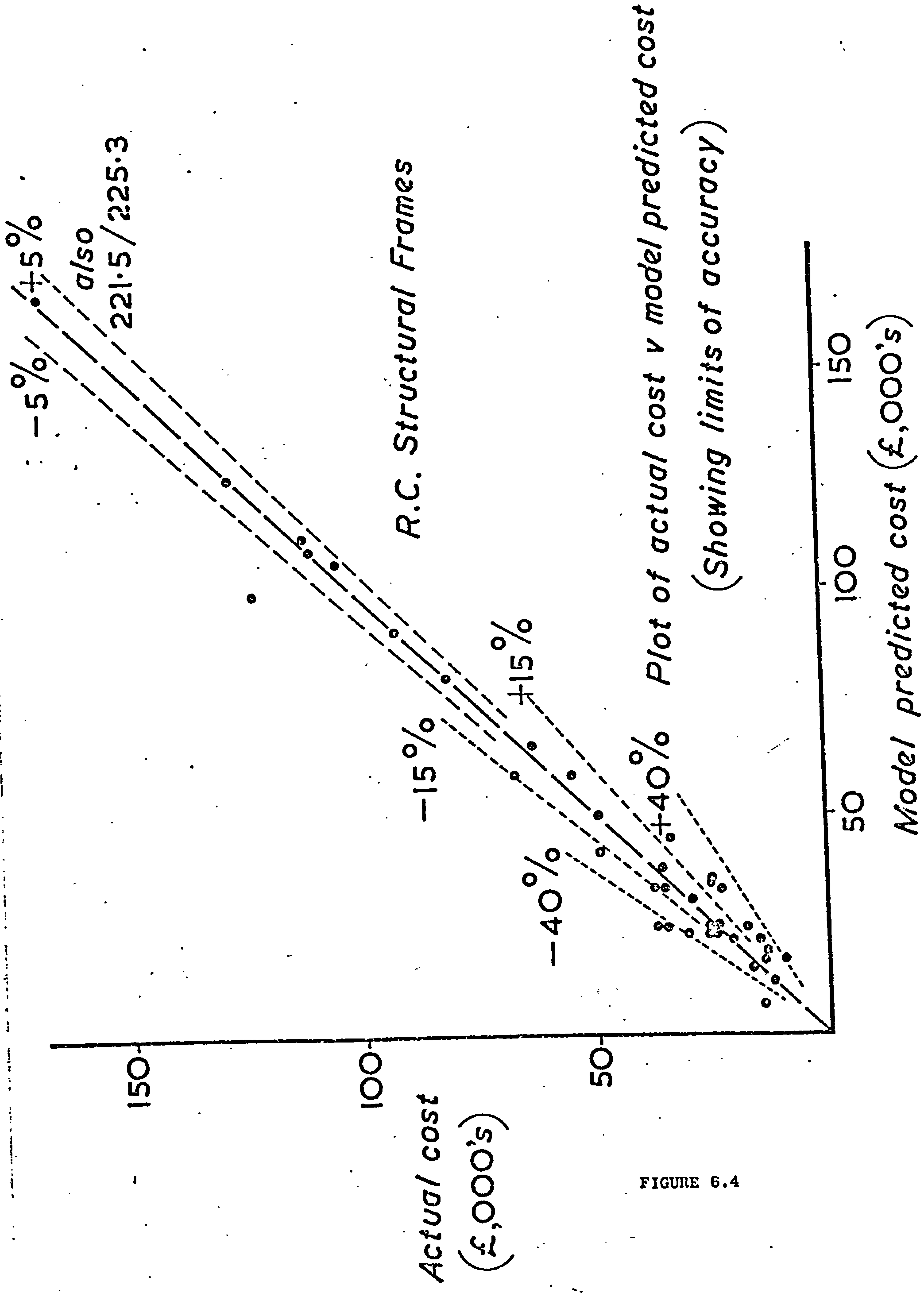

R.C. Structural Frames
Plot of actual cost v model predicted cost
(Showing limits of accuracy)
also
221·5/225·3
+5%
−5%
+15%
−15%
+40%
−40%
Actual cost
(£,000's)
150
100
50
Model predicted cost (£,000's)
50
100
150

FIGURE 6.4

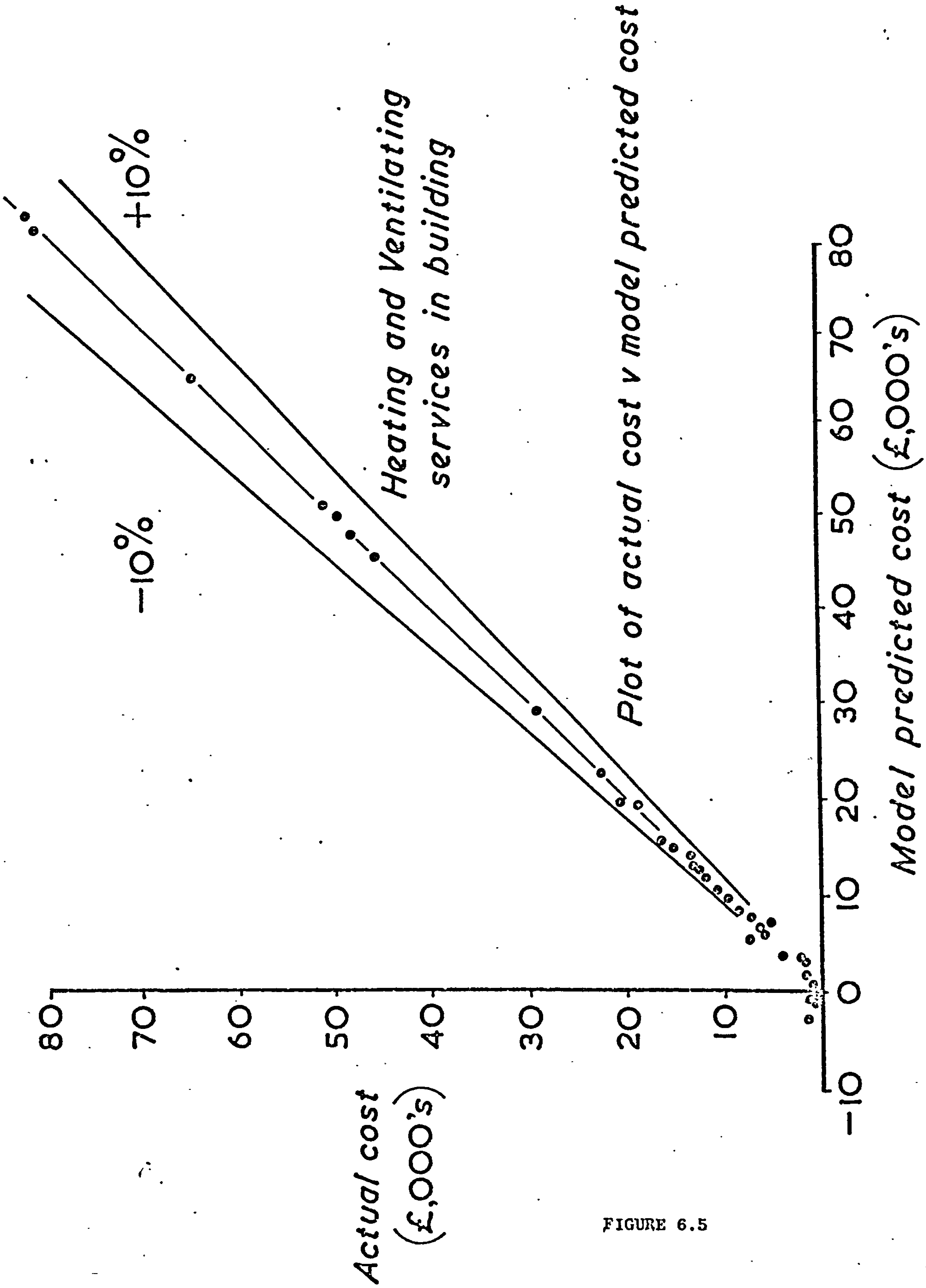

Heating and Ventilating services in building
Plot of actual cost v model predicted cost
+10%
-10%
Actual cost (£,000's)
Model predicted cost (£,000's)
80
70
60
50
40
30
20
10
0
-10

FIGURE 6.5

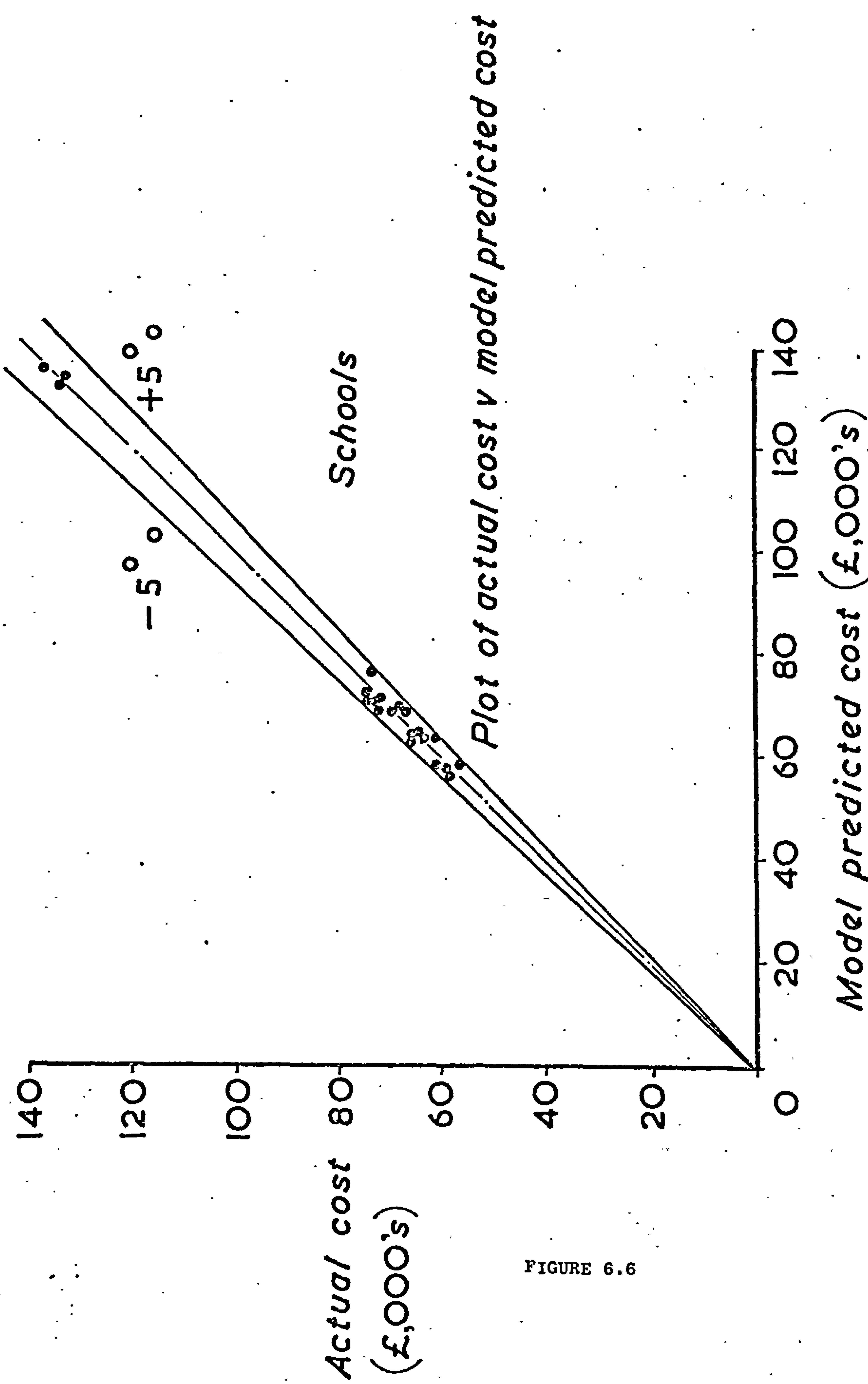
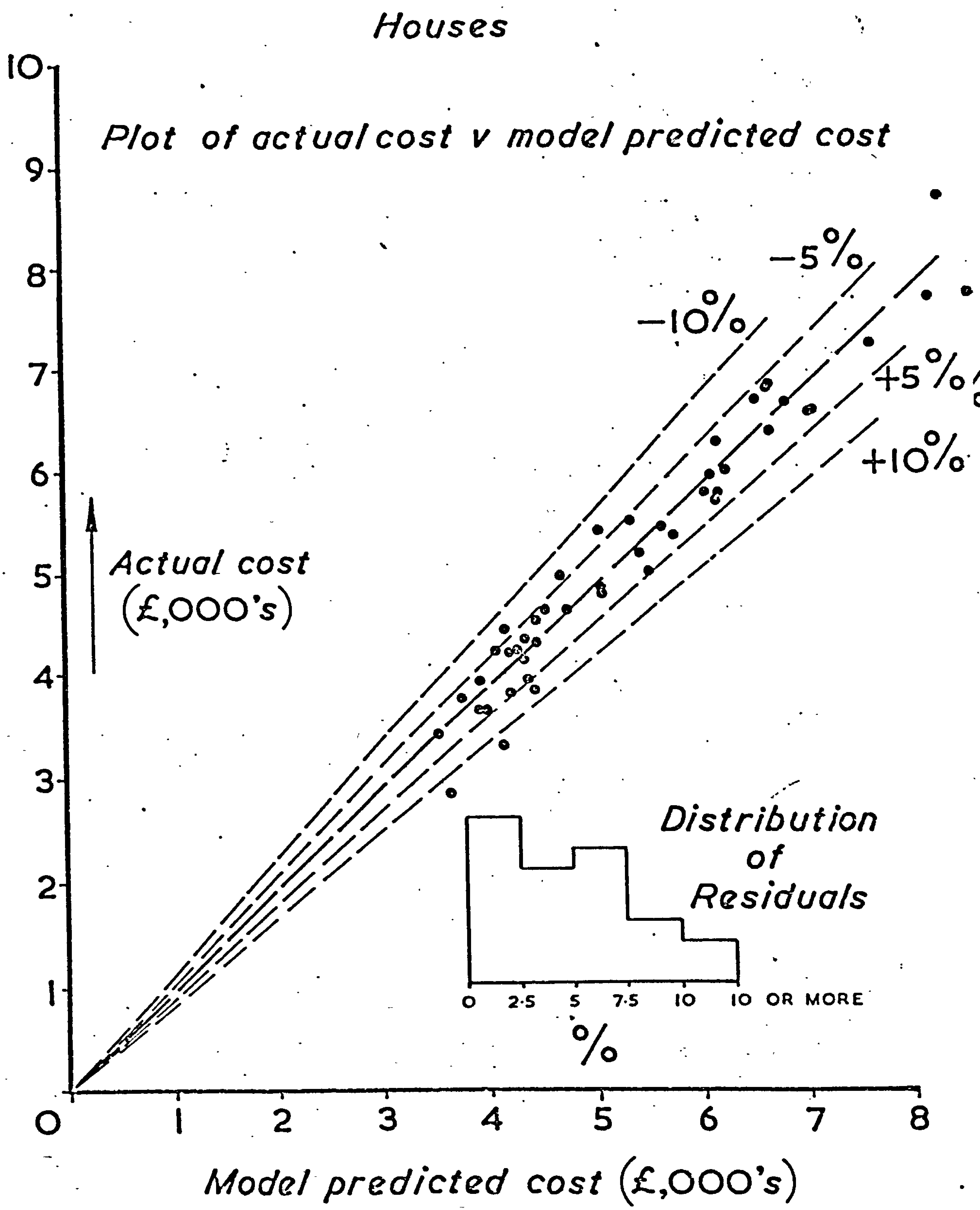
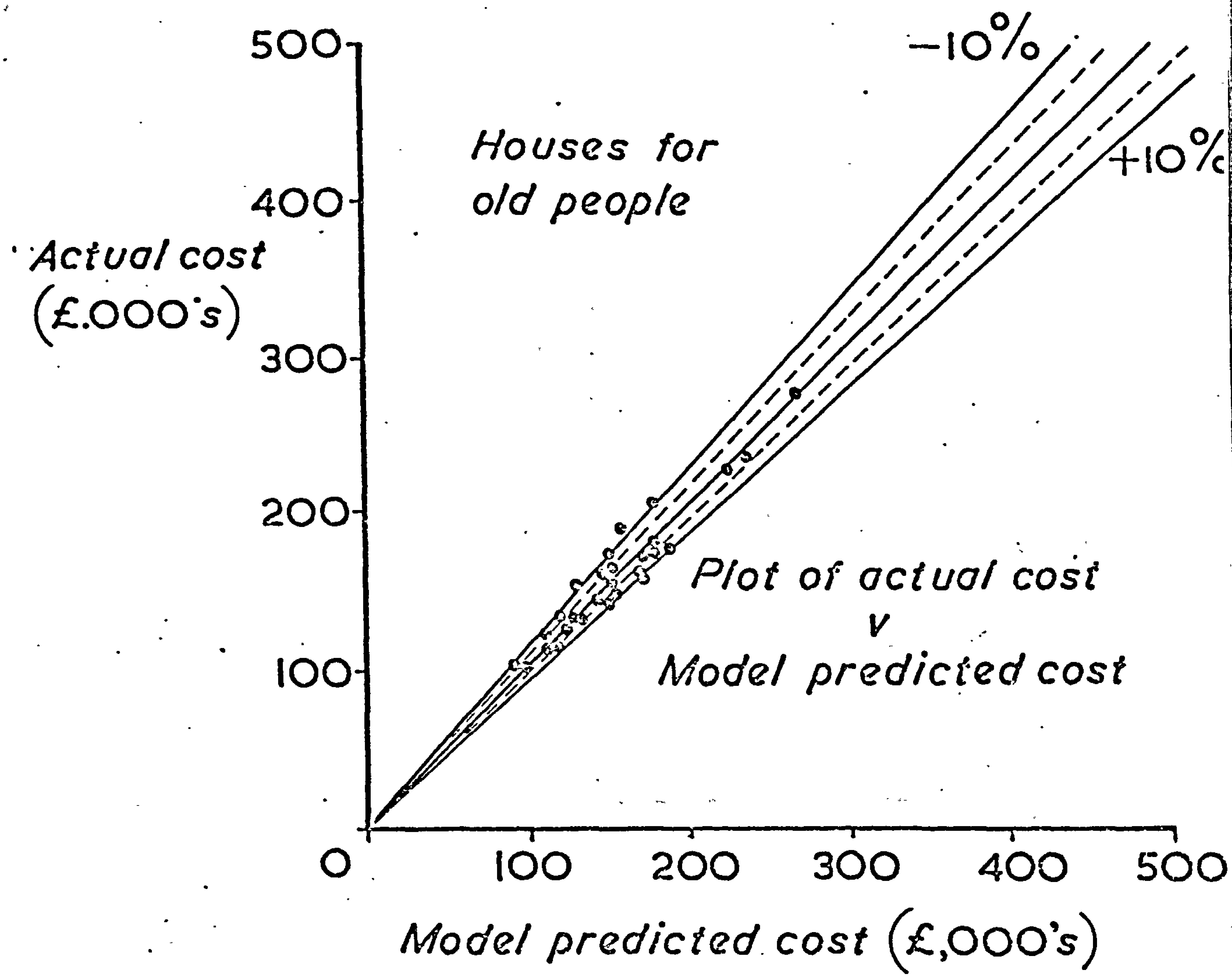

Plot of actual cost v model predicted cost
Schools
-5%
+5%
Actual cost (£,000's)
Model predicted cost (£,000's)
0
20
40
60
80
100
120
140

FIGURE 6.6



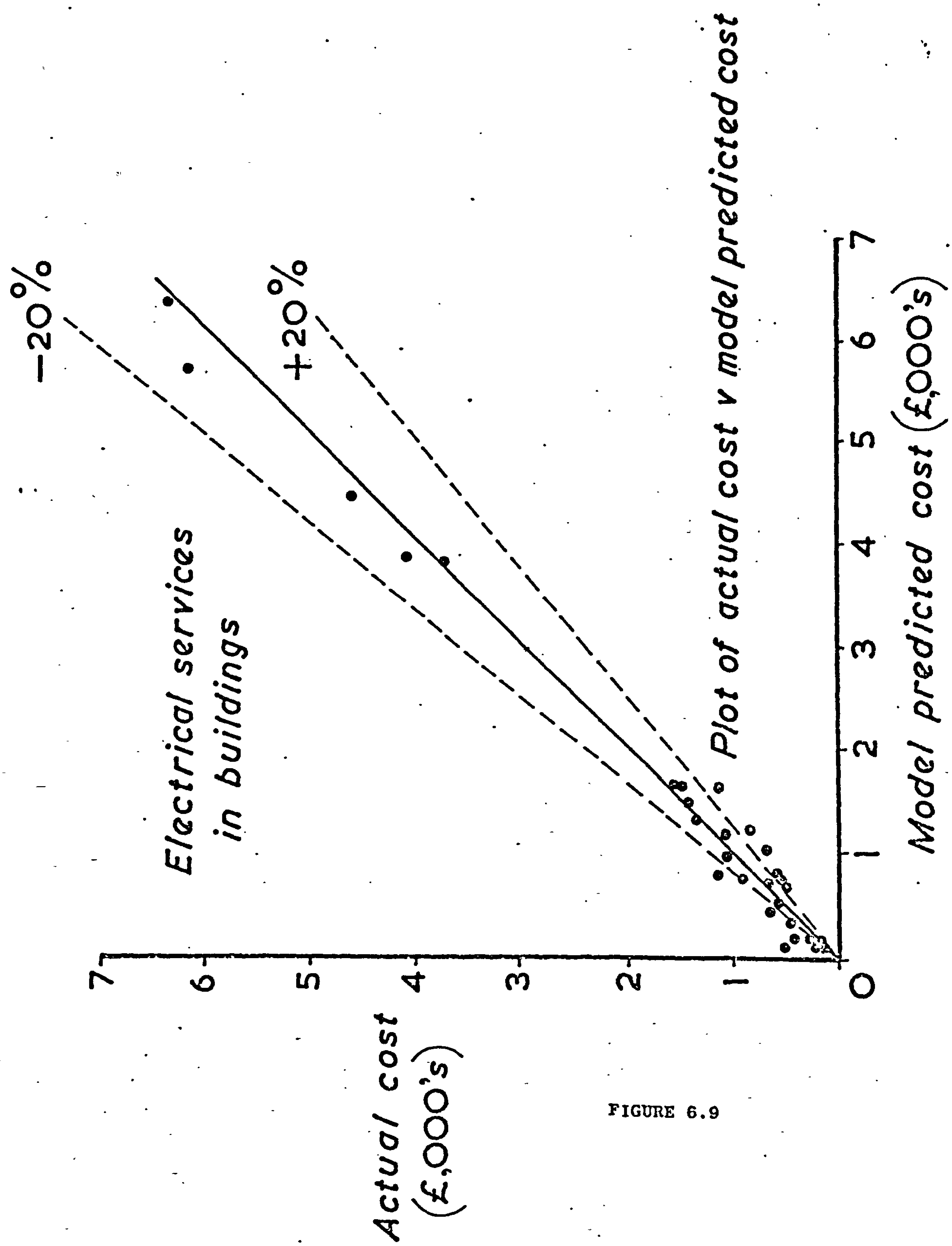
Houses
Plot of actual cost v model predicted cost
Actual cost (£,000's)
Model predicted cost (£,000's)
-5%
-10%
+5%
+10%
Distribution of Residuals
0 2·5 5 7·5 10 10 OR MORE
%
0 1 2 3 4 5 6 7 8 9 10
0 1 2 3 4 5 6 7 8

FIGURE 6.7



500
400
300
200
100
0
Actual cost
(£.000's)
Houses for
old people
-10%
+10%
Plot of actual cost
v
Model predicted cost
100
200
300
400
500
Model predicted cost (£,000's)

FIGURE 6.8



Plot of actual cost v model predicted cost
Electrical services in buildings
−20%
+20%
Actual cost (£,000's)
Model predicted cost (£,000's)
0
1
2
3
4
5
6
7

FIGURE 6.9

To summarise the results from these eight examples, The accuracy achieved ranges from $\pm$5% for very repetitive system built schools, a c.v. of approximately 2.5%, to a c.v. of 20% for non-repetitive highly variable electrical installations. Bearing in mind that these c.v.'s will deteriorate by 25% to 50% when used for cases not included in the models' data base they have similar accuracies, as displayed by the designers estimates. Take, for example, Baker's model for old peoples' homes, this had a c.v. of 9.16%. This would deteriorate to 11.5% to 13.74% in practice. This compares well with the recorded accuracy of designers estimating buildings of 16.48% for the standard deviation residuals for buildings, using the uncorrected estimates from table 6.2.

The accuracy of designers estimating tender prices for road works of 22.20% for standard deviation of residuals from table 6.2 is in the upper end of the observed regression accuracies.

6.5 Summary of Estimating Accuracies

Table 6.8 summarises the observed accuracies of both designers and regression based models as described in sections 6.1, 6.2, 6.3 and 6.4.

Table 6.8 Summary of Observed Estimating Accuracies

Designers	Buildings	Roads
Standard Deviations of (Mean bid/designer's estimate)	14.27%	19.15%
Standard Deviation of (Lowest bid/designer's estimate)	13.805%	18.632%
Standard Deviation of Residuals (Mean bid - designer's estimate)/Mean bid	12.60%	18.98%
Standard Deviation of Residuals (Lowest bid - designer's estimate)/lowest bid des	16.48%	22.20%

Regression Models	
R.C. Frames	Band width ± 40% (approx. c.v. 20%)
Building Services	Band width ± 10% (approx. c.v. 5%)
School Buildings	Band width ± 5% (approx. c.v. 2.5%)
Houses	Band width ± 10% (approx. c.v. 5%)
Homes for old people	c.v. 9.16%
Passenger Lifts	c.v. 20.9%
Electrical Services	c.v. 20%
*Motorway Drainage	c.v.'s of 12.8%, 9.2% and 6.9%

(*Note: Contractors costs being estimated)

In examining these measures of accuracy it should be firmly remembered that the regression models c.v's will deteriorate by between 25% and 50% in practice.

The conclusion drawn from this work is that accuracies shown by the designers are comparable to those achieved by regression modelling. That is it seems there is no great substantial improvement made by the use of regression models. This cannot firmly be concluded since the data does not exist which enables a regression model of either the roads or the buildings represented in the data to be compared with the designers estimates. However sufficient evidence does exist for the conclusion to be generally accepted and for the accuracies of the designers to be used for judging improvements in the system developed and tested in section 7.0 knowing that regression analysis is unlikely to offer major improvements. However a regression based estimating system could possibly be cheaper to operate.

The observed accuracies are substantially greater than the accuracies required by Grinyer and Whittaker[13] of +1% to -3.5% for their model. Thus based on this evidence the approach put forward by Grinyer and Whittaker which relies on estimates of the mean bid based on managerial judgement is unlikely to be successfully applied.

7.0 TENDER PRICE PREDICTION

7.1 Introduction and overall concept of proposed system

In section 6.0 the accuracy of designers estimating of tender prices and the accuracy of regression based models for predicting tender prices were examined. In this section the efforts to improve those accuracies using an approach based on a library of prices for standard items is reported.

The overall concept of this system is:

a) To compile a library of prices for standard items from submitted bills of quantities, including both the winning tenders and the others. To continually top up this price library with prices from the most recent contracts and to delete prices from the oldest contracts. Thus at the time of predicting the tender price of a contract the most recent information would be less than one month old.

b) At the time of preparing a tender price prediction for a particular contract, to adjust these prices to allow for inflation, using inflation indices. It was envisaged that the system when fully installed could draw on prices from several hundred contracts per month and therefore the oldest data in the working price library would only be a few months old. ✓

c) To statistically analyse the distribution of inflation adjusted prices of each standard item included in the contract whose tender price was being predicted.

d) To use the calculated mean price for each item and measures of the variability of the price for each item to produce for the contract in question an estimate of the mean tender price and its standard deviation.

The reasons that led to outlining this system were that some work was already in progress in defining standard items and in compiling a list of prices for each of the standard items. The original reason for this work was a move towards standardisation of the definition of work items and subsequently a study of the distribution of the total contract value within the bill of quantities. The extension of this into a tender price prediction system held the attraction of more reliable tender price predictions against which to judge low bids from the viewpoint of both calculating additions (see section 4.1 and reference 26) rather than judging against an arbitrary mean. Furthermore the thought that a published reliable forecast of tender prices might prevent a contractor submitting unrealistically low bids. This thought caused a philosophical debate as to whether the publication of a predicted tender price might lead to control of tender prices if contractors paid too much attention to the prediction and not enough attention to their own estimating. This debate was left unresolved and the purpose of this exercise was seen to be the production of the computer systems to support such a tender price prediction system and the testing of the accuracy of such a system against as many real contracts as possible The approach was thus a feasibility study for the ultimate system.

The remaining sections of this chapter describe the price library, the tests of accuracy and appendix T gives the full reference and user manual for the system together with the program listing of the main computer programs.

7.2 The Price Library

This section describes the library structure as it existed at the time when it was supplied to enable the tender price prediction system to be designed and developed. This structure was modified and the data augmented for the purpose of the tender price prediction system. The resultant structure of the price library is also described.

The price library is based on prices for standard items of work taken from both successful and unsuccessful tenders for Belgian public works contracts. At the time of the feasibility study the library was based on 171 contracts issued between 1971 and 1974 for road works. No data was made available for buildings contracts.

Structure of the supplied Price Library

Main Sections

The library had six sections. This represented two separate regions, Hainaut and Liege, and for each region three types of works. The following is a brief description of each section.

i) HAINAUT ETAT

Construction and maintenance contracts for major roads issued by Ministry of Public Works.

ii) HAINAUT CITES

Contracts for the construction of council estate roads issued by Provincial Authorities.

iii) HAINAUT COMMUNES

Contracts for local road improvement schemes issued by Local Authorities.

iv) LIEGE ETAT

As for i) except that the contracts are within the province of Liege.

v) LIEGE CITES

As for ii) except that the contracts are within the province of Liege.

vi) LIEGE COMMUNES

As for iii) except that the contracts are within the province of Liege.

Subdivisions

Each of the six main sections were divided into nine chapters, each chapter referring to specific work categories, as follows,

1. General setup
2. Preparatory work
3. Earthworks
4. Foundations
5. Road finishings (surfacing)
6. Sewage
7. Manholes, small scale brickwork
8. Road signs, landscaping
9. Miscellaneous, dayworks

It should be noted that the above work categories are translated from their original specification which was in French.

Items

Each item within a chapter was identified by a seven digit number. Each of these seven digits have the following meaning

First digit	- chapter number (i.e. work category)
Second and third digits	- paragraph and sub-paragraph numbers. These are subdivisions of the chapter, that is subdivisions of the work categories
Fourth to Sixth digits	- the item number within the sub-paragraph (based on standardised items designed by the National Centre for Research for Roadworks)
Seventh digit	- a quantity classification as follows 1 = 0 to 100 cubic metres 2 = 100 to 1000 cubic metres

3 = 1,000 to 10,000 cubic metres

4 = more than 10,000 cubic metres

5 = 0 to 2,000 square metres

6 = more than 2,000 square metres

7 = 0 to 200 linear metres

8 = more than 200 linear metres

9 = more than 5,000 tonnes

0 = not classified in a quantity group.

Table 7.1 shows an example, each item and its seven digit number was followed by:

- the indication QP meaning a quantity based rate of payment or PG for a lump sum payment;
- the unit of measurement (M1 for linear metres, M2 for square metres, M3 for cubic metres, P for items (or pieces), To for tonnes);
- the quantity;
- the unit price in Belgian francs offered by contractors;
- the total item price (quantity x unit price);
- the item value as a percentage of the contract value;
- the cumulative percentage of the item and all other items of greater value in the contract;
- the rank of the item according to its value in the contract, items being ranked from largest to smallest value;
- the total number of items in the contract;
- the entry number in the bill of quantities, i.e. the identification number given to the item in the bill of quantities;
- a block of eight digits including some undefined codes, the ranking and the number of the contract.

Table 7.1 Main structure of the supplied Price Library

Item number	QP for schedule of rate basis PG for lump sum basis	Unit of measurement	Quantity	Unit price	Total price	Item value as %age of contract value	Cumulative %age reached together with all the items of higher value	Ranking ditto as above	Total number of items in B.Q.	Entry number in B.Q.	Code	Ranking according to relative value of item	Code	Contract number
2311910	QP	M2	80.000	325.000	26000	0.810	85.061	25	092	057	1	025	0	003
2316590	QP	M2	367.000	80.000	29360	2.014	72.477	14	047	003	1	014	0	015
2316590	QP	M2	179.000	80.000	14320	0.982	88.452	27	047	018	1	027	0	015
2316590	QP	M2	575.000	43.000	24725	0.830	96.692	13	028	004	1	013	0	001
2316590	QP	M2	148.000	80.000	11840	0.812	91.938	31	047	037	1	031	0	015
2316890	QP	M2	1.800	600.000	1080	0.007	99.848	189	223	220	1	189	0	007
2321110	QP	M2	33.000	50.000	1650	0.011	99.637	167	223	174	1	167	0	007
2411110	QP	M1	456.000	100.000	45600	3.128	55.734	7	047	016	1	007	0	015
2411110	QP	M1	390.000	100.000	39000	2.675	61.472	9	047	001	1	009	0	015
2411110	QP	M1	200.000	100.000	20000	1.372	80.351	19	047	035	1	019	0	015

The Transformed Price Library

The data for 171 contracts whose dates spanned 1971 to 74 in the form described were made available on a magnetic tape. This magnetic tape was produced by a Burrough computer and was inevitably incompatible with the University's I.C.L.1904A computer. Conversion programs were written (see appendix V) which enabled this magnetic tape to be read and copied and understood by the University's computer. From the tape supplied the data extracted were, the item numbers, the number or prices gathered for the item, the unit prices, the quantity associated with each unit price. This extracted information was transferred to a separate magnetic tape file known as PRICE LIBRARY and the extracted information was augmented by the date of each unit price obtained from a separate source and correlated with the correct unit price via the contract number (see table 7.1). Also added to each unit price was the weighting that could be placed upon the unit price. This weighting arose when, as was sometimes the case, the entry for the unit price was not a single price but the average of prices from several tenders for the same contract. The weighting entered was the number of prices used in calculating the average. In addition to this information on the PRICE LIBRARY tape space was provided against each item for an item description and for a percentage cost breakdown into six cost categories. These six cost categories were to be labour, cement, steel, timber, plant, asphalt. The use of the cost categories will be described later.

Thus on this magnetic tape file PRICE LIBRARY there were six separate libraries

1. Hainaut Etat
2. Hainaut Cites
3. Hainaut Communes
4. Liege Etat

5. Liege Cites

6. Liege Communes

For each of these six libraries the file contained

- the library name,
- the number of items in the library,
- the reference number of the items.

For each item the file contained

- item reference number,
- the number of prices gathered for that item,
- the percentage cost break down into six categories (blanks where missing),
- the items description (blank where missing),
- the unit prices,
- the quantity associated with each unit price,
- the date of each unit price,
- the weight of each unit price.

The magnetic tape file PRICE LIBRARY was structured in a form suitable for the tender price prediction system described in section 7.3 and appendix T. At the time of the feasibility study it contained the original 171 contracts; the software for the continual topping up was under development.

7.3 Tender Price Prediction System

The computer based system is fully described in appendix T which is both a reference manual and a user manual. That is, appendix T gives full description and detail sufficient to allow any future development of the system. Appendix T also acts as a user manual in that it describes how to prepare the input data and run the system. This section describes the system in more general detail and explains the reasoning used in the system's design.

System Description

The system is designed to

- access PRICE LIBRARY the magnetic tape file of individual unit prices,
- to select the unit prices for chosen items and adjust them to allow for inflation using inflation indices,
- to statistically analyse the distribution of unit prices for each chosen item,
- to calculate the likely mean price of the contract represented by the chosen items by summing the expected value of each item derived from the items mean unit price times the quantity,
- to calculate by similation the standard deviation of the tender prices for the contract.

The system, which was given the name FAIRTENDER, comprises

1) PRICE LIBRARY, the magnetic tape file of individual unit prices as described in section 7.2.
2) A list of monthly inflation indices for labour, cement, steel, timber, plant and asphalt derived from published prices held on a magnetic tape file.
3) A computer program named TRENDS which by curve fitting and extrapolation will predict the six inflation indices for one, two or three months ahead. This program is run separately from the rest of the system. The need for this prediction tool is described later.

4) A computer program called STAT which

- selects from PRICE LIBRARY the unit prices that belong to a specific item,
- uses the inflation indices to adjust the prices from the date the price was entered in the library to the date of the prediction,
- statistically analyses the unit prices of the specified items to produce the statistics required for the simulation of tender prices. These statistics are
  - the mean and standard deviation of the distribution of unit prices assuming the distribution is normal

    or
  - the mean and standard deviation of unit prices assuming the distribution is log normal

    or
  - the constant and coefficient of a regression model of the form

    Unit price = (A constant)+(A Coefficient) x Quantity

    and the standard deviation of the residuals.

The program STAT stores these statistics for each of the 100 or so items that make up a contract on a temporary file for passing onto the simulation program. The choice of the statistics is left to the user who by experience will build up knowledge of which particular form of statistics best describes each item.

5) A computer program called SIMULATION which accepts input either from the temporary file created by STAT (see (4) above) or from cards. In addition to the methods of describing the mean unit

price and the unit price's variability offered by STAT, namely normal and log normal distributions and regression models, the card input allows the user to specify a triangular distribution by giving the smallest and largest unit price for the item. The inclusion of the triangular distribution includes all the distribution types suggested by Spooner(60) as well as regression based models not considered by Spooner. Card input also allows a unit price to be specified as a single specific unit price with no variability attached. The SIMULATION program calculates and prints the mean tender price, based on the mean of each item and prints the contribution to the total mean tender price of each ite- ranked in descending order.

The SIMULATION program also simulates the contract 'n' times, (where 'n' is specified by the user), by randomly selecting unit prices from the distribution of possible unit prices for each item and calculates the total tender price based on these random selections. The output is a list of the 'n' simulated tenders with the contribution from each item and the total tender price. The mean and standard dev iation of the 'n' calculated tender prices are also given.

6) The GENERAL PURPOSE DATA DECK is the card deck supplied by the user to produce the calculations he requires for the particular contract being simulated.

The work relating to the compiling of the inflation indices and the program TRENDS was undertaken by Petofalvi as his M.Sc. project report (61) supervised by McCaffer.

The foregoing notes are further explained in figure 7.1.

Figure 7.1 Tender Price Prediction System

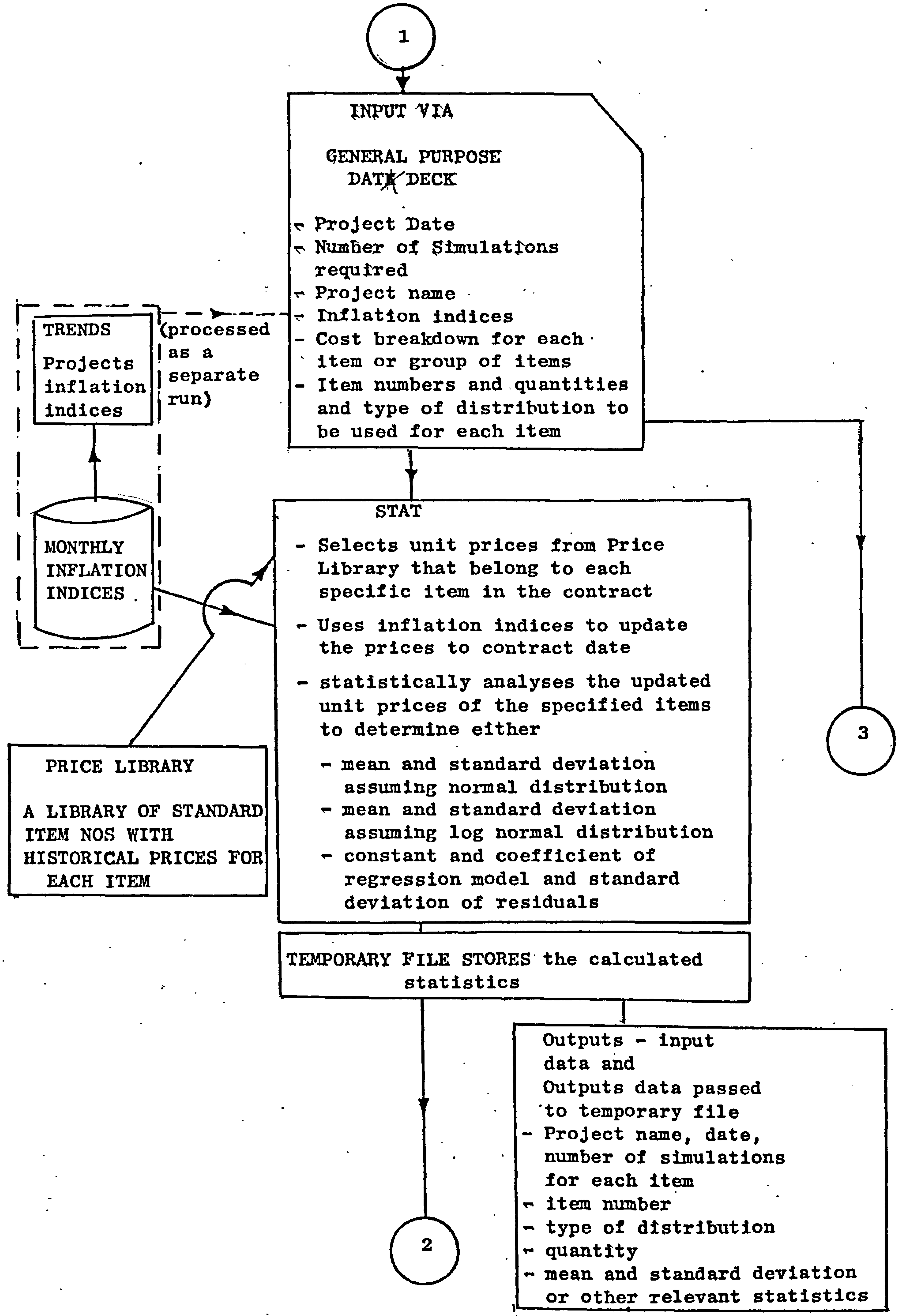


Figure 7.1 (Contd)

(2) (3)

SIMULATION

Accepts statistics relating to unit price distributions from STATS temporary file or from cards.

Calculates mean tender price for contract and contribution of each item based on the mean or expected values calculated by STAT.

Simulates the contract 'n' times by randomly selecting unit prices from the distribution of possible unit prices as calculated by STAT.

Calculates tender prices and item contribution for each simulation.

Calculates standard deviation of tender prices

Outputs

- List of items ranked by order of contribution giving item number, type of distribution, expected contribution, expected dispersion (standard deviation of contribution) based on means of unit prices
- List of items ranked by order of dispersion details as above
- Expected total price (base of means of unit prices)
- Simulation Output
  List of items, quoting item number, quantity, distribution in type and price used for each simulation
  Mean and standard deviation of simulated total prices

Return to (1) for next contract or end

1

Table 7.2 gives an example of the input required for one contract.

Tables 7.3 and 7.4 give an example of the output, ranked by order of item contribution and by order of item dispersion.

Table 7.5 gives an example of the simulation output.

Table 7.2 Sample Output showing Input for Tender Price Prediction System

The left hand side of the page shows the input as presented. The right hand side of the pages shows the output from the 'STAT' program showing the mean and standard deviations of each item price.

INPUT   OUTPUT

```
PROJ      22 10 74      10        123        3
                                    PROJ        22 10 74      10        123       3
NAME    THIRTEENTH TEST  43 ITEMS  37 IN LIBRARY
                                    NAME      THIRTEENTH TEST  43 ITEMS   37 IN LIBRARY
INDX 1.7871.3541.6351.5791.7012.768
COST  .8   .     .      .   .2
ITEM     241111     NORM SYST         1214
                                    ITEM      241111     NORM SYST      1214.00     42.47      12.54
ITEM     245111     NORM SYST         28
                                    ITEM      245111     NORM SYST        28.00    504.31     181.63
ITEM     251112     NORM CARD         84           500          3
                                    ITEM      251112     NORM CARD        84         500         3
ITEM     245219     NORM SYST         9
                                    ITEM      245219     NORM SYST         9.00   1227.00       0.00
ITEM     241111     NORM SYST         125
                                    ITEM      241111     NORM SYST       125.00     42.47      12.54
COST  .2   .     .      .8
ITEM     313331     NORM SYST         3331
                                    ITEM      313331     NORM SYST      3331.00    232.36      72.88
ITEM     343326     NORM SYST         4240
                                    ITEM      343326     NORM SYST      4240.00    184.63       1.64
ITEM     343719     NORM SYST         4240
                                    ITEM      343719     NORM SYST      4240.00     72.57       0.00
ITEM     343326     NORM SYST         1480
                                    ITEM      343326     NORM SYST      1480.00    184.63       1.64
ITEM     343348     NORM SYST         1480
                                    ITEM      343348     NORM SYST      1480.00     71.41       0.00
ITEM     344999     NORM CARD         20           750          3
                                    ITEM      344999     NORM CARD        20         750         3
ITEM     313999     NORM CARD         1        100000          3
                                    ITEM      313999     NORM CARD         1      100000         3
ITEM     343999     NORM CARD         100          435          3
                                    ITEM      343999     NORM CARD       100         435         3
COST  .4   .     .      .6
ITEM     422150     NORM SYST         4240
                                    ITEM      422150     NORM SYST      4240.00    103.22      15.28
ITEM     426140     NORM SYST         4240
                                    ITEM      426140     NORM SYST      4240.00     93.89      20.14
ITEM     428512     NORM CARD         4240         14          .1
                                    ITEM      428512     NORM CARD      4240          14          .1
ITEM     439951     NORM SYST         1480
                                    ITEM      439951     NORM SYST      1480.00    136.73       0.00
ITEM     439503     NORM SYST         1480
                                    ITEM      439503     NORM SYST      1480.00     88.42      16.86
ITEM     463588     NORM SYST         1220
                                    ITEM      463588     NORM SYST      1220.00    388.40       0.00
ITEM     463588     NORM SYST         32
                                    ITEM      463588     NORM SYST        32.00    388.40       0.00
ITEM     486310     NORM SYST         420
                                    ITEM      486310     NORM SYST       420.00    908.21     169.32
ITEM     436521     NORM SYST         3050
                                    ITEM      436521     NORM SYST      3050.00    549.99      65.72
ITEM     436541     NORM SYST         140
```

contd/.—.

```
ITEM    463171     NORM SYST        52
ITEM    486310     NORM SYST        20
ITEM    463125     NORM SYST       200
ITEM    463931     NORM SYST       100
ITEM    463711     NORM CARD       125
                                          .180        3
COST  .5               .5
ITEM    657072     NORM SYST        25
COST  .6    .3           .1
ITEM    711220     NORM SYST        33
ITEM    725991     NORM SYST         8
ITEM    792419     NORM SYST         3
ITEM    792221     NORM SYST        20
ITEM    792115     NORM SYST        50
ITEM    792312     NORM SYST        15
COST  .95              .05
ITEM    811192     NORM SYST       201
ITEM    811999     NORM CARD         3
                                          1900        3
ITEM    852111     NORM SYST        20
ITEM    852111     NORM SYST        11
ITEM    852111     NORM SYST        15
ITEM    852111     NORM SYST        15
ITEM    812151     NORM SYST        15
ITEM    812152     NORM SYST        15
END
```

```
ITEM   436541   NORM SYST    140,00     551,78     44,16
ITEM   463171   NORM SYST     52,00     350,11     52,96
ITEM   486310   NORM SYST     20,00     908,21    169,32
ITEM   463125   NORM SYST    200,00     293,24      0,00
ITEM   463931   NORM SYST    100,00     134,92     18,90
ITEM   463711   NORM CARD       125        180         3
ITEM   657072   NORM SYST     25,00     742,63    141,57
ITEM   711220   NORM SYST     33,00    6527,57    858,23
ITEM   725991   NORM SYST      8,00    1363,06    320,14
ITEM   792419   NORM SYST      3,00   10131,25   1924,63
ITEM   792221   NORM SYST     20,00    4711,58   2106,51
ITEM   792115   NORM SYST     50,00     245,04     95,86
ITEM   792312   NORM SYST     15,00    5727,86    785,08
ITEM   811192   NORM SYST    201,00    1429,27      0,00
ITEM   811999   NORM CARD         3       1900         3
ITEM   852111   NORM SYST     20,00     326,09    178,80
ITEM   852111   NORM SYST     11,00     326,09    178,80
ITEM   852111   NORM SYST     15,00     326,09    178,80
ITEM   852111   NORM SYST     15,00     326,09    178,80
ITEM   812151   NORM SYST     15,00    3445,76    565,13
ITEM   812152   NORM SYST     15,00    3895,16      0,00
END

STATSYSTEM RUN  OK
```

Table 7.3 Sample output of Tender Price Prediction System

for one contract ranked by order of item contribution

PROJECT: THIRTEENTH.TEST 43 ITEMS 37 IN LIBRARY

ITEM LIST ORDERED BY CONTRIBUTION.

ITEM CODE	DISTRIBUTION CODE	EXPECTED CONTRIBUTION	EXPECTED DISPERSION
436521	NORM	1677469.50	200446.00
343326	NORM	782831.20	6953.60
313331	NORM	773991.16	242763.28
463588	NORM	473848.00	0.00
422150	NORM	437652.80	64787.20
426140	NORM	398093.60	85393.60
486310	NORM	381448.20	71114.40
343719	NORM	307696.80	0.00
811192	NORM	287283.27	0.00
343326	NORM	273252.40	2427.20
711220	NORM	215409.81	28321.59
439951	NORM	202360.40	0.00
439503	NORM	130861.60	24952.80
343348	NORM	105686.80	0.00
313999	NORM	100000.00	3.00
792221	NORM	94231.60	42130.20
792312	NORM	85917.90	11776.20
436541	NORM	77249.20	6182.40
428512	NORM	59360.00	424.00
463125	NORM	58648.00	0.00
812152	NORM	58427.40	0.00
812151	NORM	51686.40	8476.95
241111	NORM	51558.58	15273.56
343999	NORM	43500.00	300.00
251112	NORM	42000.00	252.00
792419	NORM	30393.75	5773.89
463711	NORM	22500.00	375.00
657072	NORM	18565.75	3539.25
463171	NORM	18205.72	2753.92
486310	NORM	18164.20	3386.40
344999	NORM	15000.00	60.00
245111	NORM	14120.68	5085.64
463931	NORM	13492.00	1890.00
463588	NORM	12428.80	0.00
792115	NORM	12252.00	4793.00
245219	NORM	11043.00	0.00
725991	NORM	10904.48	2561.12
852111	NORM	6521.80	3576.00
811999	NORM	5700.00	9.00
241111	NORM	5308.75	1567.50
852111	NORM	4891.35	2682.00
852111	NORM	4891.35	2682.00
852111	NORM	3586.99	1966.80

Table 7.4 Sample output of Tender Price Prediction System for one contract ranked by order of item dispersion

PROJECT: THIRTEENTH TEST 43 ITEMS 37 IN LIBRARY

ITEM LIST ORDERED BY DISPERSION.

ITEM CODE	DISTRIBUTION CODE	EXPECTED CONTRIBUTION	EXPECTED DISPERSION
313331	NORM	773991.16	242763.28
436521	NORM	1677469.50	200446.00
426140	NORM	398093.60	85393.60
486310	NORM	381448.20	71114.40
422150	NORM	437652.80	64787.20
792221	NORM	94231.60	42130.20
711220	NORM	215409.81	28321.59
439503	NORM	130861.60	24952.80
241111	NORM	51558.58	15223.56
792312	NORM	85917.90	11776.20
812151	NORM	51686.40	8476.95
343326	NORM	782831.20	6953.60
436541	NORM	77249.20	6182.40
792419	NORM	30393.75	5773.89
245111	NORM	14120.68	5085.64
792115	NORM	12252.00	4793.00
852111	NORM	6521.80	3576.00
657072	NORM	18565.75	3539.25
486310	NORM	18164.20	3386.40
463171	NORM	18205.72	2753.92
852111	NORM	4891.35	2682.00
852111	NORM	4891.35	2682.00
725991	NORM	10904.48	2561.12
343326	NORM	273252.40	2427.20
852111	NORM	3586.99	1966.80
463931	NORM	13492.00	1890.00
241111	NORM	5308.75	1567.50
428512	NORM	59360.00	424.00
463711	NORM	27500.00	375.00
343999	NORM	43500.00	300.00
251112	NORM	42000.00	252.00
344999	NORM	15000.00	60.00
811999	NORM	5700.00	9.00
313999	NORM	100000.00	3.00
245219	NORM	11043.00	0.00
343719	NORM	307696.80	0.00
343348	NORM	105686.80	0.00
439951	NORM	202360.40	0.00
463588	NORM	473848.00	0.00
463588	NORM	12428.80	0.00
463125	NORM	58648.00	0.00
811192	NORM	287283.27	0.00
812152	NORM	58427.40	0.00

EXPECTED TOTAL PRICE = 7398435.

Table 7.5 Sample output of Tender Price Prediction System for one contract showing simulation output

N.B. This tender price was simulated 10 times. The number of simulations is specified by the user.

PROJECT: THIRTEENTH TEST 43 ITEMS 37 IN LIBRARY

SIMULATION RUNS.

ITEM	QUANTITY	DISTRIBN.	PRICE 1	PRICE 2	PRICE 3	PRICE 4	PRICE 5	PRICE 6	PRICE 7
241111	1214.00	NORM	84623.21	56871.89	38386.35	59036.47	45664.24	41236.48	42911.43
245111	28.00	NORM	18247.22	21050.15	17248.23	5582.24	9324.27	19625.32	12186.42
251112	84.00	NORM	42056.34	41935.97	42171.18	42158.06	42038.54	42572.76	42446.34
245219	9.00	NORM	11043.00	11043.00	11043.00	11043.00	11043.00	11043.00	11043.00
241111	125.00	NORM	7213.15	7062.94	4202.93	5940.12	6716.74	6871.09	5013.01
313331	3331.00	NORM	855430.03	926606.34	888477.90	730864.39	672473.76	843889.30	1263166.40
343326	4240.00	NORM	784013.98	788593.70	780038.10	779407.39	782309.35	774118.83	782522.39
343719	4240.00	NORM	307696.80	307696.80	307696.80	307696.80	307696.80	307696.80	307696.80
343326	1480.00	NORM	270168.10	271483.55	276484.94	271584.16	269193.50	270516.41	269601.76
343348	1480.00	NORM	105686.80	105686.80	105686.80	105686.80	105686.80	105686.80	105686.80
344999	20.00	NORM	15027.22	15127.20	14906.07	15051.60	14944.13	14955.13	14972.32
313999	1.00	NORM	99996.24	99995.30	100002.44	100001.39	100001.95	99998.50	100002.09
343999	100.00	NORM	43558.20	43527.67	43385.48	43308.04	43310.23	43493.24	44044.14
422150	4240.00	NORM	437917.30	430749.83	560134.40	504937.01	456167.19	384118.63	527794.31
426140	4240.00	NORM	451019.03	489028.80	258060.12	395246.09	582568.58	502014.58	401722.37
428512	4240.00	NORM	58552.30	59717.29	59674.52	59511.03	59459.89	59426.97	59105.32
439951	1480.00	NORM	202360.40	202360.40	202360.40	202360.40	202360.40	202360.40	202360.40
439503	1480.00	NORM	140970.37	132465.64	82504.74	185850.77	165500.09	124673.60	175350.05
463588	1220.00	NORM	473848.00	473848.00	473848.00	473848.00	473848.00	473848.00	473848.00
463588	32.00	NORM	12428.80	12428.80	12428.80	12428.80	12428.80	12428.80	12428.80
486310	420.00	NORM	422896.93	320059.27	307420.26	424620.57	402986.89	344926.41	370535.33
436521	3050.00	NORM	1531442.31	1913591.57	1411822.49	2148967.17	1828065.07	1570798.71	1618673.37
436541	140.00	NORM	81129.01	77968.33	66634.33	81344.61	68856.06	76779.17	76966.13
463171	52.00	NORM	18382.43	19198.18	18345.41	16736.52	22032.70	14680.41	20873.97
426310	20.00	NORM	25473.53	17848.82	17416.16	18768.17	19400.57	13968.20	16911.77
463125	200.00	NORM	58648.00	58648.00	58648.00	58648.00	58648.00	58648.00	58648.00
463931	100.00	NORM	12417.65	14072.62	16702.18	13936.42	14113.84	12338.00	14332.60
463711	125.00	NORM	22814.17	22538.18	21713.83	22317.87	21740.48	22289.50	22176.89
657072	25.00	NORM	21353.93	14191.34	20116.82	16364.18	17340.98	13563.03	23178.30
711220	33.00	NORM	187068.31	214585.63	212269.62	222663.75	143994.95	220999.26	258162.75
725991	8.00	NORM	7605.47	10405.36	10741.02	11681.64	16009.30	9683.13	11952.64
792419	3.00	NORM	26281.91	19092.71	29604.68	27863.55	26025.25	25884.75	26787.46
792221	20.00	NORM	93938.11	134698.92	85303.25	100168.63	61306.16	56900.71	751.73
792115	50.00	NORM	20227.11	13896.78	11512.38	11698.17	8486.54	9931.82	16168.57
792312	15.00	NORM	63153.91	77999.39	82210.05	79034.30	88336.86	66987.15	91031.00
811192	201.00	NORM	287283.27	287283.27	287283.27	287283.27	287283.27	287283.27	287283.27
811999	3.00	NORM	5705.16	5711.11	5707.59	5703.78	5696.67	5701.30	5709.63
852111	20.00	NORM	3982.80	6577.77	9849.64	5298.92	10864.74	14091.45	5671.10
852111	11.00	NORM	3601.98	5337.26	815.39	4610.27	3548.81	3334.37	5203.32
852111	15.00	NORM	1403.68	6975.47	1918.60	7452.51	4653.37	12672.67	4102.80
852111	15.00	NORM	3251.01	4639.82	5091.58	5303.15	3353.35	6633.45	5286.46
812151	15.00	NORM	48552.01	56637.72	50523.50	63864.79	57377.43	63378.42	50421.39
812152	15.00	NORM	58427.40	58427.40	58427.40	58427.40	58427.40	58427.40	58427.40
	TOTALS		7421986.58	7857755.00	7068818.66	8004300.19	7591284.96	7310475.24	7903158.02

contd/...

SIMULATION RUNS.

ITEM	QUANTITY	DISTRIBN.	PRICE 8	PRICE 9	PRICE 10
241111	1214.00	NORM	44892.84	42306.25	62507.78
245111	28.00	NORM	4635.47	14952.79	10640.09
251112	84.00	NORM	42139.28	41956.29	42133.82
245219	9.00	NORM	11043.00	11043.00	11043.00
241111	125.00	NORM	3658.29	3184.40	8543.26
313331	3331.00	NORM	1303644.99	556130.97	937639.44
343326	4240.00	NORM	786891.40	787531.45	776819.17
343719	4240.00	NORM	307696.80	307696.80	307696.80
343326	1480.00	NORM	273323.48	273483.31	270500.08
343348	1480.00	NORM	105686.80	105686.80	105686.80
344999	20.00	NORM	14936.78	15034.21	14939.84
313999	1.00	NORM	99999.12	99998.52	100002.66
343999	100.00	NORM	44065.10	43215.04	43678.46
472150	4240.00	NORM	472028.93	589027.11	504257.82
426140	4240.00	NORM	313627.38	528343.82	448617.96
428512	4240.00	NORM	59457.64	59310.88	59722.61
439951	1480.00	NORM	202360.40	202360.40	202360.40
439503	1480.00	NORM	118873.83	108815.21	123372.74
463588	1220.00	NORM	473848.00	473848.00	473848.00
463588	32.00	NORM	12428.80	12428.80	12428.80
486310	420.00	NORM	309844.36	327254.54	447188.72
436521	3050.00	NORM	1520711.71	1551048.82	1744475.58
436541	140.00	NORM	83768.88	89825.90	77101.63
463171	52.00	NORM	18634.56	17613.51	16060.99
486310	20.00	NORM	20505.33	15455.23	27254.48
463125	200.00	NORM	58648.00	58648.00	58648.00
463931	100.00	NORM	13672.23	12687.94	10868.15
463711	125.00	NORM	22739.71	22730.98	22775.18
657072	25.00	NORM	20623.56	16102.12	18769.18
711220	33.00	NORM	231713.11	179885.79	195413.99
725991	8.00	NORM	10606.06	10047.62	11776.73
792419	3.00	NORM	32556.95	23462.27	30840.12
792221	20.00	NORM	145481.61	164602.49	173846.52
792115	50.00	NORM	3461.16	16940.70	17611.86
792312	15.00	NORM	104298.98	88402.94	68654.64
811192	201.00	NORM	287283.27	287283.27	287283.27
811999	3.00	NORM	5702.09	5694.95	5690.12
852111	20.00	NORM	8916.19	10823.32	2929.66
852111	11.00	NORM	3320.46	3968.55	3530.47
852111	15.00	NORM	4318.29	5576.75	6920.29
852111	15.00	NORM	2853.77	3627.21	279.27
812151	15.00	NORM	58547.88	49573.25	57984.61
812152	15.00	NORM	58427.40	58427.40	58427.40
	TOTALS		7721873.89	7295937.58	7860770.40

SIMULATION TOTAL PRICE = 7603636.
STANDARD DEVIATION = 315299.

PROGRAM TE-MINATES OK

7.4 Testing the Tender Price Prediction System

A full test of the concept of the system described in section 7.1 will not be available until the system is fully installed and the organisational arrangements created that will collect unit prices on a regular basis. Nevertheless the system based on the original 171 contracts can be tested by attempting to predict more recent contracts not included in the price library. The accuracy of the predictions obtained by this test will almost certainly be poorer than that eventually obtained by a fully installed system operating on price library data that is closer in time to the time of the prediction with a large number of price entries for each item in the library.

Number of Contracts tested

The organisation who supplied the data was asked for details of as many contracts as possible for testing the tender price prediction system. A total of fifteen roads contracts were supplied. Some of the items in the 15 test contracts did not have entries in the PRICE LIBRARY because the price library was based on 171 contracts and not every possible item was represented by these 171 contracts.

Data supplied for each test Contract

The data supplied for each test contract was as follows

- A list of standard item numbers (the items which were not in the price library were marked)
- The quantity of each item
- The unit price submitted by one particular contractor
- The total price for each item submitted by the one particular contractor
- The number of contractors who submitted tenders
- The tender price of each contractor (the identity of the contractors was not revealed)
- The data of submission of the tenders.

Test Procedure

1) The details of each contract were coded as described in appendix T, the reference and user manual for the Tender Price Prediction System.

2) The items that had no entry in the library were inserted by CARD using the detailed information for the one contractor whose unit prices were known.

3) The contracts were processed using the Tender Price Prediction System described in sections 7.1 and 7.3 and appendix T.

4) The mean price predicted was compared to the calculated mean of the submitted tenders.

Tables 7.2, 7.3, 7.4 and 7.5 give examples of the test output for one contract.

Test Results

The results of the test are shown in table 7.6.

This shows that for the test contracts the estimate is an average 3.63% higher than the mean bid and the standard deviation is 8.68%. As with the designer's estimating accuracy the more interesting figure is the standard deviation which in this case is 8.68% which is a substantial improvement on 20.03% as obtained by the designers estimating of mean bids in roads from table 6.2 The figure of 8.68% also rates amongst the best of the accuracies achieved by regression based models as reported in section 6.4 This is particularly true when it is remembered that the regression based models were tested against data in their own data base and not, as was the case in this test, against contracts outwith the price library.

The system estimates being higher than the observed means is almost certainly due to the general state of the industry which during the period the price library was compiled, was more bouyant than the test dates of most of the contracts. Longer term tests would be needed to establish this relationship.

Table 7.6 Results of 15 tests of Tender Price Prediction System

Contract	Mean Tender	"FAIRTENDER" Estimate	Mean/Est %	Residual (Est-Mean)	% of Estimate	% of Mean
1	10,751,994	10,445,973	102.92	-306,021	- 2.93	- 2.85
2	17,250,246	19,454,022	88.65	2,203,776	11.33	12.78
3	8,833,579	9,777,763	90.33	944,184	9.66	10.69
4	1,350,204	1,253,187	107.75	- 97,017	- 7.74	- 7.19
5	3,072,736	3,065,402	100.20	- 7,334	- 0.24	- 0.24
6	3,029,952	2,679,604	113.12	-350,348	-13.07	-11.56
7	6,654,415	6,223,566	106.95	-430,849	- 6.92	- 6.47
8	6,732,129	7,539,190	89.28	807,061	10.70	11.99
9	4,378,357	4,424,008	99.00	45,651	1.03	1.04
10	2,626,636	3,048,243	86.20	421,607	13.83	16.05
11	2,307,077	2,271,916	101.52	- 35,161	- 1.55	- 1.52
12	2,771,075	3,105,511	89.20	334,436	10.77	12.07
13	6,667,408	7,398,435	90.09	731,027	9.88	10.96
14	8,233,900	9,510,478	86.58	1,276,578	13.42	15.50
15	4,672,855	4,987,102	93.72	314,247	6.30	6.725
		Mean of (mean/est)	96.17%	Mean of Residuals	3.63%	4.53%
		Standard deviation of (mean/est)	8.30%	Standard deviation of Residuals	8.68%	9.11%

The standard deviations obtained by the tender price prediction system are as shown in table 7.7, less than the 8.38% from table 4.9 obtained by analysing the bids. The average of 5.29% could possibly be explained by an inadequate data base, in that as more data was added to the price library the likelihood is that more variability would be obtained.

Table 7.7 The Standard Deviations of the estimates obtained from Tender Price Simulation Tests

Contract	Mean Estimate	Standard Deviation	S.D. %
1	10,445,973	873,236	8.36%
2	19,454,022	635,638	3.26%
3	9,777,763	779,429	7.97%
4	1,253,187	123,185	9.83%
5	3,065,402	118,577	3.86%
6	2,679,604	153,344	5.72%
7	6,223,566	252,544	4.05%
8	7,539,190	184,386	2.44%
9	4,424,008	109,384	2.47%
10	3,048,243	218,577	7.17%
11	2,271,916	65,562	2.88%
12	3,105,511	101,159	3.25%
13	7,398,435	315,299	4.26%
14	9,510,478	173,272	1.82%
15	4,987,102	170,886	3.42%

Average : 5.29%

The foregoing analyses have examined how well the Tender Price Prediction System predicted the 'mean bid'. This examination has compared the mean estimated by the system with the mean calculated from the submitted bids. Since this mean calculated from the submitted bids is the equivalent of a sample the limit of accuracy of this type of comparison will be the limit of accuracy of predicting the population mean from the sample mean. This accuracy depends on the sample size, and the method of measuring this accuracy is to calculate the standard error of the sample mean about the population mean. This standard error is given by $\frac{\sigma}{\sqrt{n}}$ where σ is the standard deviation of the parent population and 'n' is the sample size, in our case the number of bidders. Using the standard deviation of bids for roads contracts of 8.38% from table 4.9 the standard error for n = 2; 18 was calculated and shown in figure 7.2. The same calculation was performed for a standard deviation of 6.49% representing buildings contracts from table 4.8 and is also shown in figure 7.2. Given that the average number of bidders for the test contracts was almost 6, the average standard error for the type of calculation used is of the order of 3.3%. Thus if from the standard deviation of 8.68% observed accuracy at least 3.3% of it is explained by the method of comparison, then the accuracy achieved by Tender Price Prediction System becomes

$$\sqrt{(8.68\%)^2 - (3.3\%)^2} = 8.03\%.$$

The mean bid as predicted by the system could be converted to a prediction of the lowest bid using the relationships established in section 4.4 and the number of bidders. The test in this case would be to determine how well this predicted lowest bid compared with the actual lowest bid. The average difference between mean and lowest bid used was that as given in table 4.9 for roads contracts, based on the standard deviation as calculated by Downton's method. The resulting prediction of the lowest bid is given in table 7.8 together with the actual low bid and calculated comparisons both as ratios and residuals.

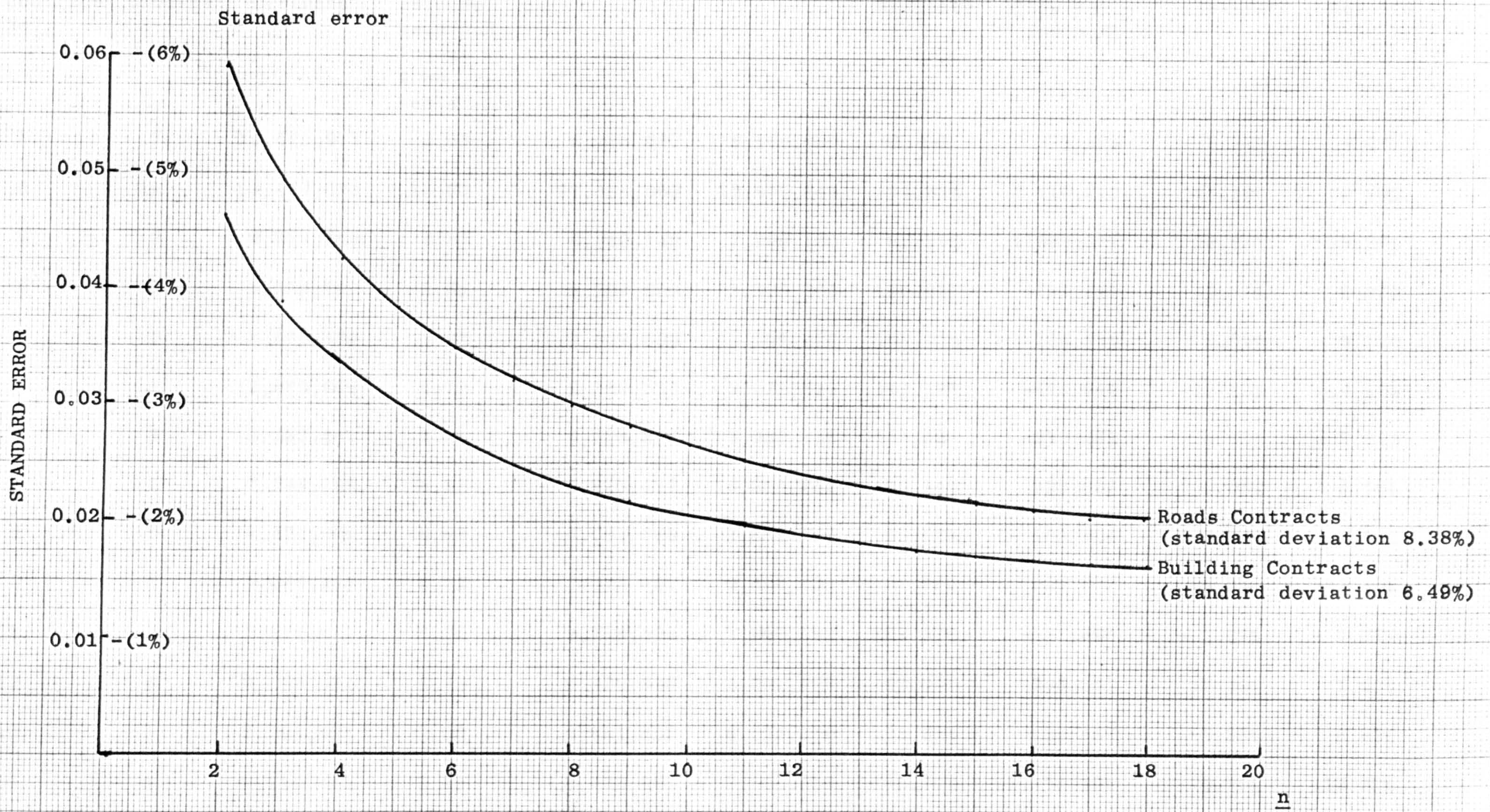


Figure 7.2 Standard Error of predicting lowest bid from mean bid v number of bidders

(Standard Error = $\frac{\sigma}{n}$)

Table 7.8 Comparison of lowest bids derived from predicted mean bids with actual lowest bids

Test Contract No.	No. of bidders	Mean Estimate	Difference between mean and lowest from table	Low Estimate	Low Bid	Low bid / Estimate	Residual (low est.- low bid)	% of low est.	% of low bid
1	7	10,445,973	8.83	9,523,593	9,150,989	96.09%	372,604	3.91%	4.07%
2	12	19,454,022	10.63	17,386,059	12,975,848	74.63%	4,410,211	25.36%	33.98%
3	6	9,777,763	8.27	8,969,142	7,299,165	81.38%	1,669,977	18.68%	22.87%
4	2	1,253,187	3.68	1,207,069	1,338,360	110.87%	-131,291	-10.87%	- 9.81%
5	2	3,065,402	3.68	2,952,595	3,068,165	103.91%	-115,570	- 3.91%	- 3.76%
6	4	2,679,604	6.72	2,499,534	2,927,574	117.12%	-428,040	-17.12%	-14.62%
7	6	6,223,566	8.27	5,708,877	5,939,466	104.03%	-230,589	- 4.03%	- 7.49%
8	7	7,539,190	8.83	6,873,479	6,250,782	90.94%	622,697	9.05%	9.96%
9	6	4,424,008	8.83	4,033,368	3,881,264	96.22%	152,104	3.77%	3.91%
10	4	3,048,243	6.72	2,843,401	2,496,400	87.79%	347,001	12.20%	13.90%
11	2	2,271,916	3.68	2,188,309	2,240,199	102.37%	- 51,890	- 2.37%	- 2.31%
12	4	3,105,511	6.72	2,896,820	2,691,299	92.90%	205,521	7.09%	7.63%
13	9	7,398,435	9.69	6,681,526	6,254,859	93.61%	426,667	6.38%	6.82%
14	6	9,510,478	8.27	8,723,961	7,564,555	86.71%	1,159,406	13.29%	15.32%
15	11	4,987,102	10.35	4,470,936	4,499,520	100.63%	- 28,584	- 0.639%	- 0.635%
					Mean	95.95%	Mean	4.05%	5.055%
					S.D.	11.09%	S.D.	11.08%	12.89%

PAGE

NUMBERING

AS ORIGINAL

PRACTICAL APPLICATIONS - CLIENTS/DESIGNERS

1) Clients/Designers can use

   i) average mean standardized bids and

   ii) CUSUM graphs, to select a keen competitive set of bidders.

2) Clients/designers can use outlier tests to identify a bid they assess as being unrealistically low and this measure can be used to augment their other assessments.

3) Clients/designers should acknowledge the negative correlations that exist between their estimates and number of bidders, e.g. by preparing an estimate on the basis of 'n' bidders and showing that at least some of the difference between their estimate and the lowest tender is due to this correlation.

4) Belgian Government has basis for tender price prediction that is substantially more accurate that existing designers estimating.

LIMITATIONS - CLIENTS/DESIGNERS

Before any of the applications listed above are attempted anywhere other than the locations from which the data were drawn the relationships established and quantified in this document would need to be re-established and re-quantified.

Such a suggested application as 1) above should be possible in a large client organization such as D.O.E. The applications will fail due to lack of data if used in organizations where the data base is too small.

Application 7) would require a degree of cooperation between contractors that does not currently exist in the U.K.

LIMITATIONS - TENDER PRICE PREDICTION SYSTEM

The design of the tender price prediction system was substantially influenced by the contract documents and conditions prevailing in Belgium at the time of data collection. Alterations would be required before the system could be used elsewhere but nevertheless the possibility of such alterations and use exists. For example one such alteration would be the provision of a facility for handling time related items rather than just quantity related items.

AVAILABILITY OF DATA

All the data related to the Belgian construction industry. Data from U.K. sources at the time of the study was insufficient or more precisely unavailable to conduct such studies.

PRACTICAL APPLICATIONS - CONTRACTORS

1) Contractors can use mean-standardized bids of other competitors from competitions other than the ones they enter to indicate the performance of other contractors.
   - Average mean standardized bids indicates
   i) disproportionate low or high bidders
and ii) success ratio.

2) Contractors can identify those who are currently keen and those who are not via CUSUM graphs.

3) Contractors can check if they themselves have any underlying tendency to favour large or small contracts. They can also check this of their competitors, bearing in mind that it only has an effect for extreme trends.

4) Contractors can check the general sensitivity of their success ratio to changes in their bid value. (They could perform the same analyses for their competitors but the information gained seems of little value).

5) From the normal distribution of bids and normal order statistics contractors can derive the average percentage difference between the mean and the lowest bid that needs to be achieved in order to win.

6) Using order statistics a contractor can determine if he is a low outlier i.e. lies within the lower 10% tail of the distribution of bids. This would be useful in situations where he has the opportunity to withdraw.

7) Contractors could use the tender price prediction sytem to evaluate their own estimates.

LIMITATIONS - CONTRACTORS

Applications 1), 2), 5) and 6) are only possible where contractors have available the published results of bidding competitions. This is not the situation in the U.K. and therefore these suggested applications are not immediately possible.

The results of comparing the predicted lowest bid with the actual as shown in table 7.8 shows the prediction was on average 4.05% above the actual low bid. This compares well with the over-estimate of 3.63% for the mean bid and probably exists for the same reason. The standard deviation of the residuals of estimate - low bid is 11.08% which represents an expected deterioration from the 8.68% obtained in estimating the mean bid. This deterioration was expected because of the additional variability introduced by the average relationship between mean and lowest bid. Nevertheless 11.08% represents a substantial improvement on the 20.14% from table 6.2 obtained by the designers' estimating. Again these results are taken to be encouraging and sufficient to recommend the full development and installation of the Tender Price Prediction System. The results do not achieve the accuracy level required by Grinyer & Whittaker's[13] approach and it seems unlikely that a system of estimating based on historical records will.

If the extreme residual belonging to test contract number 2 is removed on the grounds that it is an outlier the standard deviation of the residuals reduces from 11.08% to 9.74%. If the second most extreme residual value is removed the standard deviation reduces to 8.91%. While this course of action is tempting, the temptation is resisted, but the figures are produced to demonstrate the effect of the extreme values and the importance of removing outliers.

8.0 CONCLUSIONS

8.1 Distribution of Bids

The data collected are described in section 3.0 and in the introduction to section 4.0. One difficulty in analysing such data, that is 574 contracts each with between two and eighteen bidders, is that the data, although large in number, represent a large number of small samples. The data do not represent a large sample. Previous workers in using concepts of a distribution of bids did not support their assumptions by publishing their analyses (23), (24), (25) or, as in the case of Whittaker[3] produced an analysis that was open to criticism.

1) The basic parameters calculated in section 4.1 and described in appendix C show that the variance of buildings contracts is 0.00422 and of roads contracts is 0.00703 calculated on a weighted average of the variance of bids for each contract. The skewness is positive, i.e. skewed to the right, but small, and the kurtosis is near 3.0. These results are presented in table 4.1.

These results lead to the preliminary conclusion that the bids could be regarded as samples from a normal distribution.

An F-test on the variances for buildings and roads contracts showed them to be significantly different and so should be treated separately and cannot be amalgamated. All further analyses relating to the two types of contract were done separately.

2) The variance of bids grouped by contract value were calculated and presented in table 4.2. Although this table shows variances which are significantly different it does not show any systematic trend as contract value increases. It was therefore concluded that variance of bids had no correlation with contract value. This conclusion questioned the logic behind the limiting of price adjustments

on a basis of contract value as practised by the data supplying organisation.

3) The variance was calculated for each group of contracts for the same number of bidders as shown in figures 4.2 and 4.4. These show a very slight upward trend in variance as number of bidders increases for buildings contracts and a very slight downward trend with high variability for the roads contracts.

Similar graphs of kurtosis and skewness against number of bidders are shown in figures 4.3 and 4.5. These show kurtosis to be consistently near 3.0 and the skewness to be small but almost consistently positive. Significance tests on the skewness values show them not to be significant.

The small values of skewness and the values of kurtosis being near 3.0 support the preliminary conclusion of the bids being samples from normal distributions.

4) Section 4.3 describes the test for uniformity against normality, which was undertaken to support the preliminary conclusion of normality and to further refute Whittaker's suggestion of uniformity. Table 4.3 presents the samples whose studentized range is significant at 10% for normal samples. Table 4.3 shows the 16 samples found in the lower tail and the 21 found at the upper tail for buildings contracts near to the 18.5 expected if the samples were normally distributed. Similarly the 30 and 32 samples found in the lower and upper tail of the roads contracts were near to the 35 expected if the samples were normally distributed. Table 4.4 shows that if the samples were uniformly distributed the expected number of samples in the upper 10% would be 47 for buildings contracts and 57 for roads contracts. These figures being obtained by simulation.

The conclusion here was that the bids did not belong to a uniform distribution and that the behaviour was compatible with the assumption of normality.

5) A further test for normality was undertaken because the data represents a large number of small samples and statistical tests are generally poor for small samples. The studentized range is poor in testing longtailed or skewed distributions, except in testing for normality against uniformity. The test chosen was the Anderson-Darling statistic as described in appendix E. The key results of the calculations relating to the Anderson-Darling statistics are presented in table 4.5 and 4.6 for buildings and roads contracts respectively. These results are presented diagrammatically in figure 4.6 and 4.7 for buildings and roads contracts. These tables and figures present the probability integral transformation of the Anderson-Darling statistics. These would be uniformly distributed if the samples belonged to a normal distribution. Appendix F presents the chi-square tests on the distributions of Anderson-Darling statistics and the results are presented in table 4.7. Table 4.7 shows that the bids for buildings contracts can be regarded as samples from normal distributions. However, table 4.7 shows that bids for roads contracts cannot be regarded as samples from normal distributions.

Families of transformations for the bids for roads contracts were tested, as described in section 4.3, to determine if a transformation existed which would reduce the bids for roads contracts to normality. No such transformation was found.

The conclusion was that bids for buildings contracts were normally distributed and that bids for roads contracts were near normal. The near normality of the bids for roads contracts was based on the evidence of the small skewness and the value of the kurtosis. Also the irregularities in the incidence of Anderson-Darling statistics appear at the extreme percentage points and over the middle range appear fairly uniform. This is taken as indication that there are some non-normal samples in the data whereas the majority of the samples behave as samples from a normal distribution.

6) The relationship between the mean and lowest bids was examined to determine if normal order statistics can predict these relationships, thus further confirming the assumption of normality. This was particularly important for the roads contracts in view of the Anderson-Darling test results, however the possibility remained that the lower tail of the distribution of roads contracts would behave as normal since the skewness, although small, was almost consistently positive.

Figures 4.8 and 4.9 present the comparison between the observed differences between mean and lowest bids and those differences predicted by normal order statistics using an overall distribution and separate distributions for each group of 'n' bidders. For both buildings and roads contracts the normal order statistics over-estimate the difference between the mean and lowest bids. Figures 4.10 and 4.11 present the same results but this time the standard deviations of the distributions are calculated by a method put forward by Downton, as described in appendix G, which reduces the weighting of extreme values. Figures 4.10 and 4.11 show the improvement gained by using Downton's estimate of standard deviations.

The conclusion was that the bids for both buildings and roads contracts displayed a relationship between mean and lowest bids that was compatible with normal order statistics. Also the use of separate distributions for each group of 'n' bidders using Downton's estimate of standard deviation was more appropriate than overall distributions.

Figures 4.10 and 4.11 also indicate the limitation on accuracy of a method of predicting lowest bids, such as Whittaker's, that relies on estimating the difference between the mean and lowest bid.

Figures 4.12 and 4.13 show the average observed difference between mean and lowest bids superimposed on the allowable price adjustments. These figures show that the price adjustment system discriminates against buildings contractors who win contracts in competitions with 8 or more bidders and similarly roads contractors who win in competitions with 6 or more bidders.

7) Section 4.5 suggests that the assumption of bids being normally distributed can be used to identify unrealistically low bids by using outlier tests. The outlier test suggested is that put forward by Grubbs. The Grubbs statistic was calculated for each of the contracts in the data and the results are presented in appendix H, and summarised in section 4.5. The results obtained are compatible with those expected from normal distributions and it is suggested that this could be used in conjunction with other numerical and subjective measures when assessing contracts.

8) Section 4.4 compares the findings of these analyses with those of Grinyer and Whittaker(13) and shows that although the shape of the distribution is demonstratably different it can be implied that the standard deviation for buildings contracts found in this work and by Grinyer and Whittaker are close.

8.2 Contractors Bidding Behaviour

The aim in this analysis was to establish if the historical data required to interpret competitors' behaviour could be drawn from contracts in which the contractor himself did not enter. Previously all standardising was done by dividing competitor's bid by the contractor's cost estimate. This was because, using the mean as the standardiser was rejected on the grounds that the mean itself was a variable. A second aim was to explore the possibility of including in any interpretive model or approach the concept of contractors relative prices changing with time, as put forward by Mercer and Russell(4).

1) In section 5.1 contractors' bidding histories based on mean standardised bids (i.e. contractor's bid divided by mean bid for the contract) and on transformed position were produced and samples shown in figure 5.1 and table 5.1.

The average of mean standardised bids for buildings contractors range from 0.87 to 1.091 and for roads contractors from 0.88 to 1.22, as shown in tables 5.2 and 5.3.

Each of these average mean standardised bids were tested against each other for significant differences, using the student t-test. The results are presented in figures 5.3 and 5.4 in section 5.2.

The observation was that some contractors have average mean standardised bids that are significantly different from the others while contractors whose average mean standardised bids are in the central range are not significantly different. This was taken to indicate that contractors bids were different and that their behaviour was not that of a homogenous group.

The average mean standardised bid was compared with the contractor's success ratio (number of winning bids/number of bids submitted). The results presented in tables 5.4 and 5.5 show a strong negative correlation between the average mean standardised bid and the success ratio. Thus calculating the average mean standardised bid of competitors indicates their success ratio. The importance of this is that the average mean standardised bid of a competitor is not reliant on data only from a contractor's own competitions. Thus this is an important widening of the potential data base to individual contractors.

2) The behaviour of each contractor, like the samples shown in figure 5.1, were tested to determine if this behaviour was random or displayed identifiable patterns of behaviour.

Section 5.3 reports a manual calculation for a few sample contractors for randomness and runs, as described in appendices J, K and L. The results from these manual calculations are presented in tables 5.6 and 5.7. The observations were that some contractors displayed a random behaviour, some had a disproportionate number of high or low bids. The runs test did not identify many non-random set of runs. The insensitivity of the runs test may be due to taking the whole data set which, viewed as a whole, did not show disproportionate numbers of runs. However there are examples of the behaviour patterns changing from predominantly high to mixed or to predominantly low behaviour. Thus the sensitivity of the runs test was suspect.

The manual analysis was computerised and extended to all contractors who submitted 20 or more bids and the randomness and runs test was also applied to the transformed position. The results are presented in tables 5.8 and 5.9.

The conclusions drawn from these tests support the usefulness of the average mean standardised bid as an indicator of high success ratio and a disproportionate number of low bids.

The results from the runs test were disappointing and again the sensitivity of the test used was suspected.

3) The runs test previously had produced inconclusive results and so the analysis was extended. A Box-Jenkins time series analysis was attempted on the standardised bids and transformed positions but this proved unhelpful. The calculation of autocorrelations coefficients was also tried and again proved unhelpful. Both these analyses and their results are given in section 5.4.

Also in section 5.4 is the description of the CUSUM graphs, samples of which are given in figures 5.4 and 5.5. These graphs indicate whether a contractor is bidding below the mean bid and therefore seeking to win contracts or bidding above the mean and therefore not seeking to win contracts. Table 5.12 indicates that in both buildings and roads contracts 85% of winning bids were preceded by at least two decrements in the contractor's CUSUM graph.

Section 5.4 also describes the classification of contractors' behaviour according to the movement in his CUSUM graphs. Trend analyses on these classifications of behaviour, as reported in tables 5.15 and 5.16, indicate that the expected trends exist, that is wins come with downward drifts in CUSUM graphs. However these trends did not always appear as significant; this is thought to be caused by the data not representing all the bids submitted by contractors.

The conclusion from the investigation into contractors' price movements is that CUSUM graphs and behaviour classification of the CUSUM behaviour are the most useful method of interpreting a competitor's behaviour. Again, since this relates the competitor's bid to the mean bid, the data is not only restricted to compeitions in which the data collecting contractor enters.

4) Section 5.5 reports an inconclusive attempt to apportion the variability in bids between the contractors and the contracts. The results of an analysis of variance presented in tables 5.21, 5.22, 5.23 and 5.24 show that residual variances are dominant and that variability cannot by this method be apportioned. One reason for the lack of measurable differences may be due to the selection of contractors who meet most often, also coinciding with contractors whose average mean - standardised bids are in the central 'not significantly different' range.

5) Section 5.6 describes simulation exercises undertaken using the contractors' histories recorded by their mean standardised bid for each contract in which they bid. The results, as the samples presented in tables 5.25 and 5.26, show straightforward simulation does not predict the winning bidder. This was regarded as important since it emphasises the need for CUSUM graphs or similar interpretation of behaviour. The simulations alone treated all historical behaviour as the same and did not differentiate between the work hungry or the others.

6) Section 5.7 reports on the analysis of the sensitivity of success rate to changes in bid value. Figures 5.6 and 5.7 show samples of the graph of success rate v changes in the contractor's bid value. Tables 5.27 and 5.28 tabulate the numerical representation of these graphs. These graphs together with tables 5.4 and 5.5, the average mean standardised bid and success ratio, indicate the amount of adjustment required by any particular contractor to achieve a desired success ratio.

The difference in the graphs is taken to imply different market judgements by different contractors.

7) Section 5.8 reports the search for trends between contractor's mean standardised bids and contract value. The results are presented in tables 5.29 and 5.30. The evidence gained from these tables and figures 5.9 and 5.10 was that identifiable trends between the contractors standardised bids and contract value existed. However these trends only had an observable effect in the extreme cases where the coefficient describing the slope of the trend line is substantial.

This analysis is useful for contractors to perform on their own company's data to monitor any unwitting bias in favour of large or small contracts.

8.3 Tender Price Prediction

1) The accuracy of designers in predicting tender prices was examined in section 6.0. Table 6.1 presents the results of calculating the ratios of (mean bid/designer's estimate) and (lowest bid/designer's estimate). This shows the achievable accuracy of designers after adjusting the mean of the estimates to be standard deviations of 14.27% and 13.80% for estimating the mean and lowest bid for buildings contracts and standard deviations of 19.15% and 18.63% for estimating the mean and lowest bids for roads contracts.

The residuals, that is (mean bid - designer's estimate) and (lowest bid - designer's estimate), have standard deviations of 16.08% and 16.63% for buildings contracts and of 20.03% and 20.14% for roads contracts. The standard deviations given above and in table 6.2 are measures of the achievable accuracy of the designers who currently estimate the tender price of these contracts. These standard deviations also act as a standard by which to judge other methods of estimating.

2) In section 6.2 figures 6.1 and 6.2 and tables 6.3 and 6.4 show the negative correlation between (lowest bid/designer's estimate) and the number of bidders. This was expected and is consistent with the assumption that the designer estimates without knowledge of the number of bidders, or takes no account of the number of bidders in his estimating. However, figure 6.1 in particular, and to a lesser extent figure 6.2, show a similar negative correlation with the number of bidders. This was not expected and is explained as evidence of price cutting, resulting from increased competition and due to the number of bidders. This is regarded as important since it presents evidence of at least two mechanisms driving down prices as the number of bidders increases, one being the winning bid moving further from the mean as the number of bidders increases and the other the apparent depression of the mean itself as the number of bidders increases.

There was no evidence of any correlation between the ratios (mean bid/designer's estimate) and (lowest bid/designer's estimate) and contract value as tables 6.5 and 6.6 indicate.

3) The correlations between (mean bid or lowest bid/designer's estimate) and number of bidders can be used to produce correction factors to adjust the mean, as described in section 6.3. These correction factors cannot, however, affect the standard deviation which is taken as the measure of accuracy. In fact as section 6.3 and in particular table 6.7 show the standard deviations increased because the correction factor which was a curve fitted

to the data did not fit the data exactly and so the resultant standard deviation is the original standard deviation plus the error introduced by curve fitting.

4) The accuracy of a numerical approach, price models based on regression analysis, is described in section 6.4. The results are summarised in table 6.8. The conclusion drawn was that the accuracy of the designers and regression analyses was similar and regression based price models offer no significant improvement in accuracy. Any advantage argued for regression based estimating systems would need to be on the grounds of economy.

The conclusion relating to the accuracy of predicting the mean bid required by Grinyer and Whittaker's method was not achieved by the methods examined.

5) Section 7.0 describes the development of a tender price prediction system based on a library of unit prices updated, used inflation indices and statistically analysed before incorporating in a simulated tender. The system is outlined in figure 7.1 and fully described in appendix T, which is a complete reference and user manual for the system. Tables 7.2, 7.3, 7.4 and 7.5 give sample output from the system.

The tests of the system undertaken are described in section 7.4 were limited to roads contracts. The results of predicting the mean bid of 15 different contracts are presented in table 7.6. Table 7.6 shows the standard deviation achieved was 8.68% which was a substantial improvement on the 20.03% obtained by the designers from table 6.2 and is amongst the best of the accuracies achieved by the regression based price models.

Using the relationship between mean and lowest bid established in section 4.4 the mean as predicted by the system was used in turn to predict the lowest bid. The results of predicting the lowest bid are given in table 7.8. The standard deviation achieved in predicting the

the lowest bid was 11.08% which again shows a substantial improvement on the 20.14% achieved by designers as shown in table 6.2.

The price library data base for this feasibility study was limited and it is therefore likely that the accuracy of predicting the mean bid could improve with more data. However the test results are seen as major improvements on the results achieved by designers estimating and the price library approach, which incorporates simple regression models, seems more fruitful than regression analysis as traditionally applied.

8.4 Summary of Conclusions

The normality or near normality of the distribution of bids for buildings and roads contracts is established. This allows the relationship between mean and lowest bids to be defined using normal order statistics. It also permits the application of outlier tests to be used in identifying unrealistically low bids.

The average mean standardised bids of contractors have a strong negative correlation with the contractor's success ratio. This allows contractors to predict success ratios of others using their mean - standardised bids. The data required for this is not limited to the competitionsin which the contractor himself enters.

Contractors have different behaviour patterns, some with disproportionate numbers of high or low bids and others behave randomly. These behaviour features correlate well with the average mean standardised bids.

Graphs of the cumulative sum of (bid - mean bid)/mean bid are useful in identifying contractors who are anxiously seeking work and those who are not. These can be used to identify serious rivals for particular contracts.

Contractors have different sensitivity of success ratios to changes in bid value, thus indicating different market judgements.

Contractors also have different trends within their standardised bids to contract value. This only affects success ratios in extreme cases.

Designers have accuracies of standard deviations of 16.63% and 20.14% for predicting the lowest bid of buildings and roads contracts respectively. Price models based on multiple regression analysis produce similar accuracies for comparable construction works.

The tender price prediction system developed, based on a library of unit prices and inflation indices achieved a standard deviation of 8.68% in predicting the mean bid and 11.08% in predicting the lowest bid for roads contracts. This could be improved with more data but nevertheless is a substantial improvement on the results achieved by designers' estimating.

REFERENCES

1. FRIEDMAN, L. "A competitive bidding strategy". Operations Research, 1956, Vol. 4, pp. 109-12.
2. GATES, M. "Bidding Strategies and Probabilities". Journal of the Construction Division, ASCE, March 1967, V.93, No.CO1, proc. paper 5159, pp. 75-107.
3. WHITTAKER, J.D. "Managerial Judgement in a Competitive Bidding Model". Ph.D. Thesis 1970, City University.
4. MERCER, A. and RUSSELL, J.I.T. "Recurrent Competitive Bidding". Operational Research Quarterly, 1969, Vol.20, No.2, pp. 209-221.
5. PARK, W. "The Strategy of Contracting for Profit". Prentice-Hall, 1966.

   PARK, W. "Bidders and Job Size determine your Optimum Mark Up". Engineering News Record, June 1968.
6. STATHAM, W. and SARGEANT, M. "Determining an Optimum Bid". Building, 1969, V.216, No. 6573.
7. MORIN, T.L. and CLOUGH, R.H. "OPBID : Competitive Bidding Strategy Model". Journal of the Construction Division, ASCE, July 1969, V.95, No.CO1, proc.paper 6690, pp. 85-106.
8. STARK, R.M. "Discussion of Bidding Strategies and Probabilities" Journal of the Construction Division, ASCE, V.93, No.CO1, proc.paper 5159, March 1967, pp. 75-107.
9. ROSENSHINE, M. "Bidding Models - Resolution of a Controversy". Journal of the Construction Division, ASCE, V.98, No. CO1, March 72, PP. 143-148.
10. FINE, B. "Reports of the Costain O.R. Group", 1968-1974. Unpublished.

11. BAUMGARTEN, R.M., BENJAMIN, N.B.H. and GATES, M. "Discussion of OPBID", Journal of the Construction Division, ASCE, V.96, No.CO1, June 1970, PP. 89-97.

12. RICKWOOD, A.K. "An Investigation into the tenability of b idding behaviour theory and techniques". M.Sc. project report, Department of Civil Engineering, Loughborough University of Technology, 1972. Supervisor: R. McCaffer.

13. GRINYER, P.H. and WHITTAKER, J.D. "Managerial Judgement in a Competitive Bidding Model". Operational Research Quarterly, 1973, Vol.24, No.2, p. 181.

14. CURTIS, F.J. and MAINE, P.W. Viewpoints "Competitive Bidding" Operational Research Quarterly, Vol.25, No.1, September 1973, p. 179.

15. GRINYER, P.H.and WHITTAKER, J.D. Viewpoints "Competitive Bidding - Reply to Curtis and Maine". Operational Research Quarterly, Vol. 25, No.1, September 1973.

16. CURTIS, F.J. and MAINE, P.W. "Closed Competitive Bidding". OMEGA, The Int.Jl. of Mgmt.Sci., 1973, Vol.1, No.5, pp. 613.

17. DIXIE, J.M. "Bidding Models - The final resolution of a Controversy". Journal of the Construction Division, ASCE, 1974, Vol. 100, No. CO3.

18. McCAFFER, R. "Is there an Economic Case for more Accurate Estimating". Conference Paper, Loughborough University of Technology, Joint Sponsors: Department of Civil Engineering, L.U.T., - Construction News and Institute of Building, 1973. Proceedings published in (19).

19. McCAFFER, R. (Editor). "Estimating". Proceedings of two conferences held at Loughborough University of Technology, 1974. Northwood Publications Ltd.

20. BARNES, N.M.L. and LAU, K.T. "Bidding Stragegies and Company Performance in Process Plant Contracting". Third International Cost Engineering Symposium, London, October 1974. Association of Cost Engineers.

21. HACKEMER, G.C. "Profit and Competition : Estimating and Bidding Strategy". Building Technology and Management, December 1970, V.8, No.12, p.6.

22. ARMSTRONG, K. "The Development and Appraisal of a Computerised Estimating System". M.Sc. Project Report, Department of Civil Engineering, Loughborough University of Technology, 1973. Supervisor: Professor E.G. Trimble.

23. BEESTON, D.T. "One Statisticians View of Estimating". Directorate of Quantity Surveying Development, Department of the Environment, Property Services Agency, 1973.

24. EMOND, L.J. "Analytical Strategy for the Competitive Price Setter". Cost and Management, September-October 1971, pp. 6-11.

25. ALEXANDER, A.B. "What Price Estimating Accuracy". Metal Fabricating Institute Inc. Rockford, Illinois, 1970, Paper No. 534.

26. Department of Economic Appliquée. Universite Libre de Bruxelles. (DULBEA). "Public Contracts and Fair Prices". Colloquium - Brussels, 1971, (The Belgian System. p. 157).

27. JOHNSON, N.L., NIXON, E., AMOS, D.E. and PEARSON, E.S. Biometrika. Vol.50. Cambridge University Press. ~~1950~~ 1963

28. LAMB, C.G. "Statistical Methods and Formulae". English Universities Press. 1967.

30. PEARSON, E.S. and HARTLEY, H.O. "Biometrika Tables for Statisticians." Cambridge University Press, 1966, Vol.1, 3rd Ed.

31. PETTITT, A.N. "Empirical Distribution of Studentized Range". Mathematics Department, Loughborough University of Technology, 1975.

32. PEARSON, E.S. and HARTLEY, H.O. "Biometrika Tables for Statisticians." Cambridge University Press, 1973, Vol.2, 2nd Edn.

33. STEPHENS, M.A. "EDF Statistics for Goodness-of-Fit and some Comparisons". J.Am.Statist.Assoc., 1974, 69, 730.

34. PETTITT, A.N. Small sample percentage points of the Anderson-Darling Statistic for Testing Normality. Maths. Res. No. 71, Loughborough University of Technology. 1975.

35. BOX, G.E.P. and COX, D.R. "An Analysis of Transformations" J. Roy. Statist.Soc., 1964, Series B.26, 211.

36. DAVID, H.A. "Order Statistics". Wiley, New York, 1970.

37. DOWNTON, F. "Linear Estimates with Polynomial Coefficients" Biometrika, 1966, 53, 129.

38. KENDALL, M.G. and STUART, A. "The Advanced Theory of Statistics". Vol.1 Distribution Theory. 3rd Edn., Griffen, 1969.

39. GRUBBS, F.E. "Sample Criteria for Testing Outlying Observations" Ann.Math.Statist., 1950, 21, 1041.

40. CONOVER, W.J. "Practical Non-Parametric Statistics". Wiley, 1971.

41. I.C.L. "Statistical Procedures 1900 Series". I.C.L. 1972, Chapter 4.

42. KENDALL, M.G. and STUART, A. "The Advanced Theory of Statistics". Vol. 3 Design, Analysis and Time Series, Griffen 1966.

43. PETTITT, A.N. "Kolmogarov-Smirnoy type Statistics and Goodness-of-Fit Statistics for grouped and discrete data". 1975. Tables available at Department of Mathematics, Loughborough University of Technology.

44. McCAFFER, R. "Contractors' Management Game". Sagset News, 1973, Vol.3, No.3. (Journal of the Society for Academic Games and Simulation in Education and Training).

45. SNEDECOR, G.W. and COCHRAN, W.G. "Statistical Methods" Iowa State U.P., 1967, 6th Edn.

46. PIM, J.C. "Competitive Tendering and Bidding Strategy Part 2: New Strategies for Old". National Builder, February 1975, P. 56.

47. NUMERICAL ALGORITHMS GROUP. I.C.L.1900 SYSTEMS, NAG Library Manual. Subroutine E02ABF.

48. DRAPER, N. and SMITH, H. "Applied Regression Analysis". Wiley - Interscience, 1966.

49. McCAFFER, R. "Some Examples of the use of Regression Analysis as an Estimating Tool". The Quantity Surveyor, December 1975, Vol.32, No.5, p. 81.

50. B.M.D. NIMBUS Biomedical Computer Programs. University of California Press, 1971.

51. McCAFFER, R. "Pre-Nimbus - A data handling program compatible with Nimbus". Department of Civil Engineering, Loughborough University of Technology, 1973.

52. TRIMBLE, E.G. "Regression Analysis - New uses for an Old Technique". Department of Civil Engineering, Loughborough University of Technology, 1973.

53. BUCHANAN, J.S. "Development of a Cost Model for the Reinforced Concrete Frame of a Building". M.Sc. Project Report, Department of Civil Engineering, Loughborough University of Technology, 1969, Supervisor: Professor E.G. Trimble.

54. GOULD, P.R. "The Development of a Cost Model for Heating and Ventilating and Airconditioning Installations in Buildings". M.Sc. Project Report, Department of Civil Engineering, Loughborough University of Technology, 1970.
Supervisor: Professor E.G. Trimble.

55. MOYLES, B.F. "An Analysis of the Contractors' Estimating Process". M.Sc. Thesis, Department of Civil Engineering, Loughborough University of Technology, 1973.
Supervisor: Professor E.G. Trimble.

56. NEALE, R.H. "The Uses of Regression Analysis as a Contractors Estimating Tool". M.Sc. Project Report, Department of Civil Engineering, Loughborough University of Technology, 1973.
Supervisor: R. McCaffer.

57. BAKER, M.J. "Cost of Houses for the Aged". M.Sc. Project Report, Department of Civil Engineering, Loughborough University of Technology, 1974. Supervisor: Professor E.G. Trimble.

58. BLACKHALL, J.D. "The Application of Regression Modelling to the Production of a Price Index for Electrical Services". M.Sc. Project Report, Department of Civil Engineering, Loughborough University of Technology, 1974. Supervisor: R. McCaffer.

59. COATES, D. "Estimating for French Drains - A Computer Based Method". M.Sc. Project Report, Department of Civil Engineering, Loughborough University of Technology, 1974. Supervisor: R.McCaffer.

60. SPOONER, J.E. "Probablistic Estimating". Journal of the Construction Division, ASCE, Vol.100, No.CO1, March 1974, Paper 10406, p. 65.

61. PETOFALVI, G. "Tender Price Prediction based on a Price Library". M.Sc. Project Report, Department of Civil Engineering, Loughborough University of Technology, 1975. Supervisor: R. McCaffer.
N.B. The work for this report which formed part of the development of the Tender Price Prediction System was limited to the development of the inflation indices, see section 7.3.

The following documents were consulted but are not specifically referred to in the text.

For background information on bidding theories:

62. CHURCHMAN, C.W., ACKOFF, R.L., and ARNOFF, E.L. "Introduction to Operations Research". Wiley, New York, 1957. Chapter 19.

63. EDELMAN, F. "The Art and Science of Competitive Bidding". Harvard Business Review, July-August 1965.

64. HEMPHILL, R.B. "A Method of Predicting the Accuracy of a Construction Cost Estimate". M.Sc. Thesis, Drexel Institute of Technology, Philadelphia Pa., 1967.

65. TORGERSON, P.E. "Bidding - Workloading Game". Journal of the Construction Division, ASCE, V.94, No.CO2, proc.paper 6141, October 1968, pp. 127-137.

66. SIMMONDS, K. "Competitive Bidding : Deciding the best combination of Non-Price Features". Operational Research Quarterly, 1968, Vol.19, No.1, pp. 5.

67. SIMMONDS, K. Viewpoints "Adjusting Bias in Cost Estimates" Operational Research, 1968, Vol.19, No.3, pp.325.

68. BROEMSER, G.M. "Competitive Bidding in the Construction Industry". Ph.D. Thesis, Stanford University, 1968.

69. STARK, R.M. "Unbalanced Bidding Models - Theory". Journal of the Construction Division, ASCE, Vol.99, No.CO2, October 1968, pp. 197.

70. WILSON, R. "Competitive Bidding - the Theory and Practice". Management Decision, Vol.4, No.2, Summer 1970.

71. PELTO, C.R. "The Statistical Structure of Bidding for Oil and Mineral Rights". Journal of the American Statistical Association, Sept.1971, Vol.66, No.335, Applications Section, pp. 456.

72. STARK, R.M. and MAYER, R.H. "Some Multi-Contract Decision - Theoretic Competitive Bidding Models". Operations Research, 1971, Vol.19, pp. 469.

73. SHAFFER, L.R. and MICHEAU, T.W. "Bidding with Competitive Strategy Models". Journal of the Construction Division, ASCE, Vol.97, No. CO1, proc.paper 8008, March 1971, pp. 113 - 126.

74. GRINYER, P.H. "Systematic Strategic Planning for Construction Firms". Building Technology and Management, 1972, Vol.10, Part 2, pp. 8-14.

75. WILLENBROCK, J.H. "Utility Function Determination for Bidding Models". Journal of the Construction Division, ASCE, Vol.99, No. CO1, July 1973, pp. 133.

76. BECKMAN, M.J. "Technical Notes - A Note on Cost Estimation and Optimal Bidding Strategy". Operational Research. 1974, Vol.22, No. 3, pp. 510.

77. PIM, J.C. "Competitive Tendering and Bidding Strategies". Part 1: Collecting Data and Evaluating Strategies". National Builder, November 1974, pp. 541.

For background information on estimating systems:

78. HUGHES, G.A. "Estimating for Civil Works". The Quantity Surveyor, Jan/Feb. 1974, pp. 88.

79. TAYLOR, E.,SEAWARD, P.D., GRAY, J. and BEISHON,R.J. "An analysis of the Behaviour of Estimators in the Civil Engineering Industry". 1974. Unpublished.

80. VERGARA, A.J. and BOYER, L.T. "Probabilistic Approach to Estimating and Cost Control". Journal of the Construction Division, ASCE, 1974, Vol.100, No. CO4, pp. 543.

For background information on continental tendering practices and economics:

81. BEYNON, G.I.M.T. "Tendering and Contract Procedures in Belgium". Cie Industrie et Travaux Emile Blaton, Brussels. 1968/69.

82. PHLIPS, L. "Business Price Policies and Inflation - Some Evidence from E.E.C. Countries". The Journal of Industrial Economics, 1969, Vol. XVIII, No.1, Page 1. Editor: B. Blackwell, Oxford.

83. BINDSLEV, BJORN. "Contract Procedures and Techniques in Europe and Scandinavia". Chartered Surveyor, Sept.1971, page 122.

APPENDIX A

"Is there an Economic Case for More Accurate Estimating"

R. McCaffer

Originally published in "Estimating - The Proceedings of two conferences held at Loughborough University of Technology

R. McCaffer (Editor)
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Referred to by section 2.0

IS THERE AN ECONOMIC CASE FOR MORE ACCURATE ESTIMATING

by R. McCaffer

"Estimating assessment relies more on a hunch than on scientific analysis" (Construction News, July 12, 1973). In the following paper the points considered are:

(1) what is the effect of estimators' hunches on the accuracy of estimating;

(2) what is the likely effect of reducing the "hunch" content in an estimate and hopefully improving the estimating accuracy.

1. The effect of estimating inaccuracies

In the estimating process the estimating department is required to make several assessments, partly based on recorded data, partly based on experience, partly based on hunches. Typical examples of these assessments are:

(i) the likely outputs or performance standards of the various trades and of the selected plant (and even the choice of plan for the job);

(ii) an assessment (translated into cost terms) of the ease or difficulty of carrying out the various work items which make up the contract;

(iii) the likely trend in material costs over the period of the contract;

(iv) the likely trend in wage rates over the period of the contract;

(v) the weather conditions, etc.

Different estimators will obviously asses the effects of the above and other variables differently hence a number of estimators are liable to produce a range of estimates.

The cost that the estimator is trying to produce (at least in theory) is the most likely cost to his company of executing the particular contract. This leaves the tendering panel to add profit margins which represent an adequate return commensurate with the risk involved. In the average general building situation where there is not a large element of highly specialised work and where there is a number of contractors of similar efficiencies especially in areas where staff and labour move from company to company a simplification can be made by assuming that the "likely cost" of a contract to each company is similar. Clearly in specialist work or where the methods of construction vary the likely cost of a contract will be different from company to company.

However assuming that a contract has a "likely cost" the range of estimates produced by each company will be "likely cost" ± A% where A% represents the accuracy of the estimators' prediction of likely cost.

This simplification can be used to explain partially why contractors' achieved profit/turnover is significantly less than the average of the profit margins added to the cost estimates at the tender stage. The explanation rests on the "break-even" mark-up" concept, a theory usually credited to Whittaker[3] and Fine[10].

1.1 Break-even mark-up.

Cost estimate range = LIKELY COST ± A% where A% is a measure of the accuracy of present estimating methods.

To calculate the tender, contractors add a profit margin to their cost estimate,

i.e. Tender = Cost estimate + Applied profit Margin

In the competitive tendering process the winning tender is usually the lowest. Therefore the estimator who produces the lowest estimate, say LIKELY COST minus A% gives his company the best chance of winning the contract. This supports the cliché "that the estimator who makes the biggest mistake wins the contract". The attendant cliché "what we lose on the swings we make on the roundabouts" is unsupported because the estimator who produces the highest estimate, say LIKELY COST plus A%, gives his company very little chance of winning the contract and it is probable that most winning tenders will have cost estimates which are low in the range LIKELY COST ± A%.

Thus the winning tender based on a cost estimate which is probably less than the likely cost usually results in the profit margin achieved on the contract being less than the margin included in the tender. Over a large number of contracts the average difference between profit margins included in tenders and achieved profit margins is the average difference between the likely costs and the estimated costs. This average difference has been called the "break-even mark-up".

If a contractor did not wish to make a profit but wanted merely to break-even and attempted to do so by adding a zero profit margin to his tenders he would, because of estimating inaccuracies, make a net loss over a number of contracts. To break even in the long term he would have to apply a profit margin greater than zero which would compensate for differences between the likely costs and estimated costs of his winning tenders. The profit margin needed to break even is called the break-even mark-up and the amount of this mark-up depends on (1) the general level of estimating accuracy and (2) the number of competitors.

For example with estimating inaccuracies of say ± 10% and with five competitors, a profit margin of the order of 7% would be needed to break even in the long term. Any long term achieved profit margins in this situation would be the excess over the 7% break-even mark-up included in tenders. If a contractor included, say 10% profit margins in his tenders the likelihood is that the average achieved profit margin would be of the order of 3%.

In an industry where the achieved mark-up (or profit/turnover ratio) is low - "Even efficient firms which are almost household names complain of margins on turnover of under 2%" (Construction News, leader article May 3, 1973) - but the applied profit margin at the tender stage is considerably higher, the break-even mark-up concept offers some explanation of the difference between achieved and applied margins and demonstrates the likely existence of estimating inaccuracies.

To reduce the break-even mark-up and hence increase achieved profit margins contractors need to improve their estimating accuracy and/or seek tendering situations with fewer competitors. Fig.A1 gives a graphical representation of the break-even mark-up based on work by B. Fine, of Richard Costain Ltd.[10]

2. <u>The effect of improving the accuracy of estimating</u>

If a contractor considered improving his estimating accuracy several questions would arise, namely:

(1) if I improve the accuracy of my estimating shall I still be successful in obtaining contracts ?

(2) if I improve the accuracy of my estimating what will the effect on my profits be ?

(3) if I derive any benefits from improving the accuracy of my estimating will these benefits remain if the rest of the competition made similar improvements ?

In an attempt to obtain answers to these questions or at least a guide as to the likely answers a simulation program was produced by Armstrong(22).

It was subsequently developed by the author and later the key results were checked by analytical means. The details of this program are not described here but briefly it combines the factors that determine a contractor's ability to secure contracts and the resulting achieved profit margins. The factors included were:

(a) the estimating accuracy of the contractor who is considering improving his accuracy (referred to as contractor E);

(b) the general estimating accuracy of his competitors;

(c) the average applied profit margin of contractor E (the profit margin he includes in his tenders);

(d) the average applied profit margins of his competitors;

(e) the number of competitors he meets when tendering.

Using different ranges of values for the factors listed, the results obtained gave some insight to the likely effects on achieved profit margins and a contractor's ability to secure contracts.

The results for the full range of situations simulated are not given, but those results which are described are typical and indicative of the results obtained for the full range and appear to give some guidance as to the effects of improving estimating accuracy.

2.1 SITUATION 1

This situation is the assumed existing set of conditions against which any change will be compared. The level of estimating accuracy and of average mark-ups are purely assumptions.

Assumptions

Contractor E and four others have estimating accuracies of likely cost ± 10%. On average all contractors include a profit margin of 10% in their tenders.

Results

All contractors win one contract in every five they tender for. The average achieved profit margin is 3%. The average difference between applied and achieved profit margins is the average difference between likely cost and the estimated cost of the winning tenders.

This means that Contractor E's average profit/turnover is 3% and his success ratio (i.e. number of contracts won/number of tenders submitted) is 1:5. The success ratio is a measure of the contractor's ability to obtain contracts.

2.2 SITUATION 2

In this situation contract E has improved his estimating accuracy and maintains the same average applied profit margin as in Situation 1. His competitors maintain their existing accuracies and profit margins. In this situation the questions being asked are:

(a) what would be the effect on the contractor's ability to obtain contracts (i.e. the effect on his success ratio);

(b) what will be the effect on his profit margins.

Assumptions

Contractor E has an estimating accuracy of likely cost ± 5%. The four other contractors have estimating accuracies of likely cost ± 10% On average all contractors include a profit margin of 10% in their tenders.

Results

Contractor E is less successful in securing contracts and now only wins between one in ten and one in eleven of the contracts he tenders for. The average achieved profit margin on the contracts he wins is approximately 8%. By doubling his estimating accuracy contractor E has vastly improved the profit margins he achieves but because his ability to secure contracts is so reduced his turnover will be reduced if he continues to submit about the same number of tenders.

The answers to the two questions are:

(a) his ability to secure contracts has been reduced from 1:5 to 1:11;

(b) the average profit margin has increased from 3% to 8% which is a marginal increase in company profits.

Notwithstanding the increase in profits the decline in ability to secure contracts which in turn affects contractor E's turnover is unsatisfactory; however two solutions are offered, either, if a sufficient amount of work is available, increase the number of tenders submitted to compensate, or reduce the applied mark-up. The effect of reducing the mark-up is studied in Situation 3.

2.3 SITUATION 3

In this situation Contractor E reduces his applied profit margin in order that his ability to secure contracts is the same as in Situation 1 (i.e. a success ratio of 1:5). The question is what effect will this have on company profit ?

Assumptions

Contractor E has an estimating accuracy of likely cost ± 5% and on average includes a profit margin of 7.5% in his tenders. The four other contractors have estimating accuracies of ± 10% and on average include a profit margin of 10% in their tenders.

Results

Contractor E wins one contract in every five he tenders for (same as in Situation 1). The average achieved profit margin of the contracts he wins is in excess of 6% (compare with 3% of Situation 1).

The conclusions so far and the answers to questions (1) and (2) are:

(1) if a contractor unilaterally improves his estimating accuracy and maintains the same average mark-up his ability to win contracts is substantially reduced;

(2) if the contractor reduced his average applied profit margin in order to improve his ability to secure contracts his average achieved profit margin will still be sunstantially higher than before.

The third question whether any benefits remain after Contractor E's competitors also made similar improvements were studied in Situations 4 and 5.

2.4 SITUATION 4

In this situation the other four contractors have also improved their estimating accuracies and have also reduced their applied profit margins.

Assumptions

All five contractors have estimating accuracies of likely cost ± 5% and on average include profit margins of 7.5% in their tenders.

Results

Contractor E and the other contractors win one contract in every five they tender for. The average achieved profit margin is just over 4%.

For Contractor E this is still an improvement when compared with the original Situation 1 (i.e. 3%) but is a deterioration from the situation where he alone has improved his estimating accuracy, Situation 3 (i.e. 6%).

2.5 SITUATION 5

In this situation all contractors' estimating accuracies remain at the new improved level and their applied profit margins return to the level that existed originally.

Assumptions

All five contractors have estimating accuracies of likely cost ± 5% and, on average, include a profit margin of 10% in their tenders.

Results

Contractor E and the other contractors win one contract in every five tendered for. The average achieved profit margin is just in excess of 6½%.

For Contractor E this compares favourably with the original Situation 1 (i.e. 3%) and with the situation where he alone improved his estimating accuracy, Situation 3 (i.e. 6%). (In Situation 3 it will be recalled that Contractor E had reduced his applied profit margin from 10% to 7½%).

The answer to question (3) is that profit improvements do remain even when competitors make similar improvements to estimating accuracy.

Finally the situation was considered where not all competitors had made similar improvements to estimating accuracies.

2.6 SITUATION 6

In this situation 4 contractors (including E) have improved their estimating accuracies, the fifth has not.

Assumptions

Four contractors (including E) have estimating accuracies of ± 5%. The fifth contractor has an estimating accuracy of ± 10%. All five have on average an applied profit margin of 10%.

Results

The ability of Contractor E to obtain contracts is slightly reduced from 1:5 to 1:6. The average achieved profit margin is 5½%. This compares favourably with the original achieved margin of 3% but less favourably with Situation 5 where all contractors have improved their accuracy. Nevertheless substantial profit improvements remain.

The other results from the range of situations tested give similar patterns of results. If the original estimating inaccuracy was assumed to be greater the increase in achieved profit margins on improving the estimating accuracy was also greater. If the original estimating inaccuracy was assumed to be smaller then the increase in the achieved profit margins on improving the estimating accuracy was also smaller.

3. Conclusions

The general conclusions drawn from this study are:

(1) that the achieved profit margins will be increased if the accuracy of estimating is improved;

(2) that if the estimating accuracy is improved and the contractor wishes to maintain the same turnover he will need to -

(a) reduce his applied profit margin

or (b) increase the number of tenders he submits

or (c) make some reduction in his applied profit margin and also increase the number of tenders he submits

(3) that the achieved profit margins will still be greater than the original profit margins when all contractors improve their estimating accuracy. This assumes that contractors fix their mark-up without reference to the current profitability of the company. However, the competitive nature of the industry would probably cause contractors to cut their margins once enhanced profitability had been achieved. It is difficult to assess this effect but at least one residual benefit would remain namely the reduction in the number of loss-making contracts.

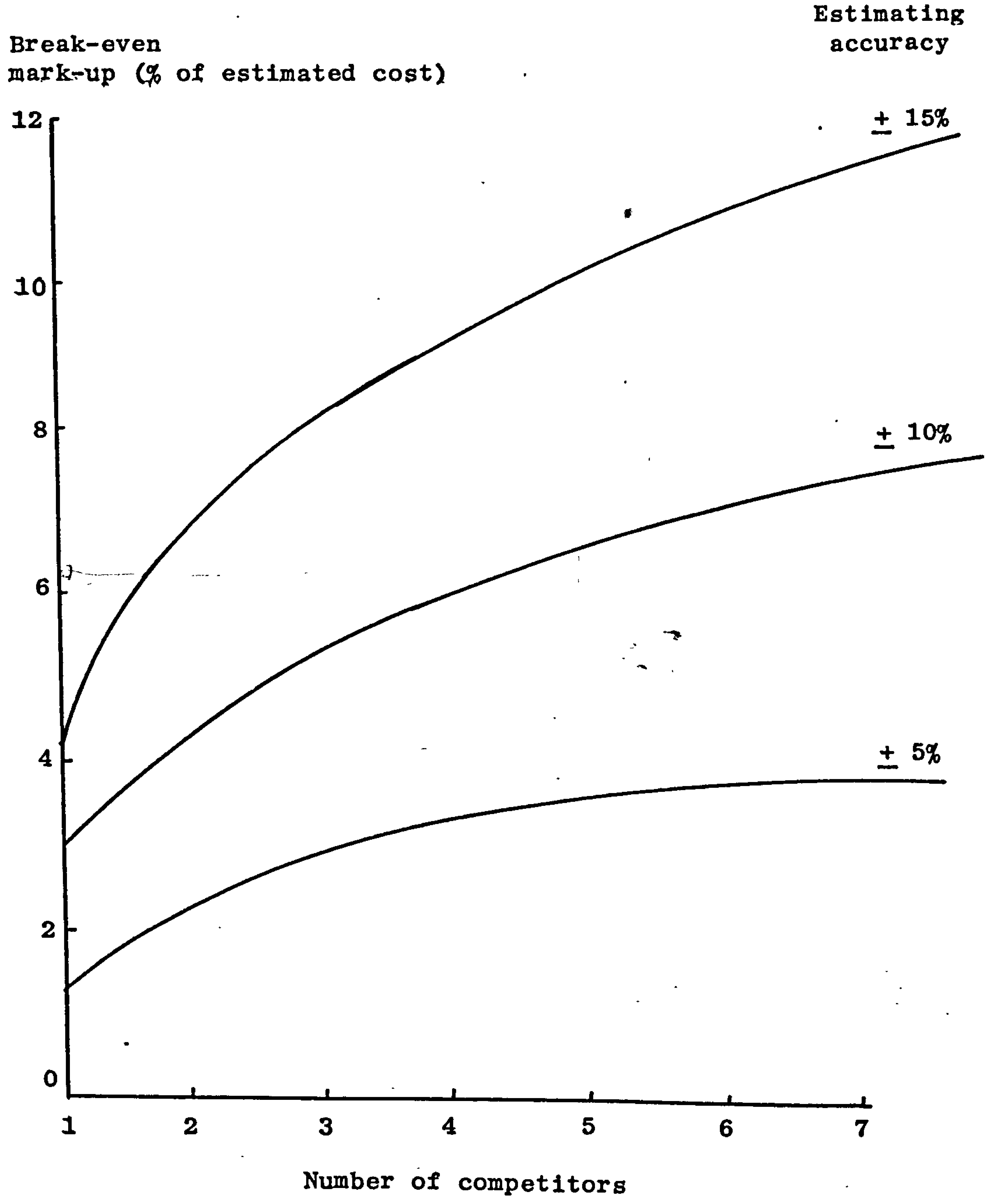


Figure A.1. Break-even Mark-up

Technical Addendum to Appendix A

(Not previously published)

This technical addendum gives the analytical reasons for the results presented in appendix A and assumes appendix A has been read.

Given a uniform distribution in the range $[a, b]$ so that any bid x is $a \leqslant x \leqslant b$

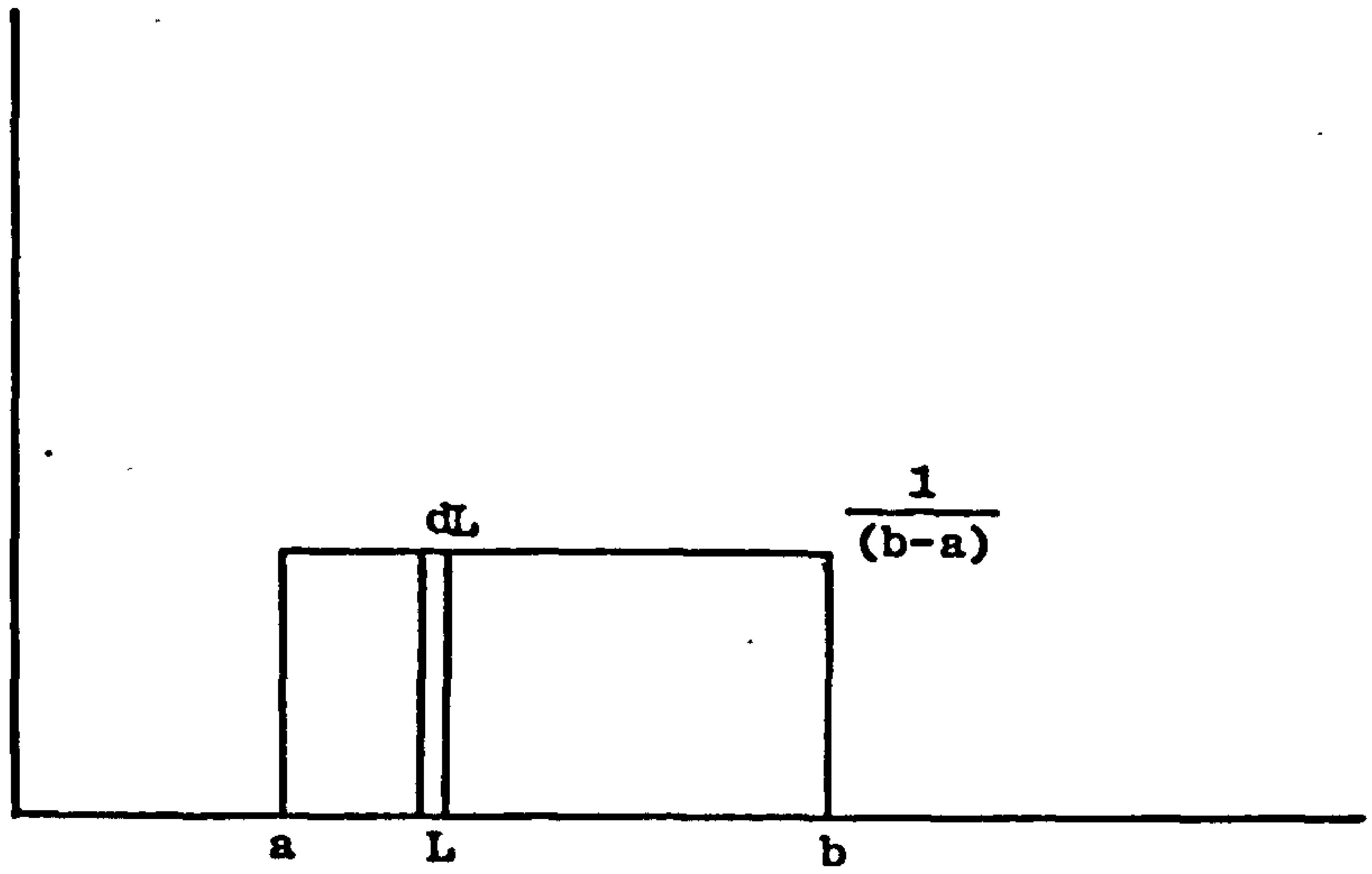


Figure A.2 Probability density function of all possible bids.

If 5 bids are selected from the distribution of all possible bids, figure A.2, and if lowest is in the range(L - dL)to L then all the other must be in range L to b, i.e.

Probability of one being in range(L - dL)to L is $\frac{dL}{b-a}$

Probability of other four being in range L to b is $\left[\frac{b-L}{b-a}\right]^4$

Thus the probability of one being in range L - dL to L and other four being in range L to b is

$$\frac{dL}{(b-a)} \left[\frac{b-L}{b-a}\right]^4$$

Since any one of the 5 bids can be lowest then the probability density function of the lowest bid is given by

$$f(L) = 5\left[\frac{1}{(b-a)}\left[\frac{b-L}{b-a}\right]^4\right]$$

The expected value of this function is given by

$$E(L) = \int_a^b 5.\frac{1}{(b-a)}\left[\frac{b-L}{b-a}\right]^4 .L.dL$$

$$= a + \frac{(b-a)}{6}$$

<u>Situation 1</u>

Thus for situation 1 (see appendix A)

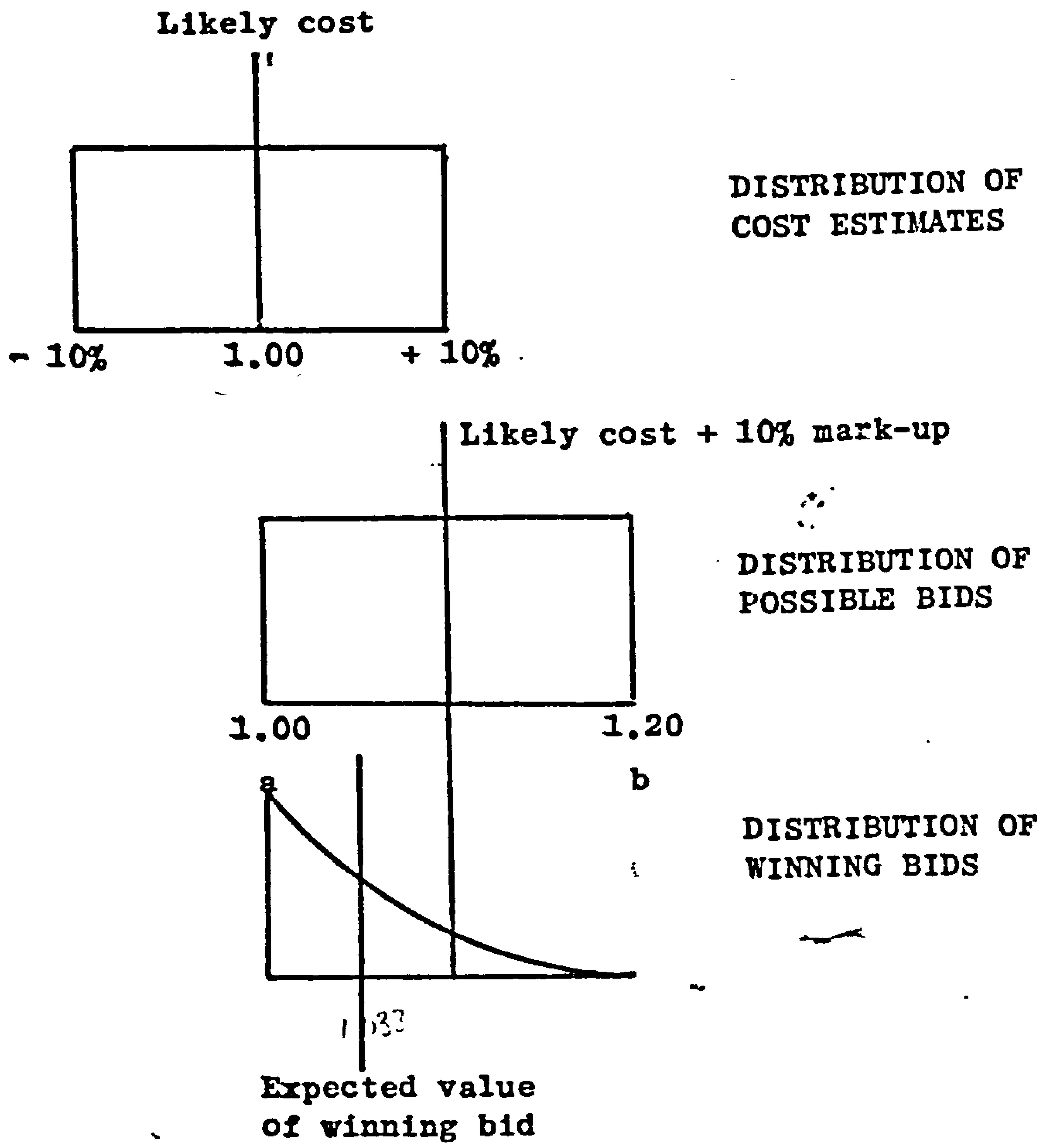


Figure A.3 Calculating the expected value of the winning bid for Situation 1.

Expected value of winning bid

$$E(L) = a + \frac{(b-a)}{6}$$

$$= 1.00 + \frac{(1.20-1.00)}{6} = 1.033$$

Thus since likely cost is defined as 1.00 the achieved marked is 3.3%.

Situation 2

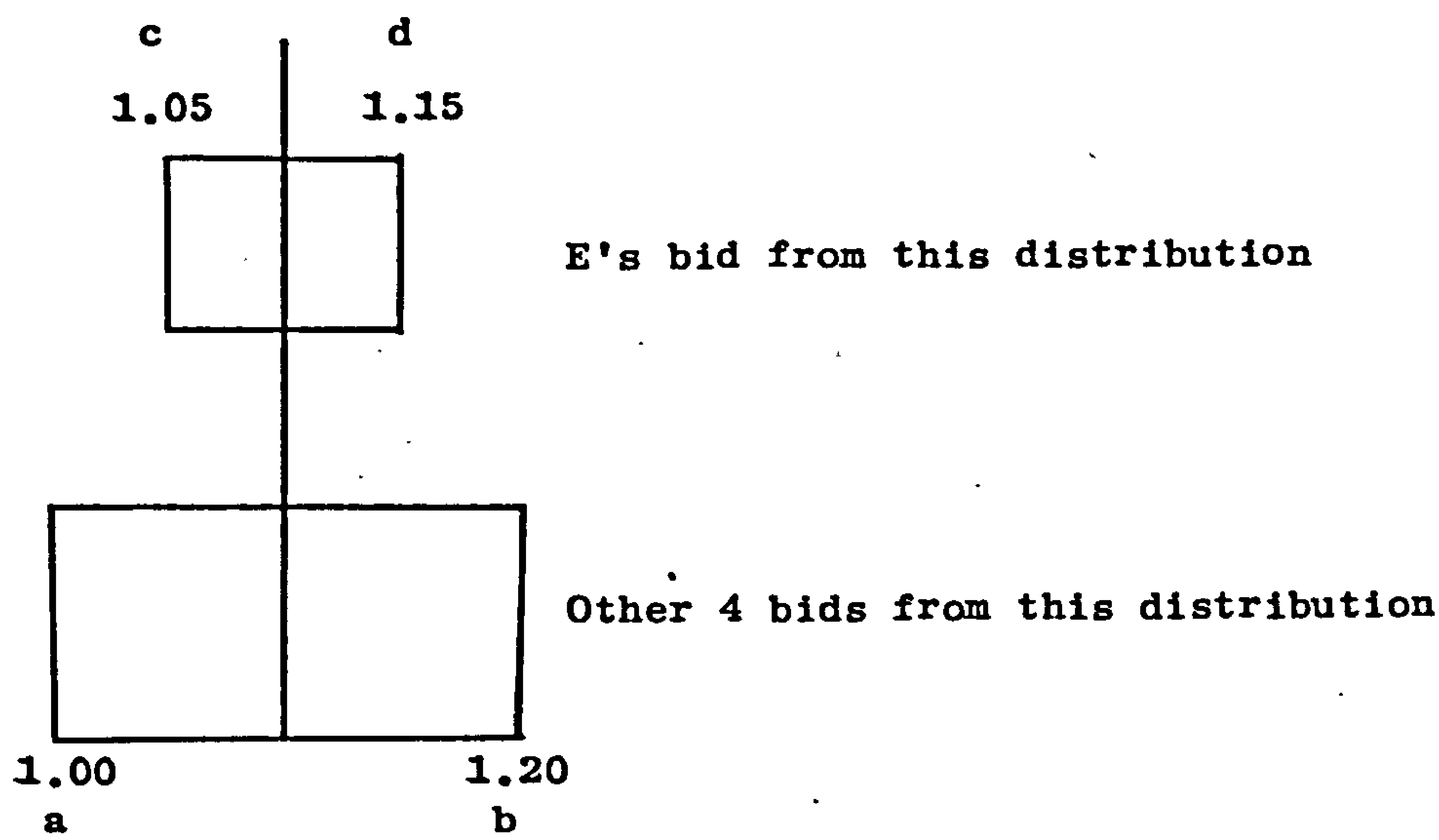


Figure A.4 The distribution of possible bids for Situation 2.

The probability of E winning with any bid in the range(L-dL)to L is

$$\frac{dL}{(d-c)} \left[\frac{b-L}{(b-a)} \right]^4$$

$$\text{i.e. } \frac{dL}{0.1} \left[\frac{1.2-L}{0.2} \right]^4$$

Since E's bid can be anywhere in range 1.05 to 1.15, E's overall

probability of winning is

$$\int_{1.05}^{1.15} \left[\frac{(1.2-L)^4}{0.1(o.2)^4} \right] dL = 0.094$$

The average or expected value of E's winning bids is

$$\frac{\displaystyle\int_{1.05}^{1.15} \frac{1}{0.1}\,\frac{(1.2-L)^4}{(0.2)^4}.L.dL}{0.094} \qquad \text{(see above)}$$

$$= \frac{0.1014}{0.094} = 1.08$$

Again since the likely cost is defined as 1.0 the achieved mark-up is 8%.

Situation 3

This situation requires E's bids to be in the range k to (k + 0.10) such that E's probability of winning is 0.2 as it was in situation 1 where all had equal chances.

$$\text{Thus} \quad \int_{k}^{k+0.1} \frac{1}{0.1}\left[\frac{1.2-L}{0.2}\right]^4 .dL = 0.2$$

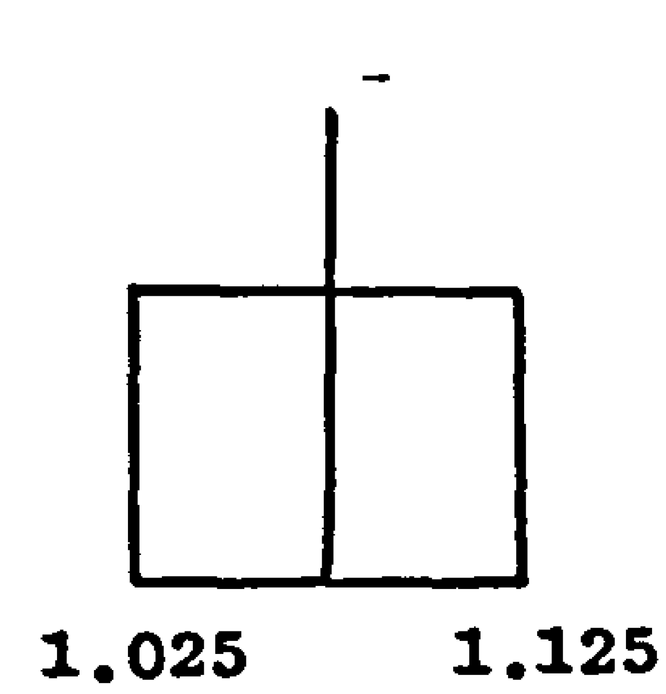
This requires

$$k^4 - 4.6\,k^3 + 7.94\,k^2 - 6.095\,k + 1.7553 = 0$$

$$\text{i.e.} \quad k = 1.025$$

and by the same method from situation 2 E's expected winning value = 1.064. That is E's achieved mark-up is 6.4%.

Situation 4



All five bids drawn from the same distribution

Figure A.5 The distribution of possible bids for all five competitors for Situation 4.

From an analysis similar to situation 1 the expected value of the winning bid is

$$1.025 + \frac{(1.125 - 1.025)}{6}$$

$$= 1.042$$

That is the achieved mark-up is 4.2% for all competitors.

<u>Situation 5</u>

This situation is similar to situations 1 and 4 except that the range of possible bids is from 1.05 to 1.15. From an analysis similar to situations 1 and 4 the expected value of the winning bid is

$$1.05 + \frac{(1.15 - 1.05)}{6}$$

$$= 1.0666.$$

That is the achieved mark-up is 6.6% for all competitors.

<u>Situation 6</u>

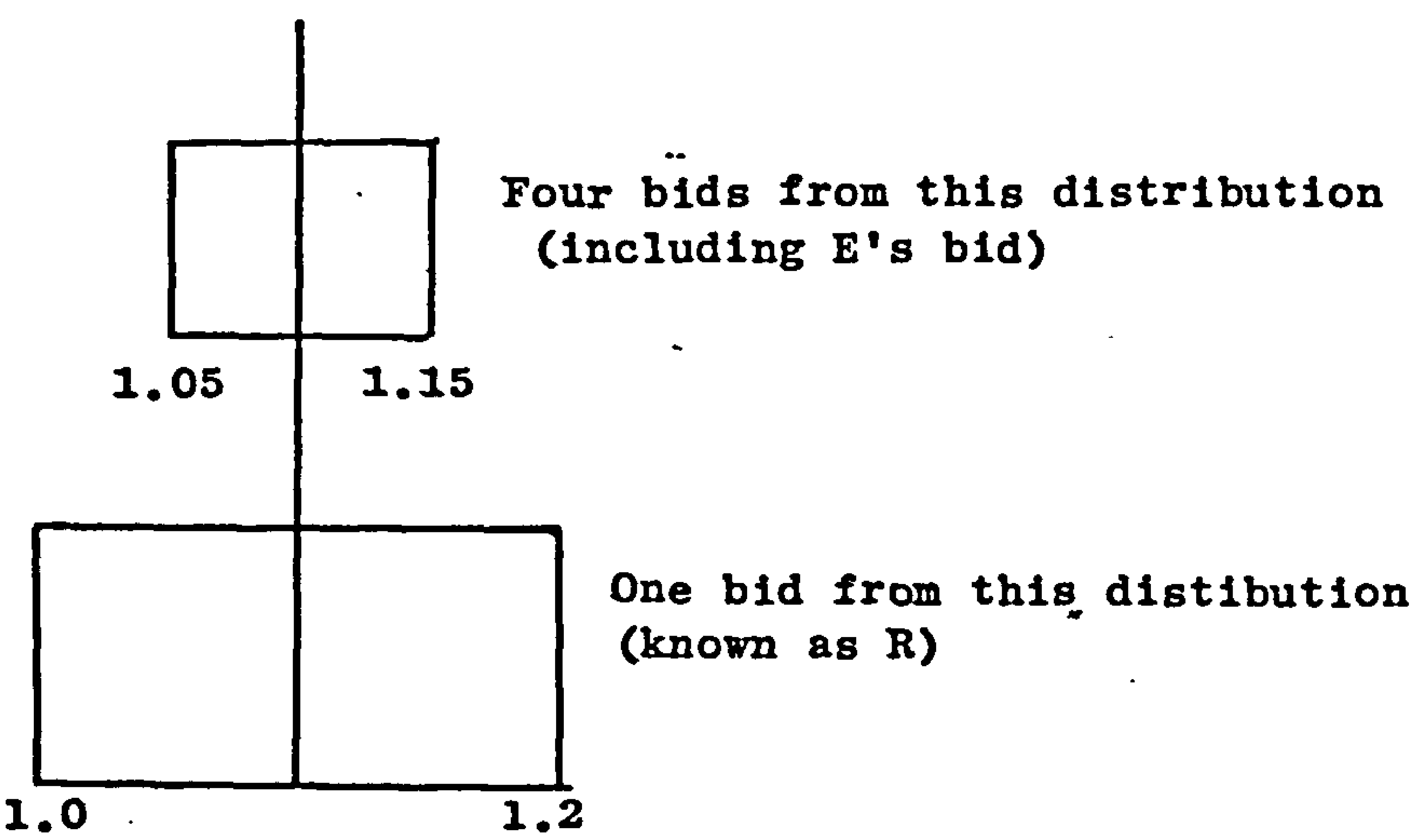


Figure A,6 The Distribution of possible bids for Situation 6.

If R's bid is in the range 1.0 to 1.05 he must win, the probability of this is

$$\frac{1.05 - 1.0}{1.2 - 1.0} = \frac{0.05}{0.2} = 1/4.$$

The probability that R bid is in the range 1.05 to 1.15 and that R's bid, which is defined as(L-dL)to L, is the winning bid depends on the other four bids being greater than L. The probability of this is

$$\int_{1.05}^{1.15} \frac{1}{0.2} \left[\frac{1.15-L}{0.1} \right]^4 .dL$$

$$= \quad 1/10.$$

If R's bid is in the range 1.15 to 1.2 he cannot win.

Thus the probability of R winning is

$$\frac{1}{4} + \frac{1}{10} = 0.35$$

and the probability of any of the others winning is

$$\frac{1}{4}.(1.0 - 0.35) = 0.1625.$$

For the expected value of E's winning bid consider R in the ranges 1.05 to 1.15 and 1.15 to 1.2, the only other range for R of 1.00 to 1.05 is irrelevant since E cannot win in this range and since E's winning bids are being considered R must be restricted to 1.05 to 1.2.

The expected value of E when R is in range 1.05 to 1.15 is the same as situation 5, i.e. 1.067.

The probability of R being in this range is

$$\frac{1.15-1.05}{1.2 - 1.05} = \frac{.1}{.15} = \frac{2}{3}$$

The expected value of E when R is in the range 1.15 to 1.2 is the expected value of the lowest of four selected from the range 1.05 to 1.15. This is given by an analysis similar to that for situation 1 which gives

$$a + \frac{(b-a)}{5} = 1.05 + \frac{(0.10)}{5} = 1.07.$$

The probability of R being in the range 1.15 to 1.2 is

$$\frac{1.2 - 1.15}{1.2 - 1.05} = \frac{1}{3}$$

Thus the expected value of E's winning bids is

$$\frac{2}{3} \times 1.067 + \frac{1}{3} \times 1.07 = 1.068.$$

That is the achieved mark-up of E is 6.8%.

APPENDIX B

Sample Coding Sheet for Original Bidding Data

Referred to in Chapter 3.0

CODING INSTRUCTIONS FOR BIDDING DATA

3 Card types each form - All entries right justified.

Card Type 1

Cols.	1 - 4	Ref. No. (Item 7)
Cols.	5 - 10	Opening Date (5,6-day, 7,8-month, 9-10 year)(Item 4)
Cols.	11 - 16	Closing Date (11,12-day,13-14-month,15-16 year)(Item 10)
Cols.	17	Item 8 - letter if any
Cols.	18	Item 8 - number of any
Cols.	19 - 30	Locality (Item 1)
Cols.	31 - 40	Designers estimate - if given (Item 9)
Cols.	41 - 45	Item 14X - if given
Cols.	46 - 50	Item 14Y - if given
Cols.	51 - 55	No. of Bidders (highest No. in Item 11)

Card Type 2

Cols.	1 - 4	Ref. No. (Item 7)
Cols.	5-8, 9-12	and every subsequent 4 col. field - Contractors Code No. - the code number of competing contractors from Item 11 - use more than one card if necessary. Code Ref. No. in first 4 cols.

Card Type 3

Cols.	1 - 4	Ref. No. (Item 7)
Cols.	11-20,21-30	and each successive 10 col. field Amount of bid (in same order as Card 2) Repeat card as necessary with same format including Ref. in cols. 1-4.

LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY, The Computer Centre

Data Punching Form

NAME	PROGRAM TITLE	DATE
ADDRESS		Page of

```
    5    10   15   20   25   30   35   40   45   50   55   60   65   70   75   80
  24 7 37013 470D4     BASCØUP                       10
  24 176 149 142 122 102 189 183 157 197 110
  24         8125005   8425376   8532528   8542500   8598265   8880510   8900148
  24         8958415   9045106   9058400
```

W.M. Ltd., London, S.W.1. 3585A

Form 20/3A

APPENDIX C

Statistical Calculations of Basic Distribution Parameters

Referred to in Section 4.1

Statistical Calculations of Basic Distribution Parameters

Each 'set' of bids, i.e. the bids belonging to one contract, were standardised by dividing each by the mean of the set.

$x_i = i^{th}$ bid $\bar{x}$ = mean standardised bid = $y_i = x_i/\bar{x}$

The following statistics were calculated for each set:

1. Mean $\bar{y} = \sum y_i/n$

   where n = Number of bidders (i.e. number in set)

2. Variance $$\sigma^2 = \frac{\sum (y_i - \bar{y})^2}{n}$$

   Variance corrected for small sample size(1)

   $$\sigma^2 = \frac{\sum (y_i - \bar{y})^2}{n} x \frac{n}{n-1}$$

3. Third moment about mean

   $$\mu_3(\bar{y}) = \frac{1}{n} . (\sum (y_i - \bar{y})^3)$$

   Third moment about mean corrected for small sample sizes(1)

   $$\mu_3(\bar{y}) = \frac{1}{n} . (\sum (y_i - \bar{y})^3). \frac{n^2}{(n-1)(n-2)}$$

   when n > 2

4. Fourth moment about mean

   $$\mu_4(\bar{y}) = \frac{1}{n} . (\sum (y_i - \bar{y})^4)$$

   Fourth moment about mean corrected for small sample sizes(1)

   $$\mu_4(\bar{y}) = \frac{1}{n} . (\sum (y_i - \bar{y})^4) . \frac{n^2(n + 1)}{(n-1)(n-2)(n-3)}$$

   when n > 3

5. Skewness

$$B_1 = (\mu_3(\bar{y}))^2 \Big/ (\sigma^2)^3$$

$$\text{Skewness} = \sqrt{B_1}$$

The skewness is accorded the same sign (+ or-). as the third moment.

6. Kurtosis

$$B_2 = \mu_4(\bar{y}) \Big/ (\sigma^2)^2$$

Within the same type of contract the average of the above statistics was calculated for each 'n'. The overall average of these statistics weighted according to the number of sets of each of 'n' bidders was calculated and taken to be the statistics describing the parent distribution from which these bids for the particular type of contract belong.

Reference: Kendall and Stuart (38)

APPENDIX D

Test for Uniformity - Studentized Range

Referred to in Section 4.3

Test for Uniformity, Studentized Range W

Studentized Range, W

$$W = \frac{Max(x_i) - Min(x_i)}{S}.$$

for a sample x_1, ..., x_n

with sample standard deviation S.

Studentized range, W, is thought to be the most powerful test of uniformity against normality. If the data were uniformly distributed W would have small values. If the data were distributed with kurtosis greater than the normal distribution then W would have large values.

Reference: Pearson and Hartley[30]

APPENDIX E

The Anderson-Darling test for normality

Referred to in section 4.3

The Anderson-Darling test for Normality

Anderson-Darling Statistic (known as A^2) described by Pearson and Hartley[32] and Stephens[33]

1. $$A = -\left[\sum_{i=1}^{n} (2i - 1)\left(\log Z_i + \log(1 + Z_{n+1-i})\right)\right] / n \; - n$$

where n is number of bidders and Z_i is

$$\phi\left[\sqrt{\frac{y_i - \bar{y}}{s^2}}\right]$$

y_i being one observation (bid)

$\bar{y}$ being the mean of one set of bids

s^2 being the variance of the set of bids

and ϕ representing the normal cumulative distribution function (i.e. the probability of being equal to or less than the calculated number in a normal distribution)

2. $$A^2 = A_* (1.0 + B/n + C/n^2 + D/n^3)$$

where B, C and D are coefficients supplied by the Department of Mathematics, University of Loughborough (Pettit[34]) as follows

Percentage Points

	<0.2332	0.2332 - 0.3405	>0.3405
B	0.25	0.5	0.96
C	6.5	4.9	-2.5
D	-32.0	-25.0	+13.0

APPENDIX F

Chi Squared Test and Calculations used in comparing the distribution of Anderson-Darling Statistics with the expected distribution for normal samples

Referred to in section 4.3

Chi Square Test and Calculations used in comparing the distribution of Anderson-Darling statistics with the expected distribution for normal sample

Calculation of the χ^2 statistic for the χ^2 test.

For each group (no. i) in the sample, there is an observed frequency O_i. There is also a frequency predicted by the model, namely the expected frequency E_i. The χ^2 statistic is then given by

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}, \quad \text{where } k = \text{no. of groups}$$

Large values of χ^2 correspond to a small likelihood of a good fit. The significance of the χ^2 value can be tested using a χ^2 tables[30] if the value of χ^2 is at the 95% point of the χ^2 distribution with k - 1 degrees of freedom, then this represents the 5% critical point. Thus with χ^2 values at below the 90% point of the distribution we have a good fit.

TABLE F.1

Grouped A^2 Values for Buildings Contracts

(1) 5% groups

Percentage point	0	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
Frequency	12	7	5	11	3	7	11	12	8	7	8	7	3	9	11	7	14	8	9	11	

(2) 10% groups

Percentage point	0	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Frequency	19	16	10	23	15	15	12	18	22	20	

Grouped A^2 Values for Roads Contracts

(1) 5% groups

Percentage point	0	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
Frequency	18	15	15	7	11	10	14	11	11	11	13	11	9	9	16	10	18	21	23	34	

(2) 10% groups

Percentage point	0	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Frequency	33	22	21	25	22	24	18	26	39	57	

TABLE F.2

χ^2 for Anderson-Darling Statistics for Buildings Contracts

(1) Using 10% groups

Percentage point	Frequency observed	Frequency expected	$(O-E)^2$	$\sum (O-E)^2/E$
0				
	19	17	4	
10%				
	16	17	1	
20%				
	10	17	49	
30%				
	23	17	36	
40%				
	15	17	4	
50%				
	15	17	4	
60%				
	12	17	25	
70%				
	18	17	1	
80%				
	22	17	25	
90%				
	20	17	9	
100%				
	170		158/17 =	9.294

Degrees of Freedom = 10 - 1 = 9.

With 9 degrees of freedom, 9.294 is at about the 58% point of the χ^2 distribution. This means that the assumption of normality can be made with 42% certainty.

TABLE F.2 (Contd)

(2) Using 15% groups (up to 90% only)

Percentage point	Frequency observed	Frequency expected	$(O-E)^2$	$\sum \frac{(O-E)^2}{E}$
0				
	24	25	1	
15%				
	21	25	16	
30%				
	31	25	36	
45%				
	22	25	9	
60%				
	23	25	4	
75%				
	29	25	16	
90%				
	150		82 ÷ 25 =	3.28

Degrees of Freedom = 6 - 1 = 5

With 5 degrees of freedom, 3.28 is at about the 34% point of the χ^2 distribution. This means that the assumption of normality can be made with 66% certainty.

(3) Using 20% groups

Percentage point	Frequency observed	Frequency expected	$(O-E)^2$	$\sum \frac{(O-E)^2}{E}$
0				
	35	34	1	
20%				
	33	34	1	
40%				
	30	34	16	
60%				
	30	34	16	
80%				
	42	34	64	
100%				
	170		98 ÷ 34 =	2.88

Degrees of Freedom = 5 - 1 = 4

With 4 degrees of freedom, 2.88 is at about the 42% point of the χ^2 distribution. This means that the assumption of normality can be made with 58% certainty.

TABLE F.3

χ^2 for Anderson-Darling Statistics for Roads Contracts

(1) Using 10% groups

Percentage point	Frequency observed	Frequency expected	$(O-E)^2$	$\sum \frac{(O-E)^2}{E}$
0				
	33	28.7	18.49	
10%				
	22	28.7	44.89	
20%				
	21	28.7	59.29	
30%				
	25	28.7	13.69	
40%				
	22	28.7	44.89	
50%				
	24	28.7	22.09	
60%				
	18	28.7	114.49	
70%				
	26	28.7	7.29	
80%				
	39	28.7	106.09	
90%				
	57	28.7	800.89	
100%				
	287		1232.10	/28.7 = 42.93

Degrees of Freedom = 10 - 1 = 9

With 9 degrees of freedom 42.93 is greater than 99.9% percentage point of the χ^2 distribution. Thus we are 99.9% certain that the roads contracts are not normal.

TABLE F.3 (Contd)

(2) Using 15% groups (up to 90% only)

Percentage point	Frequency observed	Frequency expected	$(O-E)^2$	$\sum \frac{(O-E)^2}{E}$
0				
	48	38.33	93.51	
15%				
	28	38.33	106.71	
30%				
	36	38.33	5.43	
45%				
	35	38.33	11.09	
60%				
	34	38.33	18.75	
75%				
	49	38.33	113.85	
90%				
	230		349.34/38.35	= 9.11

Degrees of Freedom = 6 - 1 = 5

With 5 degrees of freedom 9.11, χ^2 is almost the 90% point of the χ^2 distribution, thus we can be 90% certain that the roads contracts are not normal.

(3) Using 20% groups

Percentage point	Frequency observed	Frequency expected	$(O-E)^2$	$\sum \frac{(O-E)^2}{E}$
0				
	55	57.40	5.76	
20%				
	46	57.40	129.96	
40%				
	46	57.40	129.96	
60%				
	44	57.40	179.56	
80%				
	96	57.40	1489.96	
100%				
	287		1935.20/57.40	= 33.71

Degrees of Freedom = 5 - 1 = 4

With 4 degrees of freedom, 33.71 is greater than the 99.9% percentage point of the X^2 distribution. Thus we can be 99.9% certain that the roads contracts are not normal.

APPENDIX G

Downton's method of calculating standard deviation

Referred to in section 4.4

Downton's method of calculating standard deviation

Calculation of an Unbiased estimate of the standard deviation of a Normal Population

The statistic, devised by Downton, to give an unbiased estimate of the standard deviation of a normal population is denoted $\hat{\sigma}$

For the $\hat{\sigma}$ calculation, the data must be approximately normally distributed, and must be in ascending order. The x_ith smallest item is denoted x_i and there are n items.

$$\text{Then } \hat{\sigma} = \frac{2\sqrt{\pi}}{n(n-1)} \cdot \sum_{i=1}^{n} (i-1/2(n+1))x_i$$

References: Downton[37] and David[36]

APPENDIX H

The results of the test for low bids

Referred to in section 4.5

TABLE H.1 - Buildings Contracts

Contract No.	No.of bidders	G value	Asterisk identifies low bids as outliers at 10%: Using standard dev.for each group of 'n' bidders	Using o/all std. dev.
2,	(12)	3.136	*	
3,	(11)	1,216		
4,	(5)	1,448		
5,	(2)	1.076		
6,	(3)	0.528		
7,	(4)	0.481		
8,	(5)	1.290		
9,	(7)	0.540		
10,	(6)	0.308		
11,	(12)	1.322		
12,	(3)	0.628		
13,	(5)	0.232		
14,	(11)	2.117		*
16,	(3)	0.528		
18,	(7)	1.359		

Contract No.	No.of bidders	G value	Using std. dev.for each group of 'n' bidders	Using o/all std. dev.
19,	(13)	1.475		
20,	(6)	0.928		
21,	(6)	1.050		
24,	(10)	1.161		
26,	(4)	0.421		
27,	(5)	0.395		
29,	(5)	1.138		
30,	(5)	0.210		
32,	(7)	1.237		
33,	(4)	1.595		
34,	(3)	1.266		
35,	(6)	0.878		
40,	(3)	1.122		
42,	(6)	0.966		
43,	(2)	0.174		
44,	(2)	0.369		
46,	(7)	0.808		
47,	(5)	1.139		
48,	(11)	0.543		
49,	(4)	0.679		
51,	(4)	0.855		
52,	(3)	0.902		
53,	(6)	0.569		
54,	(8)	0.760		
55,	(6)	0.365		
56,	(4)	0.545		
57,	(10)	1.518		
58,	(4)	0.860		
60,	(7)	1.569		
61,	(4)	0.419		
63,	(6)	0.965		
64,	(4)	0.545		
66,	(7)	0.678		
68,	(4)	0.311		
71,	(5)	1.007		
74,	(3)	0.421		
75,	(6)	1.667		
76,	(5)	0.986		
77,	(3)	0.816		
78,	(2)	0.955		
79,	(4)	0.874		
80,	(10)	1.193		
81,	(5)	0.971		
83,	(5)	1.556		
85,	(8)	0.973		
86,	(5)	0.836		
87,	(3)	0.443		
88,	(3)	1.020		
89,	(11)	0.910		
90,	(6)	1.658		
91,	(5)	1.758		
92,	(10)	2.220	*	*
93,	(4)	1.310		
94,	(4)	1.569		
95,	(9)	2.292	*	*
96,	(8)	1.107		
97,	(10)	1.568		
100,	(5)	0.518		
101,	(4)	0.419		
102,	(7)	1.359		
103,	(6)	1.184		
104,	(5)	0.837		

Contract No.	No. of bidders	G value	Using std. dev. for each group of 'n' bidders	Using o/all std. dev.
105.	(10)	1.374		
106.	(6)	0.623		
107.	(12)	1.557		
108.	(7)	1.256		
109.	(8)	0.712		
110.	(6)	0.368		
111.	(10)	2.092		*
112.	(11)	1.123		
113.	(6)	1.170		
114.	(6)	0.288		
115.	(6)	1.482		
116.	(7)	1.225		
118.	(7)	0.768		
119.	(5)	1.557		
120.	(5)	0.464		
121.	(3)	0.213		
122.	(15)	1.948		
123.	(5)	0.898		
124.	(10)	2.046		
125.	(14)	1.526		
126.	(7)	0.770		
127.	(17)	2.415		*
129.	(7)	0.854		
130.	(13)	1.706		
131.	(6)	0.441		
132.	(4)	0.793		
133.	(12)	0.965		
134.	(8)	0.959		
135.	(11)	2.312	*	*
136.	(3)	0.319		
137.	(8)	3.122	*	*
138.	(6)	0.636		
141.	(13)	1.415		
142.	(11)	1.293		
143.	(9)	1.172		
144.	(4)	1.078		
145.	(6)	0.824		
146.	(5)	2.154	*	
147.	(7)	4.109	*	*
148.	(5)	1.461		
149.	(5)	1.208		
150.	(10)	2.300	*	*
151.	(7)	0.929		*
152.	(10)	1.254		
153.	(9)	1.324		
155.	(4)	1.087		
156.	(6)	0.959		
158.	(12)	2.297	*	*
159.	(8)	1.380		
160.	(10)	1.250		
163.	(7)	1.843		
164.	(8)	2.960	*	*
165.	(6)	2.435	*	*
166.	(5)	0.442		
167.	(5)	0.836		
171.	(5)	0.985		
172.	(4)	0.852		
173.	(11)	1.631		
174.	(11)	2.593	*	*
176.	(6)	0.773		
178.	(7)	0.739		
179.	(3)	1.104		*

Contract No.	No. of bidders	G value	Using std. dev. for each group of 'n' bidders	Using o/all std. dev.
180.	(5)	0.875		
181.	(4)	2.582	*	*
182.	(11)	1.235		
183.	(10)	1.731		
184.	(9)	0.487		
187.	(9)	2.556	*	*
188.	(13)	1.314		
189.	(12)	1.047		
190.	(10)	1.294		
191.	(6)	1.633		
192.	(9)	1.348		
194.	(5)	2.098	*	
196.	(11)	1.387		
200.	(5)	1.504		
203.	(4)	1.008		
205.	(5)	0.594		
206.	(2)	0.513		
207.	(8)	1.122		
209.	(10)	0.888		
210.	(11)	0.728		
211.	(6)	0.908		
212.	(4)	1.918	*	
213.	(6)	1.785		
215.	(16)	1.645		
216.	(8)	0.825		
218.	(11)	2.109		*
219.	(6)	2.422	*	*
222.	(10)	0.944		
223.	(9)	1.346		
226.	(3)	2.125	*	*
227.	(6)	2.092	*	
228.	(5)	1.514		
230.	(7)	0.502		
231.	(3)	0.330		
232.	(7)	1.777		
237.	(8)	1.214		
238.	(5)	2.823	*	*
239.	(10)	0.484		
241.	(9)	1.629		
242.	(7)	1.577		
243.	(17)	1.354		
245.	(3)	0.370		
246.	(4)	0.480		
248.	(8)	1.958		
249.	(5)	0.995		
250.	(9)	1.584		
251.	(5)	0.618		
252.	(5)	1.635		
253.	(7)	0.424		
254.	(4)	1.669		
257.	(5)	0.497		
Number of outliers found			20	21
Total No. of Contracts = 190				

Number of contracts identified as having outliers by both methods = 15

TABLE H.2 - Roads Contracts

Contract No.	No. of bidders	G value	Asterisk identifies low bids as outliers at 10%: Using std. dev. for each group of 'n' bidders	Using o/all std. dev.
1,	(2)	0.142		
13,	(4)	1.866	*	*
19,	(6)	0.972		
25,	(5)	0.704		
26,	(5)	1.258		
27,	(7)	0.376		
28,	(3)	0.214		
32,	(6)	0.469		*
33,	(4)	1.158	*	
33,	(3)	2.023		
35,	(6)	1.033		
36,	(4)	0.437		

Contract No.	No. of bidders	G value	Using std. dev. for each group of 'n' bidders	Using o/all std. dev.
37.	(7)	0.662		
58.	(7)	0.561		
59.	(7)	1.090		
66.	(6)	1.418		
68.	(4)	0.247		
72.	(4)	1.135		
73.	(3)	0.512		
79.	(8)	0.408		
81.	(6)	1.106		
84.	(5)	0.630		
87.	(4)	0.418		
89.	(7)	1.583		
90.	(5)	2.659	*	*
92.	(3)	0.074		
94.	(8)	0.371		
99.	(5)	0.358		
102.	(5)	2.089	*	*
105.	(3)	0.389		
107.	(7)	0.859		
112.	(4)	1.212		
113.	(5)	0.378		
114.	(6)	0.582		
115.	(5)	0.159		
119.	(3)	0.376		
121.	(4)	0.500		
127.	(5)	0.921		
128.	(2)	0.091		
131.	(3)	0.101		
135.	(4)	0.263		
140.	(4)	0.216		
144.	(4)	0.585		
145.	(3)	0.322		
149.	(7)	1.482		
152.	(7)	2.456	*	*
153.	(7)	0.537		
154.	(4)	3.294	*	*
156.	(8)	3.396	*	
160.	(5)	1.121		
161.	(3)	0.314		
162.	(5)	1.004		
163.	(4)	0.646		
165.	(4)	0.383		
166.	(8)	1.575		*
169.	(3)	0.541		
172.	(4)	0.539		
177.	(12)	1.253		
178.	(7)	1.110		
179.	(4)	0.804		
181.	(6)	2.266	*	*
182.	(7)	1.568		
186.	(6)	0.348		
188.	(4)	0.471		
189.	(6)	0.926		
192.	(4)	0.553		
192.	(6)	0.957		
194.	(4)	0.391		
196.	(3)	0.438		
199.	(11)	0.759		
203.	(4)	0.416		
205.	(6)	0.948		
213.	(3)	0.980		
219.	(5)	0.564		

Contract No.	No.of bidders	G value	Using std. dev. for each group of 'n' bidders	Using o/all std dev.
219.	(6)	0.854		
220.	(6)	2.927	*	*
225.	(8)	0.495		
229.	(4)	0.282		
230.	(5)	0.719		
234.	(8)	0.641		
238.	(12)	2.008		
242.	(2)	0.202		
248.	(5)	0.389		
250.	(6)	1.154		
253.	(3)	0.222		
256.	(4)	0.224		
258.	(4)	0.650		
259.	(3)	0.653		
260.	(8)	0.269		
261.	(8)	0.577		
262.	(8)	0.531		
265.	(6)	0.781		
266.	(8)	1.196		
268.	(4)	2.388	*	*
273.	(4)	0.304		
274.	(5)	0.576		
275.	(6)	1.316		
277.	(8)	0.575		
278.	(6)	0.708		
280.	(4)	0.228		
281.	(9)	2.021		
284.	(9)	0.403		
285.	(6)	1.050		
286.	(10)	2.015		
287.	(7)	0.943		
290.	(9)	1.022		
293.	(5)	2.420	*	*
294.	(3)	0.731		
296.	(4)	0.582		
298.	(4)	0.878		
301.	(5)	0.393		
304.	(7)	0.682		
306.	(6)	0.925		
312.	(4)	0.646		
320.	(3)	0.954		
328.	(5)	0.578		
329.	(2)	0.643		
331.	(7)	2.117	*	*
332.	(7)	1.059		
338.	(7)	1.298		
341.	(3)	0.397		
344.	(6)	0.811		
347.	(9)	0.723		
355.	(11)	1.254		
356.	(11)	3.450	*	*
359.	(3)	0.119		
361.	(10)	0.352		
362.	(7)	0.405		
366.	(5)	1.073		
369.	(10)	1.170		
370.	(11)	2.307	*	
379.	(10)	1.712		
380.	(5)	0.803		
382.	(6)	0.871		
385.	(8)	0.490		
387.	(3)	0.155		

Contract No.	No. of bidders	G value	Using std. dev. for each group of 'n' bidders	Using o/all std. dev.
391,	(5)	0.304		
402,	(3)	1.365		
418,	(2)	1.086		
422,	(4)	0.275		
423,	(4)	0.797		
433,	(6)	0.133		
456,	(3)	0.110		
457,	(6)	0.120		
475,	(3)	2.171	*	*
479,	(4)	0.615		
481,	(4)	0.579		
482,	(11)	1.056		
492,	(4)	1.678		*
493,	(5)	1.264		
494,	(4)	0.727		
497,	(5)	1.607		
498,	(6)	1.218		
499,	(8)	0.437		
504,	(3)	0.449		
505,	(10)	0.550		
506,	(8)	1.581		*
508,	(6)	0.928		
509,	(9)	1.411		
511,	(8)	0.607		
512,	(11)	0.704		
513,	(3)	0.261		
514,	(2)	0.353		
516,	(5)	0.366		
525,	(7)	0.506		
526,	(6)	0.611		
527,	(12)	3.110	*	*
528,	(5)	0.158		
529,	(5)	0.789		
530,	(9)	0.535		
531,	(5)	1.113		
533,	(9)	0.680		
534,	(6)	1.751		
534,	(4)	0.113		
538,	(3)	1.121		
543,	(5)	0.427		
546,	(3)	0.359		
548,	(3)	2.054	*	*
549,	(5)	1.328		
550,	(6)	0.895		
554,	(10)	2.710	*	
555,	(12)	0.956		
556,	(3)	0.909		
557,	(8)	0.733		
558,	(2)	0.755		
561,	(3)	0.192		
566,	(4)	0.458		
569,	(6)	1.165		
571,	(7)	0.869		
575,	(9)	0.787		
576,	(5)	1.012		
577,	(5)	1.085		
579,	(5)	0.474		
579,	(5)	0.474		
588,	(5)	1.535		
596,	(6)	0.808		
596,	(6)	0.808		
598,	(2)	1.320.	*	

Contract No.	No. of bidders	G value	Using std. dev. for each group of 'n' bidders	Using o/all std. dev.
599.	(8)	0.218		
603.	(16)	1.333		
604.	(13)	0.892		
608.	(8)	0.444		
609.	(7)	1.304		
610.	(13)	0.536		
614.	(6)	0.689		
616.	(2)	0.283		
618.	(9)	1.344		
620.	(4)	0.416		
624.	(5)	0.871		
626.	(7)	0.831		
628.	(5)	0.808		
629.	(4)	0.178		
630.	(3)	0.472		
633.	(13)	2.275		
634.	(10)	1.254		
637.	(16)	1.807		
638.	(10)	0.850		
639.	(5)	0.160		
641.	(6)	0.688		
642.	(6)	0.885		
643.	(6)	2.118	*	
644.	(4)	0.691		
648.	(8)	0.494		
649.	(12)	1.072		
650.	(4)	0.330		
651.	(6)	1.850		
653.	(4)	0.413		
654.	(9)	0.887		
655.	(4)	0.414		
657.	(5)	0.358		
660.	(5)	0.866		
661.	(5)	0.435		
662.	(10)	0.956		
665.	(14)	2.097		
666.	(15)	1.248		
667.	(18)	2.065		
668.	(14)	1.026		
671.	(6)	0.867		
673.	(12)	1.664		
674.	(10)	0.471		
679.	(4)	0.516		
680.	(7)	0.686		
681.	(13)	3.636	*	
686.	(8)	0.417		
690.	(8)	0.659		
691.	(3)	1.339		
694.	(6)	1.540		
695.	(5)	0.750		
696.	(2)	0.564		
698.	(12)	0.654		
701.	(2)	0.392		
703.	(2)	0.032		
704.	(3)	0.268		
705.	(6)	0.812		
706.	(2)	0.262		
708.	(4)	0.764		
714.	(5)	0.211		
721.	(6)	1.251		
732.	(4)	0.286		
735.	(2)	0.042		

Contract No.	No.of bidders	G value	Using std. dev.for each group of 'n' bidders	Using o/all std. dev.
734,	(7)	0.574		
735,	(5)	1.152		
736,	(4)	3.672	*	*
737,	(8)	0.478		
753,	(4)	0.138		
758,	(3)	0.254		
764,	(7)	0.786		
765,	(4)	1.137		
770,	(5)	0.285		
771,	(6)	0.193		
772,	(7)	0.971		
778,	(5)	0.434		
781,	(6)	0.173		
793,	(5)	1.210		
793,	(8)	0.300		
795,	(3)	1.484		
796,	(3)	0.212		
808,	(3)	0.296		
813,	(3)	0.880		
815,	(2)	0.165		
818,	(3)	0.317		
842,	(2)	0.667		
850,	(2)	0.539		
852,	(3)	0.213		
853,	(3)	0.225		
854,	(2)	0.408		
857,	(3)	0.457		
860,	(4)	0.545		
861,	(6)	0.525		
865,	(3)	0.211		
867,	(2)	0.037		
871,	(3)	1.152		
876,	(4)	0.835		
877,	(2)	0.406		
897,	(7)	0.972		
901,	(2)	0.407		
919,	(3)	0.131		
942,	(3)	0.111		
973,	(8)	0.435		
998,	(13)	1.584		
1000,	(10)	0.511		
1001,	(3)	0.590		
1007,	(2)	0.934		
1009,	(7)	0.867		
1020,	(2)	2.760	*	*
1024,	(8)	0.694		
1035,	(2)	0.934		
1087,	(5)	0.462		
1087,	(5)	0.462		
1094,	(3)	1.833	*	*
1102,	(6)	1.530		
1116,	(6)	0.616		
1117,	(13)	1.284		
1124,	(6)	0.367		
1136,	(3)	1.363		*
1137,	(2)	0.348		
1139,	(7)	0.656		
1143,	(3)	0.678		
1147,	(4)	0.221		
1148,	(2)	0.029		
1153,	(2)	0.118		
1156,	(3)	0.405		

1157,	(7)	1.536		
1160,	(3)	1,407		
1166,	(4)	0.379		
1168,	(3)	0.330		
1169,	(7)	2.064	*	*
1195,	(12)	1.708		
1208,	(8)	1.120		
1240,	(7)	1,003		
1246,	(4)	3.623	*	*
1248,	(3)	0.215		
1253,	(7)	1.200		
1283,	(9)	1.381		
1285,	(4)	0,893		
1286,	(6)	1.417		
1311,	(4)	0.930		
1318,	(7)	1.632		
1344,	(4)	0.715		
1363,	(6)	0,935		
1382,	(6)	1.135		
1383,	(3)	2,294	*	*
1400,	(4)	0.961		
1402,	(3)	2.114	*	*
1408,	(3)	1.100		
1415,	(5)	0,648		
1420,	(6)	1,154		
1446,	(4)	0,812		
1448,	(3)	1,096		
1456,	(5)	0,702		
1461,	(5)	1.022		
1462,	(2)	0.697		
1486,	(5)	1,756		
1497,	(7)	0,642		
1514,	(3)	2.002	*	*
1520,	(5)	1.480		
1528,	(7)	0.763		
1529,	(6)	0,851		
1534,	(4)	1.018		
1545,	(5)	0,667		
1548,	(3)	1.660	*	
1553,	(8)	0,723		
1554,	(5)	0.712		
1558,	(6)	1.189		
1564,	(5)	1.349		
1567,	(6)	2,752	*	*
1594,	(2)	0.219		
1597,	(5)	0,500		
1599,	(5)	0.924		
1611,	(2)	0,457		
1613,	(3)	0,528		
1625,	(2)	0.171		
1665,	(3)	0.253		
1667,	(4)	0,218		
1668,	(4)	0.619		
1676,	(4)	0,674		
1679,	(2)	0.457		
1679,	(9)	3,001	*	*
1692,	(6)	0,989		
1699,	(4)	1,299		
1715,	(2)	0,507		
1723,	(3)	0,156		
1758,	(2)	0,531		
1783,	(3)	0,640		
Number of outliers found			32	29

Total No. of contracts = 384

Number of contracts identifed as having outliers by both methods = 24

APPENDIX I

t-test for Contractor's average mean standardised bids

Referred to in section 5.3

Calculation of the Student's t Statistic.

The means of two samples, $\bar{x}_1$ and $\bar{x}_2$ are calculated thus;

$$\bar{x}_1 = \frac{1}{n_1} \sum x_1 \quad ; \qquad \bar{x}_2 = \frac{1}{n_2} \sum x_2 ,$$

where n_1, n_2 are the sample sizes.

The variances s_1^2 and s_2^2 of each sample are calculated thus;

$$s_1^2 = \frac{1}{n_1 - 1} \sum (x - \bar{x}_1)^2 ; \quad s_2^2 = \frac{1}{n_2 - 1} \sum (x - \bar{x}_2)^2$$

The pooled sample variance is given by

$$S^2 = \frac{(n_1 - 1) S_1^2 + (n_2 - 1) S_2^2}{(n_1 - 1) + (n_2 - 1)}$$

$$= \frac{\sum (x - \bar{x}_1)^2 + \sum (x - \bar{x}_2)^2}{n_1 + n_2 - 2}$$

and then the Student's t statistic is

$$t = \frac{| \bar{x}_1 - \bar{x}_2 |}{S} \sqrt{\frac{n_1 n_2}{n_1 + n_2}}$$

Then, if t_r is the significant value of t (with $(n_1 + n_2 - 2)$ degrees of freedom) at the r% level, if $t \geqslant t_r$, the means of the samples are significantly different at the r% level. Values of t_r are tabulated. The significance level used in the test was 10%.

Reference: Lambe[28]

APPENDIX J

The Binomial Test for Randomness

Referred to in section 5.3

The Binomial Test for Randomness

(i) The data was classified into H, L or O. The 'O' or neutral items were ignored.

(ii) The number of H's and L's in a group of contracts belonging to one contractor were counted.

(iii) It is assumed that each contract is independent and that an H can occur as frequently as L.

(iv) The number of H's was taken as the "test statistic". This number of H's was compared to a table of the Binomial distribution (Table 3, page 368, CONOVER, W.J., Practical nonparametric statistics, Wiley 1971). The value obtained from the tables is α. If the number of H's lies outwith the range $(H + L)/2 \pm \alpha$ the sequence is not random. If the number of H's lies within $(H + L)/2 \pm \alpha$ the sequence is random. The hypothesis being tested is that the bid is justas likely to be H or L for each contract. Rejection of the hypotheses implies that either the bid is more likely to be H than L or the bid more likely to be L than H, depending on whether the test statistic is greater than or less than $(H + L)/2$.

Reference: Conover[40]

APPENDIX K

The Wald-Wolfowitz Runs Test

Referred to in section 5.3

The Wald-Wolfowitz Runs test

(i) The data was classified in H, L or O. The 'O' or neutral items were ignored.

(ii) The number of times the sequence changed from H to L or L to H were counted. This gave a count of the number of runs, T, which is the test statistic.

(iii) Using N_1 being either the number of H's or L's whichever is the smaller and N_2 being the number of H's or L's whichever is the larger and consulting Table 23 "Quantiles" of the Wald-Wolfowitz Total Number of Runs Statistic, page 414, CONOVER, W.J. Practical Nonparametric Statistics, Wiley 1971, the number of runs likely between say 5% and 95% of the distribution of runs in random samples is obtained.

(iv) If the runs T lies outwith the range obtained the number of runs is not random.

Reference: Conover[40]

APPENDIX L

Calculation for preliminary tests

for randomness and runs

Position of sequence of Contractors : Buildings Contracts

Contractor 122

H H L H L L H L L L L O H L L H H H H H H L H

H H L H L H H H H H H H H H H H L H H L L H H

H L H H L H H H H H H L L H L H H O O O H H L

H L L O H H H O. H

No. of H's	=	49
No. of L's	=	23
No. of O's	=	6
No. of Contracts	=	78
No. of Wins	=	4
No. of Runs (T)	=	31
Test for Randomness	=	Not Random
Test for Runs	=	Random

Contractor 133

L L. L L H L H L H H H H H L L L L H L H H L L

O L H L L L H L L L L H L L L H H H H H H L L

L L L O H H H H H H L L L L O L H L L

No. of H's	=	26
No. of L's	=	36
No. of O's	=	3
No. of Contracts	=	65
No. of Wins	=	11
No. of Runs	=	22
Test for Randomness	=	Random
Test for Runs	=	Not Random

Contractor 103

H	H	L	H	L	L	L	H	H	L	H	H	H	H	H	H	L	H	L	H	H	L
H	L	H	L	H	L	L	H	O	L	L	H	H	L	H	L	L	H	L	L	L	L
L	H	L	O	H	H	H	L	L	O	L	H	L	L	L	H	L	H	O			

No. of H's	=	29
No. of L's	=	30
No. of O's	=	4
No. of Contracts	=	63
No. of Wins	=	13
No. of Runs (T)	=	34
Test for Randomness	=	Random
Test for Runs	=	Random

Position sequence of Contractors : Roads Contracts

Contractor 301

H	L	H	H	L	L	L	H	H	L	L	H	H	L	L	L	L	L	L	H	O
L	L	L	L	L	L	O	H	L	H	H	L	L	L	H	L	L	L	L	H	L
L	L	L	H	O	L	H	H	L	L	L	O		L	L	L	L	L	H	H	L
L	L	L	L	L	H	L	H	L	L	L	L	O	L	H	L	L	L	L	L	H
H	L	H	H	H	L	L	H	H	H	L	L	L								

No. of H's	=	29
No. of L's	=	62
No. of O's	=	5
No. of Contracts	=	96
No. of Wins	=	21
No. of Runs (T)	=	35
Test for Randomness	=	Not Random
Test for Runs	=	Random

Contractor 306

L	L	L	L	H	H	L	L	H	L	L	L	H	L	L	H	H	H	O	L	L	L
H	L	H	H	H	O	O	L	H	H	H	H	H	L	O	H	L	H	O	O	H	L
O	H	L	L	H	L	L	L	L	H	H	L	H	H								

No. of H's	=	25
No. of L's	=	26
No. of O's	=	7
No. of Contracts	=	58
No. of Wins	=	12
No. of Runs (T)	=	25
Test for Randomness	=	Random
Test for Runs	=	Random

Contractor 309

L	L	L	L	H	L	O	L	L	L	L	L	H	O	H	H	L	L	L	O	O	H
H	L	H	H	L	H	O	O	O	L	H	H	H	L	H	L	H	L	H	H	H	H
L	H	H	L	H	H	H	H	H	L	H	H	H	H	H	H	H	O	H	H	H	H
H	O	O	H	O	O	H	H	H													

No. of H's	=	41
No. of L's	=	22
No. of O's	=	12
No. of Contracts	=	75
No. of Wins	=	8
No. of Runs (T)	=	23
Test for Randomness	=	Not Random
Test for Runs	=	Random

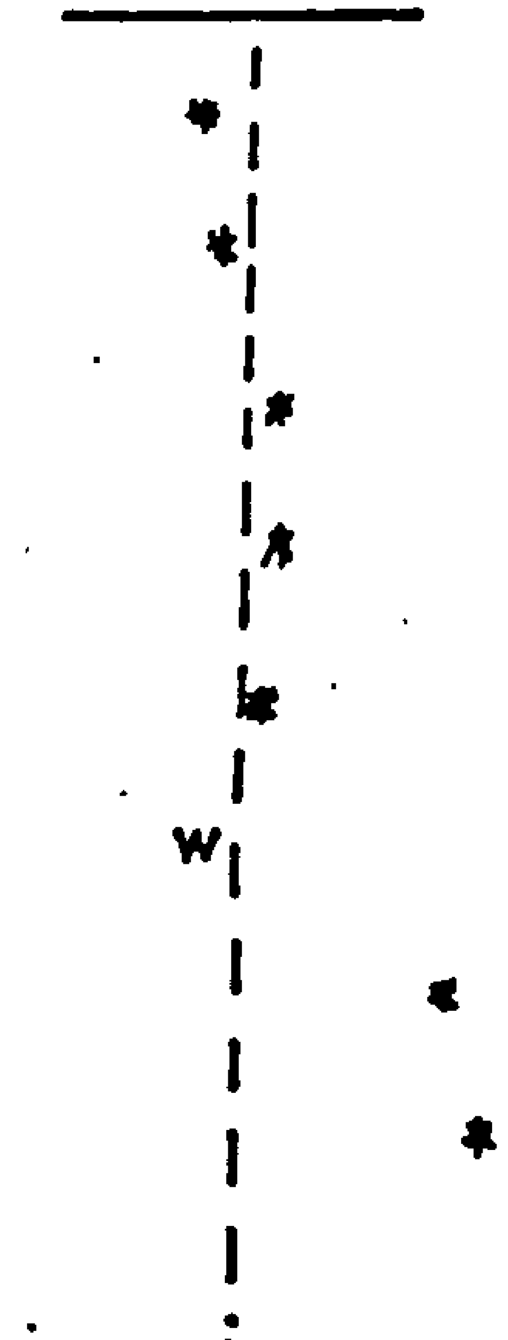
APPENDIX M

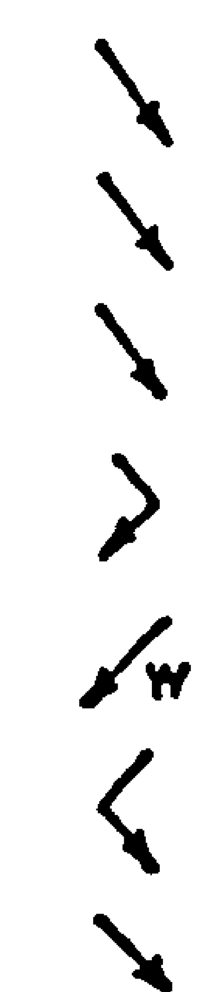
Method of Calculating CUSUM Value

Referred to in section 5.4

WORKED EXAMPLE OF THE 'CUSUM' PROGRAM SHOWING HOW CUSUM PLOT IS OBTAINED

CONTRACT	BID	POSITION	MEAN BID	BID - MEAN BID / MEAN BID	CUSUM	GRAPH	INDICATION ON BIDDERLIST
1	3 500 000	2	4 000 000	-0.125	-0.125		
2	480 000	4	400 000	0.02	-0.105		
3	1 000 000	4	850 000	0.18	0.072		
4	2 300 000	2	2 300 000	0	0.072		
5	980 000	2	1 000 000	-0-02	0.052		
6	4 800 000	1	5 800 000	-0-17	-0.120		
7	340 000	4	200 000	0.7	0.58		
8	920 000	5	840 000	0.1	0.68		





The indication on the bidderlist chart is always 'one behind' what is happening. In bidding situations this is all the information that contractors would have on the behaviour of other companies.

APPENDIX N

Method of classifying CUSUM behaviour

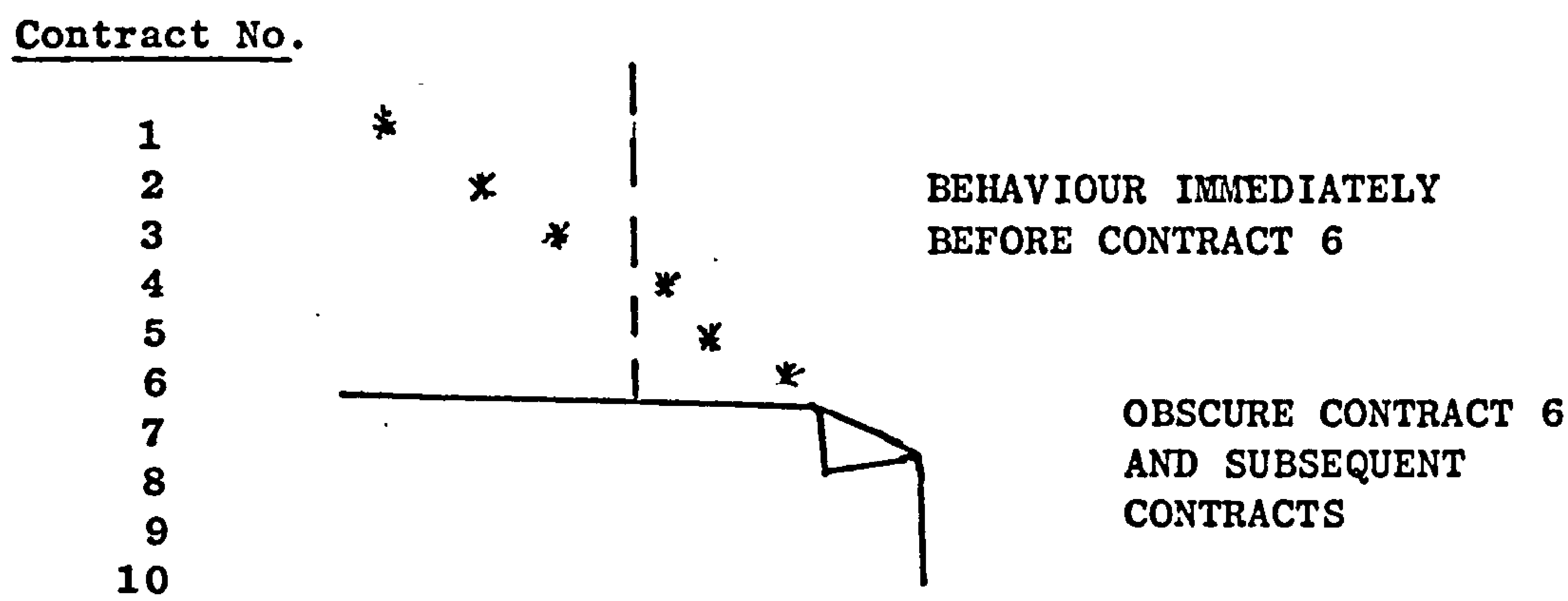
Referred to in section 5.4

EXAMPLE OF OBTAINING BIDDING BEHAVIOUR

E.G. FOR CONTRACTOR 103 AT CONTRACT 6

CUSUM PRINTOUT

CONTRACTOR 103



BIDDERLIST PRINTOUT

LIST OF BIDDERS FOR EACH CONTRACT

Contract No.	Contractors			
4	xxx	xxx	xxx	
5	xxx	xxx		
6	xxx	103	xxx	xxx
7	xxx			

CONTRACTOR'S REF. NUMBER

BEHAVIOUR IMMEDIATELY BEFORE CONTRACT 6

APPENDIX O

Test for Trend

Referred to in section 5.4

Test for Trend

<u>The Test for Trend.</u> The statistical test that is applied to the tables is a test for trend(40), and is a means of comparing the given distribution against the distribution that would result if there was no significant trend at all: that is, comparing the given distribution against the 'expected' values. The test statistic is

$$D^{+} = \max_{i} \sum_{j=1}^{n} \left(N_j - \frac{N}{n}\right)$$

where D^{+} is the maximum value recorded

i is the ranking position at which the highest value of D is recorded

j is the current ranking position

N_j is the number of components at j

N is the total number of components at all ranking positions

n is the number of ranking positions.

In this form, the test is for trend towards the front of the rank. The test for trend towards the rear of the rank is

$$D^{-} = \max_{i} \sum_{j=1}^{n} \left(\frac{N}{n} - N_j\right)$$

where the symbols are as before, except for D^{-}, which again is the largest positive number.

This test is a one-way test. Other tests that may be applied include the Chi-squared test (i.e. two-way test, which gives more reliable results), when N is greater than 100.

For the purpose of this test the test for trend is adapted to

$$D^{\pm} = \max_{i} \sum_{j=1}^{n} (N_j - \frac{N}{n})$$

where $D^{\pm}$ is redefined as the maximum negative or the maximum positive value, whichever has the larger absolute value. If the taken value of $D^{\pm}$ is positive, then the trend will be towards the front of the ranking order. If the trend is towards the rear of the ranking order, $D^{\pm}$ will be negative. The significance of these trends can be found from tables of significance which exist for this test. An example of the use of this test is shown below.

EXAMPLE OF TREND ANALYSIS

Trend Analysis given by $$D^{\pm} = \max_{i} \sum_{j=1}^{n} (N_j - \frac{N}{n})$$

where N is total number of companies in that behaviour

and n is the no. of bidders.

e.g. Class C : 5 bidders of behaviour

Behaviour ✓	Position 1	2	3	4	5	TOTAL (N)	(N/5)	D Recorded
No in that position:	12	7	4	9	5	37	7.4	
D value:	4.6	4.2	0.8	2.4	0			
Max D to date:	4.6	4.6	4.6	4.6	4.6			4.6

This positive value of D means that the trend is towards the winning end of the pattern; however at this value of D with this number of bidders it is not significant.

(Tables of significance taken from Petitt[43])

APPENDIX P

Contractors Management Game by R. McCaffer

Originally published by SAGSET NEWS, July 1973

Vol.3, No.3

(Journal of the Society for Academic Games and Simulation in Education and Training)

BASIC AIMS

The game is designed to demonstrate the problems of overall control of a contracting company whose entire turnover is made up of contracts obtained by tendering in the type of competitive market found in the construction industry.

Briefly control of a contracting company means preparing targets for turnover and profit and forecasting cash requirements, monitoring the company performance against these standards and taking the necessary corrective action. The game allows up to twenty companies to 'operate' within their 'market' for a simulated period of five years facing the problems of control already outlined and hopefully finding solutions to some of these problems.

TARGET POPULATION

The game is aimed at three categories of participant.

i. Postgraduate students undertaking a one-year MSc. course in Construction.

ii. Undergraduate civil and environmental engineering students

iii. Employees of contracting companies in company training situations, especially involving several departments and their inter-relationships.

BACKGROUND

The majority of building and civil engineering contracts in the U.K. construction industry are offered jobs through a process of competitive tendering. This is the process whereby the client or his representative prepares the contract documents including drawings, specifications and bills of quantities, and arranges that two or more contractors submit a tender or price for the contract. Based on this tender and other relevant information the client is free to choose which contractor should be awarded the contract.

A contractor who is tendering has to prepare an estimate for the cost of the work based on the client prepared contract documents and any other investigations he wishes to make. To this cost estimate the contractor adds a mark up which is an allowance for profit and company overheads not directly associated with the particular job. The sum of estimate and mark up is the tender or bid.

Tender = Estimate of contract costs + Mark up (includes profit margin and allowances for company overheads)

The actual cost of executing the contract incurred by the successful contractor will be at variance with his original estimate. The contribution, that is the margin remaining for company overheads and profit, is the tender value less the actual cost.

Contribution = Tender - Actual cost

Company profit is the sum of the contributions from all contracts won less the company's overheads.

Company profit = (Contributions from all contracts won) -(Company's overheads)

Usually such a figure as this would be related to some time period, for example one year.

Almost all contracts in the construction industry allow a series of interim payments to be made to the contractor. The amount of these interim payments is based on a valuation of the work already completed less a retention held by the client until the completion of the contract.

Typical retentions in the U.K. construction industry are 5% to 10% of contract value. Typical achieved profit margins are less than 10% and are often less than 5% of contract value. Thus it is not unusual for a company to find all its 'profits' locked up in retentions. The resulting adverse cash flow problems may in the real situation be offset by negotiating favourable credit conditions with materials suppliers and plant hire companies. However frequent cash problems arise in the industry as demonstrated by the high bankruptcy rate.

GAME FEATURES

In the game each of the participants play the role of a company. Each company obtains all its work through the competitive process. In the real world situation although many companies are dependent on the competitive market for most of their work few rely on it completely and make up the remainder of their turnover with negotiated contracts or other diversifications.

The game does not attempt to simulate the estimating procedures of a contractor but enters the process when control decisions such as "do we want this job ?" and if so "at what figure are we prepared to tender ?"

Such important decisions are made against the background of uncertainty. The uncertainty arises from the difficulties in predicting the behaviour of competitors and the knowledge that the cost estimate is inaccurate.

The cash flows of a company in the game are calculated given predetermined retention conditions, payment delays from clients and credit limits from suppliers. Although these important variables in controlling cash flow are fixed the company in the game has control of its cash flow through the number of contracts it takes on, the turnover mix (i.e. is the turnover made up of all small short jobs or large jobs of long duration) and the profit levels at which the company operates.

GAME DESCRIPTION & INFORMATION FLOW

The game is computer based and allows up to twenty teams to manage their own contracting companies over a simulated five years. Decisions are required every quarter. The frequency of the 20 decision periods is restricted by computer turn-round and the time needed between decisions for analysis. Operating at two periods per week the game can be played within ten weeks. Restricted manual versions of the game have been played during the course of an afternoon.

The main control information available to companies is the 'state of company' report (see Table P.6); this report is described in detail later.

At the start companies are given the starting 'state of company' report, information on the 'state of the market' and a list of jobs on offer during the next period. The jobs on offer are described in terms of the particular company's cost estimate and the job duration in quarters. Each company's cost estimate is drawn from a distribution whose mean is 'likely cost' and whose range is 0.9 of 'likely cost' to 1.1 of 'likely cost'. 'Likely cost' is the notional 'true cost'. Thus by drawing estimates from this range, estimating inaccuracies of ± 10% are being assumed.

The decisions each company has to take are:-

(a) How many jobs will they bid for;

(b) Which jobs will these be;

(c) What mark-up should they apply to each job.

The information is collected using the form shown in Fig. 2.

With this information from all companies the tenders for all jobs are calculated and listed in Table P.4 . The company with the lowest tender is awarded that particular contract.

The 'state of company' report is now updated with the new contracts and costs etc. added.

Each company receives his new 'state of company' report and a list of jobs for the next period.

INFORMATION AVAILABLE TO COMPANIES

Market information

An analysis of the value of the contracts which were available over the last two years are given as shown in Fig.P.1. An indication as to the rate of growth or contraction of the market is given and reviewed annually.

Job lists

A list of jobs available each quarter is given to each company. The jobs are described in terms of the particular company's cost estimate and the job duration, as shown in TableP.1.

The list shown in TableP.1 is based on a list of job likely costs. This list of likely costs and duration is drawn from a predetermined distribution of contracts. The distribution was based on figures obtained from the Annual Bulletin of Construction Statistics 1970 issued by the Department of the Environment.

The estimate is calculated by varying the likely cost by a factor of variation in the range of 0.9 to 1.1. Table 2 shows the calculations for the estimates. TableP2 is not available to the participants.

At this stage companies are asked to submit tenders. Two extreme forms of the game have been used, they are:

(a) When all companies know exactly what companies are bidding for which jobs. This represents the fullest information possible. A situation which is unlikely in practice.

and (b) When companies are completely in the dark about what jobs interest their competitors. Again this will be a rare situation in real life but slightly more realistic than (a).

The real world situation lies somewhere between (a) and (b).

Tender list

When all tenders have been calculated each company receives its own list of jobs for which it tendered, see Table P.3.

A complete list of all jobs and tenders with the winning (lowest) tender starred is placed on public display available to all companies, see Table P.4.

Jobs won list

Each company which is successful in obtaining a contract receives a list of the jobs the company won, see Table P.5. This list gives the company the 'actual cost' of the jobs the company has won. The 'actual cost' is based on the likely cost and is drawn from a distribution whose mean is likely cost and whose range is 0.95 of likely cost to 1.05 of likely cost. The purpose of introducing this variable is to simulate the variability in performance in executing contracts. The variability represents the ease or difficulty of the contract.

State of company report

This is the main control document and is issued at the start of the game showing the company's initial capacity, work load, overheads, profit and cash position. An updated report is issued every quarter containing any new jobs or costs incurred.

The report shows the complete company records for six years, at any point in the game, say period 1.3; everything earlier than 1.3 is historical information - everything later than 1.3 is the effect of existing work load and overheads if no action is taken by the company.

The following description of the entries in this report include an explanation of any assumptions made. Reference should be made to Table P.6. The upper table is the company's profit and loss statement. The entries are:

Time Period This gives the year and quarter number.

Workload Actual Cost Actual costs are direct contract costs. Each job won is assumed to have a uniform 'spend rate' (i.e. a job whose actual cost is £150,000 and lasts 3 quarters will cost £50,000 per quarter). All contracts commence in the quarter immediately succeeding the quarter in which the contract is awarded.

The figures shown are a total of the actual costs in the time period for all the company's contracts.

Contribution Contribution is the difference between tender value and actual costs (i.e. using the previous example, if the contract with an actual cost of £150,000 was awarded at a sum of £165,000 the contribution would be £15,000. Again if the duration is 3 quarters this would mean a quarterly contribution of £5,000).

The figures shown are totals of the contributions earned in the time period for all the company's contracts.

Tendering Costs Companies are charged ¼% of the estimated cost of each job they tender for. The figure shown in each time period is the total tendering costs incurred in that time period.

Work Sub-Contracted If companies exceed their capacity (capacity is expressed in terms of actual cost) then it is assumed that the company has reluctantly to sub-contract the excess work. The starting capacity of each company is decided at the commencement of the game; as the game proceeds each company can choose to grow or contract (i.e. get smaller). This choice is only allowed every 6 months and limited to within ± 10% (i.e. if a company has an annual capacity of £4m, and in a particular quarter had £1.2m of work in Actual cost then £0.2m would be sub-contracted).

Company overheads are linked to capacity (see company overheads).

Sub-Contracting Costs All excess work sub-contracted costs an extra 6% (i.e. using the example of the £0.2m of sub-contracted work the total cost of this work would now be £0.2m + 6% of £0.2m = £212,000).

Company Overheads This represents all costs not directly charged to a contract. Company overheads are directly related to the size of the company (i.e. the company's capacity).

The minimum overheads of any company are £60,000 p.a. (i.e. £15,000 per quarter). The maximum overheads of any company are £800,000 p.a. (i.e. £200,000 per quarter). Otherwise company overheads are 4% of the company's capacity.

If a company decides to increase its capacity, the corresponding increase in company overheads becomes effective immediately. If a company decides to decrease its capacity there is a delay of 4 quarters (1 year) before there is a corresponding decrease in company overheads. This simulates the easy acquisition of overheads (e.g. new staff etc.) and the more difficult process of reducing overheads.

Interest + Charge - Earned This shows in each time period the interest charged or earned and is based on the company's cumulative cash in the preceding quarter. Interest is earned at 3% per quarter if the cumulative cash in the previous quarter is greater than zero. If the cumulative cash is less than zero in the previous quarter then interest is charged at 3% per quarter for the first ten percent of the initial company annual capacity, at 4% per quarter for the balance between ten per cent and fifteen per cent of the initial company annual capacity and at 5% per quarter thereafter.

Profit/Loss This is the profit (+) or loss (-) earned in each quarter. This figure is the contribution less tendering costs, subcontracting costs, overheads and interest (either + or -).

Annual Profit/Loss The annual profit (+) or annual loss (-) earned in each year.

Between the upper and lower tables the current quarterly capacity and the limits for the interest charges are given. The lower table is the company's cash statement. The entries are:-

Time period As before.

Contracts payments This shows the cash payments resulting from the contracts. The work load (actual cost) shown in the profit table was a cost liability. The contract payments show the cash flow at the time the payments are made. A delay between cost liability and payment of one quarter is assumed. This payment delay is regarded as the mean payment delay a contractor might have if he allows say, a one-week delay for labour, a four-week delay for materials, and a 6-week delay for hired plant.

Sub-Contractor payments This is the payment of the excess sub-contracting costs of 6% of work sub-contracted. Again a payment delay of one quarter is assumed.

Company overheads These occur quarterly.

Contract receipts This is monies received from clients. Payment is received one quarter after the work is executed. The payment is calculated as the tender value of the work done less 10% retention. (If a contract has a tender value of £165,000 and lasts 3 quarters, the quarterly contract receipts would be £55,000 less 10%, i.e. £49,500).

Retention receipts This is the payment of monies held in retention. Half of the retention for a contract is paid one quarter after the practical completion of the contract. The remaining half is paid two quarters after the practical completion.

Interest charges As before.

<u>Net cash flow</u> The net cash flow in any quarter is the difference between cash in and cash out. Cash in is the sum of contract and retention receipts. Cash out is the sum of contract payments, sub-contract payments, tendering costs and company overheads.

<u>Cumulative cash flow</u> This is a running total of the quarterly cash flows, including any monies taken for tax and dividends.

<u>Cash for dividends, tax, etc.</u> This represents money drawn annually for paying dividends to shareholders and taxation. The company is not given any discretion in this matter which is a simplification. However it is necessary to simulate the removal of substantial cash sums from the company for the purposes of dividends and taxation. The sum of money taken for these purposes is calculated as follows:-

(a) If the company shows a profit every year. The sum taken is 85% of the annual profit.

(b) If the company shows a loss in any year no dividends or tax is paid that year.

(c) If the company shows a profit following a period of loss the sum taken is 85% of the profit left having recovered all losses since the last dividend was paid.

If the profit earned after a loss making period is insufficient to cover losses then no payments are made.

At the foot of the cash statement the annual average of the cash account is given.

EVALUATION AND COMMENT

The game was designed to demonstrate the problems of overall control of a contracting company. This control can be thought of at two levels:-

(1) Overall plans: preparation of targets for turnover and profit. Decisions as to the ideal size of company, target market share and cash requirements.

(2) Quarterly decisions which are

(a) How many jobs should be tendered for

(b) Which jobs

(c) At what mark-up

To take these decisions effectively the participant needs, or needs to develop, some analytical skills and a knowledge of the interdependency of one set of decisions or targets on other decisions or targets.

Used in the context of undergraduate and postgraduate teaching within the Department of Civil Engineering at Loughborough where students' studies include finance, managerial economics, statistics and operational research, the opportunity to apply their skills in an integrated and changing situation has proved stimulating and useful in demonstrating the problems of company control described.

Some points that the game has successfully demonstrated are:-

(a) the difficulties of recovering overheads with a fluctuating work load

(b) the differences between profit and cash

(c) the effect of charging for cash at realistic interest rates

(d) the concept of break-even mark-up which is that mark-ups must contain a positive allowance for profit even if the company only wishes to break even in the long run. The reasons being that contractors tend to win contracts in which their estimating errors places their estimate low in the range of possible estimates.

The game is capable of being extended in several ways depending on the objectives of the user. At undergraduate level one of the main uses is as an exercise in developing some analytical skills. In other situations the financial aspects may be more important and extra features such as preparation of twice-yearly reports to shareholders or the maintaining of inter-firm comparison ratios can be added.

At the time of writing no comments can be made about the use of the game with employees of contracting companies as the game in this context is currently being played and therefore any comment would be premature.

A difficulty in operating the game has been what should be done with companies in serious cash difficulties. In real life, of course, they would be declared bankrupt, the company would be wound up and their place in the industry would be filled by expansion of other companies and the creation of new companies.

In the game situation at least three possibilities exist:-

i. Declare the company bankrupt and have them leave the game

ii. Declare the company bankrupt and allow the team to set up a new company

iii. Do not have bankruptcy and allow the company to continue struggling.

So far possibility iii. has been used with plans to have a trial with possibility ii. Possibility i. so far has been rejected as bad practice. In an educational setting it seems unwise to announce to a team that they have failed and must leave the game and receive no more education !

MARKET ANALYSIS OF LAST TWO YEARS

FIG. P1

CONTRACTORS MANAGEMENT GAME BIDDING FORM

To be completed and returned to:
R. McCaffer,
Department of Civil Engineering,
University of Technology,
Loughborough, Leics. LE11 3TU.

GAME PARTICIPANTS MUST COMPLETE ONE FORM EACH PERIOD

1. Game Name ____________________

2. Company No. [   ]

3. Period [   ]

4. Are any jobs being bid for this period Yes / No *

5. If YES answer all remaining questions.
   If NO answer question 6 if appropriate
   sign form and return.

6. Companies are allowed to change their "size" if required every second period (i.e. the "even" period). If change is permitted this period do you wish to alter the size of your company Yes / No *

   If YES by what percentage (limited to range ± 10%) [   ]

   * delete as necessary

LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY
DEPARTMENT OF CIVIL ENGINEERING

7. Enter total number of jobs being bid for this period
   1 2
   [|]

8. For each job being bid for enter the job number in Cols. 1 and 2 (jobs with single number only e.g. 4 should be entered in Col. 2) and the mark up in Cols. 3 to 8 (use the existing decimal point when entering mark up)

1 2 3 4 5 6 7 8

continue in next column

1 2 3 4 5 6 7 8

Signature ______________

Date ______________

FIG P2

TABLE P.1

COMPANY NO. 6 ESTIMATES FOR JOBS ON OFFER IN PERIOD 1.4

JOB NO.	ESTIMATE	DURATION
1	79144.	5.0
2	68204.	7.0
3	140214.	6.0
4	60771.	6.0
5	82313.	4.0
6	362419.	4.0
7	231731.	5.0
8	169285.	6.0
9	397236.	4.0
10	904443.	5.0
11	804460.	7.0
12	485357.	6.0
13	1106858.	8.0

TABLE P.2

COMPANY NO. 6 ESTIMATE BUILD UP FOR JOBS ON OFFER IN PERIOD 1.4

JOB NO.	LIKELY COST	RANDOM NO.	ESTIMATED COST
1	78095.	1.01	79144.
2	64491.	1.06	68204.
3	146959.	0.95	140214.
4	61806.	0.98	60771.
5	81086.	1.02	82313.
6	357180.	1.01	362419.
7	223638.	1.04	231731.
8	176444.	0.96	169285.
9	396064.	1.00	397236.
10	924497.	0.98	904443.
11	840853.	0.96	804460.
12	507561.	0.96	485357.
13	1075434.	1.03	1106858.

(This table is not available to participants)

(Random factors - only two decimal places shown; in calculations up to seven decimal places are used)

TABLE P.3

COMPANY TENDER REPORT
COMPANY NUMBER 6
PERIOD 1.4

JOB NO.	ESTIMATED COST	MARK UP	TENDER
5	82313.	16.00	95484.
6	362419.	15.00	416782.
7	231731.	13.00	261856.
8	169285.	13.00	191292.
9	397236.	15.00	456821.
10	904443.	15.00	1040109.
11	804460.	13.00	909039.
12	485357.	13.00	548454.

TABLE P4

TENDER REPORT
PERIOD 1.4

CO. NO. / JOB NO.	1	2	3	4	5	6	7	8	9	10
1	0.	85146.	0.	88972.	0.	0.	0.	* 84196.	0.	88347.
2	0.	* 67302.	0.	74075.	0.	0.	0.	73571.	0.	70662.
3	0.	163501.	0.	164866.	0.	0.	0.	174584.	0.	* 156561.
4	0.	69805.	0.	71577.	0.	0.	0.	* 65303.	0.	67160.
5	0.	0.	0.	93718.	0.	95484.	91462.	91292.	0.	* 87712.
6	0.	0.	0.	394082.	0.	416732.	* 385429.	411881.	0.	387456.
7	0.	0.	0.	243623.	0.	261856.	* 229517.	250337.	0.	249304.
8	0.	0.	0.	211904.	0.	191292.	192834.	203212.	191380.	* 188441.
9	0.	0.	0.	450541.	0.	456821.	* 426233.	456505.	437905.	451008.
10	0.	0.	0.	1053299.	0.	1040109.	1035525.	1052390.	1031071.	*1003759.
11	0.	0.	0.	0.	0.	909039.	980385.	1000342.	961471.	* 881901.
12	0.	0.	0.	0.	0.	* 548454.	550992.	577758.	592324.	580283.
13	0.	0.	0.	0.	0.	0.	*1097308.	1247866.	1189771.	1198819.

TABLE P5

COMPANY NO. 6 DETAILS OF JOBS WON IN PERIOD 1.4

JOB NO.	ACTUAL COST	TENDER	DURATION(QTRS)
12	492218.	548454.	6.0

COMPANY NUMBER 6
PERIOD 1.4
COMPANY REPORT ASSUMING NO MORE JOBS TENDERED FOR

TIME PERIOD	WORKLOAD ACTUALCOST	CONTRI-BUTION	TENDERING COSTS	WORK SUB-CONTRACTED	SUB-CONT. COSTS	COMPANY. OVERHEADS	INTEREST +CHARGE -EARNED	PROFIT/LOSS	ANNUAL PROF/LOSS
1.1	600000.	60000.	2496.	0.	0.	24000.	-600.	34104.	0.
1.2	600000.	60000	11980.	0.	0.	25200.	357.	22463.	0.
1.3	817064.	69158	7792.	187064.	11224.	25200.	1663.	23279.	0.
1.4	980756.	83026.	8593.	350756.	21045.	25200.	1398.	26790.	106635.
2.1	762792.	62398.	0.	132792.	7968.	25200.	4608.	24622.	0.
2.2	740622.	60394.	0.	110622.	6637.	25200.	4359.	24198.	0.
2.3	662414.	54016.	0.	32414.	1945.	25200.	3614.	23258.	0.
2.4	518819.	44786.	0.	0.	0.	25200.	5196.	14390.	86468.
3.1	467029.	39893.	0.	0.	0.	25200.	9128.	5565.	0.
3.2	380359.	31974.	0.	0.	0.	25200.	10353.	-3579.	0.
3.3	0.	0.	0.	0.	0.	25200.	11981.	-37181.	0.
3.4	0.	0.	0.	0.	0.	25200.	13825.	-39025.	-74220.
4.1	0.	0.	0.	0.	0.	25200.	13714.	-38914.	0.
4.2	0.	0.	0.	0.	0.	25200.	15660.	-40860.	0.
4.3	0.	0.	0.	0.	0.	25200.	17703.	-42903.	0.
4.4	0.	0.	0.	0.	0.	25200.	19848.	-45048.	-167725.
5.1	0.	0.	0.	0.	0.	25200.	22101.	-47301.	0.
5.2	0.	0.	0.	0.	0.	25200.	24466.	-49666.	0.
5.3	0.	0.	0.	0.	0.	25200.	26949.	-52149.	0.
5.4	0.	0.	0.	0.	0.	25200.	29556.	-54755.	-203871.
6.1	0.	0.	0.	0.	0.	25200.	32294.	-57494.	0.
6.2	0.	0.	0.	0.	0.	25200.	35169.	-60369.	0.
6.3	0.	0.	0.	0.	0.	25200.	38187.	-63387.	0.
6.4	0.	0.	0.	0.	0.	25200.	41357.	-66557.	-247807.

WORK CURRENTLY SUB-CONTRACTED ABOVE £ 630000.
INTEREST CHARGED AT 3% PER QTR FOR THE FIRST £ -240000.BORROWED.4% BETWEEN £ -240000 && -360000.& THEN 85%
COMPANY CASH STATEMENT

TIME PERIOD	CASH OUT: CONTRACT PAYMENTS	CASH OUT: SUB-CONT PAYMENTS	CASH OUT: TENDERING COSTS	CASH OUT: COMPANY O/HEADS	CASH IN: CONTRACT RECEIPTS	CASH IN: RETENTION RECEIPTS	INTEREST +CHARGE -EARNED	NET CASH FLOW	CUMULATIVE CASH FLOW	CASH FOR DIVS.TAX ETC.
1.1	600000.	0	2496.	24000	594000.	0.	-600.	-31896.	-11896.	0.
1.2	600000.	0	11980.	25200	594000.	0.	357.	-43537.	-55433.	0.
1.3	600000.	0	7792.	25200	594000.	49500.	1663.	8846.	-46587.	0.
1.4	817064.	11224	8593.	25200	797599.	49500.	1398.	-16380.	-153607.	90640.
2.1	980756.	21045	0.	25200	957403.	82500.	4608.	8294.	-145313.	0.
2.2	762792.	7968	0.	25200	742671.	82500.	4359.	24852.	-120461.	0.
2.3	740622.	6637	0.	25200	720915.	2417.	3614.	-52741.	-173202.	0.
2.4	662414.	1945	0.	25200	644787.	8459.	5196.	-41509.	-288209.	73498.
3.1	518819.	0	0.	25200	507245.	15283.	9128.	-30620.	-318829.	0.
3.2	467029.	0	0.	25200	456230.	5448.	10353.	-40684.	-359513.	0.
3.3	380359.	0	0.	25200	371100.	9459.	11961.	-36961.	-396474.	0.
3.4	0.	0	0.	25200	0.	41233.	13825.	2189.	-394285.	0.
4.1	0.	0	0.	25200	0.	0.	13714.	-38914.	-433200.	0.
4.2	0.	0	0.	25200	0.	0.	15660.	-40860.	-474060.	0.
4.3	0.	0	0.	25200	0.	0.	17703.	-42903.	-516963.	0.
4.4	0.	0	0.	25200	0.	0.	19848.	-45048.	-562011.	0.
5.1	0.	0	0.	25200	0.	0.	22101.	-47301.	-609311.	0.
5.2	0.	0	0.	25200	0.	0.	24466.	-49666.	-658977.	0.
5.3	0.	0	0.	25200	0.	0.	26949.	-52149.	-711125.	0.
5.4	0.	0	0.	25200	0.	0.	29556.	-54756.	-765882.	0.
6.1	0.	0	0.	25200	0.	0.	32294.	-57494.	-823375.	0.
6.2	0.	0	0.	25200	0.	0.	35169.	-60369.	-883745.	0.
6.3	0.	0	0.	25200	0.	0.	38187.	-63387.	-947132.	0.
6.4	0.	0	0.	25200	0.	0.	41357.	-66557.	-1013689.	0.

ANNUAL AVERAGE OF CASH ACCOUNT
YEAR 1 -66891. YEAR 2 -181796. YEAR 3 -367280. YEAR 4 -496538. YEAR 5 -686324. YEAR 6 -916985.

APPENDIX Q

Analysis of Variance for two factors

Referred to in section 5.5

Appendix Q - Analysis of Variance for Two Factors

The data to be analysed is arranged in a table with 'a' rows and 'b' columns; the element in the ith row and jth column is x_{ij}. The sum of the ith row is denoted by $X_{i.}$, the sum of the jth column by $X._j$, and the total sum by $X..$

1) Correction C $= \dfrac{(\sum x_{ij})^2}{ab} = \dfrac{X..^2}{ab}$

2) Total Sum of Squares TSS $= \sum x_{ij}^2 - C$

3) Rows Sum of Squares RSS $= \dfrac{X_{1.}^2 + X_{2.}^2 + \ldots + X_{a.}^2}{b} - C$

4) Columns Sum of Squares CSS $= \dfrac{X._1^2 + X._2^2 + X._b^2}{a} - C$

5) Residual Sum of Squares ESS = TSS-(RSS + CSS)

The results table is presented as follows:

Source of Variation	Degrees of Freedom	Sum of squares	Mean Square (Variances)	F Ratio (Variance Ratios)
Rows	a-1	RSS	RSS/(a-1)=RMS	RMS/EMS
Column	b-1	CSS	CSS/(b-1)=CMS	CMS/EMS
Residuals	EDF=(a-1)(b-1)	ESS	ESS/EDF = EMS	
TOTAL	TDF=ab-1	RSS+CSS+ESS		

If certain of the values x_{ij} are missing, they can be estimated, using

$$E\left[x_{ij}\right] = \bar{X}_{i.} + \bar{X}._j - \bar{X}..$$

where $\bar{X}_{i.}$ $\bar{X}._j$ and $\bar{X}..$ are the means of the ith row, jth column and the whole table respectively.

If n values are estimated, the values of EDF and TDF are reduced by n.

The F ratio which compares the variance due to either the contractor or the contract with the residual variance offers a method of testing whether these variances are significantly different from the residual vairance. This is done by comparing the F-ratio with tabulated values for the appropriate degrees of freedom.

References: Snedecor and Cochran[45] and Lambe[28]

APPENDIX R

Residuals of Mean Bid - Designer's Estimate and Low Bid - Designer's Estimate for Buildings and Roads Contracts

Referred to in section 6.1

TABLE R.1 Buildings Contracts Residuals of (Mean Bid - Designer's Estimate) and (Lowest Bid - Designer's Estimate)

RESIDUAL (% of lowest bid)	LOWEST BID	RESIDUAL	RESIDUAL (% of original estimate)	ORIGINAL ESTIMATE	MEAN BID	RESIDUAL	RESIDUAL (% of original estimate)	RESIDUAL (% of mean bid)	No. of bids
47.14	4495000.	2118730.	32.04	6613730.	5581458.	1032272.	15.61	18.49	8
5.94	5190403.	308300.	5.61	5498703.	6037101.	-538398.	-9.79	-8.92	10
9.84	5533890.	544404.	8.96	6078294.	6279016.	-200722.	-3.30	-3.20	10
-6.58	5549158.	-365253.	-7.05	5183905.	5908651.	-724747.	-13.98	-12.27	10
40.61	5916013.	2402390.	28.88	8318403.	6565621.	1752782.	21.07	26.70	13
1.01	6228256.	63170.	1.00	6291426.	6505226.	-213800.	-3.40	-3.29	6
-2.53	6233810.	-157682.	-2.60	6076128.	6625182.	-549054.	-9.04	-8.29	7
6.11	6450689.	394066.	5.76	6844755.	7047533.	-202778.	-2.96	-2.88	7
38.93	6500000.	2530132.	28.02	9030132.	7448961.	1581171.	17.51	21.23	7
-5.07	7178549.	-363984.	-5.34	6814565.	7737014.	-922450.	-13.54	-11.92	4
8.71	7525742.	655126.	8.01	8180868.	8198412.	-17544.	-0.21	-0.21	11
-13.56	7665000.	-1039196.	-15.68	6625804.	8346115.	-1720311.	-25.96	-20.61	6
20.38	7972472.	1624786.	16.93	9597258.	8420458.	1176800.	12.26	13.98	11
-10.73	8476000.	-909125.	-12.01	7566875.	8826140.	-1259265.	-16.64	-14.27	11
42.83	8685000.	3719872.	29.99	12404872.	9461488.	2943384.	23.73	31.11	13
-15.19	8796000.	-1335830.	-17.91	7460170.	9687335.	-2227165.	-29.85	-22.99	5
-15.66	8845496.	-1385326.	-18.57	7460170.	9629925.	-2169755.	-29.08	-22.53	5
16.45	8879511.	1460998.	14.13	10340509.	9711707.	628802.	6.08	6.47	10
-1.57	9398879.	-147900.	-1.60	9250979.	9782047.	-531068.	-5.74	-5.43	8
3.81	9465267.	361050.	3.67	9826317.	10139261.	-312944.	-3.18	-3.09	11
20.73	10291490.	2133673.	17.17	12425163.	11259102.	1166061.	9.38	10.36	10
-12.89	10561749.	-1361904.	-14.80	9199845.	11307284.	-2107439.	-22.91	-18.64	3
-3.46	10561749.	-365224.	-3.58	10196525.	11152788.	-956263.	-9.38	-8.57	3
25.96	10664585.	2768699.	20.61	13433284.	11821080.	1612204.	12.00	13.64	12
-38.31	10865435.	-4162846.	-62.11	6702589.	11286512.	-4583923.	-68.39	-40.61	7
4.61	12134734.	559140.	4.40	12693874.	13770703.	-1076829.	-8.48	-7.82	4
3.79	12272709.	465318.	3.65	12738027.	12869832.	-131805.	-1.03	-1.02	4
-6.59	12374000.	-815870.	-7.06	11558130.	13754960.	-2196830.	-19.01	-15.97	9
-12.56	12580000.	-1580000.	-14.36	11000000.	13165871.	-2165871.	-19.69	-16.45	6
-11.05	12705396.	-1404032.	-12.42	11301364.	13790393.	-2489029.	-22.02	-18.05	5
68.07	12987897.	8841178.	40.50	21829075.	16680538.	5148537.	23.59	30.87	17
-14.84	12989000.	-1927211.	-17.42	11061789.	13133200.	-2071411.	-18.73	-15.77	5
10.49	13000000.	1363351.	9.49	14363351.	14212698.	150653.	1.05	1.06	9

Residual (% of lowest bid)	Lowest bid	Residual	Residual (% of original estimate)	Original Estimate	Mean Bid	Residual	Residual (% of original estimate)	Residual (% of mean bid)	No. Bids
-11.11	13415263.	-1490863.	-12.50	11924400.	14351377.	-2426977.	-20.35	-16.91	6
4.13	13464404.	555626	3.96	14020030.	14166985.	-146955.	-1.05	-1.04	4
-11.33	13540682.	-1534386	-12.78	12006301.	14409254.	-2402953.	-20.01	-16.68	4
0.88	13897930.	122100	0.87	14020030.	14564726.	-544696.	-3.89	-3.74	5
25.48	13950000.	3554026	20.30	17504028.	19733493.	-2229465.	-12.74	-11.30	12
-0.18	14275000.	-25000	-0.18	14250000.	15179506.	-929506.	-6.52	-6.12	5
-20.66	14518792.	-2999442	-26.04	11519350.	14984305.	-3464955.	-30.08	-23.12	5
-3.74	14925927.	-558847.	-3.89	14367080.	16321615.	-1954535.	-13.60	-11.98	7
-7.43	14949907.	-1111434	-8.03	13838473.	15334799.	-1496325.	-10.81	-9.76	4
-9.45	15130272.	-1430272	-10.44	13700000.	16650553.	-2950553.	-21.54	-17.72	6
5.92	15277389.	905056	5.59	16182448.	16730584.	-548136.	-3.39	-3.28	7
-4.92	15783425.	-776940.	-5.18	15006485.	16970854.	-1964369.	-13.09	-11.57	8
-8.05	15812000.	-1272545.	-8.75	14539455.	16691279.	-2151824.	-14.80	-12.89	5
-13.71	15876016.	-2176016.	-15.88	13700000.	16477463.	-2777463.	-20.27	-16.86	4
-17.34	16074697.	-2787721.	-20.98	13286976.	16269861.	-2982885.	-22.45	-18.33	2
-6.35	16245220.	-1032136.	-6.78	15213084.	17017927.	-1804843.	-11.86	-10.61	6
-5.96	16363425.	-975142.	-6.34	15388283.	18823135.	-3434852.	-22.32	-18.25	15
-2.94	16598500.	-487868.	-3.03	16110632.	17282399.	-1171768.	-7.27	-6.78	4
-1.94	16939631.	-328465.	-1.98	16611166.	17831189.	-1220023.	-7.34	-6.84	4
-3.23	16958988.	-547068.	-3.33	16411920.	17574569.	-1162649.	-7.08	-6.62	6
27.66	17341562.	4796908.	21.67	22138470.	19151651.	2986819.	13.49	15.60	11
-8.23	17748254.	-1460788.	-8.97	16287466.	18743368.	-2455902.	-15.08	-13.10	7
-11.50	17800000.	-2047324.	-13.00	15752676.	18545874.	-2793198.	-17.73	-15.06	4
-7.20	17813000.	-1282301	-7.76	16530699.	18946219.	-2415520.	-14.61	-12.75	8
1.89	17927736.	338757.	1.85	18266493.	21145579.	-2879086.	-15.76	-13.62	10
-10.88	17980000.	-1956267.	-12.21	16023733.	18597540.	-2573807.	-16.06	-13.84	10
-11.74	18233604.	-2139742.	-13.30	16093862.	19067801.	-2973939.	-18.48	-15.60	5
1.84	18233604.	336407.	1.81	18570011.	19067801.	-497790.	-2.68	-2.61	5
-4.60	18331000.	-843418.	-4.82	17487582.	19515201.	-2027619.	-11.59	-10.39	8
-19.69	18343123.	-3612606.	-24.52	14730517.	19094112.	-4363596.	-29.62	-22.85	4
23.01	18574895.	4274312	18.71	22849207.	20623755.	2225452.	9.74	10.79	14
-6.25	18667542.	-1166216.	-6.66	17501326.	19714964.	-2213638.	-12.65	-11.23	6
-14.98	18818658.	-2818658	-17.62	16000000.	20114601.	-4114601.	-25.72	-20.46	6
12.64	19698360.	2489106	11.22	22187469.	21652792.	534677.	2.41	2.47	11

Residual (% of lowest bid)	Lowest Bid	Residual	Residual (% of original estimate)	Original Estimate	Mean Bid	Residual	Residual (% of original estimate)	Residual (% of mean bid)	No. of bids
-15.33	20905000.	-3204473.	-18.10	17700527.	22339630.	-4639103.	-26.21	-20.77	7
-10.60	21537322.	-2282322.	-11.85	19255000.	22073322.	-2818322.	-14.64	-12.77	5
28.09	21586152.	6063848.	21.93	27650000.	25973312.	1676688.	6.06	6.46	11
-18.40	21710799.	-3994136.	-22.54	17716663.	21834367.	-4117704.	-23.24	-18.86	2
0.98	22194477.	218037.	0.97	22412514.	24354772.	-1942258.	-8.67	-7.97	10
-9.15	22205000.	-2032706.	-10.08	20172294.	23621601.	-3449307.	-17.10	-14.60	3
-6.98	22944678.	-1600762.	-7.50	21343916.	23462669.	-2118753.	-9.93	-9.03	4
-13.72	22948824.	-3148824.	-15.90	19800000.	24177539.	-4377539.	-22.11	-18.11	5
-8.08	23304465.	-1881983.	-8.79	21422482.	24046361.	-2623879.	-12.25	-10.91	9
-4.32	23532483.	-1017617.	-4.52	22514866.	25865641.	-3350775.	-14.88	-12.95	12
-15.70	23600000.	-3704990.	-18.62	19895010.	23943194.	-4048184.	-20.35	-16.91	4
-7.75	23670000.	-1834460.	-8.40	21835540.	24329141.	-2493601.	-11.42	-10.25	5
-11.93	24345608.	-2904692.	-13.55	21440916.	24971309.	-3530393.	-16.47	-14.14	4
5.11	24456470.	1250273.	4.86	25706743.	28911061.	-3204318.	-12.46	-11.08	11
-4.26	24857836.	-1057836.	-4.44	23800000.	25259117.	-1459117.	-6.13	-5.78	6
15.68	24980006.	3917948.	13.56	28897954.	29219984.	-322030.	-1.11	-1.10	10
-18.32	25021958.	-4583255.	-22.42	20438703.	25550082.	-5111379.	-25.01	-20.01	5
-5.67	25664452.	-1454481.	-6.01	24209971.	29281949.	-5071978.	-20.95	-17.32	12
1.19	26301839.	313784.	1.18	26615623.	27769028.	-1153405.	-4.33	-4.15	6
3.84	26400000.	1013000.	3.70	27413000.	27836800.	-423800.	-1.55	-1.52	5
-6.19	26500000.	-1641641.	-6.60	24858359.	27100000.	-2241641.	-9.02	-8.27	4
-6.55	26600000.	-1741641.	-7.01	24858359.	27125000.	-2266641.	-9.12	-8.36	4
-9.57	29205952.	-2794461.	-10.58	26411491.	30141664.	-3730173.	-14.12	-12.38	3
-12.99	29205962.	-3794471.	-14.93	25411491.	30141668.	-4730177.	-18.61	-15.69	3
-2.71	29379456.	-796039.	-2.78	28583417.	30873039.	-2289622.	-8.01	-7.42	6
-8.78	29547030.	-2593007.	-9.62	26954023.	32468167.	-5514144.	-20.46	-16.98	6
-15.69	29718905.	-4664376.	-18.62	25054529.	30669872.	-5615343.	-22.41	-18.31	2
1.97	29760604.	584889.	1.93	30345493.	33898875.	-3553382.	-11.71	-10.48	8
-16.24	31270000.	-5077724.	-19.39	26192276.	33440000.	-7247724.	-27.67	-21.67	3
-3.61	31925174.	-1153579.	-3.75	30771595.	33499136.	-2727541.	-8.86	-8.14	5

Residual (% of lowest bid)	Lowest Bid	Residual	Residual (% of original estimate)	Original Estimate	Mean Bid	Residual	Residual (% of original estimate)	Residual (% of mean bid)	No. of bids
-10.04	33220000.	-3354170	-11.16	29885830.	33854230.	-3968400.	-13.28	-11.72	3
23.12	33716108.	7795776	18.78	41511884.	36049635.	5462249.	13.16	15.15	10
24.42	33782184.	8249749	19.63	42031933.	39436526.	2595407.	6.17	6.58	10
-1.68	34868908.	-585006	-1.71	34283902.	38126469.	-3842567.	-11.21	-10.08	9
33.62	34997690.	11767743	25.16	46765433.	39955982.	6809451.	14.56	17.04	17
19.56	35107000.	6868613	16.36	41975613.	38529336.	3446277.	8.21	8.94	11
6.38	35455000.	2262470	6.00	37717470.	36401183.	1316287.	3.49	3.62	5
-8.96	35895000.	-3217420	-9.85	32677580.	36745852.	-4068272.	-12.45	-11.07	5
-14.74	35943118.	-5298656	-17.29	30644462.	37963110.	-7318648.	-23.88	-19.28	7
-6.33	38379902.	-2428468	-6.75	35951434.	41993609.	-6042175.	-16.81	-14.39	8
-11.56	38784000.	-4484000	-13.07	34300000.	40177775.	-5877775.	-17.14	-14.63	7
-44.46	39059302.	-17365193	-80.05	21694109.	43877390.	-22183281.	-102.25	-50.56	5
3.30	41282280.	1363420	3.20	42645700.	47675025.	-5029325.	-11.79	-10.55	6
-11.46	41364405.	-4739509	-12.94	36624896.	43284564.	-6659668.	-18.18	-15.39	8
-5.69	42082317.	-2392954	-6.03	39689363.	46829664.	-7140301.	-17.99	-15.25	11
-17.02	42370874.	-7211289	-20.51	35159585.	43204873.	-8045289.	-22.88	-18.62	4
-10.58	42370874.	-4483421	-11.83	37887453.	43204873.	-5317420.	-14.03	-12.31	4
-24.00	43088533.	-10342172	-31.58	32746361.	45816045.	-13069684.	-39.91	-28.53	5
-7.13	43635865.	-3110998	-7.68	40524867.	45185818.	-4660951.	-11.50	-10.32	6
-27.72	44253548.	-12269079	-38.36	31984469.	44796686.	-12812217.	-40.06	-28.60	5
-8.73	44399620.	-3875563	-9.56	40524057.	46211434.	-5687378.	-14.03	-12.31	4
-9.31	45500000.	-4234141	-10.26	41265859.	48793513.	-7527654.	-18.24	-15.43	5
-26.93	46369603.	-12488603	-36.86	33881000.	50498970.	-16617970.	-49.05	-32.91	10
-3.26	46486745.	-1514624	-3.37	44972121.	50224912.	-5252791.	-11.68	-10.46	3
-29.22	53500000.	-15631368	-41.28	37868632.	54597000.	-16728368.	-44.17	-30.64	6
18.02	57956000.	10444000	15.27	68400000.	64275590.	4124410.	6.03	6.42	6
-10.33	60742749.	-6275736	-11.52	54467013.	62702913.	-8235900.	-15.12	-13.13	4
-18.16	65984766.	-11984766	-22.19	54000000.	68119308.	-14119308.	-26.15	-20.73	6
-1.11	69964268.	-777270	-1.12	69186998.	73730105.	-4543107.	-6.57	-6.16	7
-15.46	73981982.	-11437538	-18.29	62544444.	82985450.	-20441006.	-32.68	-24.63	7
-12.92	81610000.	-10545263	-14.84	71064737.	89511167.	-18446430.	-25.96	-20.61	4
-18.61	85605000.	-15929257	-22.86	69675743.	87736872.	-18061129.	-25.92	-20.59	6
-5.29	112087001.	-5934912	-5.59	106152089.	118719591.	-12567502.	-11.84	-10.59	7
0.40	119971400.	476135	0.40	120447535.	129596976.	-9149441.	-7.60	-7.06	9
-0.10	133200000.	-137340	-0.10	133062660.	140517887.	-7455227.	-5.60	-5.31	5

% of Designer's Estimate

	MEAN (%)	VARIANCE	S.D. (%)
LOWEST	-5.1499	2.7676E-02	16.6362
MEAN	-12.0362	2.5886E-02	16.0890

% of Low or Mean Bid

	MEAN (%)	VARIANCE	S.D. (%)
LOWEST	-2.4454	2.7191E-02	16.4898
MEAN	-9.5112	1.5895E-02	12.6074

TABLE R.2 Roads Contracts Residuals of (Mean Bid - Designer's Estimate) and (Lowest Bid - Designer's Estimate)

RESIDUAL (% of lowest bid)	LOWEST BID	RESIDUAL	RESIDUAL (% of original estimate)	ORIGINAL ESTIMATE	MEAN BID	RESIDUAL	RESIDUAL (% of original estimate)	RESIDUAL (% of mean bid)	No. of bids
-12.58	381258.	-47953.	-14.39	333305.	387428.	-54123.	-16.24	-13.97	2
46.07	446379.	205666.	31.54	652045.	542468.	109577.	16.81	20.20	3
-18.15	457000.	-82938.	-22.17	374062.	471183.	-97121.	-25.96	-20.61	5
17.22	516834.	89005.	14.69	605839.	562682.	43157.	7.12	7.67	4
-3.16	536223.	-16952.	-3.26	519271.	550714.	-31443.	-6.06	-5.71	3
15.21	539000.	82005.	13.21	621005.	590184.	30821.	4.96	5.22	6
-10.31	546272.	-56294.	-11.49	489978.	551621.	-61643.	-12.58	-11.17	3
-11.02	555000.	-61179.	-12.39	493821.	580343.	-86522.	-17.52	-14.91	5
15.41	566210.	87227.	13.35	653437.	625835.	27602.	4.22	4.41	4
-0.92	586334.	-5388.	-0.93	580946.	649549.	-68603.	-11.81	-10.56	5
19.80	599726.	118764.	16.53	718490.	625300.	93190.	12.97	14.90	4
46.70	617265.	288233.	31.83	905498.	618392.	287107.	31.71	46.43	2
8.83	631103.	55750.	8.12	686853.	662555.	24298.	3.54	3.67	7
28.98	638307.	184971.	22.47	823278.	692042.	131236.	15.94	18.96	5
-25.88	640824.	-165824.	-34.91	475000.	650411.	-175411.	-36.93	-26.97	2
15.36	693483.	106517.	13.31	800000.	773471.	26529.	3.32	3.43	6
15.10	697019.	105271.	13.12	802290.	713485.	88805.	11.07	12.45	4
-0.81	707030.	-5709.	-0.81	701321.	713461.	-12140.	-1.73	-1.70	3
7.15	717181.	51267.	6.67	768448.	743352.	25096.	3.27	3.38	4
-1.47	737463.	-10846.	-1.49	726617.	760832.	-34215.	-4.71	-4.50	3
16.51	739471.	122083.	14.17	861554.	783660.	77894.	9.04	9.94	8
6.58	742120.	48806.	6.17	790926.	791627.	-701.	-0.09	-0.09	5
-21.96	769947.	-169080.	-28.14	600867.	786234.	-185367.	-30.85	-23.58	3
13.26	774679.	102721.	11.71	877400.	826023.	51377.	5.86	6.22	4
4.44	813422.	36081.	4.25	849503.	853029.	-3526.	-0.42	-0.41	7
10.82	831504.	90007.	9.77	921511.	900451.	21060.	2.29	2.34	6
51.98	870095.	452279.	34.20	1322374.	908008.	414366.	31.33	45.63	3
-11.91	878192.	-104580.	-13.52	773612.	918747.	-145135.	-18.76	-15.80	3
7.82	886300.	69269.	7.25	955569.	927620.	27949.	2.92	3.01	6
1.57	899000.	14117.	1.55	913117.	923910.	-10793.	-1.18	-1.17	3
-6.20	900330.	-55832.	-6.61	844498.	952221.	-107723.	-12.76	-11.31	5
-35.09	903800.	-317172.	-54.07	586628.	953913.	-367285.	-62.61	-38.50	2

Residual (% of lowest bid)	Lowest Bid	Residual	Residual (% of original estimate)	Original Estimate	Mean Bid	Residual	Residual (% of original estimate)	Residual (% of mean bid)	No. of bids
-35.09	903800.	-317172.	-54.07	586628.	953913.	-367285.	-62.61	-38.50	2
14.91	903897.	134784.	12.98	1038681.	960810.	77872.	7.50	8.10	6
0.25	929520.	2311.	0.25	931831.	996896.	-65065.	-6.98	-6.53	6
23.03	976359.	224853.	18.72	1201212.	1111207.	90004.	7.49	8.10	4
-8.98	1024098.	-91949.	-9.86	932149.	1149782.	-217633.	-23.35	-18.93	3
8.94	1053388.	94184.	8.21	1147572.	1102606.	44966.	3.92	4.08	4
-6.84	1072015.	-73315.	-7.34	998700.	1077550.	-78850.	-7.90	-7.32	2
-10.60	1076000.	-114048.	-11.86	961952.	1153257.	-191305.	-19.89	-16.59	5
-8.64	1098470.	-94950.	-9.46	1003520.	1124235.	-120715.	-12.03	-10.74	2
5.14	1116125.	57356.	4.89	1173481.	1290226.	-116745.	-9.95	-9.05	6
-28.12	1120000.	-314950.	-39.12	805050.	1186000.	-380950.	-47.32	-32.12	5
-28.44	1125000.	-319950.	-39.74	805050.	1211272.	-406222.	-50.46	-33.54	5
12.01	1196266.	143645.	10.72	1339911.	1265325.	74586.	5.57	5.89	8
30.89	1197216.	369793	23.60	1567009.	1310883.	256126.	16.34	19.54	5
-2.49	1209352.	-30148.	-2.56	1179204.	1284075.	-104871.	-8.89	-8.17	4
146.23	1250464.	1828536.	59.39	3079000.	1366658.	1712342.	55.61	125.29	6
55.09	1274439.	702142.	35.52	1976581.	2095610.	-119029.	-6.02	-5.68	4
6.12	1351210.	82633.	5.76	1433843.	1386747.	47096.	3.28	3.40	3
-5.29	1356240.	-71776.	-5.59	1284464.	1382476.	-98012.	-7.63	-7.09	4
5.84	1500717.	87615.	5.52	1588332.	1606176.	-17844.	-1.12	-1.11	8
9.61	1520000.	146000.	8.76	1666000.	1603803.	62197.	3.73	3.88	3
-2.81	1525083.	-42858.	-2.89	1482225.	1542630.	-60405.	-4.08	-3.92	2
3.74	1542300.	57700.	3.61	1600000.	1709505.	-109505.	-6.84	-6.41	5
-9.92	1590000.	-157681.	-11.01	1432319.	1617817.	-185498.	-12.95	-11.47	3
-11.43	1675000.	-191445.	-12.90	1483555.	1733278.	-249723.	-16.83	-14.41	5
-2.78	1692960.	-47110.	-2.86	1645850.	1782627.	-136777.	-8.31	-7.67	4
-20.29	1763000.	-357720.	-25.46	1405280.	1794107.	-388827.	-27.67	-21.67	3
0.34	1771000.	6019.	0.34	1777019.	1824532.	-47513.	-2.67	-2.60	4
17.05	1789200.	305050.	14.57	2094250.	1880850.	213400.	10.19	11.35	5
-23.69	1796000.	-425517.	-31.05	1370483.	1864275.	-493792.	-36.03	-26.49	3
3.15	1825720.	57508.	3.05	1883228.	1974066.	-90838.	-4.82	-4.60	8

Residual (% of lowest bid)	Lowest Bid	Residual	Residual (% of original estimate)	Original Estimate	Mean Bid	Residual	Residual (% of original estimate)	Residual (% of mean bid)	No. of bids
18.99	1828751.	347330.	15.96	2176081.	1989316.	186765.	8.58	9.39	6
28.97	1847910.	535390.	22.46	2383300.	2118511.	264789.	11.11	12.50	8
-8.56	1862660.	-159421.	-0.36	1703239.	1892353.	-189114.	-11.10	-9.99	3
-3.83	1916565.	-73340.	-3.98	1843225.	2302494.	-459269.	-24.92	-19.95	3
63.30	1944662.	1230933.	38.76	3175595.	2171355.	1004240.	31.62	46.25	5
-2.67	1993224.	-53289.	-2.75	1939935.	2086260.	-146325.	-7.54	-7.01	5
13.35	2023000.	270005.	11.78	2293005.	2323639.	-30634.	-1.34	-1.32	4
10.46	2030678.	212422.	6.47	2243100.	2119080.	124020.	5.53	5.85	4
1.50	2110600.	31700.	1.48	2142300.	2263268.	-120968.	-5.65	-5.34	6
-10.11	2112780.	-213530.	-11.24	1899250.	2152260.	-253010.	-13.32	-11.76	3
14.55	2120000.	308442.	12.70	2428442.	2284323.	144119.	5.93	6.31	7
0.93	2150875.	19999.	0.92	2170874.	2294198.	-123324.	-5.68	-5.38	4
3.01	2272479.	68374.	2.92	2340853.	2592900.	-252047.	-10.77	-9.72	4
-23.58	2329806.	-549451.	-30.86	1780355.	2344044.	-563689.	-31.66	-24.05	3
0.88	2330000.	20595.	0.88	2350595.	2565732.	-215137.	-9.15	-8.39	7
0.42	2396731.	10089.	0.42	2406820.	2441379.	-32559.	-1.35	-1.33	3
4.16	2420000.	100579.	3.99	2520579.	2587032.	-66453.	-2.64	-2.57	6
-17.80	2494000.	-444000.	-21.66	2050000.	2498113.	-448113.	-21.86	-17.94	2
11.19	2494580.	279202.	10.07	2773782.	3069244.	-295462.	-10.65	-9.63	5
4.64	2581453.	119860.	4.44	2701313.	2735734.	-34421.	-1.27	-1.26	7
-2.89	2670000.	-77158.	-2.98	2592842.	2894587.	-301745.	-11.64	-10.42	4
-0.15	2697000.	-4000.	-0.15	2693000.	2773796.	-80796.	-3.00	-2.91	5
-14.08	2704000.	-380648.	-16.38	2323352.	2842831.	-519479.	-22.36	-18.27	4
2.05	2732000.	56098.	2.01	2788098.	2767020.	21078.	0.76	0.76	6
-15.76	2749882.	-433393.	-18.71	2316489.	2828194.	-511705.	-22.09	-18.09	5
-31.15	2770500.	-863013.	-45.24	1907487.	2917038.	-1009551.	-52.93	-34.61	6
5.24	2789901.	146206.	4.98	2936107.	2877389.	58718.	2.00	2.04	5
24.38	2804373.	683679.	19.60	3488052.	3045262.	442790.	12.69	14.54	5

Residual (% of lowest bid)	Lowest Bid	Residual	Residual (% of original estimate)	Original Estimate	Mean Bid	Residual	Residual (% of original estimate)	Residual (% of mean bid)	No. of Bids
5.32	2830000.	150481.	5.05	2980481.	3029297.	-48816.	-1.64	-1.61	8
-5.55	2872887.	-159443.	-5.88	2713444.	2913835.	-200391.	-7.39	-6.88	6
3.98	2933769.	116854.	3.83	3050623.	3286684.	-236061.	-7.74	-7.18	7
0.87	2943950.	25500.	0.86	2969450.	2967700.	1750.	0.06	0.06	2
-2.39	2968700.	-71086.	-2.45	2897614.	3071958.	-174344.	-6.02	-5.68	5
-3.70	3000000.	-111000.	-3.84	2889000.	3160227.	-271227.	-9.39	-8.58	8
83.40	3057142.	2549697.	45.47	5606839.	3825024.	1781815.	31.78	46.58	6
-2.02	3086051.	-62468.	-2.07	3023583.	3368191.	-344608.	-11.40	-10.23	5
-14.70	3093533.	-454796.	-17.24	2638737.	3177287.	-538550.	-20.41	-16.95	4
-30.05	3109560.	-934565.	-42.97	2174995.	3116967.	-941973.	-43.31	-30.22	2
12.90	3113576.	401642.	11.43	3515218.	3435412.	79806.	2.27	2.32	4
3.17	3122456.	98929.	3.07	3221385.	3267659.	-46274.	-1.44	-1.42	4
-27.16	3180250.	-863761.	-37.29	2316489.	3491355.	-1174866.	-50.72	-33.65	4
4.67	3188290.	148863.	4.46	3337153.	3289112.	48041.	1.44	1.46	8
5.18	3204408.	166136.	4.93	3370544.	3405112.	-34568.	-1.03	-1.02	6
7.50	3245156.	243337.	6.98	3488493.	3465323.	23170.	0.66	0.67	6
34.37	3256790.	1119510.	25.58	4376300.	3499370.	876930.	20.04	25.06	4
18.45	3275000.	604103.	15.57	3879103.	3388523.	490580.	12.65	14.48	7
-7.94	3298000.	-262000.	-8.63	3036000.	4426000.	-1390000.	-45.78	-31.41	4
30.33	3320988.	1007400.	23.27	4328388.	3724236.	604152.	13.96	16.22	9
-10.36	3417808.	-353918.	-11.55	3063890.	3502944.	-439054.	-14.33	-12.53	4
43.34	3450800.	1495489.	30.23	4946289.	3761000.	1185288.	23.96	31.52	8
-18.61	3484666.	-648612.	-22.87	2836054.	3742730.	-906676.	-31.97	-24.22	4
-11.99	3524920.	-422694.	-13.63	3102226.	3797757.	-695531.	-22.42	-18.31	3
18.82	3770928.	709661.	15.84	4480589.	4139866.	340723.	7.60	8.23	5
7.39	3850000.	284416.	6.88	4134416.	4074255.	60161.	1.46	1.48	4
5.94	3892575.	231251.	5.61	4123826.	4181634.	-57808.	-1.40	-1.38	6
-5.25	3940012.	-206853.	-5.54	3733159.	4482926.	-749767.	-20.08	-16.72	3
-11.12	3989600.	-443765.	-12.52	3545835.	4267124.	-721289.	-20.34	-16.90	7
-8.74	4101275.	-358385.	-9.58	3742890.	4301349.	-558460.	-14.92	-12.98	8
10.40	4122461.	428538.	9.42	4550999.	5147359.	-596360.	-13.10	-11.59	4
-35.87	4333230.	-1554319.	-55.93	2778911.	4427610.	-1648699.	-59.33	-37.24	3
17.59	4352000.	765469.	14.96	5117469.	4985384.	132085.	2.58	2.65	7
19.50	4387414.	855586.	16.32	5243000.	4650978.	592022.	11.29	12.73	11

Residual (% of lowest bid)	Lowest Bid	Residual	Residual (% of original estimate)	Original Estimate	Mean Bid	Residual	Residual (% of original estimate)	Residual (% of mean bid)	No. of bids
4.67	4647200.	217092.	4.46	4864292.	5042199.	-177907.	-3.66	-3.53	5
9.93	4663827.	463071.	9.03	5126898.	4820455.	306443.	5.98	6.36	9
19.10	4710300.	899562.	16.04	5609862.	5052365.	557497.	9.94	11.03	6
-7.28	4799358.	-349428.	-7.85	4449930.	4911542.	-461612.	-10.37	-9.40	2
12.15	4829995.	586752.	10.83	5416747.	5054442.	362305.	6.69	7.17	4
-1.31	4911672.	-64572.	-1.33	4847100.	5188273.	-341173.	-7.04	-6.58	4
-43.10	4949562.	-2133233.	-75.75	2816329.	5132943.	-2316614.	-82.26	-45.13	3
0.41	4984074.	20231.	0.40	5004305.	5484463.	-480158.	-9.59	-8.75	6
10.56	5202000.	549500.	9.55	5751500.	5394689.	356811.	6.20	6.61	5
10.56	5202000.	549500.	9.55	5751500.	5394689.	356811.	6.20	6.61	5
2.71	5246890.	141938.	2.63	5388828.	5595471.	-206643.	-3.83	-3.69	6
-17.11	5281000.	-903681.	-20.64	4377319.	5754768.	-1377449.	-31.47	-23.94	9
-15.89	5371000.	-853476.	-18.89	4517524.	5701649.	-1184125.	-26.21	-20.77	5
14.07	5418060.	762528.	12.34	6180588.	5713117.	467471.	7.56	8.18	6
-22.80	5670007.	-1292688.	-29.53	4377319.	5808801.	-1431482.	-32.70	-24.64	4
20.91	5676000.	1186794.	17.29	6862794.	6096465.	766329.	11.17	12.57	4
32.43	5863000.	1901657.	24.49	7764657.	6784527.	980130.	12.62	14.45	5
30.08	6227909.	1873099.	23.12	8101008.	7211954.	889054.	10.97	12.33	8
15.88	6579198.	1044825.	13.70	7624023.	7039531.	584492.	7.67	8.30	10
-20.97	6659439.	-1396431.	-26.53	5263008.	6854719.	-1591711.	-30.24	-23.22	2
-30.89	6717455.	-2075095.	-44.70	4642360.	6841327.	-2198967.	-47.37	-32.14	3
-10.46	6768032.	-708230.	-11.69	6059802.	7084789.	-1024987.	-16.91	-14.47	5
-8.58	8138710.	-697919.	-9.38	7440791.	8335397.	-894607.	-12.02	-10.73	4
-16.59	8279699.	-1373563.	-19.89	6906136.	8572715.	-1666579.	-24.13	-19.44	6
-39.35	8620849.	-3392673.	-64.89	5228176.	8890424.	-3662248.	-70.05	-41.19	2
-19.03	8800647.	-1674647.	-23.50	7126000.	9455225.	-2329225.	-32.69	-24.63	8
-18.96	9904000.	-1878225.	-23.40	8025775.	10926783.	-2901008.	-36.15	-26.55	5
-20.54	9980000.	-2050331.	-25.86	7929669.	10046500.	-2116831.	-26.70	-21.07	2
8.70	10236156.	890158.	8.00	11126314.	10860816.	265498.	2.39	2.44	4
-5.94	10756000.	-638993.	-6.32	10117007.	11022050.	-905043.	-8.95	-8.21	3
-7.82	11315000.	-885000.	-8.49	10430000.	11809535.	-1379535.	-13.23	-11.68	7
2.03	13317349.	270515.	1.99	13587864.	13745104.	-157240.	-1.16	-1.14	7
-1.00	14362118.	-143544.	-1.01	14218574.	15080259.	-861685.	-6.06	-5.71	10
-0.78	16800000.	-131438.	-0.79	16668562.	18098129.	-1429568.	-8.58	-7.90	12
-3.58	16892600.	-604162.	-3.71	16288438.	17774024.	-1485586.	-9.12	-8.36	8
-8.27	16920000.	-1399227.	-9.02	15520773.	20513502.	-4992729.	-32.17	-24.34	7

Residual (% of lowest bid)	Lowest Bid	Residual	Residual (% of original estimate)	Original Estimate	Mean Bid	Residual	Residual (% of original Estimate)	Residual (% of mean bid)	No. of Bids
-13.05	18054280.	-2356371.	-15.01	15697909.	19707808.	-4009899.	-25.54	-20.35	12
16.07	21675517.	3483540.	13.85	25159066.	23689701.	1469365.	5.84	6.20	4
-1.96	23448000.	-460725.	-2.00	22987275.	24056437.	-1069162.	-4.65	-4.44	13
14.31	27750000.	3972208.	12.52	31722208.	29815934.	1906274.	6.01	6.39	14
-13.64	31388822.	-4282474.	-15.80	27106348.	35186441.	-8080093.	-29.81	-22.96	7
19.25	43785000.	8429370.	16.14	52214370.	51605596.	608774.	1.17	1.18	10
-0.51	48453775.	-248848.	-0.52	48204927.	49878272.	-1673345.	-3.47	-3.35	10

% of Designer's Estimate

	MEAN (%)	VARIANCE	S.D. (%)
LOWEST	-1.4488	4.0586E-02	20.1459
MEAN	-8.1085	4.0153E-02	20.0383

% of Low or Mean Bid

	MEAN (%)	VARIANCE	S.D. (%)
LOWEST	2.5037	4.9293E-02	22.2021
MEAN	-4.3578	3.6038E-02	18.9837

APPENDIX S

Extract from

"Some Examples of using Regression Analysis as
an Estimating Tool

by

R. McCaffer

Originally published December 1975
The Quantity Surveyor, Vol.32, No.5

Referred to in Section 6.4

The extract deals with the description of regression analysis as a cost modelling tool

Estimating based on statistical methods has the appeal of condensing historical records into a useable form. One of these statistical methods is multiple Linear Regression Analysis and an example of its use was described in the January/February 1974 edition of "The Quantity Surveyor" by G.A. Hughes. Regression Analysis as a cost modelling tool is a technique which enables the cost of project to be expressed in very few items. For example the cost model of say residential apartment blocks may be

Cost (at model's base date)

= 36001.75 + (169.84 x Area of Single Units)
+ (137.38 x Area of Double Units)
+ (2553.8 x No. of Storeys)
+ (3049.53 x No. of Lifts x No. of Storeys)
+ (139.85 x Total Access Area)
+ (395.88 x Common Room Areas)
+ (13335.43 x No. of Garages)

and if the model variables had the following values in one particular case

Area of single units	=	1044
Area of double units	=	281
No. of Storeys	=	3
No. of Lifts	=	1
Total Access Area	=	550
Common Room Areas	=	87
No. of Garages	=	1

the estimator could quickly show that cost (at model's base date)

= 36001.75 + (169.84 x 1044)
+ (137.38 x 281)
+ (2553.8 x 3)
+ (3049.53 x 1 x 3)
+ (139.85 x 550)

+ (395.88 x 87)

+ (13335.43 x 1)

= £393,422.97

(Note: The above formula is only applicable for the same type of buildings used in the analysis and should not be applied to other types of buildings. For further information contact the author.)

The technique also enables the estimator to say how accurate the estimate is, in numerical rather than subjective terms. If his assessed accuracy was ± 9% this would imply that for most cases the cost is expected to be within £358,014 to £428,831.

Obviously it is much quicker to calculate likely costs in this way rather than by approximate design, approximate quantities and approximate rates. In several cases we have found these cost prediction models were significantly more accurate than designers' early estimates. Thus in appropriate cases cost models based on regression analysis can provide a substantial improvement on existing methods of estimating.

All this doesn't come about by accident, it is necessary to assemble data relating to past projects and to do some fairly extensive analytical work to produce the cost prediction models. In practice it is valuable to update the models periodically by including recent data and discarding the oldest data. There seems a good case for assembling the relevant data centrally and providing the models for estimating purposes to subscribing members.

This paper briefly describes, in non-statistical terms, multiple regression analysis as it is used as a cost modelling technique. The results of some studies done within the Department of Civil Engineering at Loughborough University of Technology are given. Most of the examples are aimed at the estimating as done by the construction industry's professional advisors and not, with one exception, by contractors.

Regression Analysis - The Technique

Regression Analysis is a technique that will find an expression or formula or mathematical model which best describes the data collected. For example, if you were attempting to predict the cost of say residential apartment schemes the data that might be available to you from past schemes may be -

(1) The cost of the scheme

(2) The total area of the single units

(3) The total area of the double units

(4) The number of storeys

(5) The number of lifts

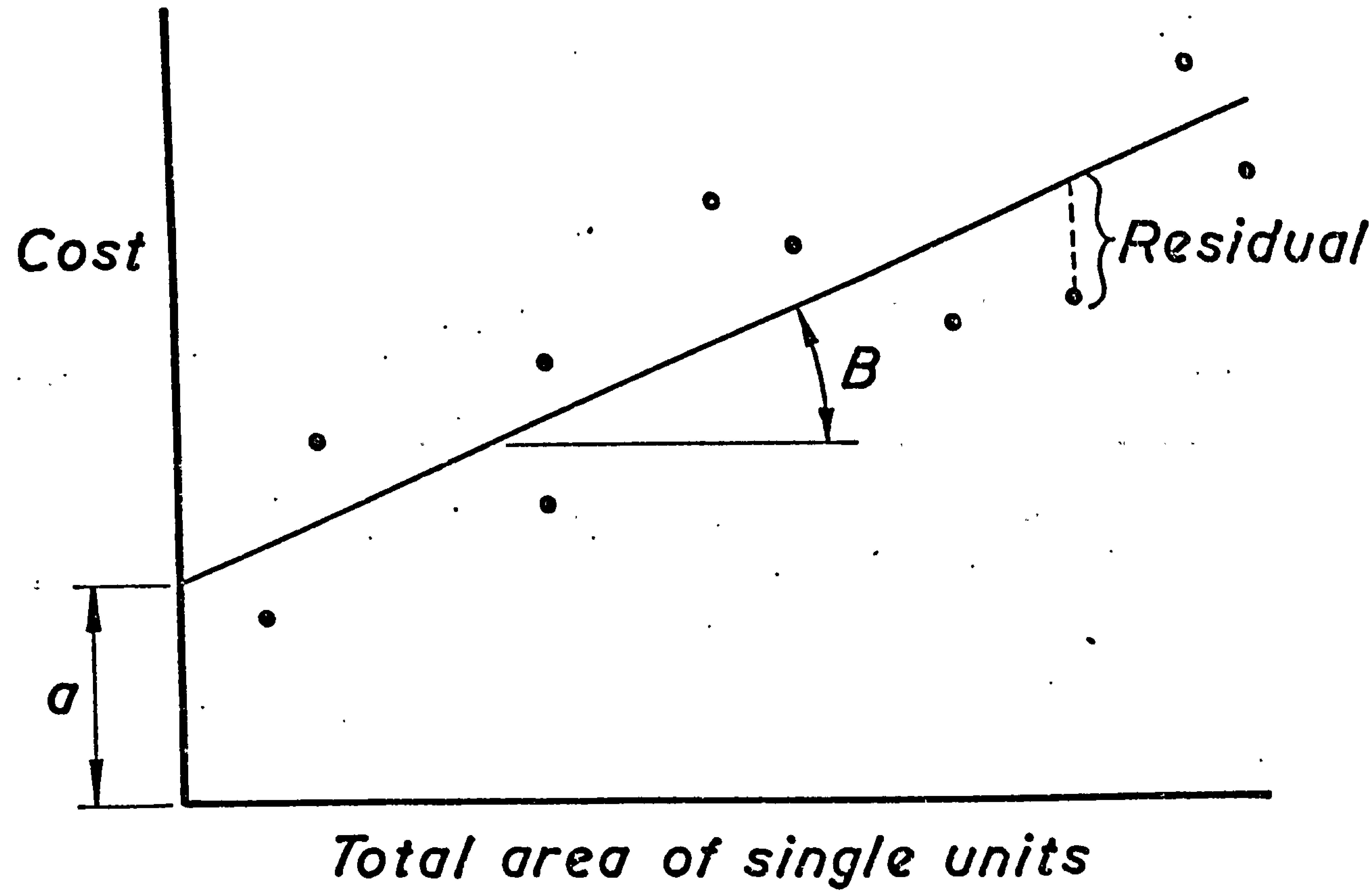
(6) The total area of common rooms

(7) The total area of corridors and access space

etc... etc...

The list given is indicative of the data that could be obtained from drawings and contract documents. To undertake a regression modelling or cost modelling exercise data of this type would be required for a number of such schemes. The exact number required will be discussed later.

The first stage in finding a 'cost model' which best describes the data collected would be to find the one variable or item of data that explains most of the variation in costs between the different schemes. This is likely to be the variable that has the highest correlation with cost. For example figure S.1 shows cost plotted against one variable.



A simple regression model

Cost = a + B (Total area of single units)

Figure S.1

By finding a straight line which 'best fits' this plotted data we have a 'simple regression model'.

This cost model is

COST = a + B (total area of single units)

where 'a' is the intercept on the vertical axis and 'B' is the slope of the line in relation to the horizontal axis.

For example, the cost in pounds may turn out to be 325 + 7 × total area of single units in sq. metres.

How well this 'model' fits the data can be determined by examining the residuals. That is the difference between the cost predicted by the model (i.e. a point on the line) and the actual cost recorded in the data (one of the plotted points). Examining the residuals is in effect examining the model's accuracy. The greater the residuals the less accurate is the model.

The second stage in finding the best model is to determine the second variable that explains most of the variation in costs after taking account of the first variable. For example, figure S.2 shows cost plotted against variable (1) the total area of single units as in figure S.1 on one axis and against variable (4) the number of storeys on a second axis. The data points being plotted are no longer on a sheet of paper but in space and a sloping plane now fits the data not a single straight line.

When the best fitting plane is found we have a 'multiple linear regression model'.

The cost model is

$$\text{COST} = a + B_1 \text{ (total area of the single units)} + B_2 \text{ (no. of storeys)}$$

where 'a' is the intercept on the cost axis, B_1 is the slope of the plane in relation to axis 1 and B_2 is the slope of the plane in relation to axis 2. It should be noted that 'a' and 'B_1' will not be the same as 'a' and 'B' from the simple model. Again the accuracy of the model is judged by the residuals and the scatter of these residuals about the determined model.

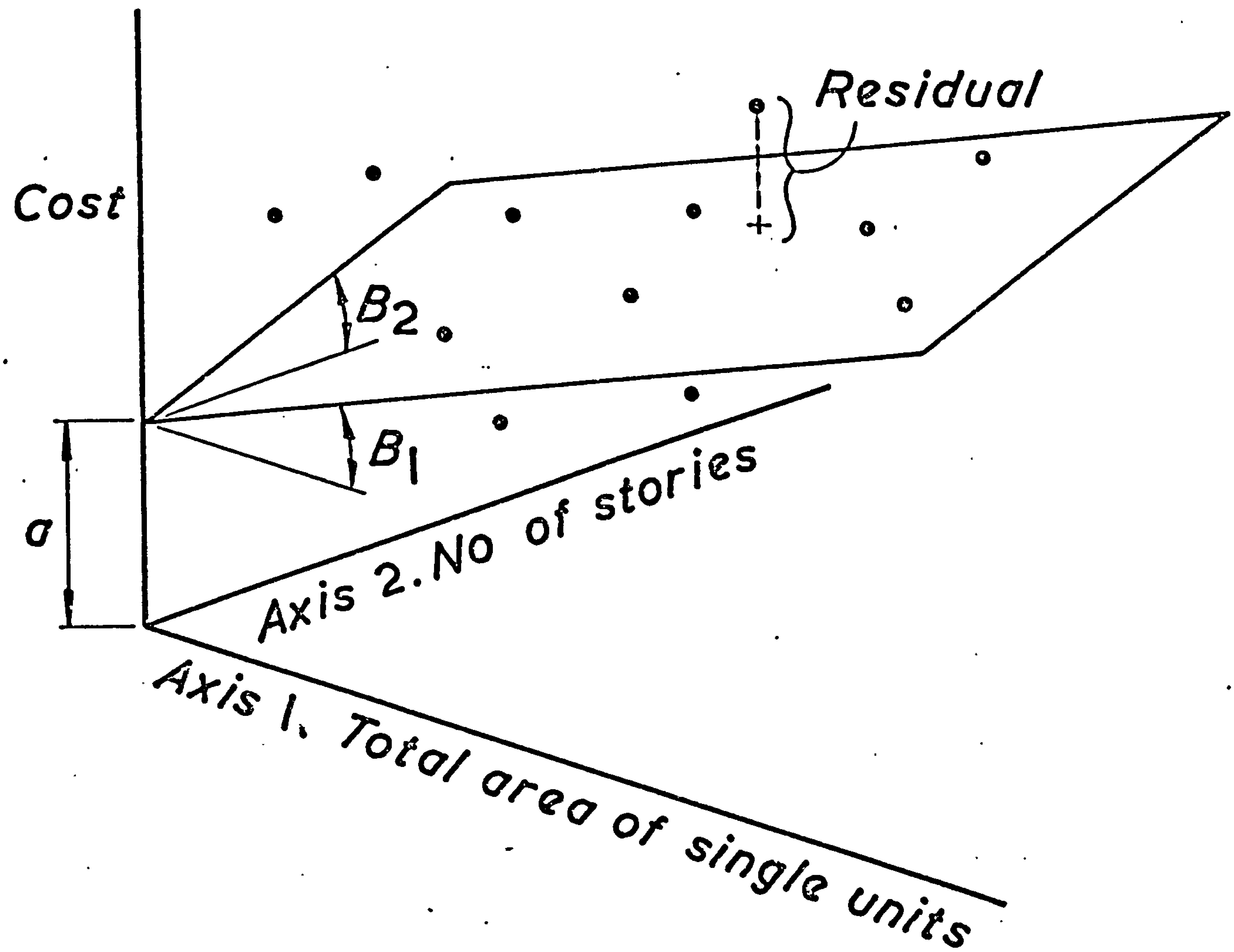
The process can be extended to include the third most significant variable and the cost model could become

$$\text{COST} = a + B_1 \text{ (Total area of single units)} + B_2 \text{ (No. of storeys)} + B_3 \text{ (Total area of corridors and access space)}$$

However, it is impossible to present this graphically.

The model need not contain only three variables but can be extended to include any number of variables until the best model possible is found, that is until the residuals are made as small as possible. However the more variables included in the model the greater is the amount of data required to construct the model. A very rough guide is that the minimum number of past schemes required for model building is two to three times the number of variable included in the final model.

Although the technique is based on items of data which are assumed to vary linearly with cost this can be overcome by transforming the data before fitting a model. For example if the cost of a particular item falls off with increasing quantity, see figure S.3, the quantity item could be transformed by raising to a power, see figure S.4.



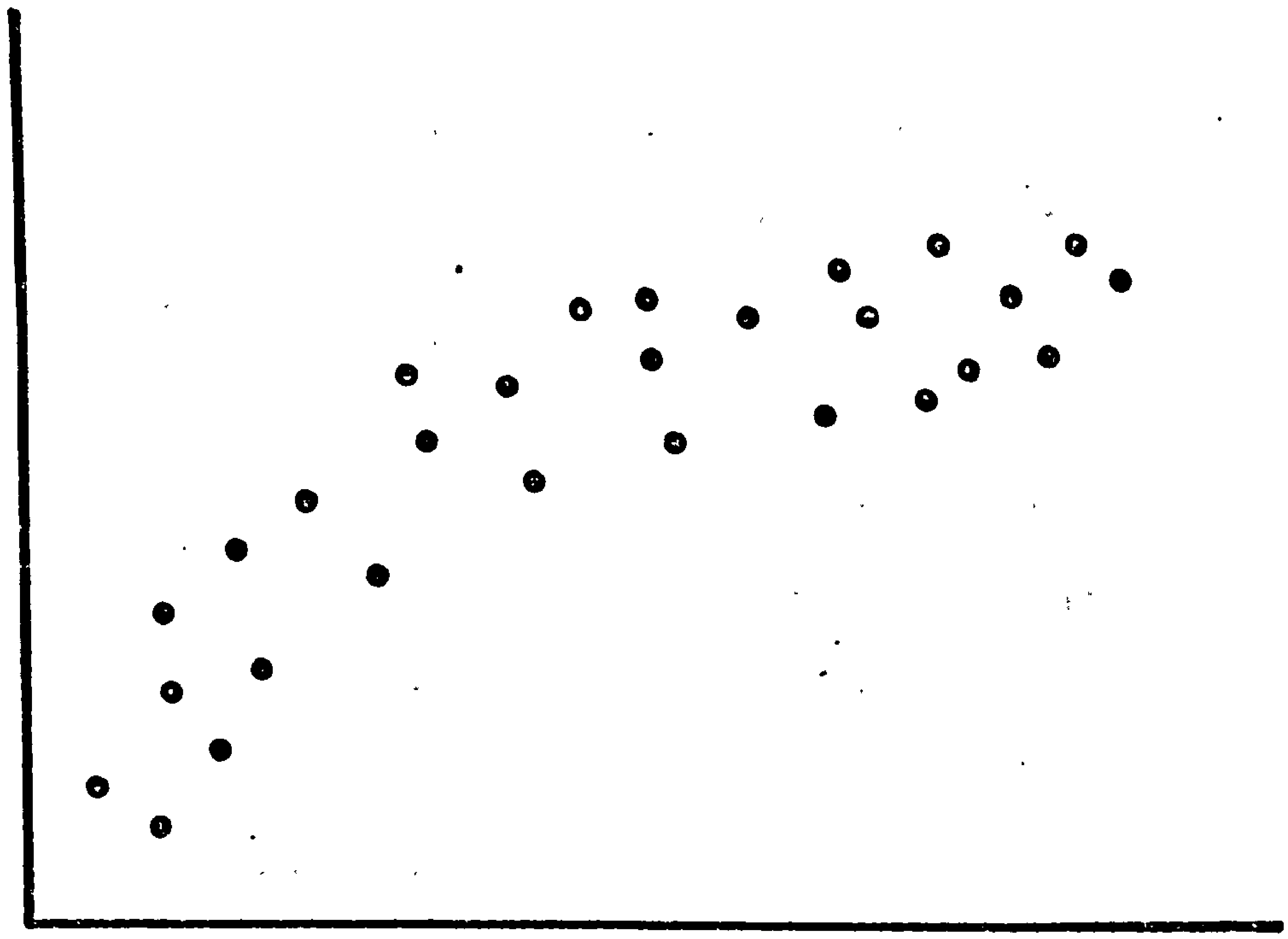
Multiple regression model

Cost = a + B1 (Total area of single units) + B2 (No of stories)

Figure S.2

Cost

Figure S.3

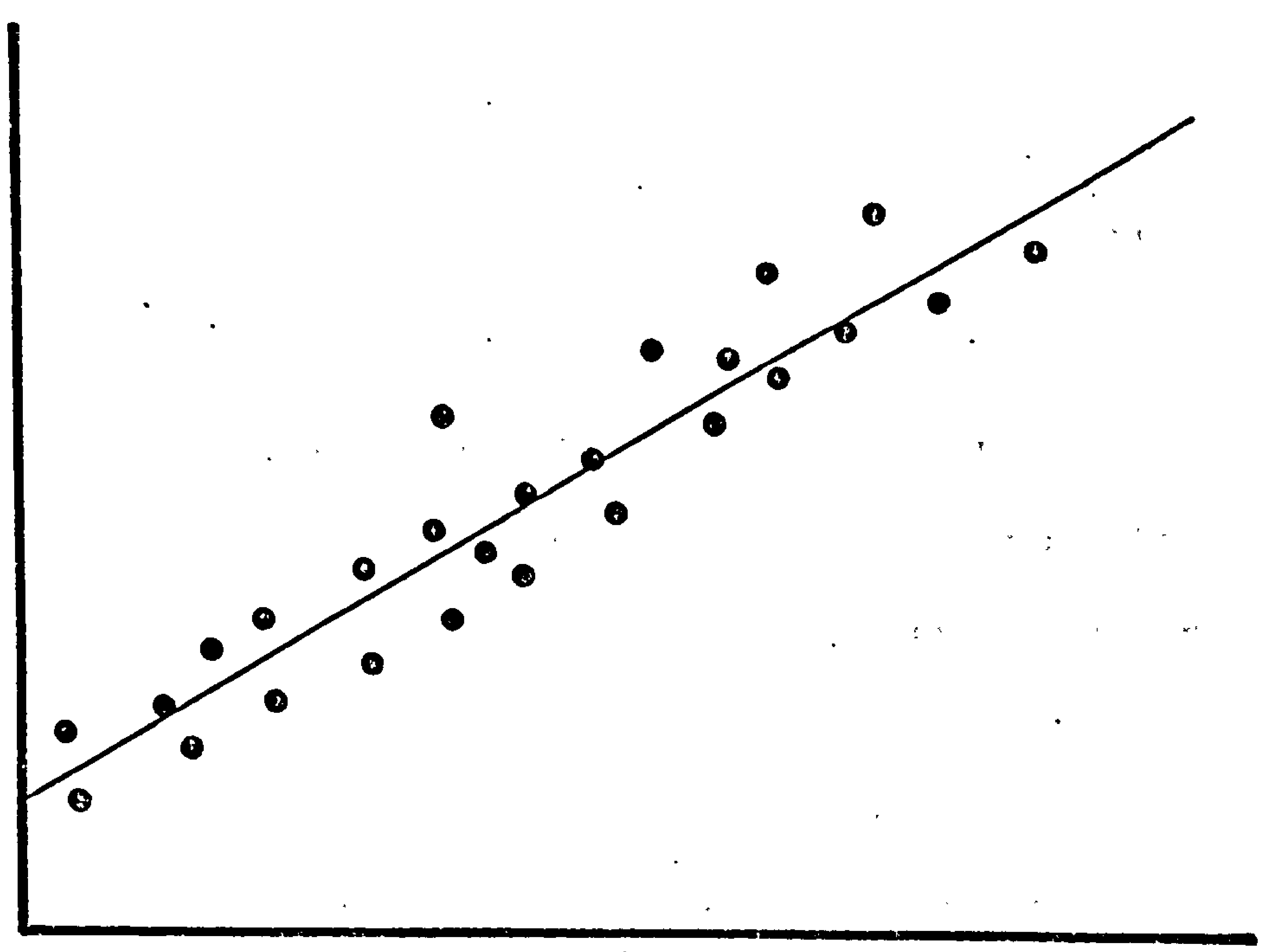


Quantity

In this case cost does not vary linearly with quantity.

Cost

Figure S.4



$(\text{Quantity})^{\alpha}$

By transforming quantity to $(\text{quantity})^{\alpha}$ *a linear relationship with cost could be obtained.*

Transformations of data are also used to re-arrange the collected data. For example if you had cost as one variable and floor area as another this could be transformed into cost/unit area.

The Model's Accuracy

The accuracy of the model is judged by the scatter of the residuals, the difference between the model's predicted cost and the actual cost. The scatter of these residuals can be examined in two ways, one is to plot them as in figures 6.4 to 6.9, the other way is to calculate the "coefficient of variation". The scatter of the residuals can be determined by calculating the standard deviation of the residuals, this expressed as a percentage of the mean cost of all schemes gives the coefficient of variation

$$\text{coefficient of variation} = \frac{\text{standard deviation of residuals}}{\text{mean cost of all schemes}} \times 100$$

This coefficient, say 12%, gives the band into which most cases, say 65%, would fall, i.e. + or - 12%. Therefore a model with as small a coefficient of variation as possible is desired.

The residuals plotted or the coefficient of variation describe the accuracy of the model as it fits the data used to determine the model. The real test is how accurately does the model predict cases that are not included in its own data base. Experience indicates the coefficient of variation (c.v.) will increase by 25% to 50% when the derived model is applied to data outwith its own data base, that is a model with a c.v. of 10% will deteriorate to 15% - 20% when used on other cases of similar type.

The Model's Meaning

The model derived may be of the form

$$\begin{aligned} COST = a &+ B_1 \text{ (total area of single units)} \\ &+ B_2 \text{ (total area of double units)} \\ &+ B_3 \text{ (total area of triple units)} \\ &+ B_4 \text{ (No. of storeys)} \\ &- B_5 \text{ (total area of circulation space)} \\ &\text{etc.} \end{aligned}$$

This model as a whole predicts costs within its accuracy limits. It cannot be used other than as a whole and observing the negative sign on B_5 say if we increase circulation space the cost will decrease. Because by increasing the circulation space will change other variables and so alter the model's prediction. Each variable in the model is explaining some of the variability in cost, if one or more variables share too much of this explanation they will be compensated by a negative variable in the model. Therefore the model can only be taken as a whole.

Building a Model

To construct a regression model access to the appropriate data is obviously needed.

The steps described above are only practicable using computers. There are several computer packages available that permit the user, say a quantity surveyor, to present his data, in a prescribed manner to the computer package and all the calculations are done automatically. The inexperienced user of the technique must at this stage seek the advice of either an experienced user or of a statistician before drawing conclusions.

At Loughborough the computer package used is 'Nimbus'[50] supported with programs for storing data and selecting difference combinations of variables which were developed within the Department of Civil Engineering. Having developed our own computer systems (51) regression analysis and cost model building have been reduced to a routine exercise given access to data.

For a full statistical explanation of regression analysis Draper and Smith[48] is recommended and for further background "Regression Analysis - New Uses for an Old Technique" by Trimble[52] is recommended.

APPENDIX T

Tender Price Simulation System

Reference and User Manual

Referred to in section 7.0

This Tender Price Simulation System, Reference and User Manual was prepared as a separate document in September 1975.

The contribution of G. Petofalvi, M.Sc. Course student 1975[60] was the compilation of the inflation indices and the development of the TRENDS program as described in sections 5.2 and 5.3 of this appendix.

This appendix is numbered separately from the main document.

TENDER PRICE SIMULATION SYSTEM.

REFERENCE AND USER MANUAL

CONTENTS

1.0. OVERALL SYSTEM DESCRIPTION

The system is designed to access a library of individual unit prices, update selected prices using inflation indices, statistically analyse the price distribution of each item selected and simulate a tender price (the sum of many individual items), producing predictions of the mean tender price and its likely standard deviation.

The system comprises:

i) A library of individual items or unit prices collected from past contract documents. The prices are drawn from both the successful and unsuccessful bidders. The library is capable of being updated by adding recent prices and removing old prices.

ii) A list of monthly inflation indices derived from published prices for labour, plant and major materials. The latest indices can be added to the existing list.

iii) A program called "TRENDS" which by curve fitting and extrapolating will predict the inflation indices for one, two or three months ahead. This is required because the latest index information is always at least one month old and price predictions are required about one month ahead leaving the indices two months out of date. This program is run separately.

iv) A program called "STAT" which

- selects from the library prices belonging to a specified item.

- uses the inflation indices to update the prices from the date the price was entered in the library to the date of the prediction.

- analyses the prices of the specified items to produce the statistics required for simulation. These statistics are either mean and standard deviation of a normal distribution or mean and standard deviation of a lognormal distribution, or a regression model of the form, unit price = A + B x Quantity, and the standard deviation of the residuals.

The STAT program stores this information on a temporary file for the simulation program. The temporary file will contain data on the 100 or so items which collectively will form a project.

v) The program called "SIMULATION" accepts input from cards or from the temporary file created by "STAT". In addition to the methods of describing price variability created by STAT, namely, normal and lognormal distributions and regression models, the card input also offers a triangular distribution specified by the mode, the largest and smallest unit price recorded.

The SIMULATION program calculates and prints the mean tender price, based on the mean of each item and outputs the contribution to the tender price of each item, ranked in descending order.

The project is simulated "n", times by randomly selecting unit prices from the distribution of possible unit prices and calculating the total tender price. The output is a list of "n", projects with the total contribution of each item, the total tender price and the mean and standard deviation of the "n" calculated tender prices.

vi) The General Purpose Data Deck is the card deck required to run the system.

2.0. BRIEF DESCRIPTION OF SYSTEM INPUT.

This section describes in general terms the decision required from the user. Section 4.0. describes the input in detail.

The decisions or information required from the user to simulate a contract are:

i) Is the unit price variability data for all items being supplied from the price library via the statistics program "STAT" or from cards? If the price library option is chosen, the data can still be supplied from cards for individual items.

ii) The output is required ranging from a full listing of input and output to a very short listing of main information with some intermediate alternatives.

iii) The contract date.

iv) The number of simulation runs.

v) A starting value for the random number generator. This allows sequences of "random numbers" to be repeated if required.

vi) The position of the price library on the price library tape.*

* Hainault is in positions 1, 2 & 3, Liege in 4, 5 & 6; Etat is in positions 1 & 4, Cités in 2 & 5 and Communes in 3 & 5.

vii) The project name.

viii) The predicted value at the date of the contract of the six inflation indices.

ix) One card for each item in the contract giving the item reference number, the distribution being used to describe the variability of the price of the item, whether the price variability data is being supplied by cards or from the price library via the statistics program, the quantity of the item, data relating to price variability if being supplied from card.

x) The percentage breakdown of items into labour, plant and materials.

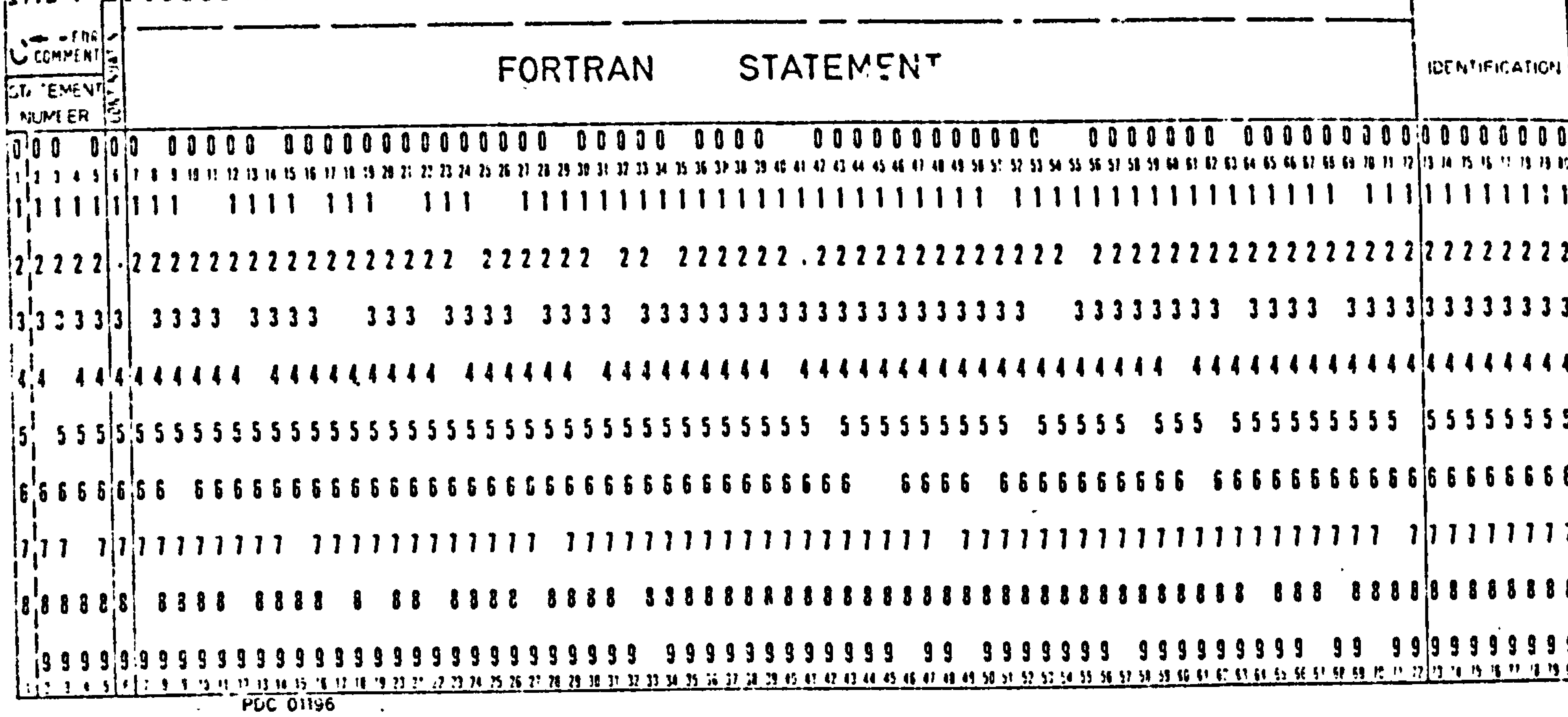
xi) A terminator.

3.0 THE SYSTEM OUTPUT

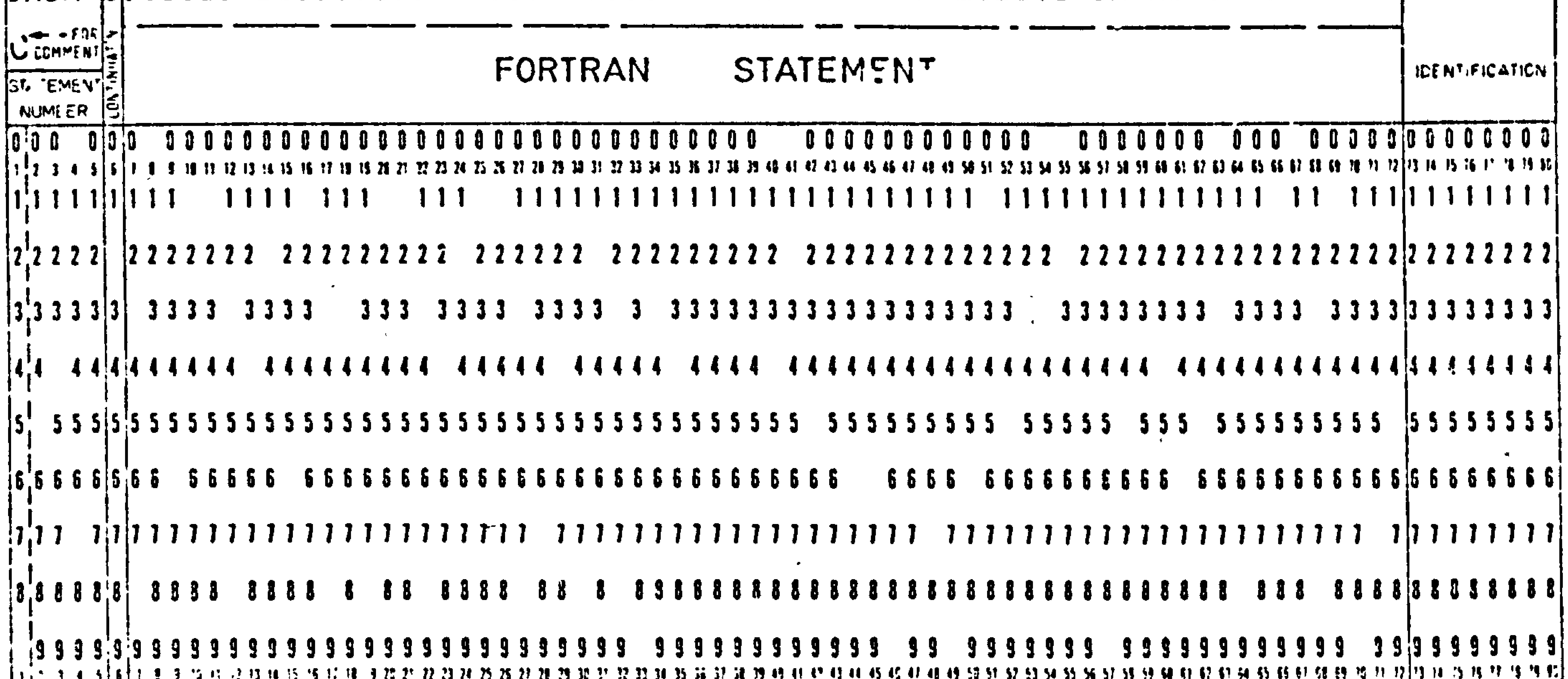
This section gives examples of the output.

OUTPUT OF 'TRENDS'

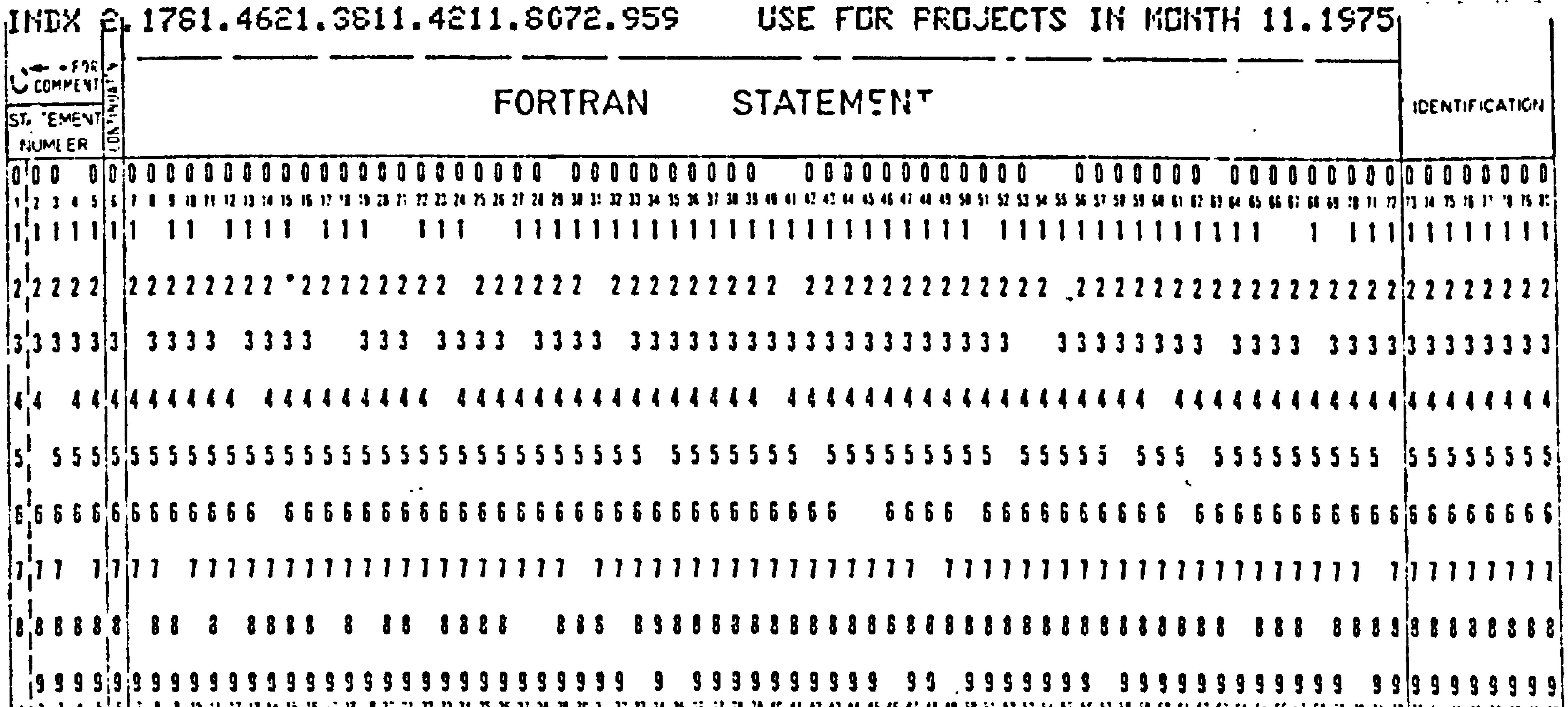
INDX 2.0611.4071.3811.4211.7042.920 USE FOR PROJECTS IN MONTH 9.1975



INDX 2.0611.4261.3811.4211.7462.934 USE FOR PROJECTS IN MONTH 10.1975



INDX 2.1781.4621.3811.4211.8072.959 USE FOR PROJECTS IN MONTH 11.1975



PROJ	03 07 75	50	123	4	
NAME	MODERNISATION DE ROUTES DIVERSES DANS LA TRAVERSE DE VISE.				
ITEM	241159	NORM SYST	925.00	97.38	32.11
ITEM	241159	NORM SYST	650.00	97.38	32.11
ITEM	221159	NORM SYST	2750.00	52.15	24.88
ITEM	221159	NORM SYST	4000.00	52.15	24.88
ITEM	222259	NORM SYST	1600.00	44.78	28.15
ITEM	231959	NORM SYST	700.00	70.49	16.44
ITEM	211199	NORM SYST	60.00	1493.43	308.43
ITEM	241259	NORM SYST	250.00	65.61	12.70
ITEM	226599	NORM SYST	300.00	116.54	38.64
ITEM	226599	NORM SYST	250.00	116.54	38.64
ITEM	242109	NORM SYST	140.00	132.49	80.85
ITEM	245319	NORM SYST	22.00	1323.18	429.45
ITEM	245219	NORM SYST	22.00	1062.65	348.14
ITEM	265119	NORM SYST	20.00	572.58	367.18
ITEM	792113	NORM SYST	150.00	377.23	116.64
ITEM	317111	NORM SYST	250.00	163.42	41.17
ITEM	342910	NORM SYST	250.00	248.44	84.96
ITEM	795191	NORM SYST	20.00	1485.81	551.25
ITEM	792111	NORM SYST	25.00	323.71	50.87
ITEM	792214	NORM SYST	4.00	3484.12	762.05
ITEM	792306	NORM SYST	16.00	6320.70	0.00
ITEM	792421	NORM SYST	48.00	364.38	0.00
ITEM	712253	NORM SYST	26.00	4230.80	236.72
ITEM	463010	NORM SYST	230.00	183.47	88.96
ITEM	463010	NORM SYST	450.00	183.47	88.96
ITEM	344110	NORM SYST	305.00	1693.29	608.26
ITEM	344130	NORM SYST	3800.00	248.51	24.22
ITEM	429219	NORM SYST	9.00	9352.57	4305.42
ITEM	429321	NORM SYST	30.00	659.50	48.39
ITEM	792213	NORM SYST	70.00	6491.98	1275.33
ITEM	481111	NORM SYST	2075.00	270.55	0.00
ITEM	486589	NORM SYST	475.00	494.67	0.00
ITEM	412130	NORM SYST	1000.00	579.86	0.00
ITEM	474810	NORM SYST	1035.00	1728.49	307.70
ITEM	474106	NORM SYST	6250.00	168.61	64.54
ITEM	422105	NORM SYST	8800.00	163.77	80.91
ITEM	422155	NORM SYST	8825.00	145.18	32.46
ITEM	426135	NORM SYST	3610.00	203.00	78.99
ITEM	426810	NORM SYST	50.00	1974.10	957.51
ITEM	431111	NORM SYST	200.00	623.74	102.69
ITEM	436011	NORM SYST	100.00	586.13	0.00
ITEM	912513	NORM SYST	50.00	418.67	0.00
ITEM	912581	NORM SYST	50.00	898.29	257.10
ITEM	851211	NORM SYST	300.00	38.84	0.00
ITEM	344120	NORM SYST	2200.00	216.61	122.84
ITEM	436211	NORM SYST	2200.00	427.51	57.81
ITEM	436411	NORM SYST	400.00	459.82	0.00
ITEM	261159	NORM SYST	10.00	1514.89	141.07
ITEM	463931	NORM CARD	50	84	0
ITEM	343063	NORM CARD	150	172	0
ITEM	226033	NORM CARD	110	1163	822
ITEM	313331	NORM CARD	1400	131	7
ITEM	313331	NORM CARD	550	131	7
ITEM	313331	NORM CARD	1000	131	7
ITEM	313331	NORM CARD	100	131	7
END					

PROJECT: MODERNISATION DE ROUTES DIVERSES DANS LA TRAVERSE DE VISE.

ITEM LIST ORDERED BY CONTRIBUTION.

ITEM CODE	DISTRIBUTION CODE	EXPECTED CONTRIBUTION	EXPECTED DISPERSION
424810	NORM	1788987.15	318469.50
422105	NORM	1441176.00	712008.00
422155	NORM	1281213.50	286459.50
424106	NORM	1053812.50	403375.00
344130	NORM	944338.00	92036.00
436211	NORM	940522.00	127182.00
426135	NORM	732830.00	285153.90
412130	NORM	579860.00	0.00
481111	NORM	561391.25	0.00
344110	NORM	516453.45	185519.30
344120	NORM	476542.00	270248.00
792213	NORM	454438.60	89273.10
486589	NORM	234968.25	0.00
221159	NORM	208600.00	99520.00
436411	NORM	183928.00	0.00
313331	NORM	183400.00	9800.00
221159	NORM	143412.50	68420.00
313331	NORM	131000.00	7000.00
226033	NORM	127930.00	90420.00
431111	NORM	124748.00	20538.00
712253	NORM	110000.80	6154.72
792306	NORM	101131.20	0.00
426810	NORM	98705.00	47875.50
241159	NORM	90076.50	29701.75
211199	NORM	89605.80	18505.80
429219	NORM	84173.13	38748.78
463010	NORM	82561.50	40032.00
313331	NORM	72050.00	3850.00
222259	NORM	71648.00	45040.00
241159	NORM	63297.00	20871.50
342910	NORM	62110.00	21240.00
436011	NORM	58613.00	0.00
792113	NORM	56584.50	17496.00
231959	NORM	49343.00	11508.00
912581	NORM	44914.50	12855.00
463010	NORM	42198.10	20460.80
317111	NORM	40855.00	10292.50
226599	NORM	34962.00	11592.00
795191	NORM	29716.20	11075.00
226599	NORM	29135.00	9660.00
245319	NORM	29109.96	9447.90
343063	NORM	25800.00	0.00
245219	NORM	23378.30	7659.08
912513	NORM	20933.50	0.00
429321	NORM	19785.00	1451.70
242199	NORM	18548.60	11319.00
792421	NORM	17490.24	0.00
241259	NORM	16402.50	3175.00
241159	NORM	15169.90	1410.70
792214	NORM	13936.48	3048.20
313331	NORM	13100.00	700.00
851211	NORM	11652.00	0.00
265119	NORM	11451.60	7543.60
792111	NORM	8092.75	1271.75

PROJECT: MODERNISATION DE ROUTES DIVERSES DANS LA TRAVERSE DE VISE.

ITEM LIST ORDERED BY DISPERSION.

ITEM CODE	DISTRIBUTION CODE	EXPECTED CONTRIBUTION	EXPECTED DISPERSION
422105	NORM	1441176.00	712008.00
424106	NORM	1053812.50	403375.00
424810	NORM	1788987.15	318469.50
422155	NORM	1281213.50	286459.50
426135	NORM	732830.00	285153.90
344120	NORM	476542.00	270248.00
344110	NORM	516453.45	185519.50
436211	NORM	940527.00	127182.00
221159	NORM	208600.00	99520.00
344130	NORM	944338.00	92036.00
226033	NORM	127930.00	90420.00
792213	NORM	454438.60	89273.10
221159	NORM	143412.50	68420.00
426610	NORM	98705.00	47875.50
222259	NORM	71648.00	45040.00
463010	NORM	82561.50	40032.00
429219	NORM	84173.13	38748.78
241159	NORM	90076.50	29701.75
342910	NORM	62110.00	21240.00
241159	NORM	63297.00	20871.50
431111	NORM	124748.00	20538.00
463010	NORM	42198.10	20460.80
211199	NORM	89605.80	18505.80
792113	NORM	56584.50	17496.00
912581	NORM	44914.50	12855.00
226599	NORM	34962.00	11592.00
231959	NORM	49343.00	11508.00
242199	NORM	18548.60	11319.00
795191	NORM	29716.20	11025.00
317111	NORM	40855.00	10292.50
313331	NORM	183400.00	9800.00
226599	NORM	29135.00	9660.00
245319	NORM	29109.96	9447.90
245219	NORM	23378.30	7659.08
265119	NORM	11451.60	7343.60
313331	NORM	131000.00	7000.00
712253	NORM	110000.80	6154.72
313331	NORM	72050.00	3850.00
241259	NORM	16402.50	3175.00
792214	NORM	13936.48	3048.20
429321	NORM	19785.00	1451.70
281159	NORM	15168.90	1410.70
792111	NORM	8092.75	1271.75
313331	NORM	13100.00	700.00
792306	NORM	101131.20	0.00
792421	NORM	17490.24	0.00
481111	NORM	561391.25	0.00
486589	NORM	254968.25	0.00
412130	NORM	579860.00	0.00
436011	NORM	58613.00	0.00
912513	NORM	20933.50	0.00
851211	NORM	11652.00	0.00
436411	NORM	183928.00	0.00
463931	NORM	4200.00	0.00
343063	NORM	25800.00	0.00

EXPECTED TOTAL PRICE = 1367028

PROJECT: MODERNISATION DE ROUTES DIVERSES DANS LA TRAVERSE DE VISE.

SIMULATION RUNS.

ITEM	QUANTITY	DISTRIBN.	PRICE 1	PRICE 2	PRICE 3	PRICE 4	PRICE 5	PRICE 6	PRICE 7
241159	925.00	NORM	154586.87	100442.98	64376.97	104666.15	78576.42	69937.69	73205.58
241159	650.00	NORM	80232.35	91735.59	76132.50	28755.19	43612.52	85888.09	55358.78
221159	2750.00	NORM	158710.40	126027.63	189887.89	186325.92	153875.90	298921.26	264597.28
221159	4000.00	NORM	374434.68	144811.88	407217.85	269396.36	138362.31	184450.23	127664.14
222259	1600.00	NORM	126368.23	122052.22	39873.62	89789.68	112104.83	116559.66	63150.25
231959	700.00	NORM	53203.54	56577.60	54770.15	47298.61	44530.65	52656.47	72531.96
211199	60.00	NORM	92753.56	104941.69	82172.45	80493.94	88216.98	66419.35	88783.96
241259	250.00	NORM	17203.79	20043.93	13096.78	15474.67	14344.33	15540.11	10904.17
226599	300.00	NORM	20231.76	26514.20	50400.21	26994.69	15577.21	21895.24	17526.99
226599	250.00	NORM	46708.56	18150.90	26911.01	28310.98	31542.20	30935.01	46230.28
242199	140.00	NORM	23684.23	42545.28	829.48	28282.85	8008.08	10084.19	13326.17
245319	22.00	NORM	17281.37	14297.31	36796.59	33478.43	35254.53	24382.21	35693.82
245219	22.00	NORM	24864.24	24084.73	20454.54	18477.46	18533.31	23205.82	37270.30
265119	20.00	NORM	10914.83	10669.15	25334.83	19078.24	13550.20	5383.53	21669.10
792113	150.00	NORM	67428.21	75215.90	27893.52	56001.08	94380.94	77876.51	57327.99
317111	250.00	NORM	21248.38	49528.17	48489.96	44521.29	43279.90	42480.78	34672.65
342910	250.00	NORM	94052.51	72086.42	66861.40	98931.87	57702.14	78537.77	39648.41
795191	20.00	NORM	34182.60	30424.92	8350.49	54012.30	45020.67	26982.13	49372.72
792111	25.00	NORM	6769.15	9553.48	9152.40	8151.66	8429.10	9262.74	6542.19
792214	4.00	NORM	13511.11	14422.52	12300.45	16121.33	13543.25	13445.61	15260.81
792306	16.00	NORM	101131.20	101131.20	101131.20	101131.20	101131.20	101131.20	101131.20
792421	48.00	NORM	17490.24	17490.24	17490.24	17490.24	17490.24	17490.24	17490.24
712253	26.00	NORM	113863.24	110716.71	99433.45	114077.88	101645.24	109532.88	109718.99
463010	230.00	NORM	43511.00	49571.78	43235.97	31282.42	70631.38	16006.13	62022.41
463010	450.00	NORM	168968.00	78633.26	73718.67	89701.30	97177.18	32958.89	67755.98
344110	305.00	NORM	814047.73	666103.15	559025.57	403857.08	432268.58	569425.72	729510.56
344130	3800.00	NORM	892020.93	972612.26	1100661.94	965979.76	974619.48	888142.63	985272.34
429219	9.00	NORM	116636.73	88118.14	2938.59	65353.72	5692.11	62421.73	50786.35
429321	30.00	NORM	20928.63	17990.74	20421.20	18881.98	19282.63	17733.03	21676.94
792213	70.00	NORM	365102.73	451840.70	444540.34	477303.89	229330.26	472057.24	589201.07
481111	2075.00	NORM	561391.25	561391.25	561391.25	561391.25	561391.25	561391.25	561391.25
486589	475.00	NORM	234968.25	234968.25	234968.25	234968.25	234968.25	234968.25	234968.25
412130	1000.00	NORM	579860.00	579860.00	579860.00	579860.00	579860.00	579860.00	577860.00
424810	1035.00	NORM	1082356.54	2318890.70	1898274.15	1739843.41	1752187.83	1538792.31	1634823.26
424106	6250.00	NORM	1383427.88	274068.37	782576.58	926805.98	818025.80	1136670.19	405369.66
422105	8800.00	NORM	1750322.21	1088753.78	2116098.22	823543.11	643584.96	1966453.74	2334420.33
422155	8825.00	NORM	1124907.33	1445310.41	1634840.36	1522813.67	1401481.90	1175194.85	1322448.31
426135	3610.00	NORM	1038072.71	530367.62	737293.04	998195.09	635316.04	1079140.30	1336441.94
426810	50.00	NORM	87315.77	99069.90	141309.77	31237.16	123613.55	97775.57	92555.69
431111	200.00	NORM	80712.06	141626.29	98040.43	74306.69	83507.88	140707.60	101983.53
436011	100.00	NORM	58613.00	58613.00	58613.00	58613.00	58613.00	58613.00	58613.00
912513	50.00	NORM	20933.50	20933.50	20933.50	20933.50	20933.50	20933.50	20933.50
912581	50.00	NORM	63382.60	53544.75	67645.04	42996.15	40642.60	50180.37	51836.21
851211	300.00	NORM	11652.00	11652.00	11652.00	11652.00	11652.00	11652.00	11652.00
344120	2200.00	NORM	520759.71	291585.36	625907.47	429662.86	620052.43	761643.71	733290.25
436211	2200.00	NORM	820528.30	806609.19	768158.59	1202959.84	1218003.97	826386.56	1026256.20
436411	400.00	NORM	183928.00	183928.00	183928.00	183928.00	183928.00	183928.00	183928.00
281159	10.00	NORM	15303.11	13569.24	15699.08	15013.11	15421.62	13682.59	15973.13
453931	50.00	NORM	4200.00	4200.00	4200.00	4200.00	4200.00	4200.00	4200.00
343063	150.00	NORM	25800.00	25800.00	25800.00	25800.00	25800.00	25800.00	25800.00
226033	110.00	NORM	117455.15	205257.92	226567.09	222467.93	296303.87	84490.62	48041.78
313331	1400.00	NORM	180458.81	179680.01	189983.60	175543.89	197510.42	179449.84	188132.82
313331	550.00	NORM	68175.50	69116.06	75609.07	69639.13	69621.82	73337.60	76110.03
313331	1000.00	NORM	145239.92	130832.92	137090.03	129494.70	125548.46	135839.32	125400.32
313331	100.00	NORM	14979.04	13069.69	13114.90	13242.22	13166.75	12802.20	12128.20
	TOTALS		14266811.54	13051252.70	14918454.27	13638235.09	12849059.65	14495626.36	15051851.32

PROJECT: MODERNISATION DE ROUTES DIVERSES DANS LA TRAVERSE DE VISE.

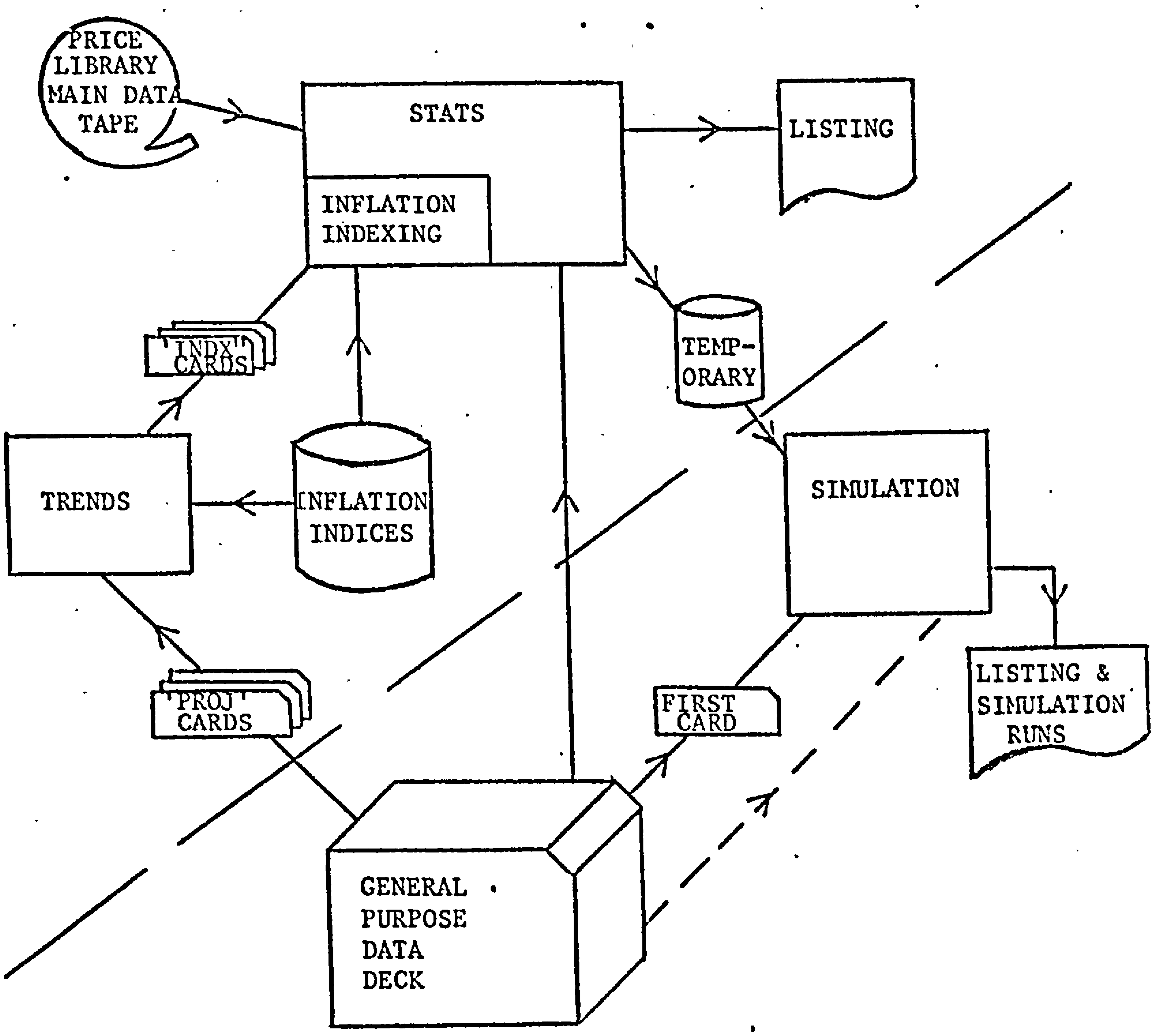
SIMULATION RUNS.

ITEM	QUANTITY	DISTRIBV.	PRICE 50	PRICE
241159	925.00	NORM	60856.68	
241159	650.00	NORM	41626.80	
221159	2750.00	NORM	176187.92	
221159	4000.00	NORM	78463.35	
222259	1600.00	NORM	171212.37	
231959	700.00	NORM	53192.49	
211199	60.00	NORM	84228.74	
241259	250.00	NORM	13617.44	
226599	300.00	NORM	35362.15	
226599	250.00	NORM	18355.17	
242199	140.00	NORM	19127.80	
245319	22.00	NORM	26076.94	
245219	22.00	NORM	18788.82	
265119	20.00	NORM	13606.04	
792113	150.00	NORM	53480.40	
317111	250.00	NORM	41696.23	
342910	250.00	NORM	45604.60	
795191	20.00	NORM	41685.41	
792111	25.00	NORM	7953.96	
792214	4.00	NORM	18522.17	
792306	16.00	NORM	101131.20	
792421	48.00	NORM	17490.24	
712253	26.00	NORM	118282.91	
463010	230.00	NORM	45301.23	
463010	450.00	NORM	52722.51	
344110	305.00	NORM	993628.39	
344130	3800.00	NORM	758598.30	
429219	9.00	NORM	95832.77	
429321	30.00	NORM	21062.49	
792213	70.00	NORM	414465.60	
491111	2075.00	NORM	561391.25	
486589	475.00	NORM	234968.25	
412150	1000.00	NORM	579860.00	
424810	1035.00	NORM	1764319.57	
424106	6250.00	NORM	648890.97	
422105	8800.00	NORM	497561.67	
422155	8825.00	NORM	1502252.18	
426135	3610.00	NORM	1017283.34	
426810	50.00	NORM	72056.07	
431111	200.00	NORM	123328.75	
436011	100.00	NORM	58613.00	
912513	50.00	NORM	20933.50	
912581	50.00	NORM	24658.33	
851211	300.00	NORM	11652.00	
344120	2200.00	NORM	320442.57	
436211	2200.00	NORM	1069241.06	
436411	400.00	NORM	183928.00	
281159	10.00	NORM	14796.68	
463931	50.00	NORM	4200.00	
343063	150.00	NORM	25800.00	
226033	110.00	NORM	67160.88	
313331	1400.00	NORM	188204.60	
313531	550.00	NORM	68905.69	
313331	1000.00	NORM	126521.45	
313331	100.00	NORM	12874.15	

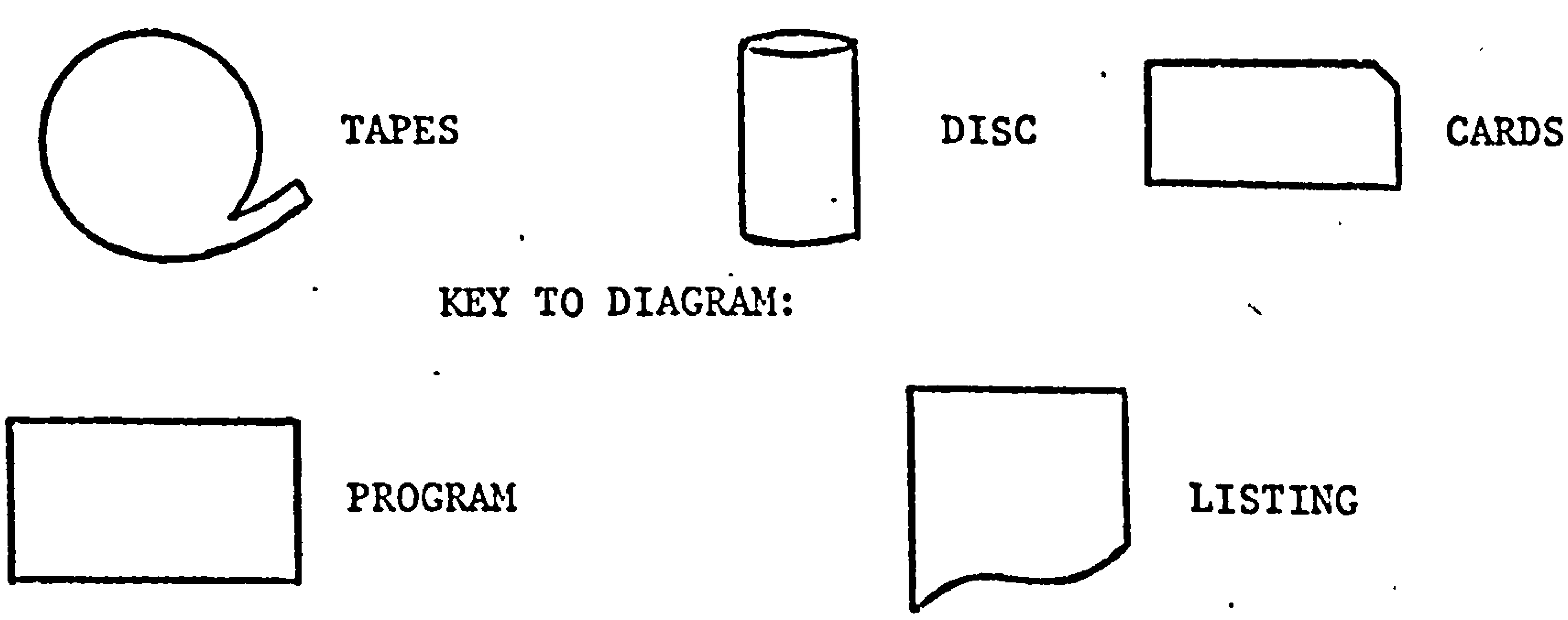
```
TOTALS            12837987.04

SIMULATION TOTAL PRICE = 13713528.
  STANDARD DEVIATION   =   893134.

                 PROGRAM TERMINATES  OK
```

3.1. CONCEPTUAL FLOW CHART

Simulating a batch of contracts.



All stages above the dashed line are omitted if a statsystem run is not required, in which case the whole G.P. Data Deck is input by "SIMULATION, not just the first card.



4.0. PREPARING THE DATA.

The user runs the system through the general purpose data deck. Section 2.0 describes in general terms the information required by the user; this section gives, in detail the format and order of required information.

4.1. CARD DECK REQUIRED.

The general purpose data deck requires the following types of cards in the following order:

1) A system card.
2) A project date and simulation card.
3) A project name card.
4) An index card.
5) A cost card.
6) For each item an item card.
7) Either and END card if the run is complete or an END ∧ MORE card if another project is to be simulated which then requires another set of cards from 2) to 6).
8) A comment card for explaining data.

(1) The system card.

Only one of these cards is required for each run. This card defines whether all the price variability data is supplied from the price library or from cards. If the price library is chosen the data can still be supplied from cards for any individual item.

Cols. 1 to 4 ALLC for all cards, or
STAT for the price library.

This card also allows the choice of listing required from the statistics program. The output from the simulation program is standard and cannot be varied but a choice must be made as to whether or not to list the input to it.

Cols. 11 to 14 ^^^^ A listing of all the input and output to the statistics program, if used or if the STAT program is not used, a listing of the input of the simulation program.

LIST Produces the same as above and in addition, even when the statistics program (STAT) is used, the input to the simulation program is still listed.

SHRT Only the input to the simulation program is listed.

NØLI Only the output from the statistics program is listed.

(2) Project Date and simulation card.

One of these cards is required for each project. This card supplies the project date, the number of simulations required and the initialisor of the random number generation and the location of the price library on the price library tape.

Cols. 1 to 4 PROJ

Cols. 13	&	14	day of month (I2) eg. 27
Cols. 16	&	17	month number (I2) eg. 08
Cols. 19	&	20	Year number (I2) eg. 75
Cols. 29	&	30	the number of simulation required (I2)
Cols. 38	&	40	A 3digit (I3) number which acts as the initialisor to the random number generator. If a specific number is used the random sequence can be repeated. If left blank the random number generator initialises on a number based on time and date and the sequence is not repeatable.
Col. 50			The location number of the price library on the price library tape 1 to 6 1 is Hainault Etat 2 is Hainault Cites 3 is Hainault Communes 4 is Liége Etat 5 is Liége Cites 6 is Liége Communes.

(3) Project Name Card.

One of these cards is required for each project and supplies the project name

Col. 1	to	4	NAME
Cols. 9	to	80	The project name

(4) Index Card.

One of these cards is required for each project and supplies the predicted index values for the inflation indices for labour, plant and 4 major materials. This card is produced by the inflation index predicting program "TRENDS".

Cols.	1	to	4	INDX
Cols.	6	to	10	index for Labour (F5.3)
Cols.	11	to	15	index for Cement (F5.3)
Cols.	16	to	20	index for Steel (F5.3)
Cols.	21	to	25	index for Timber (F5.3)
Cols.	26	to	30	index for Plant (F5.3)
Cols.	31	to	35	index for Road Asphalt (F5.3)

(5) Cost Card.

This card specifies the cost breakdown of the item (in proportion of one) into Labour, Plant, and Materials. One of these cards is required for each item or group of items with the same cost breakdown. The first cost card which will be inserted immediately after the Index Card will specify the cost breakdown for the item cards which follow until the next cost card is inserted. If each item has a different cost breakdown, each item must be preceded by a cost card.

Cols.	1	to	4	COST
Cols.	6	to	10	the proportion of cost due to Labour (F5.3)
Cols.	11	to	15	" " " " " " Cement (F5.3)
Cols.	16	to	20	" " " " " " Steel (F5.3)
Cols.	21	to	25	" " " " " " Timber (F5.3)
Cols.	26	to	30	" " " " " " Plant (F5.3)
Cols.	31	to	35	" " " " " " Asphalt (F5.3)

(6) Item Card.

One of these cards is required for <u>each item</u> in a project. If there are 100 items there will be 100 of these cards. The card supplies data about the item, the quantity and the distribution used to describe the variability of the price of the item.

Cols. 1 to 4 ITEM

Cols. 10 to 15 the six digit reference number used to describe items (I6).

Cols. 21 to 24 the distribution used to describe the variability of the items price.

NØRM - A normal distribution.

LØGN - A log-normal distribution.

TRIA - A triangular distribution (available only if price input is from cards).

REGR - A regression model of the type UNIT PRICE = a + b x quantity + e, where 'e' is a noramlly distributed random error variable.

Cols. 26 to 29 SYST - if the distribution parameters are to be calculated by the statistics program STAT.

CARD - if the distribution parameters are given in the card.

Cols. 31 to 40 The quantity of the item (F 10.0)

Cols. 41 to 50 ; 51 to 60 and 61 to 70 will supply the distribution parameters if the CARD option has been selected.

If CARD and NORM are selected

Cols. 41 to 50 the mean (F10.0)

Cols. 51 to 60 the standard deviation (F10.0).

If CARD and LØGN are selected

Cols. 41 to 50 the mean of the logs of the prices (F10.0).

Cols. 51 to 60 the standard deviation of the logs of the prices (F10.0).

If CARD and TRIA are selected

Cols. 41 to 50 the smallest price (F10.0).

Cols. 51 to 60 the mode of the price distribution (F10.0)

Cols. 61 to 70 the largest price (F10.0).

If CARD and REGR are selected using a regressive model of the form UNIT PRICE = a + b x quantity + e

Cols. 41 to 50 a) the constant term (F10.0)

Cols. 51 to 60 b) the coefficient of the Quantity (F10.0)

Cols. 61 to 70 c) the standard deviation of 'e' (F10.0) the residuals.

(7) END or END∧MORE Card.

This card terminates the run or returns to PROJ card for the next project.

If the run is to terminate

Cols. 1 to 4 END

If the run is to process another project

Cols. 1 to 4 END

Cols. 5 to 8 MORE

(8) Comment Card.

The comment card can be used to give explanation or described data and any number can be inserted at any point after the SYSTEM CARD and before the END Card.

Cols. 1 to 4 CØMM

Cols. 5 to 80 the comment in text.

A sample input deck on coding form is shown in Section 4.2.

4.3. ERROR MESSAGES

If a fatal data error is detected, the programs will output a message thus: e.g.

****ERRØR****

'ITEM' CARD EXPECTED BUT NØT FØUND

and a post-mortem will then be entered.

If a non-fatal data error is found the following message may appear: e.g.

WARNING NØ DATA FØUND-ITEM IGNØRED,

and the program will continue having taken the action mentioned in the message.

LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY, The Computer Centre — Fortran Coding Form

NAME | PROGRAM TITLE: PRICE LIBRARY | DATE
ADDRESS | Page 1 of 1

```
JØB PL,LUCES1,GP2442*
CARTRIDGE #100022
VØLUME 0000
EDSFILES 2,3
RECALLDUMP CCCC,PL07
DØWN 22
RUN
RECALLDUMP CCCC,PL04
DØWN
RUN
****
DØCUMENT DATA
STAT        LIST
PRØJ          03 07 75        50        123        4
NAME      MØDERNISATIØN DE RØUTES DIVERSES DANS LA TRAVERSE DE VISE.
INDX  2.0051.4101.2701.3841.6402.996
CØST   .8
ITEM        241159          REGR SYST           925
ITEM        241253          NØRM SYST           250
CØST   .3    .2    .05    .15    .1    .2
ITEM        343063          NØRM CARD           150        172        16
CØMM     A REAL LIFE CØNTRACT MAY CØNTAIN HUNDREDS OF ITEMS.
END
```

* ANY USERNUMBER

4.2. EXAMPLE CARD DECK

5.0. THE SYSTEM ELEMENTS

This section describes the various elements which make up the system.

It is not essential to read this Section before running the system but the following description will be useful when an error occurs.

5.1. THE PRICE LIBRARY TAPE

The main data bank for the system is the magnetic tape PRICE LIBRARY L.U.T. Computer Centre - Number 6.
Any program wishing to access this tape must have

```
INPUT 5 = MTO (PRICE LIBRARY)
```

or similar and

```
COMPRESS INTEGER AND LOGICAL
```

in the program description.
There are six libraries held on the tape in the following order:

Number	Name
1	Hainault Etat
2	Hainault Cites
3	Hainault Communes
4	Liege Etat
5	Liege Cites
6	Liege Communes

The first record of each library contains

- the library name
- the number of items in the library

and the reference number of these items.

All these are integers and can be read as follows:

```
DIMENSIØN  ITEM NUMBER(1900)
READ(5) LIB‸NAME, NO‸OF‸ITEM, ITEM NUMBER.
```

Note 1.

The variable names given are descriptive and not in FORTRAN.

Note 2.

The number of items is 1900 or less.

Note 3.

If the number of items is less than 1900 then the 1900 item reference numbers will be made up with zeros.

Note 4.

The library name is four characters

HTET for Hainault Etat

HTCI for Hainault Cites

HTCØ for Hainault Communes

LEET for Liege Etat

LECI for Liege Cites

LECØ for Liege Communes.

After the first record there is one record for each item in the library.

The items are in the same order as the item number array. (i.e. the reference number of the first item is in element 1 of the item number array).

Each item record contains the following:

ITEM : an integer, the item reference number.

NP : an integer, the number of prices gathered in the library for this item.

COST : a six element real array, the cost breakdown of the item.
The proportion of cost due to cost category 1 is held in COST (1) the proportion due to cost category 2 is held in cost (2) etc..... If the breakdown is unknown COST (1) has the value 1.0. Otherwise, the values should sum to 1.0.

DESC : an eight element real array, the item description (8A8) contains 64 blank spaces if the description is not known.

PRICE : an 'NP' element real array, the unit prices which are on record for the item.

QUANT : an 'NP' element real array, the quantities of this item as in the contract documents, from which the price was obtained.

DATE : an 'NP' element real array, the date of the contract to which the price belongs in days elapsed since 1st January 1970 (i.e. 1/1/70 = 1)

WEIGHT : an 'NP" element real array, the weight of each price. Some prices collected are not individual prices but the medians of prices from one set of bids belonging to one contract. The weight is the number of bids.

The data on this tape can be copied across to a Direct Access disc File, for quick access to any item's details. Thus, a program to process the data of the second library on the tape could include the following:

```
CØMPRESS INTEGER AND LØGICAL
INPUT5=MTO(PRICE LIBRARY)
CREATE6=ED1/DIRECT(USEREDSFILE 3(1))
:
DIMENSIØN ITEMREF(1900),NREC(1900),CØST(6),DESC(8),PDATA(400,4)
```

instead of the four arrays PRICE, QUANT, DATE and WEIGHT, one four - column array PDATA has been used. Notice that NP ≤ 400 for each item.

```
DEFINE FILE 6(1995, 62, U, IASSØC)
READ (5) LIBR,NI
  DØ 1 I = 1,NI
1 READ (5)
```

this will have skipped the first library on the tape

```
READ(5) LIBR,NI,ITEMREF
  DØ 2 I=1,NI
  READ(5)ITEM,NP,CØST,DESC,((PDATA(J,K),J=1,NP),K=1,4)
  NREC(I)=IASSØC
2 WRITE(6'IASSØC)ITEM,NP,CØST,DESC,((PDATA(J,K),J=1,NP),K=1,4)
```

Now, to retrieve the data pertaining to the item whose reference no. is held in element LØC of the ITEMREF array...

```
READ(6'NREC(LØC))ITEM,NP,CØST,DESC,((PDATA(I,J)I=I,NP),J=1,4)
```

at this point, ITEM should equal ITEMREF(LØC). Also, at the K-th appearance of this item, a median unit price of "PDATA(1,K)" was quoted for "PDATA(2,K)" units, at a date "PDATA(3,K)" days past 1970 and in all, "PDATA(4,K)" tenders were submitted.

5.2. THE INFLATION INDICES DISC.

5.2.1. DESCRIPTION

The updating of prices located on the Price Library tape is achieved by using inflation indices. These indices are permanently stored on a magnetic disc.

Any program wishing to access this disc must have

CARTRIDGE ⌗ 100022 in the job description.

```
INPUT 3 = EDO(INFL-INDICES(1)) and
CØMPRESS INTEGER AND LOGICAL
```

in the program description, and

```
DIMENSION.X(100,6,2)
READ(3)N,X
```

.... in the program itself.

There are six indices

No. 1 for Labour

2 for Cement

3 for Steel

4 for Timber

5 for Plant

6 for Road Asphalt.

Together with the indices the disc contains an entry number, and, the date of issue of the indices expressed in daynumbers after 1-01-70.

Indices are issued monthly.

Entry 1 contains the first series of indices recorded. This series has been issued for January 1971. (There is no contract recorded in the Price Library with a date preceding January 1971).

The series of monthly records form a 3-dimensional array of X (100,6,2).

The first subscript contains the entry number (max. 100), the second gives the index number, the third defines the date of issue of the series of indices (if it is '2') or the indices themselves (if it is '1').

(e.g. X(N,5,2) is the date of issue of the latest plant index since N (stored on the disc) is the highest entry number yet used).

The disc should be updated monthly when new indices are available.

Indices for labour are officially published by the Belgian Ministry of Public Works.

Indices for materials are calculated from official prices published monthly by the Belgian National Confederation of Construction.

Indices have been taken as equal to 1.000 at January 1971. Prices associated with this date have been as follows:

1.	Labour	57.40	Belgian	Francs.
2.	Cement	798.50	"	"
3.	Steel	6300.00	"	"

4. Timber 38.00 Belgian Francs.

6. Road Asphalt 1373.00 " "

The Plant index is made up from:

0,5 Labour

0,4 Steel as at 3 months before and

0,1 Fuel

The price of fuel at January 1971 has been 2.58 B.Fr.

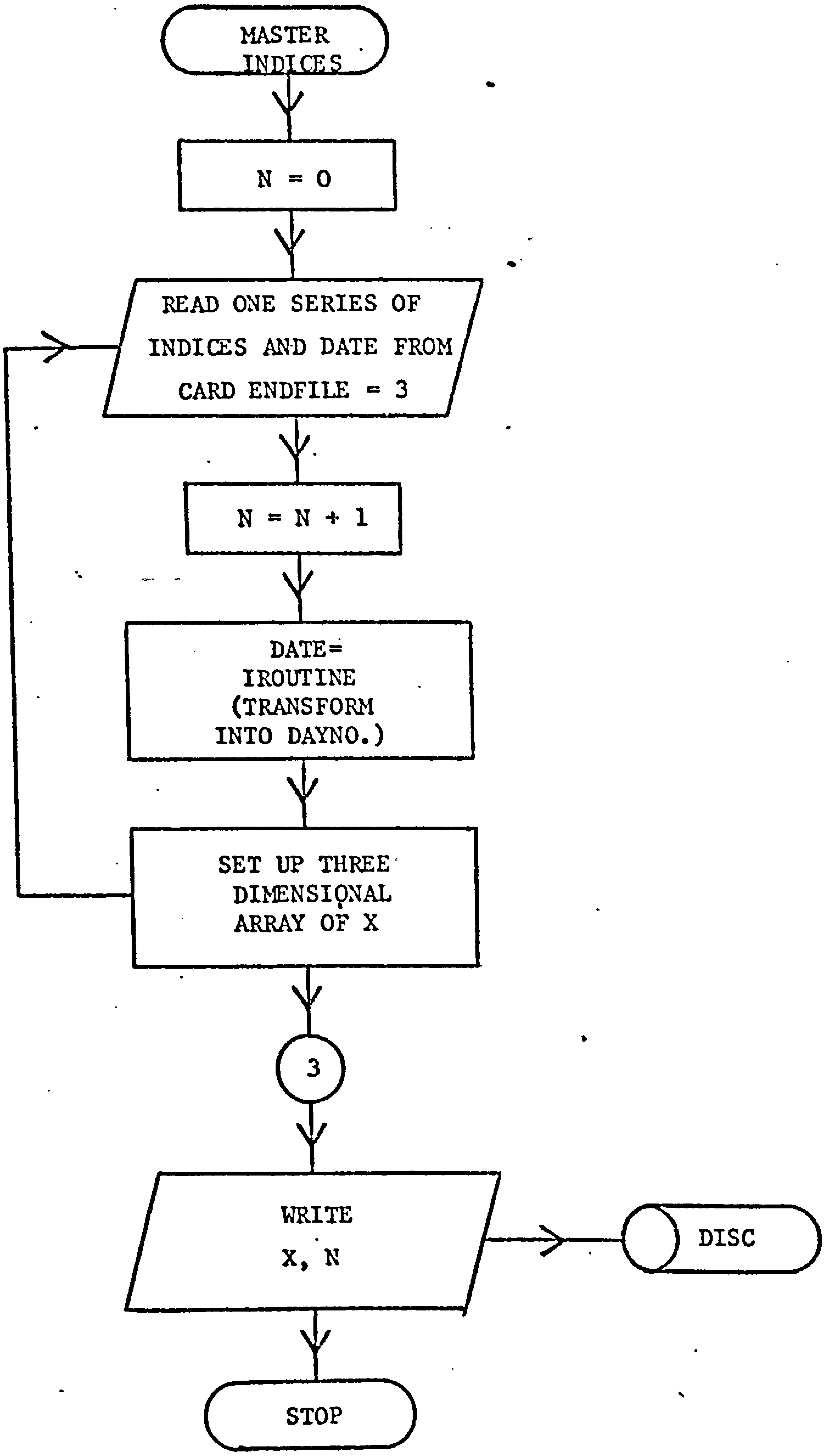
To update the indices only one card is needed

Col. 1	Number of year (after 1970)
Col. 2 - 3	Number of month
Col. 4 - 5	Number of day (01)
Cols. 11 - 20	New labour index (F.10.3)
Cols. 21 - 30	New Cement index (F.10.3)
Cols. 31 - 40	New steel index (F.10.3)
Cols. 41 - 50	New timber index (F.10.3)
Cols. 51 - 60	New plant index (F.10.3)
Cols. 61 - 70	New asphalt index (F.10.3)

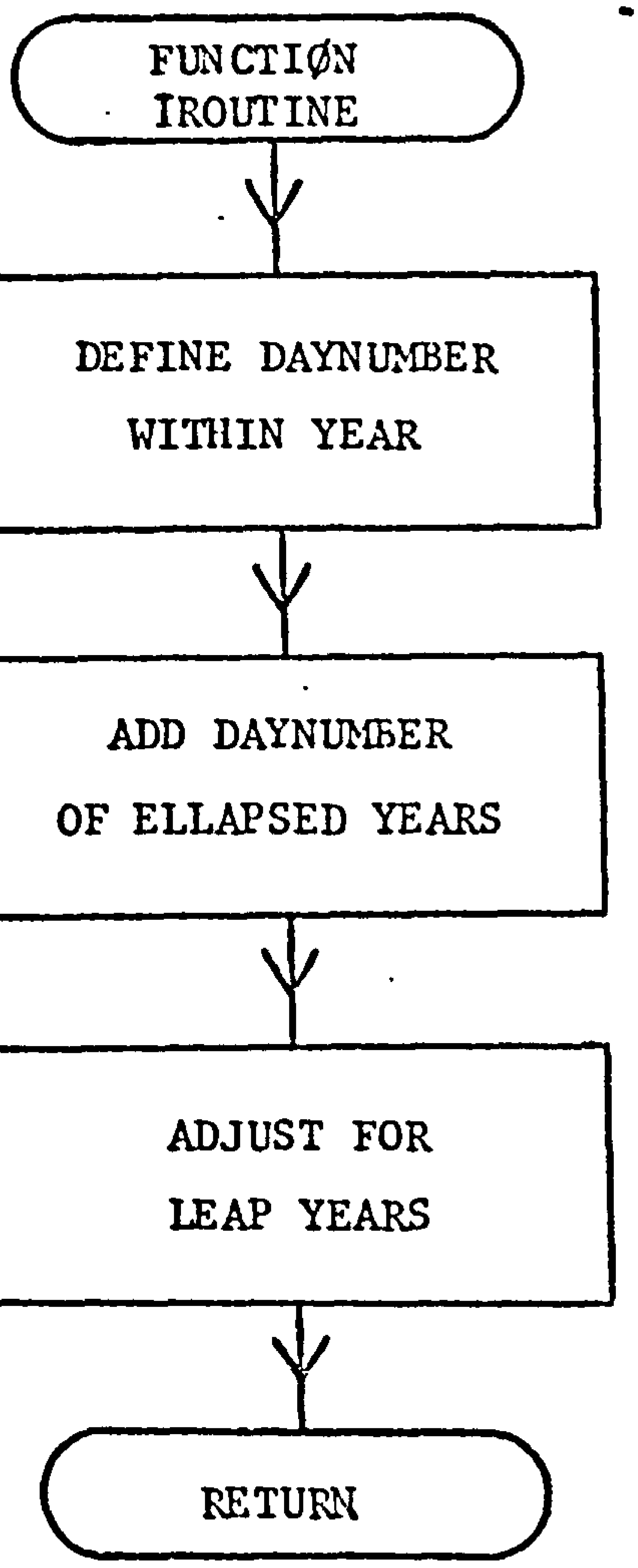
For updating the program 'INFLI' or a similar program must be used.

5.2.2. FLOWCHARTS

FLOWCHART OF PROGRAM 'INFLI'
Reading in data on the
INFLATION INDICES DISC.



'INFLI' continued



5.2.3. LISTING

LOUGHBOROUGH UNIVERSITY COMPUTER CENTRE GEORGE 2L MK3F STREAM B   RUN ON 08/09/75 AT 21.24

```
        JOB INFLI,C,GP2442
        CARTRIDGE #100072
        LUFORTRAN
        DOWN 22
        RUN
        ****
```

FORTRAN COMPILATION BY #XFAT MK 5A   DATE 08/09/75 TIME 21/24/39

```
      LIST
      SEND TO (ED,SEMICOMPUSER,AXXX)
      DUMP ON (ED,PROGRAM USER)
      WORK (ED,WORKFILEUSER)
      RUN
      PROGRAM(AAA2)
      INPUT 1=CR0
      OUTPUT 2=LP0
      USE 3=EDO(INFL-INDICES(1))
      COMPRESS INTEGER AND LOGICAL
      TRACE 2
      END
```

```
      MASTER INDICES
      DIMENSION X(100,6,2),Y(6)
C   THIS PROGRAM RECORDS SERIES OF EXISTING INFLATION INDICES ON MAGNETIC DISC.
      INTEGER DATE
C   N COUNTS THE NUMBER OF SERIES OF INDICES.
      N=0
C   WRITE HEADINGS.
      WRITE(2,5)
    5 FORMAT(1H1,'INFLATION INDICES',10X,'1.0 AS AT 1-01-71')
      WRITE(2,9)
    9 FORMAT(1H ,'-----------------')
      WRITE(2,6)
    6 FORMAT(1H ,2X,'NO',6X,'DAYNUMBER',10X,'1',9X,'2',9X,'3',9X,'4',9X,
     1'5',9X,'6')
      WRITE(2,8)
    8 FORMAT(1H ,10X,'AFTER 1-01-70',4X,'LABOUR',4X,'CEMENT',4X,'STEEL',
     15X,'TIMBER',4X,'PLANT',5X,'ASPHALT')
      WRITE(2,10)
   10 FORMAT(1H ,/)
C   READ A SERIES OF EXISTING INDICES AND THEIR DATE OF ISSUE FROM A CARD.
    1 READ(1,2,END=3)IYR,IMTH,IDY,Y
    2 FORMAT(I1,2I2,5X,6F10.3)
      N=N+1
C   FUNCTION 'ROUTINE' TRANSFORMS THE DATE INTO DAYNUMBER AFTER 1-01-70.
      DATE=ROUTINE(IYR,IMTH,IDY)
C   SET UP A THREE DIMENSIONAL ARRAY:
C   THE FIRST DIMENSION GIVES THE NUMBER OF ENTRY.
C   THE SECOND DIMENSION GIVES THE INDEXNUMBER.
C   THE THIRD DIMENSION D SIGNATES THE DATE OF ISSUE OF INDICES (2), OR
C   THE INDICES THEMSELVES.
      DO 4 I=1,6
```

```
              X(N,I,2)=DATE
            4 X(N,I,1)=Y(I)
      C     PRINT THIS SERIES OF INDICES AND THEIR DATE OF ISSUE EXPRESSED AS DAYNUMBER
      C     AFTER 1-01-70.
              WRITE(2,7)N,DATE,(X(N,I,1),I=1,6)
            7 FORMAT(1H ,I4,10X,I5,3X,6F10.3)
      C     READ NEXT SERIES OF EXISTING INDICES TOGETHER WITH THEIR DATE OF ISSUE FROM
      C     NEXT CARD.
              GO TO 1
      C     WRITE NUMBER OF ENTRY, INDICES AND DATE (IN DAYNUMBERS) OF EACH SERIES OF
      C     INDICES ON MAGNETIC DISC.
            3 WRITE(3)N,X
              ENDFILE 3
              STOP
              END

 END OF SEGMENT, LENGTH   144, NAME  INDICES


              FUNCTION IROUTINE(K,L,N)
      C     TRANSFORMS DATES INTO DAYNUMBERS AFTER 1-01-70.
      C     K=NUMBER OF YEAR
      C     L=NUMBER OF MONTH
      C     N=NUMBER OF DAY
              INTEGER DAYNO
              M=0
              IF(L.EQ.1)M=M+0
              IF(L.EQ.2)M=M+31
              IF(L.EQ.3)M=M+59
              IF(L.EQ.4)M=M+90
              IF(L.EQ.5)M=M+120
              IF(L.EQ.6)M=M+151
              IF(L.EQ.7)M=M+181
              IF(L.EQ.8)M=M+212
              IF(L.EQ.9)M=M+243
              IF(L.EQ.10)M=M+273
              IF(L.EQ.11)M=M+304
              IF(L.EQ.12)M=M+334
              DAYNO=K*365+M+N
      C     ADJUST FOR LEAP YEARS
              IF((K.EQ.6).AND.(L.GT.2).OR.(K.GT.6))DAYNO=DAYNO+2
              IF((K.EQ.2).AND.(L.GT.2).OR.(K.GT.2))DAYNO=DAYNO+1
              IROUTINE=DAYNO
              RETURN
              END

 END OF SEGMENT, LENGTH   25?, NAME  IROUTINE


              FINISH
```

5.3. TRENDS - THE INFLATION INDEX

5.3.1. DESCRIPTION.

This program forecasts inflation indices one, two or three months ahead.

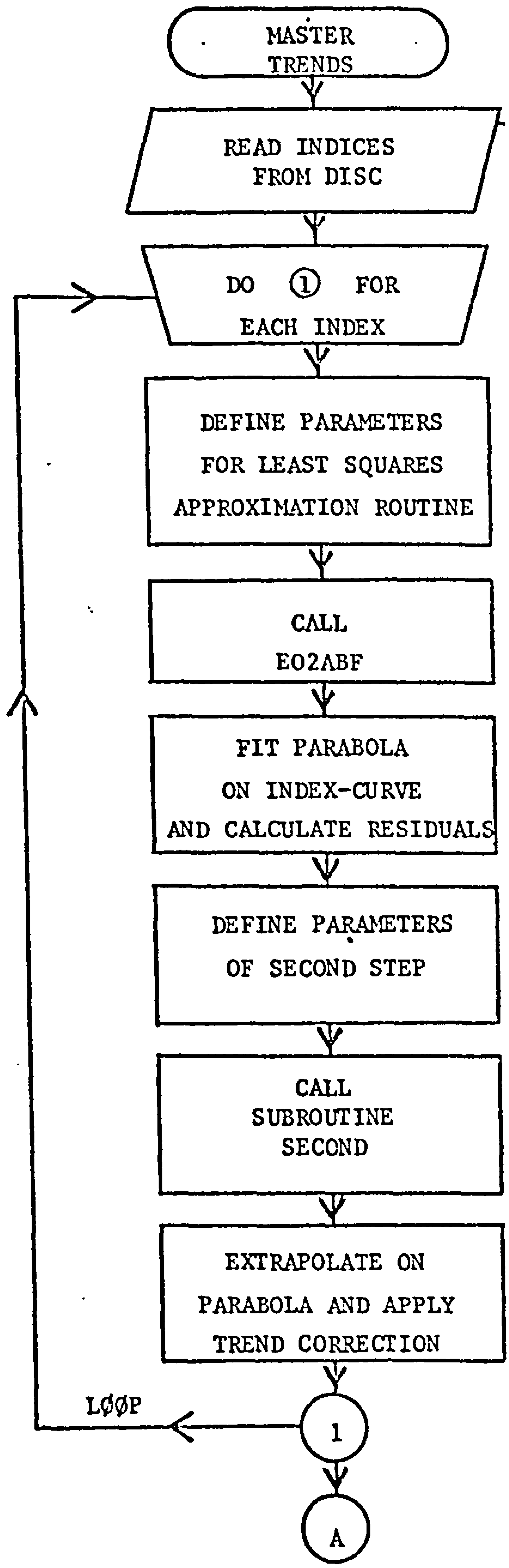
INPUT used : Six series of existing inflation indices (labour, plant and 4 materials together with their dates of issue, stored on disc file.

METHOD USED : Weighted least squares polynomial approximation in two stages.
In the first stage a parabola is fitted to each series of indices and in the second stage a polynomial of degree zero, one, two or three is fitted (whichever fits at best) to the last six months' errors in fit (residuals). Forecasts are made by extrapolating on the parabola.
By extrapolating on the polynomial fitted to the residuals we get the expected error in our forecast. A correction is then made in order to compensate for the error.

OUTPUT : 'INDX' followed by the 6 indices to apply for updating prices and the number of month they are concerning; this for 1, 2 and 3 months ahead.

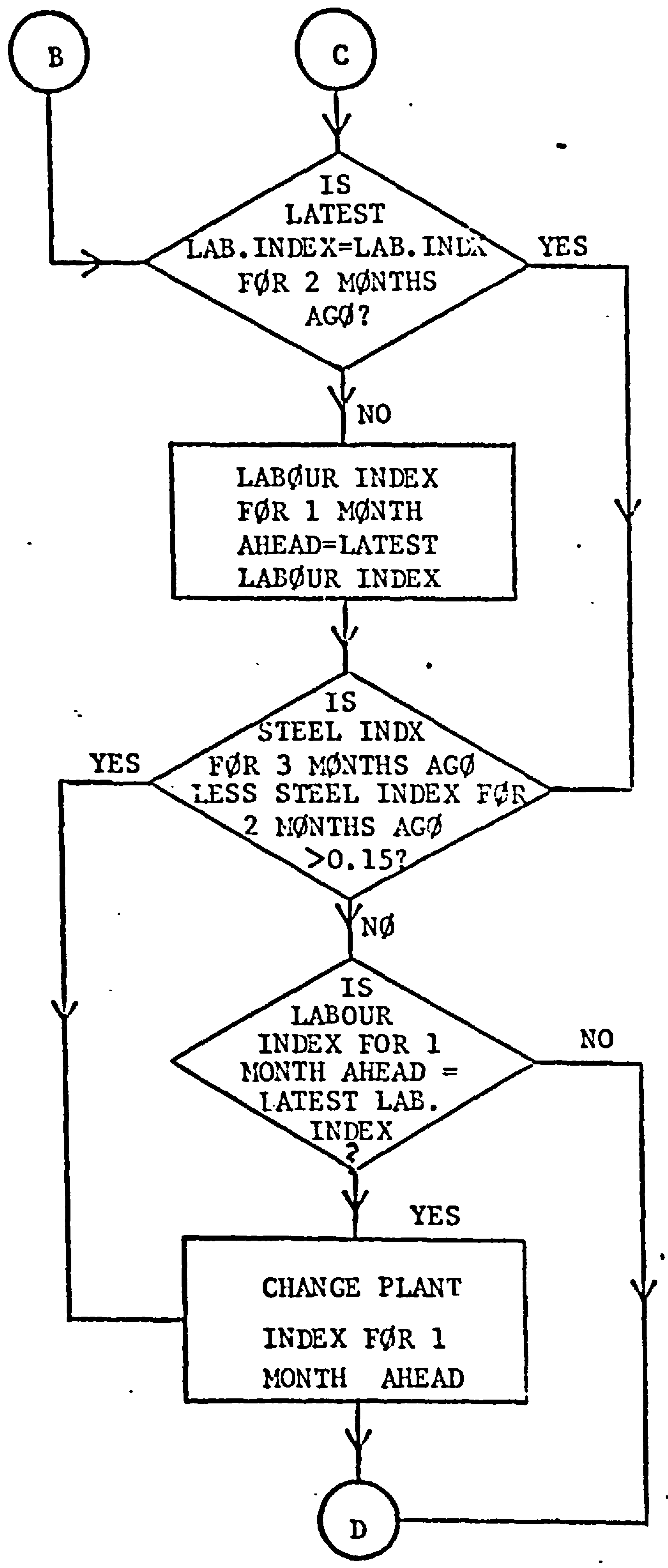
5.3.2. FLOWCHARTS

FLOWCHART OF PROGRAM 'TRENDS'



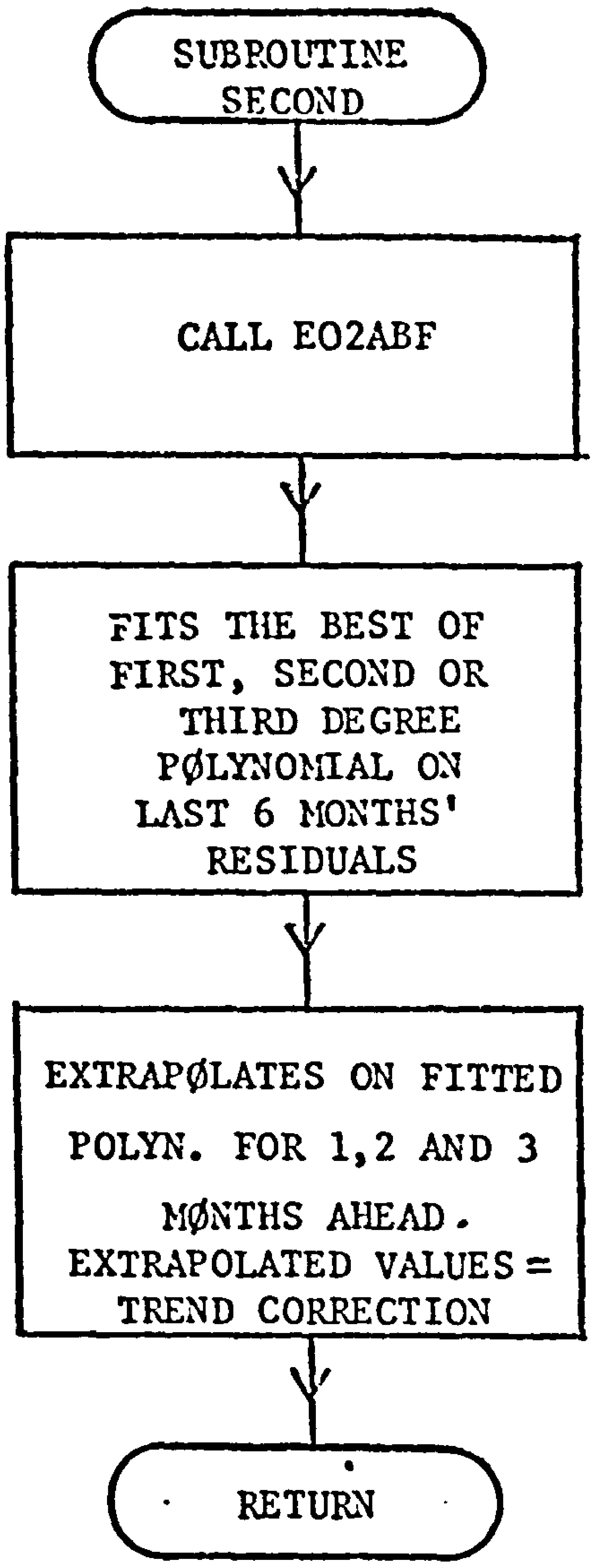
'TRENDS' continued

'TRENDS' continued



'TRENDS' continued

'TRENDS' continued



5.3.3. LISTING

```
LOUGHBOROUGH UNIVERSITY COMPUTER CENTRE GEORGE 2L MK3F STREAM B      RUN ON 12/09/75 AT 15.41

        JOB GY,C,GP2442
        CARTRIDGE #100022
        LUFORTRAN
        DOWN 22
        RUN
        ****

FORTRAN COMPILATION BY #XFAT MK 5A    DATE  12/09/75  TIME  15/41/36

                 LIST
                 SEND TO (ED,SEMICOMPUSER,AXXX)
                 DUMP ON (ED,PROGRAM USER)
                 WORK (ED,WORKFILEUSER)
                 RUN
                 LIBRARY (ED,SUBGROUPNAGF)
                 PROGRAM(GYXXX)
                 INPUT 1=CR0
                 OUTPUT 2=LP0
                 OUTPUT 4=CP0
                 USE 3=EDU(INFL-INDICES(1))
                 COMPRESS INTEGER AND LOGICAL
                 TRACE 2
                 END

                 MASTER TRENDS
                 DIMENSION X(100,6,2),A(99),B(99),W(99),SI(3),P(3),RES(6,99)
                 DIMENSION FIT(6,99),AZ(99),BZ(99),CZ(6),WZ(6),PZ(4),SIZ(4)
                 DIMENSION FITZ(6,6),RESZ(6,6),UP(6,3),UPI(6,3),MONTH(3),IYEAR(3)
                 LOGICAL L,LZ
                 L=.TRUE.
                 LZ=.FALSE.
C     READS FROM DISC INFLATION INDICES WITH DATES OF ISSUE.
                 READ(3)N,X
C
C     DEFINES PARAMETERS FOR A WEIGHTED LEAST-SQUARES APPROXIMATION ROUTINE.
C
C     NUMBER OF DATAPOINTS EQALS NUMBER OF VALUES ON DISC FOR THE SAME INDEX.
                 M=N
C     POLYNOMIAL TO BE FITTED IS PARABOLA.
                 K1=3
C     I DESIGNATES THE INDEXNUMBER.
                 DO 1 I=1,6
C     DEFINES THE FUNCTION VALUES (A), AND THEIR POSITIONS(B).
                 DO 2 J=1,N
                 A(J)=X(J,I,1)
                 B(J)=J
               2 CONTINUE
C     ASSIGNS WEIGHTS TO THE FUNCTION VALUES.
                 DO 3 K=1,N
                 W(K)=1.
               3 CONTINUE
                 CALL E02ABF(M,B,A,W,K1,N1,SI,P,L)
C     CALCULATES POINTS OF BEST FITTING PARABOLA.
```

```
      DO 4 J=1,N
      BX=B(J)
      N2=N1+1
      F=P(N2)
      DO 5 K=1,N1
      I1=N2-K
      F=F*BX+P(I1)
    5 CONTINUE
      FIT(I,J)=F
C   CALCULATES RESIDUALS
      RES(I,J)=A(J)-FIT(I,J)
    4 CONTINUE
C
C   THE SECOND STEP FITS A POLYNOMIAL OF DEGREE ZERO, ONE, TWO OR THREE TO THE
C   LAST SIX POINTS' RESIDUALS IN ORDER TO DEFINE TRENDS.
C
C   DEFINES PARAMETERS OF SECOND STEP.
      MZ=6
      KZ1=4
      DO 6 J=1,N
      BZ(J)=J
    6 CONTINUE
      DO 7 J=1,6
      AZ(J)=RES(I,J+(N-MZ))
    7 CONTINUE
      DO 8 J=1,6
      CZ(J)=BZ(J+(N-MZ))
    8 CONTINUE
      DO 9 J=1,6
      WZ(J)=1.
    9 CONTINUE
      CALL SECOND(MZ,CZ,AZ,WZ,KZ1,NZ1,SIZ,PZ,LZ,N,X,FITZ,RESZ,UP,I)
C   EXTRAPOLATES ON PARABOLA TO ONE, TWO AND THREE PERIODS.
      DO 10 J=1,3
      UPI(I,J)=P(3)
      DO 11 K=1,2
      I1=3-K
      UPI(I,J)=(UPI(I,J))*(N+J)+P(I1)
   11 CONTINUE
C   APPLIES CORRECTION FOR TREND TO EXTRAPOLATED VALUES.
      UPI(I,J)=UPI(I,J)+UP(I,J)
   10 CONTINUE
    1 CONTINUE
C
C
C   WHEN TO CHANGE FORECASTED INDICES?
C   IF ANY OF THE PREDICTED INDICES IS SMALLER THAN THE LATEST RECORDED ONE,
C   NEGLECT THE PREDICTED INDEX AND TAKE THE LATEST PUBLISHED ONE FOR THAT
C   PERIOD.
C
      DO 22 J=1,6
      DO 22 K=1,3
   22 IF(UPI(J,K).LT.X(N,J,1))UPI(J,K)=X(N,J,1)
C
C   WHEN TO CHANGE AN INDEX FORECASTED FOR THREE MONTHS AHEAD?
C
C   IF THE STEEL-INDEX CHANGED MORE THAN .15 POINTS DURING THE LAST THREE MONTHS
C   CALCULATE THE NEW PLANT INDEX BY USING THIS INFORMATION AND NEGLECT THE
C   FORECASTED PLANT INDEX.
      IF(ABS(X(N-3,3,1)-X(N,3,1)).GT..15)UPI(5,3)=X(N,5,1)+.5*(UPI(1,3)-
     1X(N,1,1))+.4*(X(N,3,1)-X(N-3,3,1))
C
```

```
C     WHEN TO CHANGE INDICES FORECASTED FOR TWO MONTHS AHEAD?
C
C     IF THE LATEST PUBLISHED INDEX FOR LABOUR IS NOT THE SAME AS THE PREVIOUS ONE
C     THE LATEST PUBLISHED INDEX SHOULD REPLACE THE FORECASTED LABOUR INDEX.
        IF(X(N,1,1).EQ.X(N-1,1,1))GO TO 12
        UPI(1,2)=X(N,1,1)
C     IF THE STEEL INDEX CHANGED MORE THAN .15 POINTS BETWEEN THREE AND ONE MONTHS
C     AGO,OR IF THE LATEST PUBLISHED LABOUR INDEX REPLACED THE FORECASTED ONE,
C     CALCULATE A NEW PLANT INDEX AND NEGLECT THE FORECASTED PLANT INDEX.
   12 IF(ABS(X(N-3,3,1)-X(N-1,3,1)).GT..15)GO TO 13
        IF(UPI(1,2).NE.X(N,1,1))GO TO 14
   13 UPI(5,2)=X(N,5,1)+.5*(UPI(1,2)-X(N,1,1))+.4*(X(N-1,3,1)-X(N-3,3,1)
     1)
C
C     WHEN TO CHANGE INDICES FORECASTED FOR ONE MONTH AHEAD?
C
C     IF THE LATEST PUBLISHED INDEX FOR LABOUR IS NOT THE SAME AS THE ONE OF TWO
C     MONTHS BEFORE,THE LATEST PUBLISHED INDEX SHOULD REPLACE THE FORECASTED
C     LABOUR INDEX.
   14 IF(X(N,1,1).EQ.X(N-2,1,1))GO TO 15
        UPI(1,1)=X(N,1,1)
C     IF THE STEEL INDEX CHANGED MORE THAN .15 POINTS BETWEEN THREE AND TWO MONTHS
C     AGO,OR IF THE LATEST PUBLISHED LABOUR INDEX REPLACED THE FORECASTED ONE,
C     CALULATE A NEW PLANT INDEX AND NEGLECT THE FORECASTED PLANT INDEX.
   15 IF(ABS(X(N-3,3,1)-X(N-2,3,1)).GT..15)GO TO 16
        IF(UPI(1,1).NE.X(N,1,1))GO TO 17
   16 UPI(5,1)=X(N,5,1)+.5*(UPI(1,1)-X(N,1,1))+.4*(X(N-2,3,1)-X(N-3,3,1)
     1)
C
C     DEFINE YEAR AND MONTH WHEN ANYONE OF THE SERIES OF PREDICTED INDICES IS
C     TO BE USED
   17 MNTH=N
C     FIND THE NUMBER OF YEARS ELAPSED SINCE THE FIRST SERIES OF INDICES WERE
C     RECORDED.
        IYR=MNTH/12
C     FIND THE NUMBER OF THE MONTH THE LATEST INDICES ARE FROM.
        MNTH=MNTH-(IYR*12)+1
C     DEFINE NUMBER OF CURRENT YEAR
        IYR=IYR+1
C     FIND NUMBERS OF MONTH OF PREDICTED INDICES
        DO 18 I=1,3
        MONTH(I)=MNTH+I
        IYEAR(I)=IYR
C     THE MONTH AFTER DECEMBER IS JANUARY OF THE FOLLOWING YEAR.
        IF(MONTH(I).GT.12)GO TO 19
        GO TO 18
   19 MONTH(I)=MONTH(I)-12
        IYEAR(I)=IYEAR(I)+1
   18 CONTINUE
C
C     PUNCH CARDS WITH SERIES OF PREDICTED INFLATION INDICES FOR ONE, TWO AND
C     THREE MONTHS AHEAD INDICATING IN WHICH MONTS THEY SHOULD BE USED.
        DO 20 J=1,3
        WRITE(4,21)(UPI(I,J),I=1,6),MONTH(J),IYEAR(J)
   20 CONTINUE
   21 FORMAT('INDX ',6F5.3,4X,'USE FOR PROJECTS IN MONTH',I3,'.197',I1)
        STOP
        END

END OF SEGMENT, LENGTH  1034, NAME  TRENDS
```

```
      SUBROUTINE SECOND(M,C,A,W,K1,N1,SI,P,LZ,N,X,FIT,RES,UP,I)
      DIMENSION X(100,6,2),A(99),C(6),W(6),SI(4),P(4),FIT(6,6),RES(6,6)
      DIMENSION UP(6,3)
      LOGICAL LZ
      LZ=.FALSE.
      CALL FUZABF(M,C,A,W,K1,N1,SI,P,LZ)
C     CALCULATES POINTS OF BEST FITTING POLYNOMIAL (MAX. DEGREE EQUALS 3).
      N2=N1+1
      DO 1 J=1,6
      CX=C(J)
      IF(N1)3,3,0
      F=P(N2)
      DO 2 K=1,N1
      I1=N2-K
      F=F*CX+P(I1)
    2 CONTINUE
      GO TO 4
    3 F=P(1)
    4 FIT(I,J)=F
C     CALCULATES RESIDUALS.
      RES(I,J)=A(J)-FIT(I,J)
    1 CONTINUE
C     CALCULATES TREND BY EXTRAPOLATING TO ONE, TWO AND THREE PERIODS.
      IF(N1)7,7,0
      DO 5 J=1,3
      UP(I,J)=P(N2)
      DO 6 K=1,N1
      I1=N2-K
      UP(I,J)=(UP(I,J))*(N+J)+P(I1)
    6 CONTINUE
    5 CONTINUE
      GO TO 9
    7 DO 8 J=1,3
      UP(I,J)=P(1)
    8 CONTINUE
    9 RETURN
      END

END OF SEGMENT, LENGTH   311, NAME  SECOND

      FINISH
```

5.4. THE STATISTICS PROGRAM

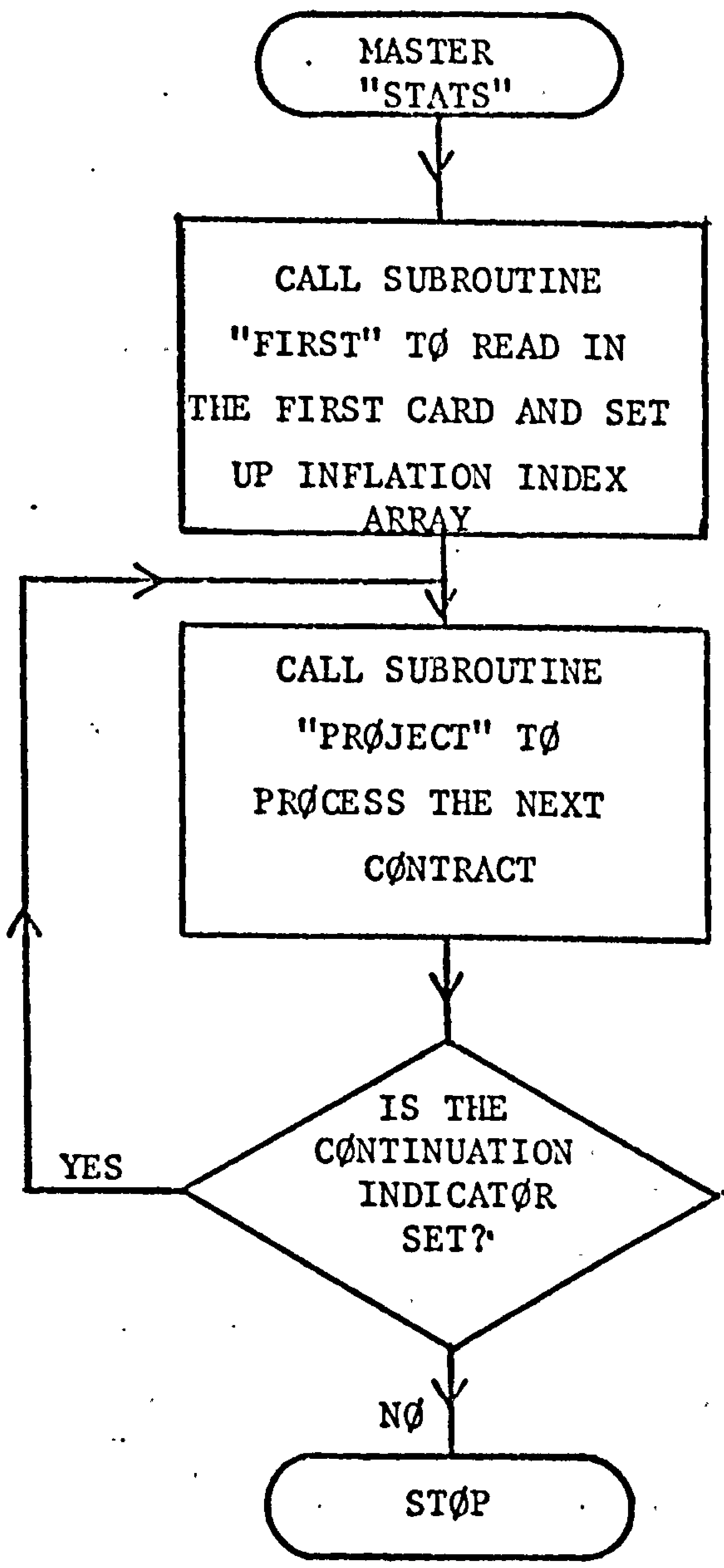
5.4.1. DESCRIPTION

This program selects from the library prices belonging to a specified item. It then uses the inflation indices to update the prices from the date the price was entered in the library to the date of the prediction.
Thereafter it analyses the prices of the specified item to produce the statistics required for simulation.
These statistics are either mean and standard deviation if a normal distribution, or mean and standard deviation of a log-normal distribution or a regression model of the form, UNITPRICE = A + B x QUANTITY and the standard deviation of the residuals. The program stores this information on a temporary file for the SIMULATION program.

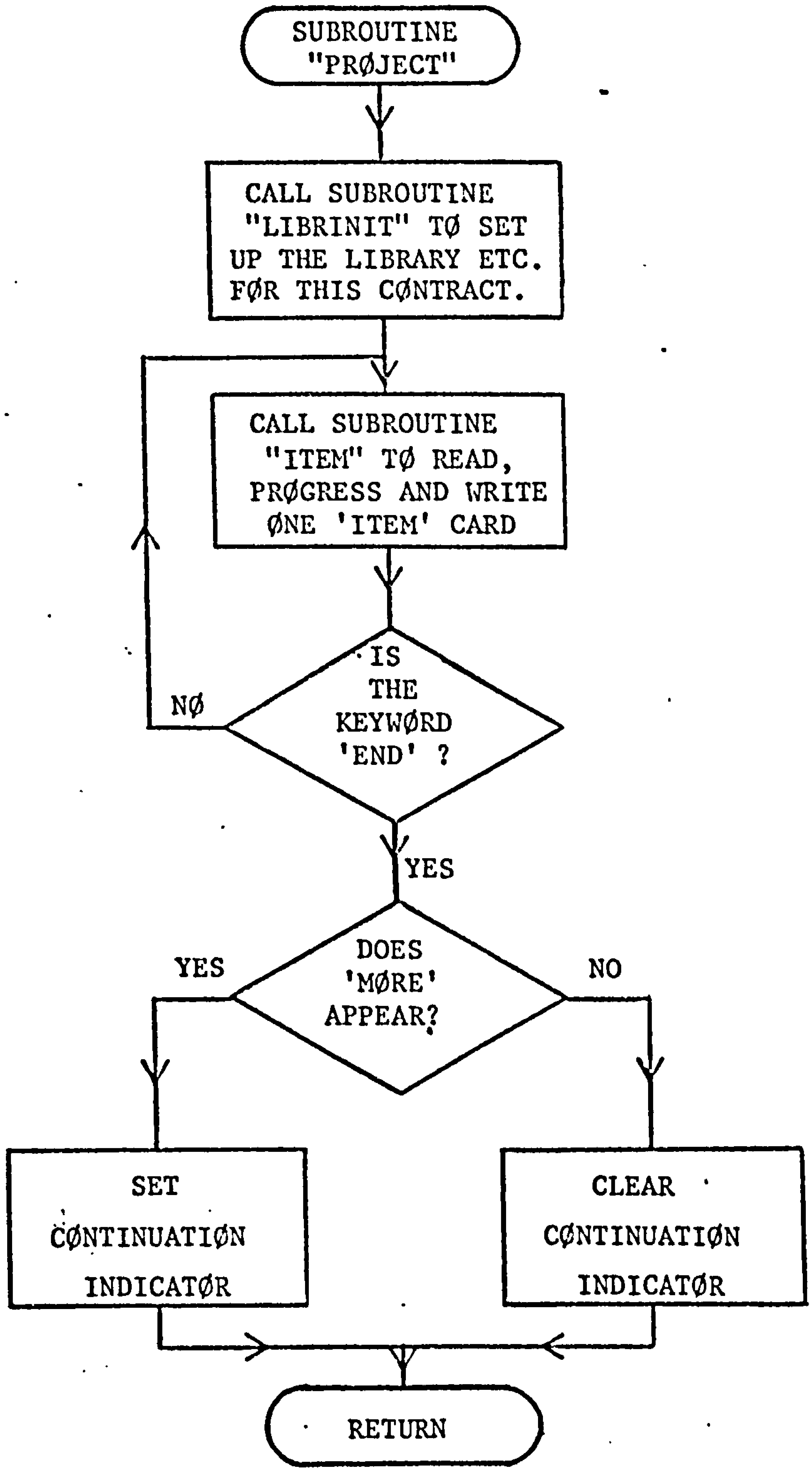
5.4.2. FLOWCHARTS

FLOWCHART OF PROGRAM PL07,

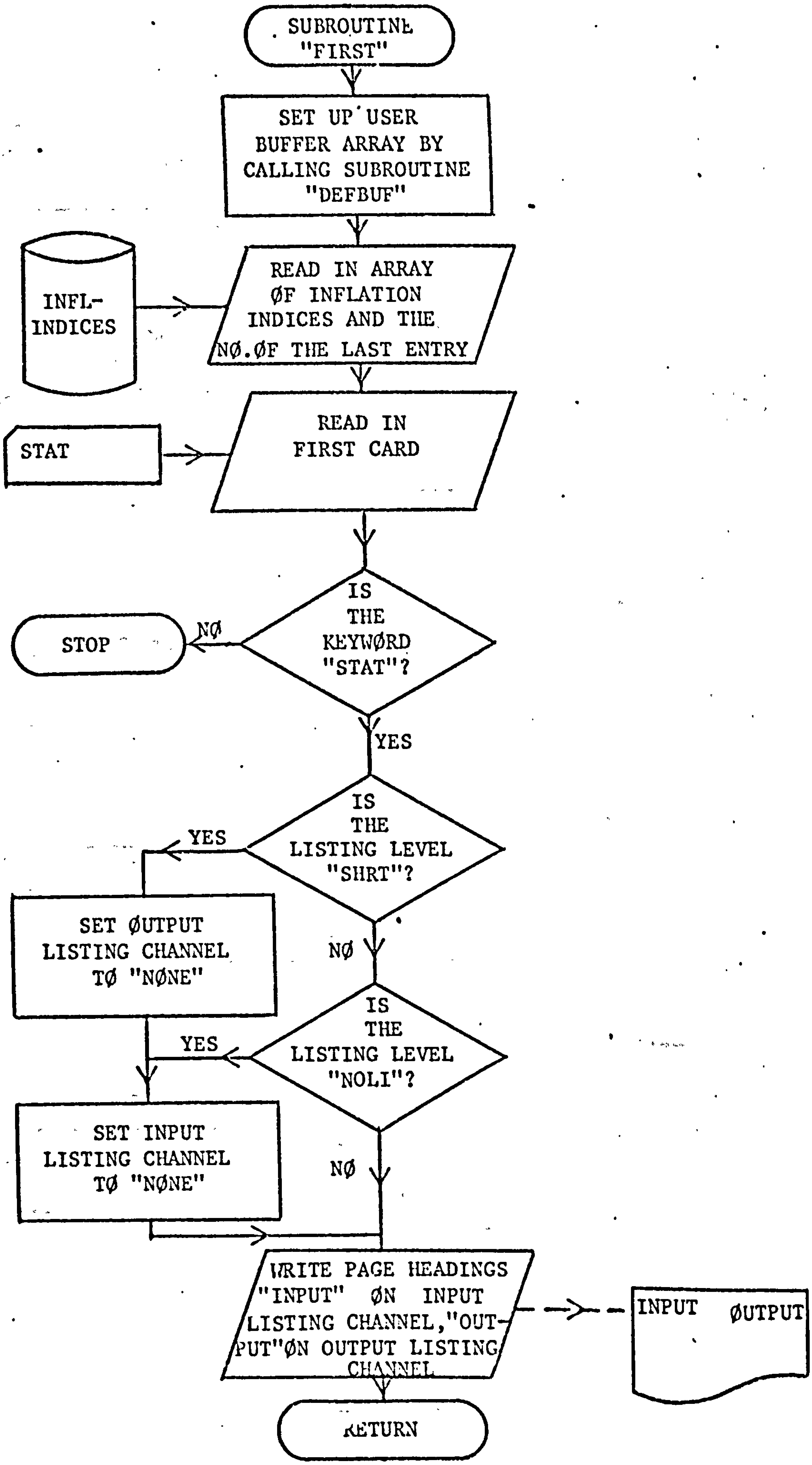
PRICE LIBRARY STATS.



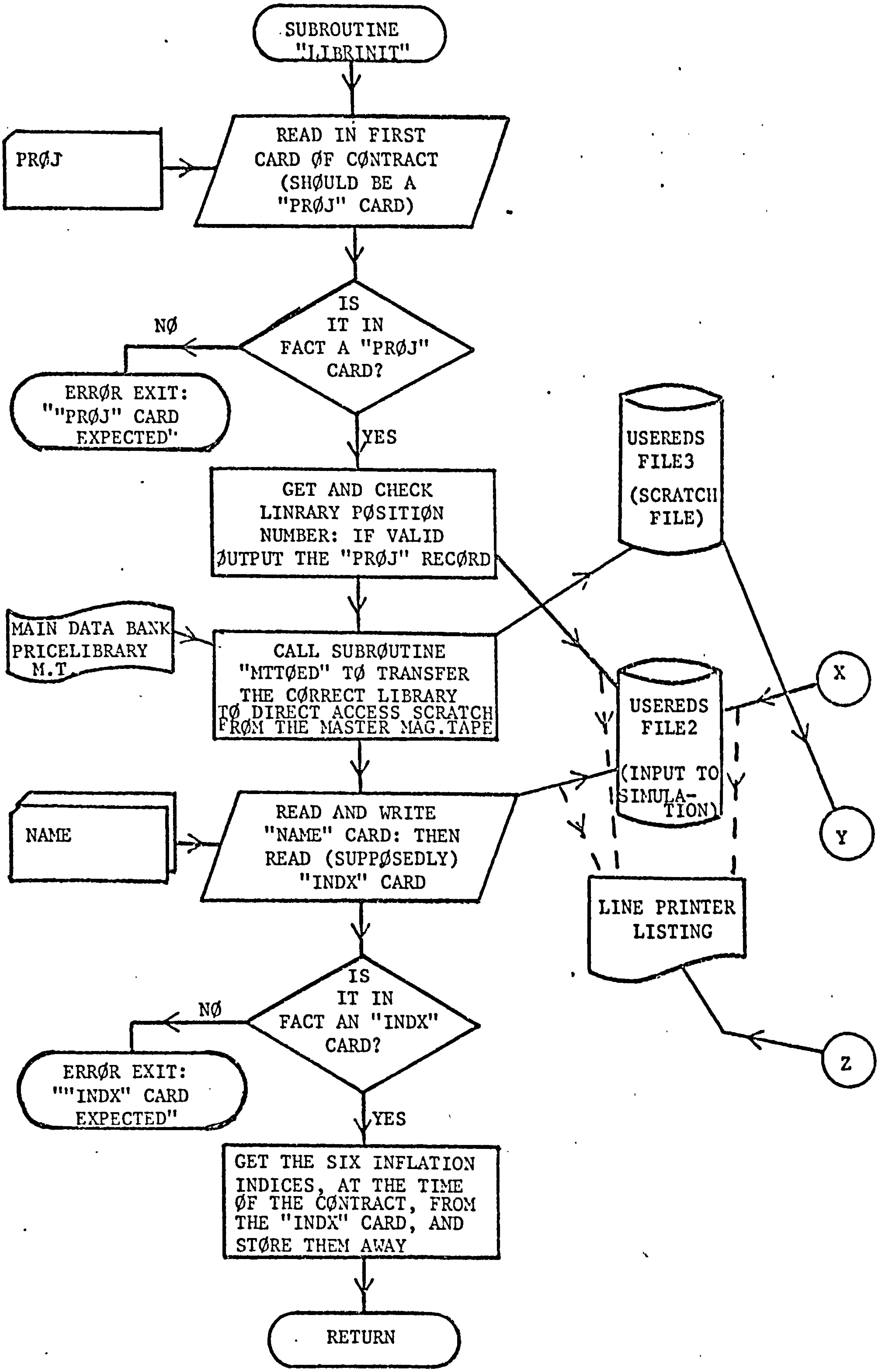
'STATS' continued



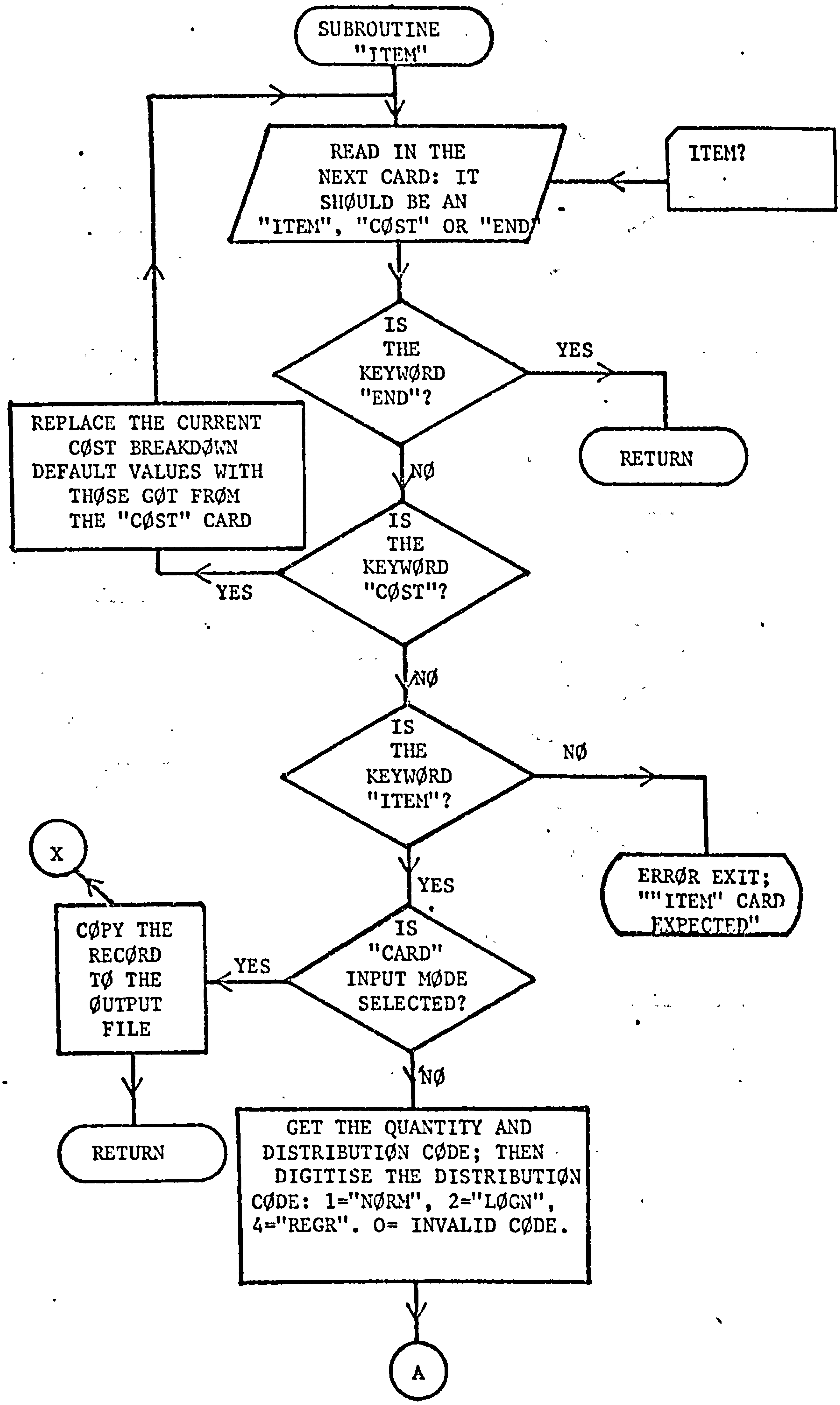
'STATS' continued



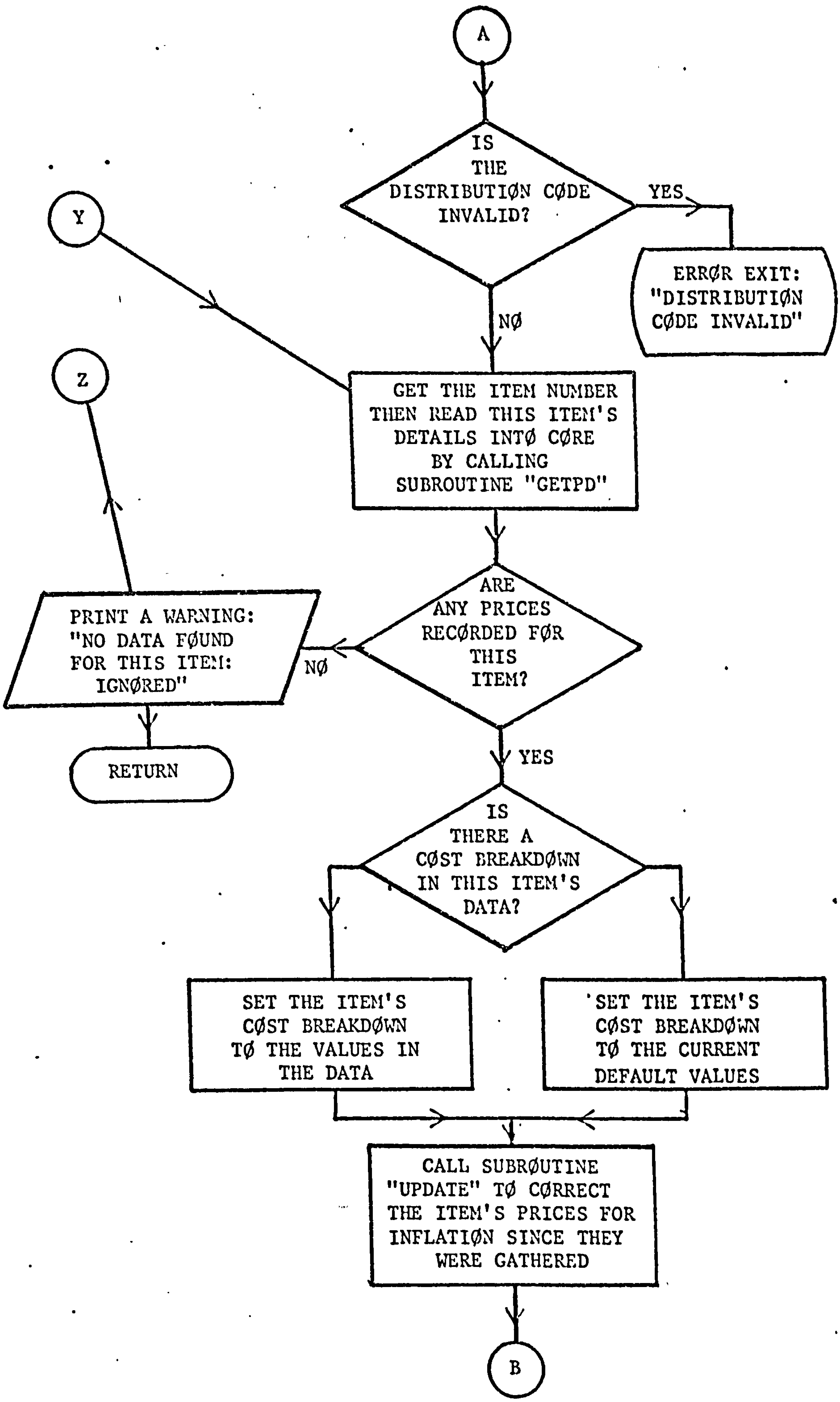
'STATS' continued



'STATS' continued

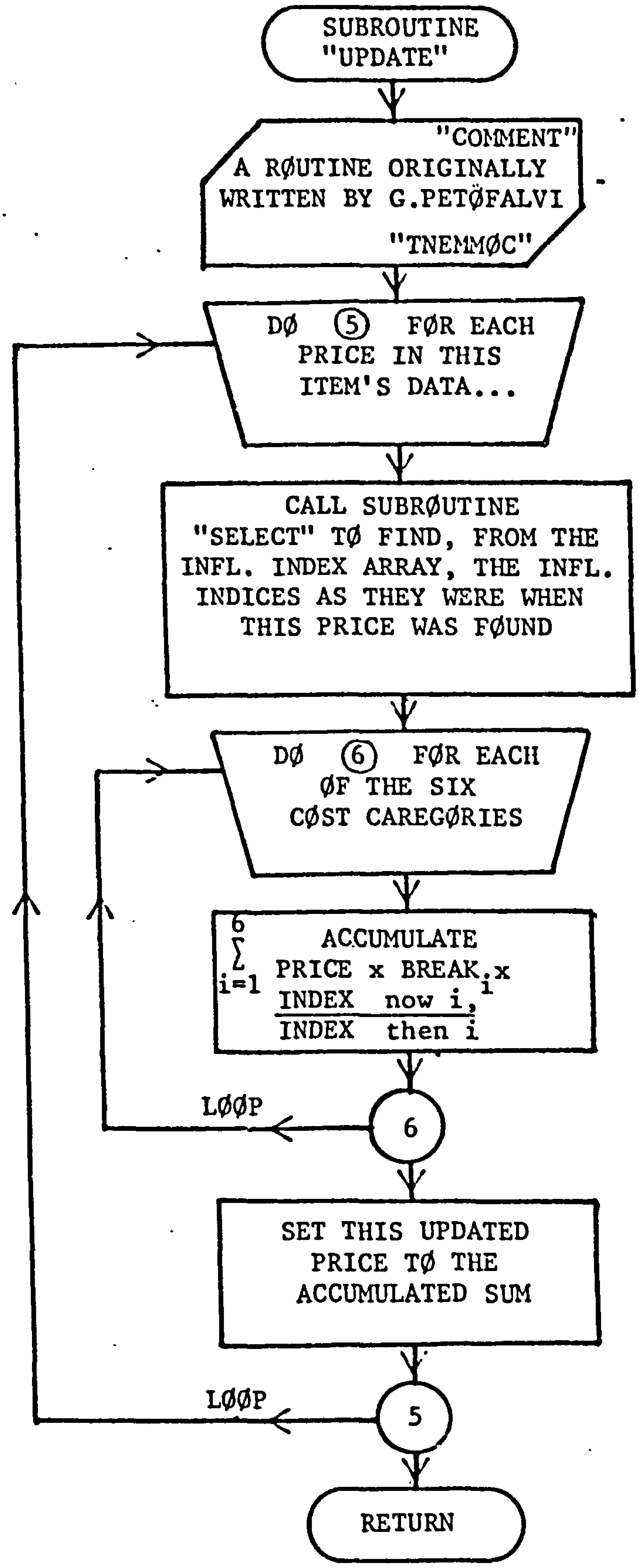


'STATS' continued



'STATS' continued

'STATS' continued



5.4.3. LISTING

```
LOUGHBOROUGH UNIVERSITY COMPUTER CENTRE GEORGE 2L MK3F STREAM A      RUN ON 18/09/75 AT 13.42

         JOB SSDUMP,'CCES1,CAGA2341
         LUFORTRAN
         CREATEDUMP CCCC,PL07,1C
         LUFORTRAN CRO(PL04SOURCE)
         CREATEDUMP CCCC,PL04,1C
         ****

FORTRAN COMPILATION BY #XFAT MK 5A    DATE  18/09/75  TIME  13/42/35

                 LIST
                 SEND TO (ED,SEMICOMPUSER,AXXX)
                 DUMP ON (ED,PROGRAM USER)
                 WORK (ED,WORKFILEUSER)
                 RUN
                 MAP
                 LIBRARY (ED,SUBGROUPUSUR)
                 LIBRARY (ED,SUBGROUPNAGF)
                 PROGRAM (PL07)
                 COMPACT
                 COMPRESS INTEGER AND LOGICAL
                 INPUT  1 = CRO
                 OUTPUT 2 = LPG
                 USE    3 =     /ARRAY
                 OUTPUT 4 = ED1/FORMATTED(USEREDSFILE2(1))
                 INPUT  5 = MTO (PRICELIBRARY)
                 CREATE 6 = ED2/DIRECT(USEREDSFILE3(1))
                 USE    7 =     /NONE
                 INPUT  8 = ED3 (INFL-INDICES)
                 TRACE 1
                 END


                 MASTER PRICE LIBRARY STATS
           C  TRANSCRIBES A GENERAL-PURPOSE CARD DECK TO DISC, AND ADDS MISSING
           C  PARAMETERS.  THE DISC FILE IS THEN SUITABLE INPUT FOR P.L. SIMULATION.
           C  THE MT FILE 'PRICELIBRARY' IS USED TO FIND THE ITEMS' DETAILS.
                 COMMON /ASSOC/IAV
                 DEFINE FILE 6(1992,67,U,IAV)
           C  READ IN INITIAL DETAILS AND INFLATION INDEX TABLE
                 CALL FIRST
           C  PROCESS NEXT PROJECT
               1 CALL PROJECT(ICONT)
           C  IF MORE CONTRACTS TO COME, LOOP BACK
                 IF(ICONT)0,0,1
           C  SUCCESS MESSAGE
                 WRITE(2,2)
               2 FORMAT(1H0/1H0,T40,18HSTATSYSTEM RUN  OK)
                 STOP 'STATSYSTEM RUN  OK'
                 END

END OF SEGMENT, LENGTH    25, NAME  PRICELIBRARYSTATS
```

```
      SUBROUTINE FIRST
C  INITIALISES BUFFER ARRAY, AND LISTING CHANNELS.  ALSO LOADS INFLATION INDEX
C  TABLE INTO COMMON BLOCK.  TERMINATES PROGRAM IF STATSYSTEM RUN UNNECESSARY.
      COMMON /IO/BUFF(10),LISTIN,LISTOUT,LIST  /INFL/N,X(100,6,2)
      LOGICAL KEYW,COMP4
      CALL DEFBUF(3,80,BUFF)
      READ(8)N,X
      CALL RLEASE(8)
C  LISTIN IS LISTING CHANNEL FOR INPUT CARDS.  LISTOUT IS THAT FOR OUTPUT
C  RECORDS.  LIST IS 'LPO' IF ANY LISTING AT ALL WILL HAPPEN, ELSE 'NONE'
      LISTIN,LISTOUT,LIST=2
      WRITE(LIST,1)
    1 FORMAT(1H1)
      CALL INBUF
C  ENSURE THAT STATSYSTEM RUN IS ACTUALLY REQUIRED
      IF(.NOT.KEYW(4HSTAT))GO TO 7
      READ(3,2)LISTS
    2 FORMAT(10X,A4)
C  IF 'NOLI', ONLY LIST OUTPUT RECORDS
      IF(COMP4(LISTS,4HNOLI))LISTIN=7
C  IF 'SHRT', DO NOT LIST EITHER
      IF(COMP4(LISTS,4HSHRT))LISTIN,LISTOUT,LIST=7
      WRITE(LIST,3)
    3 FORMAT(1H0/1H0)
      WRITE(LISTIN,4)
    4 FORMAT(1H+,T26,5HINPUT)
      WRITE(LISTOUT,5)
    5 FORMAT(1H+,T64,6HOUTPUT)
      WRITE(LIST,6)
    6 FORMAT(1X)
      RETURN
C  TERMINATE RUN
    7 WRITE(2,8)
    8 FORMAT(1H0,T8,27HSTATSYSTEM RUN NOT REQUIRED/1H0,T23,
     118HPROGRAM TERMINATES)
      STOP 'STATSYSTEM RUN ABORTED'
      END

END OF SEGMENT, LENGTH   102, NAME  FIRST


      SUBROUTINE PROJECT(/ICONT/)
C  CO-ORDINATES THE ANALYSIS OF ONE CONTRACT.
      COMMON /IO/J,IMORE
      LOGICAL COMP4
C  READ IN PROJECT DEFINITION CARDS AND LOAD THE RELEVANT LIBRARY ONTO DISC
      CALL LIBINIT
C  PROCESS ONE 'ITEM' CARD
    1 CALL ITEM(ICON)
C  IF MORE ITEMS TO COME, LOOP BACK
      IF(ICON)0,0,1
C  IF SECOND WORD OF 'END' CARD IS 'MORE', SET CONTINUATION INDICATOR
      ICONT=0
      IF(COMP4(IMORE,4HMORE))ICONT=1
      RETURN
      END

END OF SEGMENT, LENGTH    30, NAME  PROJECT
```

```
      SUBROUTINE INBUF
C   READS THE NEXT CARD INTO THE BUFFER ARRAY AND LISTS IT ON THE INPUT LISTING
C   CHANNEL.  CARDS BEGINNING 'COMM' ARE LISTED ON THE GENERAL LISTING CHANNEL
C   BUT ARE OTHERWISE IGNORED.
      COMMON /IO/BUFF(10),LISTIN,L,LIST
      LOGICAL KEYW
    4 READ(1,1,END=2)BUFF
    1 FORMAT(10A8)
      IF(KEYW(4HCOMM))GO TO 5
      WRITE(LISTIN,3)BUFF
    3 FORMAT(1X,10A8)
      RETURN
    5 WRITE(LIST,3)BUFF
      GO TO 4
C   ERROR MESSAGE IF DATA STREAM RUNS OUT
    2 CALL EREND(8,30HEND OF INPUT FOUND PREMATURELY)
      END

END OF SEGMENT, LENGTH    44, NAME  INBUF


      LOGICAL FUNCTION KEYW(IWORD)
C   RETURNS '.TRUE.' IF THE KEYWORD OF THE CURRENT CARD MATCHES THE 4-CHARACTER
C   STRING PROVIDED; '.FALSE.' OTHERWISE.
      COMMON /IO/KWORD
      LOGICAL COMP4
      KEYW=COMP4(KWORD,IWORD)
      RETURN
      END

END OF SEGMENT, LENGTH    23, NAME  KEYW


      SUBROUTINE EREND(N,MESSAGE)
C   PRINTS OUT THE N-WORD MESSAGE AND INITIATES A POST-MORTEM
      DIMENSION MESSAGE(N)
      WRITE(0,1)MESSAGE
    1 FORMAT(14H ****ERROR****,4X,20A4)
      PAUSE 'ERROR IN STATSYSTEM RUN'
      END

END OF SEGMENT, LENGTH    36, NAME  EREND


      LOGICAL FUNCTION COMP4(IWORD,ITEST)
C   RETURNS '.TRUE.' IF THE TWO 4-CHARACTER STRINGS SUPPLIED ARE IDENTICAL;
C   '.FALSE.' OTHERWISE.
      K=4
      CALL COMP(K,IWORD,1,ITEST,1)
      COMP4=K.EQ 4
      RETURN
      END

END OF SEGMENT, LENGTH    39, NAME  COMP4
```

```
      SUBROUTINE LIBRINIT
C   INTERPRETS THE 'PROJ' AND 'INDX' CARDS, AND SETS UP THE MAIN P.L. DATA AND
C   ASSIGNS THE CURRENT INFLATION INDICES.
      COMMON /INFL/N,X(100,6,2),TODAY(6)  /IO/R(11),LIST
      LOGICAL KEYW
      WRITE(LIST,1)
    1 FORMAT(1H0)
      CALL INBUF
      IF(.NOT.KEYW(4HPROJ))CALL EREND(5,20H'PROJ' CARD EXPECTED)
C  READ AND CHECK LIBRARY POSITION
      READ(3,2)NLIB
    2 FORMAT(T50,I1)
      IF(NLIB.LT.1.OR.NLIB.GT.6)CALL EREND(7,27HLIBRARY NUMBER OUT OF RA
     1NGE)
      CALL OUTBUF
C  READ IN P.L. DATA
      CALL MTTOFD(NLIB)
      CALL INBUF
      CALL OUTBUF
      CALL INBUF
      IF(.NOT.KEYW(4HINDX))CALL EREND(5,20H'INDX' CADR EXPECTED)
      READ(3,3)TODAY
    3 FORMAT(5X,6F5.3)
      RETURN
      END

END OF SEGMENT, LENGTH    67, NAME  LIBRINIT

      SUBROUTINE ITEM(/ICON/)
C   READS IN ONE 'ITEM' CARD, AND, IF NECESSARY, READS IN THE ITEM'S DETAILS
C   FROM DISC IN ORDER TO ESTIMATE THE REQUIRED PARAMETERS.  THEN WRITES ONE
C   'ITEM' RECORD TO THE OUTPUT FILE.
      COMMON /US/PDATA(400,3),NP,COST(6),CCOST(6)
      DIMENSION RES(20),UPD(400)
      LOGICAL KEYW,COMP4
      ICON=1
   14 CALL INBUF
      IF(KEYW(3HEND))GO TO 1
      IF(KEYW(4HCOST))GO TO 14
      IF(.NOT.KEYW(4HITEM))CALL EREND(5,20H'ITEM' CARD EXPECTED)
C  IF 'CARD' PARAMETERS, JUST COPY ACROSS TO THE OUTPUT FILE
      READ(3,2)ISYST
    2 FORMAT(T26,A4)
      IF(.NOT.COMP4(ISYST,4HCARD))GO TO 3
      CALL OUTBUF
      RETURN
C  READ QUANTITY AND DISTRIBUTION CODE, AND ASSIGN DISTRIBN. TYPE NUMBERS
    3 READ(3,4)IDIS,QTY
    4 FORMAT(T21,A4,T31,F10.0)
      KDIS=0
      IF(COMP4(IDIS,4HNORM))KDIS=1
      IF(COMP4(IDIS,4HLOGN))KDIS=2
      IF(COMP4(IDIS,4HNEGR))KDIS=4
      IF(KDIS.EQ.0)CALL EREND(7,25HDISTRIBUTION CODE INVALID)
C  READ ITEM NUMBER AND GET ITS PDATA ARRAY THROUGH COMMON
      READ(3,5)ITEM
```

```
      5 FORMAT(9X,I6)
        CALL GETPD(ITUM)
C  IF NO DATA EXISTS FOR THIS ITEM, PRINT A WARNING AND IGNORE THIS ITEM
        IF(NP.GT.0)GO TO 17
        CALL WARNPR(9,36HNO DATA FOUND FOR THIS ITEM: IGNORED)
        RETURN
C  IF NO COST BREAKDOWN ON RECORD, USE THE EXISTING ONE
     17 IF(COST(1).LT.0.)CALL FMOVE(CCOST(1),COST(1),6)
C  INFLATION-UPDATE PRICES IN PDATA ARRAY: ANSWERS APPEAR IN UPD ARRAY
        CALL UPDATE(NP,PDATA,UPD,COST)
C  ACCORDING TO DISTRIBUTION TYPE, CALCULATE AND WRITE PARAMETERS
        GO TO (6,7,0,8),KDIS
C  'NORM';MEAN AND STANDARD DEVIATION
      6 AVE=UTS1(NP,UPD(1))
        SD=UTS6(NP,UPD(1),AVE)
        WRITE(3,9)ITUM,QTY,AVE,SD
      9 FORMAT(4HITEM,I11,5X,10HNORM SYST ,3F10.2)
        GO TO 10
C  'LOGN': MEAN AND S.D. OF LOGS
      7 DO 11 I=1,NP
     11 UPD(I)=ALOG(UPD(I))
        AVE=UTS1(NP,UPD(1))
        SD=UTS6(NP,UPD(1),AVE)
        WRITE(3,12)ITUM,QTY,AVE,SD
     12 FORMAT(4HITEM,I11,5X,10HLOGN SYST ,F10.2,2F10.5)
        GO TO 10
C  'REGR': CONSTANT, COEFFICIENT OF QUANTITY, AND S.D. OF RESIDUALS
      8 IFAIL=1
        CALL G02CAF(NP,PDATA(1,2),UPD,RES,IFAIL)
C  IF REGRESSION IS NOT VALID, TREAT THIS ITEM AS A 'NORM'
        IF(IFAIL)0,18,0
        CALL WARNPR(10,38HREGRESSION FAILS: CONVERTING TO 'NORM')
        GO TO 6
     18 SDR=SQRT(RES(18))
        WRITE(3,13)ITUM,QTY,RES(7),RES(6),SDR
     13 FORMAT(4HITEM,I11,5X,10HREGR SYST ,2F10.2,F10.5,F10.2)
        GO TO 10
C     OUTPUT 'ITEM' RECORD
     10 CALL OUTBUF
        RETURN
C  'END' CARD FOUND: CLEAR CONTINUATION INDICATOR
      1 ICON=0
        GO TO 10
C  'COST' CARD FOUND: READ IN DEFAULT COST BREAKDOWN
     14 READ(3,15)CCOST
     15 FORMAT(5X,6F5.3)
        AVE=UTS1(6,CCOST(1))
        IF(ABS(6.*AVE-1.).GT.0.01)CALL EREND(10,37HCOST BREAKDOWN DOES NOT
      1 ADD UP TO 1.0)
        GO TO 16
        END

END OF SEGMENT, LENGTH   282, NAME  ITEM

        SUBROUTINE OUTBUF
C   OUTPUTS THE BUFFER ARRAY TO THE FILE, AND LISTS IT ON THE OUTPUT LISTING
C   CHANNEL.
        COMMON /IO/BUFF(10),L,LISTOUT
        WRITE(4,1)BUFF
```

```
    1 FORMAT(10A8)
      WRITE(LISTOUT,2)BUFF
    2 FORMAT(T41,10A8)
      RETURN
      END

END OF SEGMENT, LENGTH    26, NAME  OUTBUF


      SUBROUTINE MTTOED(NLIB)
C  TRANSCRIBES THE 'NLIB'TH LIBRARY ON THE P.L. TAPE TO DISC.
      DIMENSION COST(6),DESC(8)
      COMMON /ITEMS/NI,ITNO(1000),ITAV(1000)  /WS/PDATA(400,3)
    1        /ASSOC/IAV
C  SKIP TO CORRECT POSITION ON TAPE
      CALL GOTOLIB(NLIB)
C  READ IN INITIAL ARRAYS
      READ(5)LIB,NI,ITNO
C  COPY ACROSS THE ITEM DETAILS
      DO 1 K=1,NI
      READ(5)ITEM,NP,COST,DESC,((PDATA(I,J),I=1,NP),J=1,3)
      ITAV(K)=IAV
    1 WRITE(6'IAV)ITEM,NP,COST,DESC,((PDATA(I,J),I=1,NP),J=1,3)
      RETURN
      END

END OF SEGMENT, LENGTH   115, NAME  MTTOED


      SUBROUTINE GETPD(ITEM)
C  READS IN THE PDATA ARRAY (ETC.) FOR THE SPECIFIED ITEM AND PASSES IT
C  THROUGH COMMON.
      COMMON /WS/PDATA(400,3),NP,COST(6)  /ITEMS/K(1001),ITAV(1000)
      DIMENSION DESC(8)
C  FIND THIS ITEM IN THE INITIAL ARRAYS
      LOC=IBINSEARCH(ITEM)
C  IF UNFOUND, SET NO. OF PRICES TO ZERO
      IF(LOC)1,1,0
C  READ THE RECORD AND CHECK THE ITEM NUMBER
      READ(6'ITAV(LOC))ITCHK,NP,COST,DESC,((PDATA(I,J),I=1,NP),J=1,3)
      IF(ITCHK.NE.ITEM)CALL ERFND(12,48HLOGIC ERROR IN GETPD; WRONG ITEM
     1'S DETAILS FOUND)
      RETURN
    1 NP=0
      RETURN
      END

END OF SEGMENT, LENGTH    77, NAME  GETPD


      SUBROUTINE WARNPR(N,MESSAGE)
C  PRINTS THE N-WORD WARNING AND RETURNS
      DIMENSION MESSAGE(N)
      WRITE(0,1)MESSAGE
    1 FORMAT(10H *WARNING*,4X,20A6)
      WRITE(0,2)
```

```
      2 FORMAT(1X)
        RETURN
        END

END OF SEGMENT, LENGTH    34, NAME  WARNPR

        SUBROUTINE UPDATE(NP,PDATA,RESULT,BREAK)
C     FORMS A VECTOR CORRESPONDING TO THE FIRST COLUMN OF THE PDATA ARRAY,
C     CONTAINING THE PRICES IN THAT COLUMN, INFLATION UPDATED.
        DIMENSION PDATA(400,3),RESULT(NP),BREAK(6),XN(6)
        COMMON /INFL/N,X(100,6,2),UPI(6)
        INTEGER DATE
C     FOR EACH PRICE (ROW OF PDATA)
        DO 1 K=1,NP
        DATE=NINT(PDATA(K,3))
C     FILL THE XN ARRAY WITH THE INDICES AS THEY WERE THEN
        CALL SELECT(DATE,XN)
C     ACCUMULATE THE UPDATED PRICE
        SUM=0.
        DO 2 I=1,6
      2 SUM=SUM+PDATA(K,1)*BREAK(I)*UPI(I)/XN(I)
      1 RESULT(K)=SUM
        RETURN
        END

END OF SEGMENT, LENGTH    84, NAME  UPDATE

        SUBROUTINE GOTOLIB(NLIB)
C     SKIPS TO THE 'NLIB'TH LIBRARY ON THE P.L. TAPE
        REWIND 5
        IF(NLIB.EQ.1)RETURN
        DO 1 I=1,NLIB-1
        READ(5)LIB,NI
        DO 1 J=1,NI
      1 READ(5)
        RETURN
        END

END OF SEGMENT, LENGTH    58, NAME  GOTOLIB

        FUNCTION IBINSEARCH(ITEM)
C     PERFORMS A BINARY SEARCH OF THE ITNO ARRAY, LOOKING FOR ITEM-NO. 'ITEM',
C     RETURNS ZERO IF UNFOUND.
        COMMON /ITEMS/NI,ITNO(1000)
        LOC=0
C     ASSIGN STEP LENGTH AND DIRECTION
        ISTEP=2**IFIX(ALOG2(FLOAT(NI)))
        IF(ISTEP GE.NI)ISTEP=ISTEP/2
        IDIR=+1
C     STEP ALONG ARRAY IN DIRECTION IDIR, A NON-ZERO LENGTH ISTEP
      4 IF(ISTEP)1,1,6
        LOC=LOC+IDIR*ISTEP
C     HALVE STEP LENGTH, THEN DECIDE WHICH DIRECTION TO STEP NEXT
```

```
      ISTEP=ISTEP/2
      IF(LOC-NT )0,0,2
      IF(ITEM-ITNO(LOC))2,0,3
C  FOUND
      IBINSEARCH=LOC
      RETURN
C  IT'S LOWER DOWN THE ARRAY
    2 IDIR=-1
      GO TO 4
C  IT'S HIGHER UP THE ARRAY
    3 IDIR=+1
      GO TO 4
C  NOT FOUND
    1 IBINSEARCH=0
      RETURN
      END

END OF SEGMENT, LENGTH    79, NAME  IBINSEARCH

      SUBROUTINE SELECT(DATE,XN)
C   FINDS WHAT THE INFLATION INDICES WERE AT DATE 'DATE' , AND PASSES THEM BACK
C   THROUGH THE ARRAY.
      DIMENSION XN(6)
      COMMON /INFL/N,X(100,6,2)
      INTEGER DATE
      DO 1 J=1,N
      JC=N+1-J
      ID=NINT(X(JC,1,2))
      IF(ID.GT.DATE)GO TO 1
      DO 2 I=1,6
    2 XN(I)=X(JC-1,I,1)
      RETURN
    1 CONTINUE
      CALL EREND(8,31HDATE OF A PRICE IS TOO LONG AGO)
      END

END OF SEGMENT, LENGTH    80, NAME  SELECT

      BLOCK DATA DEFAULT BREAK
C   SETS THE DEFAULT COST BREAKDOWN
      COMMON /US/R(400,3),N,R2(6),CCOST(6)
      DATA CCOST/0.17,0.16,0.17,0.17,0.16,0.17/
      END

      FINISH
```

5.5. THE SIMULATION PROGRAM

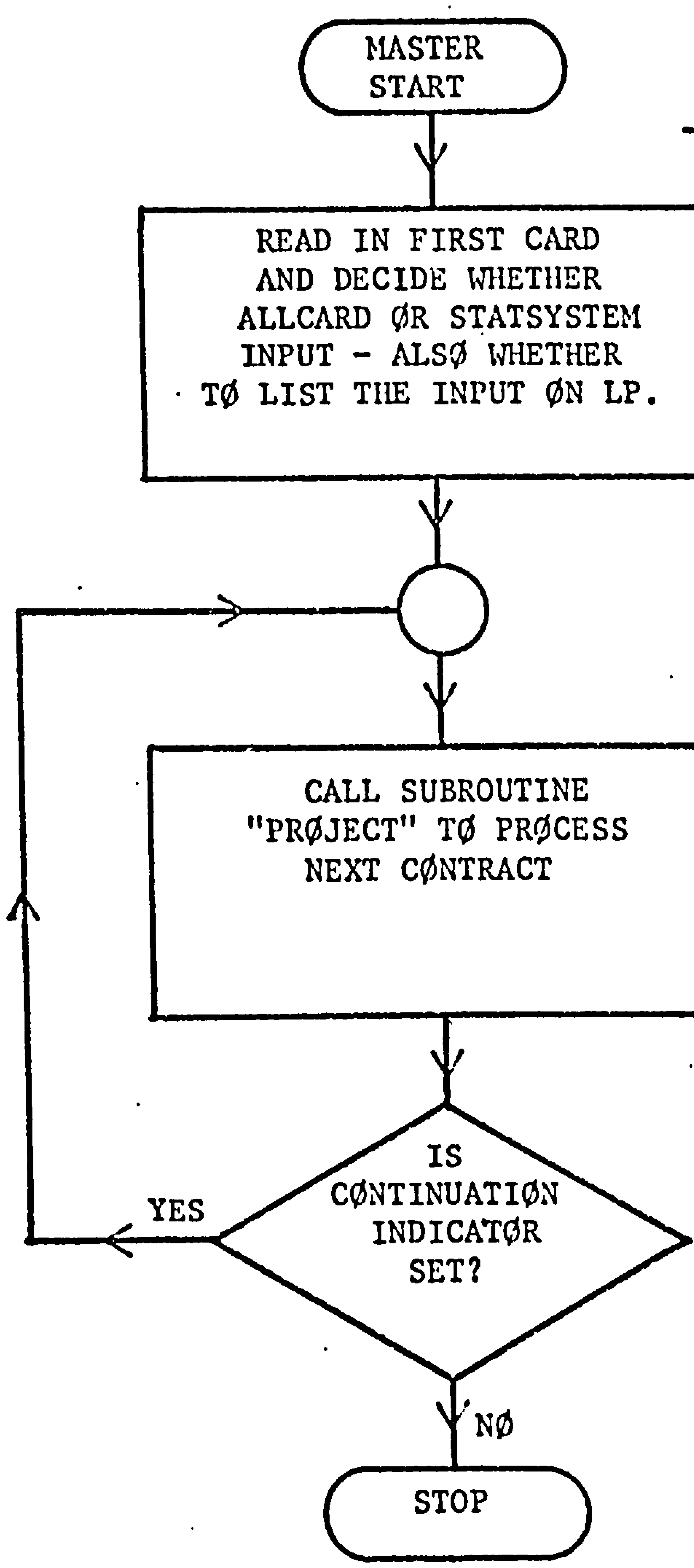
5.5.1. DESCRIPTION.

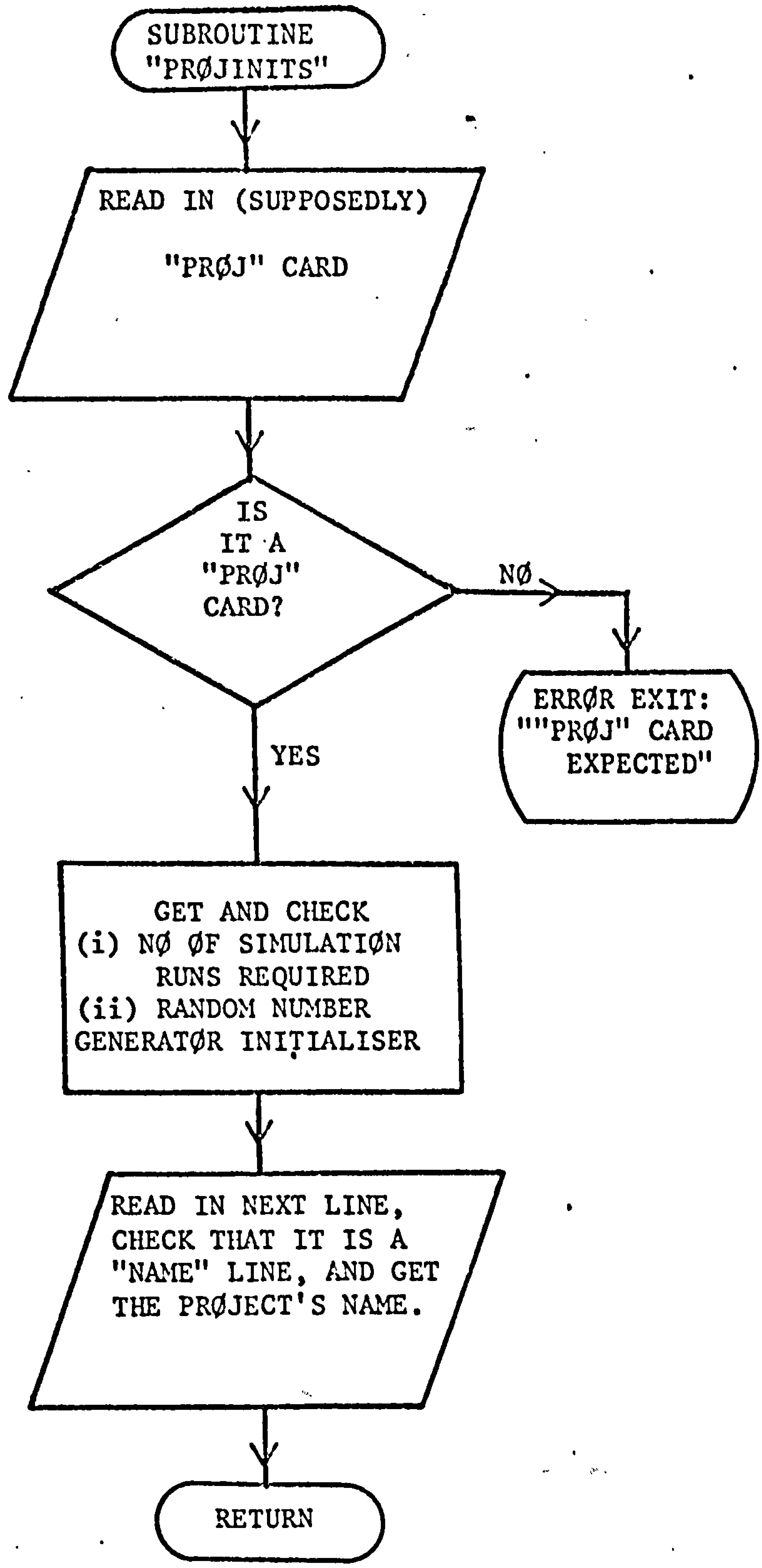
This program accepts input from cards or from the temporary file created by the 'STAT' program.
In addition to the methods of describing price variability created by the 'STAT' program, namely normal, log-normal distributions and regression models, the card input also offers a triangular distribution specified by the mode, the largest and smallest unit price recorded.
The program calculates and prints the mean tender price based on the mean of each item and outputs the contribution to the tender price of each item, ranked in descending order.
The project is simulated 'n' times by randomly selecting unit prices from the distribution of possible unit prices and calculating the total tender price.
The output is a list of 'n' projects with the total contribution of each item, the total tender price and the mean and standard deviation of the 'n' calculated tender prices.

5.5.2. FLOWCHARTS

FLØWCHART OF PROGRAM PL04,

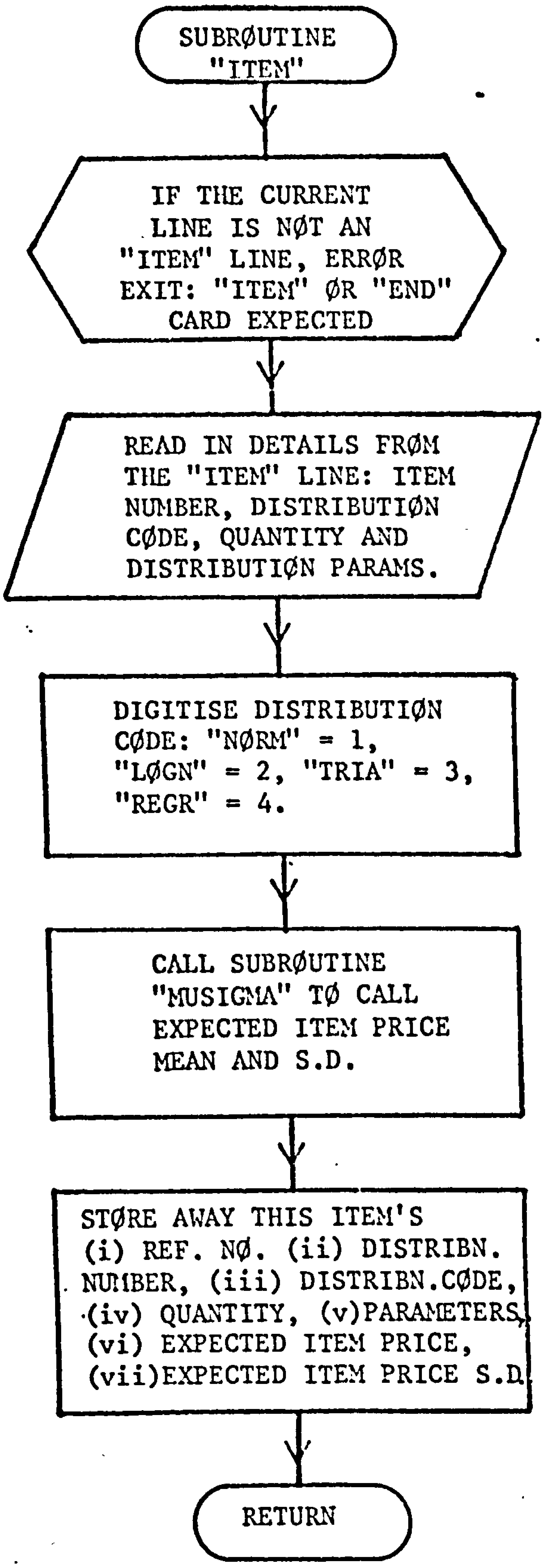
PRICE LIBRARY SIMULATIØN.



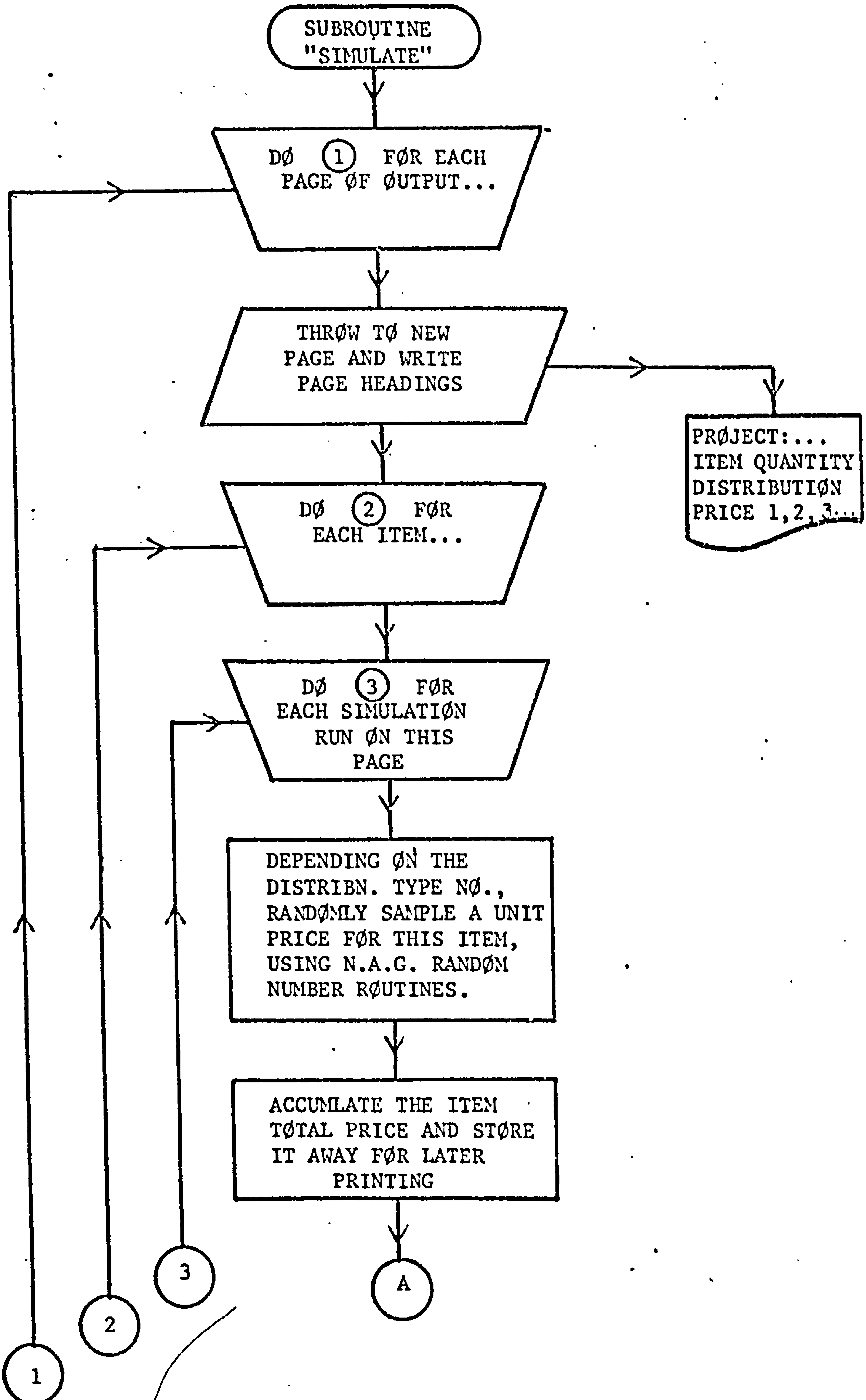

SUBROUTINE "PRØJINITS"
READ IN (SUPPOSEDLY) "PRØJ" CARD
IS IT A "PRØJ" CARD?
NØ
ERRØR EXIT: ""PRØJ" CARD EXPECTED"
YES
GET AND CHECK (i) NØ ØF SIMULATIØN RUNS REQUIRED (ii) RANDOM NUMBER GENERATØR INITIALISER
READ IN NEXT LINE, CHECK THAT IT IS A "NAME" LINE, AND GET THE PRØJECT'S NAME.
RETURN


SUBROUTINE "PRØJECT"
CALL SUBROUTINE "PRØJINITS" TØ READ IN THE INITIAL CØNTRACT CARDS - "PRØJ", "NAME"
READ IN NEXT LINE - SHØULD BE EITHER "ITEM", ØR "END".
IS IT AN "END" LINE?
YES
NØ
CALL SUBROUTINE "ITEM" TØ SET UP THE PARAMETERS FØR THIS ITEM
DØES "MØRE" APPEAR?
YES
NØ
SET CØNTINUATIØN INDICATØR(TØ SHØW THAT MØRE CØNTRACTS ARE TØ CØME)
CLEAR CØNTINUATIØN INDICATØR (TØ SHØW THAT NØ MØRE CONTRACTS ARE TØ CØME)
WRITE ØUT ITEM LIST IN ØRDER ØF (i)EXPECTED CØNTRIBUTIØN (ii)EXPECTED DISPERSIØN
ITEM LIST ØRDERED BY CØNTRIBUTIØN
ITEM LIST ØRDERED BY DISPERSIØN
EXPECTED TØTAL PRICE
CALCULATE AND PRINT EXPECTED TENDER PRICE BY SUMMING EXPECTED ITEM PRICES
ARE ANY SIMULATION RUNS REQUIRED?
INITIALISE THE RANDØM NUMBER SEQUENCE, THEN CALL SUBRØUTINE "SIMULATE" TØ CARRY ØUT THE SIMULATIØN RUNS FØR THIS CØNTRACT
RETURN

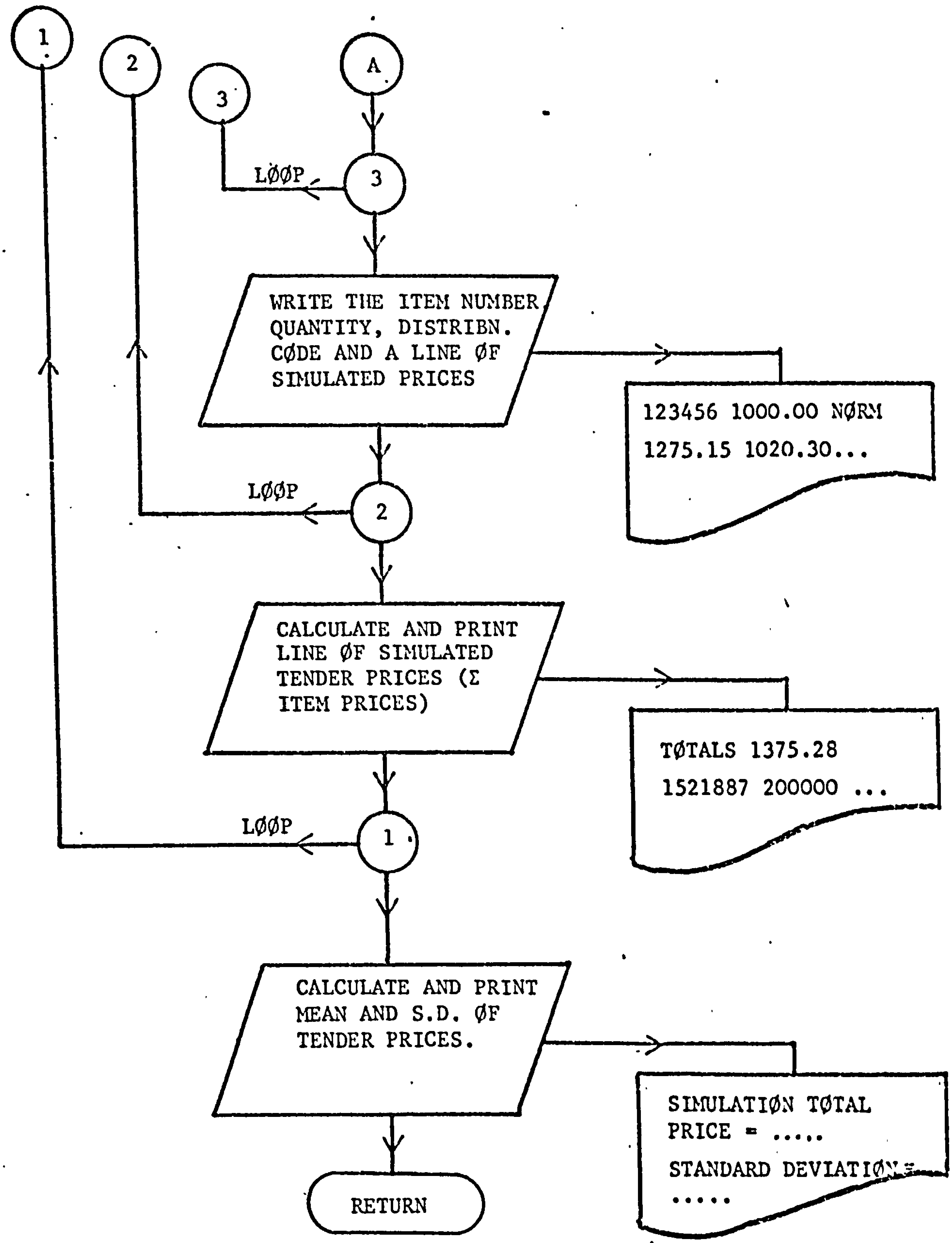
'SIMULATION' continued

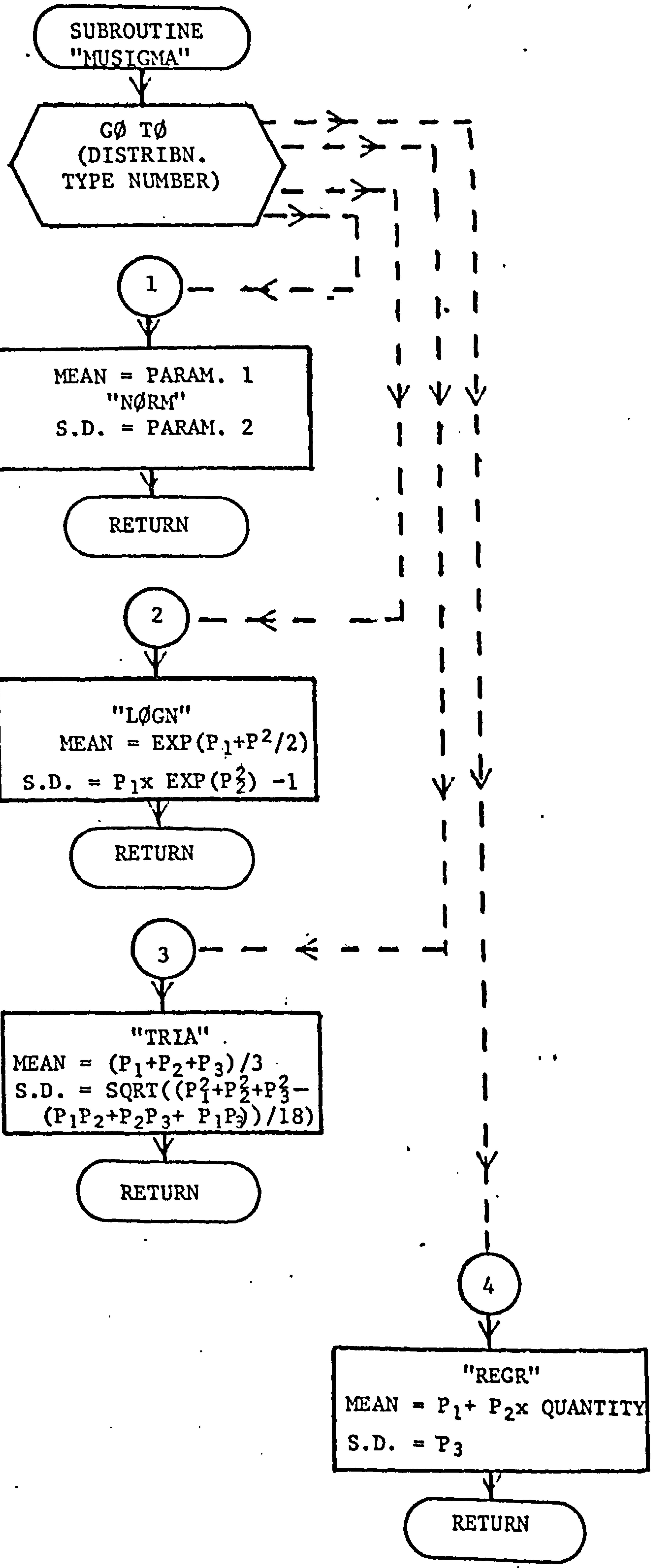


'SIMULATION' continued



'SIMULATION' continued




SUBROUTINE "MUSIGMA"
GØ TØ (DISTRIBN. TYPE NUMBER)
1
MEAN = PARAM. 1
"NØRM"
S.D. = PARAM. 2
RETURN
2
"LØGN"
MEAN = EXP(P1+P2/2)
S.D. = P1x EXP(P2) -1
RETURN
3
"TRIA"
MEAN = (P1+P2+P3)/3
S.D. = SQRT((P1+P2+P3–(P1P2+P2P3+ P1P3))/18)
RETURN
4
"REGR"
MEAN = P1+ P2x QUANTITY
S.D. = P3
RETURN

5.5.3. LISTING

FORTRAN COMPILATION BY #XFAT MK 5A   DATE 18/09/75 TIME 13/52/21

```
          LIST
          SEND TO (ED,SEMICOMPUSER,AXXX)
          DUMP ON (ED,PROGRAM USER)
          WORK (ED,WORKFILEUSER)
          RUN
          MAP
          LIBRARY (ED,SUBGROUPUSUB)
          LIBRARY (ED,SUBGROUPNAGF)
          PROGRAM (PL04)
          COMPACT
          COMPRESS INTEGER AND LOGICAL
          INPUT  1 = CR0
          OUTPUT 2 = LP0
          INPUT  3 =     /ARRAY
          INPUT  4 = ED1/FORMATTED(USEREDSFILE2(1))
          OUTPUT 5 =     /NONE
          TRACE 1
          END


            MASTER PRICE LIBRARY SIMULATION
      C   READS IN THE SEPARATE ITEMS MAKING UP A CONTRACT, AND TAKES RANDOM SAMPLES
      C   FROM THEIR DISTRIBUTIONS OF PRICES.  SUMMARISES THE EXPECTED TOTAL PRICE,
      C   AND, BY SIMULATION, AN ESTIMATE OF THE VARIABILITY; AND HENCE, AN ESTIMATE
      C   OF THE LOWEST BID.  OPTIONS OF INPUT FROM CARDS OR CARD IMAGES, EG FROM THE
      C   STAT/REGRESSION SYSTEM.
            COMMON /BUFFER/BUFF(10),INP,LIST
            LOGICAL KEYW,COMP4
      C  SET UP BUFFER ARRAY AND ALLOCATE INPUT CHANNEL AS CR0, LISTING CHANNEL AS LP0
            CALL DEFBUF(3,80,BUFF)
            INP=1
            LIST=2
            WRITE(2,1)
          1 FORMAT(1H1)
      C  READ INITIAL CARD: KEYWORD 'ALLC'= ALLCARD INPUT: 'STAT'= STATSYSTEM INPUT
            CALL INBUF
```

```
      READ(3,3)ITEX
    3 FORMAT(10X,A4)
      IF(KEYW(4HALLC))GO TO 2
      IF(.NOT.KEYW(4HSTAT))CALL ERFND(6,23HINPUT MODE CARD INVALID)
C  STATSYSTEM INPUT; ONLY LIST DATA IF 'LIST' OR 'SHRT' APPEARS
      INP=4
      LIST=5
      IF(COMP4(ITEX,4HLIST).OR.COMP4(ITEX,4HSHRT))LIST=2
      GO TO 4
C  ALLCARD INPUT; DO NOT LIST DATA IF 'NOLI' APPEARS
    2 IF(COMP4(ITEX,4HNOLI))LIST=5
C  PROCESS NEXT PROJECT
    4 WRITE(LIST,1)
      CALL PROJECT(ICONT)
C  IF CONTINUATION EXPECTED, PROCESS NEXT CONTRACT
      IF(ICONT)0,0,4
      WRITE(2,5)
    5 FORMAT(1H0/1H0,T23,22HPROGRAM TERMINATES  OK)
      STOP 'RUN OK'
      END

END OF SEGMENT, LENGTH    79, NAME  PRICELIBRARYSIMULATION

      SUBROUTINE INBUF
C   READS A RECORD FROM THE SELECTED INPUT CHANNEL INTO THE BUFFER ARRAY, AND
C   LISTS IT ON THE SELECTED LISTING CHANNEL.  LINES BEGINNING 'COMM' ARE LISTED
C   BUT IGNORED.  IF THE DATA STREAM RUNS OUT, AN ERROR MESSAGE IS PRINTED.
      COMMON /BUFFER/BUFF(10),INP,LIST
      LOGICAL KEYW
    1 READ(INP,2,END=3)BUFF
    2 FORMAT(10A8)
      WRITE(LIST,4)BUFF
    4 FORMAT(8X,10A8)
      IF(KEYW(4HCOMM).OR.KEYW(4HINDX).OR.KEYW(4HCOST))GO TO 1
      RETURN
    3 CALL ERFND(8,29HEND OF DATA FOUND PREMATURELY)
      END

END OF SEGMENT, LENGTH    45, NAME  INBUF

      LOGICAL FUNCTION KEYW(KWORD)
C   TESTS THE FIRST FOUR CHARACTERS OF THE CURRENT LINE AGAINST THE PARAMETER.
C   RETURNS '.TRUE.' IF THEY ARE EQUAL, '.FALSE.' OTHERWISE.
      COMMON /BUFFER/IWORD
      LOGICAL COMP4
      KEYW=COMP4(IWORD,KWORD)
      RETURN
      END

END OF SEGMENT, LENGTH    23, NAME  KEYW

      SUBROUTINE ERFND(N,MESSAGE)
C   PRINTS THE SUPPLIED ERROR MESSAGE AND INITIATES A POST-MORTEM.
```

```
      DIMENSION MESSAGE(N)
      WRITE(0,1)MESSAGE
    1 FORMAT(14H ****ERROR****,5X,20A4)
      WRITE(0,2)
    2 FORMAT(1H0,T23,18HPROGRAM TERMINATED)
      PAUSE 'RUN FAILS'
      END

END OF SEGMENT, LENGTH    37, NAME  ERFND


      LOGICAL FUNCTION COMP4(IWORD,ITEST)
C   TESTS THE TWO FOUR-CHARACTER STRINGS AGAINST EACH OTHER; RETURNS '.TRUE.'
C   IF THEY ARE EQUAL, '.FALSE.' OTHERWISE.
      I=4
      CALL COMP(I,IWORD,1,ITEST,1)
      COMP4=I.EQ.4
      RETURN
      END

END OF SEGMENT, LENGTH    39, NAME  COMP4


      SUBROUTINE PROJECT(/ICONT/)
C   PROCESSES AND SIMULATES ONE CONTRACT.  SUPERVISES THE LOADING OF DATA INTO
C   COMMON BLOCKS.
      DIMENSION IXDIS(200),IXCON(200)
      COMMON /PARAMS/IDATA(200,3),RDATA(200,6) /COUNT/NI
     1       /INIT/PROJ(9),NREP,IRAND
      LOGICAL KEYW,COMP4
C  READ IN PROJECT INITIAL DETAILS AND NAME; ZEROISE ITEM COUNT
      CALL PROJINITS
C  READ NEXT 'CARD'
    1 CALL INBUF
C  IS IT THE END OF THE CONTRACT INPUT?
      IF(KEYW(4HEND ))GO TO 2
C  READ IN ITEM DETAILS; NUMBER, DISTRIBUTION, QUANTITY ETC
      CALL ITEM
C  NEXT ITEM
      GO TO 1
C  IF 'MORE' TO COME, SET CONTINUATION INDICATOR
    2 READ(3,3)ITEX
    3 FORMAT(4X,A4)
      ICONT=0
      IF(COMP4(ITEX,4HMORE))ICONT=1
C  TAGSORT INDEX ARRAY TO GIVE DESCENDING ORDER OF CONTRIBUTION AND DISPERSION
      DO 8 I=1,NI
    8 IXCON(I),IXDIS(I)=I
      CALL UTS10(NI,RDATA(1,5),IXCON(1))
      CALL UTS10(NI,RDATA(1,6),IXDIS(1))
C  WRITE OUT ORDERED SUMMARIES
      WRITE(2,4)PROJ
    4 FORMAT(1H1,T20,10HPROJECT:  ,9A8)
      WRITE(2,5)
    5 FORMAT(1H0/35H0ITEM LIST ORDERED BY CONTRIBUTION.)
      WRITE(2,6)
    6 FORMAT(1H0,T10,4HITEM,T17,12HDISTRIBUTION,T34,8HEXPECTED,T48,
     14HEXPECTED/T10,4HCODE,T21,4HCODE,T32,12HCONTRIBUTION,T47,
```

```
                 210HDISPERSION)
                  CALL KEYLIST(IXCON)
                  WRITE(2,4)PROJ
                  WRITE(2,7)
                7 FORMAT(1H0/33H0ITEM LIST ORDERED BY DISPERSION.)
                  WRITE(2,6)
                  CALL KEYLIST(IXDIS)
C  CALCULATE AND PRINT THE EXPECTED TOTAL PRICE
                  EAVE=UTS1(NI,RDATA(1,5))*NI
                  WRITE(2,9)EAVE
                9 FORMAT(1H0/23H0EXPECTED TOTAL PRICE =,F10.0)
C  SET UPPER AND LOWER LIMITS ON INDIVIDUAL ITEM PRICES
                  CALL MINMAX
C  IF NO SIMULATION RUNS REQUIRED, RETURN
                  IF(NREP.LE.0)RETURN
C  INITIALISE RANDOM GENERATORS
                  IF(IRAND.EQ.0)CALL G05RBF
                  IF(IRAND.GT.0)CALL G05RAF(0.001*IRAND)
C  RUN THE SIMULATIONS
                  CALL SIMULATE
                  RETURN
                  END

END OF SEGMENT, LENGTH   157, NAME  PROJECT

                  SUBROUTINE PROJINITS
C   READS THE PROJECT INITIAL CARDS AND LOADS THE INFORMATION INTO COMMON BLOCK
C   /INIT/.  ALSO CHECKS THE SYNTAX.
                  COMMON /INIT/PROJ(9),NREP,IRAND /COUNT/NI
                  LOGICAL KEYW
C  READ 'PROJ' 'CARD'
                  CALL INBUF
                  IF(.NOT.KEYW(4HPROJ))CALL EREND(5,20H'PROJ' CARD EXPECTED)
C  READ AND CHECK NUMBER OF REPETITIONS, AND RANDOMS INITIALISER
                  READ(3,1)NREP,IRAND
                1 FORMAT(28X,I2,7X,I3)
                  IF(NREP.LT.0)CALL EREND(6,21HERROR IN REPEAT COUNT)
                  IF(IRAND.LT.0)CALL EREND(7,28HERROR IN RANDOMS INITIALISER)
C  READ 'NAME' 'CARD'
                  CALL INBUF
                  IF(.NOT.KEYW(4HNAME))CALL EREND(5,20H'NAME' CARD EXPECTED)
C  READ PROJECT NAME
                  READ(3,2)PROJ
                2 FORMAT(2X,9A8)
C  ZERO ITEMS FOUND SO FAR
                  NI=0
                  RETURN
                  END

END OF SEGMENT, LENGTH    67, NAME  PROJINITS

                  SUBROUTINE ITEM
C   LOADS DATA FROM AN 'ITEM' CARD INTO COMMON BLOCK /PARAMS/.  ALSO CALCULATES
C   EXPECTED MEAN AND DISPERSION OF AGGREGATE ITEM PRICE.
                  COMMON /PARAMS/IDATA(200,3),RDATA(200,6) /COUNT/NI
                 1        /US/ITYP,QTY,P1,P2,P3,R5,R6
```

```
      LOGICAL KEYW,COMP4
      IF(.NOT.KEYW(4HITEM))CALL FREND(8,29H'ITEM' OR 'END' CARD EXPECTED
     1)
C  READ IN ITEM CODE, DISTRIBUTION CODE, QUANTITY AND DISTRIBUTION PARAMETERS
      READ(3,1)IT,IDIS,QTY,P1,P2,P3
    1 FORMAT( 9X,I6,5X,A4,6X,4F10.0)
C  CHECK QUANTITY AND ASSIGN DISTRIBUTION TYPE NUMBER; 1=NORMAL, 2=LOGNORMAL,
C  3=TRIANGULAR AND 4=REGRESSION
      IF(QTY.LE.0.)CALL EREND(5,17HERROR IN QUANTITY)
      ITYP=0
      IF(COMP4(IDIS,4HNORM))ITYP=1
      IF(COMP4(IDIS,4HLOGN))ITYP=2
      IF(COMP4(IDIS,4HTRIA))ITYP=3
      IF(COMP4(IDIS,4HREGR))ITYP=4
C  CALCULATE E[UNIT PRICE] AND APPROX. SORT(E[V[UNIT PRICE]])
      CALL MUSIGMA(R2)
C  INCREMENT NUMBER OF ITEMS FOUND SO FAR
      NI=NI+1
      IF(NI.GT.200)CALL EREND(4,14HTOO MANY ITEMS)
C  FILL NEXT ROW OF PARAMETER ARRAYS
      IDATA(NI,1)=IT
      IDATA(NI,2)=ITYP
      IDATA(NI,3)=IDIS
      RDATA(NI,1)=QTY
      RDATA(NI,2)=P1
      RDATA(NI,3)=P2
      RDATA(NI,4)=P3
      RDATA(NI,5)=R5*QTY
      RDATA(NI,6)=R6*QTY
    2 RETURN
      END

END OF SEGMENT, LENGTH   162, NAME  ITEM

      SUBROUTINE KEYLIST(IXA)
C  PRINTS OUT SOME ITEM DETAILS IN AN ORDER SPECIFIED BY THE INDEX ARRAY
C  SUPPLIED.
      DIMENSION IXA(200)
      COMMON /PARAMS/IDATA(200,3),RDATA(200,6) /COUNT/NI
      DO 1 I=1,NI
      J=IXA(I)
    1 WRITE(2,2)IDATA(J,1),IDATA(J,3),RDATA(J,5),RDATA(J,6)
    2 FORMAT(T9,I6,T21,A4,T32,F11.2,T46,F11.2)
      RETURN
      END

END OF SEGMENT, LENGTH    53, NAME  KEYLIST

      SUBROUTINE MINMAX
C  ASSIGNS MINIMUM AND MAXIMUM ALLOWED VALUES OF ITEM PRICES.  THESE ARE
C  PLACED IN COLUMNS 5 AND 6 OF THE RDATA ARRAY.
      COMMON /PARAMS/IDATA(200,3),RDATA(200,6) /COUNT/NI
C  FOR EACH ITEM
      DO 5 K=1,NI
      ITYP=IDATA(K,2)
      GO TO (1,2,3,1),ITYP
```

```
      CALL ERFND(10,37HDISTRIBUTION TYPE NUMBER OUT OF RANGE)
C  NORMAL OR REGRESSION: 4 STANDARD DEVIATIONS EITHER SIDE OF THE MEAN
    1 R5=RDATA(K,5)-4.*RDATA(K,6)
      R6=RDATA(K,5)+4.*RDATA(K,6)
      GO TO 6
C  LOGNORMAL: BACK-TRANSFORMATION OF 4 'S.D.'S EITHER SIDE OF THE 'MEAN'
    2 R5=EXP(RDATA(K,2)-4.*RDATA(K,3))*RDATA(K,1)
      R6=EXP(RDATA(K,2)+4.*RDATA(K,3))*RDATA(K,1)
      GO TO 6
C  TRIANGULAR: THE EXTREME POINTS OF THE TRIANGLE
    3 R5=RDATA(K,2)*RDATA(K,1)
      R6=RDATA(K,4)*RDATA(K,1)
      GO TO 6
C  MINIMUM PRICE >= 0
    6 RDATA(K,5)=AMAX1(R5,0.)
    5 RDATA(K,6)=R6
      RETURN
      END

END OF SEGMENT, LENGTH   129, NAME  MINMAX

      SUBROUTINE SIMULATE
C   PERFORMS ALL THE SIMULATION ACTIVITIES OF ONE CONTRACT.  OUTPUTS ITEM NOS.,
C   WITH EACH SIMULATION PRICE, AND THE SIMULATION TOTAL PRICES.  ALSO
C   CALCULATES SIMULATION TOTAL PRICE MEAN AND STANDARD DEVIATION.
      COMMON /PARAMS/IDATA(200,3),RDATA(200,6)  /COUNT/NI
     1       /INIT/PROJ(9),NREP
      DIMENSION TOT(7),PRI(7)
      SUM,SUMSQ=0.
C  FOR EACH PAGE
      DO 1 J=1,(NREP-1)/7+1
      MIN=7*(J-1)+1
      MAX=MIN0(7*J,NREP)
C  WRITE HEADINGS
      WRITE(2,2)PROJ,(I,I=MIN,MAX)
    2 FORMAT(1H1,T20,10HPROJECT:  ,9A8/1H0/17H0SIMULATION RUNS./
     11H0,T3,4HITEM,T11,8HQUANTITY,T22,9HDISTRIBN.,7(4X,5HPRICE,I3,1X))
      DO 3 I=1,7
    3 TOT(I)=0.
      MAXI=MAX-MIN+1
C  FOR EACH ITEM
      DO 4 K=1,NI
      IDIS=IDATA(K,2)
C  FOR EACH SIMULATION RUN ON THIS PAGE
      DO 5 I=1,MAXI
C  COUNTS NO. OF RANDOMS SELECTED FOR ONE PRICE
      I=0
C  RANDOMLY SELECT A UNIT PRICE ACCORDING TO THE DISTRIBUTION
   10 GO TO (6,7,8,9),IDIS
    6 UP=G05AEF(RDATA(K,2),RDATA(K,3))
      GO TO 11
    7 UP=G05AFF(RDATA(K,2),RDATA(K,3))
      GO TO 11
    8 UP=TRINVI(G05AAF(X),RDATA(K,2),RDATA(K,3),RDATA(K,4))
      GO TO 11
    9 UP=G05AFF(RDATA(K,2)*RDATA(K,3)*RDATA(K,1),RDATA(K,4))
      GO TO 11
C  ASSIGN ITEM PRICE: IF WITHIN LIMITS, GOTO 12
   11 P=UP*RDATA(K,1)
```

```
      IF(P.GE.RDATA(K,5).AND.P.LE.RDATA(K,6))GO TO 12
C  INCREMENT CYCLE COUNTER AND LOOP BACK, UNLESS IT SEEMS POINTLESS
      I=I+1
      IF(I-20)10,0,0
      CALL ERFND(7,27HINFINITE LOOP IN SIMULATION)
C  STORE AND ACCUMULATE ITEM PRICE
   12 PRI(L)=P
    5 TOT(L)=TOT(L)+P
C  WRITE THIS ITEM'S LINE OF PRICES ETC
    4 WRITE(2,13)IDATA(K,1),RDATA(K,1),IDATA(K,3),(PRI(L),L=1,MAXL)
   13 FORMAT(1X,I6,F11.2,5X,A4,3X,7(F13.2))
C  ACCUMULATE EXPECTED TOTAL PRICES, AND THEIR SQUARES
      DO 14 L=1,MAXL
      SUM=SUM+TOT(L)
   14 SUMSQ=SUMSQ+TOT(L)**2
C  WRITE SIMULATION TOTAL PRICES
    1 WRITE(2,15)(TOT(L),L=1,MAXL)
   15 FORMAT(1H0,T16,6HTOTALS,T31,7(F13.2))
C  CALCULATE AND PRINT MEAN AND S.D. OF SIMULATION TOTAL PRICES
      AVE=SUM/NREP
      SD=0.
      IF(NREP.GT.1)SD=SQRT((SUMSQ-NREP*AVE*AVE)/(NREP-1.))
      WRITE(2,16)AVE,SD
   16 FORMAT(1H0/25H0SIMULATION TOTAL PRICE =,F10.0/
     13X,22HSTANDARD DEVIATION    =,F10.0)
      RETURN
      END

END OF SEGMENT, LENGTH   347, NAME  SIMULATE

      SUBROUTINE MUSIGMA(*)
C   DEPENDING ON THE TYPE OF DISTRIBUTION, CALCULATES THE EXPECTED VALUE OF AN
C   ITEM UNIT PRICE, AND THE EXPECTED STANDARD DEVIATION OF THIS VALUE.
C   ALL DATA PASSED THROUGH COMMON.  SYNTAX CHECKS PERFORMED.
      COMMON /WS/ITYP,QTY,P1,P2,P3,R5,R6
C  DEPENDING ON TYPE, TRANSFER CONTROL
      IF(ITYP.EQ.0)CALL ERITM(8,32HDISTRIBUTION TYPE NOT RECOGNISED,&5)
      GO TO (1,2,3,4),ITYP
C  NORMAL: PARAMETERS AS GIVEN
    1 IF(P1.LE.0.)CALL ERITM(5,20HERROR IN PARAMETER 1,&5)
      IF(P2.LT.0.)CALL ERITM(5,20HERROR IN PARAMETER 2,&5)
      R5=P1
      R6=P2
      RETURN
C  LOGNORMAL: BACK-TRANSFORMED PARAMETERS AS GIVEN
    2 IF(P2.LT.0.)CALL ERITM(5,20HERROR IN PARAMETER 2,&5)
      B=P2*P2
      R5=EXP(P1+ B/2.)
      R6=R5*(EXP( B)-1.)
      RETURN
C  TRIANGULAR: INTEGRAL METHODS APPLIED TO THE PARAMETERS
    3 IF(P1.LE.0.)CALL ERITM(5,20HERROR IN PARAMETER 1,&5)
      IF(P2.LE.P1)CALL ERITM(5,20HERROR IN PARAMETER 2,&5)
      IF(P3.LE.P2)CALL ERITM(5,20HERROR IN PARAMETER 3,&5)
      R5=(P1+P2+P3)/3.
      R6=SQRT((P1*P1+P2*P2+P3*P3-(P1*P2+P2*P3+P1*P3))/18.)
      RETURN
C  REGRESSION: MODEL PRICE AND S.D. OF RESIDUALS
    4 IF(P1.LE.0..AND.P2.LE.0.)CALL ERITM(4,15HPARAMETER ERROR,&5)
```

```
      IF(P3.LT.0.)CALL ERITM(5,20HERROR IN PARAMETER 3,&5)
      R5=P1+P2*QTY
      IF(R5.LE.0.)CALL ERITM(8,30HNEGATIVE PRICE FROM REGRESSION,&5)
      R6=P3
      RETURN
    5 RETURN 1
      END

END OF SEGMENT, LENGTH   263, NAME  MUSIGMA

      FUNCTION TRINVI(Z,A,B,C)
C  CALCULATES THE ABSCISSA OF A TRIANGULAR GRAPH SUCH THAT THE INTEGRAL OF THE
C  GRAPH FROM -INFINITY TO THAT VALUE IS 'Z' PROPORTION OF THE TOTAL AREA -
C  HENCE 'TRI'ANGULAR 'INV'ERSE 'I'NTEGRAL.
C  LET Y BE THE ACTUAL AREA, ASSUMING HEIGHT=1
      Y=Z*0.5*(C-A)
C  DECIDE IN WHICH PORTION OF THE DOMAIN THE ANSWER WILL BE
      IF(Y-0.5*(B-A))1,0,2
C  AT THE PEAK
      TRINVI=B
      RETURN
C  BEFORE THE PEAK
    1 TRINVI=A+SQRT(2.*Y*(B-A))
      RETURN
C  AFTER THE PEAK
    2 TRINVI=B+(2.*Y-B+A)**2/(C-B)
      RETURN
      END

END OF SEGMENT, LENGTH    74, NAME  TRINVI

      SUBROUTINE ERITM(N,MESSAGE,*)
C   PRINTS THE SUPPLIED ERROR MESSAGE AND RETURNS TO PARAMETER 3.
      DIMENSION MESSAGE(N)
      WRITE(0,1)MESSAGE
    1 FORMAT(12H ***ERROR***,4X,20A4)
      WRITE(0,2)
    2 FORMAT(28H ***ERROR***     ITEM IGNORED/)
      RETURN 1
      END

END OF SEGMENT, LENGTH    34, NAME  ERITM

      FINISH
```

6.0. RUNNING THE SYSTEM AT L.U.C.C.
(ante filing system)

When all the programs have been tested, they will be compiled by # X FAT and dumped on the Civil Department tape. Thus, to simulate a batch of contracts, the following cards would be needed:

```
JØB PL,LCCES1, <usernumber>
CARTRIDGE # 100022
VØLUME 6000
EDSFILES 2,3
RECALLDUMP CCCC,PL07
DØWN 22
RUN
RECALLDUMP CCCC,PL04
DØWN 22
RUN
****
DØCUMENT DATA
        - general purpose data deck, beginning 'STAT'
        - and finishing with 'END'
****
```

On the Yellow Card, a Recalldump of Dept. letter C should be requested and Cartridge Serial No. # 100022, and the master PRICE LIBRARY tape, at present L.U.C.C. file No.6.

The maximum core size is 17K.

If the system runs perfectly, the line printer listings should finish with "PRØGRAM TERMINATES ^ ØK" and the display "RUN ^ ØK" should appear in the monitor file.

APPENDIX U

Brief descriptions of the computer programs specifically developed for the analyses and work undertaken as described in the rest of this document

COMPUTER PROGRAMS

This list of 55 programs gives very brief details of the programs specifically developed to undertake the work previously described.

All programs were written in FORTRAN and run on Loughborough University of Technology's I.C.L. 1904A computer.

Apart from the initial programs which accept the raw data from cards most of the others accessed the raw data and the derived or transformed versions from magnetic tape files.

The programs listed here are available in the unpublished working papers relating to this work in the Department of Civil Engineering, Loughborough University of Technology.

PROGRAMS FOR HANDLING RAW DATA

DEVINGE READ

Reads raw data from cards (see appendix B), performs some error checks, lists on line printer and magnetic tape file

83 statements

CHRONIQUE READ

Reads raw data punched on cards (see appen dix B), performs some data checks and writes the data to magnetic tape file

114 statements, 3 sub routines

DELETIONS

Performs error checks on original data tapes and deletes contracts with errors

78 statements

PROGRAMS FOR CALCULATING STATISTICS RELATION TO

DISTRIBUTION OF BIDS

NOT GROUPED

Calculates the statistics described in section 4.1 and appendix C and shown in tables 4.1 and 4.2 and figures 4.2, 4.3, 4.4 and 4.5.

294 statements, 1 subroutine

STATSCHECK

Performs some checking calculations on the statistics produced by "NOTGROUPED"

144 statements, 1 subroutine

ANDDAR

Calculates Anderson-Darling statistics, see appendix E and tables 4.5 and 4.6.

204 statements, 3 subroutines

LOG ANDDAR

As above except for log transformations

TRANS ANDDAR

As above except calculates transformations as detailed in section 4.3

DOWN DEVIATIONS

Calculates standard deviations by Downton's method (see appendix G)

59 statements

OUTLIER - CALCULATES OUTLIER STATISTIC

Calculates Grubb's statistics, section 4.5 and appendix H. Outputs Grubb's statistics based on overall standard deviation and standard deviation of each group of contracts with 'n' bidders.

97 statements, 1 subroutine

OUTLIER 2

An improved version of outlier

59 statements

LOWN

Calculates the average observed value of the lowest standardised bid

119 statements, 1 subroutine

LOW BID ANALYSIS

Checks calculations of LOWN and produces the data for tables 4.8 and 4.9.

97 statements, 1 subroutine

PROGRAMS FOR ANALYSING INDIVIDUAL

CONTRACTORS BIDDING BEHAVIOUR

BIDHISTORY TAPES

Calculates the data output by BISHISTORY print and files on magnetic tape.

149 statements, 2 subroutines

BISHISTORY PLOT

For each contractor calculates and plots line printer graphs of contract reference number, transformed position, standardised bid and difference between contractors bid and winning bid or second lowest, see section 5.0 and table 5.1.

50 statements

BIDHISTORY PRINT

For each contractor tabulates contract reference number, date, mean bid, bid, position, number of bidders, transformed position, standardised bid and difference between contractors bid and winning bid or second lowest

63 statements, 1 function

STATBIDTIME

For each contractor calculates the average of mean standardised bid and the variance, skewness and kurtosis.

129 statements, 1 subroutine

BIDTIME

An alternative version to STATBIDTIME with different output

153 statements, 1 subroutine

SAVESORT

Sorts lists of contractors mean standardised bids in ascending order and 'saves' them in a tape file.

26 statements

HIT RATE

Calculates success ratio (number contracts won/number bids submitted) and compares with average mean standardised bid, see tables 5.4 and 5.5

45 statements

TTESTS

Performs the T-Tests described in section 5.2 and appendix I and produces the results as shown in figures 5.2 and 5.3.

138 statements, 1 subroutine

BINOMIAL TEST

Performs the calculations for the Binomial Test described in section 5.3 and appendix J.

32 statements

RUNS TEST

Performs the Wald-Wolfwitz Runs Test as described in section 5.3 and appendix K.

102 statements, 2 functions

BOX JENKINS

Performs the time series analysis as described in section 5.4 and produces results as shown in table 5.10. Uses I.C.L. Library routine.

48 statements

AUTOCORR

Calculates the autocorrelation coefficients as described in section 5.4 and produces results shown in table 5.11

60 statements

CUSUM SETUP

Calculates CUSUM values as described in section 5.4, lists to line printer and magnetic tape file for CUSUM W.

44 statements

CUSUM W

Plots the CUSUM graphs shown in figures 5.4 and 5.5. Automatically adjusts scales to fit page width.

58 statements

CUSUM BACK LOG

Calculates the number of decrements in CUSUM that precede a win for each contractor and the average of all. Table 5.12 gives results.

83 statements

CUSUM PREDICTIONS

For each contractor calculates the success rate of 1 to 5 decrements in CUSUM predicting winning bids. Also calculates the overall average of these success rates. Table 5.13 gives results.

61 statements

BIDDERLIST

Lists the bidders for each contract with adequate spacing for notes etc.

36 statements

MARKUP EFFECTS

Calculates and plots the sensitivity graphs of success ratio v changes in bid value, see section 5.7 and tables 5.27 and 5.28

44 statements

BIDHISTORY VALUE FIT

Fits straight lines to the mean standardised bids of each contractor ranked in order of contract value. Outputs plot of contractors standardised bids and straight line statistics, see section 5.8 and tables 5.29 and 5.30.

54 statements

COMPETITOR

For each contractor creates a matrix of bid ratio (competitor's bid/contractor's bid) against competitors. (These matrices are similar to the frequency distribution shown in figure 2.1.

117 statements

PROGRAMS FOR APPORTIONING VARIABILITY AND FOR SIMULATIONS

ANOVA

Calculates analysis of variance for two factors (see appendix Q).

128 statements, 1 subroutine

LOG ANOVA

Similar to ANOVA except that calculations are based on log of actual bid (see appendix Q).

93 statements, 1 subroutine

SIMPREP

Prepares input tape file for simulation for all companies, see section 5.6

79 statements, 2 subroutines

SIMCOYS

Prepares input tape file for simulation for particular specified companies, i.e. groups contractors mean standardised bids, see section 5.6.

105 statements, 1 subroutine

SIMDATA SUMMARY

Outputs a summary of data contained in simulation data tape files.

43 statements

SIMULO 2

Similar to SIMULO 3 except uses data grouped by N

133 statements, 2 subroutines

SIMULO3

Performs the simulations described in section 5.6, takes input from original data tapes and SIMCOY'S tape (see above) uses data not grouped by 'N'.

166 statements, 2 subroutines

PROGRAMS FOR ANALYSING THE ACCURACY OF DESIGNERS' ESTIMATING

DESIGNERS

Produces the statistics relating to the accuracy of designers estimating as shown in tables 6.1 and 6.2 and figures 6.1 and 6.2 in section 6.2.

110 statements, 1 subroutine

HISTOGRAMS

Produces histograms and statistics similar to DESIGNERS of the designers' estimates for inspection purposes.

128 statements

DESIGNS BY VALUE

Ranks the lowest bid/designer's estimate and the mean bid/designer's estimate in ascending order of contract value within each group of 'N' bidders, see section 6.2 and tables 6.5 and 6.6.

63 statements

DESIGNFIT

Determines the best fitting polynomial to the plot of average (low bid/designer's estimate) v No. of bidders and average (mean bid/designer's estimate) v No. of bidders. Uses standard N.A.G. curve fitting routine, see section 6.3.

39 statements

CORRECTED DESIGNERS

Takes previously calculated correction factors, applies them to designers estimates and calculates residuals and mean and standard deviation of residuals, see section 6.3 and appendix R.

116 statements

A DATA HANDLING PROGRAM FOR THE STATISTICAL PACKAGE PROGRAM "NIMBUS"

PRENIMBUS

A data handling program supporting NIMBUS, see reference 50 and 51.

461 statements, 6 subroutines

PRICE LIBRARY PROGRAMS

RONLST & RONB

Uses I.C.L. tape handling routines to copy price library tape supplied from a Burrough's computer and converts to readable form on L.U.T.'s I.C.L. 1904A.

PRICE LIBRARY SETUP

Adds one library to the price library tape, accepts data from converted supplied tape and cards.

514 statements, 20 subroutines

INDICES

Sets up inflation indices on disc, described in appendix T.

85 statements, 1 function

TRENDS

Reads the inflation indices from disc and performs extrapolations by way of predicting indices for 1, 2 or 3 months ahead. Described in appendix T.

200 statements

PRICE LIBRARY STATS

The 'STATS' element of the Tender Price Prediction System as described in section 7.0 and appendix T.

364 statements, 17 subroutines

PRICE LIBRARY SIMULATION

The 'SIMULATION' element of the Tender Price Prediction System as described in section 7.0 and appendix T.

375 statements, 13 subroutines

PROGRAMS FOR LISTING DATA TAPE

CPRINT

Prints own list of bidders for each contract. For inspection purposes.

35 statements

PRINT

Outputs the data on the original data tapes to line printer.

36 statements

PROGRAMS FOR BIDDING GAME AND ESTIMATING ACCURACY SIMULATION

BIDGAME

The support program for the bidding simulation described in appendix P.

470 statements

ESTACCURACY

A program to reproduce by simulation the analysis described in appendix A using other types of distributions (e.g. normal).

49 statements
