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AN ANALYSIS OF THE CONTRACTOR'S ESTIMATING PROCESS

by

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TABLE OF CONTENTS

		Page
Summary		i.
Introduction		iii.
Research diagram		x.
CHAPTER		
1.	The development, purpose and conditions of estimating.	1.
2.	Objectives in improving estimating methods.	9.
3.	Feedback - necessity and collection.	15.
4.	Estimating the total building cost by regression analysis.	20.
5.	The application of regression analysis to subsections of buildings.	33.
6.	The Pareto distribution in Bills of Quantities.	40.
7.	Factors affecting the accuracy of cost prediction.	46.
8.	A New Method of Estimating.	63.
9.	Field tests.	78.
10.	Conclusions.	87.
References		90.
Bibliography		92.
APPENDIX		
1.	Historical development of estimating.	93.
2.	Current methods and conditions of estimating.	99.
3.	Tables and data relating to regression analyses.	111.
4.	Computer program manual for use in the New Method of Estimating.	142.
5.	Synopsis of seminar on The New Method.	153.
6.	Selected computer print-outs from field tests on the New Method	172.
7.	Records of achieved performances on field tests	241.

SUMMARY

Typically, contracts in the Construction Industry are placed on a basis of competitive tenders. The ability to estimate costs in advance is, therefore, imperative.

Ideally, estimates should be based on recorded levels of performance but the diversity of the projects encountered often makes this feedback impractical. It has been observed that currently estimators depend to a large extent on intuition to produce prices which are acceptable to the client. Whilst these prices are typically within 10% of the total cost of the work, the estimates for individual work items may differ from the actual cost by as much as 100%.

For this reason, research was undertaken into methods which are not normally practiced in the Construction Industry. The principal objective of the research was to find and test a method of estimating which would be quicker than present methods and would achieve a more direct reflection of observed performance.

This thesis describes attempts at applying regression analysis globally to building costs. It also examines the varying levels of difficulty in estimating different categories of work and the implications of the Pareto distribution of the values of the items in a bill of quantities.

In the light of the foregoing studies, a new method of estimating was devised and tested. The New Method separates the selection and evaluation of sub-contractors, suppliers and material costing, which can be done by semi-skilled clerks, from the difficult task of labour cost prediction. Labour costs are traditionally forecast by the application of constants to unit quantities. This procedure is retained in the proposed method only as a means of obtaining initial approximate rates. These rates are applied to the bill items and

the resultant list of work items is placed in numerical order using a computer. Thus the comparatively limited number of items (say 20%), which contribute the majority of the total project cost, are identified for more exact estimating. The work items are further sorted by computer into operational format to assist in the utilization of resource estimating as a proper basis for pricing and for feedback from actual site performance.

The New Method and the practical tests to which it was subjected are described in detail. The tests were conducted within a contracting firm in parallel with their existing work and from them it was concluded that the Method has achieved its principal objectives, namely, quicker estimating and an improved standard of comparison against which to record observed costs. This latter characteristic should contribute to improved feedback and, consequently, more reliable estimates.

Although the principles described in this thesis apply equally to Building and Civil Engineering, the accepted methods of estimating in Civil Engineering are already based quite extensively on operational considerations. The value of the work described lies, therefore, principally on the Building side of the Industry.

INTRODUCTION

"For which of you intending to build a tower, sitteth not down first and counteth the cost, whether he have sufficient to finish it?" ...... St. Luke - Ch. 14, vs. 28.

For the assistance of the reader a diagrammatic plan of the research work undertaken for this thesis is shown on page x. The letters in parenthesis in this introduction relate to the sections on the diagram.

A tender submitted by a contractor for proposed building work comprises two distinct parts. The first is an estimate of the cost of doing the work aggregated from the cost of labour, plant, materials, sub-contractors and Prime Cost sums. The second is a mark-up allowance for profit, risk and establishment overheads. This division is not discernible to the client as the two are combined together by the Contractor to form his bid figure.

The work in this thesis relates solely to the first part and is called Estimating, as distinct from Bid Strategy.

Although the prime purpose of Estimating is to produce a forecast of the probable cost of constructing the works (A) it is also used to fix the Contractor's financial entitlements, as a yardstick to monitor achieved performances and as a vehicle for pre-tender planning.

The Client usually allows Contractors about a four week period to submit a tender, which is generally considered to be sufficient except where difficulties are encountered in obtaining quotations from sub-contractors.

The Estimate is normally prepared by a senior estimator usually with assistance from the planning department. If the success rate of obtaining contracts is taken to be about 1 in 7, varying with the general economic conditions, there is clearly a considerable proportion of abortive work.

Limited man power for Estimating militates against detailed precise work for every tender. As a result, Contractors usually give detailed attention only to desirable contracts. The remainder are prepared in a more approximate manner with a risk allowance to cover for unforeseen circumstances and for the less accurate method of estimating.

Estimates are prepared generally in accordance with the recommendations set out in the "Code of Estimating Practice" published by the Institute of Building. It is difficult to recruit the necessary skilled staff to prepare sufficient estimates using this system. It is, therefore, submitted that the new method, subsequently discussed, will alleviate the problem by relegating much of the less skilled work to clerical labour or computers.

Bills of Quantities based on a Standard Method of Measurement are supplied by the Client for larger projects and when not supplied, as in the case of some negotiated contracts, are usually prepared by Contractors. Although Contractors' Bills may be shorter than those produced strictly in accordance with the Standard Method, it is still an expensive process and alternative methods of cost prediction, e.g. regression analysis, have been investigated.

Estimates should be based on records of production from previous projects (B) but this is extremely difficult to achieve in practice. Construction projects are unique so that the same set of circumstances are never repeated in their entirety.

Many attempts (C) have been made to classify work into recordable sub-divisions so that overall differences can be isolated and evaluated. The main difficulty is finding a satisfactory method of classification which combines the physical content of the work with other factors such as psychology and meteorology which considerably affect levels of production.

Contractors establish accountancy headings under which site costs are allocated (D) but these costs are often either accidentally or deliberately misallocated by site staff to give a more favourable impression to the management. These costs headings do not always coincide with those used in estimating so that there is little feed-back of accurate usable cost data in practice.

A classification system which represents these variables in sufficient detail would be complex and would involve several thousand items for each site. It has been demonstrated (Ref. No. 2) that the reliability of data recorded in such circumstances is very low and this detailed classification approach for feed-back is, therefore, not considered practical. Furthermore, even if reliable booking could be guaranteed the cost of working in such detail would be prohibitive.

One possible alternative approach (E) is to record achieved total costs for a number of projects, together with the variables which are thought to control them and to undertake regression analysis to quantify the effect of the variables.

Previous studies carried out at Loughborough University into clients' costs of concrete frames and heating systems, showed that it may be possible to develop a mathematical model by regression analysis which is able to predict the complete building cost. A regression analysis can only be made if the number of sets of data available is at least 10 or 15 more than the number of variables used in the model. As the number of variables needed is about 10, a minimum of 20 sets of data is required.

It was not thought feasible to produce a single model capable of predicting the cost of all types of building work with their differences in use and quality. Therefore, each category of building requires a separate model.

Many Contractors were contacted (F) but none of them was able to provide the cost data for the requisite number of similar projects. This meant that the model would have to be based on clients' costs (G) extracted from cost analyses which are more readily available.

Two studies were undertaken. The first was made on Hertfordshire County Council schools (H) designed within a building system. A successful cost model was derived which, on subsequent tests, gave results well within the target limits of accuracy of ± 10%. A second study on traditional factory buildings (I) from published cost analyses did not produce successful results.

It was concluded that this approach might be used by Clients and Contractors having a fairly standard design and it is recommended that further studies are made using more data.

As a compromise between detailed classification and global regression analysis (J), it should be possible to apply regression analysis to sub-divisions of work, e.g. the traditional trades. This approach would achieve reliable recording, since the number of cost codes would be limited. It would also relieve the need for large numbers of similar projects since greater similarity can be expected within the sub-divisions.

The feasibility of applying regression analysis in this way (K) was investigated but it was not possible to pursue the approach in the short term because Contractors were not able to supply their costs in appropriate form. Sub-divisions in cost analysis from Bills of Quantities (L) are extremely suspect due to the variability of individual rates in the Bills and the loading of certain sections by Contractors to improve their cash flow and for other reasons.

It is suggested, however, that the use of regression analysis in this context may prove fruitful in the long term and it is recommended that studies should be undertaken when the data are available. These data will be available when sifficient projects have been completed using the proposed estimating system as it conveniently produces the true costs for each section of work.

It is generally agreed within the Building Industry that about 80% of the total value of the work in a Bill of Quantities is represented by 20% of the items. (M) If these 20% are selected for a more comprehensive study, it should be possible to obtain greater accuracy for these items. The remaining 80% of items can be treated in a more arbitrary fashion as any discrepancy would not affect the overall total accuracy to an unacceptable extent.

The Bill items are usually priced from the estimated costs of labour, plant, materials and sub-contractors (N). In practice, the achieved costs of labour and plant are found to show the greatest variance from the estimated cost and, as they represent a high proportion of the total cost, any improvement in accuracy would be advantageous. They are also the most difficult to forecast.

Material and sub-contractors' costs do not show such a wide variance except when caused by inflation or by the merchant or sub-contractor refusing to fulfil his contractural obligations. The production and calculation of these costs is not difficult to achieve and it is recommended that they are prepared by trained clerical staff.

To enable the items representing the majority of the labour and plant costs to be identified, a computer program (O) was developed which ranks the bill items in order of magnitude. The program also separates the items by activity.

A pre-tender plan is drawn up by the Estimator and Planner and a decision made as to what are to be the main activity groups - normally not more than 20. The Bill items are simply coded by giving them the number of the activity to which they relate.

It is necessary initially for the Estimator to insert the estimated costs for labour and plant for each of the relevant Bill items. This can be done by reference to standard constants of output which are multiplied by the all-in hourly rate of the labour and plant involved. The page and item number, activity, quantity and rate are punched directly on to cards without any intermediary coding system. The computer program will then :-

(a)! Calculate the extensions and totals.

(b) List the extension values in descending order of value

(c) Establish the cut-off level - normally 80% of the value of the work - those items within this limit being defined as critical.

(d) Collect the items into the relevant activity groups.

(e) Indicate which of the items in the activity groups have a critical value.

The computer output allows the Estimator to examine the highlighted critical items in greater detail. As they are also sorted into activity groups, he can use a form of operational estimating as an alternative to the initial method of pricing.

Any discrepancies between the initial and the refined estimate for any item brought to light, are easily corrected and a revised output obtained. For any activity in which the refined estimate is different from the initial estimate a simple multiplying factor is applied to all the constituent bill items. The same multiplying facility can be used selectively to adjust bill items for the improvement of the contractor's cash flow.

The system and program have been tested (P) with a large national building firm.

The activity groupings were prepared by B. Moyles and K. Armstrong of Loughborough University and the firms' estimators priced the items. Card punching and computer work was done on the computers of Loughborough University and Lanchester Polytechnic.

The national contractor was successful in obtaining one of the contracts tendered for and achieved costs have been collected from the site and grouped under the original activities.

Comparisons between estimated and achieved costs have been made on a standard form and fortunately for the Contractor, the achieved costs have nearly always been less than those estimated. Where large differences occurred, explanations were found which indicated that the estimator's original assumptions were incorrect.

It is intended in the future (Q) to collect the results of several projects so that overall trends can be evaluated. These cost data will also be used to produce detailed regression cost models for use in the preparation of new tenders.

Other forms of estimating are being developed (R) which concentrate on the operational aspect and the allocation of resources, e.g. Cost of Contractors' Operations by the Department of the Environment. It is believed that once developed and tested, these forms will be far superior to the present methods. If a construction firm wishes to use this type of system it is necessary for the Estimator/Planner to be able to produce records of their firm's past performance for inclusion in the data bank of a computer program. These data will be available when sufficient projects have been completed using the described new method of estimating.

Operational estimating techniques which predict the cost of an operation may not be compatible with the requirement of mandatory client documentation. However, the two can be reconciled by the New Method.

CHAPTER 1.

THE DEVELOPMENT, PURPOSE AND CONDITIONS OF ESTIMATING

Introduction:

This chapter briefly traces the evolution of estimating for building work from Norman times and its development up to the present day. The basic purposes and philosophies of estimating are examined and the current conditions under which an estimate is prepared have been surveyed.

1.1 Historical Development of Estimating

1.1.1 A brief historical account of the development of estimating from Norman times until the present day is given in Appendix 1.

1.1.2 The role of the building owner has changed from self-build and direct employment of craftsmen to the present method of employing a main contractor, who is responsible for constructing and co-ordinating the work.

1.1.3 In the earlier part of this period, estimating may have been practised by the client to ensure he had the necessary financial resources to complete the work. This function is now undertaken by the independent Quantity Surveyor on his behalf.

1.1.4 With the emergence of a main contractor, an agreed price of constructing the work became necessary as a prelude to the building contract. The Contractor was thus forced to develop techniques which enables him to make a reasonable forecast of the probable cost of the work.

1.1.5 From its initial development, methods of estimating have changed little over the past century.

1.2 The Purpose of Estimating

1.2.1 The purpose of estimating is not solely limited to cost forecasting. The information and discipline involved in the pre-tender process produces several benefits, which although secondary, are extremely important to the successful management of a building contract. The following paragraphs illustrate the main primary and secondary functions which benefit from the estimating process.

1.3 The Forecast of Cost

1.3.1 The primary purpose of estimating is to make a forecast of the cost of constructing the works which is as accurate as the circumstances demand. This forecast of cost normally forms the basis of the tender.

1.4 The Valuation of Work Completed

1.4.1 The estimator's forecast of cost is used by the Client's advisors and the Contractor for assessing the value of completed work. This valuation ensures that the correct payment is made in interim certificates.

1.5 The Valuation of Variations

1.5.1 It is extremely unusual for a constructed building to be identical to the original design on which the tender was based. The priced bill permits the value of omitted or additional work to be assessed on the same basis as the work included in the tender.

1.5.2 Because variations disrupt the programme and sequence of operations, the cost of performing varied work is usually more than similar work priced in the original estimate. This increase will not be recovered if the original rates are used to value the work. Hence the Contractor must resort to Clause 11(6) of the Standard Form of Building Contract which empowers the Quantity Surveyor "to ascertain the amount of such loss or expense". In such cases, the bill rates may be discarded and a valuation made from the actual costs of labour and materials incurred in the variation.

1.6 The Provision of Cost Information for the Client

1.6.1 The estimated prices are mainly related to the measurable quantities of permanent work. This enables the Client's advisers to forecast the probable cost effects of changes in the design by measuring the alternatives and pricing them in accordance with the rates in the Bill.

1.6.2 Estimating provides the data for elemental cost analyses which are used by the Quantity Surveyor in the cost control of future designs.

1.7 The Planning of Operations

1.7.1 An efficient estimating process can impose a useful discipline on the managerial control of the contract. The original pre-tender plan and method statement serve as a useful guide for drawing up the construction programme. Any proposed or actual deviations from the original plan can be comparatively costed and evaluated.

1.8 The Forecast of Future Plant Requirements

1.8.1 The estimation of plant costs require reasonably firm decisions to be made on the selection of major plant items used in the contract.

1.8.2 The company's present plant resources can be balanced against future requirements and any necessary adjustments can be made at an early stage. This is particularly important when decisions have to be made on purchase or hire.

1.9 The Comparison of Estimated with Achieved Costs

1.9.1 The estimate contains a detailed concealed forecast of the expected labour and material outputs related to individual work units. These forecast outputs can be processed to provide data for a cost and bonus system which, in theory, reconciles actual expenditure with that predicted in the estimate. When large discrepancies occur, remedial action can be taken either by attempting to increase output, or by modifying future predictions in the light of experience.

1.10 The Selection of Sub-Contractors and Suppliers

1.10.1 The company's buyer normally obtains quotations for materials and sub-contracted work for inclusion in the estimate. If the bid is successful, the lowest quotations form the basis of the orders and purchases for these items. However, many companies use the original quotations solely as a yardstick and send out further enquiries before placing orders, to try to obtain cheaper quotations.

1.11 A Base for Cash Flow Forecasting

1.11.1 Contractors have become increasingly aware of the benefit that cash flow forecasting can make to the profitability of a contract.

1.11.2 If the estimate of costs are related to the constructional time periods, it is possible to weight the costs by 'eye' or by linear programming and thus improve the project cash flow and hence time return on capital.

1.12 <u>The Establishment of Contractural Obligations</u>

1.12.1 Bills of Quantities incorporated into the legal contract establish agreement as to the quantity and quality and price of the work. The fact that Bills have been produced usually indicates that the design is either wholly or substantially complete.

1.12.2 This agreement reduces the chances of having to resort to expensive litigation to settle cases of dispute.

1.12.3 Bills may preclude the contractor's free choice of materials, particularly when he may be able to offer a less costly alternative. However, this disadvantage will be overcome by the future introduction of performance specifications based on National Standards.

1.13 <u>The Conditions and Methods of Estimating</u>

1.13.1 In order to discover what the current methods of estimating are, and the conditions under which they are prepared, an informal survey was carried out. The chief estimators of large and medium size construction firms and one consultant estimating company were personally interviewed by the author. The results of this survey, shown in Appendix 2, are summarized as follows :-

1.13.2 The estimator's role is to produce a forecast of the actual cost of constructing the work for his particular company. The currently acceptable limits of accuracy in prediction are considered to be plus or minus 10% normally distributed.

1.13.3 Estimators consider that the usual time for preparation of the estimate allowed by the client is satisfactory except where sub-traders are unduly dilatory in their replies.

1.13.4 It is usual for one "senior" estimator to be employed for each tender. A high proportion of work can be delegated to the buying department. The estimate is usually vetted by the chief estimator and the tender bid adjudicated by the Board.

1.13.5 The success rate was found to fluctuate with general economic trends, type of jobs and experience in a particular field or area. Generally the rate was between 1 in 6 and 1 in 9.

1.13.6 Most firms tend to follow the recommendations and procedure of "the Code of Estimating Practice" published by the I.O.B. Through the absence of an efficient costing system, the constants of labour materials and plant used in the compilation of the rates may bear little relationship to the actual cost of the work. Individual rates may be further adjusted to suit an improved cash flow forecast.

1.13.7 The estimating procedure for negotiated contracts is similar to that used when Bills of Quantities are provided by the Client.

1.13.8 Considerable use is made of the Bills of Quantities and outline drawings, the latter being particularly useful for the pricing of preliminary items and pre-tender planning. Locational quantities were thought to be of little value at the estimating stage and there is considerable resistance to the elemental format due to the additional work involved.

1.13.9 Little use is made of the estimated data in contract management due to difficulties of conversion to operational requirements except as a check on current income against expenditure.

1.13.10 Considerable use is made of the estimated data in the settlement of the claims, valuation of variations and the preparation of the final account. Schedules of rates, etc. which may not be based on the estimated data are used in package deal contracts.

1.14 Conclusions

1.14.1 The primary purpose of estimating is to establish a cost basis for the contractor's tender. The detail generated in its preparation produces several secondary benefits. These are :-

(i) The production of a yardstick against which to measure achieved performance.

(ii) A forecast of future resource requirements.

(iii) The preparation of a cash flow forecast and hence a method of adjustment to improve return on capital.

(iv) The definition of the money payable by the client to the contractor at interim and final stages.

(v) An aid to the client in assessing the effect of variations.

(vi) A supplement to the specification in defining precisely what the client is entitled to receive for his money.

1.14.2 The estimating process is not imperative for computing the data for all these secondary benefits. Items (i) to (iii) could be done by a contract budget, items (iv) and (v) by an agreed schedule and item (vi) by closer attention to contract documentation.

1.14.3 The present conditions of estimating compliment the traditional system of letting contracts. However, the dichotomy between the forms of estimated data and the requirements of site management makes reconciliation extremely difficult in its present form and does not encourage the keeping or use of records of achieved performance.

1.14.4 The hypothesis is postulated that if an alternative method of estimating is devised, its use could not be refuted solely because it failed to generate the secondary benefits.

1.14.5 Alternatively, a method of estimating should be devised which facilitates the use of forecast resources in contracts management and permits the actual resources to be fed back to the estimators for future predictions.

CHAPTER 2.

OBJECTIVES IN IMPROVING ESTIMATING METHODS

Introduction

Bills of Quantities following current format, work reasonably well as a control document for establishing the method and amounts of payments due to the Contractor for work executed. They also provide the Client's advisers with cost information for economic studies on future designs. The Professions are reasonably satisfied with the role and presentation of the Bills and, as they are used almost universally in the British Building Industry, they are likely to continue in approximately their present format for the foreseeable future. Therefore, any change in estimating methods must be compatible with these formats and not rely on a radical alteration of client documentation.

2.1 Increasing the Number of Estimates Submitted

2.1.1 One of the philosophies of bidding strategy is that if a company wishes to increase the number of successful contracts awarded, it must either submit more bids or submit the same number of bids but at a reduced mark-up. The latter is not generally acceptable except as a short term measure.

2.1.2 As a corollary, if a company wishes to increase its profits, it can submit a greater number of bids with a higher mark-up and still win the same number of contracts.

2.1.3 To achieve an increase in the number of estimates produced, the company must either expand its estimating department or improve the productivity of its estimating department.

2.2 Reducing the Time and Cost of Estimating

2.2.1 Companies do not receive a constant number of invitations to tender throughout the year. If the company wishes to increase the number of bids and cope with the heavy peaking which occurs at intermittent intervals, it must reduce the minimum time taken to prepare an estimate.

2.2.2 Estimators believe that the cost of preparing an estimate is about ½% of the tender figure for each contract bid. Unless the cost of estimating is reduced, any extra profit achieved by the higher mark up will be off-set by increased estimating costs.

2.2.3 There is a shortage of skilled estimators in the building industry and any company seeking to increase its staff will have to pay large salaries to attract applicants. In fairness to their existing staff, it will also have to increase their salaries pro-rata.

2.2.4 These difficulties may be partially overcome by using a computer. There are several existing computer programs for use in estimating but none of them has been widely accepted and used in the building industry. This thesis examines the application of multiple regression analysis to ascertain whether it can offer an acceptable alternative to present methods.

2.2.5 Alternatively, the estimator's work can be rationalized and organised so that a greater proportion of his work can be delegated to semi-skilled technical or clerical staff. These staff are not in short supply and their salaries are far less than those of skilled estimators. A computer may be of assistance in this case.

2.3 Flexibility

2.3.1 The format and presentation of tender documents by the client's organisation is not standardized. The Bills may be in Trade, Elemental, Sectionalized Trade, Operational or Activity format. The terminology and work descriptions are subject to the preferences of the people who prepared them and although Standard Phraseology has been introduced, its use is by no means universal.

2.3.2 Work is measured according to the principles of the Standard Method of Measurement. There are 'interpretations' of these rules in practice. The rules have been revised in 1948, 1953, 1962, 1963 and 1968 (metric version) and a working party is currently (1973) being set up to make radical changes.

2.3.3 Any new system of estimating must, therefore, be extremely flexible to cope with these differences, as constant reprograming of computers is an expensive and error-prone operation.

2.4 Simplicity

2.4.1 There is considerable resistance to change in Estimating departments which will cause problems when a Contractor seeks to implement any new method. Any new method must preferably be simple to introduce and operate and must produce comprehensible results. Individuals must be able to alter or modify the results in the light of their own thoughts or experience.

2.4.2 Current computer-based systems require extensive multi-facetted codes, e.g. ICL estimating system needs sixteen digits for each item, and Contractors believe that it is quicker to price the items manually rather than look-up, insert and punch these codes. Any coding required should preferably be small facetted, ad hoc and able to be punched directly from the Bill, without intermediate transfer to coding sheets.

2.4.3 There is a large variety in the size and sophistication of construction firms. Some have their own computer, others hire computer time and others refuse to use them. Alternative methods should be acceptable to the majority of the open-minded companies and compatible with a reasonable range of computers.

2.5 Improved Accuracy

2.5.1 There is a high incidence of bankruptcies in the construction industry. One of the many reasons for this is the submission of uneconomic tenders due to inaccurate estimating.

2.5.2 The survey of conditions of estimating (Appendix 2) showed that the current achieved accuracy in estimating is about plus or minus 10% normally distributed. Studies (ref. 1.) have indicated that if the estimating accuracy is improved to plus or minus 5%, a substantial increase in the overall company profit will be obtained. (The increase is in excess of 40% when five competitors are involved).

2.5.3 The new method must be within the ± 10% limits and preferably approach ± 5%.

2.6 Realistic Use of Feedback from Site

2.6.1 Bills of Quantities require the contractor to insert unit rates against quantities of work but, as is shown in the next chapter, contractor's costing methods cannot produce detailed information compatible with these measurements.

2.6.2 It is considered imperative that contractors should base their predictions more directly on achieved past performance and should achieve this objective with the new methods.

2.6.3 The various immeasurable factors, which cause production variance on site, will not permit great accuracy to be made in predicting costs of individual work items. The order of priority for predictive accuracy is :-

1. Total cost of the work.
2. Cost of the main sections of the work.
3. Cost of the main operations.

If these costs can be forecast accurately, the individual work items may within reason be priced in an arbitrary manner so long as the total cost of the items is compatible with the accurately forecast group cost.

2.7 Provision of Information for Contract Management

2.7.1 If the rate of success of winning contracts is about 1 in 6, it is uneconomic to use time and resources to produce detailed information for contracts management at the estimating stage unless this information is generated automatically.

2.7.2 Data used in the production of a successful estimate e.g. resource predictions, are of immense value in controlling the operation. These data must be accessible and in a form which is compatible with the various user needs. It should also be possible to compare predicted with achieved performances to enable the profitability of the contract to be monitored.

2.8 Conclusion

2.8.1 The requirements for improvements in estimating may be summarized as follows :-

(i) A reduction in the time and cost of preparation.

(ii) Flexible in operation.

(iii) Simplicity in use.

(iv) Improved accuracy in prediction.

(v) Realistic use of feedback information.

(vi) Provision of information for contract management.

2.8.2 The work in the following chapters describes attempts at discovering a solution for these requirements.

CHAPTER 3.

FEEDBACK - NECESSITY AND COLLECTION

Introduction.

It is postulated that an accurate forecast of the cost of constructing a future project can only be made if this forecast is based on the recorded costs of previous projects. Thus an estimator must have access to a system which feeds back this information.

A feedback system must indicate the cost, or quantity of resources used, allocated against the various circumstances which caused them, so that the estimator is able to relate the costs to the future project.

3.1 Methods of obtaining feedback

3.1.1. There appear to be three main possibilities of obtaining feedback of achieved performance for use in estimating. These are (a) Classification, (b) Cost models derived from multiple regression analysis and (c) a compromise between the two.

3.2 Classification

3.2.1 Classification is the only method of feedback which is applied extensively in the Building Industry. It comprises the coding of performance data and its subsequent analysis.

3.2.2 For example, all concrete work can be designated by a simple code, say 'C'. Extraction of the costs coded 'C' together with the measurements of the work done will then enable a cost per cubic metre to be determined period by period and on a cumulative basis.

3.2.3 Unfortunately, such information is unlikely to be very helpful because the unit cost will be significantly affected by factors which include :-

(i) The volume of concrete per mixer set up.

(ii) The horizontal and vertical distances of the pour from the mixer.

(iii) The method of transportation.

(iv) The workability of the mix.

(v) The degree of congestion of the reinforcement.

(vi) The total volume of the pour.

(vii) The type of work, i.e. columns, walls, beams, floors, etc.

(viii) The cross-section of the members.

(ix) The quality of the finish and formwork characteristics.

(x) Daylight hours per day.

(xi) Temperature

(xii) Relationship to an optimum gang size.

(xiii) Productivity of the operatives.

(xiv) Efficiency of the site management.

3.2.4 In order to give the unit cost some meaning, it may be thought helpful to record these factors for each pour of concrete by means of a more elaborate coding system.

3.2.5 However, besides the difficulty of quantifying some of the factors, e.g. 'productivity', a coding system with more than fourteen digits would be required just for the concrete work. A similar coding structure would be necessary for all the other work items.

3.2.6 A study carried out by Richard Costain Ltd. (Ref. 2) showed that when 30 cost headings were used on site, about 2% of the items within the heading were misallocated. With 200 headings, 50% were misallocated and with 2,000 headings 98% were misallocated. The misallocation was apparently caused by the site accountant's failure to identify the items correctly.

3.2.7 Thus the recording of data against a three digit system is unreliable and, if a coding system is used which accounts for all the variable factors, the unreliability of booking is likely to be such as to render the records almost useless.

3.2.8 This problem of recording achieved performance arises from the almost infinite variety of work, under different conditions, and using a variable work-force, which a contractor may be called upon to undertake. This variety is not equalled in any other industry and it appears worthwhile, therefore, to explore methods of recording performance which may be more suitable for the special conditions of the construction industry.

3.3 Multiple Regression Analysis

3.3.1 Multiple regression analysis is a statistical technique (Ref. 3) which in suitable circumstances will enable a mathematical formula to be made from a set of data.

3.3.2 For example, if records are kept of the total cost of a building (T) together with the quantities of relevant variables, e.g. floor area (A), number of stories (N) and area of walls (W), it would be possible to express T thus :-

$$T = a_1A + a_2N + a_3W$$

Regression analysis would enable the constants (or rather (parameters) a_1 a_2 a_3 to be calculated so as to achieve the best fit with the recorded data. The technique also permits the goodness of fit to be quantified and the user can then decide whether the accuracy is sufficient for his purposes.

3.3.3 As the principal objective is to estimate total cost, such an approach is relevant. Moreover, the recording of achieved total cost is likely to be much more reliable than the recording of costs against a complex coding system. For this reason trial analyses were undertaken for schools and factory projects. These are discussed in the following chapter.

3.3.4 The use of regression analysis requires an adequate number of sets of data. An empirical rule is that the number of sets should be at least twice the number of independent variables (A, N and W in the above simple example). This presents difficulties unless the approach is confined to particular classes of buildings, e.g. schools, factories, hospitals, high-rise dwellings, etc.

3.3.5 Typically, contractors do not have sufficient data for any one class of building and initially it was thought, therefore, that the use of regression analysis may have very limited application.

3.4 Combined Use of Classification and Regression Analysis

3.4.1 The methods of classification and regression analysis are not mutually exclusive and some approach which combines them may overcome the difficulties associated with each in isolation.

3.4.2 For example, if costs are recorded against a limited number of cost codes which relate to a readily identifiable sub-section of the work, the sub-sections of work will have greater similarity between different types of buildings than the buildings as a whole.

3.4.3 This approach, which obviates the necessity for a large number of similar types of buildings is examined in Chapter 5.

CHAPTER 4

ESTIMATING THE TOTAL BUILDING COST BY REGRESSION ANALYSIS

Introduction

Previous studies, carried out at Loughborough University, on the Client's costs of concrete frameworks and heating systems have shown in each case that the cost may be related to less then eight factors. These factors were identified and quantified using multiple regression analysis. Subsequent tests on the models using new data have produced results which were within plus or minus 5% of the actual figure. As this tolerance is within the current acceptable limits of accuracy in building work, it was decided to investigate the possibility of using this technique in producing a model which was able to express the total building cost. A model if successful could be used by Contractors to produce an estimate of cost in any tendering situation.

The technique of using regression analysis is fully described in a project report (Ref. 3) submitted by P. Gould at Loughborough University. The work was done on the University's ICL 1900 series computer using the standard XDS 3 statistical package. An aide-memoir (Ref. 4) for programming has been prepared by A. Ham of the mathematics department based on a draft prepared by P. Gould.

4.1 Selecting the Data

4.1.1 A regression analysis may only be executed where the number of sets of data exceeds the number of selected variables. The amount of this excess depends partly on the variability of the data but an excess of ten is usually sufficient in practice. It is thought that successful prediction of the total building cost will require at least 10 or 12 variables to be used. This, therefore, makes it advisable to obtain the data from a minimum of 20 contracts. A greater degree of confidence in the accuracy of the model will be achieved if this figure can be exceeded.

4.1.2 Due to many variations in the use, quality and amenity standards of different categories of building, it is not thought feasible to produce a model which is able to predict the cost for every category. Hence it was decided to produce separate models, each relating to a particular category of building as classified under the CI/Sfb system (Ref. 5).

4.1.3 The necessary restraints cause problems in data collection. Several contractors of local and national standing have been approached to ascertain their willingness to supply these data. Unfortunately, whilst the majority were prepared to co-operate, they have either not constructed the requisite number of similar projects or their records of previous contracts cannot be retrieved. Contractors are aware of this short-coming and one national company is looking into the possibilities of storing their current records on magnetic tape for future use. This excludes, for the present time, any hope of obtaining this information from the Contractor's side of the industry. The data will have to be obtained from one or more client organisations. 'Costs' in this context will then be the cost of the building to the client.

4.1.4 Client cost records are fortunately reasonably well documented and are available in the form of cost analyses. These are published at regular intervals in the technical press and also form part of the service to subscribers of the Building Cost Information Service sponsored by the Royal Institution of Chartered Surveyors. Government departments, Local Authorities and larger professional firms normally also have a reasonable number.

4.1.5 The layout and format of cost analyses has been standardized by the Royal Institution of Chartered Surveyors so that it is possible to obtain comparable data from many individual sources who would otherwise not be in a position to supply the necessary number on their own.

4.1.6 A cost analysis (Ref. 6) is a record of the client costs for a particular project apportioned amongst the various building elements. The costs are related to the gross floor area of the building and quantity factors of each element give an elemental unit rate. Provision is made for specification notes and further measured sub-divisions of each element. Outline drawings are frequently included.

4.1.7 A cost analysis appears to be a satisfactory source of information for producing a regression model as it gives the total costs and quantifies many items which may be selected as variables. Other variables may be quantified from the drawings or specification notes.

4.1.8. The Standard Form of Building Contract agreed between the Royal Institute of British Architects and the National Federation of Building Trades Employers, states in Clause 3(7) that, "None of the documents hereinbefore mentioned shall be used by the Contractor for any purpose other than this Contract and neither the Employer, the Architect nor the Quantity Surveyor shall divulge or use except for the purposes of this Contract any of the prices in the Contract Bills". In effect, this clause prohibits the parties from revealing detailed cost information to any other persons. However, in practice, this clause has been interpreted as not prohibiting the publication of groups of costs in the form of a cost analysis provided the Contractor does not object.

4.1.9 This thesis is concerned with Contractors' estimating but the client's costs are the Contractor's cost estimate plus the mark up. The study of the Client's costs will, therefore, not invalidate the principles of this work because :-

(i) It will indicate whether regression analysis is a satisfactory technique in this context and whether the method is convenient in practice.

(ii) It will, if successful, encourage contractors to assemble data relating to their own work which would then form the basis for models of contractors' costs.

(iii) A cost model, even if it is based on client's costs, is likely to provide the contractor with better feedback than is obtainable from published rates.

4.2 Rationalizing the Data

4.2.1 In order to obtain sufficient numbers of data it is necessary to assemble projects which extend back over a period of years. The cost of these projects will have increased due to fluctuations in cost, productivity and market conditions. These costs are brought up to a common date by use of a building index. The index used in this study is the one issued by the R.I.C.S because it is the only one that attempts to include all the time factors which vary the cost. (It is appreciated that this approach is not rigorous as the cost index cannot be strictly appropriate to every building).

4.2.2 Cost analyses divide a building into six main group elements, i.e. substructure, superstructure, finishings, fittings, services and external works. The costs of substructure and external works are dependent on the geography and geology of the site which cause a large variation to the quality and quantity of the work. The causes of the variations are extremely complex and it has not been possible to define simple variables for use in the model. It was decided, therefore, to produce a model which will predict the cost of the remaining four elements. The total building cost in the following context is the cost of the superstructure, finishings, fittings and services.

4.3 Selecting the Variables

4.3.1 There is considerable scope for choice of variables which may be included in any regression analysis. They may be classified under three main headings; those which reflect the physical aspects of the building, those which reflect the quality, and those which reflect the erection process.

4.3.2 A building comprises a series of multi-dimensional variables some of which can only be obtained by precise measurement from detailed plans. As it is not always possible to obtain these plans for every job, either these jobs will have to be discarded, or only commonly available variables used. If too many jobs are discarded there will be an insufficient number of jobs on which to carry out the regression. It was, therefore, decided to use those variables which could be quantified by simple reference to the available information.

4.3.3 Although the building industry has been taking rapid steps towards complete metrication, there are insufficient projects available for study in metric units. It was, therefore, decided to restrict the study to the use of variables in imperial units.

4.3.4 It is extremely difficult to express the quality of a building in mathematical terms other than cost. Having made the decision to produce separate models for each classification of work (paragraph 4.1.2) it was considered reasonable to assume that the overall quality standards of buildings within each classification are fairly similar. Hence no variables, which attempt to measure quality differences, are included in the model.

4.3.5 It is also extremely difficult to quantify variables which relate to the simplicity or difficulty of the erection process without having access to the contractors' cost build-up and method statement. However, variables of a subjective nature have been included which are generally thought to have an influence, e.g. the degree of congestion on a site.

4.3.6 Consequently, the regression analysis must be operated with a majority of physical variables. The following variables were used initially. Those showing little significance were discarded as models were developed and tested. Each variable has been given a six character mnemonic code for use in the computer program.

TOCOST - The contract sum less the value of substructure drainage and external works.

FLAREA - The gross internal floor area enclosed by the external walls

FNUNIT - The number of functional units for which the building was designed, e.g. pupil places in schools

ESHAPE - The ratio of the plan shape to a square given by the formula :-

$$\frac{\text{External perimeter} - \sqrt{\text{Gross external floor area}}}{\sqrt{\text{Gross external floor area}}}$$

WLAREA - The area of the external vertical envelope including openings

WNAREA - The area of windows and external doors

OPWLRA - The ratio of openings to WLAREA

ROOMNO - The total number of rooms

CIRCRA - The proportion of circulation space to floor area

PSUBRA - The ratio of subsiduary areas to prime function areas, e.g. storage to sales floor.

STORHT - The average storey height

STORNO - The number of storeys

PTAREA - The area of internal partitions including doors and screens

OPPTRA - The ratio of openings to PTAREA

RFAREA - The area of roof coverings including roof lights.

INAREA - The combined area of internal floor wall and ceiling finishings

SANFIT - The number of sanitary fittings

HEATLO - The thermal requirement or provision

CONGES - The area of the site divided by the plan area of the buildings

SITEAC - The length of permitted access points divided by the length of the site perimeter

BLDGAC - The length of the perimeter of the building available for access divided by the total perimeter

BLDGTM - The contract period in months.

4.3.7 As the first models were developed and tested, it was decided to convert those variables which were measured as ratios into pure measures of quantity. Thus ESHAPE, OPWLRA, CIRCRA, PSUBRA, OPPTRA and CONGES were changed to :-

ESWALL - ESHAPE x WLAREA

OPWLAR - The area of openings in external walls

CIRCAR - The area of circulation space

PSUBAR - The area of prime function space

OPPTAR - The area of openings in partitions

SITEAR - The area of the site.

4.4 Obtaining the Data

4.4.1 Two classifications of building were selected for study; the main criterion for selection was the availability of the information. The two types are system-built schools and traditional factories.

4.4.2 The Chief Quantity Surveyor of Hertfordshire County Council agreed to supply the necessary data from all the schools they have built using a system-built design (The SEAC Mark 4). All the projects were examined and, after some were discarded because they were mainly of an alteration and adaptation nature, 21 projects were available for study.

4.4.3 The data for the factories were extracted from cost analyses published by the Building Cost Information Service and the Architect's Journal under the classificationCI/Sfb 27.

4.4.4 The information was entered on to standard pro-forma and punched direct on to cards. A blank pro-forma is shown in the appendix, Figs 3.1 to 3.3

4.5 Regression Analysis applied to the School Buildings Costs

4.5.1 The measures of quantities of the variables used to produce the models are shown in Figs. 3.4 to 3.7 and for the two schools on which the models were subsequently tested in Fig. 3.8. A computer program, Figs. 3.9 and 3.10, written in Fortran IV, was used to produce statistics of averages and standard deviations relating to the schools in Fig. 3.11. The program was used to test the theory, submitted by others, that costs can be calculated by multiplying the building area by the average cost per square foot or the number of pupil places by the average cost per place. The results shown numerically Fig. 3.12 and graphically Fig. 3.13 and 3.14, refute this theory. If the acceptable limits of accuracy are plus or minus 5%, then over one third of the schools using either method are outside these limits. The errors produced by these two methods do not always coincide so that guaranteed satisfactory results cannot be achieved by using average costs in this way.

4.5.2 A series of regression analyses were undertaken using all the variables, selected groups of variables and derived variables. The most successful model produced shown in Fig. 3.15, had a multiple correlation of .997 or 99%. The print out in Fig. 3.16, gives the actual school value (column 'Y') and the value as predicted by the model (column 'estimated Y').

4.5.3 The difference between them is shown as a percentage (column 'Ratio B') and illustrated graphically in Fig. 3.17. All the results were within the permitted accuracy limits. The model was tested on the two schools not included in the original data (see Fig. 3.18) and was found to have an error of -.004% and -3.9%.

4.5.4 From the success obtained, it is thought that there is great potential in using the method and it is recommended that an extensive study is made on school buildings using additional data. An approach has been made to the Department of Education and Science and is receiving consideration.

4.6 Regression Analysis Applied to Factories

4.6.1 Following the success of the model produced for the system-built schools, it was decided to ascertain if similar success could be achieved with factory buildings. Data were obtained from published analyses for projects constructed in different areas of the country, by a wide range of contractors and using a variety of designs.

4.6.2 The measures of quantities for the variables used are shown in Figs. 3.19 to 3.21. The computer program, Fig. 3.22 similar to the one shown in Figs. 3.9 and 3.10, produced similar statistics relating to the factories shown in Fig. 3.23. The results of the area multiplied by the average cost per square foot (Figs. 3.24 and 3.25) indicate that there is extreme variability in the accuracy of cost prediction using this technique. The amount of error ranging from -45% to +38% was far in excess of that for the schools' projects.

4.6.3 A series of regression analyses were undertaken using all the variables, groups of variables and derived variables. Each of the models was tested using four factories not included in the original set of data but unfortunately, none of the models produced results which approached the desired limits of accuracy. The most successful model (Fig. 3.26) had a multiple correlation of .974 or 95%. The comparisons between the actual values and predicted values (Figs. 3.27 and 3.28) produced results which were well outside the acceptable limits. Tests on the model (Fig. 3.29 and 3.30) gave differences of 50%. 20%, 18% and 45%.

4.6.4 This failure can be partly attributed to the wide variance in the design of buildings studied in comparison with the restricted range of school buildings. It is concluded that it is not possible to produce a regression model capable of predicting the cost in such a global situation unless many more variable factors are included. This would require a large number of projects to be analysed which may be impracticable within a contractor's organisation.

4.7 Future Use of Regression Analysis

4.7.1 From the limited study on the application of regression analysis to the two types of building, it can be tentatively concluded that the technique can be successfully used where buildings have similar construction. There are very many cases where this situation arises particularly in those firms specializing in designing and constructing as one commercial interest or specializing in the construction of a particular type of building.

4.7.2 Alternatively, it may be used by client organisations for the budgetary forecasting of their capital expenditure where the expenditure is on standard units, e.g. schools, houses, etc. Client organisations may also find that the technique provides useful guidance during the scheme design stage. Such guidance should minimize the danger of tenders exceeding cost limit.

4.7.3 Studies made by the Ministry of Transport (Ref. 7) into the use of regression analysis applied to motorway costs, confirm that it is indeed practical in this case.

4.8 Reconciling a Regression Model with Current Documentation

4.8.1 A model produced by regression analysis gives the total construction cost as a lump sum. In suitable circumstances, this figure will be more accurate than current alternative methods of estimating. However, the estimate is used for other purposes which require the total figure to be broken down into subdivisions. The most common method of subdividing work is by a Bill of Quantities, the detailed pricing of which may be a contractural obligation.

4.8.2 The lump sum may be reconciled with a detailed price breakdown as follows :-

(i) The Bill items are priced approximately using standard rates extracted from price books or from firm's records. A high degree of accuracy is not demanded as long as the balance between the costs of the items is approximately correct. The prices are extended and totalled to give a trial figure - TF.

(ii) A mark up for profit, establishment overheads and risk is calculated as a lump sum preferably by using bidding strategy techniques - M.

(iii) A cost estimate is prepared by using regression analysis - RA.

(iv) All the rates in the Bill are multiplied by the ratio $\frac{RA + M}{TF}$.

4.8.3 This produces a Bill of Quantities in which the total figure is within the permitted accuracy limits and is apportioned amongst the items in accordance with acceptable principles.

4.8.4 However, it is also current practice to load or lighten certain rates to effect a better cash flow or obtain a more favourable return where work is varied, remeasured or is patently over- or under-measured. The former can be achieved simply by multiplying the work by standard or variable constants, e.g. 1.2, 1.1, 1.0, 0.9, etc. at the same time as the correcting ratio is applied. Alternatively a linear program can be used to evaluate the optimum present worth (Ref. 8). Rate loading for possible varied work requires a high degree of skill and intuition and must be done on a selective basis to individual items.

CHAPTER 5

The Application of Regression Analysis to sub-sections of Buildings

Introduction

From the difficulties discovered in applying regression analysis to the total building cost as discussed in the previous chapter, it seems that the application of regression analysis to sub-sections of buildings is likely to produce better results.

A sub-section of a building may be a work trade, an operation an element or a discrete unit of construction. If these sub-sections are fairly large and thus kept to a limited number (maximum about 20) it should be possible to collect costs of achieved performance accurately recorded against these headings.

The similarity of the sub-sections in different building types will obviate the need for a large number of similar projects. Hence this method may be used by contractors who do not concentrate on one particular building type.

The regression model could be based on either client costs (bill rates) or on the records of actual site performance.

5.1 Detailed regression analysis applied to client costs

5.1.1 Reasonably successful results have been obtained at Loughborough University in the application ofregression analysis to the client costs of work sub-sections (ref. 3 & 9) However, Report No.34 published by the Construction Industry Research and Information Association showed that whilst the tenders bid by a number of contractors for a project are within a small percentage range, the individual rates in the Bill have a much greater variance. The variance in the rates will tend to distort the costs of individual sub-sections of work.

5.2 The causes of rate variance

5.2.1 The variance in individual rates which often exceeds 100%, is caused by several reasons.

5.2.2 Contractors frequently load certain Bill items by applying a weighting factor in order to improve the cash flow and reduce the effect of retention. It has been demonstrated (Ref. 10) that the addition of as little as five per cent to the payments received for the first quarter of a contract improves the rate of return on capital employed to roughly the same extent as a 20% addition to profit margins.

5.2.3 Accuracy in the preparation of tender documents is prone to human error. Estimators, noticing errors of omission or addition, will load or lighten the rates accordingly, so that when this error is subsequently corrected in the final account, added 'profit' is obtained. The apparent cost of these items will depend on whether an estimator considers the quantity to be correct.

5.2.4 There is considerable variance in the efficiency in which Contractors carry out particular trades or types of work. For example, a firm specializing in the erection of concrete framework will tend to have lower costs, and insert lower prices for those items in the Bill, than a firm with little expertise in that field. But because the other firm may have specialisms in other parts of the job and hence a lower price, the overall effect may be nullified.

5.2.5 A high proportion of construction work is done by sub-contracting firms. The main contractors select these firms without collusion with the result that the quotations one receives may differ from those of his competitors. Therefore, the lowest quotation inserted in the Bill, with a profit addition, will not be the same for every contractor.

5.2.6 There is no agreed standard costing system within the industry, and as shown previously, those used are prone to error. Contractors allocate costs under different headings, e.g. a tower crane may be costed with the site overheads or with measured work items. Estimates, based on the results of a costing system, will include these costs in different sections of the Bill. It is difficult for anyone outside the contractors' organisation to deduce where or how these items are priced and there is no means of knowing whether the rate variance is due to this or other causes.

5.2.7 Estimators are susceptible to human error and, whilst their work is frequently checked by a chief estimator, errors do occur. The errors, being either positive or negative, are frequently self cancelling and thus give negligible effect to the total cost prediction. However, the errors do cause a distortion of the rates in a particular subsection.

5.2.8 The estimate of cost is given to the tender panel for adjudication and application of bidding strategy. The panel will modify the estimate by the addition or subtraction of a lump sum. In order to account for this modification in the Bills, it is normal practice to vary the rates of only some of the items or sections. These inflated or reduced sections will not compare with those of other contractors who have either not made modifications or have modified other work sections.

5.2.9 There seems also to be some evidence to suggest that, as estimating is very much an open-ended process, inaccuracies are inevitable. The only real control of accuracy is the 'feel' of whether the total price is about right for the category of contract within the area and volume specified.

5.3 The effect of rate variance

5.3.1 If the costs of a single sub-section are extracted from a number of projects, the costs will not only vary because the quality and quantity of the work differ, but because of the effect of the variance in individual rates. As it is not possible to neutralize or remove this variance, a regression analysis on a sub-section would be based on unreliable sets of original data and hence produce an unreliable model. It was decided, therefore, to abandon this line of approach.

5.4 Detailed regression analysis applied to records of achieved performance

5.4.1 The use of detailed regression analysis based on records of achieved performance (as distinct from forecasts) has several distinct advantages. The limited number of cost headings should permit accuracy in collection, the similarity between building types should enable sufficient sets of data to be assembled, the data will be unaffected by rate variance, the simplicity in measuring quantity factors, and the records can be collected by contractors and, as discussed in the next paragraph, by client organisations.

5.5 The use of detailed regression analysis applied to recorded costs by client organisations

5.5.1 Whilst client estimating is not really within the scope of this thesis, Client organisations do have a great need for records of actual construction costs and measures of the conditions which influence them in order to produce economic designs in the future. Traditionally, the cost implications of design decisions are based on previous cost analyses which, as indicated previously, are prone to distortion. This distortion may cause a particular design solution to be included which, in reality, was more expensive than others to construct.

5.5.2 Clients, particularly those with larger building programmes, frequently require the Contractor to submit weekly returns of labour and plant to the Architect via the Clerk of Works. At present, little use is made of these returns because, as in the Contractor's own situation, the information which they contain is not usable for other purposes.

5.5.3 It should be possible to collect this information in a suitable and accurate form verified by the Clerk of Works, which will allow the client organisation to produce its own regression models. The factors affecting these returns may be quantified by the Clerk of Works or the Quantity Surveyor or both. The models may then be used to give accurate unbiased assessments in the design process.

5.5.4 The number of sets of records required to execute a regression analysis will limit this technique to those client organisations having a large building programme. To overcome this limitation, collaboration between separate organisations or their professional advisers could be instigated on similar lines to the Cost Information Service of the R.I.C.S.

5.6 The use of detailed regression analysis applied to recorded costs by contractors

5.6.1 The feasibility of applying detailed regression analysis to recorded costs of achieved performance was investigated. However, it was not found possible to pursue this approach at the present time because contractors were not able to supply their costs allocated to any sub-divisions or give measures of quantity, etc. which caused them.

5.6.2 Although it is not practical now, it is believed that this is likely to be a practical and reliable approach to getting feedback and hence form a valuable method of estimating. This is provided contractors are prepared to make the effort.

5.6.3 The provision of the relevant data for the future use of detailed regression analysis is integrated within the proposed new estimating method discussed in Chapter 8.

5.7 <u>The use of regression analysis for resource prediction</u>

5.7.1 The Building Research Establishment are currently using regression analysis to investigate site labour requirements for Local Authority Housing.

5.7.2 Labour expenditure on a number of different types of residential dwellings has been collected from Clerks' of Works returns and contractors' records. This has been apportioned amongst different accommodation provisions, building methods and the main building trade groupings.

5.7.3 The intention is to produce results which are suitable for assessing the resource requirements in overall terms based on average consumption in the industry.

5.7.4 Conditions which affect the wide range of resource quantities required per unit have not been measured or investigated and the B.R.E. staff concerned point out that the results will not be of great value in estimating for a particular project. The conditions which cause variations in cost are discussed in Chapter 7.

5.8 Conclusions

5.8.1 In contrast to the global application, regression analysis cannot be confidently applied to the client's costs of work sections.

5.8.2 Detailed regression analysis cannot be applied to Contractor's costs at present because these costs and a measure of the factors which influence them are not available.

5.8.3 The method of collection and evaluation is a relatively simple process and as a small number of cost headings are required, the data can be collected accurately by the client and the contractor.

5.8.4 Larger client organisations are able to insist that the contractors provide them with their records of resource usage on site. These records can be used to provide the Client with achieved performance data which will be of far greater use in future design decisions than current cost analyses.

5.8.5 It is strongly recommended that Contractors begin to assemble appropriate records from future projects so that regression analyses can be undertaken. It is suggested that this technique will provide an accurate and useful tool in the cost prediction of future projects.

5.8.6 The new method of estimating described in Chapter 8 allows costs to be collected for this purpose as well as giving a comparison against those originally estimated. It will, however, be necessary to record also the factors which affect the costs.

CHAPTER 6

The Pareto Distribution in Bills of Quantities

Introduction

Chapter 3 showed the difficulties in using classification to achieve feed-back from performance which could be used as a basis for estimating. Moreover, regression analysis cannot be applied until substantial volumes of data have been assembled. It is, therefore, necessary to investigate alternative means of improving estimating methods.

6.1 Headings derived from Bills of Quantities

6.1.1 Bills of Quantities have been widely used for building work in Britain for over a century. Consequently they are well recognised and understood by all members of the building team.

6.1.2 Nearly all current estimating methods relate to the detailed pricing of the Bill and records of production output, however inaccurate, are necessary for this purpose.

6.1.3 It is, therefore, proposed to use current Bill items as cost headings. Once work has been categorized and accurate records collected, it should then be possible to pursue more sophisticated techniques of cost prediction, e.g. those based on cost models.

6.1.4 An approach using Bill items will involve only small changes to methods which are already familiar to estimators. This approach, therefore, has more chance of success in overcoming resistance to change than more radical changes even if the latter are intrinsically superior.

6.2 The number of items in a Bill of Quantities

6.2.1 The number of priceable items in Bills of Quantities prepared in accordance with the Standard Method of Measurement varies with each project. The actual number depends upon :-

(i) The format of the Bill, e.g. elemental and sectionalized bills have a greater duplication of items than traditional bills.

(ii) The simplicity and repeatability of the design.

(iii) The size of the project - although in practice this does not exert a great influence because an item may be for one or one thousand units.

6.2.2 For purposes of this thesis it is assumed that there are about 2,000 items in an average Bill of Quantities. This assumption has been based on the current opinion of senior personnel within the industry.

6.2.3 Each of these items has some theoretical cost importance and currently estimators attach a price to nearly every one. However, there are some items which have a greater cost importance than others.

6.3 A reduction in the number of Bill items

6.3.1 Because it is impractical to collect and record actual performance data and predict costs for 2,000 individual items, this number must be reduced to an acceptable figure.

6.3.2 Unless a change is made in the Standard Method of Measurement, the number of items produced by the client's quantity surveyor cannot be altered. Therefore, any reduction must be made by individual contractors to suit their own purposes.

6.3.3 There are two methods of effecting a reduction in the number of items. The first method is to consider only those bill items which have a significant cost importance. The remaining items may either be discarded or treated in an arbitrary manner. The second method is to group several bill items together, e.g. those relating to a certain operation, and consider the cost effect of the group rather than the individual items.

6.3.4 It may be advantageous to combine both methods in a new estimating system.

6.4 The pareto distribution in Bills of Quantities

6.4.1 The problem of dealing with a large number of items is similar to the situation encountered in controlling stock. In "Stock Control: A Practical Approach", K. Lockyer suggests that the Pareto effect can be used to reduce the number of items. He showed that a small proportion of the items account for a very large proportion of the total stock. Thus, tight control on these items will ensure that the majority of the stock is controlled. The Pareto curve is illustrated in Fig 6.1

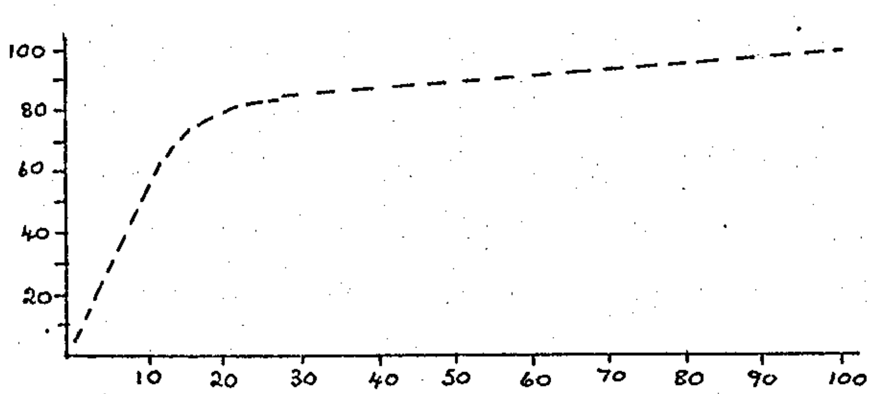

Fig 6·1

6.4.2 Investigation into the cost structure of items in Bills of Quantities (Ref. 11) have proved the existence of a Pareto distribution. The characteristic discovered was that typically 20% of the items contain at least 80% of the total cost of the building. It would, therefore, be advantageous to use this distribution to effect a reduction in the number of items to be used as the basis for estimating.

6.5 Establishment of the cost important items

6.5.1 A cost important item is defined as one contained within the 80% of the total cost of the building. The cost of the item is derived by multiplying the unit quantity by the unit cost.

6.5.2 In order to ascertain which of the 2,000 items are cost important, it is necessary to have a method of listing and ranking the items in descending order of value. Whilst it is possible to do this by eye, this type of calculation is eminently suitable for computer application.

6.5.3 A suggested method of establishing the cost important items is as follows :-

(i) Each item is given an initial estimated unit cost. As this estimated cost is for ranking purposes only, great accuracy is not essential as any errors will be corrected at a later stage.

(ii) The product of estimated unit cost x unit quantity is calculated.

(iii) The items are placed in descending order of total cost.

(iv) The nominal cut-off parameter, i.e. the 80% of the value of the items, is indicated by a dotted line or other graphic.

6.5.4 All those items above the cut-off parameter may then be considered in detail. The remainder can either be left as their initial estimate or modified by a simple multiplying factor following the re-appraisal of the cost important items.

6.5.5 The foregoing method reduces the number of items to be considered from 2,000 to about 400 cost important items but 400 is still too large and must be further reduced.

6.6 Operational grouping

6.6.1 Another method of reducing the number of items is to group together like items and consider them as one. The most obvious form for the group is the operation.

6.6.2 There are several different definitions of an operation varying from the micro to the macro level, but as it is not possible to collect records of a large number of micro operations, the operation for the purposes of estimating and feed-back is defined as that relating to a main constructional element, e.g. excavate foundations, structural framework, second fix carpentry.

6.6.3 Operational estimating has been used extensively in Civil Engineering work but attempts to introduce it into the building sphere have mainly failed. The reasons for this failure are :-

(i) The change in the Bill format was too radical for many contractors.

(ii) The operations were at the micro level.

(iii) The operations were selected by the client's advisers and did not always relate to the Contractor's own construction method.

(iv) The contractors did not have any operational records on which to base their predictions.

(v) Architects and Quantity Surveyors found operational information expensive to produce.

6.6.4 However, Building estimators are now beginning to develop operational estimating (see Appendix 5 - Seminar on

Estimating) and it is believed that this trend will continue.

6.6.5 A simple method for grouping the bill items into operations is as follows :-

(i) The Estimator and Planner determine the main operations of the project and assign a number to each operation.

(ii) Each item in the Bill is given the number of the operation to which it relates.

(iii) All the items are sorted and grouped under the relevant operational headings.

6.6.6 The items in the operational group which relate to a common production unit may be collected together and appraised as one item: alternatively, the whole operation may be operationally costed on a resource basis.

6.7 The combination of the Pareto distribution and operational grouping

6.7.1 A computer program has been written which combines the Pareto distribution and operational grouping. This program forms the basis of the proposed estimating method described in subsequent chapters.

6.8 Conclusions

6.8.1 The main work sections in Bills of Quantities with some modification form the basis of cost headings which may be used for estimating and feedback.

6.8.2 The number of items can be very substantially reduced by using the Pareto distribution and operational grouping.

CHAPTER 7

Factors Affecting the Accuracy of Cost Prediction

Introduction

An estimate has several main components whose individual values must be accurately assessed to arrive at the probable cost of the work. This chapter attempts to examine each component in detail in order to discover what factors influence them, whether these factors are capable of measurement and the effect they have on the accuracy of a cost prediction. The components are divided into six groups, namely, labour, materials, plant, sub-contractors, overheads and profit, of which the first four are strictly the concern of the estimator. The factors may interact and affect more than one component in any particular event so that this sub-division will not always be water tight.

7.1 Labour

7.1.1 Forecasting labour requirements is perhaps the most problematical area in the build up of the contractor's cost estimate. There are several interacting causes.

7.1.2 Each project is virtually unique in design (with the exception of low rise housing) so that lessons learnt are of questionable value in new similar projects.

7.1.3 A complete workforce is seldom transferred from job to job so that whilst a competent site agent may obtain favourable results in one situation, there is no guarantee that this performance will be repeated in another.

7.1.4 Studies undertaken by the Building Research Establishment have shown that a learning curve exists for building operations and that output increases with repetition up to a certain level. The increase in output is caused by job familiarity, individual awareness, self programming of work and co-operation with other members of the labour team. Although the studies were limited to housing, there is no reason to suppose that this is not applicable to other types of work where there is a degree of repetition. It is extremely difficult to assess the value of this learning curve for new projects particularly when a number of variations may be anticipated.

7.1.5 Labour productivity is dominated by the efficiency and effectiveness of site management. This was illustrated by work study carried out on a housing scheme at Welwyn Garden City. Estimators had assessed the labour content of the plumbing for each house at about 65 hours, which was averaged in practice. But, the actual time taken by individual gangs and in different areas varied from 41 hours to 80 hours per house. It was found that the lowest times were recorded where work was particularly well planned, able to be executed without interference from other trades, and closely supervised. The breakdown of a typical house in the context may be considered as follows :-

Optimum at face work content	22 hours
Moving materials, snagging, non-trade work, movement around site ..	19 hours
Not working ..	24 hours
	65 hours

Whilst one survey is not conclusive evidence as to the average time taken, it shows that the efficiency of the site organisation has a far greater effect on productivity than the quantity of work which is measured.

It is possible to keep records of individual sitemanager's performance over a range of past projects but, as it is unusual for the estimator to know at the tender stage who will in fact run the job, these would be of little value.

7.1.6 The quantity of work measured gives no indication of the probable erection time, i.e. there is little close linear relationship between quantity and time. Measurements seldom express the complexity of an operation and even when complexity is apparent, the other factors, e.g. excellent site management, may mitigate its effect.

A given area of brickwork may be either in a plain blank wall which can be built fairly quickly or in a wall with a high proportion of openings. In the latter case a considerable proportion of the time will be consumed not in building the wall but in forming the openings - a facet which will not have been mentioned. Fig.7.1 taken from B.R.S. digest No. 134, illustrates further variations in the quantity/time taken variance. A room which requires plastering will have a given area with a certain proportion of more time-consuming linear features. Unit constants would presuppose that x hours will be spent on the superficial areas and y hours will be spent on the linear. In practice, since plastering is a heavy manual operation, the men take frequent breaks from the main work and fill in the time by executing the less physical demanding linear items. If these are not present then it is probable that they would do nothing during the breaks. Workers set themselves given periods, usually in multiples of half a day, to complete certain quantities of work. If they find this target is generous then they will slacken-off to finish on the pre-determined time. The converse is also applicable.

For the sake of brevity, this philosophy has been illustrated with only two examples but it may be considered as indicative of the remainder of the trade workings.

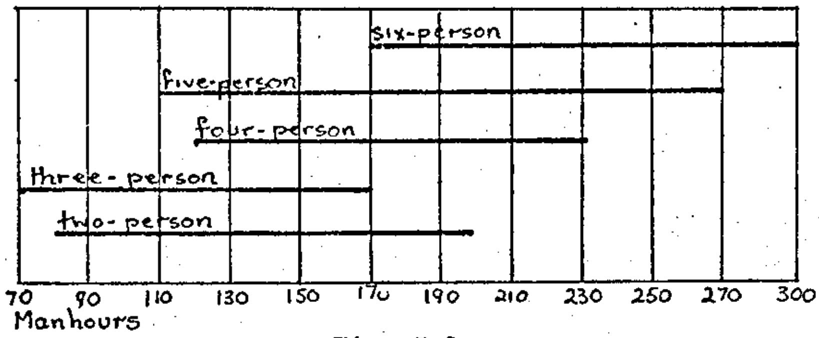

Fig. 7.1

7.1.7 Productivity is linked to incentive. The average time to erect a traditional three storey house is about 1600 manhours and on some sites this may be as low as 1200 hours. On the latter, high incentive payments are made to obtain greater output and when efficiently operated they have the desired result. It is interesting to note that the cost of the work often remains the same, i.e. (1600 x £1. = £1600.) = (1200 x £1.33 = £1600.) but the saving in time and reduction of men utilised also brings about a saving which benefits the contractor by a reduction in on-costs and overheads. Incentive payment schemes are frequently inefficiently administered which makes the project more expensive than if one were not used and disputes over bonus, etc. are perhaps the greatest cause of labour unrest in the building industry.

Many firms do not have an incentive policy linked to company standards and where such schemes are in operation it is usual for each site to set its own target. This may or may not achieve the results as originally estimated in the tender.

7.1.8 Labour outputs vary from area to area. Some parts of the country have traditionally poor output and strong union militancy. These are fairly well recognised by local and national contractors with experience of working in those areas. Difficulties become acute when union officials select a particular site as a target for militancy.

7.1.9 Efficient group working is dependent on the gang size, its members and the ratio of skilled to non-skilled operatives. There is no agreed standard group so that it may vary from company to company, job to job and even at different periods within a single job. It is the latter two that affect a company estimator in that his predictions are not confirmed in practice. It is not always possible to adhere to the gang sizes specified in the pre-tender plan as it may not be practicable to obtain additional labour at a reasonable cost. However, there is a greater possibility that estimating related to operational gang sizing will be more accurate than applying constants to measured units.

7.1.10 Efficient working is dependent upon the requisite materials being delivered at the right time and in the desired place. The building industry suffers from peaking of demand of various basic materials which are not easy to forecast. In recent years there have been periodical shortages of timber, cement, copper, bricks, steel, etc. on which early ordering has had only a marginal effect on their supply to a particular site. When they become unavailable, the progress of work becomes spasmodic and the management is faced with the decision whether to lay the men off or keep them on, doing work for which they are overtrained with an uneconomic cost penalty, and at much less speed.

7.1.11 The complexity of modern buildings demands the skills from many specialist sub-contracting firms, some of which are nominated by the client and are not known at the tendering stage. Their work, interlinked with that of the main contractor, has a consequential effect particularly on subsequent operations. There is considerable variance in their performance, which is not capable of objective assessment, so that theoretical suppositions of their programme and performance may be of little relevance in practice.

7.1.12 It may be thought that where detailed plans, specifications and Bills of Quantities have been prepared, the constructed building will be very similar to that proposed in these documents. In the majority of cases this assumption will be correct but there are a considerable number of projects where they bear little resemblance. This may be caused by revision before work is commenced, when the Contractor's tender is above the client's cost limit, where there is a change in the use of the building, e.g. factory in lieu of a warehouse, or where the original design does not work in practice. The variations may invalidate the predicted method of operation and whilst the price of the work will be adjusted in accordance with recognised rules, it is probable that it will not adequately recompense the contractor for the extra costs involved, unless he has weighted his rates for a favourable return.

7.1.13 The quality of the workmanship for a particular project is specified in the preambles of a Bill of Quantities by reference to national standards and codes of practice. Local practice and certain clients may allow some degree of latitude in the application of these standards so that estimators often supplement them by a subjective assessment as to the class of job. A bank will demand workmanship of a very high quality and a factory may be of low quality even though some of the materials and specifications used will be common to both.

The time taken to perform building work and the skill of the men employed are directly related to the quality of workmanship demanded and where this quality is contravened, the work will have to be demolished and rebuilt.

Problems occur when the quality demanded on site by an over-zealous Clerk of Works or Architect is higher than that assumed to be typical for that class of work.

Assessments can be made for the quality effect on labour outputs and payments but the estimator may not know at that stage, who will be the client's authority in charge of quality and hence the degree of latitude which will be permitted. The estimator may also not know the effectiveness of his own company's personnel in complying with these standards.

7.1.14 The weather exerts a considerable influence on the workmen's output. It may be simply stated that output is high in periods of fine warm weather (other things being equal) and low when it is cold and wet. Reference to climatic records kept by the Meteorological Office will indicate when these periods are likely to occur and due allowance made. However, this allowance can be affected by unusually inclement weather, for which extension of time but no extra payment can be claimed, or when the sequence of work is not done in accordance with the pre-tender programme. The latter is particularly critical for groundworks executed in winter rather than summer months.

7.2 Materials

7.2.1 Material requirements are thought to be the most accurate area of the contractor's cost estimate but there are several factors which cause disparity.

7.2.2 Material delivered to site has an element of waste which is either inherent in the material itself or is created by working or shaping to the desired form.

7.2.3 Inherent waste may be deduced from standard data as in the case of loss of bulk when mixing concrete, but this waste may have a considerable variance in practice due to the relative expertise of the quality control personnel. Most firms leave bulk materials in disorganised heaps around the site and keep valuable smaller goods in high security compounds. The high percentage of waste occurring in the former may appear of marginal cost but aggregated to the value of work they pertain, this cost may amount to a considerable sum. A large percentage could be saved by adequate care and attention which is again dependent on the site personnel.

7.2.4 Material damage is related to the number of times it is handled. A common figure for damage to facing bricks is 2% but if the stacks are badly situated they may have to be subsequently moved to other situations incurring further two per cents.

7.2.5 The quantities measured in the contract bills are nett, i.e. no allowance is made for inexactitude for which the contractor is held responsible. This inexactitude can carry a heavy cost penalty particularly in horizontal planes where extra material put in to bring the surface up to the correct level may be as much as 25%.

7.2.6 The National Federation of Building Trades Employers estimate the annual loss of material by theft to be £100. million per annum. Building operatives virtually consider 'off-cuts' to be their own property which they take home to carry out repairs on their own or client's property. Where supervision is lax, it is not unknown for them to increase the proportion of 'off-cuts' in normal use or remove various fittings, etc. from the stores. Theft by persons not employed by the company can be contained by adequate security arrangements but their effectiveness is by no means certain.

7.2.7 The accuracy of materials delivered to site are verified by comparison with delivery notes. It is a difficult, tedious process to check the quantities accurately, especially bulk deliveries which necessitate a weighbridge, and discrepancies are bound to occur. Newspapers have constantly reported court cases where fraud or theft has occurred due to collusion between the site checker and the delivery drivers.

7.2.8 Waste caused by cutting or forming depends on the geometric shape of the material in relation to the finished product. The Architect can exert a great influence on this by designing the finished sizes in harmony with basic sizes of materials. This affinity is not always manifest in bill descriptions and is particularly noticeable in superficial items. For example, plasterboard is obtainable in standard lengths of 2400, 2700, 3000mm, etc. so that if a floor to ceiling height of 2800mm is specified, a 3000mm sheet will have to be used with 6% waste and the additional cost of cutting. It would be obviously less expensive if the height was 3000mm but the area measured would not reflect this.

Skilled craftsmen produce less waste than those that are not so adept but once again the estimator is left in the realms of doubt as he will not know the level of skill that will actually be used on site.

7.2.9 It is normal building practice for the contractor to unload the delivered materials from the lorries, which is usually considered a task for the casual unassigned site labour force. However, where this particular type of labour force is unavailable it is necessary to use whatever other men there are available, including tradesmen. Whilst the time taken in unloading may approximate to that allowed, it also incurs a considerable cost in the disruption of sequence of work. This disruptive cost, which should really be apportionable to the cost of the materials, is never included in the estimate.

7.2.10 Particular materials are delivered in crates or special packaging which are charged for on a returnable basis. As the cost of these packages can aggregate to a reasonable sum of money, it is hoped that these will, in fact, be returned. Observation on any site will show them being used as kindling or temporary works. The efficiency of return is dependent on the site supervisory staff and also the cost of transporting the items. It is extremely difficult to allow for these costs at the tender stage and the position can be aggravated by the client using a high proportion of Nominated suppliers whose point of manufacture is outside their normal delivery radius.

7.2.11 It is the practice in the building industry to allow trade quantity and cash discounts on the vast majority of good used by the Contractor. The trade discount will always apply and causes no problem but the other two may be varied during the construction period. Quantity discounts may give extra reductions for an increase in the number of units ordered at one time, but great care has to be taken when calculating the net cost to ensure what the order size will be. As an example, a scheme may include 100 baths for which x discount will be quoted, but depending on the planning and progress of the work, not all these baths will be needed at any one time so that one order may only be for a quarter of the total. In this instance, the firm may only get the 25 quantity discount. The rules for obtaining a discount for cash are fairly standard and well recognised i.e. 5% cash discount when payment is made within 30 days from the end of the month in which the goods were delivered. Prompt payment, therefore, is a condition precedent to obtaining the goods 5% cheaper and one would expect that this will be done. It is not unusual for either the invoice to be overlooked or undilatory action on behalf of the accounts staff, which causes loss of this right. In cases of extreme financial pressure, the contractor's liquidity position may not allow him to make timely payment.

7.2.12 Certain materials need protective storage on site against damage caused by the elements. The contractor will allow in the preliminary bill for a certain area of sheds for this purpose and believe that the balance will be located in the part completed building. As the use of the building for this purpose may be prohibited by the client, or the original provision may not be sufficient to cope with larger deliveries ordered for the quantity discounts or over delivery by the supplier, the storage costs may be considerably more than anticipated.

7.2.13 Inherent in the fixed-in-position cost of the materials is an allowance for their distribution and hoisting.

The planning/estimating team may theorize on the most logical initial storage place and mode of subsequent distribution, but there are many cases where this decision is not practicable. Initial storage places may have to be re-sited to allow for the insertion of re-located services, or the method of erection changed to incorporate certain items of plant, which although having greater productivity require extra space in which to move. Unless the building is operationally analysed, hoisting difficulties may not make themselves apparent at the tender stage.

7.3 Mechanical Plant

7.3.1 The use of mechanical plant in the construction industry has considerably increased during the last decade with the scarcity of manpower, the demand for rapid erection and the use of larger components.

7.3.2 The economics of plant require that there is sufficient work, in sufficient quantity, for which the plant was designed, to keep it continuously employed as near as possible to its maximum capacity. Various items of plant can perform more than one operation but some of these other operations will be done less favourably than another type of machine which is particularly suited. It requires great skill to select the optimum type for a particular job and balance that typo with the requirements of other tasks to minimize the total number of machines. Initial selection is made by the planning/estimating team and suitably costed. However, the circumstances of the project may change the type of main machine necessary, e.g. the soil is much harder to excavate than was thought, so that a more powerful and more expensive machine is necessary. Whilst the extra cost for that operation may be recovered from the client, it is unlikely that the contractor will be recompensed for the larger machine doing the subsiduary work, for which it is over employed.

7.3.3 Contractors have the option of purchasing or hiring the various items of mechanical plant they use but whichever option they take, they normally charge it to the site on a time basis. In deciding whether to purchase or hire plant the following considerations are normally taken into account :-

(i) The extent to which it will be used on present or future contracts.

(ii) The provision of storage space.

(iii) The availability of proper servicing facilities

(iv) The amount of capital available, interest rates, tax reliefs and investment grants.

(v) The recruitment of trained personnel.

(vi) The general level of hire cost rates.

None of these points are ever fixed or certain so that the validity of a decision taken at one time can be challenged as circumstances change. This may cause the charging rate to vary considerably over a given period during a project.

7.3.4 Unit costs for items of work where plant is involved, is simply computed by hire rate x output per time period + an allowance for profit and establishment overheads. Estimators have records of machine output, for use in their calculations, which have usually been derived from past site performances. It would seem that more records of their work are kept than for labour because of the relative simplicity of the recording process but as the outputs are susceptible to many of the variances that pertain to labour, the chances of inaccurate prediction are fairly high.

7.3.5 Machines are very costly to transport to the site and selection takes into account the number of visits to be made, based on the proposed programme of work. Where parcels of work are held up through unforeseen circumstances then either extra visits have to be made or the machine will have to stand idle.

7.3.6 Because of the lack of adequate servicing and frequent misuse, the incidence of breakdowns can be quite high - dependent on the quality of the site management team. These occurrences involve not only loss in productivity of the machine but may incur a far greater loss in disrupting subsequent operations. This is particularly critical where the task has to be done by that plant, e.g. tower crane, and cannot be completed by any alternative means.

7.4 Sub-contractors

7.4.1 The incidence of sub-contracting has greatly increased over the last two decades. This is probably due to the complexity of modern buildings, labour shortage, structuring of large firms and taxation policy.

7.4.2 There are several trades which have nearly always been sub-let, e.g. plastering, plumbing, glazing and painting, because many companies did not have a sufficient volume of work to keep these specialist workmen fully employed.

7.4.3 It is now common practice to sub-contract items of work which, in the past, have been in the main contractor's domain, e.g. excavation, formwork, brickwork and carpentry.

7.4.4 As a result, a considerable proportion of the contract work may be sub-contracted and any inaccuracies will exert a considerable influence on the main contractor's profit margins.

7.4.5 Sub-contracts may be one of two types. Either labour only sub-contracts, which are contracts for the sole provision of labour, or normal sub-contracts which provide for the supply of labour and materials.

7.4.6 Estimators are generally in favour of sub-letting work as the receipt of a firm quotation often relieves them of the responsibility for making their own time/cost predictions on the direct employment of personnel. The latter, as shown previously, are subject to great inaccuracies.

7.4.7 When the market is fairly stable, labour-only sub-contracting can be a reasonably accurate method of cost prediction. The current rates for work are identifiable and well known, e.g. £x. per thousand for bricklaying, even if current quotations are not obtained for each job. These rates are reasonably fixed as many of the factors affecting direct employment do not apply. The sub-contractors either take the risks themselves or mitigate their effect by greater self-motivation.

7.4.8 The danger exists when proposed labour-only sub-contracting is subsequently prohibited. Building unions may select specific sites to be a closed shop, thus forcing all workers to be members of a trades' union. In effect, this removes all 'lump' labour from the site.

7.4.9 Clients, notably in the public sector, impose a contractual prohibition on the use of labour only. Contractors attempt to evade this restriction either by a sale and repurchase transaction for materials, thus making the sub-contract for labour <u>and</u> materials, or by ignoring its existence. However, if the client insists on the prohibition, the contractor will have to revert to direct employment.

7.4.10 Normal sub-contracting is permissible with the Architect's prior consent (Standard Form of Building Contract Clause 17) and it is usual to seek quotations for this work at the time of tendering. Estimators often experience considerable difficulty in obtaining quotations through the indifferent laxity of these firms. The reason for this attitude is that although a sub-contractor may submit the lowest quotation at tender stage, no binding contract exists. Before letting the work, contractors frequently re-test the market to discover any possible cheaper competitors. This naturally tends to discourage any initiative at tender stage and as many as fifty per cent of the original lowest sub-contractors may be subsequently underbid or not do the work.

7.4.11 Where quotations cannot be obtained before tender submission, estimators have to use considerable skill and judgment in inserting cover prices based on their assessment as to what they will be quoted at a future date.

7.4.12 However, the basic process of selection acquisition and evaluation is mainly of a clerical nature which is capable of being done by suitably trained staff, instead of an estimator.

7.5 Conclusions

7.5.1 There are many factors which cause variations in the achieved performance of labour and plant. Inaccuracy of prediction is, therefore, particularly marked in these areas.

7.5.2 As labour and plant contribute a high proportion of the cost of the contractor's own work, an increase in the predictive accuracy will produce an improvement in the overall profitability of the contract.

7.5.3 Labour and plant prediction requires a high degree of skill and judgment as many of the factors which influence output are incapable of measurement at present.

7.5.4 The present format of Bills of Quantities does not lend itself to intuitive assessment of the many factors which affect production. Other formats, i.e. operational, may prove to be of greater value.

7.5.5 The selection, acquisition and evaluation of the cost of materials and sub-contractors, is a routine technical process which can be performed by suitably trained staff. Although materials and sub-contractors' work account for a reasonable proportion of the total, their cost is less variable than that of labour and plant and their effect on the accuracy of the total cost is, therefore, substantially less marked.

7.5.6 Thus there is a need for a new method of estimating which permits the estimator to concentrate on and improve labour and plant cost prediction. The task of producing material and sub-contract forecasts may be delegated to technical clerks.

CHAPTER 8.

A NEW METHOD OF ESTIMATING

Introduction:

Previous chapters have illustrated the difficulty of devising and testing radical alternatives to current methods of estimating. However, detailed investigation described in Chapters 6 and 7 suggests that improvements could be made by :-

(i) Concentrating on the costs of labour and plant.

(ii) Introducing operational estimating.

(iii) Dealing with items selectively according to their cost importance.

(iv) Delegating routine, less skilled tasks, to clerical operatives.

A new method of estimating has been devised by the author which has the following characteristics :-

(i) As the shortage of skilled estimators prohibits any increase in their total work-load, estimators' work content is, in fact, reduced.

(ii) As there is a strong preference for the use of Bills of Quantities by the Client's advisers and the contractors, this document is retained.

(iii) Because Bill formats and descriptions are not standardized, great flexibility is provided in the use of any such documents.

(iv) The resistance to change in the use of computers is overcome by simplicity and a system of operation which is comprehensible to estimators.

(v) Individual rates in the Contract bills do not, and need not, constitute in themselves, an accurate forecast of the cost of performing the work for individual items.

8.1 Synopsis of New Method of Estimating

8.1.1 The New Method of Estimating divorces the less skilled tasks of material and sub-contractor costing from the difficult task of labour and plant estimating. The former is delegated to clerical operatives. Operation work groups for labour and plant are established and the cost-important items highlighted. This permits the estimator to concentrate on the critical items and use predictive techniques other than unit rates. The method is divided into the following stages :-

(i) Decision to tender and establishment of the relative desirability of the project.

(ii) Invitation of sub-contract quotations.

(iii) Invitation of material quotations.

(iv) Pre-tender planning and operational grouping.

(v) Approximate rating.

(vi) Computer processing to establish the cost-important items and group items into operations.

(vii) Refinement of the original estimate.

(viii) Re-pricing manually or by computer.

(ix) Collation of costs.

(x) Evaluation and pricing of preliminary items.

(xi) Tender adjudication and application of bidding strategy.

8.2 Application of the Mark-up

8.2.1 There is no standard procedure in the building industry for applying the mark-up for establishment overheads, profit and risk. Contractors differ in their approach but the procedure falls into two broad categories.

8.2.2 The estimators can be instructed to produce a net estimate of the cost of constructing the work for submission to the tender adjudication panel. The panel themselves make the necessary addition for the mark-up and this figure is apportioned over some or all of the measured rates or inserted as lump sums in the preliminaries or insurances section of the Bills.

8.2.3 Alternatively, the estimators can be instructed to produce an estimate of the cost which contains the standard company mark-up. When the tender adjudication panel wish to modify this mark-up for a particular contract, the difference is usually adjusted by a lump sum omission or addition to items in the preliminaries.

8.2.4 As the mark-up procedure depends on the individual contractor and is incidental to the preparation of the actual estimate, the New Method does not make any mandatory recommendations. The contractor may adopt his usual procedure and insert the mark-up by whichever he considers appropriate.

8.3 The Decision to Tender and the Relative Desirability of the Project

8.3.1 Upon receipt of a tender enquiry from the Client, the company must decide if it wishes to submit a bid for that particular project. The decision, taken at senior management level, will be based on whether the project is within the company's expertise, within the company's defined area of operation and, if the bid is successful, compatible with the present and future work load.

8.3.2 If an affirmative decision to tender has been taken, further investigation should be undertaken to establish the relative desirability of the project. The desirability is influenced by :-

(i) The ease or difficulty of erection.

(ii) Resources currently available.

(iii) Capital available.

(iv) Profitability.

(v) Chance of success.

(vi) Prestige associated with the project.

(vii) Furtherance of additional work.

(viii) Acquaintance with the client or his advisers.

8.3.3 The relative desirability of the project will govern not only the keenness in bidding but the amount of detail necessary in preparing the estimate.

8.3.4 Those projects which are not really desirable, can be priced by a simplified method of estimating, e.g. cost per square metre, with a larger mark-up than usual added to cover profit and the risks associated with this type of estimating. This approach is the most economic way of estimating for such projects but the high mark-up reduces the chance of submitting a winning bid. If, however, the contractor is the lowest tenderer, the Bill can be priced out, subsequently, using currently acceptable market rates.

8.3.5 For projects which are considered desirable, it is recommended that the New Method of Estimating is adopted.

8.4 The Selection and Evaluation of Domestic Sub-contractors

8.4.1 The current methods of selecting sub-contractors can be improved considerably. Many contractors do not keep an adequate store of information relating to these companies and, consequently, time is wasted by referring to the yellow pages of the telephone directory or trade journals. There is no guarantee that companies selected by this method are competent to do the work. The estimator is frequently engaged on this task which can, in fact, be done by cheaper clerical staff. The following routine seeks to improve current procedure.

8.4.2 The first process, performed by the estimator, is the identification of those items of work which are either outside the limits of the company's expertise or are in excess of its normal capacity. This work will be let to a sub-contractor. Once the page and item numbers in the Bills of Quantities of the sub-contract work has been listed by the estimator, the remainder of the task can be done by clerical staff. The clerical task comprises, the identification and selection of suitable firms, the despatch of tender documents and the receipt and collation of tender bids.

8.4.3 It is recommended that contractors compile records of sub-contractors which contain :-

(i) The type of work performed by the sub-contractors.

(ii) The geographical area in which they operate.

(iii) The size range of contracts normally undertaken.

(iv) The names, addresses and telephone numbers.

(v) An assessment of each sub-contractor's efficiency in tendering for and performing the work.

These records, compiled by experience and/or questionnaire over a period of time, as the occasion arises, may be stored either on a computer or card index.

8.4.4 The selection of a list of potential sub-contractors for a project will be facilitated if the records are suitably coded. As it should not be necessary to request tenders from more than six sub-contractors for any one section of work, the best six can be selected from the list by reference to the individual efficiency ratings.

8.4.5 For each group of work items, the clerk is required to photostat copies of the pertinent pages of the Bills of Quantities, complete two copies of a standard form of enquiry and tender, and despatch them to the shortlisted sub-contractors.

8.4.6 A standard form of enquiry and tender should contain all the information necessary for the sub-contractor and include a resume of the conditions of contract. An advantage of using such a form is that it should limit future disputes and, in many cases, can be substituted for a separate form of sub-contract.

8.4.7 A clerk is responsible for collecting the tenders and for pursuing those that have not been received by a pre-determined dead-line. The collated tenders are passed to the estimator.

8.4.8 The estimator then evaluates and analyses the various tenders to select the one which is the most favourable to his company. Any extra items to be provided by the contractor, e.g. those listed under 'special provisions' in the standard form, are costed and added to the tender figure.

8.4.9 The combined total only is inserted in the Bill bracketted against the relevant items. There is no necessity to price out the items in detail at this stage as it will only be necessary if the Contractor's Bills are called for examination by the client's advisers.

8.5 The Selection and Evaluation of Material Suppliers

8.5.1 It is a function of the buying department to obtain quotations for the cost of materials required in the project. Suitably skilled staff should be employed to solicit quotations at the lowest possible price. Buying skill is not a function of the estimator and, unless specialist buyers are used, valuable discounts will not be obtained.

8.5.2 Prior to seeking quotations, the buying department require to know the type and specification of the materials and measures of the quantity expressed in commercial purchasing units. As the department is not generally equipped with the necessary skill to convert Bill measurements into purchasing units, the estimator usually has to do this conversion. However, the majority of the conversion can be performed by technical clerks which will thus release the estimator for other highly skilled tasks. The following routine illustrates the recommended procedure.

8.5.3 The Bills of Quantities, less those sections which are to be sub-contracted, are passed to a technical clerk who has two tasks to perform. The first task is the conversion of the measured bill units into purchasing units for use by the buying department. When quotations have been received, the second task is the apportionment of the material costs over the bill items.

8.5.4 The ease or difficulty in converting measured bill units varies for different work sections. For example, in 'Concrete Work', the total volume of concrete has to be split into the individual quantities of its constituent parts, i.e. cement, sand and aggregate, whilst in 'Joinery' the bill units may be used directly as the purchasing units.

8.5.5 However, the majority of measured bill units do require conversion and this is normally done by reference to standard tables of material constants, manufacturers' trade literature etc. Provided a company keep adequate records of material constants and waste incurred on site, this task does not require an estimator's skill and is thus within a clerk's capabilities.

8.5.6 The buyer should seek quotations on a Standard Form of Enquiry and Conditions of Sale. The use of such a form should overcome the difficulties encountered when the supplier's conditions of sale contradict those in the original enquiry.

8.5.7 Upon receipt of quotations, the clerk must insert the cost of materials bracketted against the groups of items to which they relate. As with sub-contractors' costs, there is no necessity to price out the items in detail, until the Bill is called for examination by the Client's advisers.

8.6 Pre-tender Planning and Operational Grouping

8.6.1 When the clerk(s) are selecting and evaluating the sub-contractors and suppliers, the pre-tender plan, i.e. the establishment of the method and sequence of constructing the project, is prepared by the planner and the estimator. Close co-operation between them is essential so that they both comprehend and agree to the tentative solution.

8.6.2 In the pre-tender plan, the project is divided into the main operations which should be large identifiable sections of work. A typical list would comprise :-

(i) Substructure.

(ii) Frame.

(iii) Roofing.

(iv) First fix.

(v) Finishing.

(vi) Second fix.

(vii) Drainage.

(viii) External works.

8.6.3 The above operations are those normally executed by the contractor's own labour and are, consequently, the ones presenting the greatest financial risk. Where the contractor does not sub-let part or parts of the other sections of work, additional operations may be included in the appropriate position.

8.6.4 Items in the list may be sub-divided, e.g. external works, into excavation, concrete, brickwork, etc. but the total number of operations should be limited to approximately 20. It has been previously demonstrated that 20 is about the maximum number of headings against which it is possible to collect accurate costs of achieved performance.

8.6.5 The estimator inserts the operation number in the bill against the items of work which the contractor proposes to execute himself. Where an item relates to more than one operation, the quantity is broken down and apportioned to each operation. A locational bill is advantageous in such cases. This numbering is not as time-consuming as it may first appear, as the majority of bill items are loosely grouped within these headings in traditional bill formats.

8.7 Approximate Rating

8.7.1 In order to identify the bill items which have the greatest cost-importance, the estimator must give an approximate rate to every bill item which will be executed by the contractor. The rate should be a reasonable forecast of the cost of labour and the plant strictly pertaining to the item (General plant is priced in Preliminaries).

8.7.2 Great accuracy is not essential in these approximate rates as the rates are used for ranking purposes only.

8.7.3 It is anticipated that any skilled estimator will be able to insert these rates by using his own knowledge and experience. There is no necessity for detailed and protracted calculations.

8.8 Computer Processing

8.8.1 A computer program, MASTER BILLEST, has been written which highlights the cost-important items and collects items together under operation headings. A description of the program and the operating instructions are shown in Appendix 4.

8.8.2 An important feature of this program is that it does not require separate coding. The Bills of Quantities are handed to a punch operator who must punch the page number, item letter, operation number, quantity and approximate rate for every contractor's bill item directly on to standard punch cards.

8.8.3 The data cards are processed by a computer which :-

(i) Prints out all the input data in Bill sequence plus the product of rate x quantity, page, section and bill totals.

(ii) Calculates the 'Pareto' value of the Bill and selects the cost-important items, i.e. those which represent 80% of the cost of the work (or some other specified percentage approximating to 80).

(iii) Collects together the items within their respective operation headings and prints out the reference and extension cost for each item, under operational headings and in bill sequence. The extensions are totalled for each operation and the cost-important items are indicated by a double asterisk.

(iv) Produces a similar output to (iii) but instead of bill sequence order, the items are arranged in descending order of extension cost.

8.9 Refinement of Original Estimate

8.9.1 On obtaining the computer print-out, the estimator has the opportunity to estimate the costs of labour and plant by an alternative method of estimating which is more reliable than unit rates. Four alternative methods are :-

(i) Close scrutiny and re-examination of the highlighted cost-important items.

(ii) Operational estimating based on forecast resource usage.

(iii) Regression analysis applied to detailed sub-sections of work as discussed in Chapter 5.

(iv) C.O.C.O. - a computerized quantative approach under development at the Department of the Environment (Ref 12).

At present only the first two are practicable as there is insufficient historic data for (iii) and (iv) is not yet available to contractors.

8.10 Correcting the Original Approximate Rates

8.10.1 For those items or operations having significant differences between the total costs by approximate rates and the total costs by the subsequent refinement, the approximate rates must be corrected.

8.10.2 Assuming that the apparent relationship between the individual approximate rates are within limits that are acceptable to the Contractor and the Client's advisers, e.g. one brick wall £5.00, rough cutting £0.50 per square metre, correction can be accomplished by multiplying all the rates in each operation by the ratio

$$\frac{\text{Operational total by subsequent estimate}}{\text{Operational total by approximate rates.}}$$

8.10.3 Where the estimator has chosen to examine only the cost-important items, e.g. those that make up 80% of the value, it is reasonable to assume that any differences discovered will also apply in the same ratio to the remaining items. Thus all the items are multiplied by

$$\frac{\text{Total of cost-important items by subsequent estimate}}{\text{Total of cost-important items by approximate rates.}}$$

8.10.4 The ratios, normally expressed to three decimal places, are punched on to a card and substituted in the data pack for the original multiplier card which has ratios of unity.

8.10.5 The program is re-run as previously but instead of multiplying all the rates by 1.000, the rates for each operation are multiplied by their appropriate correction factor. The new print-outs contain all the corrected rates and totals.

8.10.6 This correction facility may also be used to modify selected rates for improvement of the cash flow.

8.10.7 The page totals from the final output are inserted in the Bills.

8.11 Collation of Estimated costs

8.11.1 The page and bill totals of the estimated costs of labour and plant, materials and sub-contractors, are added together and the combined totals calculated. The mark-up for profit, risk, and establishment overheads are applied in accordance with company practice.

8.11.2 The completed bill is handed to the tender adjudication panel for their consideration.

8.12 Submission of the Bills to the Client

8.12.1 In building tendering procedure, the contractor is only called upon to submit a detailed priced-out copy of the Bills of Quantities if his tender is the lowest. Consequently, there is no necessity to price the bill in detail before this request is made.

8.12.2 When the bills are requested by the client, the combined totals of labour and plant, materials, sub-contractors, profit and overheads have to be converted into individual rates applied to the relevant items in the Bills. Unless rates for materials are derived by a computer based method, the task of calculating the combined rates is probably best performed manually. As long as the derived rates are within currently acceptable limits and the rates multiplied by the quantities coincide with the total tender figure, individual accuracy is not essential, as a Contractor's rates in a normal situation may differ from those of his competitors by factors of the order of 0.5 to 2.0 (Ref. 2). (It will be appreciated that under the proposed New Method the process of calculating rates is merely the allocation of an already agreed sum between bill items).

8.13 <u>The New Method and Cost Feed-back</u>

8.13.1 An incidental advantage that the New Method has over traditional estimating, is the facility for converting from traditional Bills of Quantities format to operational format. This enables achieved operational performance to be compared directly with corresponding allowances in the tender and, as the number of headings is limited, accuracy in the collection of costs should be obtained.

8.13.2 As construction work proceeds, the costs of achieved performance can be collected on a weekly or monthly basis and recorded against the established operation headings. If the percentage completion of the operations are measured at the same time, the costs may be used initially to monitor the productivity of the site by comparing them with the estimated costs multiplied by the percentage completion. Action may be swiftly taken to remedy any adverse or deteriorating results.

8.13.3 In the short term, this comparison also forms a useful check on predictive accuracy. Where differences cannot be explained by special circumstances applying to that particular project, the estimators' usual predictive techniques can be corrected accordingly for future projects. Whilst this facility is extremely useful for deducing trends and average performances based on traditional methods it does not, in itself, improve the basic method of cost prediction.

8.13.4 Continued use of the New Method and associated cost collection, will provide essential data for a new method of cost prediction based on regression analysis applied to operational costs (see Chapter 5).

8.13.5 Chapter 5 illustrated the advantages of using regression analysis applied to sub-sections of work, but conclusions were limited by the lack of recorded costs. If the variable factors affecting each operation are recorded, the costs and the variables can be analysed when sufficient like operations have been completed. When the regression results are available, the estimator will be able to use the derived formulae for estimating the cost of the operations. It is anticipated that regression analysis will be used initially in parallel with existing techniques and, as confidence is gained, eventually replace them. (Note: As a possibly better alternative, predicted and actual performance can be measured in man hours or machine hours).

8.13.6 Those contractors seeking to introduce C.O.C.O. into their estimating system cannot do so until they are able to produce sufficient records of past performance for inclusion in the computer program. The New Method may be helpful in providing these data.

8.14 Conclusions

8.14.1 The advantages claimed for the New Method of Estimating over existing techniques are :-

(i) By the delegation of routine, less skilled tasks to clerks, the estimator can concentrate on the difficult tasks of labour and plant prediction.

(ii) There should be a reduction in the time required to produce the estimate.

(iii) Simplicity.

(iv) This particular computer program and the absence of coding should overcome the resistance to computers.

(v) The method may be used on any bill format and does not require amendment when measurement methods are revised.

(vi) Operational groups are devised by the contractor to suit his own system and methods.

(vii) The gradual introduction of operational estimating may be run in parallel with traditional techniques.

(viii) The computer print-out, prior to rate loading, is a valuable tool for contract's management.

(ix) The facility and incentive to collect recorded costs of achieved performance for future use within the method.

(x) The supply of data for new estimating techniques.

CHAPTER 9.

Tests on the New Method of Estimating

Introduction

The New Method of Estimating described in the previous chapter, was initially tried out on dummy data related to a synthesied concrete frame building. This permitted the various 'bugs' in the program to be eliminated before it was tested in a live situation. It was decided to subject the New Method to two separate kinds of test. First, by submitting the basic philosophy to critical examination from an informed audience and then, if approved, by testing the model in a contractor's organisation on a live estimating project.

9.1 Testing the Basic Philosophy

9.1.1 A seminar was held at Loughborough University on the 17th February, 1972, which was attended by over 20 senior estimators. The objective of the seminar was to subject the proposed New Method to expert criticism from an informed audience. It was hoped that this would ensure that there were no flaws in the basic philosophy of the Method and ascertain if it might eventually prove to be acceptable to contractors. A list of delegates attending the day's programme and a synopsis of the proceedings are given in Appendix 5.

9.1.2 The following conclusions have been drawn from the comments made by the delegates in the discussion periods :-

(i) Estimators have considerable resistance against using statistical and computer techniques.

(ii) Estimators believe that their superiors also would not be in favour as they prefer to see how the estimate is built up and make comparisons with current market rates.

(iii) The substantial time pressure at tendering prohibits extensive coding.

(iv) Whilst time does not normally permit an estimator to price a bill accurately by present methods and prepare and price a detailed network, there is a distinct trend towards the preparation of operationally based estimates.

(v) Commercially developed estimating systems seem to be extremely costly to purchase, instal and operate.

(vi) Most of the participants would welcome a change in the client's documentation but they do not feel that a radical change is imminent.

(vii) Little use is made of feedback information either because it is in a form which is inappropriate or because there is little faith in the validity of its collection.

(viii) When feedback is used, it is concentrated on groups of work to give a comparison of predicted/achieved performance on a ratio basis.

(ix) Whilst it is recognised that there are great benefits in using estimated data for the subsequent management of the job, the additional time required to produce this information at the estimating stage is not considered worthwhile.

(x) Estimators tend already to concentrate on the high value items.

(xi) Where networks are priced, the predicted total cost is usually larger than the one deduced by unit rates.

(xii) Estimators recognise that there are several factors which affect site production and normally make an intuitive assessment to cover variability.

(xiii) There is a tendency for the Building Industry to base its bids more on market acceptability than on detailed estimates of actual cost.

9.1.3 A comparison of these conclusions with the objectives and operation of the New Method of Estimating described in the previous chapter, indicates that the use of the Method is consistent with the present and future needs of contractors' estimating because :-

(i) The simplicity of the computing program should overcome the resistance to computer usage.

(ii) The cost build-up is done by the estimator and hence is open for inspection by his seniors.

(iii) No extensive coding is required.

(iv) It combines both traditional unit rate and operational estimating.

(v) Installation costs are minimal.

(vi) It is applicable to most forms of Bill format.

(vii) Cost headings are established which permit comparison and use of feedback.

(viii) The cost headings comprise groups of work items

(ix) Estimated data are automatically generated for use by contracts management.

(x) The 'Pareto' principle in the Method conformswith many instances of current practice.

(xi) The approximate rating of items affords a comparison when an operational/network technique is used. Where differences occur, the estimator can select what he considers to be the most appropriate answer.

(xii) Future developments of the system, when sufficient projects have been processed, may enable some of the additional factors which affect production to be identified, e.g. by detailed regression analysis.

As no adverse comments were received from the delegates about the New Method it was decided to proceed with the tests in a live situation.

9.2 Testing the New Method in a Live Situation in Estimating

9.2.1 A contractor cannot be expected to accept the New Method and use it in his organisation unless it has been validated by use on live projects. Consequently, it was decided to test the method by using it for the preparation of current estimates.

9.2.2 A national contracting company, whose Head Office is located in the London area, was contacted and the chief estimator kindly agreed to co-operate by permitting the New Method to be used in conjunction with their existing techniques for two bids. The author gratefully acknowledges their co-operation and also for the assistance given by K. Armstrong who worked on the tests as part of his project for an M.Sc. in Construction at Loughborough (Ref. 1.)

9.2.3 The Method was tested, in June, July and August, 1972. Two projects were selected from the company's current tendering list both of which the company wished to obtain. The projects were a single storey factory building and a stores and office development, each to be sited in the London area.

9.2.4 The task of testing the New Method was arranged so as to minimise any disruptions to the company's estimating department. It was agreed with the Chief Estimator that his department would obtain all the necessary quotations for materials and sub-contractors and price them in their usual manner. The estimated costs for labour and plant were also prepared as usual but were kept separate from the costs of materials and sub-contractors. These estimated costs of labour and plant were the equivalent of the approximate rates required by the New Method, but in these cases, were prepared in greater detail than is normally necessary.

9.2.5 The company supplied the author with copies of the outline drawings and the Bills containing the labour and plant rates. The drawings and Bills were examined and the main operations established. The factory was broken down into 18 main operations. The company intended to construct the stores and office block as two distinct sections which also corresponded with the subdivisions in the original Bills of Quantities. For this contract 18 main operations were established for the office block and 21 for the stores block.

When added together, the total of operations, 39, is excessive but as they related to two buildings, which were to be separately constructed, it was thought that this number was permissible in this case. The appropriateness of the proposed operations was agreed with the company's planner and the estimator. A list of the selected operations for the stores block is shown in Appendix 6.

9.2.6 The operation number was assigned to each of the contractor's bill items and, together with the page number, item reference, quantity and rate, were punched directly on to data cards. The programs were run on Loughborough University's computer.

9.2.7 The complete outputs were taken to the company's offices and discussed with the estimators. The cost-important items and the total costs of the operations were examined in detail and several anomalies in the original labour and plant rates were discovered. These anomalies were corrected but, instead of using the multiplying factor card, new cards were punched for individual items and substituted in the original data packs. The programs were then re-run and final corrected outputs obtained. Examples of the final output for the stores block are shown in Appendix 6.

9.2.8 The company's estimators were favourably impressed with the New Method but realised that their refining techniques, used to improve the accuracy, were limited. This was because they did not have any usable historic data from previous projects to enable an alternative method of cost prediction to be employed. However, the fact that certain anomalies were so easily discovered in the original rates was gratefully acknowledged.

9.2.9 The company was extremely keen to proceed with the next stage of the test, i.e. the collection of cost data, as their current records of achieved costs were virtually non-existent or unusable for estimating purposes.

9.2.10 The company was successful in its tender for the stores and office blocks and it was decided to attempt the collection of usable cost data from this project.

9.3 Procedure for Collecting Records of Achieved Performance

9.3.1 In accordance with the principles of the New Method, the primary concern was the collection of costs of labour and plant. No attempt was made to collect or assign the costs of materials, overheads or profit. The contract planner, because of his involvement with the construction of the works, was designated to be responsible for the collection and assembly of the costs of achieved performance on site.

9.3.2 Costs were collected on a monthly cumulative basis and entered on to purpose designed cost record sheets. These costs were discussed and agreed with the author at nominally monthly intervals. The costs collected up to January, 1973 are shown in Appendix 7.

9.4 Comments on the results of the cost collection for the Stores and Office building

9.4.1 At first, the procedure worked extremely smoothly. Several variations had been authorised by the Architect but these had been valued by the site quantity surveyor and were inserted in the forms. Of the five activities in the substructure, i.e. excavation, concrete, reinforcement, formwork and hardcore, the first three showed significant savings from estimated costs, the formwork was about right and the hardcore was slightly over-spent due to changes in the material. The significant savings were caused by the extensive use of mechanical plant in lieu of the forecast hand operations. These results have been given to the estimators for their future use.

9.4.2 Problems arose, however, during erection of the superstructure. The contract bills were found to contain inaccuracies which made the revised estimated operation cost difficult to calculate. Many authorised variations further aggravated the situation and consequently it was not possible to calculate the revised estimated operation cost until all this work had been completed. This rather defeated a part of the aims of the test, i.e. to monitor performance, but the original figures were used as a yardstick, in the short term, and results permitted some degree of comparison. The site staff considered that the degree of comparison available had achieved very substantial improvement in the control of cost.

9.4.3 The operation 'concrete work' was performed by the contractor's own labour and the costs were accurately recorded. However, due to labour difficulties caused by the national building strike during the autumn, the formwork and reinforcement were undertaken by a sub-contractor who was initially engaged on a labour only basis. Premium payments were made to him to avoid a site shut-down and industrial action. The sub-contractor's invoices did not break down the costs between formwork and reinforcement. Initially it was possible to make an approximate apportionment between the two but when work started on the office building, it was found impossible to separate the operations of the two buildings and thus cost collection was abandoned for these operations.

9.4.4 The brickwork and blockwork was undertaken by another labour only sub-contractor and, as he was concerned with only this operation, his costs were simple to collect. Significant savings were made on this operation which the contractor affirms was mainly due to the employment of this particular sub-contractor who has a good reputation.

9.4.5 Just before the end of 1972, the contractor's site quantity surveyor left the site to work for another contractor and the planner, who undertook to collect the information, suffered an illness and was away from work for two months. No temporary replacement was made and consequently when he did return the requisite records had not been kept.

9.4.6 The problem of uncollected records was further aggravated by the formwork and reinforcement sub-contractor undertaking other operations, e.g. first and second fixing for which it was also impossible to deduce the separate costs for each heading. Delays and variations (over 200) had so disrupted the original programme of works thatthe office block had to be constructed concurrently with the stores block. Each block was using labour for short periods in rotation which it was impossible to separate out. The planner reluctantly thought that it was impracticable to continue and, in view of the time limit for this thesis, the test was halted.

9.5 Conclusions

9.5.1 From the limited tests carried out on the New Method it appears to work extremely well in estimating and can make a valid contribution to accuracy even when only unsophisticated refinement techniques are available. It is hoped that greater estimating accuracy will be achieved when use of the Method is accompanied by more sophisticated refinement techniques, e.g. detailed regression analysis, which have been developed from the feedback results from previous projects carried out under the Method.

9.5.2 The feedback test did not achieve many ultimate satisfactory results. Although construction projects are notoriously variable, it was felt that the disturbances on this particular site were much worse than the typical situation. This was mainly due to the complicated labour problems during the national building strike, coupled with the excessive number of variations and disruptions to programme. Whilst accurate costs were collected for the substructure of the stores block and may prove useful, the superstructure was, in the main, unsatisfactory. This, unfortunately, has supported the hypothesis that accurate costs are impossible to collect and assign to a large number of headings. Future feedback tests should limit the number of headings to an absolute maximum of 20 and, where there is more than one building to be constructed during the same time period on a common site, the values and costs of like operations for the different buildings must be aggregated. However, even though the tests were not entirely successful, the Contractors did obtain some useful information and they commented that it was a vast improvement on their present system. It was anticipated that future attempts at cost collection would not be so affected by the disruptions that happened on this particular site.

CHAPTER 10

Conclusions

10.1 Estimating as it is, in the main, currently practiced is an art rather than a science. Little use is made of (accurate) quantitative methods in cost prediction with the result that estimating is not very accurate at present (Chapter 1).

10.2 Pressures are exerted on estimators to improve predictive accuracy but the level of the performance achieved on site is not within the estimator's control. An estimated cost may coincide with the achieved cost for one project (and, therefore, be considered accurate) but for another similar project there may be a large disparity. However, studies have shown that there would be considerable value in improving the accuracy and the speed of estimating (Chapter 1).

10.3 Estimating accuracy should be improved by interpreting the results of achieved performance but the dearth or non-existence of such records makes the introduction of new quantitative methods difficult to produce in the short term (Chapter 2).

10.4 Feedback of recorded costs of achieved performance by means of a classification system is not currently very successful and is intrinsically unsatisfactory (Chapter 3).

10.5 Regression analysis applied globally to the tender prices of similar types of building achieved a measure of success for those types which are constructed within a closely defined system. This technique may prove useful for client or contractor application where an extensive standard type of building programme is envisaged. Further research is strongly advocated in this field but as large numbers of data are required, it should be undertaken or sponsored by an appropriate organisation, e.g. a government department. However, with the exception of special situations having fairly limited variability, it does not seem appropriate for general application (Chapter 4).

10.6 Methods of estimating should provide for the ready comparison between predicted and achieved costs for use by the estimator and to monitor the achievements of the contracts management (Chapter 2).

10.7 Methods of estimating should select the cost important items and provide for the refinement of the figures for such items (Chapter 6).

10.8 Methods of estimating should be flexible so as to accommodate alternative Bill formats (Chapter 2). Provision should be made for the separation of operations during estimating even if such separation is not made in the Bill (Chapter 6).

10.9 Methods of estimating should distinguish between the cost categories of the elements comprising a tender which have different variability and each should be treated appropriately (Chapter 7).

10.10 The New Method of Estimating described in this thesis (Chapter 8), complies with the foregoing conclusions and has been tested before an informed audience and in live situations, At a recent luncheon given by the Editor of Construction News, a description of the New Method was given to seven senior estimators. This has resulted in an approach to the author to demonstrate the Method to a company with a view to its future adoption.

10.11 The application of detailed regression analysis to operation costs appears to be the most hopeful method of achieving reliable feedback of performance for subsequent estimates (Chapter 5). It is recommended that further studies be undertaken to investigate this approach if such costs are collected.

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APPENDIX 1.

HISTORICAL DEVELOPMENT OF ESTIMATING

1.1 Estimating from Norman Times until the 16th Century

1.1.1 Fairly comprehensive building records for this period are kept in museums, libraries and public records offices but as most of them are in Anglicised Latin, these documents can only be translated by experts.

1.1.2 The various clients supervised their own developments combining the role of architect and builder. The Statute of Labourers in the thirteenth century fixed a mandatory maximum for wage rates and the Crown could impose penalties on employers or workmen who disregarded the law. This, in theory, gave stability to labour costs but some good workmen were paid in excess of the maximum as an inducement and this trend was increased by the scarcity of labour caused by the Black Death (1347-50).

1.1.3 Most major projects were built by separate teams of workmen grouped in a Guild-type structure. The craftsmen were under the supervision of a master-craftsman who usually produced the working drawings.

1.1.4 At first, the workmen were paid on a day or weekly basis so that no estimate was necessary as a prelude to a contract of employment. The prudent client would no doubt have satisfied himself that he had the financial resources to complete a project by making a cost estimate of the proposed work. There are no records as to how this was done but the fraternity of the aristocracy may have allowed comparitive cost estimates to be made from the recorded costs of completed w ork. The stability of wage rates and the similarity of construction facilitated these comparisons.

1.1.5 However, the construction period for larger building works usually extended over two or three centuries and the cost records included for alterations and repairs. This made comparative costing a hazardous and difficult proposition for larger buildings.

1.1.6 Piece-work payment was gradually introduced from the middle of the fourteenth century, e.g. a mason-layers rate for walling at Langley in 1366 was 66s. 8d. for a perch of 21 feet. Piece-work required the master-craftsman to estimate the number of man-hours needed to complete the unit of work in order to negotiate the rate for payment before work commenced. The craftsman specialized in one particular trade using fairly repetitive design and construction methods so that this was not a difficult task. Presumably, he bore the risk or liability when his calculations were in error.

1.1.7 Once piece-work was established and unit rates were generally recognised, the client was able to make his own cost predictions based on the anticipated quantity of work. Material costs could be obtained from local suppliers when these were not supplied by the client and plant consisted of simple hand tools with scaffolding cut from local woods. As the client employed the men directly, there were no profit margins to be considered other than those for the master-craftsmen, which were included in their rates.

1.2 Estimating in the 17th and 18th Centuries

1.2.1 The 17th century saw the development of a specialist who was able to co-ordinate the work of the economically separated and competing groups of workers. This person, known as the Architect, came from the ranks of educated gentlemen, who had had the necessary experience in constructing buildings for their own purposes.

1.2.2 The Fire of London 1666 added impetus to the trend for the employment of an architect and the enormous amount of re-building proved too great a demand on the existing contracting structure. The developing Bourgeois economic culture evolved the building craftsman as an entrepreneur and the new commercial building organizations tended to spring from enterprising craftsmen from the old Guilds.

1.2.3 The work was let to trade contractors as a result of competition on a schedule of rates, or on a primitive Bill of Quantities which was remeasured on completion. Whilst the trade contractor was able to estimate his costs as in the previous century, he was not skilled in the measurement of the work. There was no standard method of measuring work and the trade contractor felt at a disadvantage in relation to the educated architect, who agreed the amount of money to be paid by the client. In consequence the trade contractor appointed a man, who was as skilled in calculating as the architect, to measure the work and negotiate payment on his behalf.

1.2.4 These men became known as measurers and operated the system of measure and value; the value being based on the trade contractor's schedule of rates. These measurers became highly skilled in pressing their claims and the architect, in self-defence, had to employ a measurer to act on his behalf. This situation gave rise to intense and bitter complaints and litigation.

1.2.5 Certain units of work were established, e.g. rod of brickwork, square of carpentry, square foot of glazing, foot run of masonry, but the contents, inclusions and exclusions of work within these units were subject to local custom.

1.2.6 Advance estimates of cost required by the client, or by the 1667 London Building Act for the cost of replacing the burnt houses, were prepared by the Architect and his surveyor. These estimates were based on the cost per cubic or square foot, or an embryonic trade by trade Bill of Quantity which did not form part of the Contract.

1.3 Estimating from the late 18th Century to the present day.

1.3.1 Towards the end of the eighteenth century, this pattern was proving to be unsatisfactory. The Industrial Revolution made increasing demands on the building industry by changing the character and complexity of building work. The country was also suffering from the stresses and demands of the Napoleonic Wars..

1.3.2 The need had arisen for one contractor to be responsible for the supervision, co-ordination and control of all the building operations. This need was fulfilled by one of the craftsman entrepreneurs taking charge of the whole construction process through a single contract from the Architect.

1.3.3 This person was usually a bricklayer because bricks being the principal building material, he tended to be larger and have more capital at his disposal than the other trades. He incorporated the other principal trades within his own organisation and sub-let the other specialist trades.

1.3.4 Contracts were let on a competitive basis and each Contractor would employ a measurer to measure or guess the quantities from the drawings. The estimate was prepared by an estimator, in smaller firms usually the principal, who was initially only experienced in one craft. The estimate for the remaining crafts were made either by consulting one of the company's trade foremen or by obtaining a quotation from a sub-contractor. As the system evolved the estimator gained knowledge and experience of the rates, labour and material constants, and mode of measurement of the other trades until he was able to do the whole process himself.

1.3.5 The quantities measured by the Contractor were not recognised in the contract and payment was made on a measure and value basis. There was no guarantee that the contract figure would be similar to the final payment and frquent over spending on govennment contracts, e.g. Buckingham Palace 1828, caused public anxiety.

1.3.6 In order to ensure that some measure of control could be exercised on the client's financial commitment, Bills of Quantities were measured from the drawings and sent to each Contractor, e.g. Houses of Parliament 1834. These Bills formed part of the Contract. The Bills were broken down into trade groupings for ease of estimating which is still the most common format used today.

1.3.7 Estimating unit rates was still a hazardous operation, particularly on a national basis, because the measurement and description of bill items varied according to local custom and the personality of the Quantity Surveyor. Unless the estimator was familiar with these customs he could not know which detailed work items should be included in any particular rate.

1.3.8 The first edition of the Standard Method of Measurement introduced in 1922, standardized the method of measuring work in Bills of Quantities. This allowed the Estimator to build up common rates from standard constants of labour and material etc. The subsequent revisions to the method have continued the basic philosophy and hence estimating has developed into the present form.

APPENDIX 2.

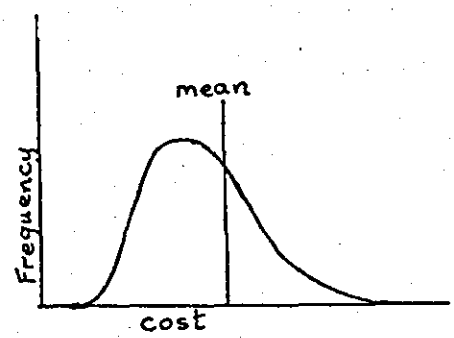
CURRENT METHODS AND CONDITIONS OF ESTIMATING

The following observations are the result of an informal survey carried out by personal interview with chief estimators of large and medium size construction firms.

2.1 The Accuracy of Estimates

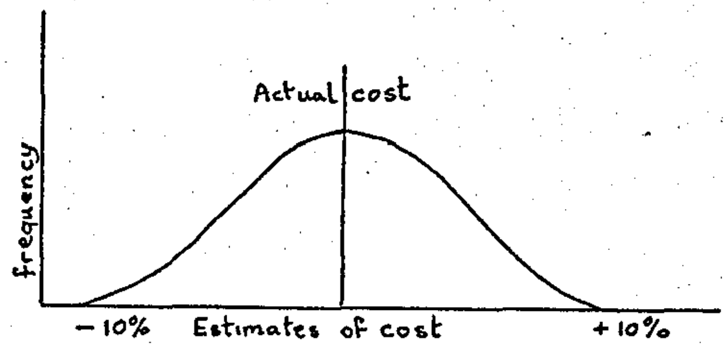
2.1.1 Estimators believe that the primary purpose of estimating is to make a forecast of the cost of constructing the works.

2.1.2 Although each project will have only one ultimate actual cost, this cost will vary for different contractors depending upon their efficiency and skill. If a mean is taken of their theoretical actual costs for one project, the distribution may be speculated as follows :-



The distribution is skewed because it is extremely difficult to reduce costs below the mean in construction work.

2.1.3 It is the duty of an estimator to predict the actual cost for his company and this cost may differ from his competitors due to the relative efficiency of the firm. His own estimate will differ from the actual cost because of the difficulty in forecasting. There seems to be a consensus of opinion among research workers who have studied this problem (Ref. 13, 14, 15) that the limits of accuracy are at best plus or minus 10% normally distributed as follows :-



Many of the estimators believe that their own personal limits are plus or minus 5% (see Appendix 5.) but it has been shown by Dr. Barns (Ref. 15.) that inaccuracies may be far greater than this in practice.

2.2 The Time available for Preparing an Estimate

2.2.1 It is normal practice for the client to state in the tender documents a date by which tenders must be submitted. The length of time allowed varies with the size of the contract; small works being allowed about two weeks and contracts in excess of £1m. about 6 weeks. Some clients allow more time than others; it was consistently noted that the Department of the Environment allowed more time than other clients. The average time allowed was between three and four weeks.

2.2.2 Most Estimators felt that about four weeks allowed sufficient time to prepare the tender but great difficulty was experienced in obtaining prices from their own potential sub-contractors and suppliers. Upon receipt of the Bill, the relevant sections were abstracted for external quotations, copied and despatched. However, as time progressed, estimators normally had to télephone the various sub-contractors to exert pressure for a reply. Frequently the estimators were compelled to use verbal quotations or, as a last resort, insert 'cover rates'.

2.2.3 Whilst most estimators did not require more than four weeks to prepare an estimate, they would, in fact, like more time as it helped to alleviate the work load at any given period.

2.3 Personnel Used in Preparation of an Estimate

2.3.1 It is common practice for one estimator to be used on contracts having a value of up to £1 million. Contractors feel that it is beneficial to have one man who, by job familiarity, can appreciate the cost consequences of the design in each of the work sections. As mentioned previously, the time element is sufficient for this premise especially where much of the work is sublet.

2.3.2 It was noticed during the survey that most estimators seen to be 'Senior Estimators', i.e. persons who would be responsible for the preparation of the complete estimate. Little use was made of juniors except on a fetch and carry basis. Estimators seemed to have a surveying background, transferring to estimating at the senior level.

2.3.3 The task of obtaining quotations for materials and sublet work is frequently delegated to the buyer, who works in parallel with the estimator. The present tendency is for the contractor to erect only the basic framework of the job containing trades such as excavation, concrete, brickwork, etc. The remainder of the finishing trades is sublet to specialist firms. This domestic sub-letting combined with the Prime Cost sum work nominated by the Architect, reduces the content of the work executed by the Contractor to a small percentage of the total value of the contract. Hence the estimate for a company's workforce is related to a relatively minor percentage, the buyer playing an increasingly important role in the production of an estimate.

2.3.4 It is the chief estimator's task to vet the prices prepared by the senior estimator and, in conjunction with the tender adjudication panel, to compute the bid figure. Whilst he seldom adjusts the prices because of error, he can make frequent alterations, depending on company policy, for profit adjustments. The adjustments may prove that unit rates are merely a means to an end and not a true reflection of the cost of the work. Many estimators insert rates which they know are acceptable to the Chief Estimator rather than a true estimate of the cost of the work.

2.4 <u>The Success Rate of Obtaining Contracts</u>

2.4.1 The ratio of success to tenders submitted was found to be extremely variable. At the end of 1970 the ratio for different contractors was from 1 in 6 to 1 in 9. Many estimators felt that the building market was running at a low level at that time and that it did not reflect their normal success rate in the past.

2.4.2 The above figures are gross: estimators felt that for jobs which particularly interested the company, the success rate was 1 in 4-5. Within a firm, individual estimators may have a greater success rate than their colleagues particularly where their work was not greatly affected by the bidding panel. One individual interviewed went for ten months without obtaining a contract. Firms tend to be more successful in certain areas in the country where they have previous experience of operations. A greater success rate is also obtained for the type of work in which a firm may specialize. This may be attributed to greater confidence in their costing system or the exclusion of risk items.

2.4.3 No evidence was found to uphold the professions belief that Contractors are constantly obtaining cover prices to avoid the risk of exclusion from future invitations. Those interviewed admitted that they were more interested in some jobs than in others but they wanted all the jobs for which they tendered. It was their practice to return invitations if they were not interested in obtaining that particular contract.

2.5 Methods of Pricing where Bills of Quantities are Provided by the Client

2.5.1 Estimators tend to follow the recommendations set out in the Institute of Building Publication, 'Code of Estimating Practice', for the original build-up of the estimate.

2.5.2 It is normal practice to obtain fresh quotations for materials for each separate contract although occasionally prices are used from previous recent estimates.

2.5.3 Allowances for wastage on materials are usually the percentages commonly used throughout the trade. None of the firms contacted had any proven figures or had instigated any studies to ascertain the current value. Abbott (Ref. 17.) found that wastage of material on site was considerably in excess of that normally allowed. Material constants for the unit rates were based on experience or handbooks.

2.5.4 The labour outputs were based on experience or derived from the firm's list of standard labour constants. These outputs were modified as a result of previous representations by site personnel who found the figures incompatible with outputs achieved in practice. It was noted that only adverse site reports were received - presumably those that were in the site's favour were concealed in order to enhance the site's apparent efficiency. Most firms have tried to instigate a feedback system from their cost and bonus schemes but no system as yet devised was able to give an efficient service.

2.5.5 The greatest apparent accuracy in forecasting labour costs was found in the firms which employed labour-only sub-contractors, paying them on the quantity of permanent work constructed, e.g. £x. per 1,000 bricks laid.

2.5.6 The larger contractors owned the majority of their own plant or had their own plant-hire subsiduary company. Normal hire rates were included in the price build-up, but the machine outputs were liable to the same variancies as described for labour.

2.5.7 A percentage was added to each rate for normal profit and establishment overheads.

2.5.8 The built-up rate may be subsequently adjust on account of the following :-

(i) Where it is apparent that the quantity in the Bills is deliberately or accidentally overmeasured, the rates for these items are reduced and the balance added to other items.

(ii) Conversely the rates for undermeasured items are increased.

(iii) The rates for work carried out early in the contract are increased and for work carried out at the end reduced, to improve the cash flow.

(iv) A good knowledge of cost limits imposed by the client will indicate whether the bid figure will need to be adjusted by subsequent agreement between the parties. Rates in likely areas of proposed variations can be priced in a favourable manner.

(v) The Bidder, in considering the estimate, will frequently make adjustments for profit and risk dependent upon market conditions. The adjustment is made by either modifying all the items in the estimate, or, more usually, modifying the items in the preliminary Bill. The latter method has the advantage of speed and reduced error potential especially where the tender/estimate difference is relatively small.

2.6 Methods of Pricing where Bills of Quantities are not Supplied by the Client

2.6.1 In negotiated contracts and package deals, either the surveying section of the Contractor's organisation or his external consultants provide the estimator with a Bill of Quantities from which the tender is prepared.

2.6.2 Estimators prefer the work to be measured in the greatest possible detail and to be in accordance with the rules of the Standard Method of Measurement.

2.6.3 In essence, the Estimator's work is similar to that in which quantities are provided by the client with the exception that the measured data are possibly not as accurate and not as well specified because of the time factor in its preparation.

2.6.4 Where this time factor necessitates the use of an abbreviated 'all-in' Bill, reactions are not favourable as some difficulties are encountered with the sub-contractors. Estimators are able to price their own executed work quite adequately in this case but they resent the lack of detail provided by the non-measurement of the subsidiary work items. This resentment is ill-founded as studies subsequently discussed have shown that it is impossible to price the subsidiary items with any accuracy.

2.6.5 The system may be different where the contractor bids to erect his own building system. Cost accounts for past performance may be based on operations or construction elements which can be used in the build up of the estimate under these headings.

2.7 Documentation Supplied by the Client

2.7.1 The client's Architect usually supplies the estimator with a copy of the Bills of Quantities and 1/100 scale drawings. One or two cases were reported where the latter were only available for inspection at the Architect's office or obtainable if the cost of reproduction was paid. D.O.E. frequently supplied a full set of drawings which were welcomed by the estimators although they did not make appreciable use of those showing greater detail.

2.7.2 Estimators use the drawings for pricing of work which cannot be quantified in the contract documents. The more frequent examples are plant utilization, type and repetition of formwork, lifts of scaffolding, security, access, working space, site planning, phasing, extent of external works and position of existing services. It is interesting to note that with the exception of the first two items the remainder can all be classified as 'preliminaries'.

2.7.3 Specifications are considered obsolete. The quality of the work is thought to be adequately described in the Bills. Contract managers find schedules and annotated Bills particularly useful.

2.7.4 There is considerable opposition to the use of elemental bills as any assistance they gave in locating the work items into the component parts of the building was off-set by the disadvantage of having to abstract common sub-traded work from several elements. A refinement of the Elemental Bill is the Sectionalised Trade Bill where differing trades within an element are kept on separate pages of different coloured paper. This permitted collation of like trades by shuffling the pages. None of the estimators interviewed had experienced this format but they felt that it would overcome most of their objections to elemental format.

2.7.5 None of the Estimators interviewed had had experience of operational or activity Bills. The few Estimators that had priced a locational Bill, i.e. a Bill with an appended matrix apportioning the gross quantities amongst predetermined subdivisions of the building, considered it offered no particular advantage for estimating purposes. Estimators prefer to make their own quantity assumptions from the drawings. This opinion may change if the use of this type of Bill increases with computerisation of Quantity Surveying methods.

2.7.6 Where the Contractor is given greater responsibility for the design, e.g. package deals, negotiated contracts or with outline layout drawings/ performance specifications in competitive contracts, the method and sequence of 'communications' is remarkably similar to the situation when the client accepts full responsibility for the design. The main difference from the latter is that the architect and quantity surveyor are either members of the contractor's organisation or, more usually for small contractors, independent professional firms selected and appointed by him. The detail drawing and Bills usually follow the traditional pattern.

2.8 Tendering Conditions

2.8.1 There are eight basic types of procedures for letting contracts. These are open competitive, selective competitive, negotiated either with or without competition, package deals, serial contracts, development contracts and cost reimbursement.

2.8.2 With the exception of cost reimbursement, current estimating procedures are similar for each of these types especially where there is one building to be constructed. However, when there has been either a previously priced bill for a similar job by the same builder, or a notational bill prepared for a serial contract, considerable flexibility may be allowed in the formation of contract documents and method of pricing for subsequent projects.

2.8.3 Present techniques in serial contracts seem to follow elemental pricing as currently practised for cost planning purposes. The original Bill is prepared in elemental format and priced in the normal manner. For subsequent projects of an identical nature the totals are updated for increased costs probably by means of an agreed formula or index. Where these jobs are of similar construction and specification but differ in size and shape, quantity factors are measured for the new work and multiplied by the updated elemental unit rate.

2.8.4 Whilst this latter technique is fairly expedient it does not always take into account certain construction factors which may affect the contractor's costs. It relies to quite a large extent on the integrity and good will of both parties.

2.8.5 If a cost model could be developed, e.g. by regression analysis, which takes into account construction difficulty factors, its use would be particularly valuable in these cases.

2.9 The Use of Estimated data in the management of the Contract

2.9.1 Prior to construction of the work, the project planner prepares the long and medium term plan. This is normally based on the pre-tender plan prepared for the estimate, although as time is available for greater forethought and effort, it is not unusual for there to be differences between them. Planners consider that the pre-tender plan provides a useful basis on which to work especially if they had personally prepared the original. Where a planner did not prepare the original, the clash of personalities involved increases the possibility of radical amendment.

2.9.2 When necessary bulk orders are placed for various materials using the quantities measured in the Bills at the cost given in the original or subsequent quotations. The exact quantities and phasing of deliveries are measured from the drawings and schedules with the Bill figures used as a check. Locational bills were found to be of great assistance in this process but it is interesting to note that many Bills incorporate a clause disclaiming liability for extra costs involved in abortive or erroneous ordering of materials based on quantities measured in the Bills. However, the mode of measurement as expressed in the Standard Method virtually precludes ordering direct from the Bill and separate calculations and assumptions have to be made.

2.9.3 Complex problems are encountered in translating the forecast labour requirements into a form which is compatible with the various user requirements. Many solutions are used and have been propounded but none are entirely successful. The most desired requirement is the incorporation of the labour costs into the Cost and Bonus Schemes. However, all those interviewed found that such costing systems are either extremely difficult, or too expensive, to operate. Bonus schemes can be run from agreed outputs whether or not these have been incorporated in the original rates. The most successful costing scheme is the monthly reconciliation statement, where the labour, material, plant and sub-traded costs are compared with the measured value of work completed. This value is based on the estimated rates included in the Bills of Quantities.

2.10 The Use of Estimated Rates in the Financial Settlement of the Contract

2.10.1 Subsequent to the tender bid, the estimated data are put to their greatest use in financial settlement with the client. Under present contractural conditions the rates form part of the contract and strong emphasis is made in utilizing the rates for the preparation of interim payments, the valuation of variations and the settlement of the Final Account. This will impose unfortunate consequences on the Contractor where the original rates are in error and where no account is taken of the loss caused by disturbance and loss of continuity in production.

2.10.2 In cases where the Contractor simply submits a lump sum bid; schedules of rates, stage payments, etc. are agreed by negotiation. This method seems to work reasonably well in practice, especially where the work is not varied to a large extent. It is not found essential for the detailed estimated data to be used in the financial settlement of this work.

APPENDIX 3.

Data, computer outputs and graphs relating to regression analysis of schools and factories.

List of Contents :

Fig. 3.1) " 3.2) " 3.3)	Example of Pro-forma used for collection of regression variables.
" 3.4) " 3.5) " 3.6) " 3.7)	Measures of regression variables for schools projects.
" 3.8	Ditto, for testing purposes.
" 3.9) " 3.10)	Computer program for producing schools statistics.
" 3.11	Schools statistics.
" 3.12	Comparison of actual with average costs.
" 3.13	Plot of actual with average costs by floor area.
" 3.14	Plot of actual with average costs by functional units.
" 3.15	Regression model for schools.
" 3.16	Comparison of actual with model prediction for schools.
" 3.17	Plot of actual v. predicted costs for schools.
" 3.18	Result of test on model for schools.
" 3.19) " 3.20) " 3.21)	Measures of regression variables for factories.
" 3.22	Computer program for producing factory statistics.
" 3.23	Factory statistics.
" 3.24	Comparison of actual with average costs.
" 3.25	Plot of actual with average costs by floor area.
" 3.26	Regression model for factories.
" 3.27	Comparison of actual with model prediction for factories,
" 3.28	Plot of actual v. predicted costs for factories.
" 3.29) " 3.30)	Result of test on model for factories.

MULTIPLE REGRESSION ANALYSIS DATA SHEET

Project name	CI/SfB		Fixed price Fluctuations labour material
....	1. Civil Engineering 2. Transport Indust'l 3. Administrative		Building Type
Client - Private Govnt L.A.	4. Health and Welfare 5. Refreshment Enter'mt 6. Religious 7. Educational Cultural		Brick / Steel / Concrte | Traditional / Rat/Trad / System | Framed / Unframed
Serial No.	8. Residential		Tender Competitive Negotiated Package

INDEPENDANT VARIABLES

Code Name	Method and rules of calculation	Total Imperial	Total Metric
TOCOST	Contract Sum £.............. Less Substruct. £............ Drainage £............ Ext'l Wks £............ £ ________ £ ________ £ ________		
FUCOST	TOCOST / No. of functional units £............		
COSLIM	FUCOST / Permitted cost limit £............ / £............		

fig no 3·1

Dependant Variables

Code Name	Method and rules of calculation	Total Imperial	Total Metric
FLAREA	Internal floor area enclosed by external walls	Ft^2	m^2
FNUNIT	No. of functional units	No.	No.
ESHAPE	Ext'l perimeter of Bldg ....ft = 'a' Gross floor area measured over ext'l walls ....ft^2 = 'b' Square root of 'b' ....ft = 'c' $\frac{\text{'a'.......... - 'c'...........}}{\text{'c'............}}$		
WLAREA	Area of walls .... area of windows .... area of ext'l door .... area of fascias .... ________ ________	ft^2	m^2
OPWLRA	Area of windows .... area of doors .... ________ = 'd' ________ $\frac{\text{'d'................}}{\text{WLAREA.............}}$ = ...		
ROOMNO	Sum total of rooms		
CIRCRA	$\frac{\text{Area of corridors \& halls}}{\text{FLAREA}}$ $\frac{\text{.................}}{\text{.................}}$ =		
PSUBRA	$\frac{\text{Subsiduary areas}}{\text{Prime function areas}}$ $\frac{\text{..............}}{\text{..............}}$ =		
STOHT	Average floor/floor or Floor/roof height	ft	m
STORNO	$\frac{\text{FLAREA}}{\text{Ground floor area}}$ $\frac{\text{..............}}{\text{..............}}$		
PTAREA	Area of int'l walls .... area of doors .... area of screens .... ________ ________	ft^2	m^2
OPPTRA	Area of doors .... area of screens .... ________ = 'e' ________ $\frac{\text{'e' ....}}{\text{PTAREA..............}}$ = ...		

fig no 3.2

RFAREA	Gross area of coverings including roof lights	ft^2	m^2
INAREA	Area of floor finishings .... area of wall finishings .... area of ceiling finishings................ ________ ________	ft^2	m^2
SPANLG	Average long span	ft	m
SPANSH	Average short span	ft	m
SANFIT	Total number of sanitary fittings etc.	No.	No
HEATLO	Thermal requirement of Building	BTU	W
CONGES	'b'.................. / Area of site .... =		
SITEAC	Length of entrance .... / Perimeter of site .... =		
BLDGAC	Bldg perim. available for access .... / Bldg perimeter 'a' .... =		
BLDGTM	Contract period in months		
BLDGIX	M.P.B.W index / date of contract....................		
SITEDS	Distance from Contractor's office to site	miles	km
SERLEN	Length from mains connection to building gas............... water.............. electricity............. ________ ________	yds	m

fig no 3.3

Variable	School No. 1	School No. 2	School No. 3	School No. 4	School No. 5	School No. 6
TOCOST	56575	60444	65685	62864	128169	68993
FLAREA	10041	11381	14519	11068	24219	12400
FNUNIT	255	285	320	285	575	285
ESHAPE	1.424	1.767	1.293	1.617	2.100	1.633
WLAREA	6751	7259	9388	8087	16848	8829
OPWLRA	0.392	0.465	0.481	0.416	0.564	0.558
ROOMNO	32	40	50	29	76	50
CIRCRA	0.033	0.041	0.043	0.019	0.043	0.028
PSUBRA	0.084	0.080	0.109	0.057	0.114	0.082
STORHT	10	10	10	10	10	11
PTAREA	7675	9769	11268	8283	16783	7191
OPPTRA	0.178	0.100	0.122	0.121	0.144	0.176
RFAREA	10724	12127	12740	12329	25346	13120
SANFIT	51	65	70	58	120	65
CONGES	0.077	0.097	0.082	0.096	0.097	0.025
SITEAC	0.049	0.068	0.070	0.061	0.169	0.165
WNAREA	2674	3377	4518	3363	9497	4927

fig no 3.4

Variable	School No.7	School No.8	School No.9	School No.10	School No.11	School No.12
TOCOST	70893	132207	58378	69270	62719	64423
FLAREA	14458	25136	11126	13452	12100	13360
FNUNIT	320	575	255	320	255	320
ESHAPE	0.889	1.614	1.303	1.701	1.420	1.517
WLAREA	10664	17877	8471	9148	9911	9043
OPWLRA	0.556	0.636	0.493	0.491	0.438	0.658
ROOMNO	49	84	38	30	47	45
CIRCRA	0.065	0.059	0.027	0.065	0.049	0.051
PSUBRA	0.120	0.122	0.102	0.082	0.104	0.090
STORHT	11	11	11	10	11	10
PTAREA	11905	19972	8850	8166	9345	9442
OPPTRA	0.127	0.102	0.173	0.130	0.092	0.113
RFAREA	15200	28175	11524	13419	12700	13889
SANFIT	70	110	51	70	64	52
CONGES	0.306	0.121	0.217	0.180	0.658	0.313
SITEAC	0.081	0.155	0.214	0.087	0.279	0.194
WNAREA	5934	11365	4177	4498	4341	5954

A 3.

fig no 3.5

Variable	School No.13	School No.14	School No.15	School No.16	School No.17	School No.18
TOCOST	53726	63722	67209	56111	71034	129727
FLAREA	10172	11873	13878	10857	13645	24382
FNUNIT	255	285	320	255	320	575
ESHAPE	2.108	1.863	1.349	1.462	1.714	1.013
WLAREA	7744	10661	8033	8626	9776	15958
OPWLRA	0.859	0.608	0.555	0.590	0.344	0.555
ROOMNO	41	43	40	42	55	80
CIRCRA	0.054	0.084	0.040	0.043	0.055	0.050
PSUBRA	0.096	0.164	0.108	0.107	0.120	0.128
STORHT	10	10	10	10	10	11
PTAREA	7124	8232	10354	7425	9806	19693
OPPTRA	0.172	0.163	0.130	0.155	0.099	0.099
RFAREA	10976	13277	14649	10607	13780	25231
SANFIT	58	46	60	55	66	111
CONGES	0.055	0.025	0.061	0.193	0.046	0.089
SITEAC	0.155	0.057	0.097	0.267	0.073	0.090
WNAREA	6656	6479	4461	5089	3360	8863

A 3.

fig no 3.6

Variable	School No.19	School No.20	School No. 21
TOCOST	69976	71974	58788
FLAREA	13104	14603	10253
FNUNIT	285	291	255
ESHAPE	1.377	1.797	1.498
WLAREA	8360	10779	8184
OPWLRA	0.525	0.550	0.381
ROOMNO	41	45	38
CIRCRA	0.060	0.034	0.030
PSUBRA	0.116	0.082	0.069
STORHT	11	11	10
PTAREA	10515	10331	8258
OPPTRA	0.141	0.115	0.200
RFAREA	14319	15270	10605
SANFIT	65	65	62
CONGES	0.103	0.114	0.139
SITEAC	0.085	0.093	0.154
WNAREA	4389	5932	3119

fig no 3.7

Variables of Two subsequent schools used to test predictive accuracy of models

	School 'X'	School 'Y'
TOCOST	61274	75032
FLAREA	11211	12766
FNUNIT	285	320
ESHAPE	1.665	1.615
WLAREA	8120	8869
ROOMNO	47	35
CIRCRA	0.0575	0.0298
PSUBRA	0.0361	0.0721
STORHT	10	10
PTAREA	7851	10298
OPPTRA	0.135	0.154
SANFIT	55	67
CONGES	0.054	0.360
SYTEAC	0.082	0.071
BLDGTM	10	14
WNAREA	3619	4738

fig no 3.8

```
      MASTERSUMS
      DIMENSION DATA(21,3),FACOST(21),FNCOST(21),AVARCO(21),CENTAR(21),A
     2VUNCO(21),CENTUN(21)
      N=21
      WRITE (2,200)
  200 FORMAT (1H1,31HSTATISTICS FROM SCHOOL PROJECTS//)
      WRITE (2,201)
  201 FORMAT (1H ,10X,9HSCHOOL NO,6X,4HCOST,2X,10HFLOOR AREA,2X,
     213HCOST PER SQFT,2X,6HPLACES,2X,14HCOST PER PLACE)
      READ (1,101) ((DATA(I,J), J=1,3),I=1,21)
  101 FORMAT  (F8.2,F7.2,F7.2)
      DO 20 I=1,N
      TOCOST=TOCOST+DATA(I,1)
      TOAREA=TOAREA+DATA(I,2)
   20 TOUNIT=TOUNIT+DATA(I,3)
      AVCOSQ=TOCOST/TOAREA
      AVENUN=TOCOST/TOUNIT
      DO 21 I=1,N
      FACOST(I)=DATA(I,1)/DATA(I,2)
   21 FNCOST(I)=DATA(I,1)/DATA(I,3)
      DO 22 I=1,N
   22 WRITE (2,202) I,DATA(I,1),DATA(I,2),FACOST(I),DATA(I,3),FNCOST(I)
  202 FORMAT(1H ,13X,I2,6X,F9.2,2X,F8.2,7X,F6.3,4X,F6.2,5X,F7.3)
      AVCOST=TOCOST/N
      AVAREA=TOAREA/N
      AVUNIT=TOUNIT/N
      WRITE (2,206)AVCOST,AVAREA,AVUNIT
  206 FORMAT(1H0,10X,8HAVCOST =,3X,F9.2,3X,8HAVAREA =,3X,F9.3,3X,
     28HAVUNIT =,3X,F9.2//)
      COSTFT=AVCOST/AVAREA
      COSTUN=AVCOST/AVUNIT
      WRITE (2,207)COSTFT,COSTUN
  207 FORMAT(1H0,10X,18HAV COST PER SQFT =,F9.3,10X,18HAV COST PER UNIT
     2=,F9.3//)
      DO 23 I=1,N
      CODEV=(DATA(I,1)-AVCOST)**2
      TOCODE=TOCODE+CODEV
      SQDEV=(DATA(I,2)-AVAREA)**2
      TOARDE=TOARDE+SQDEV
      FUDEV=(DATA(I,3)-AVUNIT)**2
   23 TOFUDE=TOFUDE+FUDEV
```

Computer program for schools statistics

fig no 3.9

A.3.

```
      SDCOST=SQRT(TOCODE/N)
      SDAREA=SQRT(TOARDE/N)
      SDFUNI=SQRT(TOFUDE/N)
      WRITE(2,203)SDCOST
  203 FORMAT(1H ,24HSTAN DEV OF SCHOOL COST=,F8.2//)
      WRITE(2,204)SDAREA
  204 FORMAT(1H ,24HSTAN DEV OF SCHOOL AREA=,F8.2//)
      WRITE(2,205)SDFUNI
  205 FORMAT(1H ,24HSTAN DEV OF SCHOOL UNIT=,F8.2//)
      WRITE(2,208)
  208 FORMAT(1H1,10X,11HACTUAL COST,3X,13HAREA X AVCOST,3X,7HPERCENT,3X,
     225HFUNCTIONAL UNITS X AVCOST,3X,7HPERCENT)
      WRITE(2,210)
  210 FORMAT(1H ,24X,9HPER SQ FT,17X,19HPER FUNCTIONAL UNIT//)
      DO 25 I=1,N
      AVARCO(I)=DATA(I,2)*COSTFT
      CENTAR(I)=(DATA(I,1)/AVARCO(I))*100
      AVUNCO(I)=DATA(I,3)*COSTUN
      CENTUN(I)=(DATA(I,1)/AVUNCO(I))*100
      WRITE(2,209)DATA(I,1),AVARCO(I),CENTAR(I),AVUNCO(I),CENTUN(I)
  209 FORMAT(1H ,12X,F9.2,7X,F9.2,4X,F6.2,15X,F9.2,7X,F6.2)
   25 CONTINUE
      STOP
      END
```


Computer program for schools statistics (con't)
fig no 3.10

STATISTICS FROM SCHOOL PROJECTS

SCHOOL NO	COST	FLOOR AREA	COST PER SQFT	PLACES	COST PER PLACE
1	56575.00	10041.00	5.634	255.00	221.863
2	60444.00	11381.00	5.311	285.00	212.084
3	65685.00	14519.00	4.524	320.00	205.266
4	62864.00	11068.00	5.680	285.00	220.575
5	128169.00	24219.00	5.292	575.00	222.903
6	68993.00	12400.00	5.564	285.00	242.081
7	70893.00	14458.00	4.903	320.00	221.541
8	132207.00	25136.00	5.260	575.00	229.925
9	58578.00	11126.00	5.265	255.00	229.718
10	69270.00	13452.00	5.149	320.00	216.469
11	62719.00	12100.00	5.183	255.00	245.957
12	64423.00	13360.00	4.822	320.00	201.322
13	53726.00	10172.00	5.282	255.00	210.690
14	63722.00	11873.00	5.367	285.00	223.586
15	67209.00	13878.00	4.843	320.00	210.028
16	56111.00	10857.00	5.168	255.00	220.043
17	71034.00	13645.00	5.206	320.00	221.981
18	129727.00	24382.00	5.321	575.00	225.612
19	69976.00	13104.00	5.340	285.00	245.530
20	71974.00	14603.00	4.929	291.00	247.333
21	58788.00	10253.00	5.734	255.00	230.541

AVCOST = 73480.33   AVAREA = 14096.524   AVUNIT = 328.14

AV COST PER SQFT = 5.213   AV COST PER UNIT = 223.928

STAN DEV OF SCHOOL COST=23664.25

STAN DEV OF SCHOOL AREA= 4510.20

STAN DEV OF SCHOOL UNIT= 103.74

Schools' statistics
fig no 3.11

ACTUAL COST	AREA X AVCOST PER SQ FT	PERCENT	FUNCTIONAL UNITS X AVCOST PER FUNCTIONAL UNIT	PERCENT
56575.00	52340.28	108.09	57101.61	99.08
60444.00	59325.24	101.89	63819.44	94.71
65685.00	75682.56	86.79	71656.92	91.67
62864.00	57693.68	108.96	63819.44	98.50
128169.00	126245.32	101.52	128758.53	99.54
68993.00	64636.94	106.74	63819.44	108.11
70893.00	75364.58	94.07	71656.92	98.93
132207.00	131025.33	100.90	128758.53	102.68
58578.00	57996.01	101.00	57101.61	102.59
69270.00	70120.65	98.79	71656.92	96.67
62719.00	63073.14	99.44	57101.61	109.84
64423.00	69641.09	92.51	71656.92	39.90
53726.00	53023.14	101.33	57101.61	94.09
63722.00	61889.87	102.96	63819.44	99.85
67209.00	72341.24	92.91	71656.92	93.79
56111.00	56593.81	99.15	57101.61	98.27
71034.00	71126.69	99.87	71656.92	99.13
129727.00	127094.99	102.07	128758.53	100.75
69976.00	68306.65	102.44	63819.44	109.65
71974.00	76120.42	94.55	65163.01	110.45
58788.00	53445.36	110.00	57101.61	102.95

Comparason of actual costs with average costs
fig no 3.12

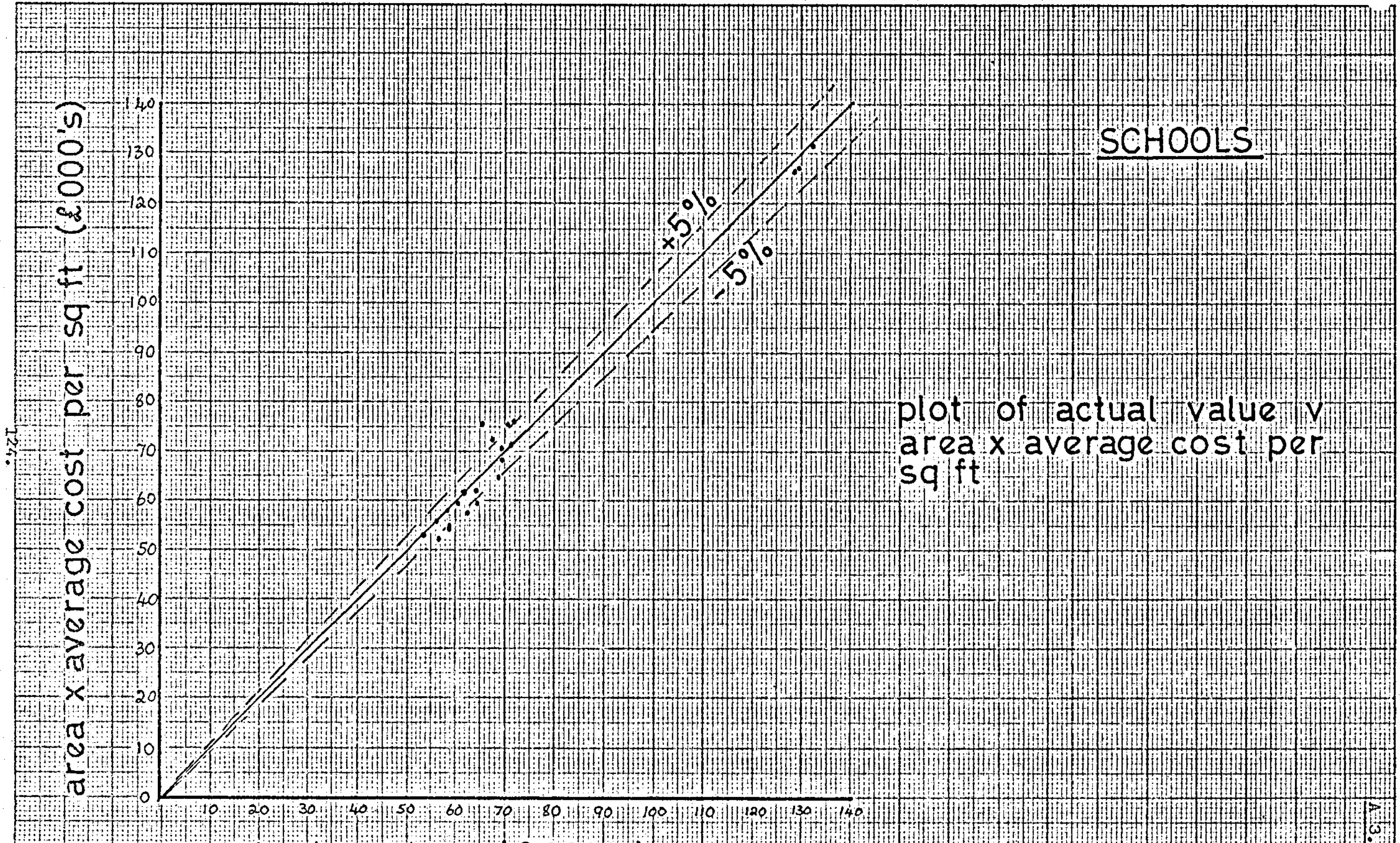
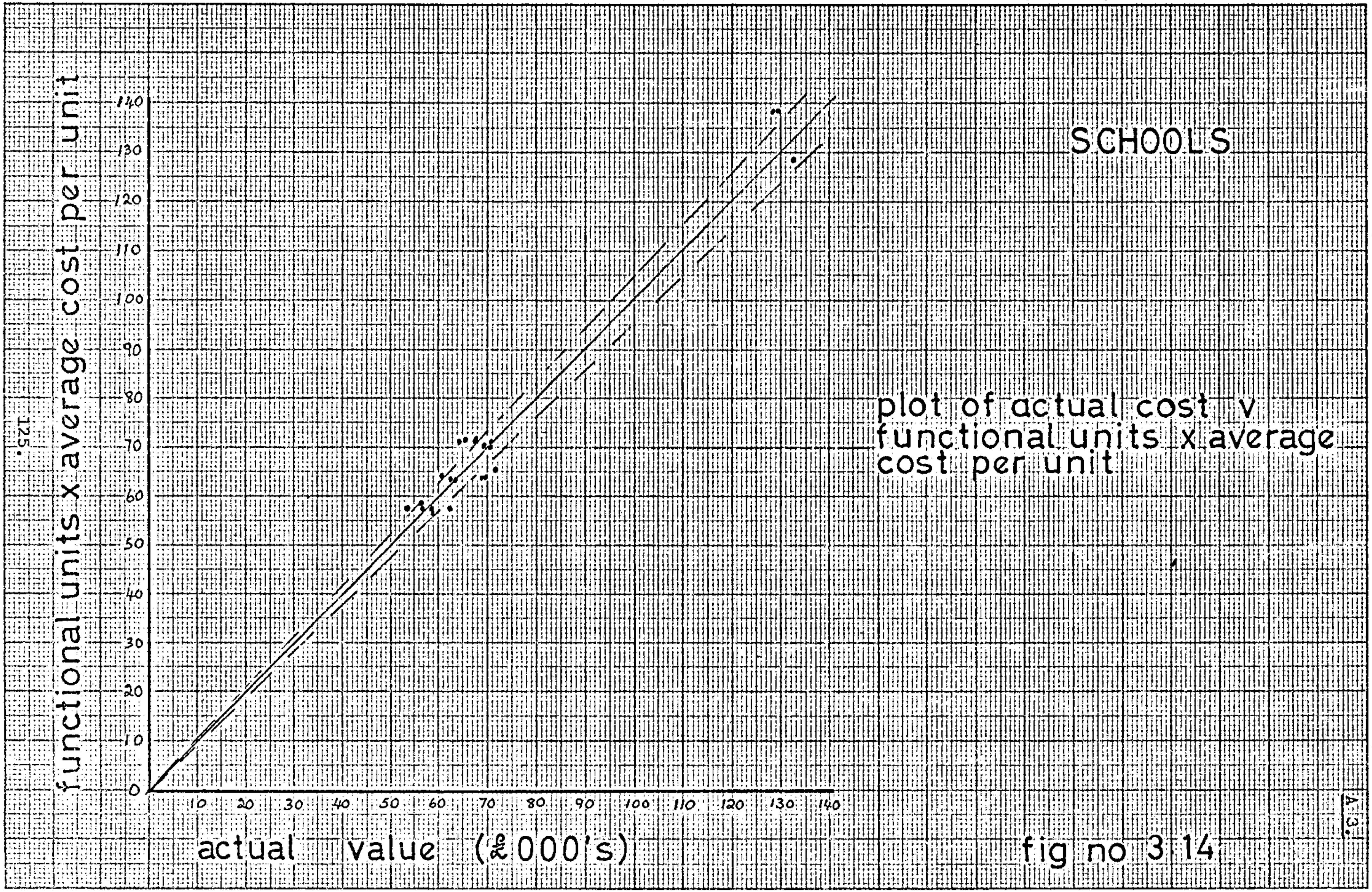

SCHOOLS
plot of actual value v area x average cost per sq ft
area x average cost per sq ft (£000's)
actual value (£000's)
+5%
-5%
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140

fig no 3.13

A.3.


SCHOOLS
plot of actual cost v functional units x average cost per unit
functional units x average cost per unit
actual value (£000's)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
fig no 3.14
A.3.

DEPENDENT VARIABLE TOCOST DEGREES OF FREEDOM 10

INDEPENDENT VARIABLES AT SIGNIFICANT LEVEL 99.50 %

FLAREA ESWALL WLAREA ROOMNO STORHT PTAREA SANFIT CIRCRA FUUNIT PRAREA

VARIABLES IN THE REGRESSION SET

VAR NAME	REGRESSION COEFF	STANDARD ERROR	CONFIDENCE INTERVAL	T STAT	PART CORR	MULTIPLE CORRELATION	E S S
FLAREA	1,2865653	.471347E 1		0,27	0.09	0.997	.698055E 8
ESWALL	0.3087415	.246864E 0		1.25	0.37	0.997	.801270E 8
WLAREA	0.4805223	.108506E 1		0.44	0.14	0.997	.706481E 8
ROOMNO	-77,3321955	.128383E 3		0.60	-0.19	0.997	.718032E 8
STORHT	6754,5013648	.204164E 4		3.31	0.72	0.994	.145129E 9
PTAREA	0.0092960	.790655E 0		0.01	0.00	0.997	.692902E 8
SANFIT	128,9891362	.111061E 3		1.16	0.34	0.997	.786357E 8
CIRCRA	-2,6158707	.462190E 1		0.57	-0.18	0.997	.715087E 8
FUUNIT	209,2805072	.458863E 2		4.56	0.82	0.991	.213420E 9
PRAREA	-2.1186177	.478971E 1		0.44	-0.14	0.997	.706449E 8

VARIABLES NOT IN THE REGRESSION SET

VAR NAME	T STAT	PART CORR	MULTIPLE CORRELATION	E S S

E.S.S. .692892E 8

RESIDUAL ERROR .263228E 4

MULT CORR 0.997

INTERCEPT TERM -69492.3834610

Regression model for schools fig no 3.15

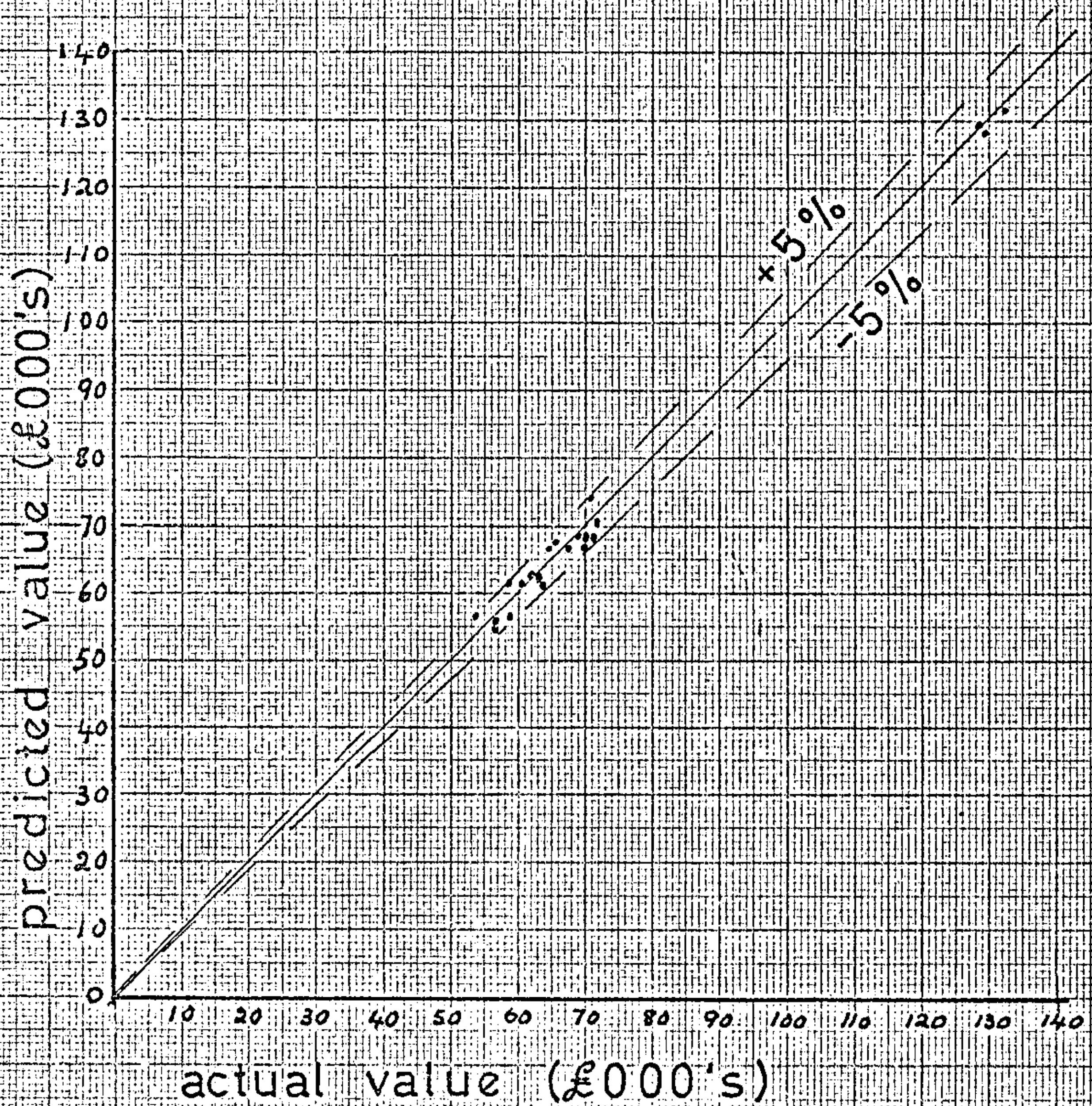
A.3.

RESIDUALS COVA TRANAM

OBS	Y	ESTIMATED Y	Y-ESTY	1ST DIFF	2ND DIFF	RATIO A	RATIO B
ROW001	.565750E 5	.542404E 5	.233459E 4	.233459E 4	.233459E 4	7.8660	95.8735
ROW002	.604440E 5	.616356E 5	-.119161E 4	-.352620E 4	-.586079E 4	2.0493	101.9714
ROW003	.656850E 5	.678812E 5	-.219617E 4	-.100457E 4	.252163E 4	6.9609	103.3435
ROW004	.628640E 5	.623306E 5	.533384E 3	.272956E 4	.373412E 4	0.4106	99.1515
ROW005	.128169E 6	.129514E 6	-.134523E 4	-.187862E 4	-.460817E 4	2.6117	101.0496
ROW006	.689930E 5	.684827E 5	.510285E 3	.185552E 4	.373413E 4	0.3758	99.2604
ROW007	.708930E 5	.739633E 5	-.307035E 4	-.358063E 4	-.543615E 4	13.6053	104.3310
ROW008	.132207E 6	.131555E 6	.651649E 3	.372220E 4	.730283E 4	0.6132	99.5069
ROW009	.583780E 5	.615166E 5	-.313863E 4	-.379048E 4	-.751268E 4	14.2172	105.3764
ROW010	.692700E 5	.696972E 5	-.427212E 3	.271142E 4	.650190E 4	0.2634	100.6167
ROW011	.627190E 5	.627774E 5	-.584284E 2	.368783E 3	-.234264E 4	0.0049	100.0932
ROW012	.644230E 5	.663543E 5	-.193130E 4	-.187287E 4	-.224165E 4	5.3831	102.9978
ROW013	.537260E 5	.565704E 5	-.284443E 4	-.913132E 3	.959735E 3	11.6768	105.2943
ROW014	.637220E 5	.627009E 5	.102110E 4	.386553E 4	.477866E 4	1.5048	98.3976
ROW015	.672090E 5	.667126E 5	.496402E 3	-.524696E 3	-.439022E 4	0.3556	99.2614
ROW016	.561110E 5	.553358E 5	.775222E 3	.278819E 3	.803515E 3	0.8673	98.6184
ROW017	.710340E 5	.687159E 5	.231810E 4	.154288E 4	.126406E 4	7.7553	96.7366
ROW018	.129727E 6	.128527E 6	.120027E 4	-.111783E 4	-.266070E 4	2.0792	99.0748
ROW019	.699760E 5	.672602E 5	.271583E 4	.151556E 4	.263339E 4	10.6448	96.1189
ROW020	.719740E 5	.707848E 5	.118917E 4	-.152666E 4	-.304222E 4	2.0409	98.3478
ROW021	.587880E 5	.563308E 5	.245715E 4	.126798E 4	.279464E 4	8.7136	95.8203

Actual v predicted values for schools fig 3.16

A.3.



SCHOOLS

plot of actual value v predicted value for model no 3

fig no 3.17

Test on Model for School Building

Variable Name	Regression Co-efficient	School X		School Y	
		Quantity	Result	Quantity	Result
FLAREA	1.286	11211	14417	12766	16417
ESWALL	0.309	13519	4177	14323	4425
WLAREA	0.480	8120	3897	8869	4257
STORHT	6754.501	10	67545	10	67547
PTAREA	0.009	7.851	71	10298	93
SANFIT	128.989	55	7094	67	8642
FUUNIT	209.280	285	59644	320	66969
			156845		168350
	Less				
ROOMNO	77.332	47	3634	35	2706
CIRCAR	2.615	610	1595	369	964
PRAREA	2.118	10806	22887	11907	25219
CONST.			69492		69492
			97608		98381
	Cost predicted by model for first quarter 1971		59237		69969
	Update for second quarter 1971		x 1.031		x 1.031
			61073		72138
	Actual Cost		61274		75032
	Percentage Error		- .004%		- 3.9%

fig no 3.18

Factories - Information Source

Variable	BCIS No.29	BCIS No.30	BCIS No.31	BCIS No.32	BCIS No.33	BCIS No.35	BCIS No.36	BCIS No.49	BCIS No.50	BCIS No.51
TOCOST	140075	166340	37350	203885	130976	98192	35469	63007	51872	55387
FLAREA	79696	82692	13677	106376	79200	90000	24550	26541	25021	24820
ESHAPE	0.33	0.32	0.606	0.333	0.320	0.239	0.353	0.682	0.51	0.55
WLAREA	26351	26590	8315	35497	25374	23100	10230	17632	14298	13965
OPWLRA	0.063	0.159	0.043	0.058	0.088	0.076	0.154	0.092	0.101	0.149
ROOMNO	29	29	12	45	11	6	36	20	18	18
PSUBRA	90.34	88.88	88.26	86.46	97.98	100	95.78	78.37	83.93	84.61
STORHT	22.90	19.69	16.23	20.41	22.05	19.42	15.5	18.25	17.64	16.90
STORNO	1.00	1.028	1.00	1.073	1.00	1.00	1.00	1.00	1.00	1.00
PTAREA	9711	12198	1971	27936	1552	8406	11328	4947	5136	10055
OPPTRA	0.760	0.056	0.190	0.083	0.142	0	0.069	0.056	0.071	0.170
RFAREA	80199	81324	14319	102564	80370	92034	26505	25101	30195	23931
INAREA	10659	102789	17793	145431	83349	90135	846	32625	43857	36288
SANFIT	59	63	11	170	13	0	48	10	27	25

fig no 3.19

Variable	BCIS No.53	A.J. 6.4.66	A.J. 2.3.66	A.J. 19.7.67	A.J. 31.7.68	A.J. 11.12.63	A.J. 18.9.63	A.J. 7.5.71	A.J. 19.3.69	A.J. 7.5.71
TOCOST	41526	32518	74076	88484	89282	46144	69166	56292	52924	52269
FLAREA	28017	11437	29720	32000	33770	23500	37327	15047	25600	24080
ESHAPE	0.437	0.568	0.954	0.308	0.632	0.250	0.468	0.435	0.365	0.590
WLAREA	11336	6505	28376	9856	21352	5887	17483	6542	9344	14205
OPWLRA	0.169	0.991	0.355	0.288	0.261	0.047	0.160	0.204	0.188	0.205
ROOMNO	28	15	60	57	20	14	21	32	12	14
PSUBRA	85.21	74.32	88.15	25.89	71.65	88.22	94.48	75.30	80.00	82.09
STORHT	14.90	13.50	13.80	11.75	16.35	11	15.43	17.71	13	17
STORNO	1.00	1.205	1.00	1.00	1.16	1.00	1.00	1.021	1.00	1.00
PTAREA	8342	5988	21376	13922	11864	4950	16774	9149	7508	4938
OPPTRA	0.92	0.093	0.045	0.065	0.079	0	0.063	0.667	0.084	0.083
RFAREA	27603	9837	31590	32850	29502	20970	31680	15084	23562	25938
INAREA	13986	17487	38241	39528	43398	48069	44082	11583	31689	29061
SANFIT	48	17	70	44	20	20	20	16	38	14

fig no 3·20

Variable	A.J. 7.5.71
TOCOST	88992
FLAREA	28681
ESHAPE	0.383
WLAREA	10994
OPWLRA	0.660
ROOMNO	23
PSUBRA	75.34
STORHT	16.00
STORNO	1.00
PTAREA	4983
OPPTRA	0.106
RFAREA	30894
INAREA	37944
SANFIT	28

fig no 3.21

```
      N=21
      WRITE (2,200)
  200 FORMAT (1H1,32HSTATISTICS FROM FACTORY PROJECTS//)
      WRITE (2,201)
  201 FORMAT (1H ,10X,10HFACTORY NO,6X,4HCOST,2X,10HFLOOR AREA,2X,
     213HCOST PER SQFT)
      READ(1,101) ((DATA(I,J),J=1,2),I=1,21)
  101 FORMAT(F9.2,F9.2)
      DO 20 I=1,N
      TOCOST=TOCOST+DATA(I,1)
   20 TOAREA=TOAREA+DATA(I,2)
      AVCOSQ=TOCOST/TOAREA
      DO 21 I=1,N
   21 FACOST(I)=DATA(I,1)/DATA(I,2)
      DO 22 I=1,N
   22 WRITE(2,202) I,DATA(I,1),DATA(I,2),FACOST(I)
  202 FORMAT(1H ,13X,I2,6X,F9.2,2X,F9.2,7X,F9.2)
      AVCOST=TOCOST/N
      AVAREA=TOAREA/N
      WRITE (2,206)AVCOST,AVAREA
  206 FORMAT(1H0,10X,8HAVCOST =,3X,F9.2,3X,8HAVAREA =,3X,F9.3//)
      COSTFT=AVCOST/AVAREA
      WRITE (2,207)COSTFT
  207 FORMAT(1H0,10X,18HAV COST PER SQFT =,F9.3//)
      DO 23 I=1,N
      CODEV=(DATA(I,1)-AVCOST)**2
      TOCODE=TOCODE+CODEV
      SQDEV=(DATA(I,2)-AVAREA)**2
   23 TOARDE=TOARDE+SQDEV
      SDCOST=SQRT(TOCODE/N)
      SDAREA=SQRT(TOARDE/N)
      WRITE(2,203)SDCOST
  203 FORMAT(1H ,25HSTAN DEV OF FACTORY COST=,F8.2//)
      WRITE(2,204)SDAREA
  204 FORMAT(1H ,25HSTAN DEV OF FACTORY AREA=,F8.2//)
      WRITE(2,208)
  208 FORMAT(1H1,10X,11HACTUAL COST,3X,13HAREA X AVCOST,3X,7HPERCENT)
      WRITE(2,210)
  210 FORMAT(1H ,24X,9HPER SQ FT//)
      DO 25 I=1,N
      AVARCO(I)=DATA(I,2)*COSTFT
      CENTAR(I)=(DATA(I,1)/AVARCO(I))*100
      WRITE(2,209)DATA(I,1),AVARCO(I),CENTAR(I)
  209 FORMAT(1H ,12X,F9.2,7X,F9.2,4X,F6.2)
   25 CONTINUE
      STOP
      END
```

Computer program for factory statistics

fig no 3.22

STATISTICS FROM FACTORY PROJECTS

FACTORY NO	COST	FLOOR AREA	COST PER SQFT
1	140075.00	79696.00	1.76
2	166340.00	82692.00	2.01
3	37350.00	13677.00	2.73
4	203885.00	106376.00	1.92
5	130976.00	79200.00	1.65
6	98192.00	90000.00	1.09
7	35469.00	24550.00	1.44
8	63007.00	26541.00	2.37
9	51872.00	25021.00	2.07
10	55387.00	24820.00	2.23
11	41526.00	28017.00	1.48
12	32518.00	11437.00	2.84
13	74076.00	29720.00	2.49
14	88484.00	32000.00	2.77
15	89282.00	33770.00	2.64
16	46144.00	23500.00	1.96
17	69166.00	37327.00	1.85
18	56292.00	15047.00	3.74
19	52924.00	25600.00	2.07
20	52269.00	24080.00	2.17
21	88992.00	28681.00	3.10

AVCOST = 79725.05 AVAREA = 40083.429

AV COST PER SQFT = 1.989

STAN DEV OF FACTORY COST=44808.30

STAN DEV OF FACTORY AREA=27660.44

Statistics from factory projects fig no 3.23

ACTUAL COST	AREA X AVCOST PER SQ FT	PERCENT
140075.00	158513.57	88.37
166340.00	164472.55	101.14
37350.00	27203.25	137.30
203885.00	211579.50	96.36
130975.00	157527.04	83.15
98192.00	179008.00	54.85
35469.00	48829.40	72.64
63007.00	52789.46	119.36
51872.00	49766.21	104.23
55387.00	49366.43	112.20
41526.00	55725.19	74.52
32518.00	22747.94	142.95
74076.00	59112.42	125.31
88484.00	63647.29	139.02
89282.00	67167.78	132.92
46144.00	46740.98	98.72
69166.00	74242.57	93.16
56292.00	29928.15	188.09
52924.00	50917.83	103.94
52269.00	47894.58	109.13
88992.00	57045.87	156.00

```
***SOFOR*** MESSAGE

***SOFOR*** JOB CB000
***SOFOR*** COMPILE - INPUT              50
***SOFOR***         - OUTPUT             62
***SOFOR***         - CPU TIME            3
***SOFOR*** RUN - INPUT                  21
***SOFOR***     - OUTPUT - REQUEST      200
***SOFOR***              - ACTUAL        62
***SOFOR***     - CPU TIME - REQUEST     10
***SOFOR***                - ACTUAL       1
```

Comparason of actual costs with average costs for factory projects fig 3.24

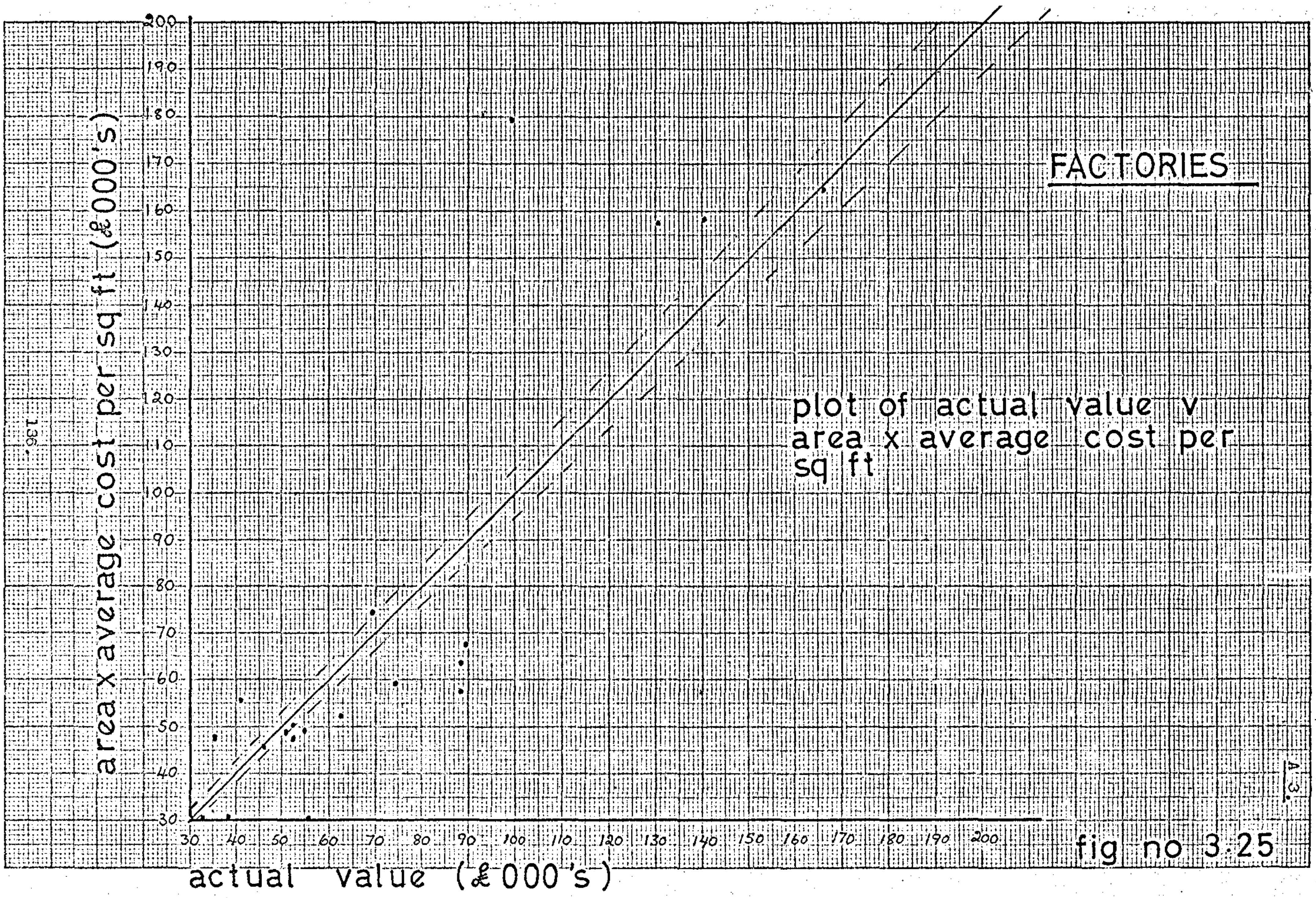


fig no 3.25

136.

A 3.

REGRESSION ANALYSIS COVA TRANAM CUT OFF PARAMETER .100000E- 5

DEPENDENT VARIABLE TOCOST DEGREES OF FREEDOM 11

INDEPENDENT VARIABLES AT SIGNIFICANT LEVEL 99.50 %

FLAREA WLAREA ROOMNO STORHT PTAREA INAREA SANFIT ESWALL PRAREA

VARIABLES IN THE REGRESSION SET

VAR NAME	REGRESSION COEFF	STANDARD ERROR	CONFIDENCE INTERVAL	T STAT	PART CORR	MULTIPLE CORRELATION	E S S
FLAREA	2.7975665	.174665E 1		1.60	0.43	0.968	.267784E 10
WLAREA	1.0920431	.530743E 1		0.21	0.06	0.974	.217979E 10
ROOMNO	152.8855908	.597133E 3		0.26	0.08	0.974	.218437E 10
STORHT	3008.9933639	.276585E 4		1.09	0.31	0.971	.240507E 10
PTAREA -	0.5306896	.129152E 1		0.41	-0.12	0.974	.220476E 10
INAREA	0.2532176	.187280E 0		1.35	0.38	0.970	.253231E 10
SANFIT	164.9391743	.183918E 3		0.90	0.26	0.972	.233020E 10
ESWALL -	0.2948388	.445067E 1		0.07	-0.02	0.974	.217230E 10
PRAREA -	2.2331354	.105759E 1		2.11	-0.54	0.963	.305157E 10

E.S.S. .217143E 10

RESIDUAL ERROR .140500E 5

MULT CORR 0.974

INTERCEPT TERM -36848.1922703

Regression model for factory projects fig no 3.26

RESIDUALS COVA TRANAM

OBS	Y	ESTIMATED Y	Y-ESTY	1ST DIFF	2ND DIFF	RATIO A	RATIO B
ROW001	.140075E 6	.132156E 6	.791882E 4	.791882E 4	.791882E 4	2.8879	94.3467
ROW002	.166340E 6	.150508E 6	.158321E 5	.791325E 4	-.557305E 1	11.5433	90.4821
ROW003	.373500E 5	.379973E 5	-.647319E 3	-.164794E 5	-.243926E 5	0.0193	101.7331
ROW004	.203885E 6	.208964E 6	-.507855E 4	-.443123E 4	.120482E 5	1.1878	102.4909
ROW005	.130976E 6	.127200E 6	.377647E 4	.885502E 4	.132862E 5	0.6568	97.1167
ROW006	.981920E 5	.115264E 6	-.170717E 5	-.208482E 5	-.297032E 5	13.4218	117.3861
ROW007	.354690E 5	.436898E 5	-.822075E 4	.885100E 4	.296992E 5	3.1123	123.1773
ROW008	.630070E 5	.719194E 5	-.891241E 4	-.691653E 3	-.954265E 4	3.6580	114.1451
ROW009	.518720E 5	.683816E 5	-.165096E 5	-.759722E 4	-.690557E 4	12.5524	131.8276
ROW010	.553870E 5	.602574E 5	-.487037E 4	.116393E 5	.192365E 5	1.0924	108.7934
ROW011	.415260E 5	.552847E 5	-.137587E 5	-.888835E 4	-.205276E 5	8.7179	133.1328
ROW012	.325180E 5	.291514E 5	.336662E 4	.171253E 5	.260137E 5	0.5220	89.6469
ROW013	.740760E 5	.713806E 5	.269541E 4	-.671213E 3	-.177966E 5	0.3346	96.3613
ROW014	.884840E 5	.979852E 5	-.950119E 4	-.121966E 5	-.115254E 5	4.1573	110.737[illegible]
ROW015	.892920E 5	.831780E 5	.611400E 4	.156152E 5	.278118E 5	1.7215	93.1528
ROW016	.461440E 5	.364778E 5	.946625E 4	.335225E 4	-.122629E 5	4.1268	79.7854
ROW017	.691660E 5	.607013E 5	.846466E 4	-.100158E 4	-.435384E 4	3.2997	87.7618
ROW018	.562920E 5	.451488E 5	.111432E 5	.267856E 4	.368014E 4	5.7184	80.2046
ROW019	.529240E 5	.494926E 5	.343143E 4	-.771179E 4	-.103903E 5	0.5423	93.5163
ROW020	.522690E 5	.597572E 5	-.748819E 4	-.109196E 5	-.320783E 4	2.5823	114.3263
ROW021	.889920E 5	.691421E 5	.198499E 5	.273381E 5	.382577E 5	19.1456	77.6947

A.3.

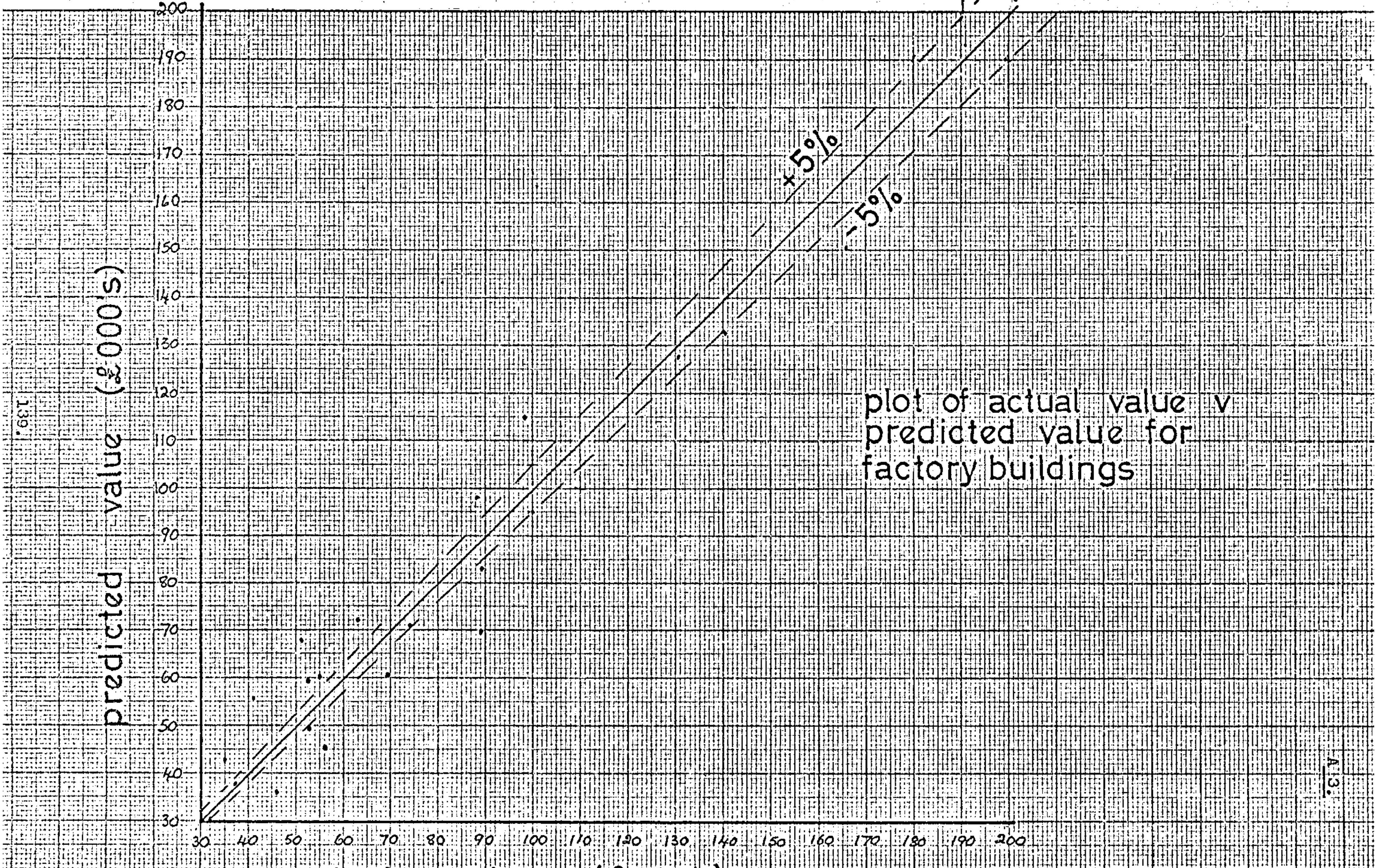

predicted value (£ 000's)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
+5%
-5%
plot of actual value v
predicted value for
factory buildings
actual value (£ 000's)

fig no. 3.28

Tests on Model for Factory Buildings

Variable Name	Regression Co-efficient	Oxford Mail Factory A.J. 14th April 1972		Burton- on - Trent Factory BCIS 9 (89)	
		Quantity	Result	Quantity	Result
FLAREA	2.797	51648	144,460	17240	48220
WLAREA	1.092	22053	24,081	12979	14173
ROOMNO	152.885	99	15,135	33	5045
STORHT	3008.993	12.31	37,041	13.78	41464
INAREA	0.253	73422	18,576	48127	12176
SANFIT	164.939	49	8,082	54	8907
			247,375		129985
Less					
PTAREA	0.530	33576	17,795	6704	3553
ESWALL	0.295	9416	2778	9734	2871
PRAREA	2.233	38736	86,497	8733	19501
CONSTANT			36,848		36848
			143,918		62773
	Cost predicted by model =		£103,457		£ 67212
	Actual Cost		£399,565		£149033
	Less substructure drainage services and external works		£215,888		£ 95179
			£183,677		£ 53854
	Update to first quarter 1972 =		£207,446		£ 55891
	Percentage error		-50%		+20%

fig no 3.29

Tests on Model for Factory Building

Variable Name	Regression Co-efficient	12 Factory units at Redditch - BC1S		Factory Building A. J. 20th August 1969	
		Quantity	Result	Quantity	Result
FLAREA	2.797	55983	156,584	103,000	288,091
WLAREA	1.092	29983	32,741	64656	70,604
ROOMNO	152.885	132	20,180	2	306
STORHT	3008.993	13.63	41,013	41	123,368
INAREA	0.253	90756	22,961	164142	41,528
SANFIT	164.939	96	15,834	5	824
			289,313		524,721
Less					
PTAREA	0.530	25269	13,392	516	273
ESWALL	0.295	56200	16,579	40603	11,978
PRAREA	2.233	48252	107,747	103,000	230,000
CONSTANT			36,848		36,848
			174,566		279,099
	Cost predicted by model		£ 114,747		£ 245,622
	Actual Cost		£ 172,793		£1,001,200
	Less substructure drainage services and external works		£ 77,661		£ 566,706
			£ 95,132		£ 434,494
	Update to first quarter 1971		£ 97,153		£ 552,469
	Percentage Error		+ 18%		- 45%

fig no 3.30

APPENDIX 4.

MASTER BILLEST : Program manual

Introduction:

A computer program 'BILLEST' has been developed by the author and K. Armstrong, a post graduate student in Construction Management at Loughborough University of Technology. The program is written in standard Fortran IV and was programmed to be used on the I.C.L. 1904 computer system of Loughborough University. Fortran IV is a standard computer language and consequently the program can easily be run on different installations. The Loughborough University installation is operator controlled. This means that the user has no means of interrupting the processing of the program. Thus input errors cannot be corrected nor can missing information be added to the program once processing has commenced. To help overcome such problems, the program has error diagnostics built in.

The program has been prepared in such a way that a person with no knowledge of computers or of programming can prepare the input cards for processing. The user needs access to a card punch machine, an ability to punch six program control cards and the ability to slot the six program control cards into their correct position in the pack of program cards. The user must also be able to assemble the various sets of cards that comprise the 'INPUT PACK'. It is recommended that a senior person, e.g. an estimator, is made responsible for the preparation of the 'INPUT PACK'. Once he has become familiar with the collection and preparation of data and with the card changes which are required, he will have no difficulty in obtaining successful program runs.

4.1 Terminology

CARD	Standard computer card used to input information into the computer. Each card contains eighty columns permitting up to eighty characters to be input.
INTEGER	Whole numbers. They must never be written with a decimal point, and commas cannot be used when writing or punching them.
REAL	Numbers that include a decimal point. Commas cannot be used when writing or punching them.
FIELD WIDTH	Describes the number of columns available on a card for writing characters in.
RIGHT JUSTIFY	A number is said to be right justified if it is written as far to the right of the available field width as possible.
LEFT JUSTIFY	A number is said to be left justified if it is written as far to the left of the available field width as possible.

4.2 Program Description

The program is divided up into a number of sections, or 'subroutines', each of which serves a specific purpose within the overall program.

The Master Segment : MASTER BILLEST contains the key 'DIMENSION' statement and 'program control cards' and directs the use of the subroutines within the program.

SUBROUTINE FNTPGE reads in and prints out a series of twelve cards that produce the front page of the output document.

SUBROUTINE INPUTA reads in the data cards corresponding to an item line from the Bill of Quantities. These cards are punched direct from the Bill of Quantities.

Each card is checked to ensure that it does not contain an illegal work category number. As the cards are read in, a check is made to ensure that the number of cards does not exceed the maximum number of cards permitted, and that the number of bill sections does not exceed the maximum number of sections permitted. The maximum numbers of work categories, input cards and bill sections are governed by the 'DIMENSION' statement and 'program control cards' in the Master Segment. If any of the above errors should occur then the program would normally 'FAIL'. Instead, any error that occurs will be listed in an error message in the 'ERROR OUTPUT' giving the card reference. The program will continue to read in data and any further errors will also be listed. Once all the cards have been checked, provided no errors have occurred, the program will continue. If any errors have occurred the final error message will be printed before the program is made to halt prematurely. The final error message gives a listing of the three critical 'DIMENSION' cards and the four 'program control cards'. The 'DIMENSION' cards and the 'program control cards', should be punched according to the final error message, preferably on coloured cards, and exchanged for the corresponding cards in the Master Segment. Once the cards have been exchanged, the complete 'INPUT PACK' should be reinput. The program should now run correctly.

<u>SUBROUTINE INPUTB</u> reads in the work category multiplication factors used for uprating the work categories and also the section and work category headings.

<u>SUBROUTINE INOUT</u> lists the 'control card' data used to control the program and also the actual figures input which correspond to them for comparison. A list of the work categories and corresponding multiplication factors is also output.

SUBROUTINE BILL takes each of the bill items in turn calculates the extension and cumulates the page, the section and the bill totals. The subroutine then prints out the items and totals in typical bill format.

SUBROUTINE SRTWRT calculates the 'Pareto' value of the bill total and then selects the 'major bill items'. The 'Pareto' value is the proportion of the total bill value which is estimated to represent the major bill items, e.g. 80% of the total bill value is represented by 20% of the bill items. The subroutine prints out for each activity a list of the items coded to the activity, in page and item order, with the major items indicated with a double asterisk. Finally, the subroutine again prints out for each activity a list of items coded to the activity in descending order of extension, again with the major items indicated with a double asterisk.

4.3 The 'DIMENSION' statement and 'program control cards'

The 'DIMENSION' statement and 'program control cards' are the critical cards contained in the Master Segment, MASTER BILLEST, which determine the capacity of the program.

The 'DIMENSION' statement cards are :-

```
------DIMENSION IACT (????, 4), ACT (????, 2),
-----1ICNT (??),FACTOR (??),ACTTO(??),TITLE3(??,6),
-----2SECTN(??),TITLE2(??,6)
```

The 'program control cards' are :-

```
------NN =????
------NL =??
------NU =??
------NR =??
```

(N.B. - denotes a blank card column).

The value to which NN is set controls the number of 'bill item' data cards which may be input. It must be remembered that this figure needs to be greater than the actual number of 'bill items' because the section end cards, and the bill end card, must also be counted. The value to which NN is set must also be punched right justified, into the four spaces marked ? in the following IACT(????), and ACT(????,2), in the first of the 'DIMENSION' statement cards.

The value to which NL is set controls the number of work categories that may be read in. The value to which NL is set must also be punched, right justified, into the two '?' spaces following ICNT(, FACTOR(, ACTTO(, TITLE3(, in the second of the 'DIMENSION' statement cards.

The value to which NU is set controls the number of bill sections that may be read in. The value to which NU is set must also be punched right justified, into the two '?' spaces following SECTN(, TITLE2(, in the third of the 'DIMENSION' statement cards.

The value to which NR is set controls the percentage of the total bill value which is used in the 'Pareto' calculation to determine the 'major bill items'.

N.B. The value to which these cards should be set will be automatically given by the program error output.

4.4 The data cards

4.4.1 FRONT PAGE CARDS consist of a pack of twelve cards, the content of which will form the front page of the computer output document, and provide a method of distinguishing one document from another. Each card may contain up to 80 characters.

The first five cards provide five output lines for the title and address of the contract. The sixth card provides a line for the name of the client, the seventh card a line for the date of tendering. The remaining five cards provide lines for the title and address of the contracting firm. For presentation purposes the characters on the first seven cards should be centred on the middle of the card, the final five cards should be set to the right hand half of the card. It is essential that at least the first card is filled in, the remaining eleven cards must be input but may be left blank.

4.4.2 <u>BILL ITEM CARDS</u> represent a line punched from the Bill of Quantities and for each item contains, the page number, the item letter, the activity, or work category, coding; the quantity and the rate. The program is arranged to accept this data in a form which makes it easy to punch this data direct from the Bill of Quantities.

The page number is punched as an integer number left justified on the card, one blank column must follow, next the item letter, again followed by one blank column, next the activity coding, again an integer number and again followed by one blank column. The final two numbers are both real numbers and must contain a decimal point, the item quantity must be followed by one blank column. Bill item cards should be input in the page and item order of the bill.
In all there are more bill item cards than the actual number of items that the contractor has chosen to do, because the end of each section is marked by a special bill item card.
On each of these, five zeros are punched each separated from the next by a blank column. One of these special bill item cards is inserted after the last bill item in each section and an extra one is inserted after the final bill section to indicate the end of the bill.

4.4.3 MULTIPLYING FACTOR CARD carries for each work category a factor which will be used to uprate the items in the work category. For normal running the factor is set at '1', but if after checking the labour or plant value of the work category it is decided to uprate the work category by one and a half times, then the factor would be set at 1.5. The factors are listed across the input card, the first factor is punched, left justified and followed by a blank column, each succeeding factor must also be followed by a blank column. Each factor must be punched with a decimal point. The order of the factors on the card, working from left to right, corresponds with the numerical order of the work category numbers.

4.4.4 SECTION HEADING CARDS each carry the heading of one of the bill sections that has been priced. The heading can comprise up to 48 characters and must be punched left justified on the card. The cards must be input in the same order as they occur in the bill. There must always be the same number of 'section heading cards' as there are sections in the bill, if no heading is actually listed then a blank card must be used.

4.4.5 WORK CATEGORY NAME CARDS each carry the name of one of the chosen work categories. The name can comprise up to 48 characters and must be punched left justified on the card. The cards must be input in the numerical order corresponding to the work categories. There must always be the same number of 'work category name cards' as work categories; if a work category is omitted from the order then a blank card must be inserted in its place.

4.5 The INPUT PACK

The full INPUT PACK is comprised of the following seven sets of cards, in the same order as listed below :

MACRO CARDS

1. MACRO CARDS — These cards are unique to the computer owned and to the system operated. Reference should be made to the computer advisory service.

PROGRAM CARDS

2. PROGRAM CARDS — Pack of standard cards. Each card gives one line of the program. The critical 'DIMENSION statement cards' and 'program control cards' are contained in this pack and should be indicated with coloured cards.

DATA CARDS

3. FRONT PAGE CARDS — A set of twelve cards used to output the front page of the output document. The first card must have characters punched on it, the remaining eleven cards may be blank.

4. BILL ITEM CARDS — A set of cards comprising one card for each of the bill items which the contractor intends to do, plus one special card for each of the bill sections, plus one special card for the end of the bill. These cards to be arranged in bill page and item order with a special card at the end of each section and the extra special card at the end of the final section.

5. MULTIPLYING FACTOR CARD — Probably one card may be two, containing a multiplying factor for each of the work

categories. If no uprating is required then each multiplying factor must be input as '1'. If two cards are needed the final multiplying factor on the first card must be arranged to finish in column 80. This can be done by adding zeros after the decimal point. The first multiplying factor on the second card must be commenced in column 1.

6. SECTION HEADING CARDS — One card for each section from which the contractor intends to work, containing the name of the section. The heading is limited to 48 characters. If no heading is required then the corresponding number of blank cards must be inserted. These cards are to be arranged in the same order as the bill sections.

7. WORK CATEGORY HEADING CARDS — One card for each work category, containing the name of the work category. Each name is limited to 48 characters. If no heading is required or there is an unused work category number then the corresponding number of blank cards must be inserted. These cards are arranged in order corresponding to that of the work categories.

4.6 Error Diagnostics

To prevent a wastage of storage space within the computer, a system has been adopted which will check the amount of storage space that will be required by the data as the cards are read in.

If this exceeds the amount of storage space that has actually been allocated by the 'DIMENSION' statement and 'program control cards' in the Master Segment, then once all the data has been read in the program will output a message indicating the changes that need to be made to these cards. Provided these changes are made the program should then run successfully.

In conjunction with the above program control, three specific error checks are made as the cards are read in. These check to ensure that the number of work categories is not exceeded, that the number of bill item cards does not exceed the allocation, and that the number of sections does not exceed the number of sections allocated. In each case, if a card fails one or all of these checks the appropriate error messages which will indicate the incorrect card will be output.

The program will check all input cards before stopping, thus all errors should be located with one pass.

Examples of the error messages are given in Appendix 6.

4.7 Program Outputs

The program produces three outputs for each run and these are :-

BILL OUTPUT : The output of all the items in page and item sequence in a format corresponding to that of the Bill of Quantities. This output gives page and section totals, and is concluded with a summary of the section totals and the bill total.

WORK CATEGORY: Items in Bill Sequence : The output for each work category of all the items coded to the work category in page and item sequence. The output gives the total value for the work category and indicates the 'major bill items' with a double asterisk.

WORK CATEGORY: Items in Descending Order of Extension : The output for each work category of all the items coded to the work category in descending order of extension. The output again gives the total value for the work category and indicates the 'major bill items' with a double asterisk.

APPENDIX 5.

SEMINAR - IMPROVEMENTS IN ESTIMATING FOR BUILDING AND CIVIL ENGINEERING

In order to subject the proposed new estimating methods to expert criticism from an informed audience, a seminar was held at Loughborough University on 17th February, 1972. To obtain the maximum benefit from audience participation the numbers were originally limited to twenty. The letter of invitation specifically requested that delegates should be able to contribute to the proceedings from their own experience in the field.

The following delegates attended :-

R. Cooper	Harry Neal Ltd.
I. L. Dixon	John Wilmot Construction Ltd.
D. Price	I.B.M. (U.K.) Ltd.
R. Flanagan	Aston University
D. Brennan	Brims & Co. Ltd.
G. A. Hendry	Tarmac Construction Ltd.
A. H. Jackson	G. Longden & Son Ltd.
A. F. Johnson	Taylor Woodrow Ltd.
G. Long	David Charles Construction Ltd.
G. Lunn	Mitchell Construction Ltd.
D. R. Mudd	Lovell Construction Ltd.
R. Ogden	Pochin (Contractors) Ltd.
P. M. Parkin	G. Longden & Son Ltd.
D. G. Potter	Howard Farrow Construction
C. Read	Capital Cities Computer Centres Ltd.
R. E. Hayward	J. L. Kier Ltd.
B. L. Knight	Whittall & Sons Ltd.
F. H. Sinnock	John Laing Construction Ltd.
P. P. Smith	Fram Gerrard Ltd.
W. Stratham	Wm. Moss & Sons Ltd.
C. R. Tassie	Wates Ltd.
P. G. Whyatt	John Mowlem & Co. Ltd.
C. J. Williams	Reema Construction Ltd.
A. H. Wootton	Aston University.

The programme of events for the day was :-

10.15 Registration of Delegates.

10.30 Introduction by the Chairman, Geoffrey Trimble, Professor of Construction Management.

10.45	Paper 1 - Current proposals in Estimating for building and civil engineering, by Brian Moyles.
11.45	Group discussion of Mr. Moyles' paper.
13.00	Lunch in Rutland Hall (Senior Common Room).
14.15	Paper 2 - by Stuart Bradburn of I.C.L.
15.15	Group discussion of Mr. Bradburn's paper.
16.00	Summing-up and conclusions.

A recording of the proceedings was made on tape (which is in the possession of the author) and the following transcript was subsequently taken from the tape. As it was impossible to relate the names of all the delegates to their voices, many of the comments made in the discussion periods have to remain anonymous.

SYNOPSIS OF SEMINAR

The Morning Session

Professor Trimble welcomed the guests and introduced the speakers. He stated that the numbers had been limited to about 20 because he hoped this would bring the maximum response and comments in the discussion periods. He explained that one of the reasons for this seminar was to give Mr. Moyles the opportunity to present his ideas to an informed audience so that the results of his research would be subjected to practical criticism. Professor Trimble made the point that a bid is composed of three factors, i.e. direct costs, overheads and profit, and we were looking today at the estimating of the direct cost.

The author presented his paper on estimating which was based on the work described in this thesis. Particular reference was made to the use of regression analysis for calculating the global cost, the computer hased system he has developed for estimating and the proposals for better use of feedback by regression applied to sub-divided work units.

Comments from the delegates during discussion

Anon.	Over a period of 10 years, I have played a game with our comp. I would guess the figure and when worked up, I would be within ± 5% (excluding profit and prelims) so why do we bother to do it in detail?
"	It is odd occasions when you are wildly adrift.
"	What I mean is that you can do it without going to the computer.
"	Is the Bid an estimate of cost or a publicly acceptable figure?
"	Keenness of pricing - there should be none. Going into more detail tends to put the price up - several others dissented.
"	We use similar techniques as those mentioned in civil engineering work and they work very well, but the use of regression for the whole job is not on as we could not find 20 previous projects of a similar nature except motorways. We would hesitate to price a bill first from unit rates. Civil Engineering is becoming less labour intensive and more plant intensive, therefore, the rates are based on a work study of the method and plant to be used and the rates worked back from there. Unit rates are all right for minor labour items.
B. Moyles	Civil Engineering is operationally based and the building industry is unit rate based. (He clarified detailed regression equations).
Anon.	In Civil Engineering 20% of the items may not be labour intensive but plant intensive. In

another job, plant may have changed to give greater outputs.

Anon. You cannot make a man do twice as much but you can with plant. In civil engineering jobs, labour may be only 12½% of job cost.

Professor Trimble The top 20% sifting process is still useful in this case.

Anon. The estimator gets the feel of the high value items and naturally concentrates on these items. This is done already.

B. Moyles Yes, but this system does it automatically without the estimator having to compare quantity and rates.

Anon. He abstracts the quantity and looks at other drawings.

B. Moyles Civil bills have less items and less sifting is necessary.

Professor Trimble Is the audience reasonably satisfied with estimating procedures? Are estimates properly related to achieved performance?

Anon. We have a Company cost system to give monetary costs grouped into main centres.

Professor Trimble How do you use this for new work when the quantities are different?

Anon. We are not that sophisticated. We look at the plant and labourratios of achieved against predicted and where discrepancies arise, new forecasts are amended accordingly.

Professor Trimble Reliability of estimating is related to reliability of feedback. Detailed regression would be helpful in this case.

Anon. In building we are very wary of feedback information. The estimator is looking forward and optimistically hopes that better performance will be achieved.

" Feedback can only give you a trend, if you use it blindly you would never get a job and be twice as high as anyone else.

B. Moyles Are you estimating at less than the probable cost?

Anon. Yes, but the ignorant Irish navvy has probably made a mistake in the allocation of cost in the first place.

" Cost returns incorporate variations unauthorised and authorised, site, weather, etc. Estimators say that it should not have cost that much and if it did, we got the money back in some other way.

" Too many people in the construction industry are optimistic in that they say it was bad last time and the time before but will be okay next time.

" We have turned full circle on cost feed-back - tried on detailed items but with too many variables. It was no good. Now back to trade and elements to get the general trend and if abnormal major items occur we set up a special system for that item. Headings now are concrete formwork, reinforcement, brickwork, etc. broken down by trade against value/cost and broken down labour, plant, material. For trend purposes this is sufficient.

" Feedback is used to predict trends because we have no confidence in the cost recording.

Anon. If feedback of general information is given to the planning department, this should be used in the pretender. We are finding it better to take the 20% items, operationally cost them and compare with the planner's resourcing schedule and see where difference occurs in total elements. This is where feedback is useful in comparisons of achieved performance as you deal with larger units and the margin for error is reduced. This is the safest way of using feedback.

Professor Trimble Could we hear more from Mr. Potter regarding his use of feedback by trade where the quantities are different?

Mr. Potter We attempt to analyse by work types in civils and building with no more sophistication than looking up previous contracts of that particular nature and comparing original build up of rates. In each new contract major quantities are abstracted and checked against previous jobs. I do not agree that labour is a critical item as wastage of materials is very important when comparisons of like previous jobs shows a difference, we make necessary adjustments to the original figures to arrive at new forecast. We can and do price some jobs now just on materials and the labour and plant on a histogramme. It is difficult to estimate fringe costs with a histogramme.

Anon. I would question the accuracy limits ± 5% although I would agree that some jobs are outside this range. If one considers that this is only on the work which is directly under the Contractor's control this is a vastly high percentage.

Anon. With Mr. Potter's feedback on materials, does not this come back to the case of construction of the job which is very difficult to quantify.

Mr. Potter I would agree (quoting examples) which an estimator quantified in his mind. Our company has used C.O.C.O. which was the same thing that their company had been doing for 10 years but very much quicker. We still buy the odd job but these are getting less.

Anon. We have priced a network but these came about 10% more in time and 10% more in value than the estimator allowed. From looking at past records over 2 years the company did 3% better than the mark-up in the bills. You cannot identify averagely where your money came from and in practice you do rather better than your network predictions.

Anon. (A comment was made about the effect that different architects and engineers can have on the flow of drawings and hence on cost of construction).

Professor Trimble You can rate the architects or engineers from previous contracts to use in feedbacks.

Anon. I agree with previous speakers that estimators don't believe in feedback information because it does not give the conditions under which the work was actually done.

Mr. Potter Feedback based on unit rates are not worth the paper they are written on.

Professor Trimble Why don't you write down the circumstances which give a good return for a particular job. What are these factors?

Anon. Weather, shelter, restrictions in working, local will to work, labour disputes, characteristics of site staff and design staff, specification (concrete good or bad to place), reinforcement, congestion.

Professor Trimble — (Reiteration of detailed regression) - And if we take the overall cost records as Mr. Potter suggested and then rated other circumstances you can pick out these other items which contribute.

B. Moyles — May I point out that from certain tests on the regression model, it may be shown that although we believe certain conditions exert certain influences, in fact, they don't have any direct influence or that its amount may be negligible.

Anon. — Estimators are apprehensive of using statistical methods to evaluate. We prefer to make subjective assessments in the particular situation.

Professor Trimble — This is a question of discipline and motivation. Do you think there is a need for more accurate estimating to contribute to profitability?

Anon. — Predictions based on all past performances are all liable to unusual circumstances.

" — If you have enough past data, the statistical approach would be very accurate but there is seldom enough past records and then it becomes a matter of guesswork.

Professor Trimble — Isn't this a defeatist situation. If there is an incentive to collect performance data in the future, the cost of so doing would be quite cheap.

Anon. — How much importance does Mr. Moyles attach to his case study of 22 system schools as they are of identical nature with some designers, same P.C. sum rates, etc.

B. Moyles — I used these schools because I could get the data and to show that the system works.

Anon. — We could do this ourselves on a manual system.

B. Moyles — I am developing a similar model for factories, and getting better results. There are problems of data collection and the differences between tender and cost prices. This could be done in an individual firm if they have the number of contracts. (Further explanation ofdetailed regression), e.g. 'gash' labour is about 32% of site labour costs so why apportion in detail?

Anon. — What do you think directors will think of the statistical approach when they have to put their money on it? The danger in averaging is that you may not get the job. Successful contractors must look at trying to find a cheaper way of doing the job.

" — How can you get cheaper than the last job, time and time again?

" — Our company is over 150 years old and we have cost records going back over a number of years and they are all useless to the estimator. A few job reports which are useful, e.g. piling, but they don't get many jobs of such a similar nature and next time we think everybody else will know how much it cost us to do that piling, so we have to start thinking of something else.

" — The company wants us to get the next job.

The seminar was then adjourned for lunch.

Afternoon Session

Mr. S. Bradburn presented his paper on the current systems of computerised estimating in operation and under development by I.C.L. A brochure giving an outline of his work is included with the tapes. The system incorporates an extensive coding system, communication with a Visual Display Unit and the subsequent use of the estimated data.

Comments on paper by S. Bradburn and further comments on paper by B. Moyles

Anon. What is the cost of using your system and the V.D.U? Is it quicker, does it save actual time?

S. Bradburn Computer only charges when it is searching and calculating. It does not charge when the estimator is thinking about the problem.

Anon. Does anyone use it at the moment?

S. Bradburn We are working on it - but no-one at the moment. Two companies are using part of it for obtaining tenders and are developing it.

Anon. What a pity current documentation doesn't allow the Contractor to carry on from resources levelling to resource pricing in one operation from the networks.

S. Bradburn I got the feeling this morning that more and more people are suggesting that the sensible way to estimate is on a time basis.

Anon. You have to look at your resources to get your network and it does not take much to apply rates to resources at that point. You have spent most of the afternoon trying to adapt yourself to the present Bill of Quantities.

S. Bradburn — I was hoping to show that we are not wed to any of the systems I was describing. The point is a lot of time and money is being spent by Contractors on systems and this is the way they are going about it. We are looking forward to when a lot of these laborious routines will be discarded and Contractors are doing the things they ought to be doing. It is true that three of those systems are wedded to that sort of approach but it is no exaggeration that 90% of the clients want that sort of approach to it. Management is not prepared to put itself out on a limb and do something else.

Anon. — In building, tender time prohibits doing a tender and a network and, even with a computer, price it.

S. Bradburn — It does save on comping time

Anon. — But that is a simultaneous operation to pricing.

" — We have problems with elemental bills where we are held up for one painting sub-contractor and cannot comp. all the bills up. Is the expensive operation drawing up a programme for a particular Contractor?

S. Bradburn — He can use a standard software approach but he has to set up the system.

Anon — Is this expensive?

S. Bradburn — Yes, but they have most of this information anyway but they do not make subsequent use of it.

Anon. — In order to get any use out of the system, the abstracting coding must be good enough to identify the item and in our company, it requires 16 digits.

We have just priced a bill with 8,500 items - coded 136,000 digits which nobody can do but the estimator. It took five weeks to code and unless you can overcome this, you will kill it stone dead because of the time limit.

S. Bradburn — Computer manufacturers cannot improve the way in which the construction industry handles information. There is a proposal to revise the C.E.S.M.M. and industry has the opportunity of changing it, and say this is the way we want information presented to us, e.g. separate materials out of it.

Anon. — The hope of changing it is remote because it is all tied to litigation which has been fought over in the courts and there is a tremendous weight of precedence and anyone thinking of changing it has got to fight all the cases again in the courts.

S. Bradburn — Perhaps it is nearer than we think.

Mr. Dixon — In Herts., our bills for system schools came ready coded.

S. Bradburn — If they change the S.M.M. then other bills may come ready coded.

Professor Trimble — Why can't we use the priced networks? Is it because of the difficulty in distributing total cost over the Bill rates? It can be done by multiplying the trial rates by P/p where P is the total based on trial rates and p is the total based on the network.

Anon. — When we have been using it on two-stage tenders, this has been done but normally one hasn't got the time and information to prepare an accurate network with any confidence in it, and you would have to run it side by side for some time. When we have priced networks, it normally comes well over the tender price.

Professor Trimble — Any new system should be run in parallel for some time but you would see the problem as there not being enough time available?

Anon. — Yes.

" — I think it is possible by pricing operations and if the bill is such that you can abstract approximate rates, you can compare this with the priced network and where differences occur, analyse them to find out which is the correct answer.

Directors don't like this method - they like to see how individual rates are built up.

Professor Trimble — Even though tenders are fairly close, analysis has shown that variance in individual rates is quite enormous. Are you any more accurate by estimating separate rates than the method put forward this morning?

Anon. — No. One person may price formwork high and concrete low, but if you ask the person why there were such high discrepancies between them, he would probably have a good reason for this.

B. Moyles — When the director questions you about your figures, surely he cannot challenge the accuracy of your figures?

Anon. — No, but he is checking up to see if there is nothing left out or too much put in and is also challenging the assumption I have made.

Professor Trimble — What actually happens when they question a particular unit constant, how do you verify it?

Anon. — We ask about half a dozen people in the office. But it is very rare that they make big money total differences, its more a matter of balance.

" — Are they balancing within a market conception or are they balancing with knowledge of the company?

" — A bit of both.

" — I think one of the problems is that we are pricing to a market and as most products are unique, we are fabricating our organisation to that end and not looking at the factors we are pricing for. Pricing programmes is relevant in this case.

" — This is much easier in some contracts than others, e.g. tunnels which are a linear process. In other cases you have to price the bill because if you price the programme you may put too much in or leave too much out.

" — Without realizing it, bills are more a schedule of rates.

" — Why don't we use Spon's rates ± for certain trades which in our experience differ and leave the rest to be accounted for in the mark-up? Aren't we just wasting our time with the system we have heard about this afternoon?

" — Yes, and keep a standard list of prices.

" — Computers may give you added benefit with cash flow predictions.

" — The trouble with computing these routine matters is that you can do them faster in your head. A computer can quickly calculate and look things up but most of an estimator's time is making decisions. We must look at the things a computer can do well and use it for that purpose.

Professor Trimble. I should like to ask Mr. Reed for comments on his work at the Watford Computer Centre.

C. Reed The system under development allows the splitting up of labour plant sub-contractors in detail amongst the bill items and vice-versa, but as was said this morning, if you go into this much detail at the estimator's stage it rather begs the question - you get bound up with a lot of input data, but if you do, you must use this data for other purposes, e.g. bonus targetting. It is in this field that the computer has its advantages.

Anon. The site staff disagree with the targets set by the estimator and the difficulty is getting a target which is acceptable to both parties.

" It is realistic to use them, as assumptions made are not always valid in the construction of the work.

B. Moyles Has anybody priced an operational bill?

Anon. Not lately but when we did, we found that a number of estimators were converting back to get the outputs. The compromise we are coming to, is to price out the odds and sods and price the main items operationally and then combine the two. Any adjustments are normally made in the preliminaries and not in the rates themselves.

" One of the worst bills to price at the moment is

	the D. of E. Roadworks bill (hearty agreement) - it isn't operational and has no preliminaries.
B. Moyles	Has anyone any suggestions for improvement in the bills?
Anon.	D. of E. bill - the drainage section.
"	We have set up a computer programme to deal specifically with this section.
"	The weakness is that there are often insufficient drawings in the first place.
"	Bills are often inflated and abused by the other side (clients).
"	I would prefer an operational Bill.
Professor Trimble	Would anybody favour the American system (with all the liabilities for omissions) and prepare a bid from drawings?
Anon.	Yes. Contractors are to blame for the present situation by attempting to get too much detail. It would be better to make an allowance in their tender for the risk and not to go into such detail.

The proceedings were summed up and concluded by Professor Trimble, B. Moyles and S. Bradburn.

The author has drawn the following conclusions from the comments made by the delegates.

1. Estimators have considerable resistance to using statistical and computer techniques.

2. Estimators believe that their superiors would also not be in favour as they prefer to see how the estimate is built up and make comparisons with current market rates.

3. The substantial time pressure at tendering prohibits extensive coding.

4. Time may not permit an estimator to price a bill accurately by the present method <u>and</u> prepare and price a network.

5. Commercial estimating systems would seem to be extremely costly to purchase, instal and operate.

6. The Building Industry continues to base its bids on market acceptability rather than on detailed actual cost.

7. There is a distinct trend towards operational costing which is then compared with the traditional rates.

8. Most of the participants would welcome a change in the clients documentation but they do not feel that a radical change is imminent.

9. Little use is made of feedback information either because it is in a form which is unacceptable or because there is little faith in the validity of its collection.

10. When feedback is used, it is concentrated on groups of work to give a comparison of predicted/achieved on a ratio basis.

11. Where networks are priced, the prediction is usually larger than the one deduced by unit rates.

12. Whilst it is recognised that there are great benefits in using estimated data in the job management, it is not worth the time at the estimating stage in going into this detail.

13. Estimators recognise that there are several factors which affect site production and normally make a subjective assessment to cover variability.

14. Estimators tend toconcentrate on the high value items.

THE PROPOSED SYSTEM WOULD SEEM TO FIT IN WITH THE ABOVE REQUIREMENTS AND ITS USE WOULD BE CONSISTENT WITH THE PRESENT AND IMMEDIATE FUTURE NEEDS.

A copy of the foregoing synopsis was sent to Mr. D. Potter of Howard Farrow Construction Ltd. His letter of agreement to its accuracy is shown overleaf.

Howard Farrow Construction Limited
Highfield Road London NW11 9PE Telephone 01-458 3232
Inland and overseas telegrams HowdFarrow London NW11

A 5.

Farrow

DGP/ml

17th April, 1972.

Mr. B.F. Moyles,
Lecturer in Quantity Surveying,
Lanchester Polytechnic,
Priory Street,
Coventry CV1 5FB

Dear Mr. Moyles,

Further to your letter dated the 10th April, 1972 I now return herewith the synopsis of the seminar.

Thank you for giving me the opportunity of studying it, to the best of my recollection, and subject to the usual minor vagaries of transcript, the contents appear to be an accurate record of the proceedings.

May I take this opportunity of saying that I consider the seminar to have been a "day well spent" even if the attitude of some contractors remains "surprising".

Yours sincerely,

David Potter

D.G. Potter.

APPENDIX 6.

Computer print-out for the Stores section of the Stores and Office Block

	Page
Typical error listing	173
Listing of standard data	174
List of work categories	175
Labour and plant rates in Bill Order	176
Summary of section totals	190
Labour and plant rates collected into work categories in bill order	191
Labour and plant rates collected into work categories in descending order of value	216

```
THE FOLLOWING INPUT ERRORS HAVE OCCURRED AND NEED TO BE
CORRECTED BEFORE THE PROGRAM CAN BE RESUMED


ERROR 01  :  THE WORK CATEGORY NUMBER ALLOCATED TO BILL ITEM  46A
             EXCEEDS THE VALUE OF THE PROGRAM CONSTANT NL

ERROR 02  :  THE VALUE OF THE PROGRAM CONSTANT NN IS EXCEEDED AT
             BILL ITEM 107L

ERROR 01  :  THE WORK CATEGORY NUMBER ALLOCATED TO BILL ITEM 108A
             EXCEEDS THE VALUE OF THE PROGRAM CONSTANT NL

ERROR 02  :  THE VALUE OF THE PROGRAM CONSTANT NN IS EXCEEDED AT
             BILL ITEM 108A

ERROR 02  :  THE VALUE OF THE PROGRAM CONSTANT NN IS EXCEEDED AT
             BILL ITEM   00

ERROR 02  :  THE VALUE OF THE PROGRAM CONSTANT NN IS EXCEEDED AT
             BILL ITEM   00

ERROR 03  :  THE NUMBER OF SECTIONS INPUT EXCEEDS THE ALLOCATION
             OF PROGRAM CONSTANT NU

THE INPUT ERRORS WILL BE CORRECTED IF THE DIMENSION AND CONTROL
CARDS IN THE MASTER SEGMENT ARE CHANGED TO READ AS FOLLOWS :-

 DIMENSION IACT(  96,4),ACT(  96,2),
1ICNT( 3),FACTOR( 3),ACTTO( 3),TITLE3( 3,6),
2SECTN( 3),TITLE2( 3,6)
 NN=  96
 NL=   3
 NU=   3
 NR=  80
```

LISTING OF STANDARD DATA.

PROGRAM CONSTANTS

THE ALLOCATION FOR BILL ITEMS IN THE PROGRAM	NN	500
THE NUMBER OF BILL ITEMS INPUT FOR PROGRAM RUN	N5	358
THE ALLOCATION FOR WORK CATEGORIES IN THE PROGRAM	NL	25
THE NUMBER OF WORK CATEGORIES INPUT FOR PROGRAM RUN	N1	22
THE NUMBER OF BILL PAGES INPUT FOR PROGRAM RUN	NS	45
THE NUMBER OF THE FIRST BILL PAGE	N6	301
THE ALLOCATION FOR BILL SECTIONS IN THE PROGRAM	NU	10
THE NUMBER OF BILL SECTIONS INPUT FOR PROGRAM RUN	N3	6
THE PARETO FACTOR PERCENTAGE	NR	80%

CONTINUATION OF STANDARD DATA

LIST OF THE WORK CATEGORIES,

EGORY MBER	ITEMS IN CATEGORY	MULTIPLYING FACTORS	CATEGORY
1	26	1.0	SUBSTRUCTURE : EXCAVATION
2	17	1.0	SUBSTRUCTURE : FORMWORK
3	8	1.0	SUBSTRUCTURE : REINFORCEMENT
4	14	1.0	SUBSTRUCTURE : CONCRETE
5	4	1.0	SUBSTRUCTURE : BRICKWORK
6	2	1.0	SUBSTRUCTURE : FILL
7	2	1.0	SUBSTRUCTURE : MONOLITHIC FLOOR SLAB
8	14	1.0	DRAINAGE : EXCAVATION
9	4	1.0	DRAINAGE : CONCRETE BED
10	1	1.0	DRAINAGE : LAY PIPES
11	13	1.0	DRAINAGE : MANHOLES
12	7	1.0	SUPERSTRUCTURE : FORMWORK
13	7	1.0	SUPERSTRUCTURE : REINFORCEMENT
14	11	1.0	SUPERSTRUCTURE : CONCRETE
15	52	1.0	SUPERSTRUCTURE : BRICKWORK AND BLOCKWORK
16	0	1.0	
17	3	1.0	SUPERSTRUCTURE : CARPENTER FIRST FIX
18	154	1.0	SUPERSTRUCTURE : CARPENTER SECOND FIX
19	6	1.0	CABLE DUCT : EXCAVATION
20	4	1.0	CABLE DUCT : FORMWORK
21	6	1.0	CABLE DUCT : REINFORCEMENT
22	3	1.0	CABLE DUCT : CONCRETE

LISTING OF STANDARD DATA COMPLETE

SECTION 1 SUBSTRUCTURE

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
301B	1	40.000	2.7000	108.00
301C	1	15.000	2.7000	40.50
301D	1	100.000	3.1500	315.00
301E	1	10.000	4.0500	40.50
THE PAGE TOTAL IS				504.00
302A	1	305.000	2.7000	823.50
302B	1	25.000	2.7000	67.50
302C	1	495.000	0.0000	0.00
302D	1	5.000	1.3500	6.75
302E	1	15.000	2.7000	40.50
302F	1	10.000	4.0500	40.50
302G	1	10.000	1.3500	13.50
302H	1	25.000	2.7000	67.50
302J	1	15.000	4.0500	60.75
302K	1	20.000	1.3500	27.00
302L	1	100.000	2.7000	270.00
302M	1	50.000	4.0500	202.50
302N	1	210.000	0.1800	37.80
302O	1	100.000	0.2000	20.00
302P	1	15.000	0.2000	3.00
302Q	1	55.000	0.2500	13.75
THE PAGE TOTAL IS				1694.55
303A	1	505.000	0.2500	126.25
303B	1	50.000	0.2500	12.50
303C	6	335.000	0.6700	224.45
303D	6	370.000	0.6700	247.90
303E	4	210.000	0.2400	50.40
303F	4	700.000	0.2400	168.00
303G	4	210.000	0.0000	0.00
303H	4	33.000	0.5500	18.15
303J	4	90.000	1.2500	112.50
303K	4	45.000	3.0000	135.00
303L	4	20.000	0.7000	14.00
303M	4	20.000	1.0500	21.00
303N	4	130.000	0.0000	0.00
THE PAGE TOTAL IS				1130.15
304A	4	1.000	6.0000	6.00
304B	4	3.000	0.8500	2.55
304C	4	7.000	0.9000	6.30
304D	7	738.000	0.4000	295.20

SECTION 1 SUBSTRUCTURE

CONTINUATION

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
THE PAGE TOTAL IS				310.05
305A	7	1500.000	0.0700	105.00
305B	3	7850.000	0.0310	243.35
305C	3	3000.000	0.0600	180.00
305D	3	250.000	0.0900	22.50
305E	3	2750.000	0.0400	110.00
305F	3	3750.000	0.0500	187.50
305G	3	50.000	0.0600	3.00
305H	3	30.000	0.0900	2.70
305J	3	1750.000	0.0400	70.00
305K	2	6.000	1.0000	6.00
305L	2	2.000	1.0000	2.00
305M	2	250.000	2.6000	650.00
305N	2	310.000	2.6000	806.00
305O	2	45.000	2.7000	121.50
THE PAGE TOTAL IS				2509.55
306A	2	110.000	0.9000	99.00
306B	2	1.000	2.2000	2.20
306C	2	65.000	3.2000	208.00
306D	2	40.000	3.2000	128.00
306E	2	10.000	0.3500	3.50
306F	2	7.000	0.6500	4.55
306G	2	2.000	0.7500	1.50
306H	2	3.000	1.1000	3.30
306J	4	110.000	0.1200	13.20
306K	4	6.000	0.2000	1.20
306L	2	102.000	0.1500	15.30
306M	2	106.000	0.1500	15.90
306N	2	10.000	0.1500	1.50
306O	2	22.000	0.1800	3.96
THE PAGE TOTAL IS				501.11
307A	1	44.000	1.5000	66.00
307B	1	2.000	2.6000	5.20
307C	1	55.000	1.8000	99.00
307D	1	8.000	3.3000	26.40
307E	5	11.000	3.5000	38.50
307F	5	5.000	0.3600	1.80
THE PAGE TOTAL IS				236.90
308C	19	15.000	4.5000	67.50
308D	19	5.000	0.9000	4.50

SECTION 1 SUBSTRUCTURE

CONTINUATION

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
308E	19	10.000	0.0000	0.00
308F	19	12.000	2.7000	32.40
308G	19	12.000	0.1800	2.16
308H	19	17.000	1.5000	25.50
THE PAGE TOTAL IS				132.06
309A	22	12.000	0.7500	9.00
309B	22	12.000	0.8000	9.60
309C	22	15.000	0.8000	12.00
309D	21	190.000	0.0800	15.20
309E	21	190.000	0.0800	15.20
309F	21	150.000	0.0600	9.00
309G	21	150.000	0.0800	12.00
309H	21	20.000	0.0000	0.00
309J	21	5.000	0.0000	0.00
309K	20	7.000	2.5000	17.50
309L	20	29.000	3.5000	101.50
309M	20	23.000	0.9000	20.70
309N	20	23.000	0.7000	16.10
309O	5	1.000	2.0000	2.00
THE PAGE TOTAL IS				239.80
310A	5	1.000	7.5000	7.50
THE PAGE TOTAL IS				7.50

THE SECTION TOTAL IS	7265.67

SECTION 2 DRAINAGE

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
311A	8	5.000	0.3000	1.50
311B	8	10.000	0.3000	3.00
311C	8	15.000	0.4500	6.75
311D	8	20.000	0.7000	14.00
311E	8	43.000	0.0000	0.00
311F	9	50.000	1.0000	50.00
311G	9	50.000	0.0000	0.00
THE PAGE TOTAL IS				75.25
312C	8	10.000	2.7000	27.00
312D	8	1.000	3.6000	3.60
312E	8	3.000	0.4500	1.35
312F	8	8.000	0.0000	0.00
312G	8	2.000	2.7000	5.40
312H	8	2.000	4.0500	8.10
312J	8	5.000	0.1800	0.90
312K	8	8.000	0.2000	1.60
312L	8	22.000	0.6000	13.20
312M	9	5.000	0.3500	1.75
THE PAGE TOTAL IS				62.90
313A	9	5.000	0.4500	2.25
313B	11	3.000	1.5000	4.50
313C	11	130.000	0.0500	6.50
313D	11	16.000	0.0700	1.12
313E	11	2.000	2.2000	4.40
313F	11	10.000	0.3500	3.50
313G	11	3.000	1.3500	4.05
313H	11	16.000	3.5000	56.00
313J	11	14.000	0.1300	1.82
313K	11	11.000	0.2000	2.20
313L	11	14.000	0.9000	12.60
THE PAGE TOTAL IS				98.94
314D	11	9.000	0.1500	1.35
314E	11	3.000	1.5000	4.50
314G	11	1.000	0.0500	0.05
314H	10	1.000	5.0000	5.00
THE PAGE TOTAL IS				10.90

SECTION 2 DRAINAGE

CONTINUATION

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
THE SECTION TOTAL IS				247.99

SECTION 3 SUPERSTRUCTURE : CONCRETE WORK

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
316A	14	62.000	2.0000	124.00
316B	14	7.000	2.0000	14.00
316C	14	135.000	0.7500	101.25
316D	13	650.000	0.0450	29.25
316E	13	300.000	0.0600	18.00
316F	13	300.000	0.0730	21.90
316G	13	300.000	0.0000	0.00
316H	13	75.000	0.0000	0.00
316J	12	107.000	2.5000	267.50
316K	12	68.000	0.5000	34.00
316L	12	68.000	0.4500	30.60
THE PAGE TOTAL IS				640.50
317A	14	120.000	0.1500	18.00
317B	14	9.000	0.3000	2.70
317C	14	174.000	0.1200	20.88
317D	15	43.000	0.4800	20.64
317E	15	3.000	0.7200	2.16
317F	15	24.000	0.7200	17.28
317G	15	13.000	0.9600	12.48
THE PAGE TOTAL IS				94.14
THE SECTION TOTAL IS				734.64

SECTION 4 SUPERSTRUCTURE : BRICKWORK AND BLOCKWORK

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
319A	15	2.000	3.2000	6.40
319B	15	1.000	2.0000	2.00
319C	15	45.000	2.7000	121.50
319D	15	600.000	3.2000	1920.00
319E	15	1.000	1.4500	1.45
319F	15	1000.000	0.3600	360.00
319G	15	250.000	0.1500	37.50
319H	15	153.000	0.3600	55.08
319J	15	84.000	0.4800	40.32
319K	15	3.000	0.7200	2.16
319L	15	104.000	0.0400	4.16
THE PAGE TOTAL IS				2550.57
320A	15	3.000	1.0500	3.15
320B	15	250.000	2.7500	687.50
320C	15	1.000	3.1000	3.10
320D	15	17.000	0.3600	6.12
320E	15	115.000	0.4800	55.20
320F	15	7.000	0.0400	0.28
320G	15	10.000	0.4000	4.00
320H	15	755.000	1.5100	1140.05
320J	15	910.000	1.6500	1501.50
320K	15	661.000	0.1500	99.15
320L	15	641.000	0.2400	153.84
320M	15	409.000	0.2900	118.61
THE PAGE TOTAL IS				3772.50
321A	15	31.000	0.0200	0.62
321B	15	32.000	0.3600	11.52
321C	15	3.000	0.2000	0.60
321D	15	90.000	0.2500	22.50
321E	15	226.000	0.4000	90.40
321F	15	661.000	2.2600	1493.86
321G	15	65.000	2.6000	169.00
321H	15	462.000	0.4800	221.76
321J	15	38.000	0.7200	27.36
THE PAGE TOTAL IS				2037.62
322A	15	1.000	0.2900	0.29
322B	15	349.000	0.1400	48.86
322C	15	348.000	0.1300	45.24
322D	15	317.000	0.2500	79.25
322E	15	47.000	0.2700	12.69
322F	15	1810.000	0.1500	271.50
322G	15	232.000	0.0500	11.60
322H	15	440.000	0.1400	61.60

SECTION 4 SUPERSTRUCTURE : BRICKWORK AND BLOCKWORK

CONTINUATION

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
THE PAGE TOTAL IS				531.03
323A	15	4400.000	0.0200	88.00
THE PAGE TOTAL IS				88.00

THE SECTION TOTAL IS 8979.77

SECTION 5 SUPERSTRUCTURE : CARPENTRY AND IRONMONGERY

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
324A	17	57.000	0.2800	15.96
324B	17	426.000	0.3200	136.32
324C	17	401.000	0.3600	144.36
324D	18	2.000	1.5000	3.00
324E	18	18.000	1.5000	27.00
324F	18	20.000	1.5000	30.00
324G	18	1.000	2.1000	2.10
THE PAGE TOTAL IS				358.74
325A	18	3.000	2.7000	8.10
325B	18	4.000	2.1000	8.40
325C	18	32.000	1.8000	57.60
325D	18	4.000	1.8000	7.20
325E	18	24.000	1.8000	43.20
325F	18	2.000	2.7000	5.40
325G	18	4.000	2.1000	8.40
325H	18	6.000	0.0000	0.00
325J	18	106.000	0.0000	0.00
325K	18	1.000	0.0000	0.00
325L	18	8.000	0.2400	1.92
THE PAGE TOTAL IS				140.22
326A	18	4.000	0.0000	0.00
326B	18	4.000	0.0000	0.00
326C	18	7.000	0.3600	2.52
326D	18	313.000	0.3600	112.68
326E	18	108.000	0.3600	38.88
326F	18	3.000	1.2000	3.60
326G	18	106.000	0.3000	31.80
326H	18	11.000	0.5000	5.50
326J	18	28.000	0.5300	14.84
326K	18	20.000	0.4000	8.00
326L	18	80.000	0.4000	32.00
THE PAGE TOTAL IS				249.82
327A	18	20.000	0.0000	0.00
327B	18	14.000	0.1600	2.24
327C	18	48.000	0.2000	9.60
327D	18	4.000	0.1000	0.40
327E	18	75.000	0.1300	9.75
327F	18	2.000	1.8000	3.60
327G	18	15.000	0.1000	1.50
327H	18	6.000	0.2800	1.68
327J	18	13.000	0.2800	3.64
327K	18	3.000	0.1000	0.30

SECTION 5 SUPERSTRUCTURE : CARPENTRY AND IRONMONGERY

CONTINUATION

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
THE PAGE TOTAL IS				32.71
328A	18	25.000	0.2800	7.00
328B	18	5.000	0.2800	1.40
328C	18	6.000	0.3000	1.80
328D	18	11.000	0.3000	3.30
328E	18	4.000	0.1000	0.40
328F	18	11.000	0.3500	3.85
328G	18	6.000	0.3500	2.10
328H	18	6.000	0.7000	4.20
328J	18	1.000	1.5000	1.50
THE PAGE TOTAL IS				25.55
329A	18	6.000	0.3000	1.80
329B	18	5.000	0.3500	1.75
329C	18	7.000	0.4000	2.80
329D	18	14.000	0.0000	0.00
329E	18	14.000	0.0000	0.00
329F	18	12.000	0.0000	0.00
329G	18	6.000	0.0000	0.00
329H	18	33.000	0.0000	0.00
329J	18	17.000	0.3400	5.78
329K	18	4.000	1.2000	4.80
THE PAGE TOTAL IS				16.93
330A	18	3.000	2.4000	7.20
330B	18	4.000	2.4000	9.60
330C	18	1.000	1.8000	1.80
330D	18	38.000	0.1000	3.80
330E	18	2.000	0.3200	0.64
330F	18	17.000	0.0000	0.00
330G	18	5.000	0.0000	0.00
330H	18	5.000	0.0000	0.00
330J	18	2.000	1.0800	2.16
330K	18	2.000	0.1000	0.20
330L	18	5.000	0.0000	0.00
330M	18	11.000	0.0000	0.00
THE PAGE TOTAL IS				25.40
331A	18	5.000	0.4000	2.00
331B	18	3.000	0.5500	1.65
331C	18	9.000	0.5500	4.95
331D	18	3.000	0.5500	1.65
331E	18	3.000	0.4500	1.35

SECTION 5 SUPERSTRUCTURE : CARPENTRY AND IRONMONGERY

CONTINUATION

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
331F	18	3.000	1.9000	5.70
331G	18	11.000	0.0000	0.00
331H	18	5.000	0.0000	0.00
331J	18	11.000	0.0000	0.00
331K	18	5.000	0.0000	0.00
331L	18	11.000	0.0000	0.00
331M	18	3.000	0.0000	0.00
THE PAGE TOTAL IS				17.30
332A	18	5.000	0.0000	0.00
332B	18	10.000	0.0000	0.00
332C	18	6.000	0.2800	1.68
332D	18	90.000	0.1000	9.00
332E	18	18.000	0.3200	5.76
332F	18	22.000	0.0000	0.00
332G	18	2.000	0.0000	0.00
332H	18	18.000	0.2000	3.60
332J	18	11.000	0.1800	1.98
332K	18	8.000	0.1000	0.80
THE PAGE TOTAL IS				22.82
333A	18	2.000	0.0000	0.00
333B	18	10.000	0.0000	0.00
333C	18	40.000	0.0000	0.00
333D	18	32.000	0.0000	0.00
333E	18	3.000	0.3000	0.90
333F	18	2.000	0.7000	1.40
333G	18	2.000	0.7000	1.40
333H	18	1.000	0.0000	0.00
333J	18	30.000	1.6000	48.00
333K	18	12.000	1.2000	14.40
333L	18	2.000	0.0000	0.00
THE PAGE TOTAL IS				66.10
334A	18	272.000	0.1000	27.20
334B	18	44.000	0.3500	15.40
334C	18	3.000	0.1000	0.30
334D	18	9.000	0.0000	0.00
334E	18	18.000	0.2000	3.60
334F	18	20.000	0.0000	0.00
334G	18	3.000	0.0000	0.00
334H	18	3.000	0.1000	0.30
334J	18	48.000	0.2000	9.60
334K	18	5.000	0.2000	1.00
334L	18	7.000	0.2000	1.40
334M	18	24.000	0.2000	4.80

SECTION 5 SUPERSTRUCTURE : CARPENTRY AND IRONMONGERY

CONTINUATION

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
334N	18	4.000	0.5000	2.00
334O	18	2.000	0.5000	1.00
THE PAGE TOTAL IS				66.60

335A	18	51.000	0.0000	0.00
335B	18	9.000	0.0000	0.00
335C	18	10.000	0.0000	0.00
335D	18	20.000	0.2000	4.00
335E	18	20.000	0.6000	12.00
335F	18	40.000	0.2000	8.00
335G	18	16.000	0.6000	9.60
335H	18	16.000	0.2400	3.84
335J	18	48.000	1.2000	57.60
335K	18	16.000	0.9000	14.40
335L	18	8.000	1.5000	12.00
335M	18	24.000	0.9000	21.60
335N	18	5.000	1.2000	6.00
THE PAGE TOTAL IS				149.04

336A	18	9.000	0.1000	0.90
336B	18	28.000	0.1200	3.36
336C	18	146.000	0.1800	26.28
336D	18	1.000	2.0000	2.00
336E	18	2.000	2.4000	4.80
336F	18	3.000	1.2000	3.60
THE PAGE TOTAL IS				40.94

THE SECTION TOTAL IS 1212.17

SECTION 6 NOMINATED ACCOUNTS

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
364E	14	98.000	1.2500	122.50
364F	14	53.000	4.5000	238.50
364G	14	8.000	2.2500	18.00
THE PAGE TOTAL IS				379.00
365A	13	93.000	0.1000	9.30
365B	12	80.000	3.5000	280.00
365C	12	35.000	4.0000	140.00
365D	12	78.000	1.0000	78.00
365G	14	1.000	275.0000	275.00
THE PAGE TOTAL IS				782.30
366A	14	50.000	1.0000	50.00
366B	13	50.000	0.1150	5.75
366C	12	50.000	3.7500	187.50
366D	15	200.000	0.4000	80.00
366E	15	200.000	0.5000	100.00
THE PAGE TOTAL IS				423.25
367A	15	50.000	0.3000	15.00
367B	15	50.000	0.3000	15.00
367C	15	50.000	0.3000	15.00
THE PAGE TOTAL IS				45.00
368B	15	100.000	0.2700	27.00
368C	15	100.000	0.2700	27.00
THE PAGE TOTAL IS				54.00
369A	18	1.000	13.5000	13.50
369E	18	36.000	0.2000	7.20
369F	18	24.000	0.2000	4.80
369G	18	66.000	1.8000	118.80
369H	18	1.000	0.6000	0.60
369J	18	1.000	0.8000	0.80
369K	18	3.000	0.8000	2.40
THE PAGE TOTAL IS				148.10
370Z	18	1.000	373.0000	373.00

CONTINUATION

ITEM	CATEGORY	QUANTITY	RATE	EXTENSION
THE PAGE TOTAL IS				373.00
371Z	18	1.000	224.0000	224.00
THE PAGE TOTAL IS				224.00
372A	18	6.000	1.2000	7.20
372B	18	6.000	0.8000	4.80
372C	18	12.000	0.6000	7.20
372Z	18	1.000	280.0000	280.00
THE PAGE TOTAL IS				299.20
373Z	18	1.000	165.0000	165.00
THE PAGE TOTAL IS				165.00
374D	18	1.000	13.5000	13.50
374E	18	1.000	25.0000	25.00
374F	18	5.000	0.3500	1.75
374G	18	5.000	0.4200	2.10
374H	18	3.000	2.5000	7.50
374J	18	3.000	2.7000	8.10
374K	18	3.000	3.0000	9.00
THE PAGE TOTAL IS				66.95
THE SECTION TOTAL IS				2959.80

SUMMARY OF SECTION TOTALS

SECTION	VALUE
SUBSTRUCTURE	7265.67
DRAINAGE	247.99
SUPERSTRUCTURE : CONCRETE WORK	734.64
SUPERSTRUCTURE : BRICKWORK AND BLOCKWORK	8979.72
SUPERSTRUCTURE : CARPENTRY AND IRONMONGERY	1212.17
NOMINATED ACCOUNTS	2959.80
THE BILL TOTAL IS	21399.99

WORK CATEGORY 1 SUBSTRUCTURE : EXCAVATION

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
301B	108.00	**
301C	40.50	
301D	315.00	**
301F	40.50	
302A	823.50	**
302B	67.50	
302C	0.00	
302D	6.75	
302E	40.50	
302F	40.50	
302G	13.50	
302H	67.50	
302J	60.75	
302K	27.00	
302L	270.00	**
302M	202.50	**
302N	37.80	
302O	20.00	
302P	3.00	
302Q	13.75	
303A	126.25	**
303B	12.50	
307A	66.00	
307B	5.20	
307C	99.00	
307D	26.40	

THE WORK CATEGORY TOTAL IS 2533.90

WORK CATEGORY 2 SUBSTRUCTURE : FORMWORK

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
305K	6.00	
305L	2.00	
305M	650.00	**
305N	806.00	**
305O	121.50	**
306A	99.00	
306B	2.20	
306C	208.00	**
306D	128.00	**
306E	3.50	
306F	4.55	
306G	1.50	
306H	3.30	
306L	15.30	
306M	15.90	
306N	1.50	
306O	3.96	

THE WORK CATEGORY TOTAL IS 2072.21

WORK CATEGORY 3 SUBSTRUCTURE : REINFORCEMENT

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
305B	243.35	**
305C	180.00	**
305D	22.50	
305E	110.00	**
305F	187.50	**
305G	3.00	
305H	2.70	
305J	70.00	

THE WORK CATEGORY TOTAL IS 819.05

WORK CATEGORY 4 SUBSTRUCTURE : CONCRETE

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
303E	50.40	
303F	168.00	**
303G	0.00	
303H	18.15	
303J	112.50	**
303K	135.00	**
303L	14.00	
303M	21.00	
303N	0.00	
304A	6.00	
304B	2.55	
304C	6.30	
306J	13.20	
306K	1.20	

THE WORK CATEGORY TOTAL IS 548.30

WORK CATEGORY 5 SUBSTRUCTURE : BRICKWORK

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
307E	38.50
307F	1.80
309D	2.00
310A	7.50

THE WORK CATEGORY TOTAL IS 49.80

WORK CATEGORY 6 SUBSTRUCTURE : FILL

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
303C	224.45 **
303D	247.90 **
THE WORK CATEGORY TOTAL IS	472.35

WORK CATEGORY 7 SUBSTRUCTURE : MONOLITHIC FLOOR SLAB

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
304D	295.20 **
305A	105.00 **

THE WORK CATEGORY TOTAL IS 400.20

WORK CATEGORY 8 DRAINAGE : EXCAVATION

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
311A	1.50
311B	3.00
311C	6.75
311D	14.00
311F	0.00
312C	27.00
312D	3.60
312E	1.35
312F	0.00
312G	5.40
312H	8.10
312J	0.90
312K	1.60
312L	13.20

THE WORK CATEGORY TOTAL IS 86.40

WORK CATEGORY 9 DRAINAGE : CONCRETE BED

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
311F	50.00
311G	0.00
312M	1.75
313A	2.25

THE WORK CATEGORY TOTAL IS 54.00

WORK CATEGORY 10 DRAINAGE : LAY PIPES

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
314H	5.00
THE WORK CATEGORY TOTAL IS	5.00

WORK CATEGORY 11 DRAINAGE : MANHOLES

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
313B	4.50
313C	6.50
313D	1.12
313E	4.40
313F	3.50
313G	4.05
313H	56.00
313J	1.82
313K	2.20
313L	12.60
314D	1.35
314E	4.50
314G	0.05

THE WORK CATEGORY TOTAL IS 102.59

WORK CATEGORY 12 SUPERSTRUCTURE : FORMWORK

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
316J	267.50	**
316K	34.00	
316L	30.60	
365B	280.00	**
365C	140.00	**
365D	78.00	
366C	187.50	**

THE WORK CATEGORY TOTAL IS 1017.60

WORK CATEGORY 13 SUPERSTRUCTURE : REINFORCEMENT

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
316D	29.25
316E	18.00
316F	21.90
316G	0.00
316H	0.00
365A	9.30
366B	5.75

THE WORK CATEGORY TOTAL IS 84.20

WORK CATEGORY 14 SUPERSTRUCTURE : CONCRETE

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
316A	124.00	**
316B	14.00	
316C	101.25	
317A	18.00	
317B	2.70	
317C	20.88	
364E	122.50	**
364F	238.50	**
364G	18.00	
365G	275.00	**
366A	50.00	

THE WORK CATEGORY TOTAL IS 984.83

WORK CATEGORY 15 SUPERSTRUCTURE : BRICKWORK AND BLOCKWORK

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
317D	20.64	
317E	2.16	
317F	17.28	
317G	12.48	
319A	6.40	
319B	2.00	
319C	121.50	**
319D	1920.00	**
319E	1.45	
319F	360.00	**
319G	37.50	
319H	55.08	
319J	40.32	
319K	2.16	
319L	4.16	
320A	3.15	
320B	687.50	**
320C	3.10	
320D	6.12	
320E	55.20	
320F	0.28	
320G	4.00	
320H	1140.05	**
320J	1501.50	**
320K	99.15	
320L	153.84	**
320M	118.61	**
321A	0.62	
321B	11.52	
321C	0.60	
321D	22.50	
321E	90.40	
321F	1493.86	**
321G	169.00	**
321H	221.76	**
321J	27.36	
322A	0.29	
322B	48.86	
322C	45.24	
322D	79.25	
322E	12.69	
322F	271.50	**
322G	11.60	
322H	61.60	
323A	88.00	
366D	80.00	
366E	100.00	
367A	15.00	
367B	15.00	
367C	15.00	

WORK CATEGORY 15 SUPERSTRUCTURE : BRICKWORK AND BLOCKWORK

ITEMS IN BILL SEQUENCE

CONTINUATION (** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
368B	27.00
368C	27.00

THE WORK CATEGORY TOTAL IS 9311.28

WORK CATEGORY 17 SUPERSTRUCTURE : CARPENTER FIRST FIX

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
324A	15.96
324B	136.32 **
324C	144.36 **

THE WORK CATEGORY TOTAL IS 296.64

WORK CATEGORY 18 SUPERSTRUCTURE : CARPENTER SECOND FIX

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
324D	3.00	
324E	27.00	
324F	30.00	
324G	2.10	
325A	8.10	
325B	8.40	
325C	57.60	
325D	7.20	
325E	43.20	
325F	5.40	
325G	8.40	
325H	0.00	
325J	0.00	
325K	0.00	
325L	1.92	
326A	0.00	
326B	0.00	
326C	2.52	
326D	112.68	**
326E	38.88	
326F	3.60	
326G	31.80	
326H	5.50	
326J	14.84	
326K	8.00	
326L	32.00	
327A	0.00	
327B	2.24	
327C	9.60	
327D	0.40	
327E	9.75	
327F	3.60	
327G	1.50	
327H	1.68	
327J	3.64	
327K	0.30	
328A	7.00	
328B	1.40	
328C	1.80	
328D	3.30	
328E	0.40	
328F	3.85	
328G	2.10	
328H	4.20	
328J	1.50	
329A	1.80	
329B	1.75	
329C	2.80	
329D	0.00	
329E	0.00	

WORK CATEGORY 18 SUPERSTRUCTURE : CARPENTER SECOND FIX

ITEMS IN BILL SEQUENCE

CONTINUATION

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
329F	0.00
329G	0.00
329H	0.00
329J	5.78
329K	4.80
330A	7.20
330B	9.60
330C	1.80
330D	3.80
330E	0.64
330F	0.00
330G	0.00
330H	0.00
330J	2.16
330K	0.20
330L	0.00
330M	0.00
331A	2.00
331B	1.65
331C	4.95
331D	1.65
331E	1.35
331F	5.70
331G	0.00
331H	0.00
331J	0.00
331K	0.00
331L	0.00
331M	0.00
332A	0.00
332B	0.00
332C	1.68
332D	9.00
332E	5.76
332F	0.00
332G	0.00
332H	3.60
332J	1.98
332K	0.80
333A	0.00
333B	0.00
333C	0.00
333D	0.00
333E	0.90
333F	1.40
333G	1.40
333H	0.00
333J	48.00
333K	14.40
333L	0.00

WORK CATEGORY 18 SUPERSTRUCTURE : CARPENTER SECOND FIX

ITEMS IN BILL SEQUENCE

CONTINUATION

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
334A	27.20	
334B	15.40	
334C	0.30	
334D	0.00	
334E	3.60	
334F	0.00	
334G	0.00	
334H	0.30	
334J	9.60	
334K	1.00	
334L	1.40	
334M	4.80	
334N	2.00	
334O	1.00	
335A	0.00	
335B	0.00	
335C	0.00	
335D	4.00	
335E	12.00	
335F	8.00	
335G	9.60	
335H	3.84	
335J	57.60	
335K	14.40	
335L	12.00	
335M	21.60	
335N	6.00	
336A	0.90	
336B	3.36	
336C	26.28	
336D	2.00	
336E	4.80	
336F	3.60	
369A	13.50	
369E	7.20	
369F	4.80	
369G	118.80	**
369H	0.60	
369J	0.80	
369K	2.40	
370Z	373.00	**
371Z	224.00	**
372A	7.20	
372B	4.80	
372C	7.20	
372Z	280.00	**
373Z	165.00	**
374D	13.50	
374E	25.00	
374F	1.75	

WORK CATEGORY 18 SUPERSTRUCTURE : CARPENTER SECOND FIX

ITEMS IN BILL SEQUENCE

CONTINUATION (** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
374G	2.10
374H	7.50
374J	8.10
374K	9.00

THE WORK CATEGORY TOTAL IS 2191.78

WORK CATEGORY 19 CABLE DUCT : EXCAVATION

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
308C	67.50
308D	4.50
308E	0.00
308F	32.40
308G	2.16
308H	25.50
THE WORK CATEGORY TOTAL IS	132.06

WORK CATEGORY 20 CABLE DUCT : FORMWORK

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
309K	17.50
309L	101.50 **
309M	20.70
309N	16.10

THE WORK CATEGORY TOTAL IS 155.80

WORK CATEGORY 21 CABLE DUCT : REINFORCEMENT

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
309D	15.20
309E	15.20
309F	9.00
309G	12.00
309H	0.00
309J	0.00

THE WORK CATEGORY TOTAL IS 51.40

WORK CATEGORY 22 CABLE DUCT : CONCRETE

ITEMS IN BILL SEQUENCE

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
309A	9.00
309B	9.60
309C	12.00

THE WORK CATEGORY TOTAL IS 30.60

WORK CATEGORY 1 SUBSTRUCTURE : EXCAVATION

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
302A	823.50	**
301D	315.00	**
302L	270.00	**
302M	202.50	**
303A	126.25	**
301B	108.00	**
307C	99.00	
302B	67.50	
302H	67.50	
307A	66.00	
302J	60.75	
301C	40.50	
301E	40.50	
302E	40.50	
302F	40.50	
302N	37.80	
302K	27.00	
307D	26.40	
302O	20.00	
302Q	13.75	
302G	13.50	
303B	12.50	
302D	6.75	
307B	5.20	
302P	3.00	
302P	3.00	

THE WORK CATEGORY TOTAL IS 2533.90

WORK CATEGORY 2 SUBSTRUCTURE : FORMWORK

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
305N	806.00	**
305M	650.00	**
306C	208.00	**
306D	128.00	**
305O	121.50	**
306A	99.00	
306M	15.90	
306L	15.30	
305K	6.00	
306F	4.55	
306O	3.96	
306E	3.50	
306H	3.30	
306B	2.20	
305L	2.00	
306G	1.50	
306N	1.50	

THE WORK CATEGORY TOTAL IS 2072.21

WORK CATEGORY 3 SUBSTRUCTURE : REINFORCEMENT

ITEMS IN DESCENDING ORDER OF EXTENSION

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
305B	243.35 **
305F	187.50 **
305C	180.00 **
305E	110.00 **
305J	70.00
305D	22.50
305G	3.00
305H	2.70

THE WORK CATEGORY TOTAL IS 819.05

WORK CATEGORY 4 SUBSTRUCTURE : CONCRETE

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
303F	168.00	**
303K	135.00	**
303J	112.50	**
303E	50.40	
303M	21.00	
303H	18.15	
303L	14.00	
306J	13.20	
304C	6.30	
304A	6.00	
304B	2.55	
306K	1.20	
306K	1.20	
306K	1.20	

THE WORK CATEGORY TOTAL IS 548.30

WORK CATEGORY 5 SUBSTRUCTURE : BRICKWORK

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
307F	38.50
310A	7.50
3090	2.00
307F	1.80

THE WORK CATEGORY TOTAL IS 49.80

WORK CATEGORY 6 SUBSTRUCTURE : FILL

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
303D	247.90 **
303C	224.45 **

THE WORK CATEGORY TOTAL IS 472.35

WORK CATEGORY 7 SUBSTRUCTURE : MONOLITHIC FLOOR SLAB

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
304D	295.20 **
305A	105.00 **

THE WORK CATEGORY TOTAL IS 400.20

WORK CATEGORY 8 DRAINAGE : EXCAVATION

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
312C	27.00
311D	14.00
312L	13.20
312H	8.10
311C	6.75
312G	5.40
312D	3.60
311B	3.00
312K	1.60
311A	1.50
312F	1.35
312J	0.90
312J	0.90
312J	0.90

THE WORK CATEGORY TOTAL IS 86.40

WORK CATEGORY 9 DRAINAGE : CONCRETE BED

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
311F	50.00
313A	2.25
312M	1.75
312M	1.75

THE WORK CATEGORY TOTAL IS 54.00

WORK CATEGORY 10 DRAINAGE : LAY PIPES

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
314H	5.00
THE WORK CATEGORY TOTAL IS	5.00

WORK CATEGORY 11 DRAINAGE : MANHOLES

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
313H	56.00
313L	12.60
313C	6.50
313B	4.50
314F	4.50
313E	4.40
313G	4.05
313F	3.50
313K	2.20
313J	1.82
314D	1.35
313D	1.12
314G	0.05

THE WORK CATEGORY TOTAL IS 102.59

WORK CATEGORY 12 SUPERSTRUCTURE : FORMWORK

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
365B	280.00	**
316J	267.50	**
366C	187.50	**
365C	140.00	**
365D	78.00	
316K	34.00	
316L	30.60	

THE WORK CATEGORY TOTAL IS 1017.60

WORK CATEGORY 13 SUPERSTRUCTURE : REINFORCEMENT

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
316D	29.25
316F	21.90
316E	18.00
365A	9.30
366B	5.75
366B	5.75
366B	5.75

THE WORK CATEGORY TOTAL IS 84.20

WORK CATEGORY 14 SUPERSTRUCTURE : CONCRETE

ITEMS IN DESCENDING ORDER OF EXTENSION

(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION	
365G	275.00	**
364F	238.50	**
316A	124.00	**
364E	122.50	**
316C	101.25	
366A	50.00	
317C	20.88	
317A	18.00	
364G	18.00	
316B	14.00	
317B	2.70	

THE WORK CATEGORY TOTAL IS 984.83

WORK CATEGORY 15 SUPERSTRUCTURE : BRICKWORK AND BLOCKWORK

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
319D	1920.00 **
320J	1501.50 **
321F	1493.86 **
320H	1140.05 **
320B	687.50 **
319F	360.00 **
322E	271.50 **
321H	221.76 **
321G	169.00 **
320L	153.84 **
319C	121.50 **
320M	118.61 **
366E	100.00
320K	99.15
321E	90.40
323A	88.00
366D	80.00
322D	79.25
322H	61.60
320E	55.20
319H	55.08
322B	48.86
322C	45.24
319J	40.32
319G	37.50
321J	27.36
368B	27.00
368C	27.00
321D	22.50
317D	20.64
317F	17.28
367A	15.00
367B	15.00
367C	15.00
322F	12.69
317G	12.48
322G	11.60
321B	11.52
319A	6.40
320D	6.12
319L	4.16
320G	4.00
320A	3.15
320C	3.10
317E	2.16
319K	2.16
319B	2.00
319E	1.45
321A	0.62
321C	0.60

WORK CATEGORY 15 SUPERSTRUCTURE : BRICKWORK AND BLOCKWORK

ITEMS IN DESCENDING ORDER OF EXTENSION

CONTINUATION (** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
322A	0.29
320F	0.28

THE WORK CATEGORY TOTAL IS 9311.28

WORK CATEGORY 17 SUPERSTRUCTURE : CARPENTER FIRST FIX

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
324C	144.36 **
324B	136.32 **
324A	15.96

THE WORK CATEGORY TOTAL IS 296.64

WORK CATEGORY 18 SUPERSTRUCTURE : CARPENTER SECOND FIX

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
370Z	373.00 **
372Z	280.00 **
371Z	224.00 **
373Z	165.00 **
369G	118.80 **
326D	112.68 **
325C	57.60
335J	57.60
333J	48.00
325E	43.20
326E	38.88
326L	32.00
326G	31.80
324H	30.00
334A	27.20
324F	27.00
336C	26.28
374E	25.00
335M	21.60
334B	15.40
326J	14.84
333K	14.40
335K	14.40
369A	13.50
374D	13.50
335E	12.00
335L	12.00
327E	9.75
327C	9.60
334J	9.60
330B	9.60
335G	9.60
332D	9.00
374K	9.00
325B	8.40
325G	8.40
325A	8.10
374J	8.10
326K	8.00
335F	8.00
374H	7.50
325D	7.20
330A	7.20
369E	7.20
372A	7.20
372C	7.20
328A	7.00
335N	6.00
329J	5.78
332E	5.76

WORK CATEGORY 18 SUPERSTRUCTURE : CARPENTER SECOND FIX

ITEMS IN DESCENDING ORDER OF EXTENSION
CONTINUATION (** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
331F	5.70
326H	5.50
325F	5.40
331C	4.95
334M	4.80
369F	4.80
372B	4.80
329K	4.80
336E	4.80
328H	4.20
335D	4.00
328F	3.85
335H	3.84
330D	3.80
327J	3.64
326F	3.60
327F	3.60
332H	3.60
334F	3.60
336F	3.60
336B	3.36
328D	3.30
324D	3.00
329C	2.80
326C	2.52
369K	2.40
327B	2.24
330J	2.16
324G	2.10
328G	2.10
374G	2.10
331A	2.00
334N	2.00
336D	2.00
332J	1.98
325L	1.92
328C	1.80
329A	1.80
330C	1.80
329B	1.75
374F	1.75
327H	1.68
332C	1.68
331B	1.65
331D	1.65
327G	1.50
328J	1.50
334L	1.40
328B	1.40
333F	1.40

WORK CATEGORY 18 SUPERSTRUCTURE : CARPENTER SECOND FIX

ITEMS IN DESCENDING ORDER OF EXTENSION
CONTINUATION (** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
333G	1.40
331E	1.35
334K	1.00
3340	1.00
333F	0.90
336A	0.90
332K	0.80
369J	0.80
330F	0.64
369H	0.60
327D	0.40
328F	0.40
327K	0.30
334C	0.30
334H	0.30
330K	0.20
330K	0.20
330K	0.20
330K	0.20
330K	0.20
330K	0.20
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330K	0.20
330K	0.20
330K	0.20
330K	0.20
330K	0.20

WORK CATEGORY 18 SUPERSTRUCTURE : CARPENTER SECOND FIX

ITEMS IN DESCENDING ORDER OF EXTENSION
CONTINUATION (** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
330K	0.20
330K	0.20
330K	0.20
330K	0.20

THE WORK CATEGORY TOTAL IS 2191.78

WORK CATEGORY 19 CABLE DUCT : EXCAVATION

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
308C	67.50
308F	32.40
308H	25.50
308D	4.50
308G	2.16
308G	2.16

THE WORK CATEGORY TOTAL IS 132.06

WORK CATEGORY 20 CABLE DUCT : FORMWORK

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
309L	101.50 **
309M	20.70
309K	17.50
309N	16.10

THE WORK CATEGORY TOTAL IS 155.80

WORK CATEGORY 21 CABLE DUCT : REINFORCEMENT

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
309D	15.20
309E	15.20
309G	12.00
309F	9.00
309F	9.00
309F	9.00

THE WORK CATEGORY TOTAL IS 51.40

WORK CATEGORY 22 CABLE DUCT : CONCRETE

ITEMS IN DESCENDING ORDER OF EXTENSION
(** INDICATES A MAJOR ITEM)

ITEM	EXTENSION
309C	12.00
309B	9.60
309A	9.00

THE WORK CATEGORY TOTAL IS 30.60

APPENDIX 7.

Records of achieved performance collected for the Stores Block of the Stores and Office project

			Page
Costs of substructure	-	excavation	242
" " "	-	concrete	243
" " "	-	reinforcement	244
" " "	-	formwork	245
" " "	-	hardcore	246
Costs of superstructure	-	concrete	247
" " "	-	formwork	248
" " "	-	reinforcement	249
" " "	-	brickwork and blockwork	250

contract STORES AND OFFICE BLOCK section STORES

date 19 - 10 - 1972

CTIVITY OST ODE	ESTIMATED ACTIVITY COST	AUTHORISED VARIATIONS + OR −	REVISED EST. ACT. COST	% WORK COMP.	VALUE OF WORK EXECUTED	PREVIOUS RECORDED COSTS	COSTS INCURRED IN THIS PERIOD	TOTAL COSTS TO DATE	REMARKS
UBS.							£		
XCAVATION	£2533	-£106	£2427	100	£2427	Re-check on time sheets	746 hrs @ 90p= 671 60 " @ 100p= 60 machine costs = 328	£1059	Operation carried out by machine as against the estimated value calculated on hand dig around piles Complete remeasure carried out by the surveyor Complete check through time sheets to give final accurate costs Site decision to use small machine on excavation proved valid

242.

A 7.

contract STORES AND OFFICE BLOCK section STORES

date 19 - 10 - 1972

CTIVITY OST ODE	ESTIMATED ACTIVITY COST	AUTHORISED VARIATIONS + OR −	REVISED EST. ACT. COST	% WORK COMP.	VALUE OF WORK EXECUTED	PREVIOUS RECORDED COSTS	COSTS INCURRED IN THIS PERIOD	TOTAL COSTS TO DATE	REMARKS
UBS.							£		
ONCRETE	£548	−£85	£463	100	£463	Re-check on time sheets	350 hrs @ 90p = 315 30 " @ 100p = 30	£345	This activity done entirely by own labour Complete remeasure by the Surveyor Complete check through time sheets to give final accurate costs

contract STORES AND OFFICE BLOCK section STORES

date 19 - 10 - 1972

CTIVITY OST ODE	ESTIMATED ACTIVITY COST	AUTHORISED VARIATIONS + OR −	REVISED EST. ACT. COST	% WORK COMP.	VALUE OF WORK EXECUTED	PREVIOUS RECORDED COSTS	COSTS INCURRED IN THIS PERIOD	TOTAL COSTS TO DATE	REMARKS
UBS.							£		
ein-orcement	£924	−£80	£844	100	£844	Re-check on time sheets	Sub-contractor 650 30 hrs @ 90p = 27 10 " @ 100p = 10	£687	This activity mainly done by sub-contracto Complete remeasure by the Surveyor Accurate breakdown of sub-contractors' cost available in this instance

contract STORES AND OFFICE BLOCK section STORES

date 19 - 10 - 1972

ACTIVITY COST CODE	ESTIMATED ACTIVITY COST	AUTHORISED VARIATIONS + OR −	REVISED EST. ACT. COST	% WORK COMP.	VALUE OF WORK EXECUTED	PREVIOUS RECORDED COSTS	COSTS INCURRED IN THIS PERIOD	TOTAL COSTS TO DATE	REMARKS
SUBS.							£		
Form-work	£2072	-£126	£1946	100	£1946	Re-check on time sheets	Sub-contractor 1905 119 hrs @ 100 = 119 50 " @ 90 = 45	£2069	This activity done partly by own labour and remainder by sub-contractor Complete remeasure by the Surveyor Complete check througl time sheets to give final accurate costs Sub-contractor costs include for extra worl on caps due to inaccurate piling. Value of this extra wo built-up on a daywork basis

contract STORES AND OFFICE BLOCK section STORES

date 19 – 10 – 1972

ACTIVITY COST CODE	ESTIMATED ACTIVITY COST	AUTHORISED VARIATIONS + OR –	REVISED EST. ACT. COST	% WORK COMP.	VALUE OF WORK EXECUTED	PREVIOUS RECORDED COSTS	COSTS INCURRED IN THIS PERIOD	TOTAL COSTS TO DATE	REMARKS
SUBS.							£		
Hardcore	£472	+£119	£591	100	£591	Re-check on time sheets	744 hrs @ 90p = 669 50 " @ 100p = 50	£719	Work done by own labour Different material used from that origionally specified required an increased labour rate Complete remeasure by the Surveyor Complete check through time sheets to give final accurate costs

contract STORES AND OFFICE BLOCK section STORES

date

ACTIVITY COST CODE	ESTIMATED ACTIVITY COST	AUTHORISED VARIATIONS + OR −	REVISED EST. ACT. COST	% WORK COMP.	VALUE OF WORK EXECUTED	PREVIOUS RECORDED COSTS	COSTS INCURRED IN THIS PERIOD	TOTAL COSTS TO DATE	REMARKS
SUPERST.									
Concrete	£985	+ £250	£1235	25.8.72 41	£654	NIL	£520	£520	High level roof now changed to insitu slab resulting in extra cost
				15.9.72 82	£1058	£520	£193	£713	
				19.10.72 92	£1156	£713	£ 1032 hrs @ 90p = 929 100 " @ 100p = 100	£1029	Complete check through time sheets to give revised cost
				6.1.73 96	£1185	£1029	£ 200 hrs @ 90p = 180 30 " @ 100p = 30 £210	£1239	Costs incurred correct to date but not possible to work out "estimated value" at present due to large number of variations Note 20% of activity cost used for the execution of 4% of the work in this period

247.

A 7.

contract STORES AND OFFICE BLOCK section STORES

date

ACTIVITY COST CODE	ESTIMATED ACTIVITY COST	AUTHORISED VARIATIONS + OR −	REVISED EST. ACT. COST	% WORK COMP.	VALUE OF WORK EXECUTED	PREVIOUS RECORDED COSTS	COSTS INCURRED IN THIS PERIOD	TOTAL COSTS TO DATE	REMARKS
SUPERST.									
Formwork	£1018	+£250	£1268	25.8.72 41	£667	NIL	£920	£920	Additional formwork in high level roof All work undertaken by Sub-contractor
		+£1950	£3218	15.9.72 82	£2684	£920	£ Sub-contractor = 619 Daywork labour = 731 17 hrs @ 90p = 15 £1365	£2285	Additional value for inaccuracies in Bill beam measurements Daywork labour brought in from other site during National Building Strike at premium payments.
				6.1.72 96	£3089				No longer practical proposition to collect accurate costs because sub-contractor will not keep them separate from other activities and the office block

248

A 7.

contract STORES AND OFFICE BLOCK section STORES

date

ACTIVITY COST CODE	ESTIMATED ACTIVITY COST	AUTHORISED VARIATIONS + OR −	REVISED EST. ACT. COST	% WORK COMP.	VALUE OF WORK EXECUTED	PREVIOUS RECORDED COSTS	COSTS INCURRED IN THIS PERIOD	TOTAL COSTS TO DATE	REMARKS
SUPERST.									
Rein-forcement	£84	+ £60	£144	25.8.72 41	£94	NIL	£180	£180	Additional reinforcement in high level roof All work done by Sub-contractor
		+ £180	£324	15.9.72 82	£276	£180	£130	£310	Extra value for inaccuracies in Bill beam measurements
				6.1.73 96	£311	£310			No longer practical proposition to collect accurate costs because sub-contractor will not keep them separate from other activities and the office block

249.

A 7.

contract STORES AND OFFICE BLOCK section STORES

date

ACTIVITY COST CODE	ESTIMATED ACTIVITY COST	AUTHORISED VARIATIONS + OR −	REVISED EST. ACT. COST	% WORK COMP.	VALUE OF WORK EXECUTED	PREVIOUS RECORDED COSTS	COSTS INCURRED IN THIS PERIOD	TOTAL COSTS TO DATE	REMARKS
SUPERST. Brickwork and blockwork	£9312			25.8.72 25	£2328	NIL	Sub-contractor £1719	£1719	This includes external and internal work All work undertaken by Sub-contractor
		− £37	£9275	15.9.72 51	£4730	£1719	Sub-contractor £ 872 35 hrs @ 90p = 31 £903	£2622	Type of bond changed causing a reduction in Bill rates
250.				19.10.72 85	£7884	£2622	Sub-contractor £1606	£4228	
				6.1.73 98	£9089	£4228	Sub-contractor £1656	£5884	Difficulties experienced in pursuading Sub-contractor to return to site to complete remainder of work Large saving is due to the efficiency of this sub-contractor

A 7.