ESTIMATING, PLANNING AND CONTROL SYSTEMS BASED ON PRODUCTION DATA IN THE CONSTRUCTION INDUSTRY

by

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ABSTRACT

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The processes of estimating, planning and control within the building industry are seldom fully integrated. This study considers the integration of the processes based on production data collected from several projects. The aim of the research is to investigate the feasibility of the integrated approach as a means of improving the estimating, planning and control processes within the construction industry.

Selected cost significant work sections are considered in the study and production data are formulated based on feedback information from several first sample projects. Comparisons are made between average production data and individual project data.

A structured systems analysis of the collaborating body identifies existing processes and production orientated information requirements. A model and working system prototype are developed which illustrate integration of the processes and generation of management information.

Application of the model as a basis for estimating and planning at various levels of detail is demonstrated. Forecast-observation diagrams provide the necessary control mechanism for monitoring production outputs.

Forecasts on a second independent sample of projects are assessed based on tolerances of performances from first sample projects. Accuracy of average forecasts from the model are compared with other data sources, these being estimators' data used in the preparation of the estimate, and bonus surveyors' targets used during the production process.

The research concludes that the production data and model give a worthwhile improvement over existing methods in forecasting average productivity performances when methods of placing can be clearly identified and related to work packages. The production data and model are insufficiently accurate to give a worthwhile improvement when measured items cover work packages of varying degrees of complexity, and when proportioning methods are used to obtain production data for different categories of items which collectively represent work packages. Assessment of the model together with refinements are also discussed.

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ABBREVIATIONS AND DEFINITIONS

BRE	Building Research Establishment
BRS	Building Research Station
CCPI	Coordinating Committee for Project Information
CIOB	Chartered Institute of Building
CV	Coefficient of variation
Data Base	A file of standard items relating to construction work
DOE	Department of the Environment
Effective Tolerance	represents plus or minus one standard error of estimate from first sample projects expressed in hours
Forecasting	The terms forecasting and prediction have been used interchangeably
Incentive target	The number of hours set for an operative to complete an operation
Insignificant Item	An item of minor cost relating to a work section
NCC	National Consultative Council for the Building and Civil Engineering Industries
Productivity range ratio	Ratio between the highest and lowest actual hours for approximately the same production data hours

PSA	Property Services Agency
RMSE	Root mean square error
SD	Standard deviation
RICS	Royal Institution of Chartered Surveyors
Significant Item	An item of major cost relating to a work section
SMM	Standard Method of Measurement of Building Works
SMM6	Standard Method of Measurement of Building Works: Sixth Edition
SMM7	Standard Method of Measurement of Building Works: Seventh Edition
Standard Item	An item relating to construction work which has previously determined resources and outputs based on production data
UK	United Kingdom
USA	United States of America
Work Package	A collection of work items representing the total manhours for an operation

CHAPTER 1

INTRODUCTION

1.1 GENERAL BACKGROUND

Estimating, planning and control are processes within the contractor's organisation which ideally should be integrated. The estimating process establishes the expected cost, and planning and control processes ensure that the work is carried out as efficiently as possible. Considering the implications of planning and control, one first needs some common basis from which to work for the projection of information to site. The tender represents the contractor's bid to construct the work, and this should include a project data base by which to plan and control production.

The ability to control production is of paramount importance. The benefits to be gained through an integrated approach with other processes would provide the opportunity for more efficient working and the provision of results for variation analysis.

The accumulation of project control data is an obvious requirement and would call for effort on behalf of the contractor. Furthermore, this needs to be in a form which is accurate and detailed at a level that can be used for estimating purposes.

The integration of processes has been hindered primarily because of the incompatibility of design documentation and the requirements of production orientated information. The current bill of quantities format is different from the production information requirements of construction, and re-interpretation has to be made before any information can be utilised.

To date no inroads have been made to alleviate the present situation. Various revisions to the Standard Method of Measurement have been made, but the problem still remains. There is little published information available with regard to outputs achieved on site and outputs allowed in the estimate, so it is difficult to know whether estimating data used actually stands up in practice.

What is required is a system which can form the basis for the production of estimates, and which can also provide data for planning and control. To provide comprehensive project control, the system would be required to interface bills of quantities with the information requirements of the production process. Additionally, such information would need to be built up quickly and be responsive to changing conditions to be of practical value.

The primary aim of this research is to investigate whether it is possible to develop an integrated estimating, planning and control system based on actual production data which can be used in the construction industry to improve the processes of estimating and planning at various levels. In order to achieve this aim the following stages are required.

1. The creation of a production data base from a sample of selected projects. From a company data base used to set incentive targets an attempt will be made to develop meaningful transforms between actual hours and target hours applied to work packages based on the Standard Method of Measurement of Building Works (SMM).

2. The production data base will be integrated with estimating and planning process by the development of a logical model. This will allow the preparation of estimates from actual historical production data using the bill of quantities in accordance with the SMM. In this developed model an attempt will be made to bring together both construction measurement aspects with production information requirements.

3. Since the use of the model, which will be developed as a result of stage (2), requires computer based integration, a system prototype will be developed to test the feasibility of this approach.

4. In this final stage the model developed in stages (2) and (3) will be validated against a set of new projects. Using the actual hours obtained from the

projects, it will be possible to compare these with forecasts from the developed model.

From these stages a number of specific research objectives can be identified.

1.2 OBJECTIVES OF THE RESEARCH

The specific research objectives are:

1. to investigate existing systems and the needs of planning and control using the collaborating body as a case study;

2. to create a data base of measured items based on production data within the environment of the SMM;

3. to establish a link between conventional bills of quantities, based on the unit rate of measurement, and production orientated information requirements;

4. to investigate relationships between production data and productivity achieved on site for certain types of buildings and work categories;

5. to determine whether an integrated approach is effective for estimating, planning at various levels, and the control of construction work.

1.3 LIMITATIONS OF THE STUDY

The formulation of a production data base was made possible by data collected from a group of construction companies. Because of the prevalence of sub-contracting in the industry, data on certain types of work were not always documented and available for analysis. The study was therefore restricted to the traditional trades associated with contractors' own building work. Three cost significant work sections were considered for analysis purposes; these being, concrete work, brickwork and blockwork, and woodwork.

The planning and control of construction work were also restricted to labour effort representing productivity. This was considered to be one of the major variables within contracting organisations and one which requires considerable attention.

The assessment of productivity was also restricted to projects which were based on traditional bills of quantities utilising the Standard Method of Measurement of Building Works.

1.4 NATURE AND ORDER OF PRESENTATION

The research study itself comprises several stages of work which are brought together to illustrate estimating, planning and control aspects.

Chapter 2 first looks at the current situation in the industry by considering the related areas of the research. Whilst much has been written on the individual subject areas of estimating, planning and control, the literature survey was restricted to the areas related to the research objectives and the current state of the art.

Chapter 3 explains the precise stages of the study and the methodology used at each stage. The various techniques employed in the research are also discussed.

The first stage of the research consists of a structured systems analysis of the collaborating body, which is included in Appendix 1. Existing systems and needs were identified and documented for analysis.

The initial data collection and the formulation of the production data base are considered in Chapter 4. The various work sections and the detailed items included in the data base are discussed in detail, together with assessment of production data.

Based on the analysis work in Chapter 4, the development of a logical model is described in Chapter 5. Development of the model is based on assessment of a bill of quantities which is used to determine how such documentation can be utilised to provide the information requirements for planning construction work. It is further explained how data generation can be obtained at various levels of detail to satisfy the requirements of production staff. The logical model illustrates the various stages of the planning process which includes overall planning, short term planning and work targets.

Chapter 6 extends the development of the planning model by means of computer implementation resulting in a working system prototype. This involves the use of fifty two computer programs integrated with eight computerised data base files. Application of the model as a basis for estimating, planning and control are also discussed.

Chapter 7 concentrates on the validation of the model and the forecasting of average productivity performances by using the production data base on a number of independent construction projects. This combines the computerised system prototype and the modelling work of Chapter 4. It is demonstrated how the model can be used for planning and control of construction work, and compares model forecasts with actual outputs achieved. Establishing forecast-observation diagrams provide the necessary control mechanism for monitoring outputs.

Comparisons of accuracy are also made between model forecasts, the original estimating data, and present methods of setting targets by bonus surveyors.

Chapter 8 considers the performance of the model for forecasting purposes and identifies problem areas in its application. Suggested improvements for more accurate forecasting are considered.

Chapter 9 concludes the study and provides an assessment of the integrated approach and its effectiveness for estimating, planning and control of construction. Recommendations for further research are also discussed.

CHAPTER 2

REVIEW OF LITERATURE AND RELATED RESEARCH

2.1 INTRODUCTION

Estimating, planning and control of construction have demanded much attention in recent times. The increasing complexity of projects and decreasing tender margins have made the processes of estimating, planning and control a major issue.

The estimate forms the basis of the bid which represents the contractor's offer to do the work, and this information ought to be considerable assistance in planning and control of successful tenders.(1)

Without the integrated systems approach it is difficult to know precise situational circumstances in relation to other processes. Problems of increased costs for contractors may result, together with project overruns. This may be caused by underpricing at the estimating stage or other problems encountered during the construction phase, particularly with regard to achieving satisfactory productivity levels.(2)

The need to integrate processes within the construction industry is not a new concept and has been recognised by several authors.

The DOE(3) have recognised the need, and suggest that "estimating ought to be integrated with project planning, purchasing and cash flow planning, in order to create a sound basis for management control of liquidity, cost and progress."

Gunning[4] stresses the need for integration between the various sections of the contract, and emphasises the need for estimators, bonus personnel and cost controllers to conduct their duties based on the same productivity data.

McKenzie and Harris[5] have identified the need for greater coordination between estimating, bonusing and costing; and comment "how few firms have systems for integrated estimating, incentives, costing and feedback, and how insular each department appears to become when confronted with the prospect of data sharing."

There is little published information to suggest that integration of the processes is done effectively. Integration in large contracting organisations may well take place, but there is little factual information available to illustrate the extent of integration or the success it achieves.

The general advancement of estimating, planning and control has previously been dealt with on a piecemeal basis. Many computerised systems[6],[7] have evolved in a bid to successfully manage projects, but many have been developed in complete isolation from other processes.

Integration of individual processes is now becoming acceptable and useful as a management tool.[8] The systems described by Ryan and McCarthy,[9] and also Sharad;[10] are both integrated systems that have been developed in the USA. These systems, however, are not based on a bill of quantities. It is left to the discretion of the contractor to measure the work and formulate his own documentation, which invariably takes the form of operational format.

The most recent developments in the UK have been directed at extending estimating systems with the view to providing management information for the production process. Work by McCaffer and Sher[11] has illustrated the integrated approach from computer-aided estimating. Similarly, McCaffer and Baldwin[12] have demonstrated the extension of an estimating system for the production of management information. Bowman[13] has also shown the integration of estimating and planning for civil engineering work.

Since this research work there have been no further advancements to generate data at various levels of detail to meet the precise information needs of production management. Furthermore, whilst the integrated approach has been recognised there has been no published information to show if integration would be effective and preferable to present methods and systems.

Most of the previous research has been directed at civil engineering work. For building work a system is required which can generate information from documentation based on SMM and also provide various levels of information for management.

The integrated approach has the advantage of avoiding disparities between the various sub-systems which exist in the construction process,[14] so that information generated is based on common data rather than on a piecemeal basis.[15]

The success of an integrated system will depend largely on how information can be generated to satisfy the requirements of management. Problem areas which have hindered advancement in the past would include:

1. estimating data and the estimating process;
2. productivity, its measurement and variability;
3. the precise information requirements of production staff for planning and control of construction;
4. the documentation of construction work in relation to SMM and bills of quantities.

Previous research into these separate areas have highlighted problems and criticism which could militate against the integration of processes.

2.2 ESTIMATING DATA AND THE ESTIMATING PROCESS

The estimating process itself is one which has received much debate and criticism. The major innovation which has occurred within estimating process has been the introduction of the computer.[16] However, Erskine and Boyer[17] point out that "while computerised bid-level estimating may be the state-of-the-art, it is not yet the state of the practice in the construction industry." Many companies still operate systems that have been used for decades, which often presents barriers to the integration of estimating, planning and control.

Problems can arise because of estimators' documentation. It is not always easy to follow estimators' calculations, particularly when manual systems are involved, and this may not be in a format which can be readily used for planning and control.

Questions can also be raised against estimating data itself. Wheen[18] makes the point that while computerised methods of estimating would seem to have captured attention the question of "required precision would seem to have been overlooked."

2.2.1 The Accuracy of Estimating Data

Before estimating data can be used for planning and control of the production, one must consider its accuracy, and its variability.

The relationship of estimating data with regard to productivity performances is of paramount importance. Data used within the industry would seem to stem from a variety of sources. Percival[19] identifies several, which include; books of references, the estimate of the contract or job, feedback, analytical estimating, time study - including both sampling and direct observations.

Probably the most common sources of output data includes the various price books. Estimators may well resort to such sources when no other information is available.[20]

Research by Fleming[21] into these sources of information revealed they are extremely insensitive to change, thus indicating some doubt as to their basis as a productivity index.

Additional research[22] using statistical techniques has indicated significant differences between the various price books, indicating doubt as to their overall accuracy. Estimates based on such data could therefore be questioned if the data were to be used for planning and control purposes.

Ashworth and Skitmore[23] further comment on estimators' claims of consistent accuracy within ± 5%. Fine[24] has shown, however, on an analysis of several thousand items, that estimates matched with cost reports show a variation by more than a factor of 2. Further research into the analysis of bills of quantities and detailed examination of rates for each bill item have led to the conclusion that bill rates are extremely variable.[25]

Whilst there is no disputing the above findings, the precise meaning of the analysis of bill rates could be questioned. It is acceptable that although tender figures can be quite close, the variation of individual work items can often be considerable from one tender to another. This may be representative of differing estimating methodologies where estimators price work differently, and include for items in different parts of the bill of quantities.

There is little published information available with regard to the outputs used by estimators and the actual outputs achieved. Roderick[26] when investigating the durations of activities on site revealed that durations were very much greater than the contractor's estimate. A finding that was similar in the majority of activities. However, the results were based on the research of one project and therefore cannot be considered as being conclusive.

2.2.2 The Estimating Process

Investigations into the estimating process by researches have produces several points of criticism.

Pigott[27] makes the point that estimators often price work without reference to the drawings or site conditions. Based on the comparison of estimated cost and actual costs, Fine[28] believes that estimators' methods are inaccurate.

Ashworth and Skitmore[29] also suggest, "that there is a disparity between what is considered to be 'good practice' and what estimators are actually able to do when faced with the realities of the construction process."

The prices determined by estimators are based on expected outputs, but the precise origin of such information is often not clear. In the majority of cases information is used continuously during the estimating process, but amendments and revisions would seem to take place over very long periods of time.[30]

It is often suggested that cost insignificant items are not priced in line with normal estimating practice, but more so on an ad-hoc basis.[31] While this method may be acceptable owing to the difficulty in determining accurate prices, Pigott[32] argues that the practice is often extended to significant items. In circumstances where re-calculation of rates should be done to reflect different practical situations, the case is often an arbitrary adjustment of cost to reflect increases or decrease in labour times.

Whether such criticisms are completely true with regard to the estimating process is debatable. It is often suggested that estimators try to aim for the average performance taking all disruptive factors into consideration.[33] It is also vitally important that such factors are considered,[34] so that the estimate does correspond to actual costs incurred on site. In large organisations when preparing estimates the assessment is sometimes, but not always, the result of a team effort. This is more so on cost significant sections of work that influence a tender, and may involve discussions between planning and construction management staff before decisions are reached.

2.3 PRODUCTIVITY, ITS MEASUREMENT AND VARIATION

2.3.1 Measurement of Productivity

Whilst past research has indicated estimating data to be questionable in relation to productivity achieved, the first requirement of an integrated system is to establish accurate production data. Lorenzoni[35] suggests the formulation of base productivity levels that represent manhours expected for normal or average conditions. Similarly, Forbes[36] suggests that to increase productivity the first requirement is the measurement of output in relation to input, and in order to do so greater effort in the collection of data is an essential requirement.

Whilst there is little factual information on accurate production data in the UK, the value of performance data has been recognised in Europe and elsewhere. Production data have been compiled particularly in Holland,[37] Sweden[38] and South Africa.[39] Various methods have been used to formulate this information from group timing techniques of activity sampling,[40] to the methods used by work study engineers.[41]

Other techniques of productivity measurement have evolved over the years, including mathematical and stochastic models in a bid to provide a means of accurate prediction.[42] However, the cost effectiveness of such methods could be questioned, and a more fundamental approach aimed at identifying and resolving the situation for the building contractor is required.

Productivity itself has often been associated with time study and direct observations which have been considered to be the most reliable source of information.[43] Work study techniques have been more prominent in recent years due to the accuracy requirements of production measurement.

The work study techniques have mostly been restricted to the larger types of organisations, although its current usage would seem to be minimal.[44] Quite often the use of such techniques would be restricted to problem identification rather than a common source of production data. The technique would seem to have advanced little and possibly, in certain respects, its use has diminished.(45)

Reliance on historical data is often criticised as having inherent weaknesses. It is argued that data are representative of how long work has taken rather than how long it should have taken.(46) Such reasoning may not always be justified since operatives working under a bonus scheme which is well organised and uninterrupted are likely to produce production times which relate to a realistic time period. It is such data that forms the basis for comparisons and not data collected under any type of conditions.

Activity sampling would seem to have been the more common method used in recent years; various techniques differing in only the degree of sophistication.(47) The success of the method has been demonstrated in assessing concrete activities by Price and Harris.(48) Activity sampling as with work study, however, does not command great use by contractors, and little application has been made particular in construction.(49)

It could therefore be asked to what extent, and in particular, what form should productivity measurement take? Forbes(50) describes the macro approach of data collection rather than work study synthetics; and further suggests that there is no point in having data in greater detail than is required for estimating purposes.[51] The main point being that use of such data should lead to integration of estimating and production.[52]

Information collection depends primarily on the aim; the more detailed data required, the more expense incurred in collecting it. Forbes and Mayer[53] indicate the use of time sheets for all inclusive trade data collection, and for more detailed collection relating to sub-structure and superstructure work, the use of daily time cards.

2.3.2 Variability in Productivity

Whilst the correct documentation of production performances is an essential requirement for establishing productivity levels, variables affecting production outputs can influence the data recorded.

The factors affecting productivity can vary depending upon precise situational circumstances. Horner[54] identifies the factors affecting productivity as:

1. Quality, number, balance of labour force;
2. Motivation of labour force;
3. Degree of mechanisation;
4. Continuity of work as affected by;
    (a) supply of materials;

(b) performance of other contractors or sub-contractors;

(c) availability and adequacy of technical information;

(d) variations;

5. Complexity of project;
6. Required quality of finished work;
7. Method of construction;
8. Type of contract;
9. Quality and number of managers;
10. Weather.

BRS[55] studies for bricklaying operations have identified three factors, namely: motivation, organisation and techniques of laying. In this work category the techniques of laying can be related specifically to brickwork, but undoubtedly the first two factors are equally important to all trades.

Callahan[56] is more specific in the reasons that affect productivity and relates this to management failures; particularly with regard to "material availability, tool availability, crew scheduling, overcrowded work conditions, lack of instructions and lack of capable supervisors."

One problem in establishing data for estimating, planning and control is obtaining production performances to within acceptable tolerances. Fine[57] comments on the two basic assumptions that are made with regard to productivity prediction. These being firstly, that we have knowledge about the expected mean of output and that the expected mean is correct. Secondly, that the variable outputs have occurred in the past and such variation is likely to happen again in the future. Fine[58] also makes the point that even with good past performance data, it is unlikely that predictions will be reflected in future performances.

Productivity has shown to vary considerably. Weekly variations have been recorded as much as 10 to 1 between high and low performances.[59] Other measurements taken in bricklaying by the BRS over five sites have shown productivity of different gangs of bricklayers on the same site to vary between 1.19:1 and 1.65:1.[60] Measurements between different sites have also shown productivity at less than 2:1.[61]

Percival[62] puts the issue into its proper context and suggests that "productivity is not something that is fixed; nor is it the sole responsibility of one sector of the industry; it is something that can be achieved, and it is something that can be lost."

Whilst variation in production is unavoidable and has shown to exist in all trades, this undoubtedly emphasises the need for establishing a production data base which can form the basis of estimating, planning and control.

2.4 PLANNING AND CONTROL OF CONSTRUCTION

To integrate the estimating process with planning and control would call for information generation to suit various personnel involved in the production process.

Jain[63] describes planning and control in relation to the managerial communication and suggests "Planning and control is a function whose success lies entirely in timely communication of some form of information or other within the organisation. It may be vertically or it may be horizontally, it may be administratively or it may be functionally but it has necessarily to be timely and directly from the concerned to the concerned."

Throughout the life of a project many levels of planning will be necessary and the proper level should be used as required.[64] Furthermore, the importance of the planning effort should ensure the correct use of detail to suit the specific purpose.[65] Many different people will be concerned with a project at different stages. Some only concerned with overall planning, others with certain groups of activities, and others with specific time periods in relation to setting targets. The planning effort should therefore be able to supply the type of information that is required.[66]

From the practical point of view, Roderick[67] makes the point that the planning of work should move away from the design element concept towards the activity concept as carried out on site. This allows a more natural approach in relation to construction practice. Properly done, the planning of work ought to permit field management to be more efficient and creative within the planning process.[68]

The control of production can be considered of equal importance to planning. To ensure effective control needs the prediction of future performances together with the monitoring of actual productivity, and initiating action when required to minimise variances.[69] The yardstick approach will enable checking to be done to assess performances.[70] Producing an estimate of the manhours required can be compared with the actual hours achieved on site, and corrective action taken where necessary.[71] Lorenzoni[72] suggests the use of productivity profiles and trend charts to allow the monitoring of such actions.

The control function which is dependent on monitoring progress is itself dependent on the information recorded. The main problem that faces contractors, with data collection is an issue of cost effectiveness. Roderick[73] suggests that obtaining feedback is only acceptable if methods are easily and effectively operated on site. The need for accurate documentation is of the utmost importance and often this can be problematic owing to the variation in work content.(74)

Clare(75) identifies the difficulties in obtaining and using feedback data, as inconsistency in results from different sites, labour, weather, incomplete data, the problem of direct and indirect work, together with incorrect allocation of time.

Braid(76) revealed that a large number of contractors considered feedback as not cost effective. The identified reasons being the expense in the initial set-up, the time required to record times, together with contractors not knowing how to operate a recording system.

Further reluctance on the use of feedback data has often been expressed by estimators. Reasons given would include the uniqueness of each project where data are considered as not relevant for use on other contracts.(77) However, such reasons could be questionable since the accumulation of feedback data over a period of time would indicate average performances in various situations. Tredwell(78) suggests that data from achieved outputs and targets could provide the starting point for the estimate. Furthermore, Roderick(79) comments that it is essential to have a feedback system to obtain qualitative measurements in order to obtain an accurate assessment of the situation.

The advantage of feedback is that high variances alert management's attention. It also provides a check against project operations and indicates whether the plan is still valid.[80] Without feedback the capability to control is severely restricted during the building process.[81]

2.5 STANDARD METHODS OF MEASUREMENT AND BILLS OF QUANTITIES

The planning and scheduling techniques existing at present rely on the input of data from one or a number of sources. A problem that exists, is the coordination of such systems with present forms of measurement documentation.[82] This can be directly related to the Standard Method of Measurement and bills of quantities.

Probably the major criticism with this document has been its limited value within the production process, particularly with regard to planning and control of construction. Data are often repeatedly processed to generate required information at various stages of the project.[83] Additionally, the SMM results in bills of quantities which are often over-complicated providing extensive detailed information that is not always required to price work realistically.[84]

Various working parties[85] have been set up over the years to examine this aspect of measurement in relation to other areas of planning and control. Similarly, the DOE working party dealing with structuring project information concluded that further research was required to determine the precise requirements of production information.[86]

The total quantities measured against bill items are seen as inadequate,[87] certainly with regard to the direct relationship of construction operations. Planning is not a function which the bill was designed to serve.[88] Assessment of relevant items and quantities, however, would assist in planning analysis.[89]

It has been argued in the past that the bill represents cost information which relates to the completed design of a project and not to the production requirements of construction.[90] As such it was considered difficult to relate the estimating rates directly to working practice on site.[91] These were the arguments brought forward in the late sixties by the BRS in defence of the production orientated documentation, called the 'operational bill'. The primary aims of this new document were firstly to improve communications with the production process and secondly to attain more realistic estimating.[92] Although the conventional bill classifies work in relation to complexity by virtue of the descriptions of items, it does not differentiate in terms of location during the production process.[93] The information relates to the finished work and not to specific operations.[94]

Since the proposals were introduced by the BRS there has been little advancement in the format of bills of quantities. In the past twenty years the conventional bill is still in use based on the SMM.

The proposals to improve data coordination and communication have emerged more recently by the report 'Project Information'[95] produced by the NCC standing committee on computing and data coordination. The report identified many of the shortcomings of existing practice; which resulted in the formulation of the Coordinating Committee for Project Information (CCPI), which was set up in 1979.[96]

The objective of the CCPI being to prepare three standard conventions for: the production of drawings; specification; and measurement.[97]

The work of the CCPI has resulted in the production of the Common Arrangement (CA)[98] for bills of quantities and specifications, which is expected to produce project documents which are less variable and provide more locational orientated information.[99]

The new SMM7, prepared by the development unit, is to result in simpler bills of quantities[100] and at the same time distinguish between fully designed work and work which is not fully designed.[101] The development unit have adopted the work sections proposed by the CA to provide a framework for the SMM7.[102]

The consultative documents[103],[104] were produced in 1982 and 1984, and it is expected that the SMM7 document will be introduced sometime in 1988. The presentation of the SMM7 in classification tables would seem to be generally well received,[105] but the implications with regard to bill of quantities has not yet been fully realised. Sample bills of quantities have been produced in the consultative documents of the CA,[106] but the impact of such bills for industry and use during the production process will not be evident until during 1988.

2.6 SUMMARY

The various processes have been discussed in this chapter along with the need for integration. Various points have been highlighted of the advantages, and problem areas.

Sources of estimating data have been considered and previous research has illustrated doubts on the accuracy of published information. Based on existing pricing of bills of quantities, variation has shown to be considerable, indicating some doubt as to estimating data sources. Likewise, productivity has shown to be varied and precise production performances have shown to be difficult to predict.

In addition to these practical aspects the point of current documentation presenting barriers to integration has also been highlighted in relation to SMM and bills of quantities.

However, despite all the problems encountered, particularly with regard to estimating data and variation in productivity performances, contractors still have to price work based on the present tendering mechanism, and planning and control procedures still have to be initiated.

Previous research has illustrated the necessity to establish base productivity levels which can be extracted for estimating, together with use for planning purposes and monitoring production outputs. The integrated systems approach should make this possible, providing common data for all concerned in the production process.

Previous work in the area of integrating processes has been identified, but further work in this area needs to be carried out. In relation to building work a system is required which can form the basis for estimating, planning and control, and which can be used with current and future editions of SMM. The system would need to satisfy the precise information requirements of production staff. If data can be established initially on which to base information, such steps could provide great assistance to contractors and contribute to industry generally.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In order to achieve the objectives described in Chapter 1 the research was sub-divided into several parts. These included a systems study; data collection and analysis; model development, and validation study.

The systems study included a preliminary survey of the collaborating body, covering its trading activities and present systems.

The data collection and analysis involved a first sample of selected projects. These were used in establishing a production data base to provide the basis for estimating, planning and control of construction work.

The model development was based on the company systems study and the requirements of planning and control which were identified. The planning model also provided the vehicle to generate data at various levels of detail.

The validation study was directed at testing the effectiveness of the model and the established data base. Two methods of assessing the data were employed:

1. testing the data on the first sample of projects which were used to establish the data base;

2. using the established data base on a second independent sample of projects.

Method (1) is discussed in Chapter 4. Method (2) forms the validation study in Chapter 7.

Comparisons were also made between other independent information sources. These being estimators' data and target rates used by bonus surveyors from the selected projects.

3.2 SYSTEMS STUDY

To establish the requirements for estimating, planning and control, the first part of the research comprised a systems analysis of the collaborating body in order to identify present systems and information flows. Numerous interviews were conducted with construction personnel to obtain information on data transfer through the company which enabled the documentation of present systems.

The technique was based on the use of structured systems analysis[(107),(108)] where data flows and processes were identified. Graphical representation of present systems were documented using symbol conventions and establishing data flow diagrams (See Figure 3.1 and 3.2). Levelled data flow diagrams were also prepared to show data at a more detailed level allowing the identification of sub-systems (See Figure 3.3). The analysis allowed the documentation of existing systems,

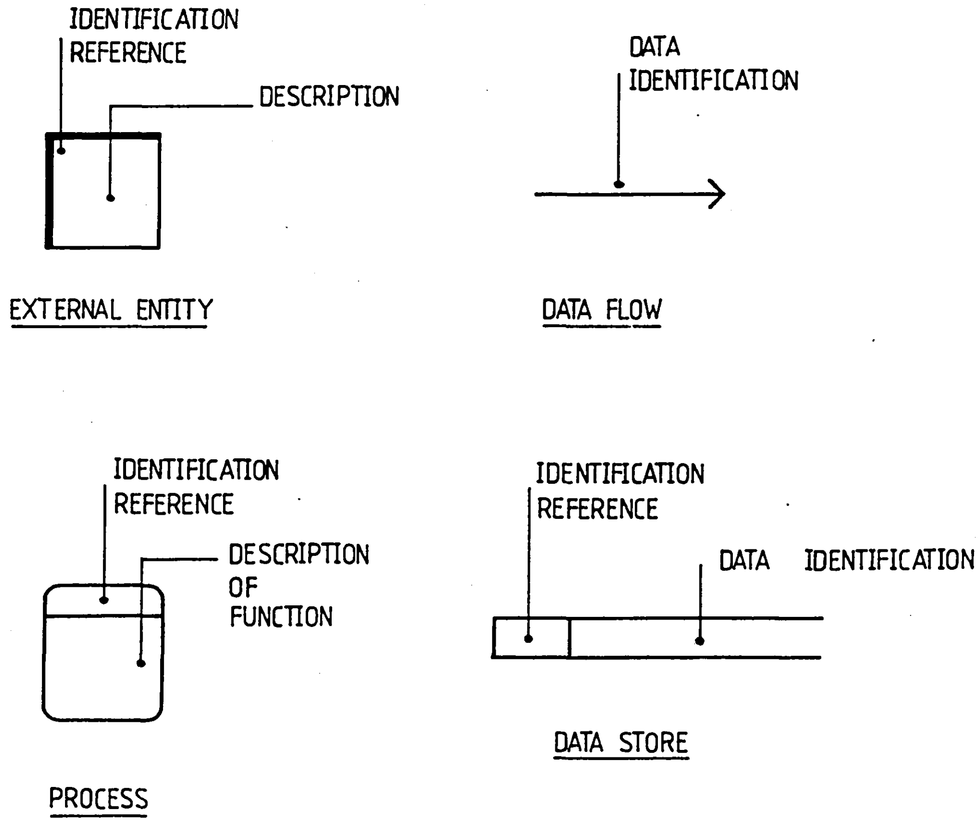

FIGURE 3.1 SYMBOL CONVENTIONS

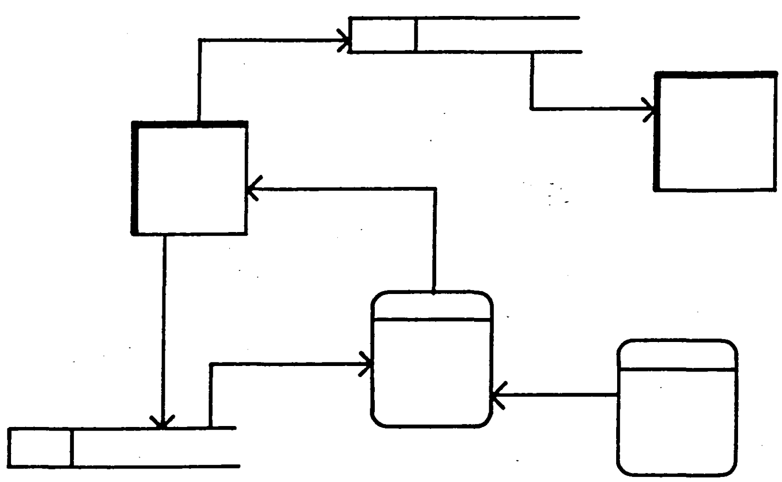

FIGURE 3.2 DATA FLOW DIAGRAM

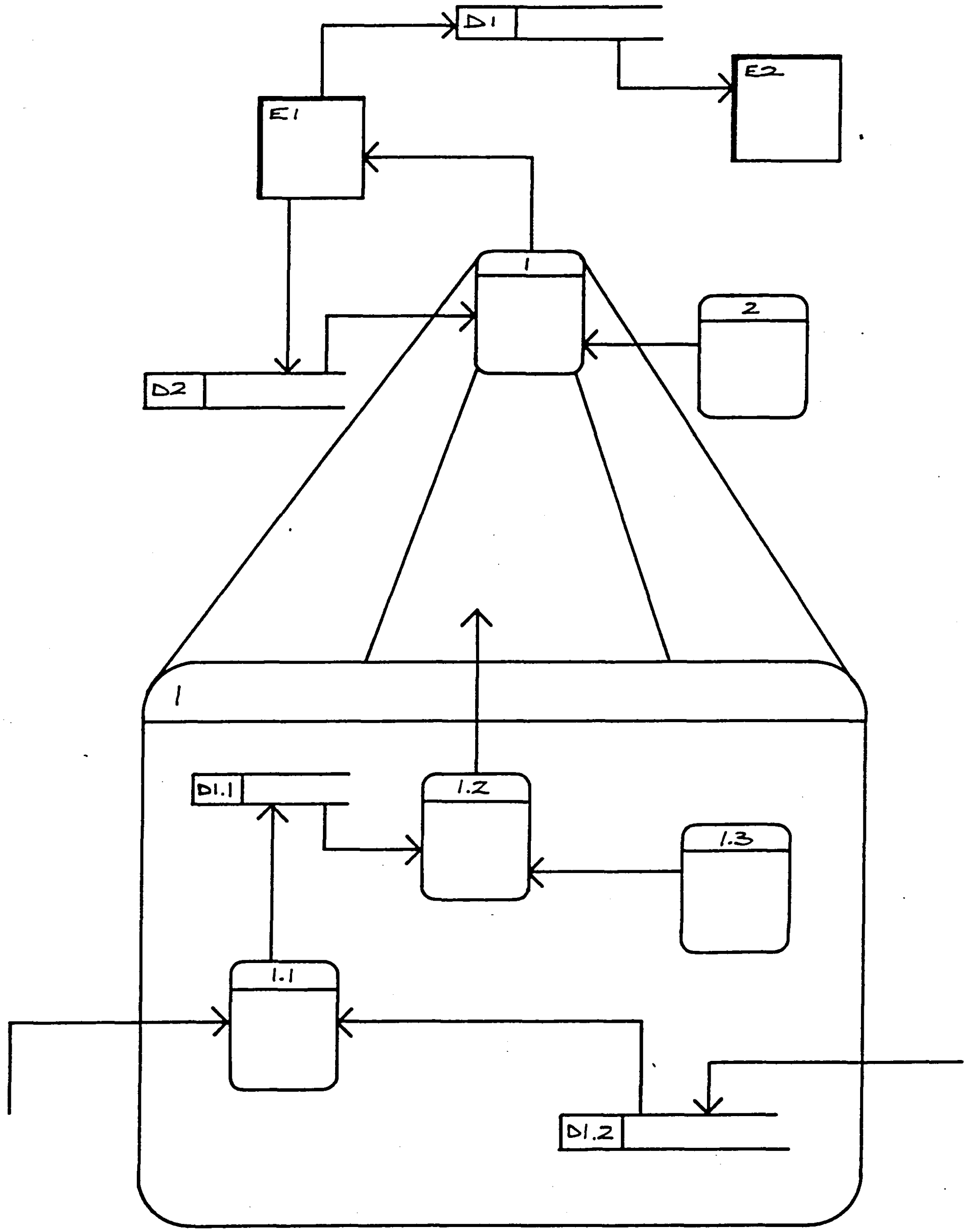

FIGURE 3.3 LEVELLED DATA FLOW DIAGRAMS

and identified areas of deficiency and information requirements.(109),(110),(111)

The detailed analysis of the collaborating body is documented in Appendix 1. The initial study covered seven companies within the organisation and separate models were developed for each company. The similarity of trading operations for each company allowed the major contracting company to be representative of a generalised information flow model, illustrating present systems. This was used as a basis for the development of a future model described in Chapter 5.

3.3 DATA COLLECTION AND ANALYSIS

From the published literature and previous work discussed in Chapter 2, it was apparent that accurate production data were not readily available within the industry. Data were therefore collected in order to establish a production data base within the environment of SMM. The systems analysis explained earlier revealed that the collaborating body did not have such data available for collection so external sources had to be sought.

A total of ten construction companies were approached requesting information. This had a mixture of success. Whilst a number of contractors did not respond to the request, problems were experienced not only with the format of data available but also with availability generally. The prevalence of sub-contracting was such that several companies were found to sublet 95% of their work and therefore did not have the required data available for analysis. Other companies' data proved to be an extension of monthly valuations and were therefore not in a suitably detailed format for analysis purposes. Several other companies declined through reasons of confidentiality.

Consequently, data were collected from one group of companies. The data available were based on a data base used by the company to set incentive targets. The data had been compiled over a number of years and had proved successful in the operation of a bonus scheme. Data were recorded on job cards and provided a suitable format for establishing a production data base.

When initiating the data collection it was decided to concentrate on selected work sections. It was considered beneficial to the study to select work sections that generally represent contractor's own work, and which also represented major sections of value. Previous work at the Property Services Agency (PSA) using bills of quantities indicated that particular work sections were of significant value in relation to the number of items in a bill of quantities.[112] The study illustrated the relevance of 20% of bill items representing 80% of the total value. Sectionalisation of the work sections in order of value were also identified.[113] For establishment of the data base, selection was made from the sections of greatest value identified in the PSA study, these being; concrete work, brickwork and blockwork, and woodwork.

Data were collected from a total of nine projects varying in size and type, ranging from small extensions to very large projects. The first sample collected included seven projects and a later sample of two projects were collected for validation purposes. It was intended to obtain data from varying work types so as to establish a data base that could be used consistently and accurately for all types of new building work.

The projects were constructed by different management teams and different operatives in various locations ranging from the midlands to the north of England. The work was represented by a sample of 65 separate data sets comprising 1577 work packages. A breakdown of the work sections and various categories considered in the study is shown in Figure 3.4.

3.4 ESTABLISHMENT OF A PRODUCTION DATA BASE

From the data collected, the first sample of seven projects were used to establish the production data base. Obtaining the input of labour effort in manhours was required at a level of detail corresponding to SMM

CONCRETE WORK

Foundations

Floor Slabs

Suspended slabs, stairs and landings

Columns

Columns and beams

Cavity fill

Generally

BRICKWORK AND BLOCKWORK

Brickwork sub-structure

Brickwork and blockwork sub-structure

Brickwork superstructure

Brickwork and blockwork superstructure

Blockwork superstructure

WOODWORK

<u>First fixings</u>

Softwood grounds

Softwood framing

Door frames

Window frames

Generally

<u>Second and other fixings</u>

Hanging doors

Architraves and skirtings

Door sets

Ironmongery

Generally

<u>FIGURE 3.4 WORK SECTIONS AND CATEGORIES</u>

and bill items regarding descriptions and respective units. A collection of such items for the selected work sections would then represent the proposed data base. This was possible by extracting information from company site documentation where data were represented in the form of actual hours and target hours for individual measured items. This provided the opportunity to model the actual hours against target hours so production data could be obtained for work items by adjusting target data.

The modelling of the data sets allowed the actual production time in relation to the target set to be established for each work section and category. The adjustment procedure was also applied to individual items within the target relating to measured work items. Such items represented the lowest level of detail within company data collection procedures, and formed the starting point for the creation of the data base. Data at this level was used to determine its accuracy and usefulness for estimating, planning and control.

Measured items for each project were obtained together with the production rate established. Similar items for each project were abstracted and averaged to form a common data base rate.

3.5 PRODUCTION DATA ANALYSED

To test the data base, assessment was made of the resulting errors of the production data in relation to actual hours. Comparisons were made with the errors resulting from the estimator's data used on each of the projects and the targets set by bonus surveyors. The results of this assessment are documented in Chapter 4.

3.6 MODEL DEVELOPMENT

The model was developed logically by utilising the technique of structured systems analysis described earlier. The model was aimed towards the practical aspects of construction allowing information to be obtained at the various levels of detail. This would also overcome the deficiencies of the present systems employed by the collaborating body. Information was generated in a form to satisfy the requirements of production staff.

Much research has been carried out on the structuring of project information, particularly with regard to construction planning units,[114] and more recently in the form of work packaging.[115] The methodology of establishing work packages in relation to construction operations was also adopted to form the basis of the model structure. Since the data base was the starting point for data generation, the logical model was developed by structuring information into various levels of work packages based on the production data base. The structuring of the model into the various levels, together with detailed flow diagrams are shown in Chapter 5. Computerisation of the model and its application are discussed in Chapter 6.

3.7 VALIDATION STUDY

The basis of the research was to establish a production data base and to determine its suitability for use in estimating, planning and control of construction work. This particular aspect was considered in the validation study. The testing of the developed model was related to a second sample of two projects.

Model errors were assessed in relation to errors from the original estimators' data and targets set by bonus surveyors. Productivity variation and other statistical measures were used to assess the data.

Effectiveness of the data base and model on the second sample projects was tested by means of tolerances based on plus or minus one standard error of estimate from first sample projects.

CHAPTER 4

DATA COLLECTION AND ANALYSIS

4.1 INTRODUCTION

In this chapter the collection and analysis of the data are considered in depth. An explanation of the data itself; the criteria used for the data collection and the procedure of analysis to formulate the data base are discussed. Comparisons of forecast errors are assessed between the established production data, estimators' data and targets set by bonus surveyors.

4.2 PROJECT DATA

As outlined in the methodology the data collection was restricted to one group of companies (See Chapter 3 Section 3.3). Certain criteria for project selection were also established.

The criteria for selection required the projects to:

1. be restricted to new building work;

2. be supervised by different management teams and have different operatives. In this way various management methods employed together with the variations in production performances would make the study more realistic and representative of construction work generally;

3. cover various locations in the UK to ensure regional variability was taken into account;

4. constitute different building types both in terms of size and value;

5. be restricted to the contractor's direct labour;

6. have data recording procedures to document production performances;

7. have a bonus scheme in operation to ensure a reasonable level of work effort;

8. be based on the bill of quantities format utilising the SMM.

Based on the above criteria the first sample of data were obtained from seven projects and later from a second sample of two projects for validation purposes. The data were collected over the period June 1985 to August 1986.

4.3 FIRST SAMPLE PROJECT DESCRIPTIONS

The projects from the first sample are shown in Table 4A together with their approximate value.

The 'hotel A' building comprised a single storey public block consisting of a reception and dining area with flat roof construction. The residential block consisted

PROJECT	PROJECT VALUE
1. Hotel A	£2.521m
2. Industrial Building	£2.591m
3. Hospital A	£10m
4. School Building	£0.156m
5. Housing	£1.082m
6. Army Training Building	£2.301m
7. Pharmacy Extension	£0.312m

TABLE 4A SUMMARY OF SELECTED PROJECTS (FIRST SAMPLE)

of a three-storey structure with pitched roof. The building was of typical brickwork and blockwork construction with in-situ concrete floors and staircases.

The industrial building project comprised a structural steel framed single-storey manufacturing area. The external walling was of brickwork and blockwork construction, including external cladding to roof level. The floor area was of in-situ concrete incorporating various ducts and drainage channels. The development also included a three storey amenity block of brickwork and blockwork construction with concrete upper floors and staircase.

The 'hospital A' project was the largest project considered in the study. The whole development consisted of two separate blocks of wards and operating theatres. Each block was of two-storey construction comprising concrete columns and beams. External walling consisted of brickwork and blockwork infill panels with glazed areas. In-situ concrete work included floors, suspended slabs, stairs and landings.

The school building was the smallest detached building of the projects selected other than houses. The building represented four separate classrooms in a simple square two-storey structure with pitched roof. The external structure comprised of brickwork and blockwork construction with in-situ concrete floors and staircases.

The housing development represented a total of fifty eight dwellings. These comprised of several types ranging from three-person two bedroom houses to seven-person five bedroom houses, including both detached and semi-detached design. Construction of the dwellings comprised of typical brickwork and blockwork walling with pitched roof construction and in-situ concrete floor slabs.

The army training building comprised of three attached blocks with pitched roofs at various levels. The single-storey block represented a training area and the two-storey blocks provided accommodation facilities. Construction of the superstructure was of traditional brickwork and blockwork construction with concrete floor slabs, stairs and landings.

The pharmacy extension consisted of a single-storey flat roof building adjoining an existing two-storey pharmacy block. Construction was traditional brickwork and blockwork external walling incorporating glazed panels. Internal work comprised in-situ concrete floor slabs with internal blockwork partitions.

4.4 DATA COLLECTION

The data were collected from site documentation which consisted of bills of quantities and production performances of construction work relating to site operations.

The means of obtaining records of labour was based on the job card method where operatives book their own time for the particular operation with bonus surveyors completing details of the measured work. This method of obtaining the total target was characteristic of all projects with the exception of housing. For the housing project, the total targets were established before work commenced.

The booking of time in relation to work completed was of particular importance because of the accuracy requirements for the formulation of the data base. Misallocation of time was minimal because of the job card method employed. This was considered to be more accurate than allocation sheets since operatives had to account for their time spent at the work place relating to specific operations.

4.5 OPERATION WORK CONTENT

The operation times collected related specifically to the time in completing the operations. This relates to the time spent at the work place fixing and setting components into position, including supporting activities. For example, in the process of bricklaying the targets set and consequently the productivity times established included for:

1. transporting materials within a twenty five metre distance;
2. laying DPCs, fixing ties, wetting bricks, mixing mortar and loading own materials;
3. forming openings and plumbings;
4. removing discarded materials on completion of an operation;
5. protecting brickwork/blockwork from the weather;
6. keeping cavities clean;
7. setting out from points given by management.

The outputs also include for the labour in supporting the bricklayers.

For concrete rates the following items were included:

1. transporting materials within a twenty five metre radius;
2. mechanical assistance, dumpers or tractors transporting to within working locations;
3. setting up compressor and hoses;
4. vibrating where required;
5. removing spillages and excess concrete on completion of the operation;
6. protecting completed work from the elements;
7. taking samples including stripping and cleaning cubes.

For woodwork, items included:

1. loading materials within a twenty five metre radius;
2. setting out from points given by management;
3. hand cutting;
4. cleaning up residue pieces on completion.

If any additional work was necessary to assist the operation, in particular transportation of materials over a twenty five metre distance, this would have to be allowed separately for the particular operations in the form of a service gang. Such allowances would not form a part of the data base.

With respect to productivity, three time periods were obtained relating to measured work. These were the actual time periods from the job cards, target times set by bonus surveyors, and the estimator's times used in preparation of the estimate.

Data collection consisted of selecting samples from the job cards covering the whole contract period. In this way it was ensured that an acceptable range of productivity performances were represented allowing for variations from the start to the end of the particular work section. The data from sites consisted of the target times and the actual hours recorded by operatives. In a few instances, the target times were identical to those in the estimate. This was highlighted when discussing targets with bonus staff, when it was confirmed that the targets used were not always the same as the estimator's allowance. The bonus surveyors worked independently of the estimate and used their own standard book of output rates.

The estimator's allowances for operations were obtained by identifying the relevant measured items on the job card and tracing the particular items in the priced bill of quantities. The labour cost element of the unit rate was then divided by the all-in labour rate and multiplied by the corresponding quantity to give the estimate hours allowed for the particular item.

In addition to the collection of production times, a number of sites were also visited where work was still in progress in order to assess complexity and methods of working.

4.6 DATA COMPATIBILITY

In collecting project data, every attempt was made to obtain data of similar work categories. This was not always possible owing to the variation in work content and different methods of grouping elements in operations. Certain items of walling were sometimes grouped together, e.g. brickwork and blockwork, whereas on other projects these were measured separately (See Figure 4.1).

It was often found that brickwork and blockwork items were grouped together in the target. This was not because of the particular method of documentation, but was characteristic of construction work on site. Where different elements were used in the measure (i.e. brickwork and blockwork items) these were kept separate from the brickwork only items.

Precise locational data, relating the target set to identifiable parts of the building, were not recorded on the job cards. In the case of brickwork and blockwork, descriptions only related to sub-structure and superstructure. The only exception was in housing were phases of brickwork and blockwork were described, i.e. DPC to joists, joists to eaves, and peaks.

In the woodwork section, certain items were recorded individually, but the majority of items were targetted collectively (See Figure 4.2). Where targets

Brickwork only item

	qnt	rate hrs/unit	target hours	actual hours
hb facings	3.15m2	1.83/m2	5.76	
hb commons	25.14m2	1.35/m2	33.94	
1b commons	56.96m2	2.52/m2	143.54	
e.o. soldier	14m	0.66/m	9.24	
			192.48	117

Brickwork and blockwork item

	qnt	rate hrs/unit	target hours	actual hours
100th blockwork	4.93m2	0.86/m2	4.24	
190th blockwork	69.88m2	1.59/m2	111.11	
hb facings	24.43m2	1.83/m2	44.71	
sill blocks	1m	0.66/m	0.66	
cavity insul.	24.43m2	0.05/m2	1.22	
			161.94	114.5

FIGURE 4.1 MEASURED TARGET ITEMS FOR BRICKWORK

AND BRICKWORK AND BLOCKWORK

Woodwork

Individual categories

	qnt	rate hrs/unit	target hours	actual hours
Door frames	61.71m	0.35/m	21.60	18

	qnt	rate hrs/unit	target hours	actual hours
Hang single doors	2nr	2	4	3

Collective category

	qnt	rate hrs/unit	target hours	actual hours
Hang double door	1nr	3.00	3.00	
Fix architraves	12m	0.30	3.60	
Pull handles	2nr	0.50	1.00	
Door closer	1nr	1.50	1.50	
Door stop	1nr	0.33	0.33	
Escutcheons	2nr	0.20	0.40	
			9.83	7

FIGURE 4.2 MEASURED TARGET ITEMS FOR WOODWORK

represented several items, it was not possible to determine operation times for each item, since the actual time recorded was for the whole target. Data sets were therefore established for collective items, i.e. joinery first fixings and joinery second fixings. These data sets were named 'generally' referring to work categories consisting of various items.

4.7 WORK SECTIONS AND CATEGORIES

The collection of data were restricted to the selected work sections as discussed in Chapter 3. The categories representing sub-division of these work sections are shown in Table 4B. This shows the various work sections and categories of data sets from each of the projects.

4.8 PRODUCTION DATA BASE ESTABLISHMENT

To establish the data base, data were collected and analysed from all the data sets of the various projects. Each of the data sets was therefore modelled using the actual hours and target hours to obtain the average performance.

Scatter diagrams were produced of actual outputs against work targets, and curves were fitted through the origin based on the method of least squares (See Figure 4.3). This enabled the true average output to be obtained from large and small target sizes of both simple and more time consuming operations (e.g. building large brickwork

	(1) HOTEL A	(2) INDUSTRIAL BUILDING	(3) HOSPITAL A	(4) SCHOOL BUILDING	(5) HOUSING	(6) ARMY TRAINING BUILDING	(7) PHARMACY EXTENSION
CONCRETE WORK	Foundations Floor Slabs Suspended Slabs, Stairs and Landings	Foundations Floor Slabs Suspended Slabs, Stairs and Landings	Foundations Suspended Slabs, Stairs and Landings Columns	Foundations	Foundations Floor Slabs Cavity Fill	Foundations Floor Slabs Suspended Slabs, Stairs and Landings Columns and Beams	Concrete Generally
BRICKWORK AND BLOCKWORK	Brickwork Sub-Structure Brickwork Superstructure Blockwork Superstructure	Brickwork And Blockwork Sub-Structure Brickwork And Blockwork Superstructure Blockwork Superstructure	Brickwork And Blockwork Superstructure Blockwork Superstructure	Brickwork And Blockwork Superstructure	Brickwork And Blockwork Sub-Structure Brickwork And Blockwork Superstructure DFC-Joists Joists-Eaves Peaks	Brickwork Sub-Structure Brickwork Superstructure	Brickwork And Blockwork Superstructure
WOODWORK	First Fixings Softwood Framing Door Frames Window Frames	Door Frames Generally	Softwood Grounds Door Frames	Generally	Generally	Generally	Generally
	Second And Other Fixings Architraves And Skirtings	Hanging Doors	Hanging Doors Ironmongery	Generally	Ironmongery Generally	Door Sets	Generally

TABLE 4B SUMMARY OF PROJECTS AND WORK SECTIONS/CATEGORIES

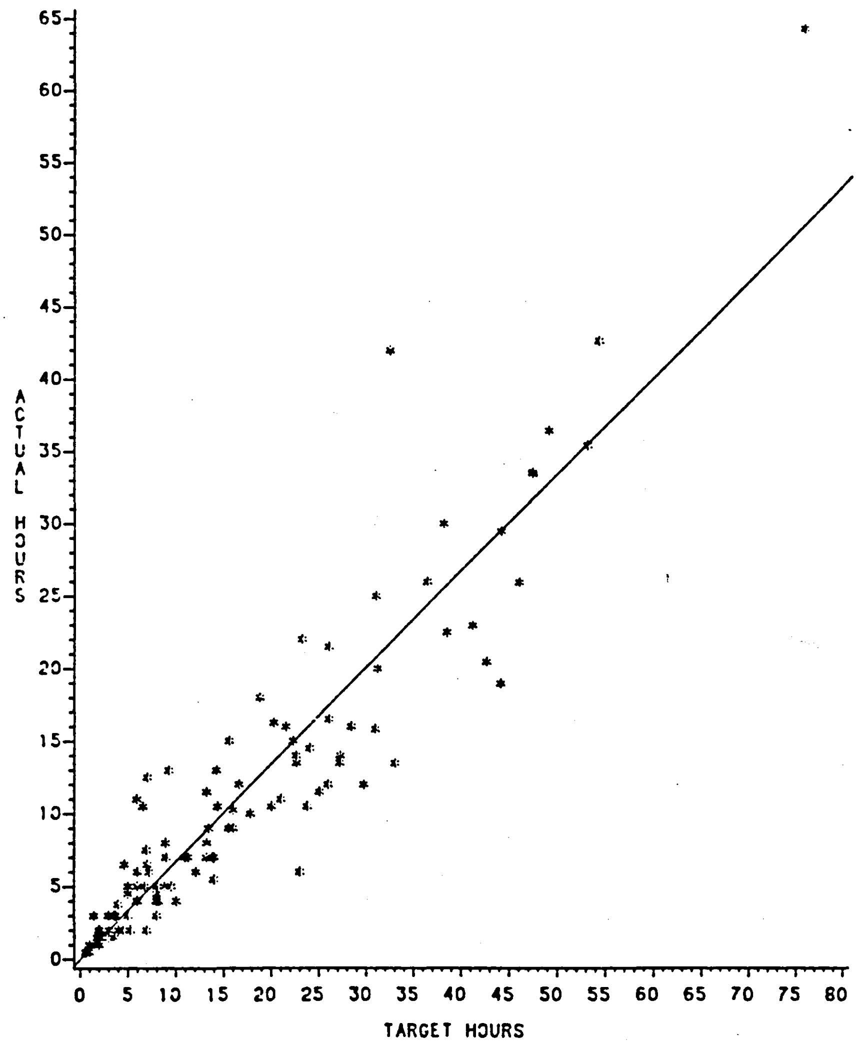

FIGURE 4.3 MODEL OF ACTUAL HOURS AGAINST TARGET HOURS

panels, and small areas of brickwork including cutting and other sundry items.)

Prior to obtaining the fitted models, various other modelling techniques were explored. The variation in outputs, however, was such that no particular method proved consistent. Various forms of transformations were tried, but in the majority of cases the single coefficient model proved to be as accurate as any other type of model. The coefficient was also the simplest form of model and was easily applied to the target rates for adjustment purposes.

Productivity performances were therefore based on the relation:

actual hours = target hours x model coefficient

This procedure was repeated for all data sets, and the unit production outputs were obtained for the bill items within each of the target operations. In applying the model adjustment to obtain the production data, certain assumptions were made regarding the items within the target. These relate specifically to the actual hours taken since this was recorded for the target as a whole and not for individual items. The model coefficient applied to the total target time has therefore been applied to the individual target rates for individual items. Establishing the actual time of each item individually could only be done by work measurement and time studies on site. Such detailed data collection was considered to be outside the scope of the study.

Measured items for each project were prepared together with the output rates (See examples in Figures 4.4 to 4.6). Similar items from each project were abstracted and the average was obtained representing a common data base rate.

This procedure was carried out for all measured items in each project, thus resulting in the formulation of a production data base. Figure 4.7 shows the abstracted items contained in the data base.

4.9 PRODUCTION DATA ANALYSED

In the previous section, the methodology was discussed on the formulation of the data base to establish output levels. Production data were therefore analysed to see the effect of the averaged data in relation to individual project data.

Although target rates are related to outputs through the concept of incentives, the target and actual output times are independent. The work packages representing the targets were therefore regenerated using the data base rates previously determined. This applied to all projects with the exception of housing. This was the only project where targets were set before

CONCRETE WORK

(1) HOTEL A

Modelled Classification	Model Coeff.
Concrete in Foundations	0.34
Concrete in Floor Slabs	0.32
Concrete in Suspended slabs, Stairs and landings	0.52

Item	Target rate (hrs/unit)	Model Coeff.	Revised Rate
Concrete in foundations (d)	0.75/m3	0.34	0.26
Concrete in stan. bases (d)	1.00/m3	0.34	0.34
Conc. in flr. slabs 100th (h)	2.50/m3	0.32	0.80
Concrete in stairs (c)	2.86/m3	0.52	1.49
Concrete in landings (c)	2.57/m3	0.52	1.34
Trowel surface finish	0.10/m2	0.32	0.03
Visqueen	0.02/m2	0.32	0.01
Mesh Reinf.	0.10/m2	0.32	0.03
Flexcell exp. jnt.	0.10/m	0.34	0.03

(d) direct placing

(h) hand placing

(c) crane assisted placing

FIGURE 4.4 ADJUSTMENT TO TARGET RATES FOR CONCRETE WORK

BRICKWORK AND BLOCKWORK

(1) HOTEL A

Brickwork in sub-structure

Item	Target rate (hrs/unit)	Model Coeff.	Revised Rate
hb commons	1.80/m2	0.55	0.99
1b commons	3.60/m2	0.55	1.98
hb facings	2.75/m2	0.55	1.51

Brickwork in Superstructure

Item	Target rate (hrs/unit)	Model Coeff.	Revised Rate
hb facings	2.75/m2	0.48	1.32
boe facings	0.60/m2	0.48	0.29
1b commons	3.60/m2	0.48	1.73
close cavity	0.50/m	0.48	0.24

Blockwork in Superstructure

Item	Target rate (hrs/unit)	Model Coeff.	Revised Rate
Blockwork 190th P2S	3.40/m2	0.34	1.16
Blockwork 100th P2S	1.50/m2	0.46	0.69

FIGURE 4.5 ADJUSTMENT TO TARGET RATES FOR BRICKWORK AND BLOCKWORK

WOODWORK

(1) HOTEL A

Modelled Classification	Model Coeff.
Window Frames	0.54
SW Framing	0.58
Door Frames	0.78
Skirtings and Architraves	0.57

Item	Target rate (hrs/unit)	Model Coeff.	Revised Rate
1200x1500 sw window frame	1.00/nr	0.54	0.54
50x75 sw framing	0.18/m	0.58	0.10
Door linings	0.26/m	0.78	0.20
Door frames	0.52/m	0.78	0.41
19x50 sw architraves	0.17/m	0.57	0.10
19x100 sw skirtings	0.35/m	0.57	0.20

FIGURE 4.6 ADJUSTMENT TO TARGET RATES FOR WOODWORK

DATA BASE ITEMS

(d) direct pour

(h) hand placing

(c) crane assisted placing

Concrete Work

conc. foundations (d)
conc. foundations (h)
conc. bases (d)
conc. bases (h)
conc. grnd. beams (h)
conc. flr. slabs 100th (h)
conc. flr. slabs 150th (d)
conc. flr. slabs 150th (h)
conc. flr. slabs 200th (d)
conc. flr. slabs 200th (h)
conc. susp. slabs 150th (h)
conc. susp. slabs 150th (c)
conc. stairs (h)
conc. stairs (c)
conc. landings (h)
conc. landings (c)
conc. columns (h)
conc. columns (c)
conc. stub columns (h)
conc. col. enclosure (h)
conc. upstands (h)
conc. plinths (h)
conc. padstones (h)
conc. beams (h)
conc. beams (c)
conc. beam enclosure (h)
conc. cavity fill (h)
visqueen/poly dpm
mesh reinf.
steel trowel finish
wood float finish
bit. sheet flr. cover
exp. poly edge board 25th
exp. poly board - slab
power float
flexcell exp. jnt.
bit. sheet turned up wall

FIGURE 4.7 DATA BASE ITEMS

Brickwork and blockwork

hb wall, commons
1b wall, commons
1.5b wall, commons
hb wall, facings
1b wall, facings
1.5b wall, facings
hb wall, engineering
1b wall, engineering
1.5b wall, engineering
100th blocks
100th blocks P2S
140th blocks
140th blocks P2S
190th blocks
190th blocks P2S
cavity insulation
DPC cavity tray
boe facings
close cavity with bwk
lintels 1200-2400
vertical joints in bwk
sill blocks
raking cutting bwk
cutting blocks
hb proj. bands 300 wide
hb proj. boe
close cavity wi. asb. slate
bed plate & frame in mortar
rake out jnts for flashing
cut back lintel
bituthene layer
cut out and tooth
fix anchors
cut bricks
clearing slots
shot fixings to steel

Woodwork
First Fixings

12.5 ply fascia
chipboard
12.5 ply soffit
t+g floor boarding
50x50 sw framing
50x50 sw framing p+s
50x75 sw framing
63x132 sw door linings

FIGURE 4.7 DATA BASE ITEMS (CONTINUED)

sw door frames p+s
sw door frames built in
900x1200 sw window frame
1200x1500 sw window frame
50x50 noggings
shaddow battens
grounds, nailed
grounds, plugged
50x50 sw bearers
25x100 sw bearers
38x100 sw bearers
50x150 sw bearers
50x200 sw bearers
25x38 head plate
25x50 base plate
52x38 sole plate
door batten
vee jntd. boards 100 wide

Second Fixings

angle fillet
19x50 sw architraves
19x100 sw architraves
14x70 sw skirtings
14x70 sw skirtings p+s
19x100 sw skirtings
window board
handrail
quadrant bead
hat+coat rail, plugged
curtain rail
slatted shelving
blockboard shelving
bath panel
capping to balustrade
hw handrail
doors, single
doors, double
doors, panelled
doors, int. flush
hw door
int/ext door sets, single
int/ext door sets, double
sink base unit
cupbd./drainer unit
wall unit
worktop 600x1000
worktop, L shaped

FIGURE 4.7 DATA BASE ITEMS (CONTINUED)

flush bolt
transome bolt
100mm butt hinges
pull handles
door closer
door stop
escutcheon
limiting stay
panic bolt
mortice lock
kicking plate
door holder
metal stop
push plate
auto alarm
cabin hook
door selector
indicator bolt
lever handle
norfolk latch
backing plate
night latch
dead lock
brass ball catch
number plate
letter plate
hat+coat hooks
magnetic catch
barrel bolt
handrail brackets
chubb window lock
door sign

FIGURE 4.7 DATA BASE ITEMS (CONTINUED)

the work commenced, and details of the measure representing the total target hours were not available.

To observe what affect the average production data base would have on accuracy, the data were assessed in several areas. First, scatter diagrams were produced to assess the behaviour in relation to the line of perfect forecasts. This line represents the point at which the actual hours would equal the production data hours. The points which lie under the line indicate overestimation or outputs better than expected, and the points which lie above the line indicate underestimation or a reduction in outputs (See Figure 4.8).

From these plots general conclusions could be drawn on the variation with regard to the size of the work package in terms of hours. Also, it could be determined if the variation was related to certain sizes of work packages or restricted to any particular size. This would give some indication of the productivity range properties of particular work categories.

Finally, accuracy of the data with regard to the estimators' data and targets set by bonus surveyors for individual projects was of particular interest. This would illustrate the accuracy of the average data base rates, and allow comparisons to be made.

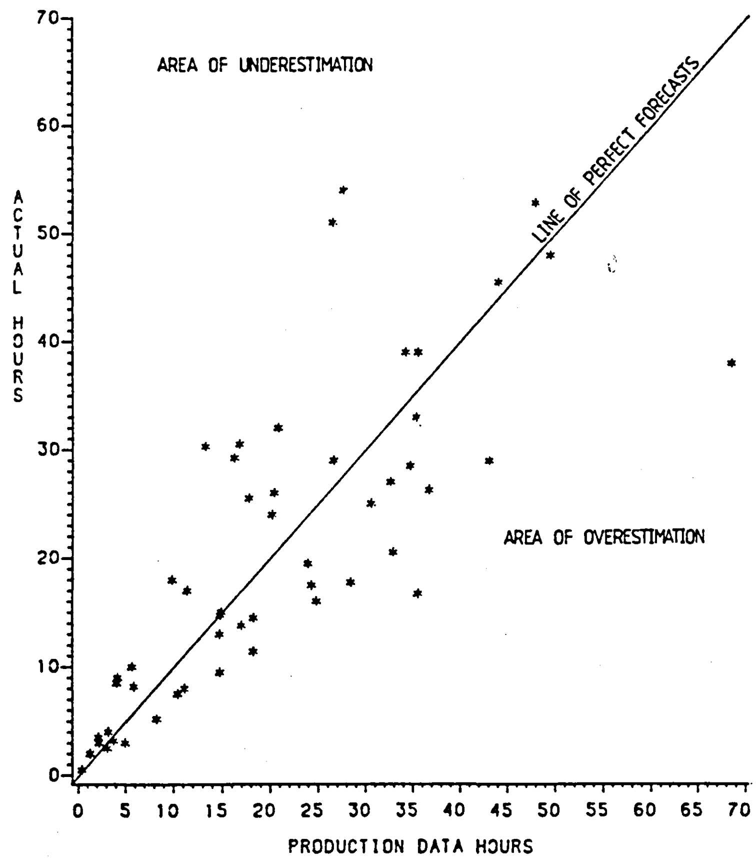

FIGURE 4.8 SCATTER DIAGRAM

4.9.1 Concrete Work

The concrete section of the data analysis comprised various categories of concrete work. From the first sample projects these were sectionalised into foundations, floor slabs, suspended slabs stairs and landings, columns, and columns and beams.

Before considering these sections the most noticeable feature of all the work categories was the extent of variation for various sizes of the work packages generated. The variation was equally varied irrespective of work package size and there was no common pattern to accuracy or variation from the points plotted (See Appendix 2.1). This seemed to occur randomly and without exception, which illustrates that size of work package does not affect the extent of variation.

In foundation work there was nothing to suggest that the type of building or complexity of foundations were influential to the outputs achieved. Simple concrete foundation operations in the 'hotel A' building produced as much variation as the more complex foundation work of the industrial building. There were extreme cases of variation in each case, with points also close to the line of perfect forecasts. In all cases the points indicated both underestimation and overestimation from the production data. Examples of these plots are shown in Appendix 2.1.

A similar situation to the foundations was evident with the floor slab category. The production performances of the simple type buildings i.e. 'hotel A' varied as much as the more complex industrial building floor slabs. The plots for this category are shown in Appendix 2.1.

The section with considerable variation in the concrete work was the suspended slabs, stairs and landings. Such behaviour is expected when considering this particular category as much is dependent on the precise method of placing concrete. This also applies to the column and column and beam categories where variation was also high (See Appendix 2.1). The complexity of work and particular method adopted will be influential to the outputs achieved.

In the data collection process three defined methods of placing were identified. These included direct placing from concrete lorries, the physical placing by hand involving labour effort, and placing concrete with a crane and skip. None of the projects considered in the study used a pump for placing concrete.

Although the method can be defined in each case, their are instances where the actions of particular operatives can greatly affect production. The way in which operatives organise themselves and adapt to particular situations can greatly affect production when compared with operations carried out by other operatives.

For each category statistical properties of the data sets were produced illustrating measures of range and dispersion. These statistics are shown in Table 4C.

The productivity range ratios were obtained by taking the range of actual hours recorded for work packages of approximately the same size. This was found to be between 2:1 and 3:1 for the concrete categories, although in one particular instance the ratio was as high as 6.4:1 for the suspended slab category. The relative dispersion within the productivity range was also reflected in the coefficient of variation figures. These generally ranged between 18% and 67% with the highest value occurring in the foundations category.

On the evidence of these statistics, it can be concluded that the variation of productivity in concrete work can be extremely high. In addition to the ability and motivation of operatives and organisation of operations, the complexity in placing concrete are undoubtedly influential to the outputs achieved.

In addition to the statistical properties obtained from the production data, comparisons were made with other sources of outputs. These being the estimators' data and the targets rates set by bonus surveyors. The production data generated were based on the data base rates which represented the average of projects, whereas the other two independent sources were specifically related to

WORK CATEGORY	PROJECT	CORR. COEFF.	PRODUCTIVITY RANGE RATIO	CV%	MEAN ACTUAL HOURS
Concrete in Foundations	Hotel A	0.929	3:1	33	9.90
	Industrial Building	0.576	2.1:1	38	28.29
	Hospital A	0.427	3.4:1	67	8.73
	School Building	0.659	-	64	9.80
	Army Training Building	0.366	1.1:1	60	21.61
Concrete in Floor Slabs	Hotel A	0.860	3.1:1	56	19.83
	Industrial Building	0.917	1.9:1	36	45.08
	Army Training Building	0.814	2:1	28	13.57
Concrete in Suspended Slabs, Stairs and Landings	Hotel A	0.986	1.2:1	18	4.01
	Industrial Building	-0.338	1.8:1	49	15.39
	Hospital A	0.594	6.4:1	61	16.84
	Army Training Building	0.799	2.3:1	65	10.81
Concrete in Columns	Hospital A	0.486	3.5:1	54	3.79
Concrete in Columns and Beams	Army Training Building	0.908	1.6:1	40	8.25
Concrete Generally	Pharmacy Extension	0.968	3:1	32	21.93

TABLE 4C RANGES AND DISPERSIONS OF CONCRETE CATEGORIES (FIRST SAMPLE) individual projects.

The variations in the targets set and the estimators' output data were based on opinions of the bonus surveyors and estimators. All have used judgement in arriving at the data and made their own assessment of the peculiarities for each of the projects. Assessment was therefore made to see how the productivity data would compare with these independent sources of data.

For comparison of differences, assessment was made in relation to the errors from the line of perfect forecasts derived from each method. In each case the mean, standard deviation, root mean square error and mean percentage errors were calculated. The root mean square error being the criterion used for comparative purposes. The results are shown in Table 4D.

To make this comparison both the bonus surveyors' targets and the estimators' data were first adjusted to remove the bonus increment. Both contain a 30% addition above the normal time expected to complete the operation.

Based on comparisons for each method and assessment of the errors, the production data have shown to produce the least error. Comparisons with estimators' data have shown production data to have improved accuracy in

WORK CATEGORY	PROJECT	ERRORS (HOURS)											
		PRODUCTION DATA				ESTIMATORS' DATA LESS BONUS INCREMENT				BONUS SURVEYORS' TARGETS LESS BONUS INCREMENT			
		MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %
Concrete in Foundations	Hotel A	-0.86	3.12	3.24	9.62	7.71	13.97	15.96	44.78	7.71	13.97	15.96	44.78
	Industrial Building	-5.86	10.40	11.94	26.13	1.84	5.11	5.43	6.11	1.75	5.06	5.35	5.83
	Hospital A	0.64	8.13	8.16	6.83	7.59	8.12	11.11	46.48	5.54	6.40	8.46	38.80
	School Building	0.90	8.15	8.20	8.67	3.58	9.53	10.18	26.76	4.13	9.14	10.03	29.65
	Army Training Building	15.08	23.43	27.86	41.10	41.80	26.50	49.49	65.93	22.54	18.86	29.39	51.05
Concrete in Floor Slabs	Hotel A	-3.37	11.08	11.58	20.47	12.12	41.50	43.23	37.99	15.71	32.33	35.94	44.25
	Industrial Building	-5.52	16.01	16.93	13.14	17.21	27.47	32.42	27.62	7.39	15.11	16.82	14.08
	Army Training Building	6.86	5.18	8.60	33.58	5.28	8.08	9.65	28.01	5.16	3.53	6.25	27.55
Concrete in Suspend Slabs, Stairs and Landings	Hotel A	1.63	1.96	2.55	28.97	4.97	4.85	6.94	55.28	2.32	1.72	2.89	36.65
	Inudstrial Building	-0.35	7.67	7.68	2.33	-1.58	2.77	3.19	11.44	-0.54	4.23	4.26	3.63
	Hospital A	0.57	10.49	10.51	3.27	39.30	40.80	56.65	70.05	21.22	22.86	31.19	55.74
	Army Training Building	1.85	10.84	11.00	14.60	7.24	11.22	13.35	40.09	0.12	2.60	2.60	1.18
Concrete in Columns	Hospital A	0.30	3.43	3.44	7.46	2.48	2.47	3.50	39.55	2.16	2.25	3.12	36.32
Concrete in Columns and Beams	Army Training Building	4.43	7.89	9.05	34.94	15.57	15.75	22.15	65.37	3.52	5.20	6.28	29.91
Concrete Generally	Pharmacy Extension	0.55	8.42	8.44	2.44	4.29	15.25	15.84	16.37	4.58	14.80	15.49	17.28

TABLE 4D COMPARISON OF ERRORS BETWEEN METHODS FOR CONCRETE CATEGORIES (FIRST SAMPLE) thirteen out of the fifteen cases. In the cases of improvement, the RMSE for production data has shown to represent an average of 56% of the RMSE for the estimators' data. Comparisons with targets set by bonus surveyors show production data to have improved accuracy in eight of the fifteen cases. In the cases of improvement, the RMSE for production data was 63% of the RMSE for bonus surveyors' targets.

The worst case for the production data occurred in the foundation work of the industrial building. The main reason for this has been caused by the reduced productivity in this particular category. The complex foundation work to support heavy industrial equipment reduced productivity, and this was influential to the error recorded.

4.9.2 Brickwork and Blockwork

In this section it was most noticeable that variation in production data was generally less in the sub-structure category than in the superstructure category.

Generally one would expect less variation in the brickwork and blockwork section than in the concrete section previously discussed. Primarily this could be attributed to the more consistent methods used for bricklaying operations as compared with placing concrete. However, variation was still predominant in superstructure brickwork and blockwork, as the scatter diagrams indicate (See Appendix 2.2). Observing the plots revealed there was no particular pattern in variation to the size of work package. Variation and accuracy were common to all work package sizes.

In the superstructure work, productivity levels varied considerably. This was common to both the brickwork, brickwork and blockwork, and the blockwork only categories. Underestimation and overestimation were evident in all data sets and no particular pattern emerged from the various types of buildings (See Appendix 2.2).

The statistical properties of this section illustrated more consistency than the concrete work. Productivity range ratios were much reduced than the concrete section ranging from 1.4:1 to 3.4:1, with coefficient of variation values from 18% to 47% (See Table 4E).

Comparison of the errors in this section generally showed improvement using production data. Comparisons with estimators' data have shown production data to have improved accuracy in ten of the thirteen cases. In the cases of improvement, the RMSE for production data was 54% of the RMSE for estimators' data. Comparisons with targets set by bonus surveyors have shown production data to have improved accuracy in nine of the thirteen cases (See Table 4F). In the cases of improvement, the

WORK CATEGORY	PROJECT	CORR. COEFF.	PRODUCTIVITY RANGE RATIO	CV%	MEAN ACTUAL HOURS
Brickwork Sub-Structure	Hotel A	0.966	2:1	29	49.10
	Army Training Building	0.975	1.4:1	19	45.90
Brickwork and Blockwork in Sub-Structure	Industrial Building	0.987	2:1	18	60.40
Brickwork in Superstructure	Hotel A	0.795	2.3:1	47	22.23
	Army Training Building	0.917	3.4:1	29	59.23
Brickwork and Blockwork in Superstructure	Industrial Building	0.807	2.4:1	37	64.29
	Hospital A	0.849	2.1:1	27	56.79
	School Building	0.770	3.2:1	47	68.00
	Pharmacy Extension	0.925	1.4:1	31	91.80
Blockwork in Superstructure	Hotel A				
	190th	0.821	2.1:1	32	38.87
	100th	0.828	2:1	41	17.95
	Industrial Building	0.838	3.2:1	28	91.70
	Hospital A	0.855	3.1:1	36	58.04

TABLE 4E RANGES AND DISPERSIONS OF BRICKWORK AND BLOCKWORK CATEGORIES (FIRST SAMPLE)

WORK CATEGORY	PROJECT	ERRORS (HOURS)											
		PRODUCTION DATA				ESTIMATORS' DATA LESS BONUS INCREMENT				BONUS SURVEYORS' TARGETS LESS BONUS INCREMENT			
		MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %
Brickwork in Sub-Structure	Hotel A	-0.59	14.38	14.39	1.22	18.74	27.73	33.47	27.64	17.32	27.36	32.38	26.08
	Army Training Building	12.36	14.40	18.98	21.20	54.60	57.70	79.44	54.33	31.30	35.50	47.33	40.54
Brickwork and Blockwork in Sub-Structure	Industrial Building	-2.28	10.46	10.71	3.92	-2.83	9.64	10.05	4.92	-2.83	9.64	10.05	4.92
Brickwork in Superstructure	Hotel A	-0.17	10.56	10.56	0.77	6.50	13.15	14.67	22.62	10.42	15.17	18.40	31.91
	Army Training Building	12.11	24.83	27.63	1.70	29.15	35.93	46.27	32.98	18.67	29.36	34.79	23.97
Brickwork and Blockwork in Superstructure	Industrial Building	-16.57	21.21	26.92	34.72	-14.15	19.06	23.74	28.22	-17.32	18.33	25.22	36.87
	Hospital A	1.75	15.67	15.77	0.03	18.27	21.07	27.89	24.34	3.30	14.83	15.19	5.49
	School Building	-22.56	28.03	35.98	49.68	-0.29	37.48	37.48	0.43	-23.29	32.10	39.66	51.79
	Pharmacy Extension	-29.39	28.65	41.04	47.10	-15.10	37.70	40.61	19.69	-10.69	18.46	21.33	13.18
Blockwork in Superstructure	Hotel A												
	190th	2.86	12.22	12.55	7.94	18.17	21.63	28.25	31.85	41.62	33.27	53.28	51.71
	100th	1.63	7.74	7.91	8.32	4.19	8.09	9.11	18.93	10.46	11.30	15.40	36.82
	Industrial Building	1.69	26.99	27.04	1.81	7.43	31.72	32.58	7.50	1.68	30.26	30.31	1.80
	Hospital A	-1.49	21.56	21.61	2.63	35.60	58.30	68.31	38.03	11.05	30.50	32.44	15.99

TABLE 4F COMPARISON OF ERRORS BETWEEN METHODS FOR BRICKWORK AND BLOCKWORK CATEGORIES (FIRST SAMPLE)

RMSE for production data represented 60% of the RMSE for bonus surveyors' targets.

4.9.3 Woodwork

In the woodwork section, one may expect the least variation associated with the various fixings. In the concrete work section, considerable influence can be expected with the particular operation and the precise methods employed. Brickwork and blockwork can be influenced by size and complexity of panels. In direct contrast, joinery fixings could be described as standard type operations being relatively consistent between projects. For example, fixing a door frame, or hanging a door, or fixing skirtings etc., are relatively common operations whatever the type of building. Provided the same type of fixings are being considered one would not normally expect variation to be excessive. However, reduced variation was not found in the production data. The scatter diagrams illustrated considerable variation for certain types of similar fixings (See Appendix 2.3).

In both first and second fixings, it was noticeable that the smaller work package generally illustrated the greater accuracy. This gives support to the formulation of small work packages to reduce variation and help control production. Productivity range ratios were between 1.4:1 and 3.1:1 with the coefficient of variation values between 19% and 104% (See Table 4G).

WORK CATEGORY	PROJECT	CORR. COEFF.	PRODUCTIVITY RANGE RATIO	CV%	MEAN ACTUAL HOURS
First Fixings Softwood Grounds	Hospital A	0.871	2:1	34	11.96
Softwood Framing	Hotel A	0.706	-	104	9.48
Door Frames	Hotel A	0.979	1.5:1	27	12.22
	Industrial Building	0.790	8:1	27	11.82
	Hospital A	0.722	2.1:1	47	18.45
Window Frames	Hotel A	0.949	1.5:1	22	7.97
Generally	Industrial Building	0.919	3:1	42	16.76
	School Building	0.921	2.2:1	47	8.92
	Army Training Building	0.815	-	44	3.38
	Pharmacy Extension	0.847	1.9:1	46	21.49
Second and other Fixings	Industrial Building	0.984	1.4:1	25	16.26
Hanging Doors	Hospital A	0.673	3.1:1	56	14.58
Architraves and Skirtings	Hotel A	0.954	2:1	31	2.42
Door Sets	Army Training Building	0.726	1.9:1	47	16.17
Ironmongery	Hospital A	0.673	2.4:1	61	9.40
Generally	School Building	0.977	2:1	26	6.00
	Pharmacy Extension	0.975	2.3:1	19	20.30

TABLE 4G RANGES AND DISPERSIONS OF WOODWORK CATEGORIES (FIRST SAMPLE)

Comparisons of errors in the woodwork section indicated production data to have the least accuracy. Comparisons with estimators' data have shown production data to have improved accuracy in five of the seventeen cases. In the cases of improved accuracy for production data, the RMSE represented 57% of the RMSE for estimators' data. In cases where the estimators' data were more accurate, the differences were less pronounced. The RMSE for estimators' data representing 70% of the RMSE for production data. Comparisons with the targets set by bonus surveyors have also shown production data to have improved accuracy in five of the seventeen cases (See Table 4H). In the cases of improvement for production data, the RMSE was 57% of the RMSE for bonus surveyors' targets. In the cases where bonus surveyors' targets were more accurate, the difference between RMSE values were less pronounced. The RMSE for bonus surveyors' targets represented 75% of the RMSE for production data.

The improved accuracy of the estimate and targets may well be accountable to the detailed measurement of items in the bill of quantities. Bill items in the woodwork section can represent complete operations (i.e. hanging a door, fixing ironmongery etc.). The estimator and bonus surveyor can relate rates directly to the particular bill item, therefore one would expect a reasonable amount of accuracy from the estimate and targets set.

WORK CATEGORY	PROJECT	ERRORS (HOURS)											
		PRODUCTION DATA				ESTIMATORS' DATA LESS BONUS INCREMENT				BONUS SURVEYORS' TARGETS LESS BONUS INCREMENT			
		MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %
First Fixings Softwood Grounds	Hospital A	-2.63	4.29	5.03	28.17	0.87	4.08	4.17	6.78	-1.49	4.14	4.40	14.23
Softwood Framing	Hotel A	1.51	11.64	11.74	13.74	3.47	8.33	9.02	26.80	3.22	4.78	5.76	25.35
Door Frames	Hotel A	7.31	12.87	14.80	37.43	3.13	7.62	8.24	20.39	6.97	12.50	14.31	36.32
	Industrial Building	0.35	3.22	3.24	5.39	1.00	9.20	9.25	13.99	1.00	9.20	9.25	13.99
	Hospital A	-6.57	8.29	10.58	55.30	-3.00	8.19	8.72	19.41	-1.91	7.50	7.74	11.55
Window Frames	Hotel A	-0.01	1.78	1.78	0.05	4.74	3.42	5.84	37.32	3.37	2.70	4.32	29.72
Generally	Industrial Building	-3.21	7.61	8.26	23.69	1.05	4.14	4.27	5.90	1.05	4.14	4.27	5.90
	School Building	0.54	4.49	4.52	5.71	-0.94	2.55	2.72	11.78	-2.04	3.72	4.24	29.69
	Army Training Building	0.87	1.97	2.15	19.33	1.11	3.29	3.47	24.72	0.44	1.38	1.45	11.52
	Pharmacy Extension	6.30	16.25	17.43	22.68	3.57	7.83	8.61	14.25	3.57	7.83	8.61	14.25
Second and other Fixings	Industrial Building	-3.28	4.07	5.23	25.23	-0.21	4.53	4.53	1.31	-0.21	4.53	4.53	1.31
Hanging Doors	Hospital A	-4.38	6.93	8.20	42.94	-3.17	7.17	7.84	27.78	-3.38	7.20	7.95	30.18
Architraves and Skirtings	Hotel A	-0.45	0.76	0.88	22.93	-0.32	1.12	1.16	15.11	0.64	1.23	1.39	20.79
Door Sets	Army Training Building	4.45	10.33	11.25	21.59	4.17	5.26	6.71	20.51	10.27	8.97	13.64	61.57
Ironmongery	Hospital A	-2.43	5.53	6.04	34.86	3.51	6.70	7.56	27.19	-2.36	5.62	6.10	33.52
Generally	School Building	1.21	3.10	3.33	16.78	-0.58	1.78	1.87	10.70	-0.73	2.14	2.26	13.85
	Pharmacy Extension	-0.86	3.75	3.85	4.40	1.69	2.64	3.13	7.68	1.69	2.64	3.13	7.68

TABLE 4H COMPARISON OF ERRORS BETWEEN METHODS
FOR WOODWORK CATEGORIES (FIRST SAMPLE)

The proportioning of adjustment to the productivity performances in establishing the production data, is insufficiently accurate in this work section. Estimators can relate rates to particular situations envisaged on site. Bonus surveyors have the advantage of being on site and knowing the precise circumstances, whereas the data base rates are obtained by proportioning.

One would not expect a great deal of difference between the types of fixings with regard to the specification providing the precise implications which would influence productivity are isolated, and separate data sets established accordingly e.g. softwood fixings and hardwood fixings. Whilst softwood and hardwood fixings were separated in the data base, further refinement will be required to distinguish between items more specifically.

4.10 SUMMARY

The main purpose of this chapter has been the formulation of the production data base, founded on past production performances. The production data were analysed with actual performances for the three selected work sections. Comparison of errors were also made with the original estimators' data and the targets set by bonus surveyors.

4.10.1 Concrete Work

In the concrete section, most noticeable was the extent of variation within the various categories. Variation was found to range from 1.1:1 to 6.4:1. From this it can be deduced that variation is not restricted to any one category. Foundations and suspended slabs, stairs and landings are the most varied, but it was also found that variation was also common to even the most simple concreting operations.

It can be concluded for concrete work that methods of placing would be an important factor accountable for excessive variation. Variation was still present even though three individual methods of placing concrete were identified and separately assessed. This illustrates the occurrence of variation even with similar method based operations.

4.10.2 Brickwork and Blockwork

The brickwork and blockwork section has illustrated less variation than the concrete section. This was expected considering the commonality in bricklaying operations. However, although variation is less in this category, it was found to range from 1.4:1 to 3.4:1. Motivation and organisational efficiency have been influential in this work section.

4.10.3 Woodwork

The woodwork section produced the least accurate results of the three work sections considered. Variation in outputs was found to be the greatest in what could be described as relatively standard type work operations.

As outlined earlier, fixing components of a standard nature should not produce substantial differences irrespective of building type; yet in woodwork the highest coefficient of variation values were found. These values ranged up to 104% with the highest variation occurring in the first fixings category. The differences in skill of operatives, particularly on woodwork items, may well be influential to this high variation.

With regard to project types, it could be argued that repetitive types of work should result in consistent variation. However, this was not evident in the 'hotel A'and 'hospital A' projects where repeated operations were common, but which also produced the highest variation. Variation was not restricted to any particular type or quantity of work involved.

CHAPTER 5

MODEL DEVELOPMENT

5.1 INTRODUCTION

In the previous chapter, production data were analysed and a data base was formulated on the basis of the first sample projects. In this chapter, the estimating and planning processes are considered in more detail, and emphasis is placed on the generation of data at various levels of detail utilising the production data base.

An analysis of a bill of quantities from a project is used to determine the method of information generation in a form that corresponds to construction operations. As a result, a logical model is built on the basis of knowledge gained in the previous chapters and the concept of work packaging.

5.2 LEVELS OF PLANNING AND CONTROL

One of the objectives of the research was to establish a link between conventional documentation and production information requirements. An essential requirement at this stage is the formulation of data in a form that satisfies operational orientated information, in line with contractors' constructional sequences. Data therefore needs to be structured in a way which will allow and present information to meet these requirements.

Present documentation using the current SMM is not in a form which would allow this to take place. The research by Skinner[116] has highlighted this point, where it was concluded that the bill of quantities is not in a suitable form for planning purposes.

The planning procedure needs to relate SMM items to constructional orientated operations. This procedure has been recognised by the introduction of Construction Planning Units (CPU)[117] and more recently in the form of work packages. Ormerod[118] in particular adopted the hierarchy approach to work packaging, and defined several sub-levels relating to the physical building process.

These work packages can be related to the requirements of planning and control identified earlier and can be described as follows:

Work Package/Operation	Construction Description
Primary Work Package/ Overall operation	Woodwork
Secondary Work Package/ Sub-operation	First Fixings
Tertiary Work Package/ Target operation	Fixing Door Frame

Whilst the tertiary level shows an individual category, this level can also be represented by a collection of individual categories from first fixings. The tertiary level represents a sub-division of the secondary level relating to specific items and quantities.

The main feature of packaging is one of flexibility and adaptability to meet the requirements of individual projects. Ideally, the information packages should meet certain criteria. Such criteria have been described by Saket, McKay and Horner.(119) "A work package must:

(1) represent an identifiable, uninterrupted operation;
(2) involve not more than one trade;
(3) be described in such a way as to discriminate against the inclusion of bill items that are not cost significant;
(4) incorporate a defined quantity of work, to which one productivity figure can be applied."

Observing such criteria would allow precise resources to be identified and analysed, thus providing information at the required level of detail.

To determine such precise requirements, a project obtained from the collaborating body based on SMM6 and traditional bills of quantities was analysed to assess the practical implications of work packaging to form operations.

The project was a typical housing contract consisting of various types of dwellings. Items from the bill were collected manually and assigned to certain operations. Figure 5.1 shows a calculation sheet of the bill items

OP. NO.	OPERATION	BILL ITEM	ITEM DESCRIPTION	QUANTITY	ALLOCATED LABOUR AND PLANT FROM ESTIMATE	TIME ALLOCATED (HOURS)		LABOUR AND PLANT/GANG TO BE USED	TIME REQUIRED	REMARKS
2	Excavation (Reduced Level)	85a	EXC. R.L. 0.25m deep	$56m^3$	JCB+B	18.48)				
		b	" " 1.00m "	$5m^3$	"	0.85)	26.13	JCB+B	1 WEEK	
		c	" " 1.00m "	$40m^3$	"	6.80)				
	(Trenches)	d	EXC.Trenches 0.25m "	$119m^3$	JCB+B	79.73)	129.33	JCB+B		
		e	" " 1.00m "	$248m^3$	"	49.60)				
		f	E.O. Rock	$74m^2$	JCB+B 1 LAB 1 LAB	29.60)	66.80	JCB+B, 2 LAB + COMPRESSOR AND TOOLS	5 WEEKS	Compressor and Tools priced in Preliminaries
		g	E.O. Brick, Conc.	$93m^3$	"	37.20)				
		h	Earthwork Support	$900m^2$	1 LAB	198.00)	439.85	2 LAB	6 WEEKS	Compactor prices in Preliminaries
		i	Level and Compact Excavation	$14,511m^2$	1 LAB	241.85)		2 LAB + COMPACTOR		
		86a	EXC. Material - Remove from Site	$450m^3$	LORRY+ DRIVER	54.00		LORRY + DRIVER	2 WEEKS	

FIGURE 5.1 CALCULATION SHEET FOR EXCAVATION OPERATION

relating to the excavation work.

From the calculation sheet it can be seen that information has been obtained for each bill item regarding labour and plant, including the total time allocated (i.e. productive plant hours and manhours). It was evident at this stage that the information in this form is of little direct use, and has to be manipulated before it can be used for planning purposes. There are several reasons for this:

1. The resources allocated to each bill item are reproduced as single resources by the collaborating body; that is, either a single operative or single item of plant.

2. From a practical point of view, for (1) above a gang would have to be formulated for certain bill items to reduce the time allocated to a realistic duration for completion.

3. Certain bill items have to be linked together for practical purposes in order that a realistic gang size can be chosen.

4. Certain bill items have to be linked together to form sub-operations which are inter-related to other sub-operations within the particular work operation (See Figure 5.1).

For overall planning it is necessary to obtain a realistic time period for each operation. Considering the previous points, certain operations will prove more involved than others. This can be illustrated by means of an example.

Figure 5.2 shows the operation for excavation. The overall operation consists of several sub-operations which include: excavate reduced level; excavate trenches; extra over excavation for rock; extra over excavation for brick and concrete; earthwork support; level and compact; and remove excavated material from site. For this particular operation the various sub-operations cannot be aggregated since the sub-operations are inter-related and in practice would form part of the same operation. Figure 5.3 illustrates possible inter-relationships between sub-operations and operations.

Whilst excavation is a typical example of inter-related sub-operations, certain operations are not always so clearly defined. Certain sub-operations will always be inter-related whilst others may not. With certain trades it is possible to aggregate all assigned bill items and obtain a duration by considering a gang for the entire operation. Certain items within the operation may be carried out at the same time (particularly with repetitive construction), but this can only be done by increasing resources, and the operation can still be

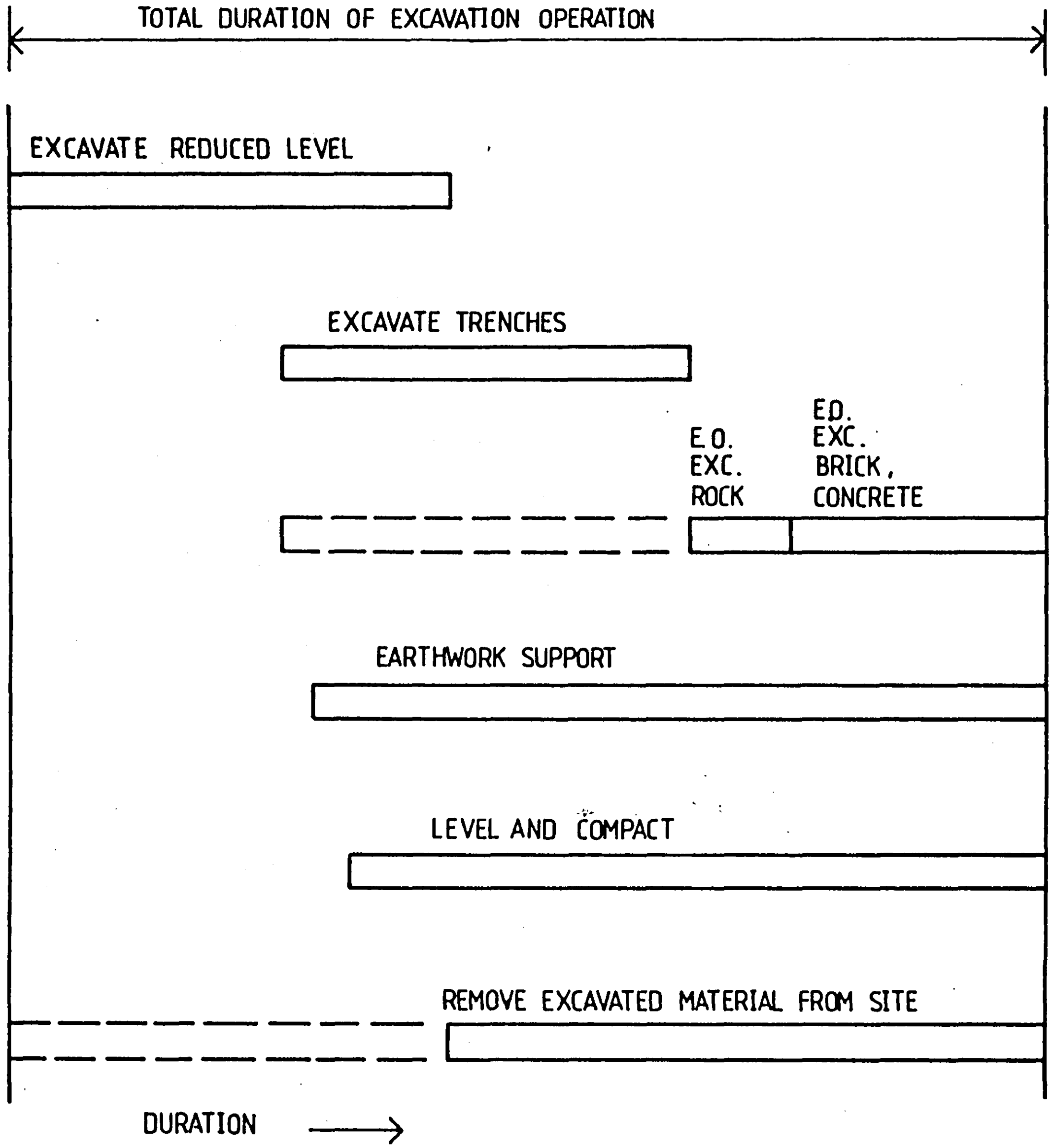

FIGURE 5.2 EXCAVATION OPERATION SHOWING INTER-RELATIONSHIPS OF SUB-OPERATIONS

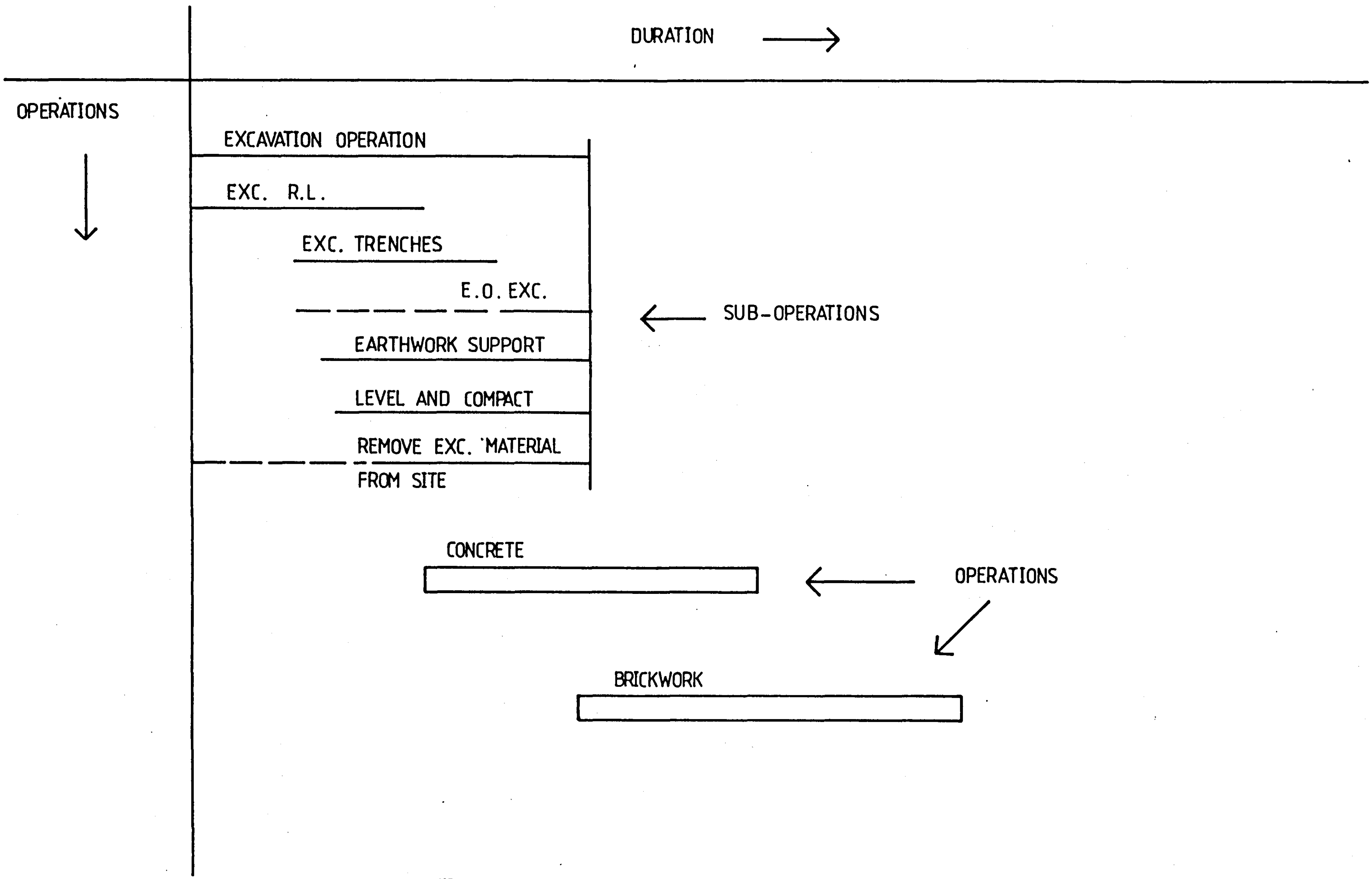

FIGURE 5.3 INTER RELATIONSHIPS OF OPERATIONS

considered as aggregated rather than inter-related. Typical examples would be brickwork or blockwork.

From the bill assessment, it can be shown that items can be collectively represented as work packages and the established data base utilised to generate information at various levels of detail. This is illustrated in Figure 5.4.

The significant items in the bill of quantities can be collectively aggregated to form the tertiary work package. For construction work, tertiary work packages form the most detailed information necessary.

The tertiary work package could be described as a section of targetted work. A section which relates to a particular sub-operation and is identifiable as an uninterrupted task e.g. a section of suspended slab.

A collection of such items and relevant quantities could therefore relate to the next higher level of secondary work package or sub-operation forming the whole of concrete in suspended slabs. This in turn could be collectively represented with other secondary work packages to form the next higher level of primary work package or overall operation. In this way it is possible to gear the information requirements in line with process of construction operations.

It is on this basis of work packaging that the model

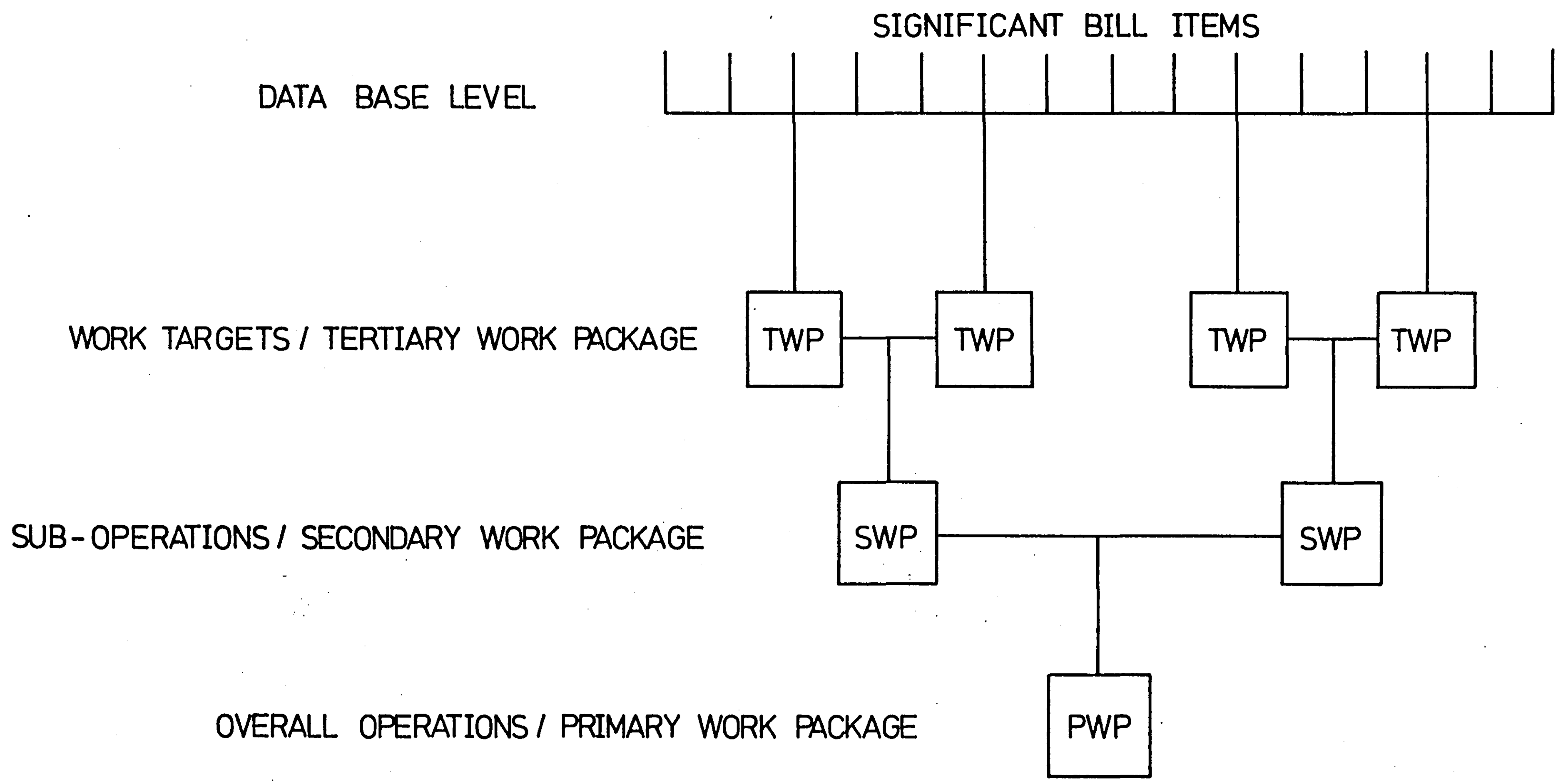

FIGURE 5.4 LEVELS OF WORK PACKAGES

development has been founded. The process of documentation has been based on the method of structured systems analysis as shown in Chapter 3. The methodology has been based on the top-down approach. Diagrams have been produced at the most abstract level, together with various levelled diagrams related to specific stages of work packages.

In practice this is likely to be the procedure of the planning process. Once a tender is successful, overall planning will be the first requirement and on large projects this may also include phase planning. Subsequent detailed short-term planning will be the level representing sub-operations, and further sub-division to the lowest level of work targets. All information, however, is based on the generation of production data.

5.3 THE GLOBAL MODEL

Figure 5.5 shows the global model of integrated estimating, planning and work targets, which illustrates the overall functional context of the proposals. This also shows the stages of planning and the related sub-divisions of detail, allowing the projection of control information to various personnel involved in the production process.

The main purpose of this context diagram is the illustration of the data flow from the production data

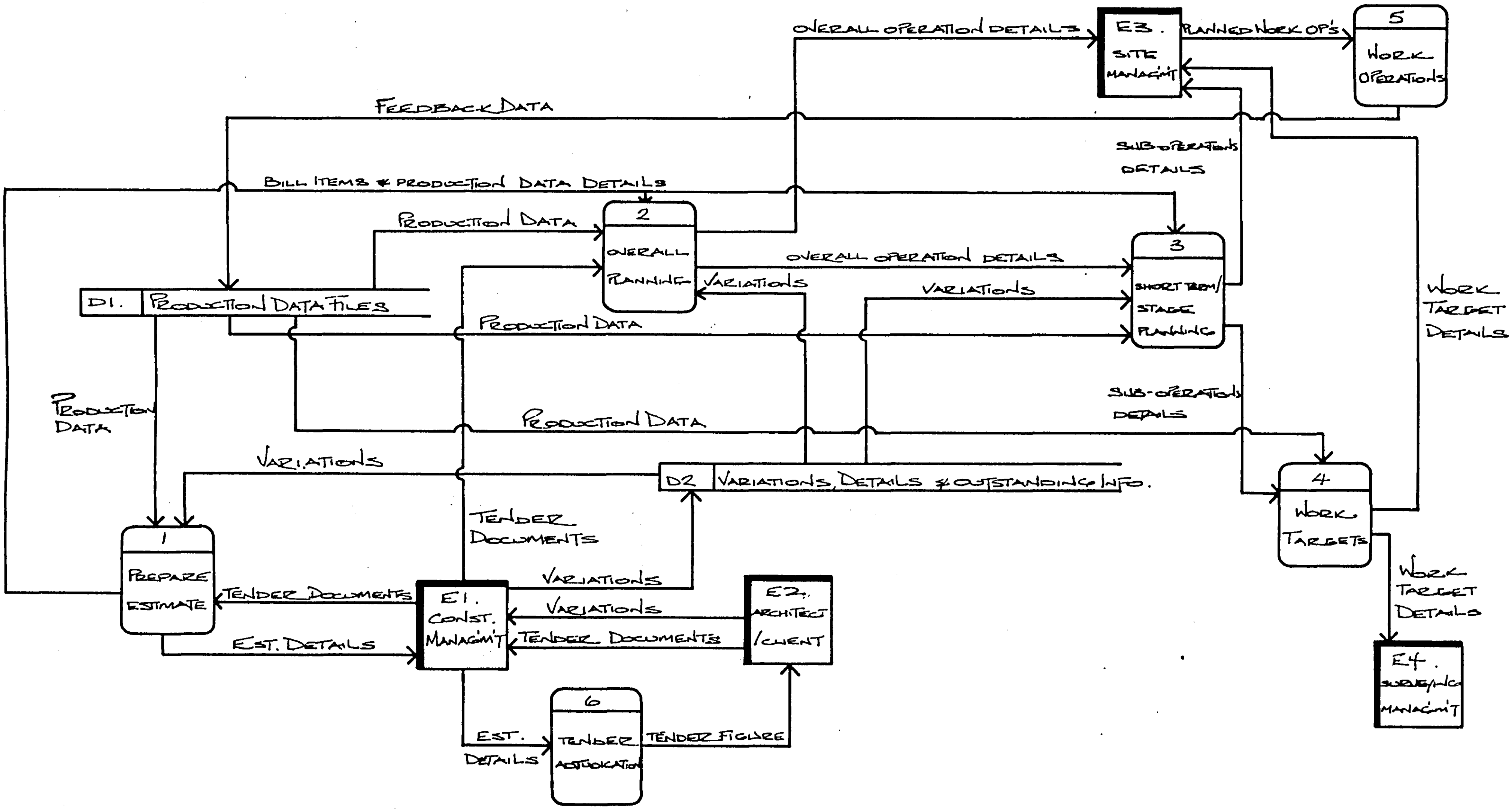

FIGURE 5.5
THE GLOBAL MODEL

base and estimate. Data flows to the overall planning process, and then on to the subsequent detailed planning processes of short term/stage planning, and work targets.

An important inclusion in the context diagram is the introduction of variations (i.e. changes in bill items and quantities), which inevitably occur during construction. The inclusion of such variations is an essential requirement of the proposed model development in order to ensure system sensitivity.

5.4 ESTIMATING PROCESS

The estimating process utilises the established production data base and data are input to represent productivity allowances for bill items. Figure 5.6 shows the flow of data from the production data base to establish a separate estimate file where the items in the bill of quantities are stored together with the production data. This file forms the basis of the estimate and all planning information generated at the various levels of detail.

To generate the net cost estimate additional data input would be required. For example, the all-in rate costs of resources included in the item would be required. Estimate details generated could then form the basis of establishing the tender by management.

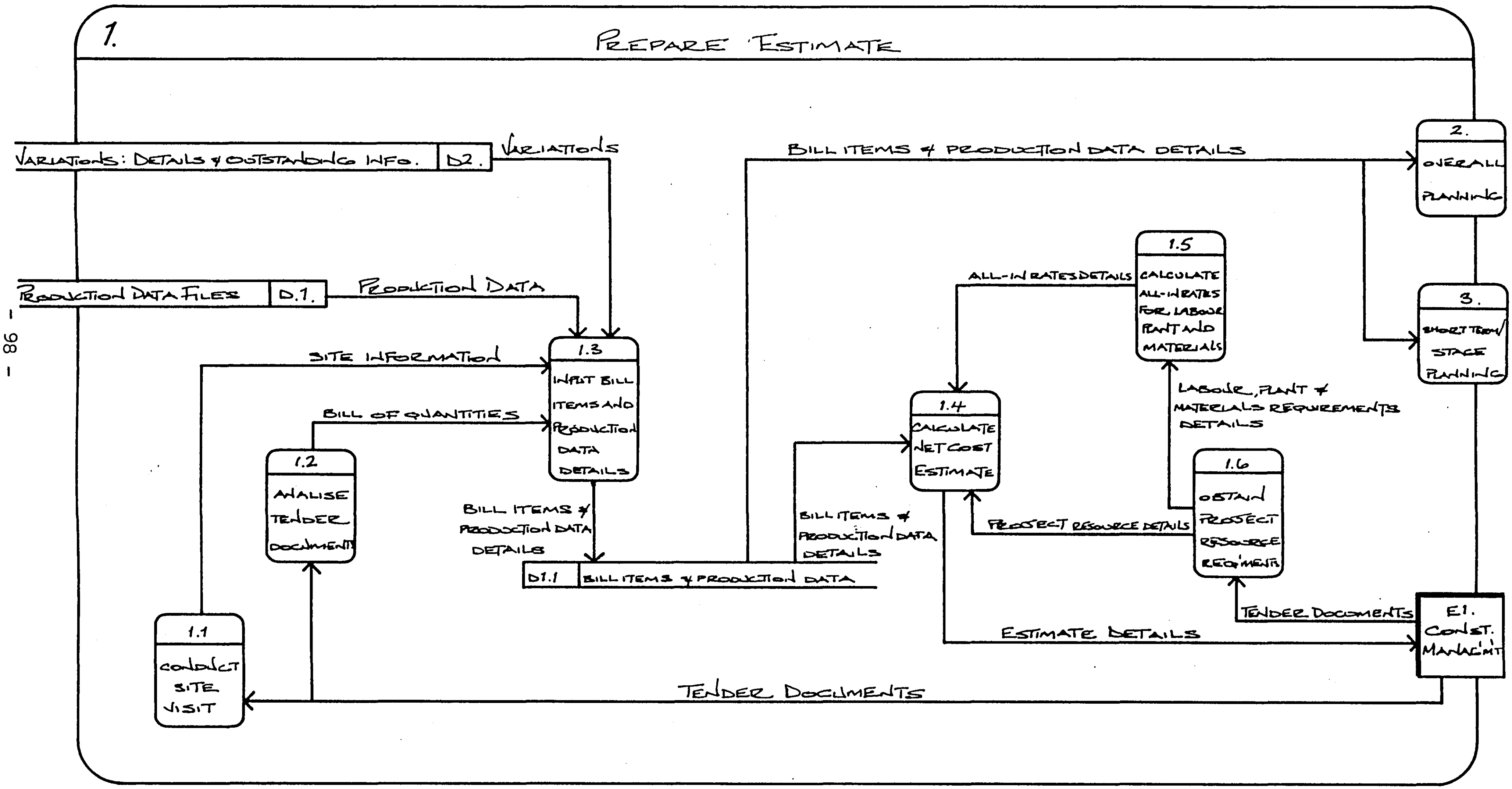

FIGURE 5.6 PREPARE ESTIMATE PROCESS

From the initial estimate file, the production data are then utilised at other levels of the planning process.

5.5 OVERALL PLANNING PROCESS

Figure 5.7 illustrates the overall planning process in a greater degree of detail. This shows the individual processes in the overall planning procedure.

From the file established at the estimating stage, it is important that the input of each bill item description gives details of the work which relates to the practical aspects of construction.

A file of overall operations or primary work packages also needs to be created, based on the tendering information and working drawings. At this level of detail, the operations need only be of a general nature describing the work in overall terms.

These two files then form the basis for the creation of a third file containing the details of the bill items and the operations to which they relate. This results in a situation where all the bill items are allocated to the subsequent operations, together with the appropriate estimate details and total quantities. This provides the opportunity to process the particular labour allowances in order to obtain the forecast of durations representing the operations.

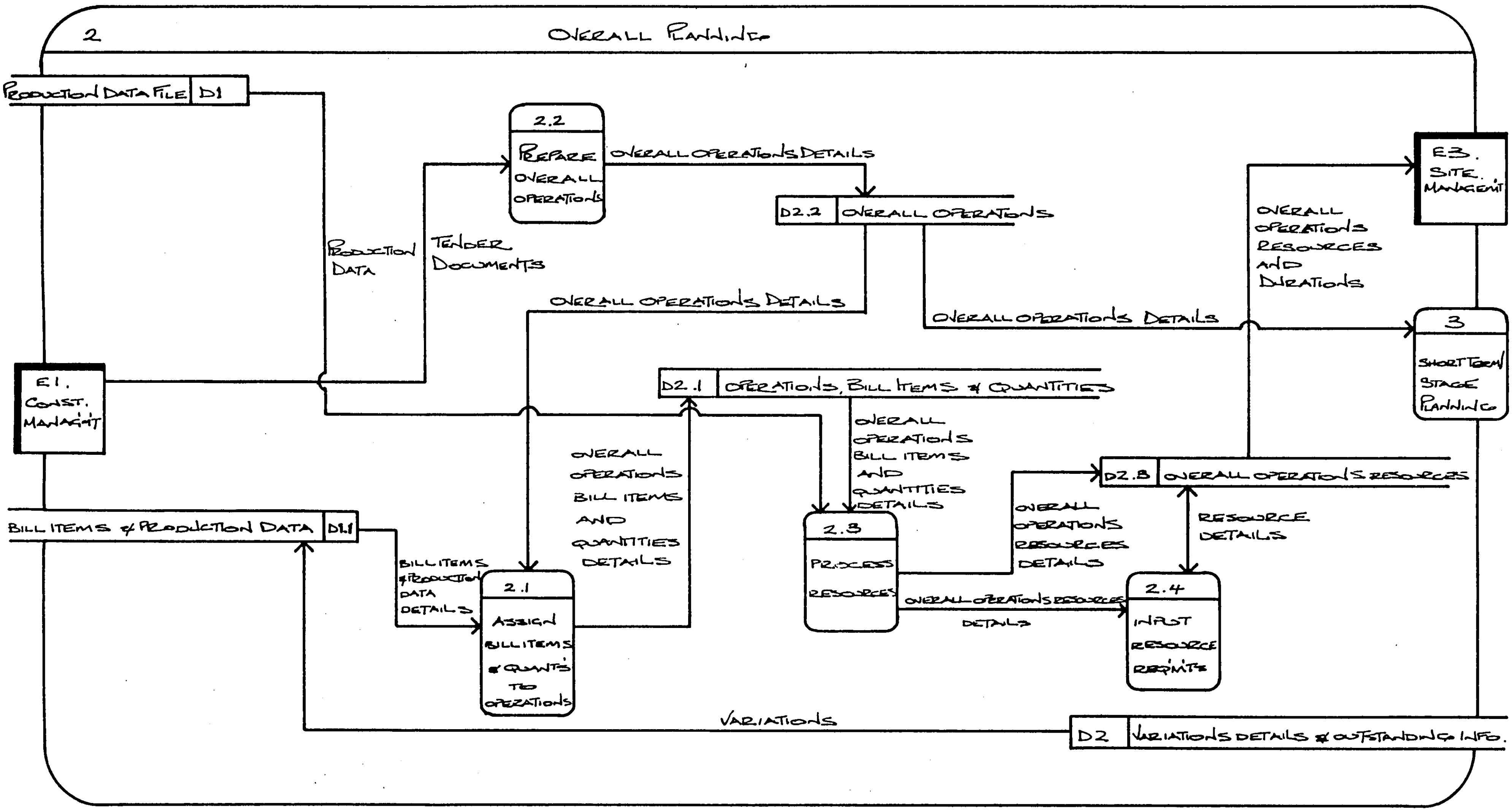

FIGURE 5.7 OVERALL PLANNING PROCESS

At this stage, it is necessary to input resource requirements to the overall operations file, since the labour hours will be represented in totals for the different labour resources. Inputting resource requirements will establish suitable durations for the operations.

5.6 SHORT TERM/STAGE PLANNING PROCESS

The short term or stage planning process represents a sub-division of the overall planning operations. This particular process is illustrated in Figure 5.8.

The same method applies to this level, but the operations need to be considered in a greater level of detail. Bill items therefore need to be sub-divided relating to particular categories within the work sections. This allows the creation of sub-operations or secondary work packages forming part of the overall operation to which they relate.

A file of sub-operations needs to be established representing these sub-divisions of work. This can then be related with the estimate file details so that the specific item categories can be assigned to the relevant sub-operations. This follows a similar pattern to the overall planning process. Processing the data after assigning will generate information for the sub-operation category based on total quantities. With the

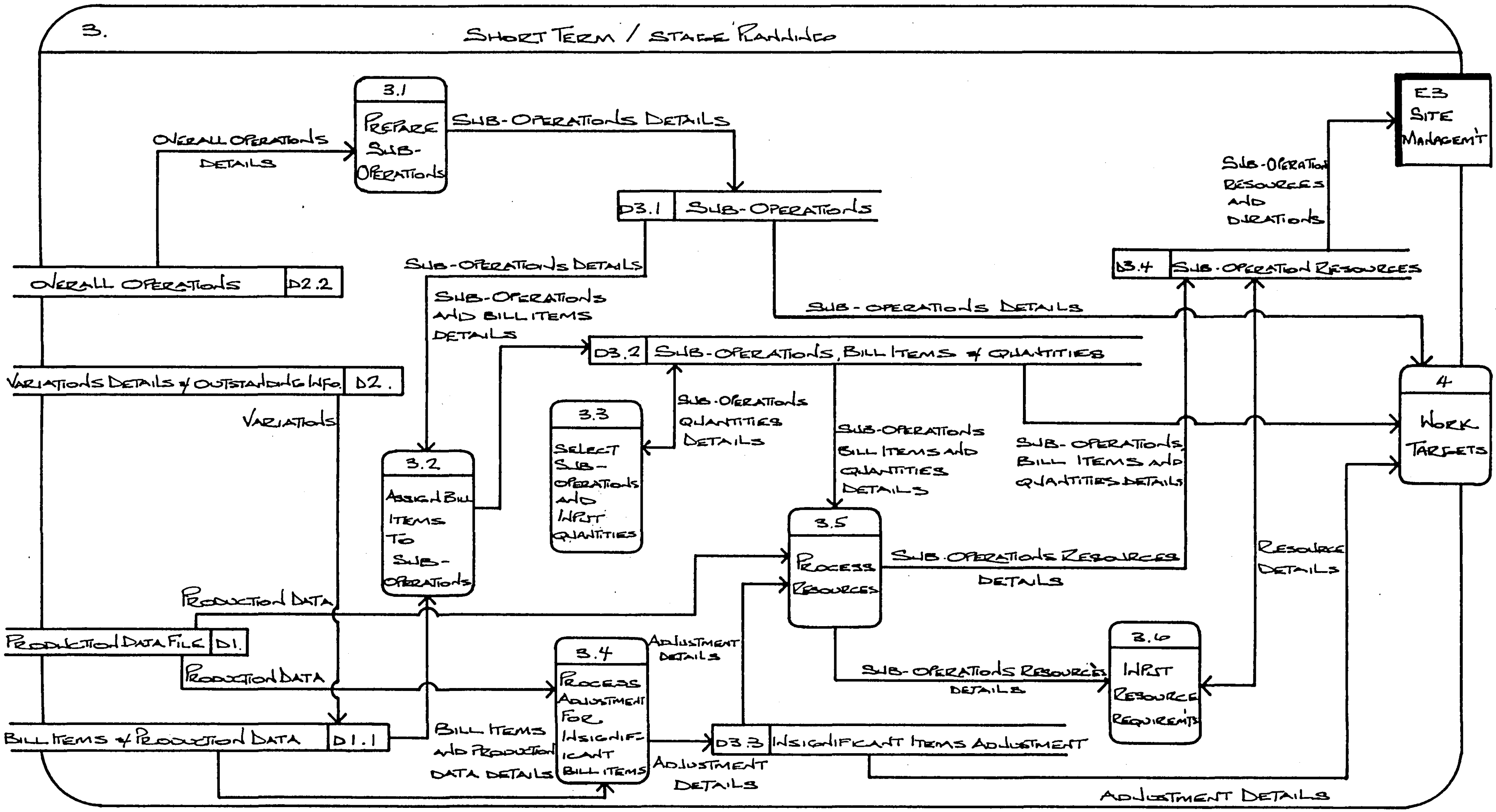

FIGURE 5.8 SHORT TERM / STAGE PLANNING PROCESS

short term planning, however, the major difference is that a sub-division of the total bill of quantities may be required to relate to the precise content of the work package. Quantities must therefore be determined before processing.

One of the major drawbacks with SMM6 is the extent of detailed measurement and the number of items which are cost insignificant. Rather than ignore these items, it is proposed with the model development that the hours representing insignificant items are proportioned over the significant items. Therefore the only quantities required are those for the relevant cost significant items.

Processing the significant items details with an addition for insignificant items will generate hours for sub-operations. Inputting the required resources for gang sizes will allow the duration to be established for each sub-operation. Projection of this information to site will facilitate management decisions at the short term planning stage.

5.7 WORK TARGETS PROCESS

The production of work targets or tertiary work packages is directly related to the short term planning process. The generation of work targets is therefore based on the information developed at the short term planning stage. The short term operations may, on certain projects, represent quite sizeable work packages, and therefore the target generated needs to allow for the sub-division of the work as circumstances dictate. A sub-operation may therefore require sub-division into several work targets.

The logical data flow diagram for the work targets is shown in Figure 5.9. This illustrates the flow of data from the sub-operation data files of the short term planning stage. Upon selecting a sub-operation, the relevant items need to be chosen, together with the corresponding quantities representing the work. This allows the generation of work targets and the preparation of work target reports for use by site management.

5.8 SUMMARY

The whole concept of the planning model is to provide a structure based on the original production data base, thereby allowing the projection of information throughout the construction process.

The methodology proposed is based on the use of bills of quantities prepared in accordance with SMM, which allows for integration with production information requirements. The structuring of the model has also allowed for flexibility and will respond to other forms of measurement, including SMM7. (This will be discussed

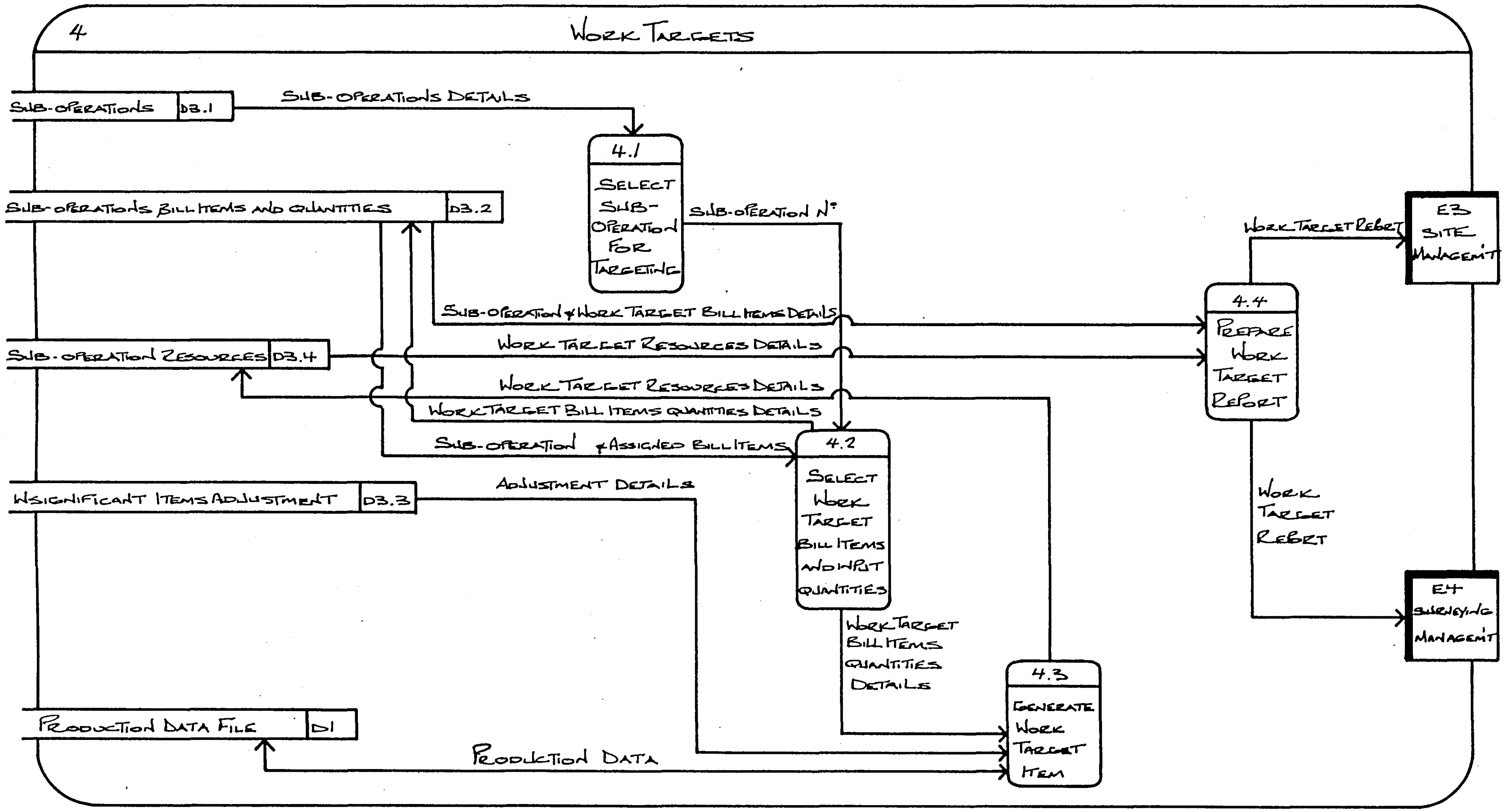

FIGURE 5.9 WORK TARGETS PROCESS

in detail later.)

The use of the bill of quantities for pricing construction work is generally accepted by industry. However, there are deficiencies with the presentation of information in this format, certainly for planning purposes. The proposals of the model therefore brings together both construction measurement aspects with production information requirements. This results in an integrated model which makes possible the production of realistic estimates, planned work operations, and the production of work targets to facilitate the control of labour.

The model so far has only been described at the logical level which illustrates the proposed methodology. The physical interpretation of the model and the development of a system prototype to further test production data and the validity of the proposals are considered in Chapter 6.

CHAPTER 6

COMPUTER IMPLEMENTATION AND APPLICATION OF THE MODEL

6.1 INTRODUCTION

In the previous section, the methodology was established by which planning could be effectively introduced, based on production data and the Standard Method of Measurement. In this chapter, the development work is taken a stage further, and the work is extended by means of computer implementation of the planning model using a standard data base package. Model development details including a data dictionary and process logic are shown in Appendix 3. Planning system files and programs are shown in Appendix 4.

The computerisation of the model is primarily developed as a research tool. This provides the opportunity to use production data for various stages of planning construction work.

6.2 CODING OF BILLS OF QUANTITIES ITEMS

In order to implement the logical model, a coding system was required to suit the work packages at various levels. Much work has been done previously on coding for the construction industry, particularly by the DOE(120) on data coordination. Other researchers have developed coding systems to suit particular system requirements.(121) A system has been established by the PSA(122) in the coding of bill items for the production of bills of quantities. This is based on the principal of acronym codes to suit item descriptions.

For the planning model a coding structure is required to suit the work packages at the various levels of detail. Each bill item has to be related to the various levels of work packages; thus allowing each item to be extracted independently or collectively to suit particular requirements.

For planning purposes items had to be related to operational packages. The most logical way of doing this was to adopt codes which could be easily recognised. Acronym coding to relate items to identifiable classifications and categories was considered to be the most suitable, as codes had to relate to practical operations.

The most suitable part of the bill item description in this respect relates to the fourth level of standard phraseology. Consequently, Fletcher and Moore[123] standard phraseology was consulted as a means of identifying items and assessing the suitability of a code to relate bill items to work packages.

6.2.1 Classification Codes

Considering primary work packages, the basic requirement is the classification to which operations relate, e.g. concrete work or brickwork and blockwork. A code describing the appropriate classification was therefore required. This was based on a six digit acronym code which would allow for expansion to describe any addition features relating to type of classification.

For example concrete work could be coded as follows:

C____ Concrete Work

Bill items coded with the appropriate class code could therefore be assigned to the particular primary work package or overall operation.

6.2.2 Category Codes

For the next level of detail, a more descriptive code was required. The coding needed to include for work packages at a lower level representing sub-operations. This could be considered similar to the fourth level of standard phraseology described earlier in relation to specific categories. In addition to the classification code, an additional code was provided to relate items to the secondary work package or sub-operational level.

As with the classification code, this was based on a six digit acronym code relating to the precise operational description. Examples of concrete category codes would be as follows:

F_____ Foundations

SS____ Suspended slabs

COL___ Columns

The coding allows for expansion to suit more detailed requirements of the particular items.

For example:

ICTCOL Isolated casings to columns

The combination of the two codes would therefore relate each bill item to the particular class and also to the particular category at a more detailed level in operational format.

The complete code for concrete in foundations would be as follows:

C_____ F_____

The item could be retrieved as part of the overall operation of concrete and also as part of the foundation work at a more detailed level of a sub-operation or work target.

The lowest level of planning relates to the tertiary work packages or work targets. For this level it was unnecessary to establish a separate code. Work targets represent a sub-division of sub-operations in terms of quantities. The work target does not normally constitute the whole of the sub-operation (unless circumstances dictate otherwise), therefore separation of the two levels can be made by quantity only.

The main feature of the work package coding is to ensure flexibility. For this reason, coding was not fixed for bill items. Similar bill items can occur in different categories and the coding allows input of codes to suit particular circumstances.

6.3 CODING OF DATA BASE ITEMS

Codes are used for the coding of items in the production data base and for individual resources relating to the production data. Data base item codes were based on four figure numeric codes to distinguish between the various items in the data base. The data base codes are therefore input against relevant bill items in addition to the acronym codes for planning purposes. Within data base items, three figure numeric codes were used for individual resources, and a five digit acronym code for the resource description. Two separate entries for resource references and hours were allowed. This would permit tradesman and supporting labourers to be segregated and allow separate resource hours to be determined. The codes used for resources were:

Reference	Resource	Description
601	CJ	Carpenter/Joiner
602	BL	Bricklayer
603	BLLAB	Bricklayer's labourer
661	GLAB	General labourer

The coded data base item for foundations including resource reference and production data would be as follows:

CODE	ITEM DETAILS		REF	RES	HOURS	REF	RES	HOURS
2805	conc. foundations (d)	m3	661	GLAB	0.24	0		0.00

A listing of the coded data base items is shown in Appendix 5.

6.4 OPERATING THE SYSTEM

The system has been designed to allow the generation of data at various levels based on a modular structure. Modules can be used independently or sequentially to suit individual project requirements.

In the case of large complex projects, all levels of planning may be desirable, and consequently all modules may be used. On the other hand, for small projects, only selected modules may be necessary and these can be used to suit particular circumstances. All the modules are integrated and are all based on the original production data, irrespective of the level of detail required. Figure 6.1 shows the overview of the planning model.

The system prototype is menu driven which allows quick access to other modules or to subsequent lower levels of individual modules. Screen displays with module headings give the precise point of entry which allows easy access to lower or higher level menus.

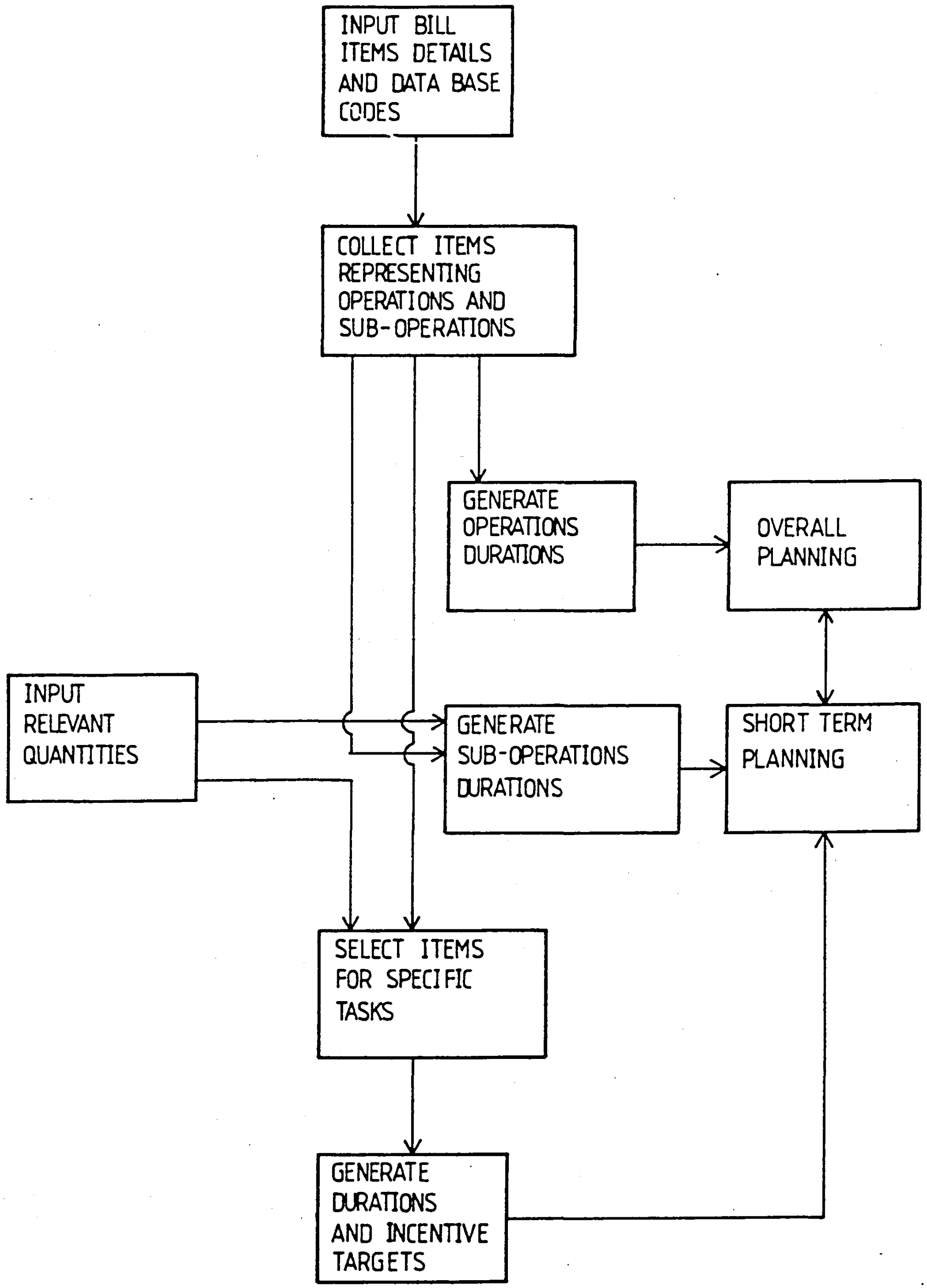

FIGURE 6.1 OVERVIEW OF PLANNING MODEL

6.5 DATA INPUT MODULE

The data input stage requires data from principally two sources:

1. The first is the item reference and description based on a similar format to the Standard Method of Measurement and bills of quantities. Input data are also required at this stage for the coding of work classification and work category, based on acronym codes.

2. The estimating data based on the production data base. Fields are also provided for input in the form of references code, resource code, and output data in the form on multiplication and division fields.

Instances will arise where an item is not in the data base file and it will be necessary to input data initially for estimating purposes which could later be appended to the data base if required.

In adopting this approach labour resources would have to be input into the corresponding fields. For example, if an item not in the data base was to be entered, appropriate codes could be inserted in the reference and resource fields. Four separate resource fields are available for the data input, and multiplication and division fields are provided for data manipulation. An example of coding an item which is not in the data base is shown in Figure 6.2.

BILL ITEMS AND ESTIMATE DETAILS

PAGE	REF	CLASS	CAT.	ITEM DETAILS	QUANT	UNIT
6	d	C	WL	Walls ne 1.5 ht 150-300th	79.00	m3

REF	RES	MULT	DIVI
661	GLAB	0.77	1.00
0		1.00	1.00
0		1.00	1.00
0		1.00	1.00

FIGURE 6.2 ENTERING DATA

If the bill item relates to an item on the production data base file, the only input required for production data is the appropriate data base item code. Such an item would therefore be coded as shown in Figure 6.3

BILL ITEMS AND ESTIMATE DETAILS

PAGE	REF	CLASS	CAT.	ITEM DETAILS	QUANT	UNIT
6	f	C	U	Upstands 0.1-0.25m2	9.00	m3

REF	RES	MULT	DIVI
2905		1.00	1.00
0		1.00	1.00
0		1.00	1.00
0		1.00	1.00

FIGURE 6.3 ENTERING DATA BASE CODES

Other facilities exist in this module for listing the entries as previously input. This allows the bill item details, including the corresponding input data, to be inspected. Two items are listed on each display and subsequent entries are listed on separate pages starting with new screen displays.

Error entries made at the input stage can be corrected by using the amend facility and selecting specific items based on page numbers and item references. This allows amendment of any entries as required. Items can also be deleted from the estimate file should this be necessary. A complete report listing of coded bill items can be obtained based on the same format as the original input (see Figure 6.4).

Based on the input, information can be generated for planning purposes. Costs estimates could be obtained using the input production data, but additional data are also required for resource costs. This part of the model was not computerised since emphasis was placed on generating data in various levels of detail for planning and control.

6.6 OVERALL PLANNING MODULE

The overall planning module is divided into various sub-modules relating to:

1. the creation of overall planning operations;
2. assigning of items to operations;
3. generating resource durations for operations based on production data.

A list of overall operations is first established by means of a data entry screen. Entries consist of operation number and work classification, with the corresponding operation description.

BILL ITEMS AND ESTIMATE DETAILS

PAGE	REF	CLASS	CAT.	ITEM DETAILS	QUANT	UNIT
5	a	C	B	Beds ne 100th	32.00	m3

REF	RES	MULT	DIVI
2830		1.00	1.00
0		1.00	1.00
0		1.00	1.00
0		1.00	1.00

PAGE	REF	CLASS	CAT.	ITEM DETAILS	QUANT	UNIT
5	b	C	F	Foundations over 300th	139.00	m3

REF	RES	MULT	DIVI
2805		1.00	1.00
0		1.00	1.00
0		1.00	1.00
0		1.00	1.00

PAGE	REF	CLASS	CAT.	ITEM DETAILS	QUANT	UNIT
5	c	C	F	Foundations 150-300th	53.00	m3

REF	RES	MULT	DIVI
2810		1.00	1.00
0		1.00	1.00
0		1.00	1.00
0		1.00	1.00

PAGE	REF	CLASS	CAT.	ITEM DETAILS	QUANT	UNIT
5	d	C	IFB	Isolated foundation bases	261.00	m3

REF	RES	MULT	DIVI
2805		1.00	1.00
0		1.00	1.00
0		1.00	1.00
0		1.00	1.00

PAGE	REF	CLASS	CAT.	ITEM DETAILS	QUANT	UNIT
5	e	C	MB	Machine bases	1.00	m3

REF	RES	MULT	DIVI
2820		1.00	1.00
0		1.00	1.00
0		1.00	1.00
0		1.00	1.00

PAGE	REF	CLASS	CAT.	ITEM DETAILS	QUANT	UNIT
5	f	C	ICTB	Iso casing to beams 0.03-0.1m2	1.00	m3

REF	RES	MULT	DIVI
2930		1.00	1.00
0		1.00	1.00
0		1.00	1.00
0		1.00	1.00

FIGURE 6.4 LISTING OF CODED BILL OF QUANTITIES ITEMS

Only the classification code is required at this level, since detail is limited to primary work packages or overall operations. An example of an overall operation entry is shown in Figure 6.5.

OP.NO.	CLASS	OPERATION DESCRIPTION
1	C	CONCRETE WORK

FIGURE 6.5 ENTRY OF AN OVERALL OPERATION

The assigning module (where items are assigned to operations) uses the two data base files previously created; one containing operation details and the other bill item and production data details. The assigning process concatenates the two files to form a combined file based on code matching of work class for overall operations and bill items. Once created, this data base file provides the basis for the use of other parts of the module. Screen listing and reports of the assigned items for selected operations, can be generated (See Figure 6.6).

OVERALL OPERATIONS AND ASSIGNED ITEMS

OPERATION NO. 1 CONCRETE WORK

PAGE	REF	CLASS	CAT.	ITEM DETAILS	QUANT	UNIT
5	a	C	B	Beds ne 100th	32.00	m3
5	b	C	F	Foundations over 300th	139.00	m3
5	c	C	F	Foundations 150-300th	53.00	m3
5	d	C	IFB	Isolated foundation bases	261.00	m3
5	e	C	MB	Machine bases	1.00	m3
5	f	C	ICTB	Iso casing to beams 0.03-0.1m2	1.00	m3
5	g	C	ICTCOL	Iso casings to cols > 0.25m2	1.00	m3

FIGURE 6.6 EXAMPLE OF AN OVERALL OPERATION AND ASSIGNED ITEMS

From the assigning process, overall operations details can be generated based on assigned items. Each bill item in the combined file relating to a selected operation is inspected for its production data resources. The resource codes are checked for each of the four resource fields.

Inspection checks to see if the code relates to a standard item*, and if this is the case, the corresponding details of code references, resource description, and resource hours are extracted from the standard items file and inserted in the overall operations resource file. If the code reference is not a standard item on the data base file, the code, resource description and hours representing the production data for the item are entered directly into the resource file.

The corresponding hours allowed for the production data are calculated based on the multiplication and division fields, and multiplied by the corresponding bill item quantity to obtain the total hours for the bill item. Each time similar reference and resource codes are located, the corresponding hours are totalled against the total hours for those codes in the resource file.

---

* A standard item represents a previously determined production data base item in terms of resources and output, and is stored within the system in a standard items file

Codes which have not been encountered previously, are stored in the resources file as a separate entry along with the corresponding hours.

At the end of processing, all the operation items have been analysed and a summary of the resources has been stored in the resource file. This takes the form of a list of all the different references and resources that have been used in the operation, together with the corresponding hours allowed. This information is displayed on the screen and prompts the user for resources input.

At each resource description a factor can be entered, if required, to provide the opportunity for adjustment to the production data. Resource numbers can also be entered to represent a chosen gang size for the particular resource.

This allows durations to be obtained based on the following algorithms:

Overall operation duration (hours) =

$$\frac{\text{Total resource hours}}{\text{Gang size}}$$

Overall operation duration (weeks) =

$$\frac{\text{Overall operation duration (hours)}}{40}$$

Adjusted overall operation duration (hours) =

$$\frac{\text{Overall operation duration (hours) x factor}}{\text{Gang size}}$$

Adjusted overall operation duration (weeks) =

$$\frac{\text{Adjusted overall operation duration (hours)}}{40}$$

The resulting display of resource requirements produces the total duration for the operation in hours and weeks. Additionally, an adjusted duration is provided, if required, in hours and weeks based on an adjustment factor and the gang size chosen (See Figure 6.7).

REF	RES	HOURS	FACTOR	NO.	HOURS	WEEKS	ADJ.HOURS	ADJ.WEEKS
661	GLAB	1803.32	0.80	4	450.83	11.2	360.66	9.0

FIGURE 6.7 EXAMPLE OF A RESOURCE AND DURATIONS

This procedure is repeated for each of the listed resources, thus producing durations for each resource within the overall operation selected.

Input data of factors and resource numbers can be changed by the amend facility, thus generating revised durations. Facilities for screen listing these details and obtaining a report listing can also be obtained as in previous modules (see Figure 6.8).

OVERALL OPERATIONS DETAILS

OPERATION NO. 1 CONCRETE WORK

RESOURCE DETAILS			RESOURCE REQUIREMENTS					
REF	RES	HOURS	FACTOR	NO.	HOURS	WEEKS	ADJ.HOURS	ADJ.WEEKS
661	GLAB	1803.32	0.80	4	450.83	11.2	360.66	9.0

OPERATION NO. 2 BRICKWORK AND BLOCKWORK

RESOURCE DETAILS			RESOURCE REQUIREMENTS					
REF	RES	HOURS	FACTOR	NO.	HOURS	WEEKS	ADJ.HOURS	ADJ.WEEKS
602	BL	9300.93	0.96	8	1162.61	29.0	1116.11	27.9
663	BLLAB	4694.87	0.96	4	1173.71	29.3	1126.76	28.1

FIGURE 6.8 EXAMPLE OF OVERALL OPERATIONS DETAILS

6.7 SHORT TERM/STAGE PLANNING MODULE

The short term/stage module is based on a similar procedure to that of the overall planning module. The major difference is that code matching is based on class and category for secondary work packages or sub-operations, since it is required to establish the planning information in more detail. This allows for separate secondary work packages or sub-operation durations to be obtained which may be inter-related within the overall operation.

A sub-operations file is set up similar to the overall operations file. Bill items are assigned to sub-operations combining the sub-operations file with the original file of bill items and production data, matching on work class and category codes.

The major difference between this module and the overall planning module is the assigning process. In short term planning, assigning is designed to concentrate on cost significant items only for particular work sections. Items considered to be cost insignificant are coded as 'SUN' (representing a sundry item) in the category code to distinguish these from significant items.

Based on the analysis work of Chapter 4, it was found that sundry items contribute little to the number of hours representing the work package. Rather than ignore these completely, subsequent items of cost insignificance are equally proportioned over the total measure of cost significant items. For in-situ concrete, the significant items are those representing measured work in cubic metres.

In the PSA[124] study involving the analysis of over fifty bills of quantities, sundries for concrete work including such items as labours, surface treatments, dowel bars and design joints, etc., have shown to be 2% to 8% of the total value of the concrete section. The percentage of sundry items within each of the targets set from the first sample projects was found to be 17.40%. It was considered, therefore, that the hours allowed for these items ought to be represented by an adjustment calculated on the basis of additional hours per cubic metre. The adjustment rate could be calculated from the total hours representing sundry items divided by the total measure of cubic metres representing significant items, thus the rate of hours per cubic metre could be obtained. When generating a duration for a specific operation the total hours for sundry items would be calculated by multiplying the cubic metres representing significant items and the rate of hours per cubic metre. This would be then be added to the total hours for significant items.

For example, calculated hours for a selected significant item representing the work would be based on the algorithm:

$$\text{Hours} = (A \times A1 \text{ hrs}) + (A \times \frac{Y}{X})$$

where: A = number of cubic metres of concrete in the operation

A1 = production data hours per cubic metre for the significant item

Y = total hours for sundry items in the concrete section

X = total number of cubic metres in the concrete work section

It was realised at the outset that this method would introduce inaccuracies in terms of the total number of hours allowed for particular stages of work. Some stages may reflect a greater number of insignificant items than other sections, and a situation develops where certain sections are overstated and others understated in terms of hours. The extent of such inaccuracies, however, was considered to be negligible for planning purposes. (See

Chapter 8 for effect on incentives.)

A similar approach of adding an adjustment for cost insignificant items was also adopted for the brickwork and blockwork section, but in this instance the basic unit of measure was the square metre. Items of minor significance in this work section include forming cavities, raking out joints, pointing, etc., and the value of these items from the PSA study were found to be 2% to 6% of the total value of work. In the first sample projects, sundry items were found to be 7.85% of the targets set for brickwork and blockwork.

The woodwork section is not calculated on this principle because of the way items are measured under SMM. The woodwork section contains significant items of different units of measure, and so a common unit covering all significant items is difficult to establish. Items in the woodwork section have therefore to be considered individually along with the appropriate quantities.

In short term planning for all work sections, the most accurate representation of a sub-operation in terms of measured items and the bill of quantities will be the particular items and corresponding quantities that represent the particular sub-operation. This means that to arrive at the allowed hours, a detailed take-off is first required for the relevant work items. This represents the most accurate form of presentation as far as the bill of quantities is concerned.

With the woodwork section this approach is unavoidable. To adopt this method for the concrete section was felt to be unnecessary, since previous assessment by the PSA showed sundry items to be less than 20% of the total value. The actual contribution of these items, would, for the contractor, not justify the time spent in taking-off quantities.

The methods of proportioning sundry items over the significant items, and individual selection of items representing work packages have therefore been introduced into the prototype development. Concrete work and brickwork and blockwork sections have been based on the first method of proportioning for sundry items. The woodwork section, because of the variation in measured items, is based on the second method of individual item selection. Computer implementation of the model is to test the validity of production data, and the methods described have been introduced for this purpose.

When the relevant bill items have been assigned to sub-operations in the short term planning module, it is necessary to select the specific items together with quantities that represent the particular work package. This is necessary when considering sub-operations since only a proportion of the total quantity may be applicable to the work package.

A screen is provided to allow the input of quantities, representing the sub-operation. If items are not included in the particular sub-operation, no quantities are entered and these items are excluded from the processing. The facility exist to change these input quantities should the need arise.

Generating the resource hours for the sub-operations is based on the procedure described for overall planning. A summary of the resources used and the corresponding hours are displayed, allowing the input of factors and resource numbers to obtain the durations for each resource. An Additional allowance in the processing is included for the proportion of insignificant items as previously explained. Example listings of sub-operations, assigned items and sub-operations are shown in Figures 6.9 to 6.11.

6.8 WORK TARGETS MODULE

Whilst the short term planning stage can represent work up to several weeks in duration, the targetting of work represents only a part of this total duration. The work targets module therefore represents a further sub-division of the short term planning module. This relates to particular sections of sub-operations in the form of work targets or tertiary work packages.

LIST OF SUB-OPERATIONS

SUB-OP.NO.	CLASS	CAT.	SUB-OPERATION
1	C	F	FOUNDATIONS
2	C	IFB	ISOLATED FOUNDATION BASES
3	C	MB	MACHINE BASES
4	C	B	BEDS
5	C	ICOL	ISOLATED COLUMNS
6	C	IB	ISOLATED BEAMS
7	C	ICTB	ISOLATED CASINGS TO BEAMS
8	C	ICTCOL	ISOLATED CASINGS TO COLUMNS
9	C	SS	SUSPENDED SLABS
10	C	WL	WALLS
11	C	U	UPSTANDS
12	C	S	STAIRS

FIGURE 6.9 EXAMPLE LIST OF SUB-OPERATIONS

SUB-OPERATION ITEMS AND QUANTITIES

SUB-OPERATION NO. 1 FOUNDATIONS

PAGE	REF	CLASS	CAT.	ITEM DETAILS	QUANT	UNIT
5	b	C	F	Foundations over 300th	139.00	m3
5	c	C	F	Foundations 150-300th	53.00	m3
5	i	C	F	Foundations over 300th	15.00	m3
25	e	C	F	Foundations over 300th	515.00	m3
25	f	C	F	Foundations 150-300th	1.00	m3

FIGURE 6.10 EXAMPLE OF SUB-OPERATION AND ASSIGNED ITEMS

SUB-OPERATIONS DETAILS

SUB-OPERATION NO. 1 FOUNDATIONS

RESOURCE DETAILS					RESOURCE REQUIREMENTS			
REF	RES	HOURS	FACTOR	NO.	HOURS	WEEKS	ADJ.HOURS	ADJ.WEEKS
661	GLAB	471.15	1.00	4	117.78	2.9	117.78	2.9

SUB-OPERATION NO. 2 ISOLATED FOUNDATION BASES

RESOURCE DETAILS					RESOURCE REQUIREMENTS			
REF	RES	HOURS	FACTOR	NO.	HOURS	WEEKS	ADJ.HOURS	ADJ.WEEKS
661	GLAB	65.16	1.00	4	16.29	0.4	16.29	0.4

SUB-OPERATION NO. 3 MACHINE BASES

RESOURCE DETAILS					RESOURCE REQUIREMENTS			
REF	RES	HOURS	FACTOR	NO.	HOURS	WEEKS	ADJ.HOURS	ADJ.WEEKS
661	GLAB	0.88	1.00	2	0.44	0.0	0.44	0.0

SUB-OPERATION NO. 4 BEDS

RESOURCE DETAILS					RESOURCE REQUIREMENTS			
REF	RES	HOURS	FACTOR	NO.	HOURS	WEEKS	ADJ.HOURS	ADJ.WEEKS
661	GLAB	677.47	1.00	4	169.36	4.2	169.36	4.2

SUB-OPERATION NO. 5 ISOLATED COLUMNS

RESOURCE DETAILS					RESOURCE REQUIREMENTS			
REF	RES	HOURS	FACTOR	NO.	HOURS	WEEKS	ADJ.HOURS	ADJ.WEEKS
661	GLAB	32.96	1.00	4	8.24	0.2	8.24	0.2

FIGURE 6.11 EXAMPLE LIST OF SUB-OPERATIONS DETAILS

Bill items and quantities representing this level of work package must therefore be selected from the appropriate sub-operation.

The work target module has been based on the sub-operation items, and relevant target items are selected from the items assigned to sub-operations. Quantities are input as previously described, and items in which quantities are not entered are ignored.

Processing utilises the adjustment method previously described, for concrete work and brickwork and blockwork, and the adjustment addition calculated is equally apportioned between the resources in the target. When the production hours are calculated they are displayed on the screen allowing the factor input, if required, to adjust production data. A percentage addition can also be applied, representing a bonus increment, to obtain the target hours.

Within this module a facility exists for a report listing of the work targets. The report can be used to record outputs for feedback information for estimating and construction management. A sample work target listing is shown in Figure 6.12.

WORK TARGET ITEM

SUB-OPERATION NO. 1 FOUNDATIONS

PAGE REF	CLASS	CAT.	ITEM DETAILS	QUANT	UNIT
5 c	CSUB	FT	Foundations 150-300th	45.00	m3

REF	RES	PROD.HRS	ACT.HRS	GANG	HRS.SAVED	REMARKS	ADJ.O/P
661	GLAB	34.34					
		34.34					
	FACTOR	1.00					
	ADJ.HRS	34.34					
	BONUS %	30					
	TARGET HRS	44.64					

FIGURE 6.12 WORK TARGET ITEM DETAILS

6.9 SYSTEM MAINTENANCE

The system maintenance module is concerned with the standard item details of the production data base. The items representing average performances which were obtained from the first sample projects, were coded and entered into a separate standard items file. In addition to the code used for each item, the production hours have been entered with the appropriate reference and resource code (See Appendix 5 for coded data base items).

Facilities within this module include for adding or amending items, together with screen and report listings. This module would also act as a regulator for the production data base. From feedback data, productivity performances could be updated accordingly.

6.10 SENSITIVITY OF THE SYSTEM PROTOTYPE TO CHANGING CONDITIONS

The changing of work content throughout the construction process is common to all projects. In certain cases architect's instructions start to appear from the first day on site; so any attempt to provide information by which to control construction operations would have to be flexible to respond to changing situations.

This problem was realised at the early stages of development, particularly for measured bill items. As a direct consequence the system prototype has the facilities within each module to make any necessary changes.

This takes the form of the create, amend, and delete facilities present in each module. The most important one initially is the input of bill items and production data. Any changes made to this file, must also be reflected throughout the operations which have been created in other modules. Changes can be made by re-assigning the items to operations so that any alterations to bill items will overwrite the existing details. Re-generating the resource durations will then produce the revised figures reflecting the changes made.

As a result, a task that would seem to render manual adjustment as a worthless exercise can be done speedily by computer implementation.

6.11 APPLICATION OF THE MODEL

The model development and system prototype have illustrated the application of the work package concept, and the generation of information at various levels of detail. Estimating from the data base is equally important for tendering purposes to ensure that the net cost estimate established is representative of the cost of the works. It is also important to provide integration between estimating, planning and control. This overall concept is illustrated in Figure 6.13.

6.11.1 Estimating

The pricing of construction work for bills of quantities in accordance with SMM is based on the unit rate concept of cost. The total cost in this context refers to the total of the cost components representing the particular bill item, which may include the various components of labour, plant and materials. The build up of the unit rate and the components of each element is shown in Figure 6.14. The cost of resources need to be provided in addition to the established production data in order to build up unit rates and obtain the net cost estimate.

The labour element is represented by two components of labour costs and labour effort. These can be expressed by the equations:

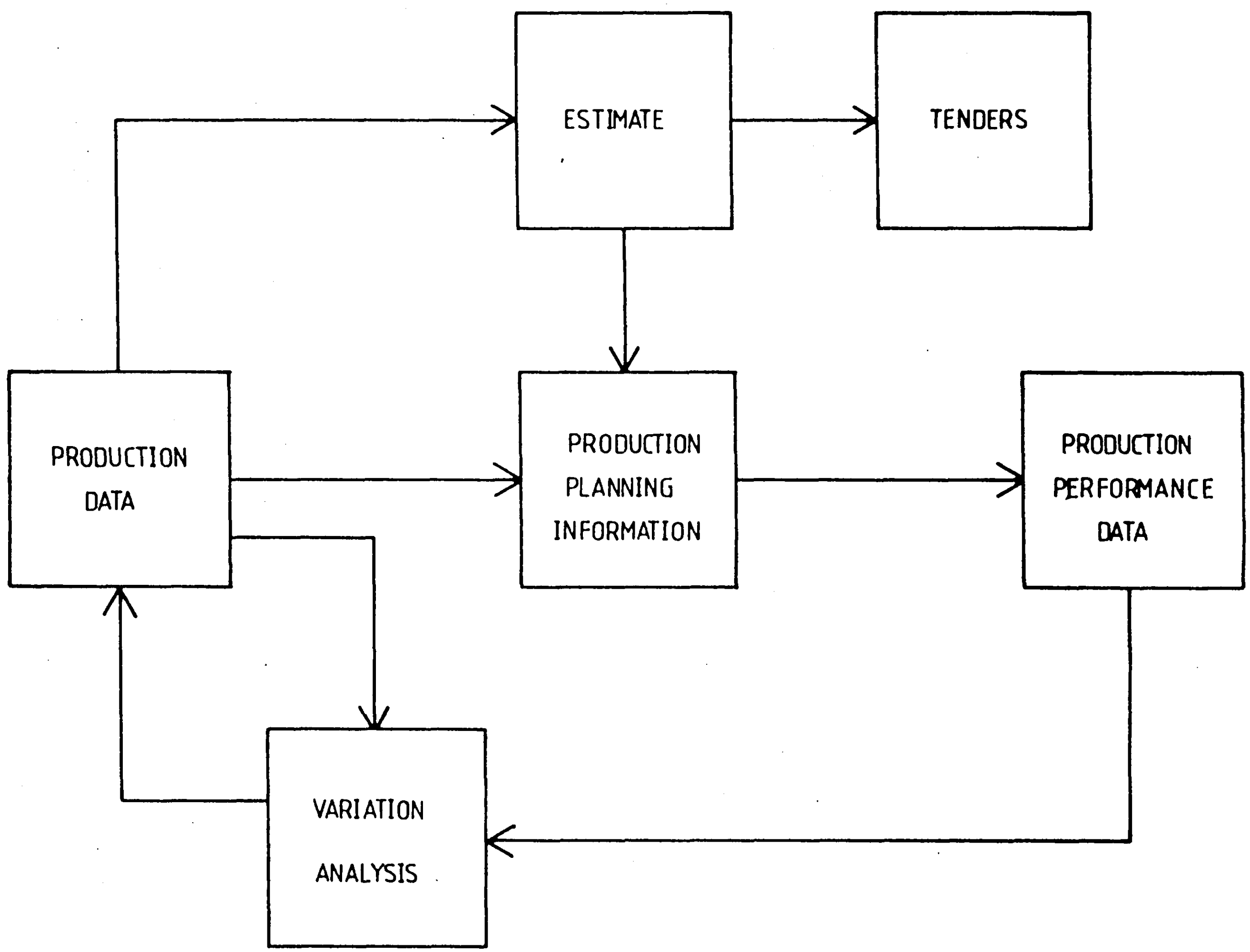

FIGURE 6.13 ESTIMATING, PLANNING AND CONTROL OF CONSTRUCTION

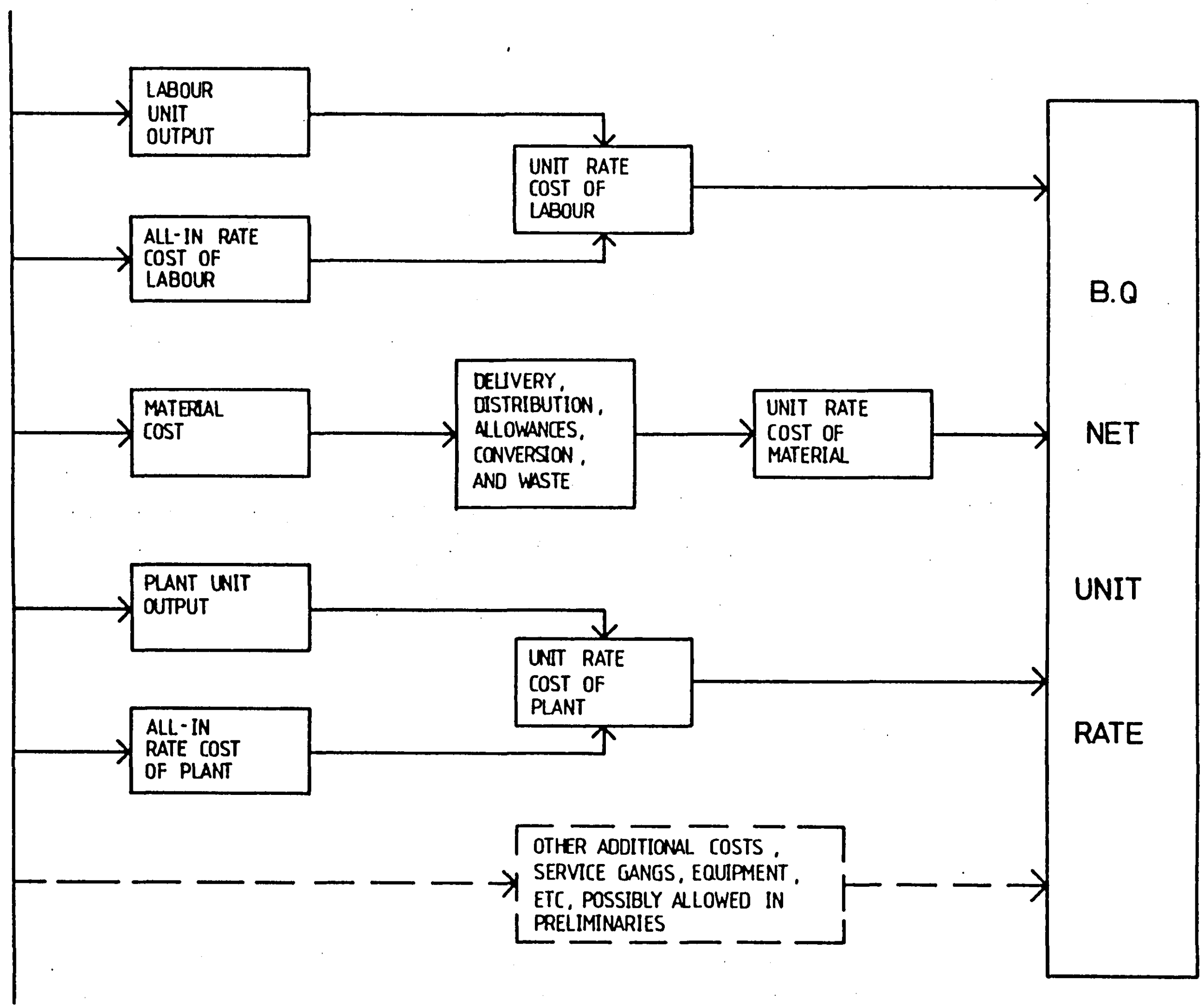

FIGURE 6.14 BUILD-UP OF THE ESTIMATE NET UNIT RATE

Unit rate labour cost $C = L \times P$

where L = all-in rate cost of labour

P = unit output of labour effort

Total labour cost $T = C \times Q$

where C = unit rate labour cost

Q = total quantity

The part of the calculation which refers to the labour effort, is the part which can be considered as the unit output of labour for the particular item. This relates to the production data in the established data base.

Production data can be defined as the time spent carrying out the operation. This includes all the specific work items included in the operation as described in Chapter 4 Section 4.5. Allowances for additional items related to the operation will have to be made accordingly. In particular, transportation of materials over greater distances than allowed in the work target will have to be included. Normally on large projects, such activities would be the responsibility of a service gang, and such costs may well be included in the preliminaries section of the bill of quantities.

The cost of the labour can be determined by calculating the all-in rate. This would include the various wage rates of operatives, together with any plus rates under the 'Working Rule Agreement'[125] and the cost of employer's overheads and allowances for wet time, absenteeism, etc. The actual number of items included in the all-in rate cost of labour will, and does, vary between contractors, but the 'Code of Estimating Practice'[126] published by the CIOB outlines recommended procedures for obtaining the total cost.

For pricing the labour element of bill items, the established data base needs to be utilised. It is essential that the estimate for labour is consistent with the information generated in the form of work packages for planning and control purposes. Thus the pricing of bill items will have to be in strict compliance with the data base.

The productivity performance of data base items can be used to obtain labour costs for significant bill items, and also sundry items identified and included in the data base.

Based on the SMM6 form of measurement, the insignificant sundry items not included in the data base would not represent any labour costs in the bill of quantities. Items that were not measured in the data collection would be deemed to be included in the significant bill items. Allowing for labour costs on such items would therefore constitute a double measure, and only the material cost of the bill item, if applicable, needs to be allowed. If such bill items represent labour only, they would not be priced and would be classed as included.

6.11.2 Planning

The planning information generated can be used directly on site to produce various detailed programmes. The generation of data at various levels of detail can be used appropriately for overall planning and the generation of work targets. The integration of estimating and planning will provide a direct relationship with the net cost estimate and planned production. This will provide information in the required amount of detail to suit the requirements of management.

6.11.3 Control of Data Base Outputs

The production data can be used to monitor future projects in relation to the productivity times expected. Such procedures would enable control by the use of forecast-observation diagram (See Chapter 7). The recording of information from site would permit variance analysis of outputs. Control can also be initiated by using tolerances derived from past forecasting errors. If consistency in variation was detected the appropriate data base rates could be updated accordingly.

6.12 IMPLICATIONS OF SMM7

Whilst SMM6 is the method of measurement that has been considered in this study, proposals have been finalised for the introduction of the new SMM7. This has been based on the work of the Development Unit, set up to prepare the SMM7, in accordance with the Coordinating Committee for Project Information (CCPI). It is anticipated that the document will be in use sometime in 1988.

When considering the development of the model and its computerisation, assessment was made of the consultative documents and the major changes likely to occur with the new SMM7. As described in Chapter 2, a prominent feature of the SMM7 is the reduction in the number of measured items for certain work sections. SMM7 is sectionalised more in line with the actual building process, providing a more direct relationship between design and construction. However, from the research work on SMM6 and its implications with regard to planning construction work, it is seen that some problems will still exist with SMM7.

6.12.1 Work Packages and SMM7

Bill items were assessed[127] to consider the implications of planning work under SMM7. Considering the way contractors organise their work, the concept of work packaging at various levels adopted earlier is still an essential requirement with SMM7.

Whilst SMM7 has been structured in work packages, situations will arise in practice where items need to be collected to represent work packages for planning purposes, particularly at the tertiary level. This will present problems since certain items required to form a tertiary work package are contained in different sections of SMM7. Typical examples would include doors, architraves, skirtings and ironmongery. In SMM7, doors are in a different section to the other items, but from the analysis of targets used on site these items are commonly grouped together to form a tertiary work package for woodwork second fixings.

Obtaining hours for a tertiary work package from items in different section of SMM7 would be difficult based on the item referencing of classification tables.

Since the recent finalisation and publication of SMM7, further research needs to be carried out in this area to consider the practical implications of SMM7.

Contractors need to generate information in the detail required for construction operations. Short term planning and the generation of work targets form an important part of the construction process, and work packages will have to be formulated to meet these requirements.

6.12.2 Production Data and SMM7

Items measured under SMM7 are deemed to include many of the insignificant items that were measured separately under SMM6. Similarly, from work measured during the production stage of the first sample projects, it was found that many of the insignificant items in the bill of quantities were not measured separately in the work targets. For practical purposes, these were deemed to be included in the main measure. In the majority of cases the sundry items included in the target were those considered to be worthy of measurement. In this respect it could be considered that the productivity performances of the significant items established in the data base would not vary considerably from those measured under SMM7. Furthermore, it is unlikely that contractors will change their practical procedures to suit SMM7, so a model developed around present practices which can respond to SMM7 type of measurement should remain relevant.

6.13 SUMMARY

In this chapter an explanation has been given to the approach adopted in linking estimating with production planning. Various modules have been discussed together with their integration. Computerisation of the model has been shown to be successful in providing a link between documentation in the form of bills of quantities and production information requirements.

The processing methodology offers a new approach to utilising production data, which introduces proportioned additions for insignificant items of in-situ concrete, and brickwork and blockwork, whilst retaining individual selection of items for woodwork. The methodology proposed in the developed model is equally applicable to both SMM6 and SMM7.

Whilst the production data base has been established, and the development of a model illustrated, the practical implications and effectiveness of the proposals need to be tested further. This testing is carried out on a second sample of independent projects which forms the subject of the validation study in Chapter 7.

CHAPTER 7

VALIDATION STUDY

7.1 INTRODUCTION

In Chapter 4 the data collection and analysis led to the formulation of the production data base from the first sample projects. Data were also analysed to consider the data base accuracy in relation to the other forms of data available. This was followed by the development of the model in Chapter 5 and its subsequent computerisation discussed in Chapter 6.

In this chapter the work of the previous chapters are brought together to test the data base further and to assess the reliability of the developed model as a vehicle for generating planning and control information.

In order to test the data base and model, a second sample of projects was selected which were independent of the first sample. A brief description of the projects is provided. The process of generating data from the projects for validation purposes is also explained.

Data are assessed at the tertiary, secondary and primary levels for concrete work, and brickwork and blockwork. No woodwork data were available from the second sample projects.

Forecast-observation diagrams are produced to observe the behaviour of the data in relation to the line of perfect forecasts. Statistical measures are recorded relating to the forecast-observation diagrams for ranges and dispersions.

The measure of effectiveness of second sample forecasts are made based on the performances from first sample projects. The effective tolerance or control limits are established from plus or minus one standard error of estimate from first sample projects. The plots of the models for first sample projects are shown in Appendix 2.4.

Accuracy of production data is also compared with present methods of forecasting which include estimators' data and the targets set by bonus surveyors.

Assessment of data at the primary level follows the same sequence of analysis.

7.2 SECOND SAMPLE PROJECT DESCRIPTIONS

The projects selected for the validation study are shown in Table 7A together with their approximate value.

The 'hotel B' project comprised a three-storey structure including basement. Accommodation consisted of one hundred and thirty bedrooms, reception and dining areas, including conference rooms.

The structure was of load-bearing brickwork with

PROJECT	PROJECT VALUE
1. Hotel B	£4.2m
2. Hospital B	£6m

TABLE 7A SUMMARY OF SELECTED PROJECTS (SECOND SAMPLE)

concrete upper floors and a pitched roof. The external brickwork was highly decorative with much circular work including arched windows. The internal work was of high class finishings including sophisticated electrical and mechanical installations.

The high quality requirements on all parts of the building resulted in a highly labour orientated project. At the peak of construction work approximately one hundred operatives were employed consisting of bricklayers, joiners, labourers and sub-contractor labour. The duration for construction of the project was approximately nineteen months.

The 'hospital B' project comprised of a two-storey maternity unit with a single-storey pharmacy. The new building also included the construction of a link corridor to an existing hospital building. Additional work included services, drainage, access roads and external works.

Construction of the maternity unit was of load-bearing brickwork with concrete upper floors and blockwork inner walls. The pitched roof consisted of steel trusses with concrete tiles and timber rafters.

The pharmacy section was of steel frame construction with a flat roof. External walls were of brickwork and blockwork with inner walls of blockwork. The link corridor was also of steel frame construction with a flat roof. External walls were of brickwork and blockwork construction. All glazed areas to the building consisted of aluminium windows.

At the peak of the construction work the project maintained sixty directly employed operatives, including bricklayers, joiners and labourers. The duration for construction of the project was approximately thirty months.

7.3 GENERATION OF SECOND SAMPLE DATA

Generating second sample data consisted of extracting sections from the bills of quantities and applying them to the computerised model. For concrete and the brickwork and blockwork section, this involved the input of the entire measured section from the bill of quantities which allowed the addition to be calculated for cost insignificant bill items, as described in Chapter 6.

The input of data into the system prototype was based on bill of quantities items and quantities. This allowed the generation of data in operational format based on the established data base. The durations of operations predicted could then be compared with the actual times recorded.

In the case of brickwork and blockwork the construction work packages included both brickwork and blockwork categories, as expected for external walling, and therefore these were not categorised into individual operations. They were coded under the same sub-operation. When integration of these work categories occurred, the appropriate items of either brickwork or blockwork were selected representing the work package.

Using the generated data for each of the data sets, forecast-observation diagrams were established for each work category in order to examine the accuracy of production data. Work categories examined were restricted to items in the data base which were representative of several projects.

7.4 SECOND SAMPLE PRODUCTION DATA ANALYSED

7.4.1 Concrete Work at the Tertiary and Secondary Levels

Assessment of concrete work was based on the categories of foundations; floor slabs; and suspended slabs, stairs and landings.

7.4.1.1 Concrete in Foundations

For foundation work in the 'hospital B' project, the productivity illustrated bias towards underestimation (See Figure 7.1). This may have been caused by the complex foundation design on this project. The evidence of varying ground conditions may also have been influential.

7.4.1.2 Concrete in Floor Slabs

The general assessment of the floor slab category produced various results; cases of overestimation and underestimation were evident. In the 'hotel B' project, outputs illustrated consistency with points scattered about the line of perfect forecasts. Consistency was maintained for work packages representing 20 hours, but above this size of work package there was an increase in scatter (See Figure 7.2).

In the 'hospital B' project there was a clear case of overestimation. The productivity on this project indicated much improvement over the 'hotel B' project. The variation on 'hospital B' also illustrated an increase with larger size work packages (See Figure 7.3).

Such behaviour suggests that organisational efficiency and motivation of operatives are accountable rather than inaccuracies in the production data.

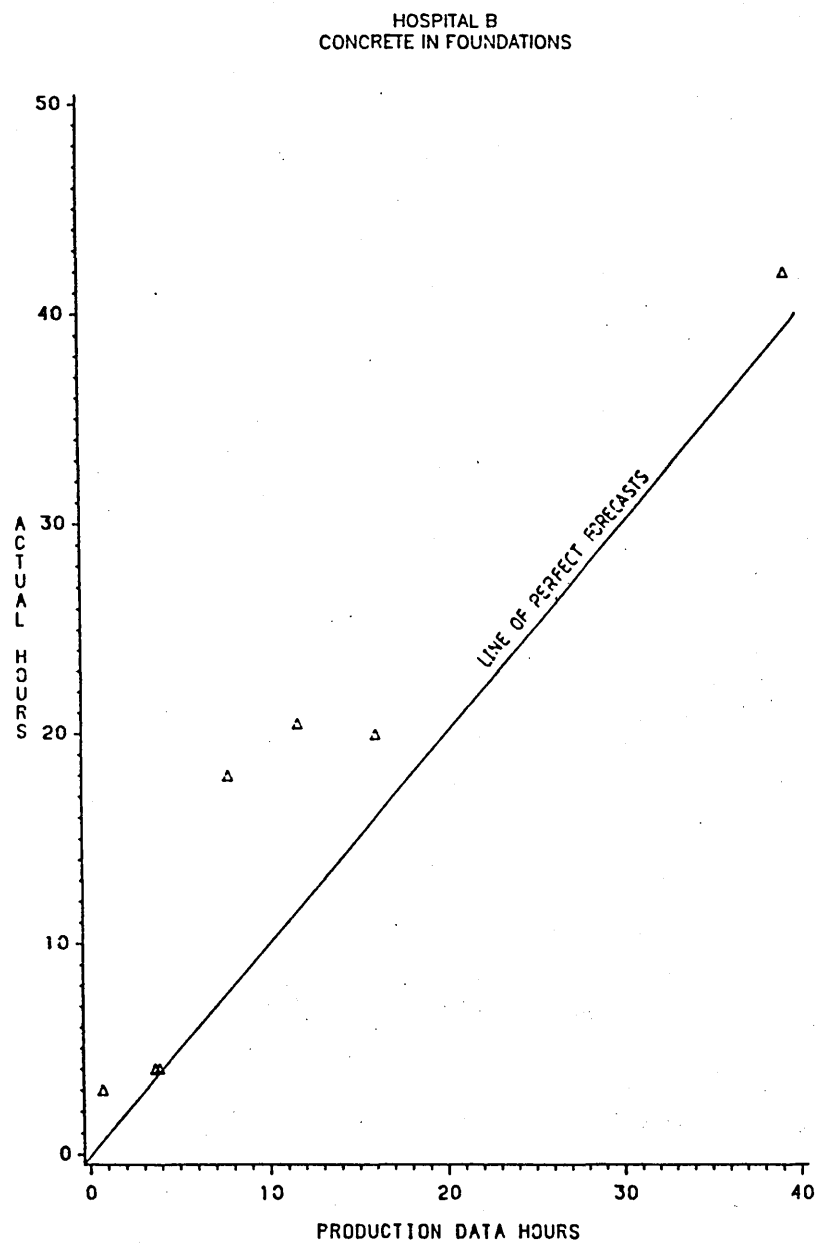

FIGURE 7.1 FORECAST-OBSERVATION DIAGRAM

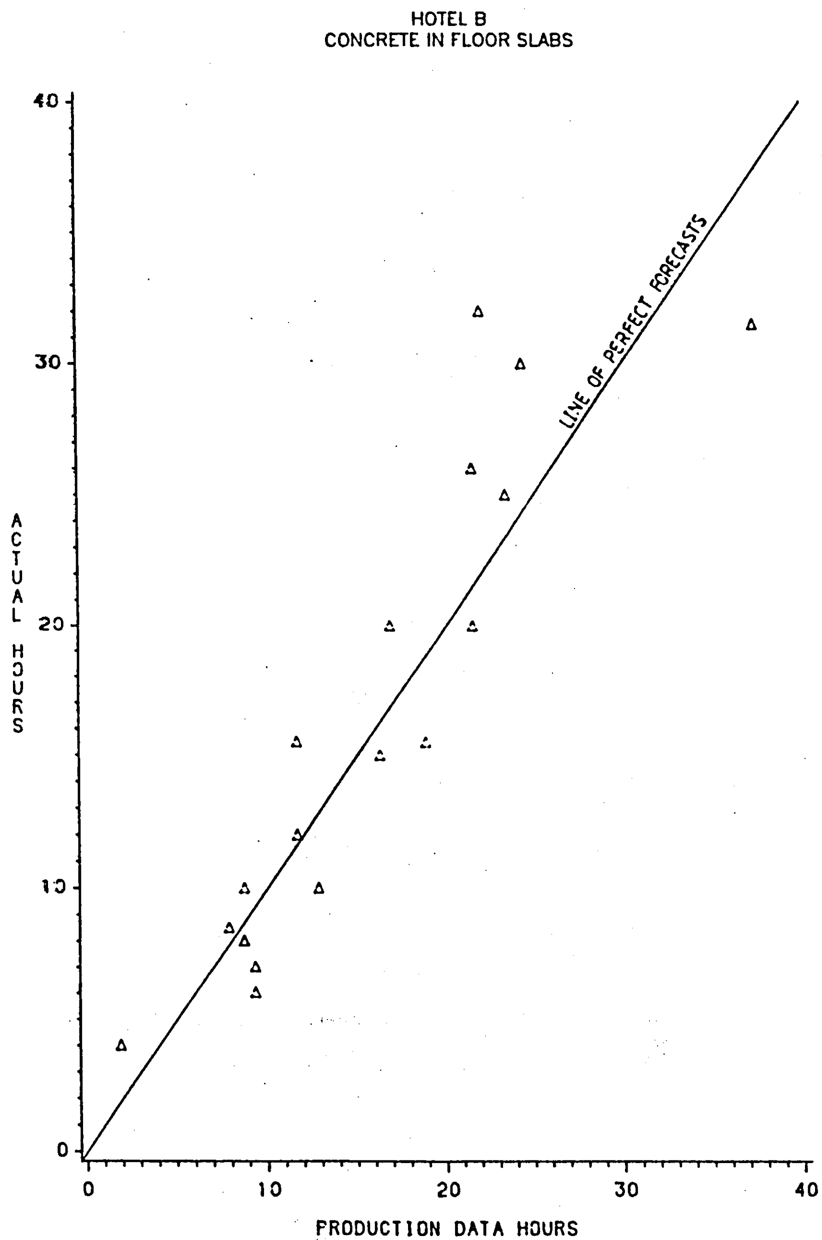

FIGURE 7.2 FORECAST-OBSERVATION DIAGRAM

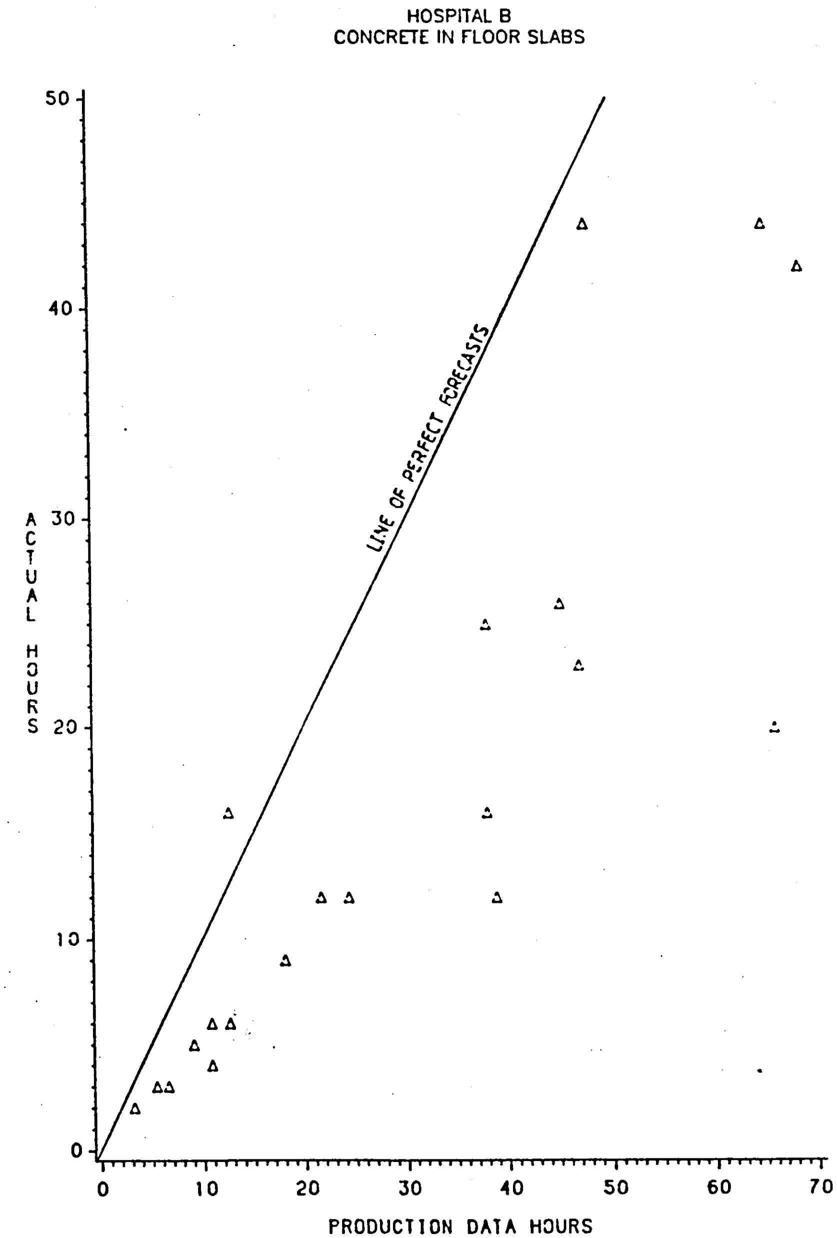

FIGURE 7.3 FORECAST-OBSERVATION DIAGRAM

7.4.1.3 Concrete in Suspended Slabs, Stairs and Landings

The category of suspended slabs, stairs and landings for 'hotel B' project produced a clear case of overestimation. With the exception of two work packages the remainder of the data set was below the line of perfect forecasts. Overestimation was common to all work package sizes illustrating high outputs on the project in relation to the production data (See Figure 7.4). The 'hospital B' project also produced overestimation in this work category which follows a similar pattern of productivity to floor slabs. This illustrates the high outputs achieved on this project above the production data base level (See Figure 7.5).

With regard to ranges and dispersion, these categories illustrated consistent scatter in terms of linearity. Although overestimation was common, all categories in this work section resulted in high correlation values. Table 7B shows the relevant figures relating to ranges and dispersion for each category.

7.4.1.4 Effective Tolerance for Concrete Work Categories

To consider the effectiveness of the data base and model forecasts, the second sample projects were assessed in relation to plus or minus one standard error of estimate from first sample projects.

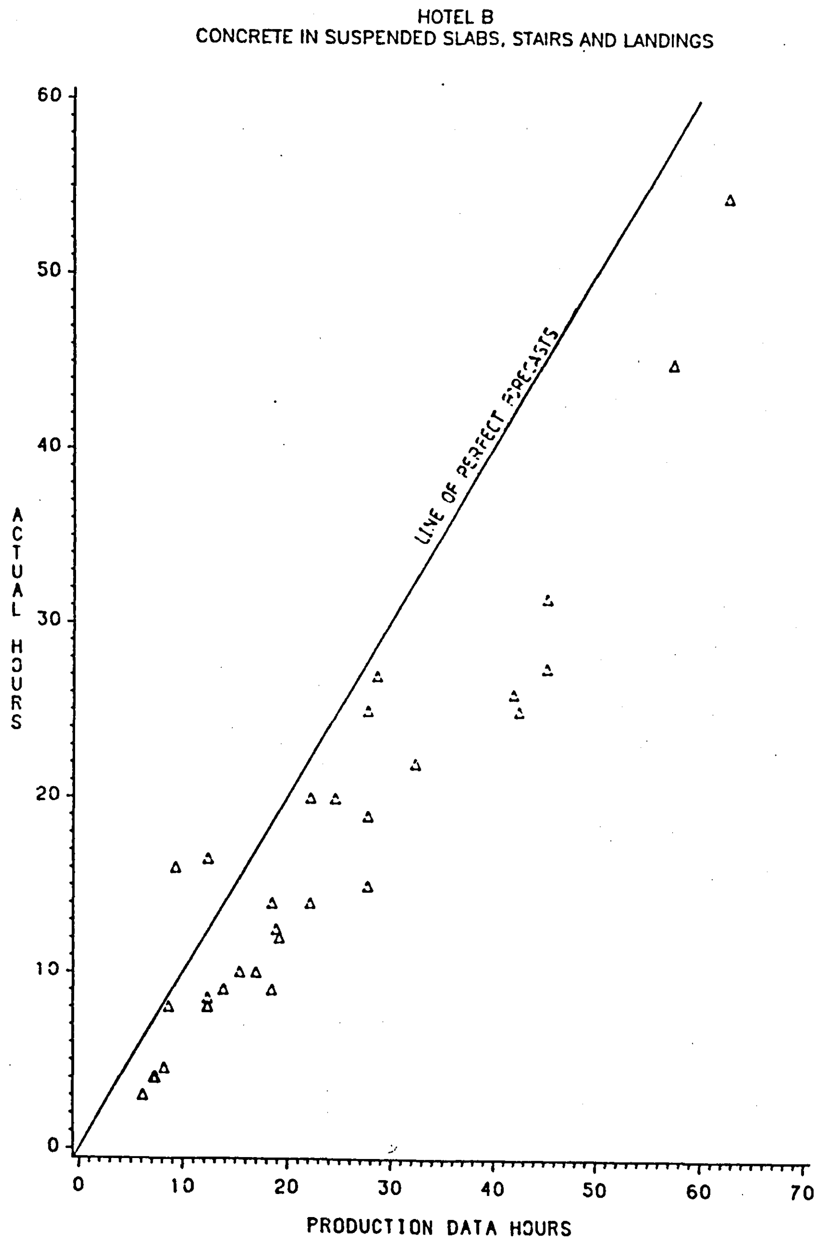

FIGURE 7.4 FORECAST-OBSERVATION DIAGRAM

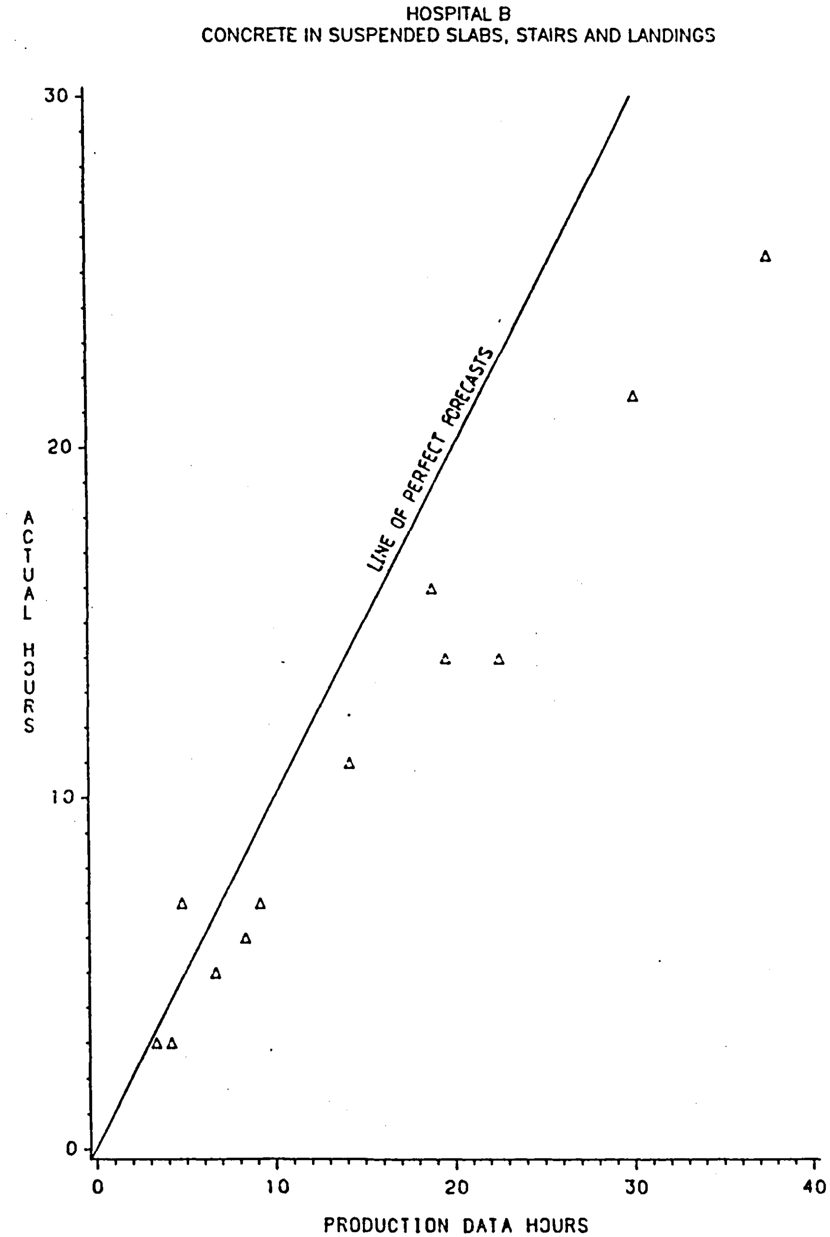

FIGURE 7.5 FORECAST-OBSERVATION DIAGRAM

WORK CATEGORY	PROJECT	CORR. COEFF.	PRODUCTIVITY RANGE RATIO	CV%	MEAN ACTUAL HOURS
Concrete in Foundations	Hospital B	0.959	-	31	15.93
Concrete in Floor Slabs	Hotel B	0.931	1.6:1	23	16.00
	Hospital B	0.867	1.9:1	41	16.50
Concrete in Suspended Slabs, Stairs and Landings	Hotel B	0.943	1.8:1	23	16.68
	Hospital B	0.983	-	14	11.08

TABLE 7B RANGES AND DISPERSIONS OF CONCRETE WORK CATEGORIES (SECOND SAMPLE)

Assessment of expected performances can be ascertained using the first sample statistics. If outputs on first and second sample projects were similar, assuming errors were normally distributed, 68% of second sample data would be expected to lie within plus or minus one standard error of estimate from first sample projects. The tolerance for concrete floor slabs represented 46% about the mean. For concrete in suspended slabs, stairs and landings, and concrete foundations the percentages about the mean were 63% and 89% respectively.

Of the five concrete data sets considered three cases had the majority of the data within the respective tolerances (See Table 7C). The remaining two data sets were slightly below the expected percentage. Employing the effective tolerance or control limits in practice would enable outputs to be monitored, but the size of such tolerances illustrates the variability that can be expected.

7.4.1.5 Comparison of Errors between Methods for Concrete Categories

As a means of assessing accuracy, the production data generated from the model were assessed in relation to the estimators' data and bonus surveyors' targets used on respective projects. The mean error, standard deviation of error, root mean square error and mean percentage error were recorded for each project

WORK CATEGORY	PROJECT	FIRST SAMPLE PROJECTS STANDARD ERROR OF ESTIMATE (HOURS)	SECOND SAMPLE DATA % WITHIN $\pm$ 1 STANDARD ERROR OF ESTIMATE FROM FIRST SAMPLE PROJECTS
Concrete in Foundations	Hospital B	15.44	100
Concrete in Floor Slabs	Hotel B	13.41	100
	Hospital B	13.41	65
Concrete in Suspended Slabs, Stairs and Landings	Hotel B	8.11	67
	Hospital B	8.11	92

TABLE 7C EFFECTIVE TOLERANCE FOR
CONCRETE WORK CATEGORIES (SECOND SAMPLE)

category. The assessment of accuracy was based on the root mean square error between forecasts and actual production performances in each case. The bonus increment included in the estimators' data and bonus surveyors' targets was first removed to allow comparative assessment. The results are shown in Table 7D.

The table illustrates that production data from the model has shown improvement on the estimators' data in all five of the concrete categories. In these cases the RMSE for production data was 45% of the RMSE for estimators' data. Comparison with the targets set by bonus surveyors has shown improvement for production data in three of the five cases. In the three cases of improvement, the RMSE for production data represented 68% of the RMSE for bonus surveyors' targets. The two cases of reduced accuracy of production data indicated the RMSE for bonus surveyors' targets to be 63% of the RMSE for production data. The inaccuracy of production data in the two cases related to different categories and different projects. Whilst the reasons for this are difficult to ascertain, production data for concrete work has generally illustrated its effectiveness.

7.4.2 Concrete Work at the Primary Level

The data were also assessed at a more coarse level, specifically related to the primary work packages of

WORK CATEGORY	PROJECT	ERRORS (HOURS)											
		PRODUCTION DATA				ESTIMATORS' DATA LESS BONUS INCREMENT				BONUS SURVEYORS' TARGETS LESS BONUS INCREMENT			
		MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %
Concrete in Foundations	Hospital B	-4.05	3.99	5.69	34.09	24.40	34.20	42.01	60.54	16.80	29.50	33.95	51.22
Concrete in Floor Slabs	Hotel B	-0.53	3.74	3.78	3.40	13.45	8.13	15.72	45.67	1.60	3.49	3.84	9.10
	Hospital B	12.97	11.94	17.62	44.01	18.90	15.70	24.70	53.39	10.58	9.55	14.25	39.07
Concrete in Suspended Slabs Stairs and Landings	Hotel B	6.37	5.50	8.42	27.62	6.58	8.33	10.62	28.29	-0.32	3.67	3.68	1.96
	Hospital B	3.88	4.09	5.64	25.94	12.65	9.81	16.01	53.29	4.23	4.62	6.26	27.61

TABLE 7D COMPARISON OF ERRORS BETWEEN METHODS FOR CONCRETE WORK CATEGORIES (SECOND SAMPLE) overall operations. Data at the primary level included assessment of all the concrete work categories in the second sample projects. Variation was obviously more pronounced in these plots since all categories were included representing a more coarse level. Generally, the scatter of the data illustrated bias towards overestimation. This was more pronounced with large work package sizes (See Figure 7.6 to 7.7).

The 'hotel B' project illustrated overestimation influenced by the high outputs achieved on the suspended slabs, stairs and landings category. Similarly, the scatter from the 'hospital B' project illustrated overestimation, and this was more pronounced on work packages above 20 hours. The highest outputs related to the floor slab category.

Range and dispersion values for all concrete work at the primary level are shown in Table 7E. Whilst the data have resulted in high value correlation coefficients, the variation in concrete work of the various categories has been reflected in the productivity range ratios.

7.4.2.1 Effective Tolerance for All Concrete Work

Measurement of the effectiveness of data at this level indicated that both projects contained above 68% of data within plus or minus one standard error of estimate from first sample projects (See Table 7F). The tolerance was representative of 66% about the mean.

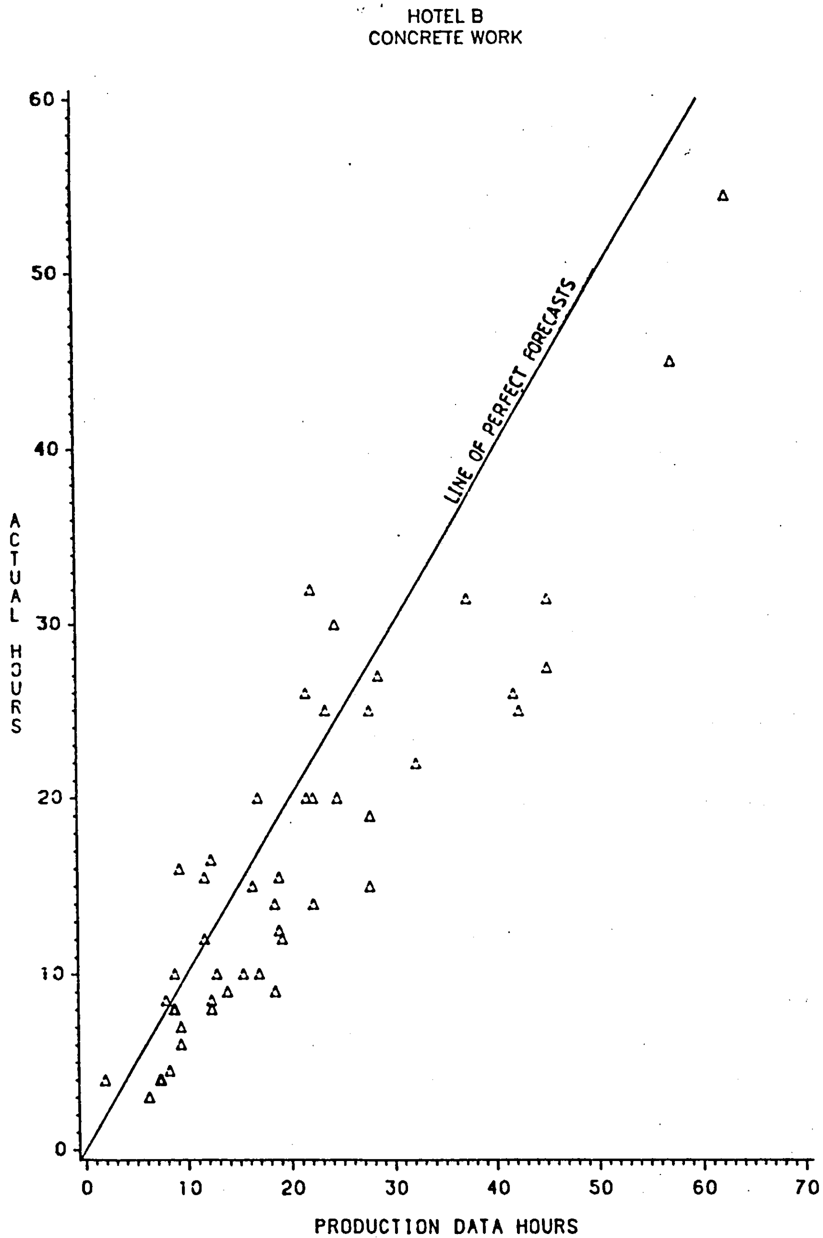

FIGURE 7.6 FORECAST-OBSERVATION DIAGRAM

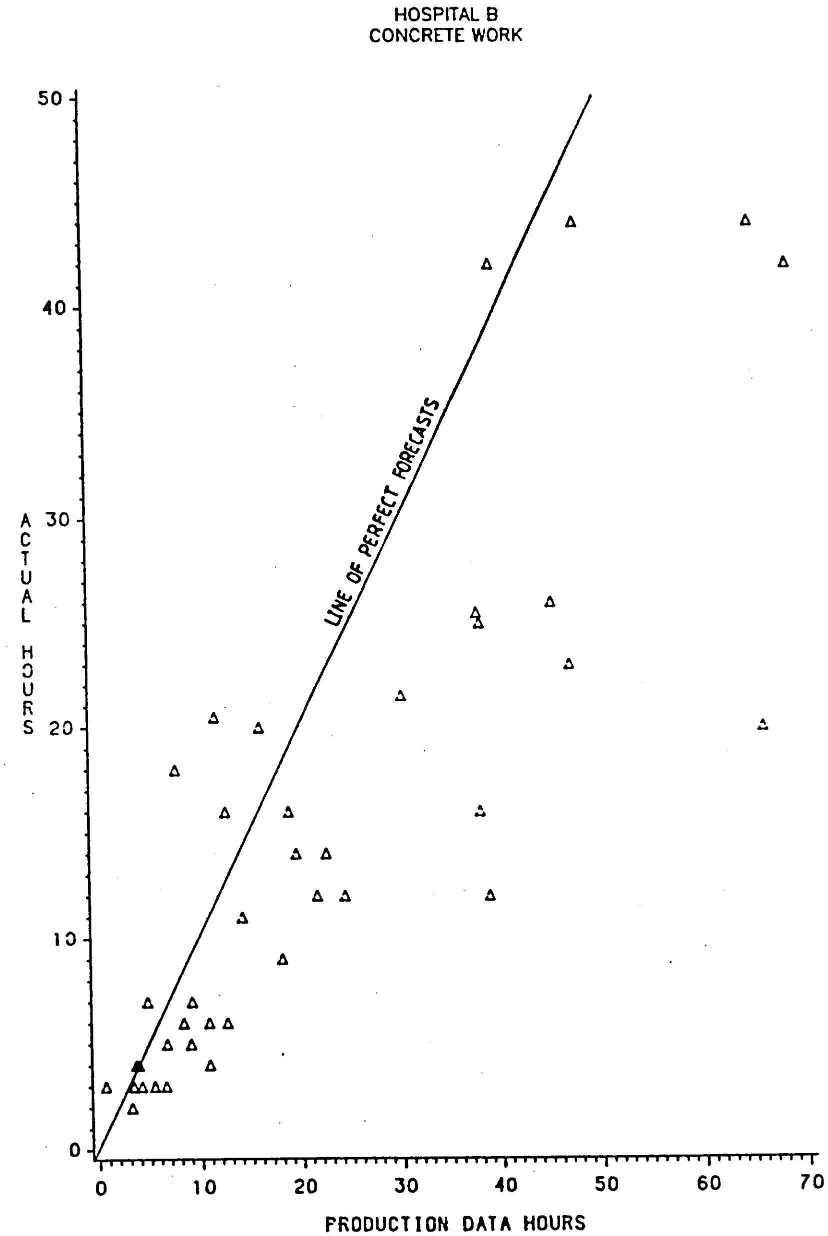

FIGURE 7.7 FORECAST-OBSERVATION DIAGRAM

PROJECT	CORR. COEFF.	PRODUCTIVITY RANGE RATIO	CV%	MEAN ACTUAL HOURS
Hotel B	0.901	2.3:1	29	16.43
Hospital B	0.837	3.5:1	47	14.73

TABLE 7E RANGES AND DISPERSIONS OF ALL CONCRETE WORK (SECOND SAMPLE)

PROJECT	FIRST SAMPLE PROJECTS STANDARD ERROR OF ESTIMATE (HOURS)	SECOND SAMPLE DATA % WITHIN ± STANDARD ERROR OF ESTIMATE FROM FIRST SAMPLE PROJECTS
Hotel B	11.50	88
Hospital B	11.50	74

TABLE 7F EFFECTIVE TOLERANCE FOR ALL CONCRETE WORK (SECOND SAMPLE)

PROJECT	ERRORS (HOURS)											
	PRODUCTION DATA				ESTIMATORS' DATA LESS BONUS INCREMENT				BONUS SURVEYORS' TARGETS LESS BONUS INCREMENT			
	MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %
Hotel B	3.85	5.93	7.07	18.98	9.09	8.83	12.67	35.62	0.38	3.69	3.71	2.26
Hospital B	7.12	11.09	13.18	32.58	17.96	18.80	26.00	54.94	9.75	14.42	17.41	39.82

TABLE 7G COMPARISON OF ERRORS BETWEEN METHODS FOR ALL CONCRETE WORK (SECOND SAMPLE)

7.4.2.2 Comparison of Errors between Methods for All Concrete Work

Comparing the accuracy of production data with estimators' data at the primary level illustrated that in both cases production data proved more accurate. The RMSE for production data represented 54% of the RMSE for estimators' data. On the 'hotel B' project the production data proved less accurate than the bonus surveyors' targets (See Table 7G). In this instance the RMSE for bonus surveyors' targets was 52% of the RMSE for production data.

7.4.3 Brickwork and Blockwork at the Tertiary and Secondary Levels

The brickwork and blockwork categories were not broken down in the same detail as concrete work. Categories related to either brickwork or blockwork or a combination of both. These can also be identified as work in sub-structure or superstructure. At the tertiary level certain quantities relate to a particular area of work. A collection of tertiary work packages represent the secondary level and relate to a particular section of a project such as sub-structure or superstructure.

7.4.3.1 Brickwork in Superstructure

In the 'hotel B' project, it was evident before using the production data for analysis that the brickwork in superstructure would be unlikely to respond with sufficient accuracy. The second sample 'hotel B' project was far more complex than any of the first sample projects used to establish the production data. There was much decorative brickwork, and numerous arches included in the design of the superstructure. It was therefore anticipated that outputs would be much reduced when compared with the first sample projects. These assumptions were evident on the plot produced where there was considerable underestimation (See Figure 7.8). With the exception of four work packages, which were consistent with the line of perfect forecasts, all other data points illustrated bias towards underestimation. This occurred in all work packages irrespective of size. Clearly, the use of the production data generated from the model is insufficiently accurate where complex and circular work are predominant, and work of this type should therefore be measured in detail.

In the 'hospital B' project, brickwork in superstructure illustrated a clear case of overestimation. The points plotted illustrated linearity in relation to work package sizes. The outputs achieved on this project were far greater than the production data forecasts, but the consistent overestimation would suggest high performance in relation to this particular project rather than inaccuracies in production data (See Figure 7.9). Productivity levels were also reflected in the high bonus earnings of operatives.

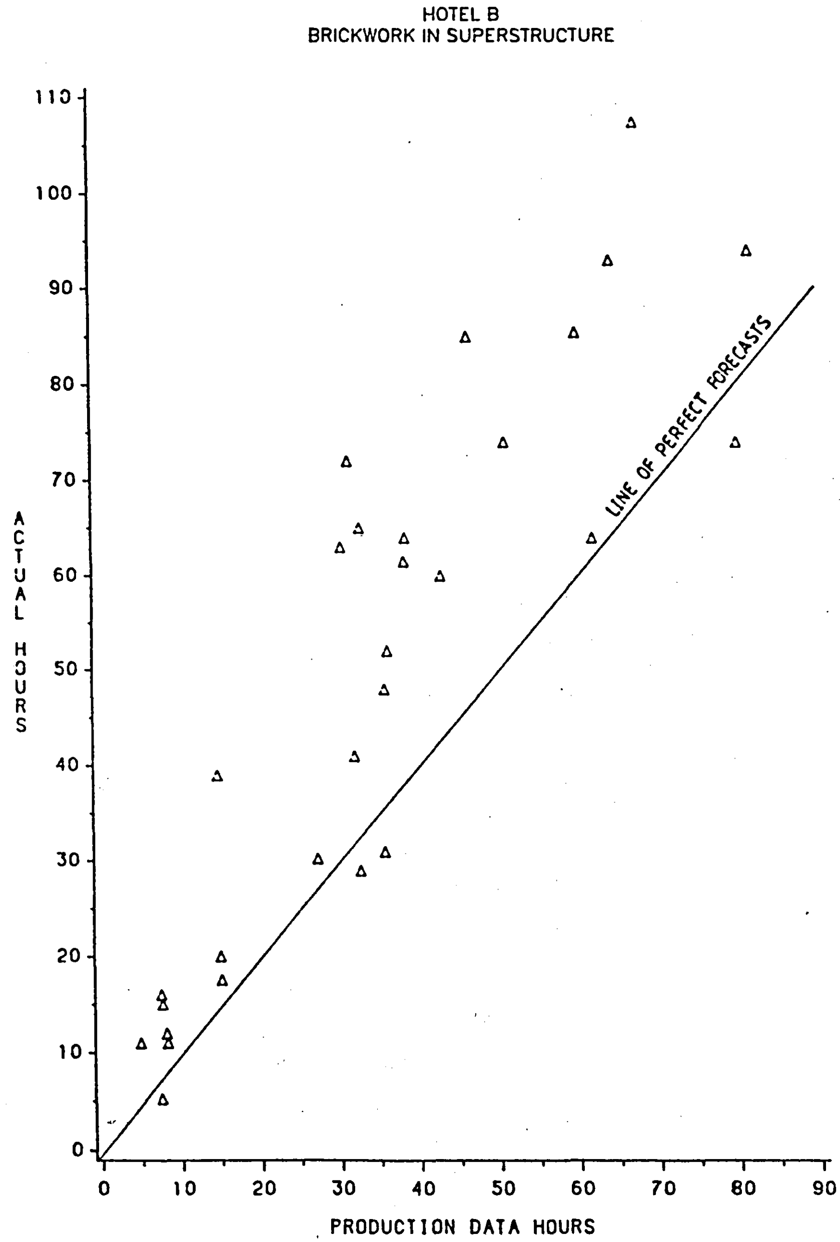

FIGURE 7.8 FORECAST-OBSERVATION DIAGRAM

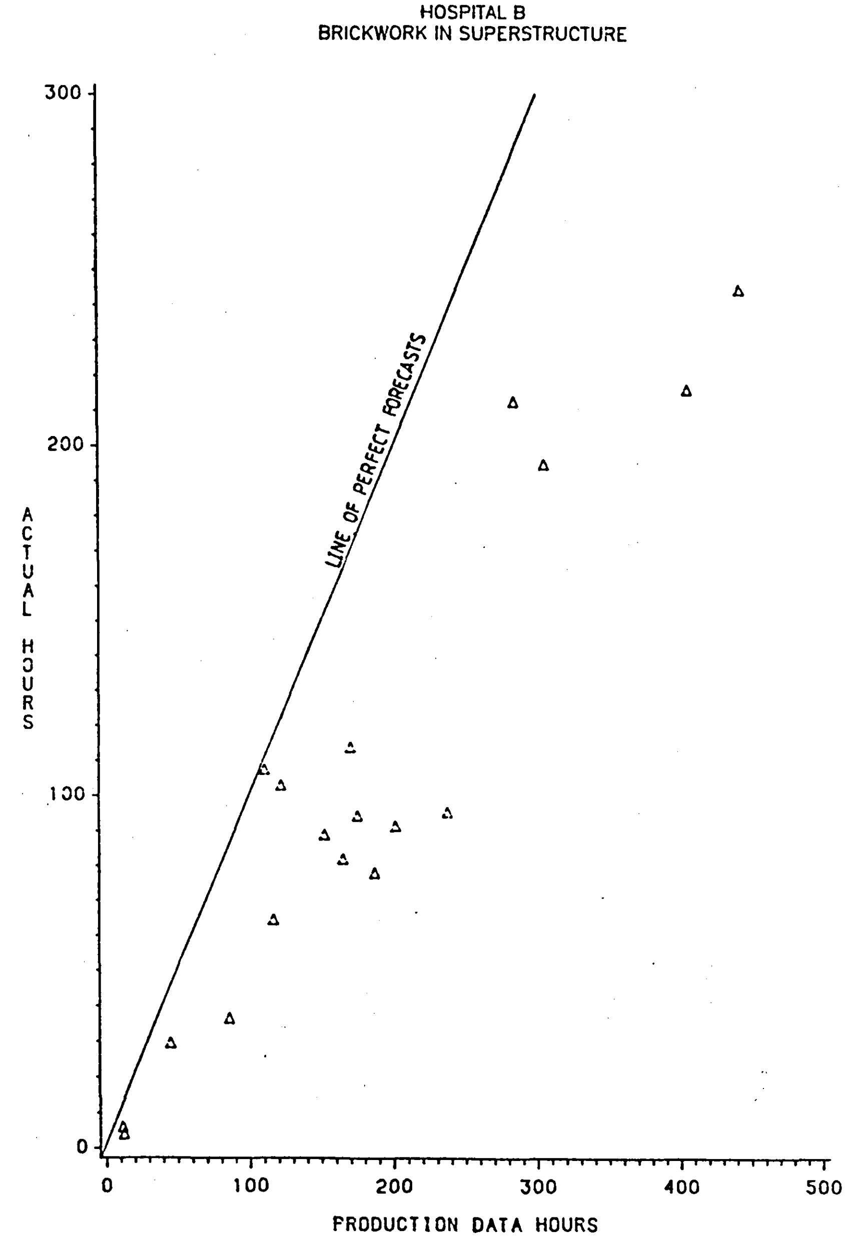

FIGURE 7.9 FORECAST-OBSERVATION DIAGRAM

7.4.3.2 Blockwork in Superstructure

For superstructure blockwork in the 'hotel B' project, production data produced an even scatter of data about the line of perfect forecasts. Slight bias towards underestimation was evident particularly for work packages up to 30 hours in size. Variation was common for all the data and this was not restricted to certain work package sizes (See Figure 7.10). Clearly, this illustrates that variation occurs irrespective of the size of work package. This would suggest that variation is primarily operative performance together with organisational efficiency.

7.4.3.3 Brickwork and Blockwork in Superstructure

A similar situation was also found for the combined brickwork and blockwork in superstructure in the 'hospital B' project (See Figure 7.11). The majority of work package sizes were above 60 hours in this category. Whilst the points indicated linearity in relation to the line of perfect forecasts, the scatter was much more widespread. The combination of brickwork and blockwork has resulted in a reduction of outputs compared with the brickwork in superstructure category shown in Figure 7.9. The various ranges and dispersion figures for brickwork and blockwork are shown in Table 7H.

HOTEL B
BLOCKWORK IN SUPERSTRUCTURE

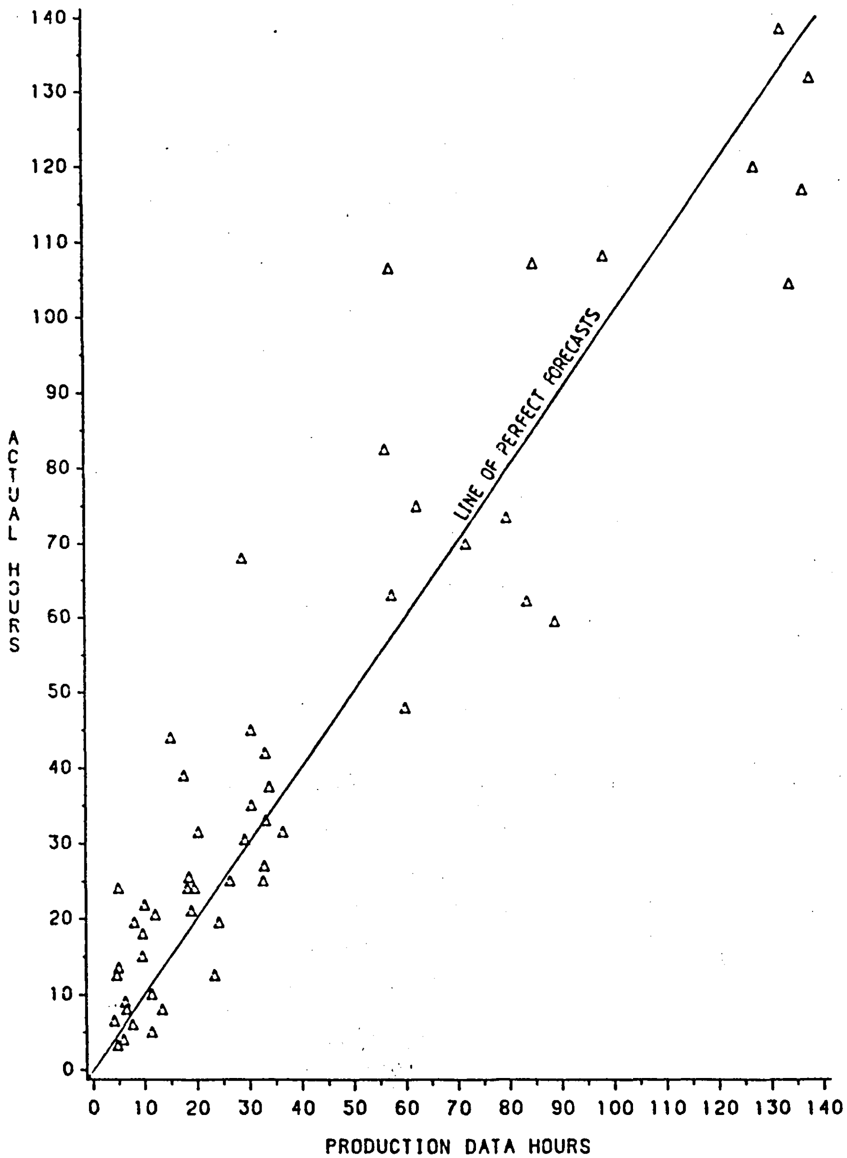

FIGURE 7.10 FORECAST-OBSERVATION DIAGRAM

HOSPITAL B
BRICKWORK AND BLOCKWORK IN SUPERSTRUCTURE

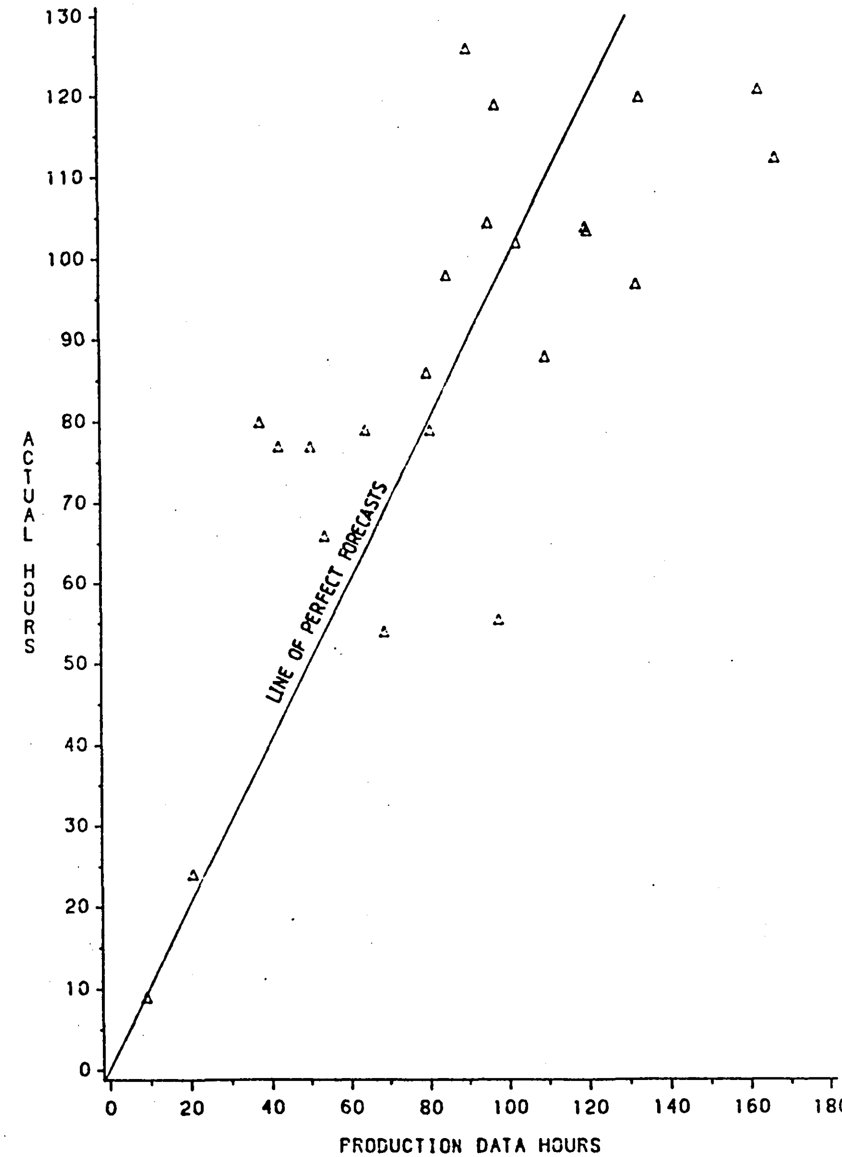

FIGURE 7.11 FORECAST-OBSERVATION DIAGRAM

WORK CATEGORY	PROJECT	CORR. COEFF.	PRODUCTIVITY RANGE RATIO	CV%	MEAN ACTUAL HOURS
Brickwork in Superstructure	Hotel B Hospital B	0.888 0.940	2.5:1 1.7:1	29 23	49.67 103.60
Brickwork and Blockwork in Superstructure	Hospital B	0.776	2.1:1	29	86.17
Blockwork in Superstructure	Hotel B	0.930	2.2:1	34	43.64

TABLE 7H RANGES AND DISPERSIONS OF BRICKWORK AND BLOCKWORK CATEGORIES (SECOND SAMPLE)

7.4.3.4 Effective Tolerance for Brickwork and Blockwork Categories

The effective tolerance for the second sample projects, based on plus or minus one standard error of estimate from first sample projects was much reduced from the tolerance for concrete work. The tolerance for brickwork in superstructure represented 35% about the mean. The tolerance for brickwork and blockwork in superstructure, and blockwork in superstructure were both 39% about the mean. The inconsistency for both brickwork, and brickwork and blockwork in superstructure were illustrated by the percentage of data contained within the tolerances. The only case which produced above 68% was for blockwork in superstructure (See Table 7I). This evidence suggests inconsistent forecasting for brickwork in superstructure, and brickwork and blockwork in superstructure. The results indicate that more detailed analysis of these categories is required to identify the causes of variation. The excessive variation is unlikely to be caused by the production data established, but because of motivation and organisational factors.

It can be concluded, therefore, that productivity for brickwork in superstructure, and brickwork and blockwork in superstructure are difficult to forecast. This is more apparent at the tertiary and secondary levels, and particularly relating to the setting of

WORK CATEGORY	PROJECT	FIRST SAMPLE PROJECTS STANDARD ERROR OF ESTIMATE (HOURS)	SECOND SAMPLE DATA % WITHIN $\pm$ 1 STANDARD ERROR OF ESTIMATE FROM FIRST SAMPLE PROJECTS
Brickwork in Superstructure	Hotel B	14.93	62
	Hospital B	14.93	28
Brickwork and Blockwork in Superstructure	Hospital B	26.22	65
Blockwork in Superstructure	Hotel B	13.22	79

TABLE 7I EFFECTIVE TOLERANCE FOR BRICKWORK AND BLOCKWORK CATEGORIES (SECOND SAMPLE) incentive targets.

7.4.3.5 Comparison of Errors between Methods for Brickwork and Blockwork Categories

The accuracy of production data generally showed improvements compared with the estimators' data. In all but one case the production data proved the more accurate. The RMSE for production data represented 64% of the RMSE for estimators' data. Reduced accuracy was evident when compared with the bonus surveyors' targets. In all cases production data indicated the least accuracy (See Table 7J). In these cases the RMSE for bonus surveyors' targets represented 69% of the RMSE for production data.

Clearly, this does provide evidence of the difficulty in effectively forecasting durations for superstructure brickwork. The model forecasts for brickwork, and brickwork and blockwork categories would appear to be too coarse. The targets used by bonus surveyors on an intuitive basis to suit individual projects and situational circumstances are the most effective.

7.4.4 Brickwork and Blockwork at the Primary Level

At the primary level, brickwork and blockwork categories were considered collectively. In the 'hotel B' project the predominance of the complex brickwork in superstructure was evident in the plot produced. (See Figure 7.12). The greater part of the data illustrated

WORK CATEGORY	PROJECT	ERRORS (HOURS)											
		PRODUCTION DATA				ESTIMATORS' DATA LESS BONUS INCREMENT				BONUS SURVEYORS' TARGETS LESS BONUS INCREMENT			
		MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %
Brickwork in Superstructure	Hotel B	-14.62	14.15	20.35	41.71	8.35	17.80	19.66	14.39	-0.14	11.57	11.57	0.28
	Hospital B	75.90	58.90	96.07	42.28	133.90	88.60	160.56	56.36	27.60	35.14	44.68	21.04
Brickwork and Blockwork in Superstructure	Hospital B	1.80	26.24	26.30	2.10	16.68	32.36	36.41	16.21	16.27	19.28	25.23	15.88
Blockwork in Superstructure	Hotel B	-3.38	14.44	14.83	8.40	12.61	21.62	25.03	22.42	-1.33	11.35	11.43	3.14

TABLE 7J COMPARISON OF ERRORS BETWEEN METHODS
FOR BRICKWORK AND BLOCKWORK CATEGORIES (SECOND SAMPLE)

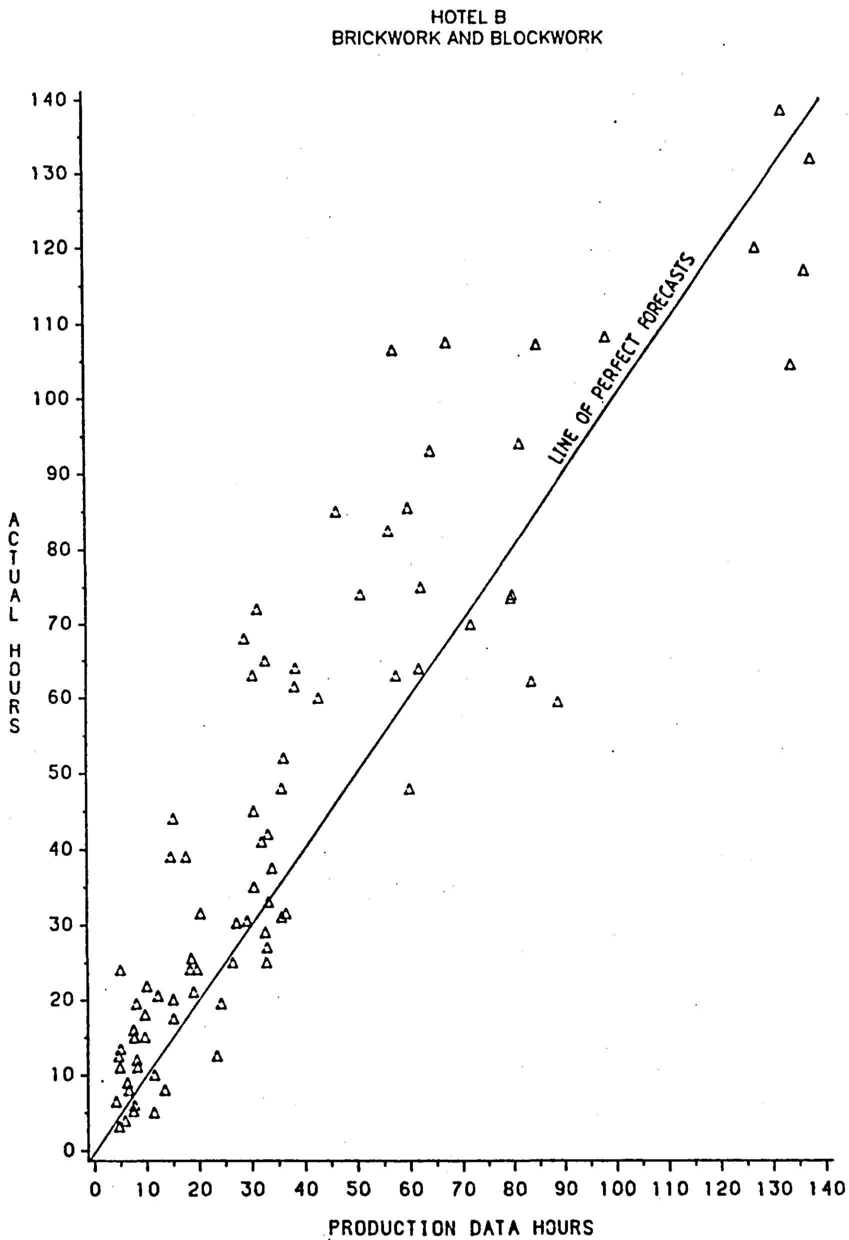

FIGURE 7.12 FORECAST-OBSERVATION DIAGRAM

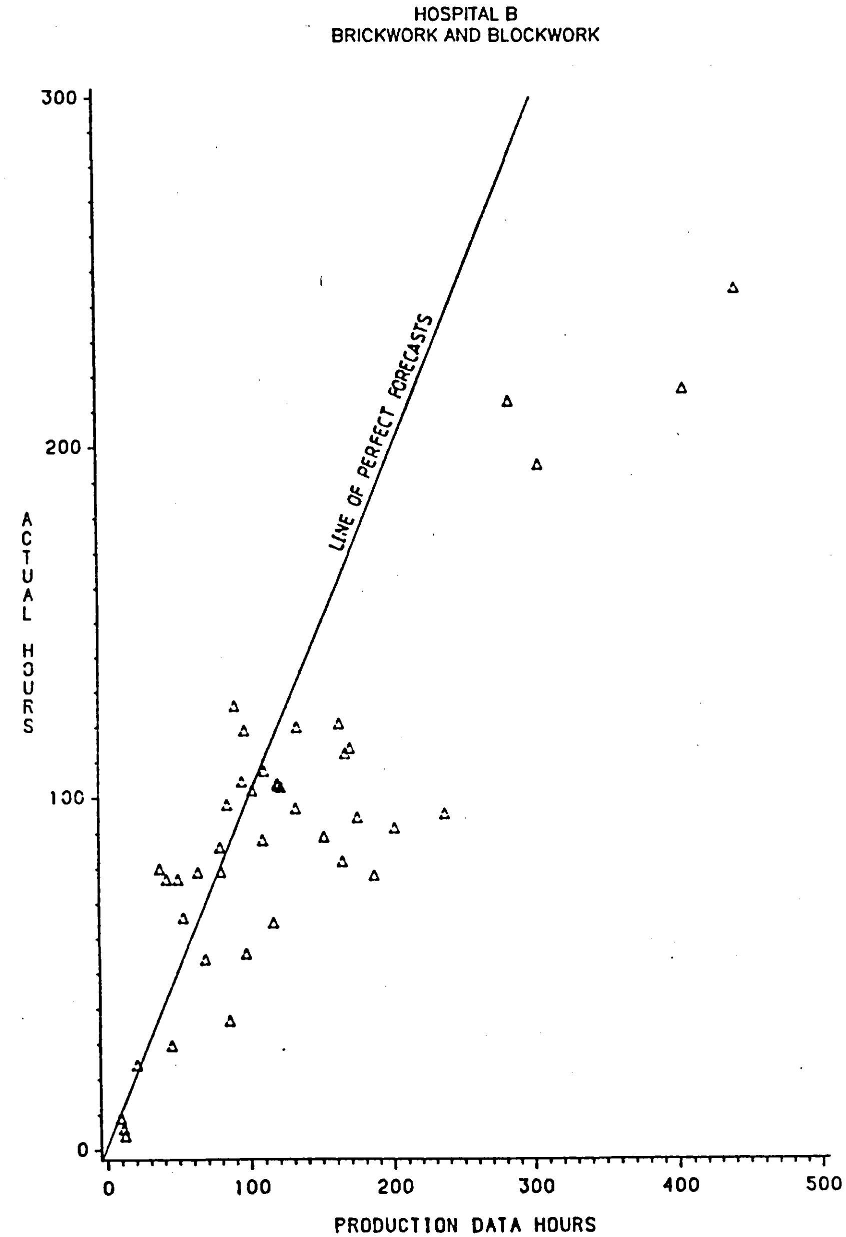

FIGURE 7.13 FORECAST-OBSERVATION DIAGRAM

PROJECT	CORR. COEFF.	PRODUCTIVITY RANGE RATIO	CV%	MEAN ACTUAL HOURS
Hotel B	0.902	2.2:1	36	45.77
Hospital B	0.870	3.5:1	35	93.83

TABLE 7K RANGES AND DISPERSIONS OF ALL BRICKWORK AND BLOCKWORK (SECOND SAMPLE)

PROJECT	FIRST SAMPLE PROJECTS STANDARD ERROR OF ESTIMATE (HOURS)	SECOND SAMPLE DATA % WITHIN ± 1 STANDARD ERROR OF ESTIMATE FROM FIRST SAMPLE PROJECTS
Hotel B	21.18	83
Hospital B	21.18	49

TABLE 7L EFFECTIVE TOLERANCE FOR ALL BRICKWORK AND BLOCKWORK (SECOND SAMPLE) underestimation. In the 'hospital B' project for brickwork and blockwork, outputs illustrated bias towards overestimation, particularly for large size work packages (See Figure 7.13). The range and dispersion values at the primary level are shown in Table 7K.

7.4.4.1 Effective Tolerance for All Brickwork and Blockwork

At the primary level, plus or minus one standard error of estimate from first sample projects represented 45% about the mean. This tolerance contained 83% of second sample data from the 'hotel B' project. In the 'hospital B' project, the percentage was 49%. This is indicative of the increased outputs on the 'hospital B' project which exceeded the outputs of first sample projects (See Table 7L).

At the tertiary and secondary levels, blockwork is the least variable of the categories considered and indicates consistency. The laying of blocks in walls could be regarded as a relatively consistent operation, generally unaffected by design features. The only difference in blocklaying would be the extent of wall area and the amount of cutting required. Such features would be relatively consistent on both internal and external walling so variation in output could well be related to operative skill and motivation, together with

PROJECT	ERRORS (HOURS)											
	PRODUCTION DATA				ESTIMATORS' DATA LESS BONUS INCREMENT				BONUS SURVEYORS' TARGETS LESS BONUS INCREMENT			
	MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %	MEAN	SD	RMSE	MEAN %
Hotel B	-7.35	15.25	16.93	19.13	11.10	20.34	23.17	19.51	-0.91	11.37	11.41	2.02
Hospital B	34.38	56.90	64.48	26.82	68.20	85.90	109.68	42.10	21.25	27.60	34.83	18.46

TABLE 7M COMPARISON OF ERRORS BETWEEN METHODS FOR ALL BRICKWORK AND BLOCKWORK (SECOND SAMPLE) organisational efficiency.

In direct contrast, brickwork is much more influenced by design features and complexity relating to the particular building. This was most noticeable on the 'hotel B' project where complex brickwork had a great bearing on the outputs achieved. This has been reflected in the results produced where effective forecasting is all the more difficult at the tertiary and secondary levels.

7.4.4.2 Comparison of Errors between Methods for All Brickwork and Blockwork

At the primary level, the production data on both projects have shown improvement over the estimators' data. The RMSE for production represented 66% of the RMSE for estimators' data. The target data used by bonus surveyors have shown to have the greatest accuracy for both projects (See Table 7M). The RMSE for bonus surveyors' targets represented 61% of the RMSE for production data.

7.5 SUMMARY

The basis of the validation study was to test the data base and model on a second sample of independent projects. This provided a more rigorous test on the established data base items than first sample projects analysed in Chapter 4.

7.5.1 Concrete Work

The established data for concrete work generally produced improved results. At the tertiary and secondary levels, three out of the five second sample categories produced above 68% of data within plus or minus one standard error of estimate from first sample projects, which illustrates the variability of concrete work. However, the variation was also present in the estimators' data and bonus surveyors' targets. Comparisons indicated that in all the five data sets the production data generated from the model were more accurate than the estimators' data. Comparisons with bonus surveyors' targets indicated that in three of the five cases production data were more accurate.

Testing the data at the primary level for all concrete work indicated above 68% of data were within plus or minus one standard error of estimate from first sample projects. Comparisons of accuracy at this level also proved more accurate than the estimators' data. On one project the bonus surveyors' targets proved the most accurate.

On evidence of these statistics at the various levels, the results provide support to the use of the model and established production data. From the projects and categories considered, production data have demonstrated more consistent accuracy.

7.5.2 Brickwork and Blockwork

The brickwork and blockwork section produced less accurate results than the concrete section. At the tertiary and secondary levels, only one of the four second sample data sets produced above 68% of data within the plus or minus one standard error of estimate from first sample projects. The categories indicating increased variation related to brickwork in superstructure on both projects. In the 'hotel B' project increased complexity is the cause of underestimation, whereas in the 'hospital B' project the high outputs achieved were the cause of overestimation. This illustrates the variability of the two extreme cases and the difficulty generally in accurate forecasting.

Comparisons with estimators' data at the tertiary and secondary levels illustrated improved accuracy for production data in three of the four categories. Bonus surveyors' targets illustrated improved accuracy in all four categories.

Considering this work section at the primary level for all brickwork and blockwork categories, the 'hotel B' project produced 83% of data within the tolerance of plus or minus one standard error of estimate from first sample projects. The data from the 'hospital B' project with its exceptionally high outputs contained 49% of data within this tolerance.

Comparisons of accuracy at this level illustrated that on both projects production data were more accurate than the estimators' data. The bonus surveyors' targets, however, proved more accurate than production data in both cases.

The results obtained in this work section illustrate improved accuracy over estimators' data. The only category from the second sample that illustrated consistency with first sample projects was blockwork in superstructure. Brickwork in superstructure and brickwork and blockwork in superstructure have illustrated inconsistency and present problems in accurate forecasting.

Whilst production data could be used at the primary level for overall planning it has illustrated insufficient accuracy at the tertiary and secondary levels. Targets set by bonus surveyors' have proved the most effective in all cases.

CHAPTER 8

ASSESSMENT OF THE MODEL

8.1 INTRODUCTION

The validation study of the previous chapter included the application of the model for generating data on a second sample of projects. Applying the model generally illustrated improved accuracy in concrete work. In brickwork and blockwork, forecasting from the model did not produce sufficient accuracy at the tertiary and secondary levels. In this chapter assessment is made of the model and the possible causes of inaccuracies are identified together with suggestions for improvement.

8.2 PERFORMANCE OF THE MODEL

Applying the model to the second sample of independent projects proved to be effective for certain concrete categories. Compared with other sources of data (i.e. the estimators' data and bonus surveyors' targets) there was a general overall improvement in accuracy. In the brickwork and blockwork categories, production data were more accurate than estimators' data, but the target data used by bonus surveyors proved the most accurate.

Reasons why this affected brickwork and blockwork were investigated. One obvious cause was the complexity of brickwork of the 'hotel B' project. This was far more complex than the brickwork used to establish productivity times from the first sample projects.

Errors were far more pronounced on the model forecasts.

The forecast durations generated from the data base were much reduced when compared with the original targets used on the project. Analysis of targets representing tertiary work packages revealed that sundry items had great influence on the total forecast time. This was caused by the complexity of the brickwork operations.

On certain targets, owing to the complex nature of the work, sundry items were found to represent a large proportion of the work package. This indicated that although sundry items have little value compared with the overall value of the brickwork and blockwork section, in relation to productivity these items become significant in terms of time.

Based on the method used in the model, the percentage addition calculated for sundry items was found to be insufficiently accurate to reflect the true time required to complete the work.

One immediate reason for the increased errors in these categories was the variation accountable to complexity. Problems are caused mainly because of the SMM used for the preparation of bills of quantities.

8.3 THE STANDARD METHOD OF MEASUREMENT

The unit rate format of bills of quantities based on SMM primarily presents a problem of setting targets. This is because targets set must be representative of the particular content of work package. Operatives must be able to earn bonus on a particular operation whether this be a small target containing complex work or a large target representing straightforward work. If the target set is not realistic and representative of the work providing the opportunity for bonus earnings then it is likely to have an adverse effect. Operatives may realise that a target is unachievable, and as a result, productivity will suffer. The operatives will earn no bonus and management will lose out from loss of productivity.

To a large extent this will depend on the particular category of work being done at the time. This occurs most noticeably where work content varies between operations yet is measured and represented as one bill item under SMM. The sections most susceptible in this respect are brickwork and blockwork. For example, in brickwork a single bill item of a large quantity can represent brickwork in several areas of a building representing varying degrees of complexity. Coupled with this are the extent of sundry items that may accompany a particular section of work. The sundry items themselves may not represent a high proportion of the work section value, but they will greatly influence the rate of working whilst they are being carried out. Typical examples in brickwork would include the cutting of bricks (excessive in small areas), building arches, and circular work generally. All such items would slow down an operation if they represented a large proportion of the work package, particularly circular work. Productivity would differ greatly from a large area of brickwork which contained no sundry items.

This problem can be directly related to the SMM which results in the use of average unit rates. It has been a problem with all previous methods and will remain so with SMM7. This causes problems of inaccurate target-setting.

From the data sets collected, work packages consisted of small complex areas of work in addition to large work packages with little sundry content. To try and obtain more accurate forecasts and to take account of this complexity, the data sets were analysed to try and fit accurate forecasting models.

With the data obtained from the first sample of projects this particular exercise was also considered. Various transformations were tried and the log log regression model was found to be the most appropriate. Plotting these models on the normal scale produced curved regression models. Several of the curves produced lines where the curvature was difficult to distinguish. The major feature was the extent of variation about the regression line (See Figure 8.1 and 8.2). Variation was such that the fitted line would not have produced substantially more accurate forecasts than a straight line passing through the origin represented by a single coefficient. In several of the data sets analysed the single coefficient produced more accurate results.

It was realised during the data collection stage that data were not recorded in complexity format. Brickwork was either measured in sub-structure or in superstructure. It was not recorded where the particular work package was built within the building.

In an attempt to assess the complexity of work packages, data were analysed for the type of items that were included in the measure. It was evident that certain work packages included sundry items such as cutting and curved work. Other work packages had no sundries, representing straightforward brick walling.

In the data sets studied from the first sample projects, it was found that the sundry items did not affect the target to any great extent. This was based on the percentage sundries identified in each of the work packages (See Chapter 6 Section 6.7).

In the validation projects, particularly 'hotel B', it

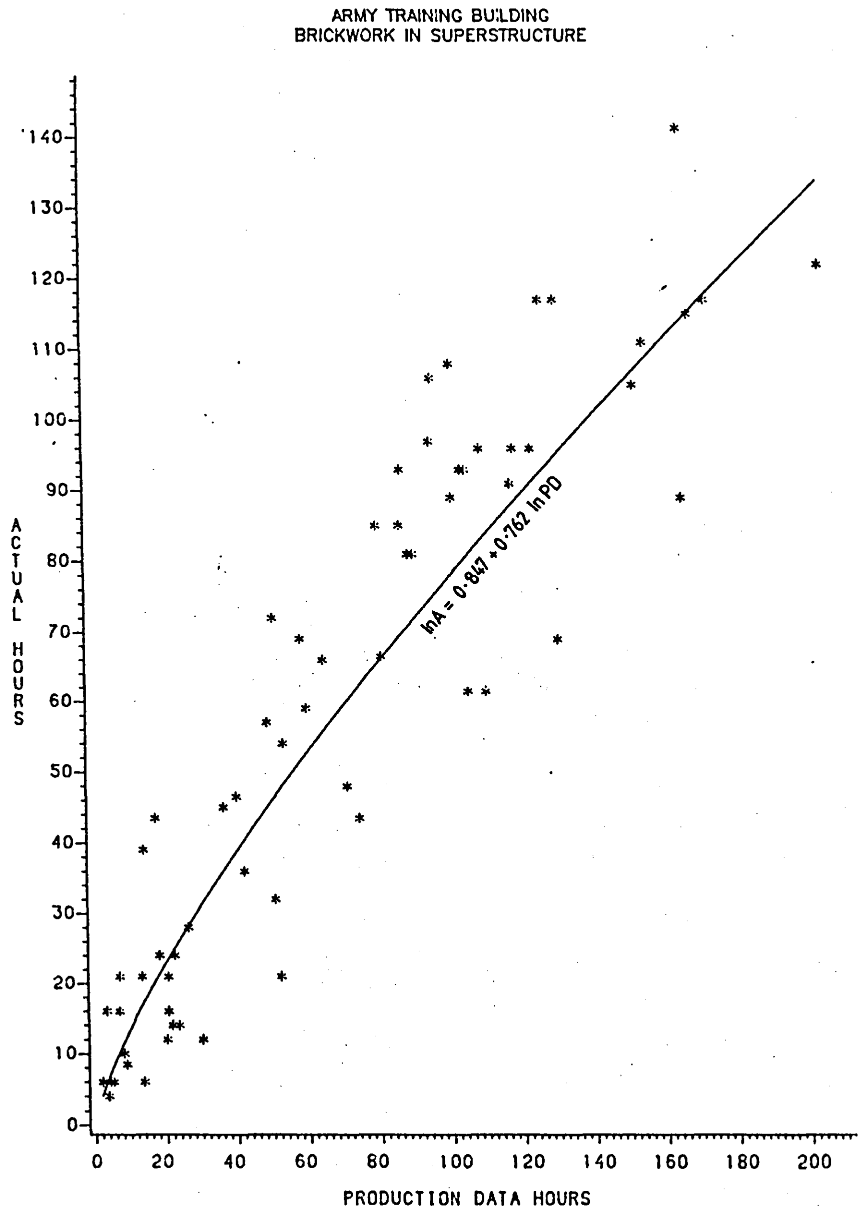

FIGURE 8.1 CURVED REGRESSION MODEL

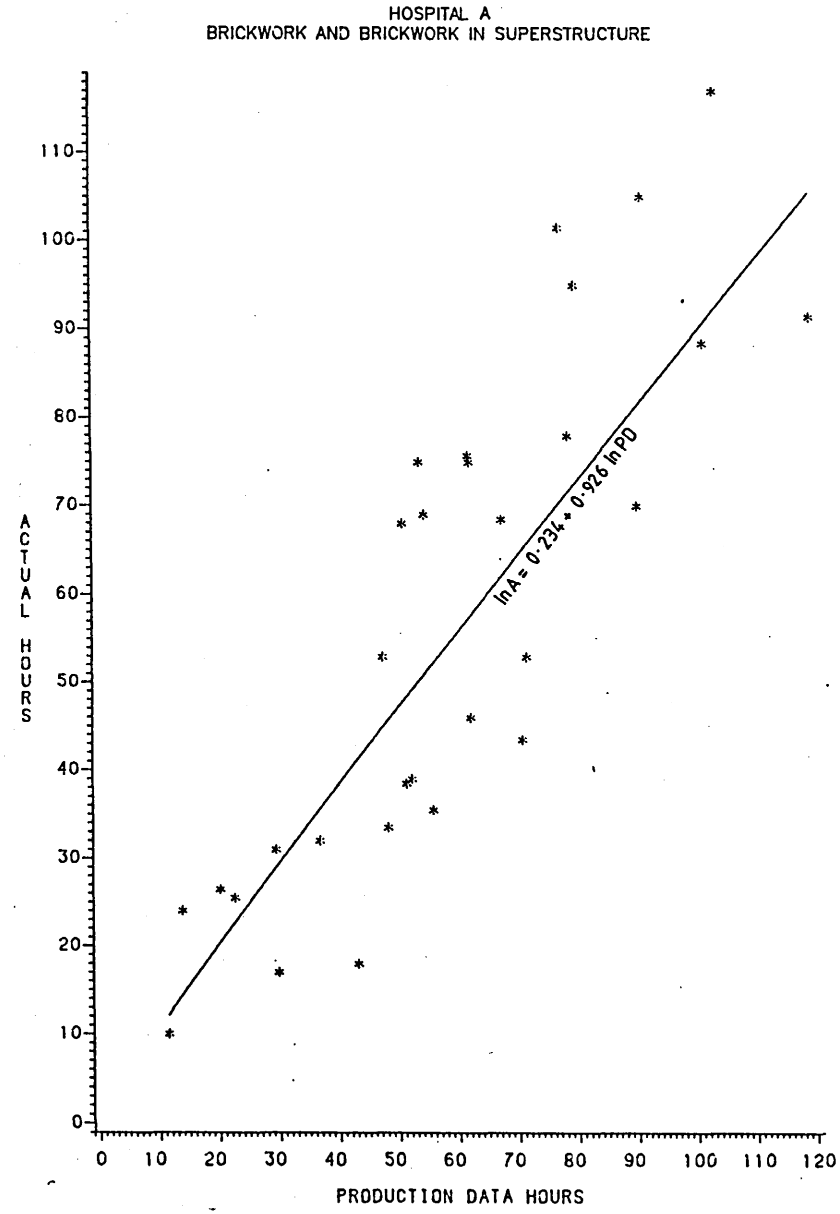

FIGURE 8.2 CURVED REGRESSION MODEL

was evident that certain targets did contain sundry items which could be regarded as significant items. In these cases such items form an important part of the target and would greatly influence productivity. Figure 8.3 shows two cases, one where sundry items represent a small percentage of the target and the other representing a large sundry content.

The method used in the model, based on the processing of significant items to generate work packages, would be insufficiently accurate for work packages with circular work. The total hours generated would not be balanced to suit the work package since the proportioned addition for sundry items would be much less than the actual sundry content, and in such circumstances would not be sufficiently accurate (See Figure 8.3).

It is clear that the type of project and construction design will influence the situation. Certain projects with little complex work would not present a problem and the model could be used adequately.

Other buildings would present problems where sufficient complexity would require accurate targets to suit each particular situation, but they are only in a minority since by far the greater proportion of buildings today do not contain complex brickwork.

Brickwork in Superstructure

	qnt	target/m2	target total	model production data	actual
hb facings	13.35m2	1.83	24.43		
e.o. soldier	8.30m	0.10	0.83		
hb commons	5.81m2	1.35	7.84		
lb commons	77.90m2	2.52	196.31		
cav. insul.	13.35m2	0.10	1.34		
			230.75	169.60	115

$$\% \text{ sundries} = \frac{2.17}{230.75} = 0.9\%$$

Brickwork in Superstructure

	qnt	target/m2	target total	model production data	actual
Brickwork	4.69m2	2.50	11.73		
Arches in bwk	2nr	2.90	5.80		
			17.53	7.50	16

$$\% \text{ sundries} = \frac{5.80}{17.53} = 33\%$$

FIGURE 8.3 SUNDRY CONTENT OF TARGET ITEMS

8.4 IMPROVEMENTS IN FORECASTING

From the analysis of data sets for the projects considered in the study, several approaches could be adopted to improve forecasting:

1. The problem could be overcome in the computerisation of the model where significant sundry items could be differentiated from other sundry items. For example, in the case of arches, the category code could be coded 'ARCH' (for arch) instead of 'SUN' (for sundries). In doing so they would not be included in the adjustment figure for sundries and would be included with the significant items.

   The appropriate quantity could then be input where these occurred in a work package, thus allowing all the time for the item to be included and thereby produce a more realistic time duration. Alternatively, such items could be targetted individually, should such circumstances dictate.

2. As stated earlier, the precise description of complexity was not identifiable from the data collection. To try to overcome this problem (considering the restriction of the present data collection method) more annotation of work would be necessary. This would allow separate data sets to be formed and analysed accordingly.

3. To investigate the problem of complex work in more detail. This would constitute further research into the analysis of complexity variables.

8.5 SUMMARY

The apparent lack of effectiveness in forecasting for brickwork and blockwork was caused by SMM. It was identified that the brickwork and blockwork section is the most affected by the unit rate of measurement, because of the variation of work that can occur within the quantity of a single bill item. Some sundry items were found to greatly influence production, particularly where such items represented circular work.

Various approaches were considered with this problem. The first was to consider the aspect of curved regression models for more accurate forecasting. In the majority of cases, the curved regression models did not produce substantially more accurate results than the single coefficient model.

Secondly, the need was revealed to identify what could be classed as significant sundry items which have a great influence on productivity. It is suggested that decisions are made based on the assessment of individual projects. This would permit significant sundry items to be identified, coded accordingly, and included in the appropriate level of work packages. Sundries in the majority of cases, however, do not substantially affect the work package duration.

Data recording procedures for productivity performances could also be improved to allow identification and documentation of complex work. This would enable separate data sets to be established accordingly relating to specific types of work.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

9.1 INTRODUCTION

The primary aim of this research was to see whether it was possible to develop an integrated estimating, planning and control system based on actual production data, which could be used in the construction industry to improve the processes of estimating and planning. In addition, a number of objectives were identified in Chapter 1. In this final chapter each of the objectives are considered together with the major findings of the research in order to present conclusions and recommendations.

9.2 INFORMATION REQUIREMENTS FOR PLANNING AND CONTROL

The systems study in Appendix 1 illustrated the existing systems within the collaborating body. Further investigation into these systems revealed the need for production orientated information requirements to provide the opportunity for greater planning and control at various levels of detail.

Existing systems indicated much time was spent in obtaining information which was required for production purposes. This was primarily because of the format in which information was presented to management. The needs of production management were identified and these were directly linked to information contained within the estimate. Ultimately, the requirements were directed at overall planning, short term planning and the generation of work targets.

9.3 THE PRODUCTION DATA BASE

The creation of a production data base proved possible by the collection of feedback data on productivity performances from site operations. Production data were established by adjusting target rates from a company data base used for incentive targets. Work items were documented in the data base in a similar format to SMM6 form of measurement.

Collection of production data covered several project types and where similar items were recorded these were averaged to establish a common data base rate. Three work sections of measured items were established in the data base for concrete work, brickwork and blockwork, and woodwork.

9.4 THE LINK BETWEEN BILLS OF QUANTITIES AND PRODUCTION INFORMATION REQUIREMENTS

Establishing a link between production information requirements and conventional bills of quantities proved possible through the development of the logical model which was the subject of Chapter 5. This illustrated the method of integrating production data with bills of quantities documentation. This formed the basis for the generation of planning information at various levels of detail and the generation of estimates. The model proved successful through the concept of work packaging to suit individual project requirements.

In developing the logical model it was concluded that integration of production data and estimating would provide the necessary information requirements for planning and control of construction.

The logical model was extended further in Chapter 6 by computer implementation for the generation of planning information. Production data, based on SMM form of measurement, were successfully represented in operational format for selected projects in the validation study. The developed system prototype also provided flexibility for generalised use in generating planning information to suit individual projects.

9.5 THE RELATIONSHIP BETWEEN ESTABLISHED PRODUCTION DATA AND PRODUCTION PERFORMANCES

Production data and actual production performances were analysed and the extent of variation was found to be inconsistent in all the three work sections of concrete work, brickwork and blockwork, and woodwork. Variation was not restricted to any particular category, or size of work package. Variation was common on the most simple operations in addition to the more time consuming operations, irrespective of the type of building.

The extent of variation made it difficult to establish accurate prediction models. Various types of curved regression models and single coefficient models were investigated but no one method proved consistently accurate. It was concluded that the single coefficient model was as accurate as any other type of model.

9.6 THE EFFECTIVENESS OF AN INTEGRATED SYSTEM

Production data forecasts from the integrated model were analysed for the three selected work sections of concrete work, brickwork and blockwork, and woodwork. The effectiveness of model forecasts and suitability of the integrated approach for estimating, planning and control have been based on the results obtained using production data. Accuracy in relation to actual hours has been assessed from the analysis of errors, and comparisons made between model forecasts and forecasts from existing methods. The root mean square error was the criterion used for comparisons on first and second sample projects. Second sample projects were also assessed on the tolerances of plus or minus one standard error of estimate from first sample projects. The assessment for each work section are:

9.6.1 Concrete Work

The concrete categories at the tertiary and secondary level illustrated considerable variation. This was reflected in the range and dispersion values recorded

(See Chapter 4 Table 4C). Variation was still evident even though three separate methods of placing concrete were identified and separately assessed. Variation was common to all operations on both simple and complex concreting operations.

Analysis of the first sample projects at the tertiary and secondary levels, illustrated improved accuracy over both estimators' data and bonus surveyors' targets. From the first sample of fifteen concrete categories, production data proved more accurate in thirteen of the fifteen cases. In comparison with bonus surveyors' targets, production data illustrated greater accuracy in eight of the fifteen cases (See Chapter 4 Table 4D).

The reduced accuracy on the other data sets were not related to particular categories or project types. Reasons why inaccuracies occur is dependent on the productivity achieved on individual categories which is influenced by motivation and organisational factors. This was evident in the second sample project data where the plots illustrated bias towards overestimation or underestimation. This signifies the variation of productivity on individual projects rather than inaccuracies in production data.

Variation of forecasts on the second independent sample projects was assessed based on the performance of first sample projects. For the concrete categories at the tertiary and secondary levels, three of the five cases produced above 68% of data within plus or minus one standard error of estimate from first sample projects (See Chapter 7 Table 7C). The data sets not within the effective tolerance illustrate the extent of variation that can occur in concrete work.

Using the model on the second sample of projects also illustrated more accurate forecasts. The production data proved more accurate than estimators' data in all five cases. Comparisons with bonus surveyors' targets also indicated improvement in three of the five cases (See Chapter 7 Table 7D).

These results obtained at the tertiary and secondary levels on the second sample projects indicate that production data would produce more realistic estimates and more accurate forecasts for planning purposes.

At the primary level, above 68% of second sample data were within plus or minus one standard error of estimate from first sample projects (See Chapter 7 Table 7F). Comparison of errors at the primary level indicated improved model forecasts on both projects compared with estimators' data, and on one project compared with targets set by bonus surveyors (See Chapter 7 Table 7G).

Although production data have illustrated improved accuracy generally in concrete work, the extent of variation calls for more research to identify variability factors in order to improve forecasts.

The formulation of small work packages to control production would be recommended to reduce variation. This would be possible using the model where targets could be generated before work commences. Variation could be monitored more closely in such situations rather than allowing large work packages to span over several weeks.

The results obtained at all levels in this work section would support the integrated approach for concrete work. This has proved successful when it is possible to identify the precise method of placing concrete which can be related to specific measured categories and work packages. The integrated approach of the model has also illustrated its improved accuracy over existing methods.

9.6.2 Brickwork and Blockwork

In the brickwork and blockwork section, the production data illustrated improved accuracy in the first sample projects. In the thirteen categories considered at the tertiary and secondary levels, production data proved more accurate than estimators' data on ten occasions. Comparisons with bonus surveyors' targets illustrated production data having the greater accuracy in nine of the thirteen categories (See Chapter 4 Table 4F).

Variation of forecasts at the tertiary and secondary levels of the second sample projects were assessed based on the standard error of estimate from the first sample projects. At this level, one of the four cases contained above 68% of second sample data within the tolerance (See Chapter 7 Table 7I).

Second sample projects at the tertiary and secondary levels indicated improved accuracy of production data over estimators' data in three of the four categories. Comparisons of production data at these levels indicated that bonus surveyors' targets were more accurate in all four cases (See Chapter 7 Table 7J).

The results obtained from the second sample projects would not support the production data and model for brickwork and blockwork at the tertiary and secondary levels.

At the primary level one of the two projects produced above 68% of data within plus or minus one standard error of estimate from first sample projects (See Chapter 7 Table 7L). The other project illustrated overestimation because of the high outputs achieved throughout the project duration.

Production data at the primary level proved more accurate than estimators' data on both second sample projects. Bonus surveyors' targets proved more accurate than production data in both cases (See Chapter 7 Table 7M).

Blockwork in superstructure was the only category which indicated any consistency. This may be accountable to blocklaying operations. Brickwork productivity is much more influenced by design features. This was most noticeable in the 'hotel B' project where much circular work influenced outputs. One reason for reduced accuracy of model forecasts was accountable to sundry items which can form a significant part of the work package. Although the sundry items do not represent a large proportion of the total value of the work section, they form part of a work operation which can greatly influence the rate of working.

Suggestions for reducing the influence of sundry items were discussed in Chapter 8. Identification of sundry items considered to be an important part of the work package would have to be included with the main items.

The SMM6 in this work section was found to be insufficiently detailed in relation to specific work packages of the construction process. Single measured items of brickwork and blockwork can represent large quantities of work which covers various work packages of varying degrees of complexity. Using average production data to cover all these situations results in loss of precision in model forecasts. In particular, inaccurate forecasts in brickwork superstructure were caused by SMM6 and this will also apply with SMM7.

Consistent forecasting in brickwork and blockwork was difficult to achieve and no accurate forecasting model was produced because of the variation present, particularly in superstructure brickwork. Increasing accuracy of forecasts in such situations calls for more research in this area.

Considering the assessment of the results of brickwork and blockwork it can be concluded that while production data has illustrated greater accuracy than estimators' data, it is insufficiently accurate for planning at the tertiary and secondary levels, particularly for setting incentive targets. The results obtained would not support the production data and model for brickwork and blockwork.

9.6.3 Woodwork

In the woodwork section, the various categories at the tertiary and secondary levels produced the highest variation of the work sections considered (See Chapter 4 Table 4G). Standard type woodwork fixings were found to produce the highest variation irrespective of type of building or size of work package.

The highest variation in productivity performances could indicate the influence of motivational factors on individual projects. In woodwork fixings, the skill factor of operatives would have a considerable influence on the actual duration of operations.

Reasons for inaccuracies in production data can be attributed to the method used in obtaining production data for woodwork items. The method of proportioning the actual duration of the work package to establish production data for measured work items has been shown to be insufficiently accurate. More detailed data collection from sites is required to relate to specific items rather than refer to a total time obtained for work packages representing a collection of items.

9.7 EVALUATION OF THE TOTAL INTEGRATED APPROACH

The system prototype herein suggests that the computer based approach is feasible. The formulation of work packages by computer based methods makes possible the establishment of model forecasts.

An integrated approach should provide for more precise information requirements of management, and investment in an integrated system within a company's organisation ought then to provide for more efficient working and greater information transfer.

The forecast-observation diagrams may assist progress monitoring, thus initiating an effective control mechanism for construction operations. Substantial deviation from the model forecasts could then prompt an investigation of production data, and, should this occur consistently, establish a need for greater control on site. This should also provide the necessary feedback of information for variance analysis and the adjustment of production data.

Any long term deterioration or changes in construction method can be reflected in the production data. This should then improve the accuracy of the processes within the integrated system. Such changes are made possible by computer implementation of the integrated systems approach and this cannot be met satisfactorily by manual methods.

Ultimately, the planning and control of operations based on production data should make possible the formulation of a progressively improved production data base, providing greater correlation between production data, planning information and estimates.

9.8 SUMMARY OF CONCLUSIONS

These conclusions are based on results arising from the exercise of an integrated system for estimating, planning and control of construction work based on production data. The exercise had the following limitations:

1. The research was restricted to the work sections of

concrete work, brickwork and blockwork and woodwork.

2. The study dealt only with projects using traditional bills of quantities applying the Standard Method of Measurement of Building Works.

3. The model was restricted to values of output of labour.

4. The study excluded sub-contract work.

5. The validation of the model was restricted to concrete work and brickwork and blockwork. The absence of woodwork data on second sample projects caused its use to be abandoned.

Nevertheless, within this limited development, it has been demonstrated that:

1. It is possible to formulate a production data base from production data and use the data base to forecast values of average productivity performance.

2. The development of the logical model and its computerisation made possible the integration of the production data with estimating and planning. This allowed the generation of planning information, using items measured in accordance with the SMM and the concept of work packaging, to suit information requirements.

3. Simple prediction models are adequate within such an integrated approach, and pursuing more complex models does not seem worthwhile.

4. This type of model makes possible monitoring of production outputs by the incorporation of forecast-observation diagrams.

5. The research has established that, when methods of placing can be clearly identified and related to work packages, the production data and model give a worthwhile improvement over estimators' data and bonus surveyors' targets in forecasting average production performance. Thus the application of the model has shown to be useful for concrete work.

6. When measured items cover work packages of varying degrees of complexity, and when proportioning methods are used to obtain production data for different categories of items which collectively represent work packages, the production data and model are insufficiently accurate to give a worthwhile improvement over estimators' data and bonus surveyors' targets. Thus the application of the model is not necessarily useful for brickwork and blockwork, and woodwork.

7. SMM7 is not sectionalised in a way to be used as a vehicle for planning construction operations. The

relationship of SMM7 to the concept of work packaging for construction operations at detailed levels was seen to present problems. Commonly grouped items appear in different sections.

9.9 RECOMMENDATIONS FOR FURTHER WORK

Although the integrated approach has been shown to be worthwhile for concrete work, the approach could be improved in a number of ways.

Firstly, productivity studies should examine the full range of outputs because of the considerable scatter in the production performances recorded.

Further studies should determine how work could be categorised in relation to complexity of work operations to investigate the possibility of establishing appropriate data sets for analysis. This would promote more accurate feedback.

Secondly, the validation on a second sample of independent projects did not include a study on woodwork because of the absence of data. Further research to assess this work section is therefore necessary.

Extending the scope of validation to other companies and including different types of projects would assist in investigating productivity variation over a wider spectrum. This would allow a more comprehensive

assessment of productivity and its variation.
Whilst labour effort was the area of study in this research work, other areas need investigation. For example, plant can represent an important part of the construction process on certain types of work and would greatly influence production planning.

The effect of the method of construction has a very important influence on labour, plant and materials in terms of proportional significance of cost. For example, piling work is a plant intensive operation where labour is a minor factor. Identification of these various situations needs to be investigated and their implications assessed in relation to planning and control.

During the study the issue of sub-contract work was not addressed because of the absence of data in specific trades. Clearly, the implications of sub-contract work is an important part of the total production process and main contractors need to be aware of the construction times of various sub-contractors and their effect on production. Production times of sub-contract trades need to be assessed and their overall impact on the planning of construction work. Integration of such work within the overall context of the production process is an important issue which requires attention.

Further research in productivity and the range of output values in the different trades and different types of buildings needs to be studied to try and assess variances. Data suitable for factor analysis may locate the source of variations in output, particularly where wide variations occur. Such work needs to be investigated in relation to the description of sites (e.g. in the case of restricted working), and design features (e.g. for complex brickwork).

Further work on system development should also be investigated to ascertain the value of incorporating automatic feedback input as a self refining mechanism.

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Appendix 1
Case Study: Systems Study of the Collaborating Body

STRUCTURED SYSTEMS ANALYSIS OF THE COLLABORATING BODY

1.1 INTRODUCTION

The first stage of the analysis was to consider the background of the company in order to give an insight of its overall trading activities. The background appraisal revealed that the group was quite diversified in its operations. The major sector of the work involves general contracting at local level which represents approximately 80% of the total turnover. Of this, 60% is undertaken by two companies with the remainder divided up amongst the other area companies. Several of the general contracting companies were therefore identified as being most likely to benefit from the research proposals and any subsequent systems to be developed (See Figure A1.1).

To conduct a detailed structured analysis of each company within the group was impractical. Each company would have proved a study on its own, and work was therefore concentrated initially on seven of the contracting companies.

The analysis was based on the top-down method using a structured systems approach as described in Chapter 3. This was further reinforced by establishing matrices showing functions and activities of construction personnel.

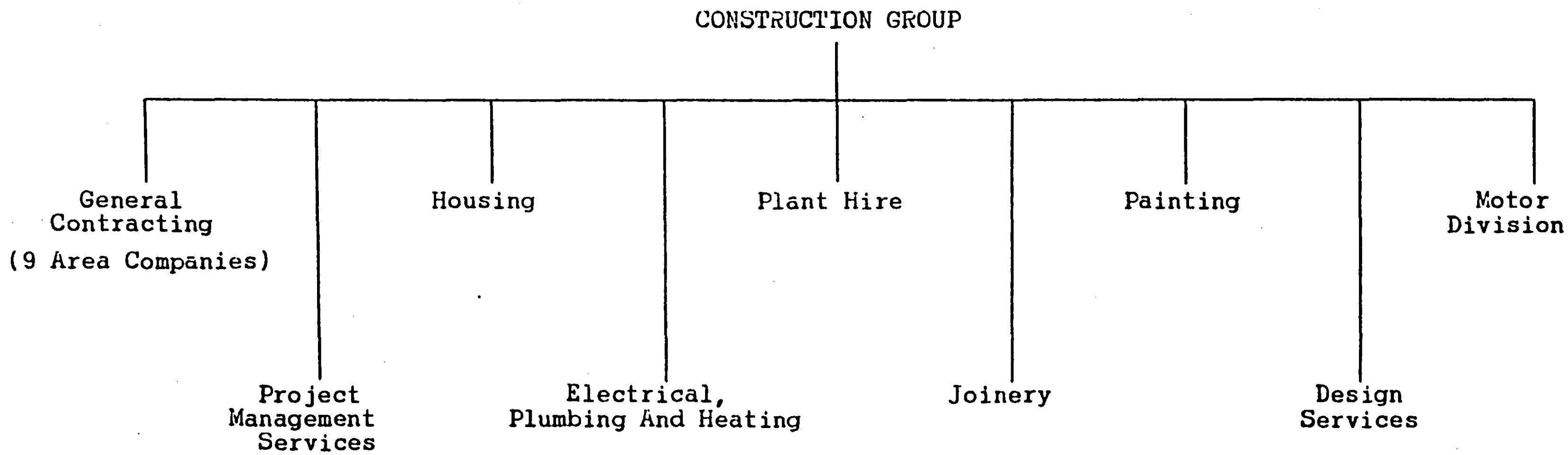


FIGURE A1.1 PRODUCT/SERVICE GROUPING

Verification of the analysis was later confirmed with personnel by discussion which included tracing precise information flows. This also enabled precise information requirements to be identified from the present systems in operation.

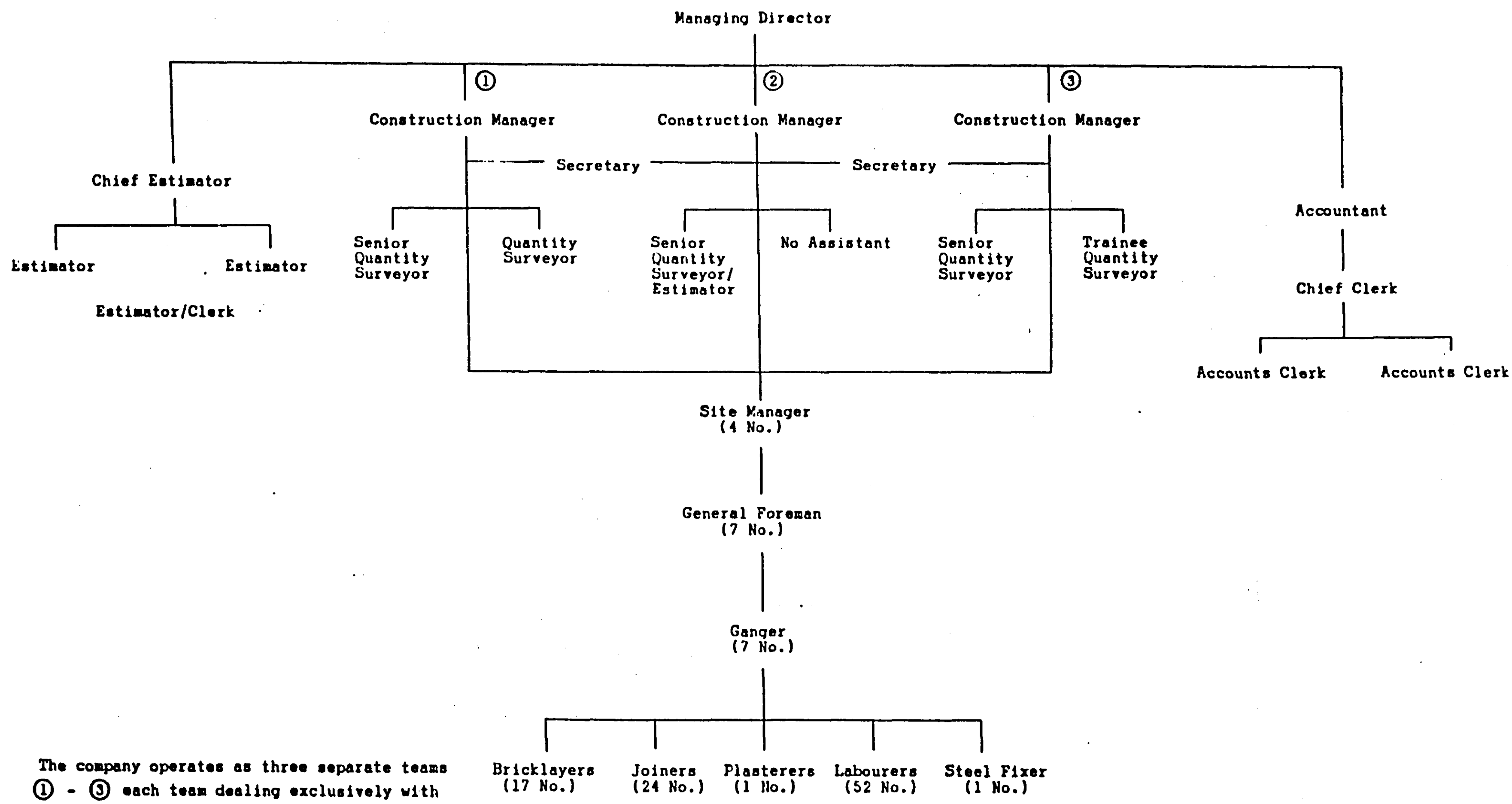
It was found that most companies operated on a similar basis. The administrative services are centralised at head office under the group company, so the documentation to and from the area companies is of the same form. The major contracting company was therefore used to establish a general information model illustrating the present systems in operation.

1.2 COMPANY SURVEY

The major contracting company operates with distinct management sections; each section operating on a team basis. Figure A1.2 shows the structure of the company with the three separate teams, each one dealing exclusively with its own contracts. Each management team operates entirely on its own, sharing a nucleus work force, which in effect produces a situation of three companies within one.

For the sake of the investigation, only one team (team 1) was the subject of investigation, since the other two teams operate on a similar basis.

Specific areas within the team were identified as



The company operates as three separate teams
1 - 3 each team dealing exclusively with
its own contracts

FIGURE A1.2 COMPANY STRUCTURE

general management, construction management, estimating and administration. Initially, the management structure was divided into contracts management and surveying, but having discussed the point with production staff, it was evident that these two areas were not distinct. The reason being that the 'team' manages the construction work and in doing so activities tend to overlap. Each member of the team may therefore perform a variety of activities, depending on particular circumstances (See Figure A1.3). Table A1A shows a matrix relating construction personnel with specific functions and activities.

In Figure A1.3 distinct activities have been shown under the construction management. The activities to the left are related to contract management and the ones to the right are related to quantity surveying. Activities towards the centre may be dealt with by any one in the team.

Administration has also been illustrated in the company model, but this could be considered separately under the group company. Unlike the other area companies which have a separate administration function linking head office and production, the major contracting company does not. Both companies operate from head office and any administration details are automatically dealt with by the group company.

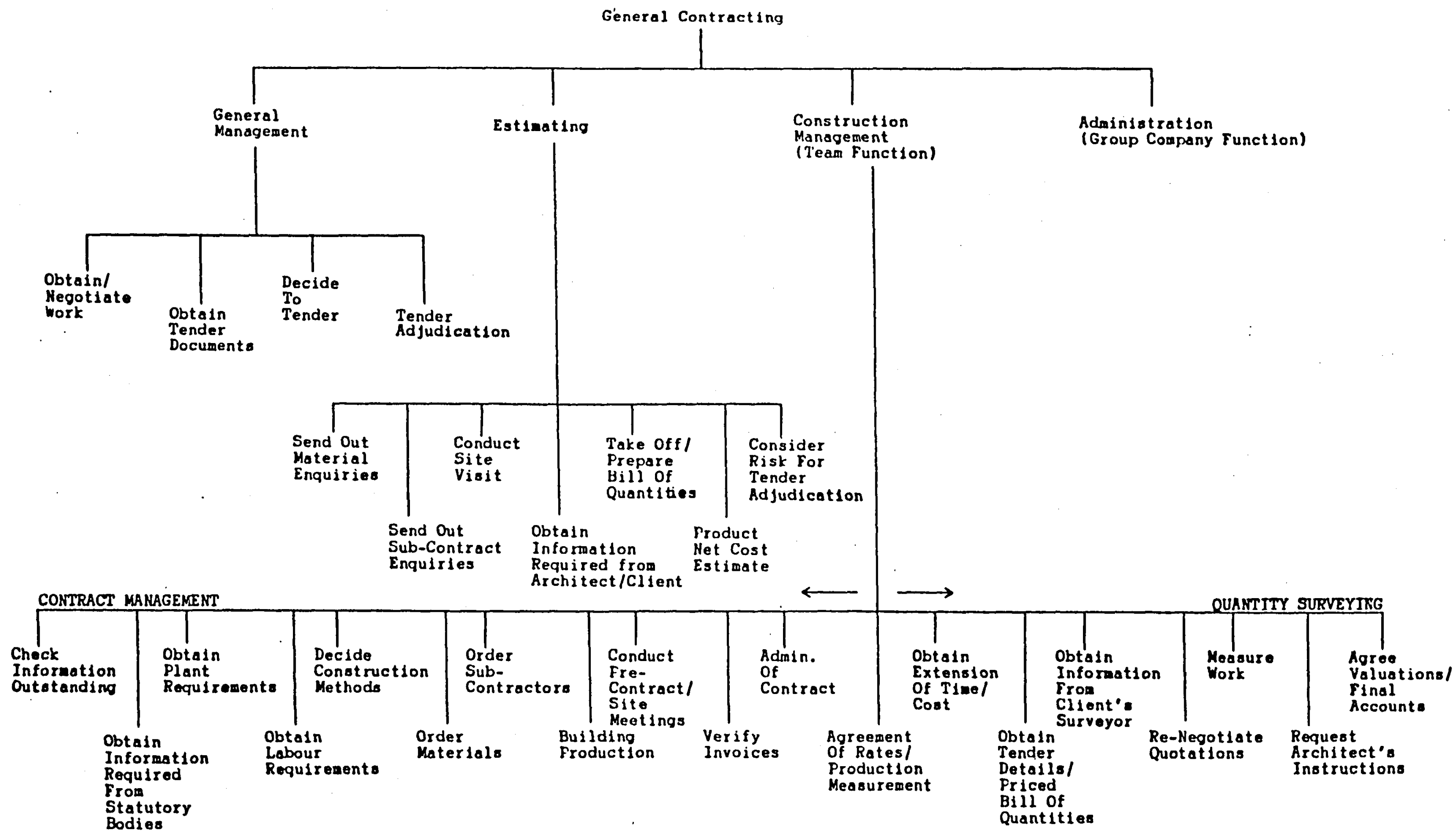


FIGURE A1.3COMPANY MODEL SHOWING FUNCTIONAL DECOMPOSITION

RESPONSIBILITY / FUNCTION/ACTIVITY	Managing Director	Construction Managers	Chief Estimator	Estimators	Estimator/Clerk	Senior Quantity Surveyor	Quantity Surveyor	Site Managers	General Foreman	Accountant	Chief Clerk	Accounts Clerks	Secretaries
GENERAL CONTRACTING	●												
General Management	●												
Obtain/Negotiate Work	●	●											
Obtain Tender Documents	●												
Decide To Tender	●												
Tender Adjudication	●												
Estimating			●	●									
Send Out Material Enquiries					●								
Send Out Sub-Contract Enquiries					●								
Conduct Site Visit			●	●									
Obtain Information From Architect/Client			●	●									
Take Off/Prepare Bill Of Quantities			●	●									
Produce Net Cost Estimate			●	●									
Consider Risk For Tender Adjudication			●										
Construction Management		●				●	●						
Check Information Outstanding		●				●		●	●				
Obtain Information Required From Statutory Bodies		●						●	●				
Obtain Plant Requirements		●						●	●				
Obtain Labour Requirements		●						●	●				
Decide Construction Methods		●						●	●				
Order Materials		●				●		●	●				
Order Sub-Contractors		●				●		●	●				
Building Production		●						●	●				
Conduct Pre-Contract/Site Meetings		●						●					
Verify Invoices		●				●							
Administration Of Contract		●				●	●						
Agreement Of Rates/Production Measurement		●				●	●						
Obtain Extension Of Time/Cost		●				●	●						
Obtain Tender Details/Priced Bill Of Quantities		●				●	●						
Obtain Information From Client's Surveyor						●	●						
Re-Negotiate Quotations		●				●	●						
Measure Work						●	●						
Request Architect's Instructions		●				●	●	●	●				
Agree Valuations/Final Accounts						●	●						
Administration										●	●	●	●
(Group Company Function)													

TABLE A1A MATRIX OF FUNCTIONS/ACTIVITIES

The other two areas shown within the structure are general management, which is dealt with by the managing director, and estimating which operates as a separate department on its own.

1.3 ANALYSIS OF PRESENT SYSTEMS AND IDENTIFICATION OF INFORMATION FLOWS

Having established the global model of the company in terms of its structure and activities, data flow diagrams were produced, which illustrated the functional activities from inception to completion (See Figure A1.4). From this overall representation a more detailed flow diagram was established of the production process, which highlighted the present system of information transfer. During the analysis stage, this also called for an insight into the head office (group company) activities and the plant company, since both provide a service to construction. Certain activities of these companies are integrated within the production process.

The precise details of production were established by discussions with contracts managers and site managers. A number of sites were visited to study the management activities and the flow of information from office to site. These details are shown in Figure A1.5.

Considering the precise planning systems within the company, most of the planning was dealt with at site

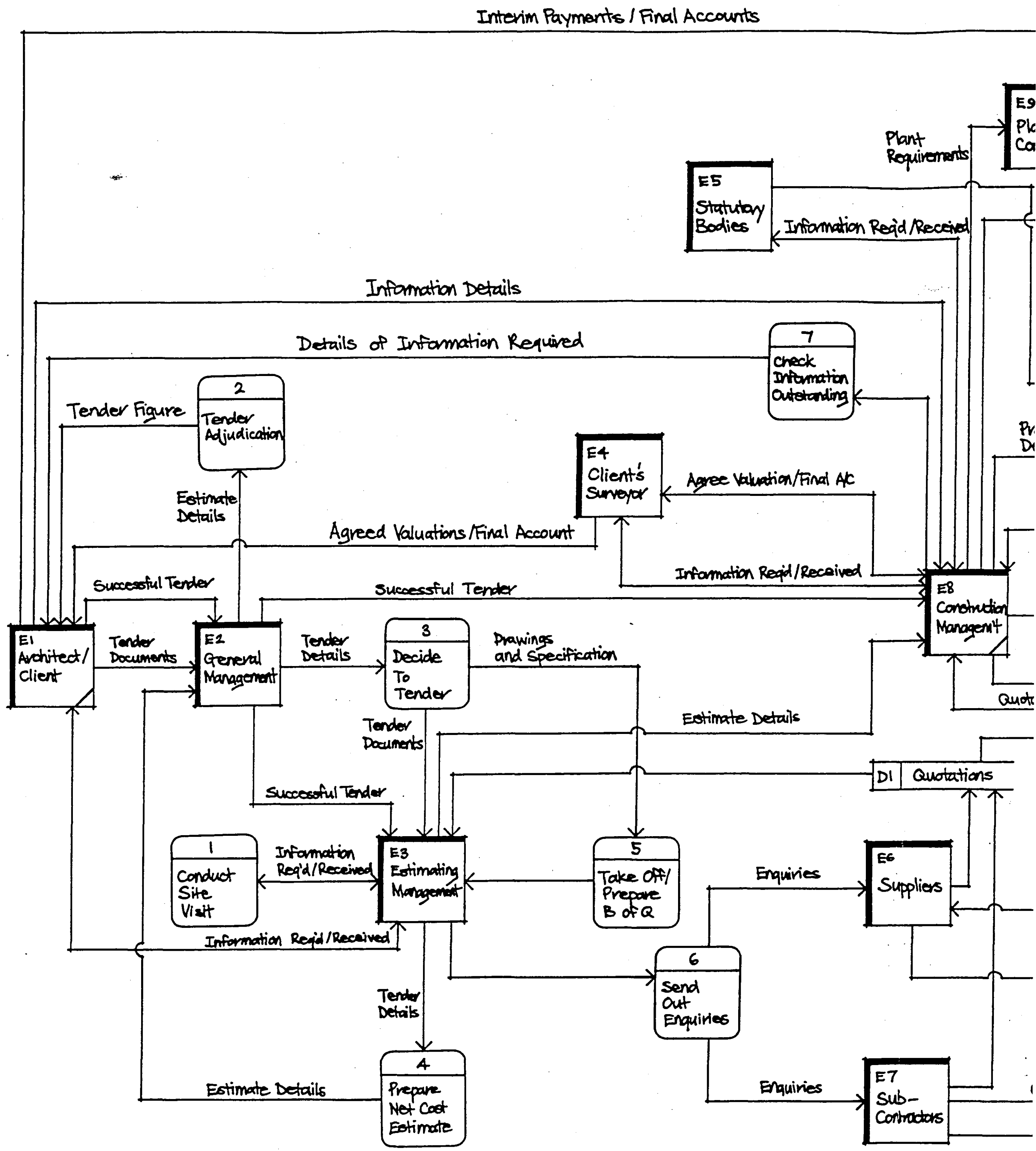
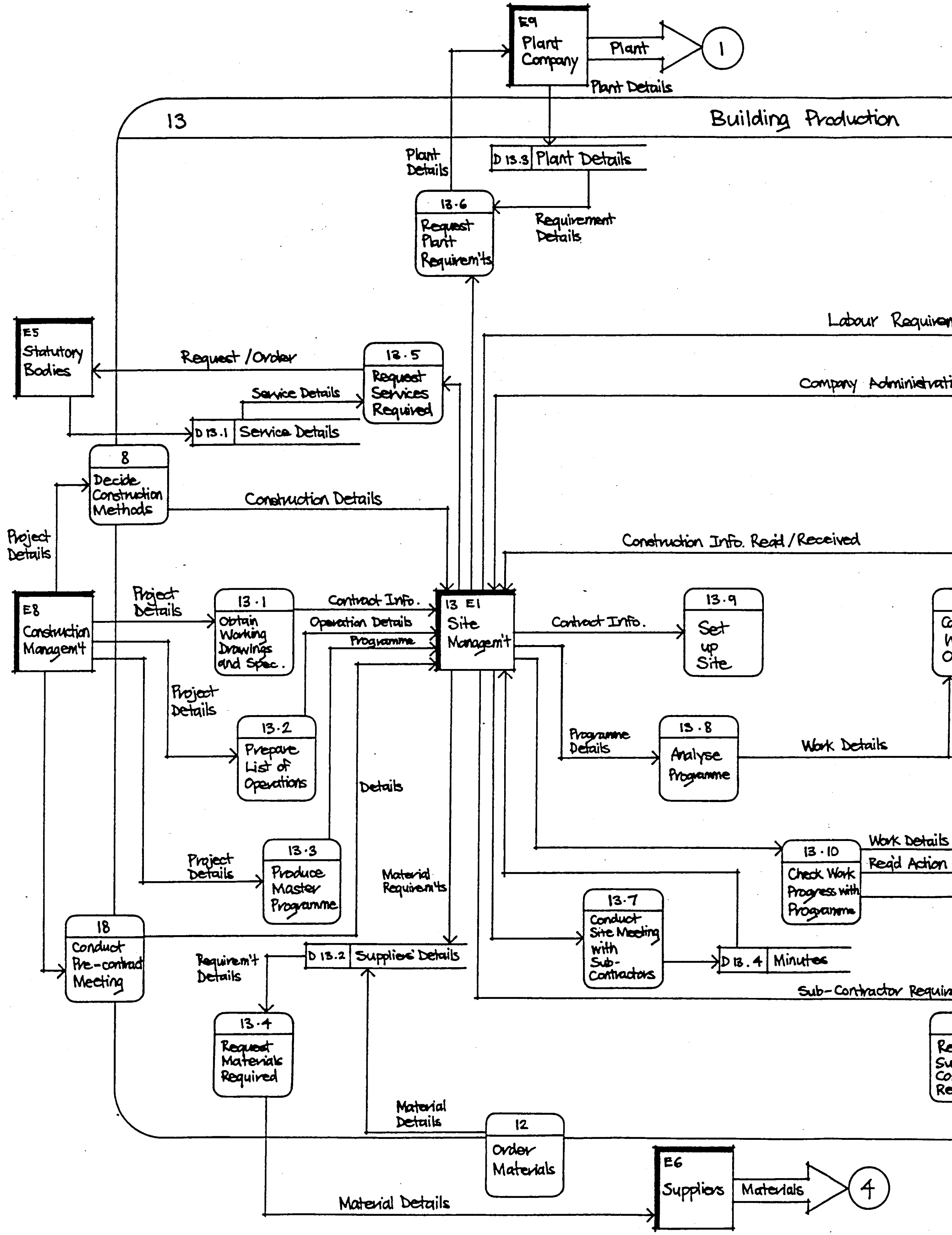


Figure A1.4 DATA FLOW DIAGRA



- A12 - Figure A1.5 COMPANY MODEL OF EXISTING BUILDING level. On one particular site visited an overall programme was prepared by the site manager, but this was not related to the estimate and was based on intuition and outline methods. Production was controlled by use of the overall programme combined with the needs of work operations.

1.4 INFORMATION REQUIREMENTS

In addition to the points raised on the data flow diagrams of the present systems, a number of observations were made which presented problems for site management.

The major points can be outlined as follows:

1. Lack of information provided at the start of the contract.
2. No information on the provision of preliminary items.
3. No information available on the labour content of the contract, including durations allowed.
4. Too much time spent sorting out information required during building production.
5. Information not available on which to base targets.
6. No feedback of information

1.5 SUMMARY

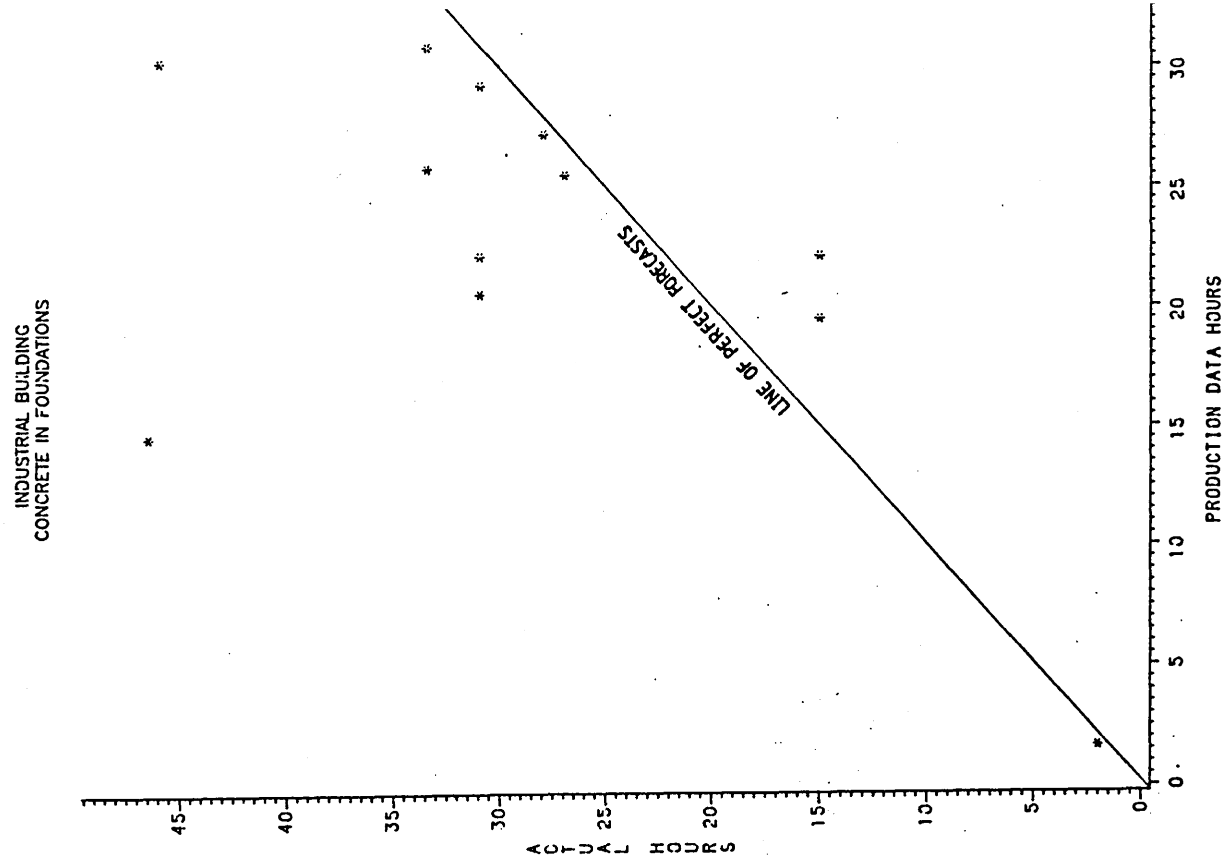
The diagrams and details drawn are an attempt to produce a model of the current systems in order to identify the extent of planning and control. From this analysis a number of observations have been made.

Probably the major problem area of the current model is the absence of any formal planning. The planning methodology is often a process that is left until the building production stage, and here, the actual extent of planning is dictated by the type of work and time availability. On small contracts, planning is often left to the site manager's experience and intuitive methods. Even on large contracts, planning is often based on assumptions rather than detailed analysis. This tends to be divorced from the methodology that was established during the estimating stage, which often results in different construction activities from those decided and forecast in the estimate.

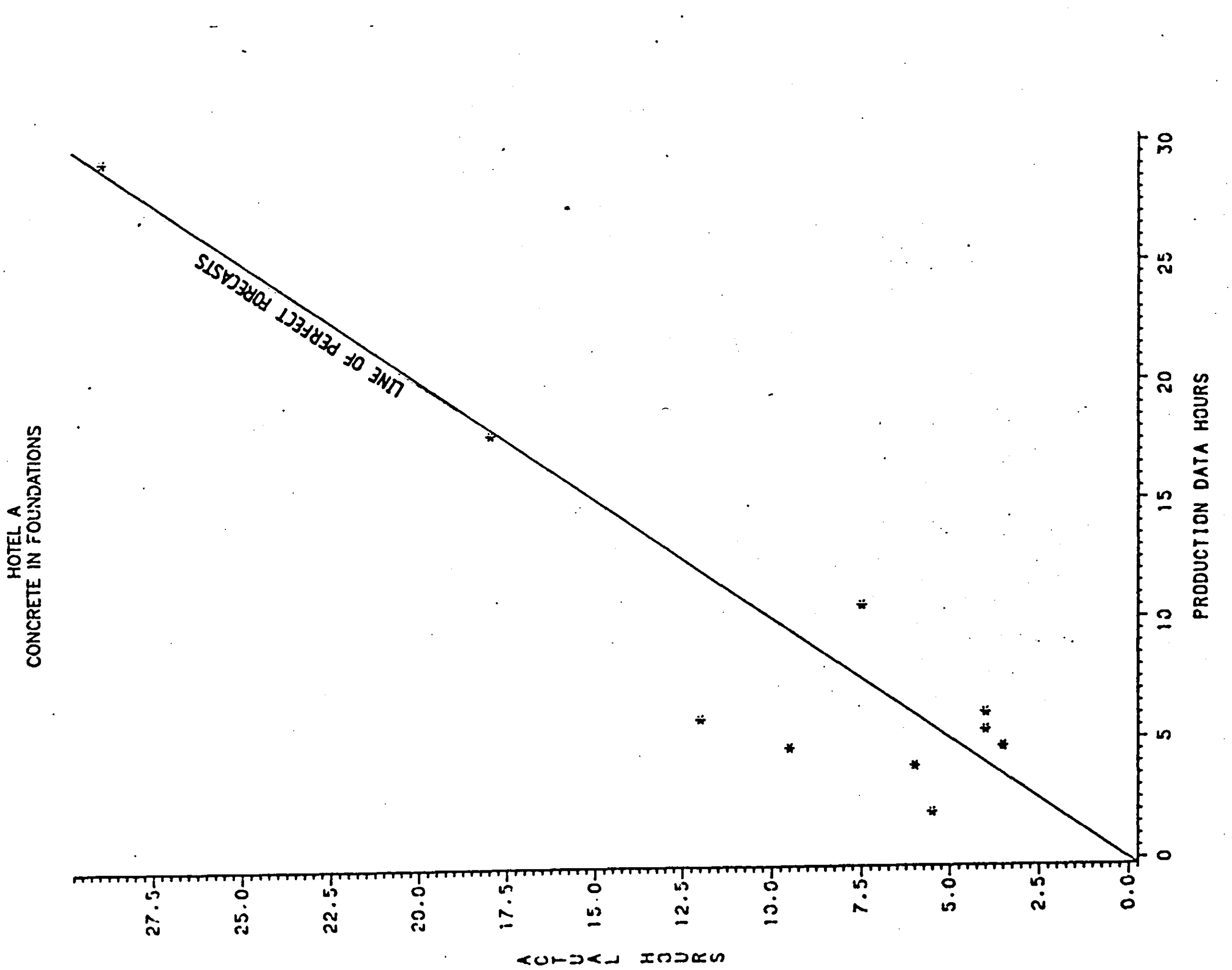
From the production side, requirements were recognised concerning production information, particularly with reference to information contained within the estimate. Information on preliminaries and in particular labour and plant resources allowed at tender stage, were amongst the major concerns of site management.

One clear observation was the need for greater integration, and particularly the projection of control information for use during the production process to assist management decisions.

Appendix 2
Plots of Actual Hours Against Production Data Hours

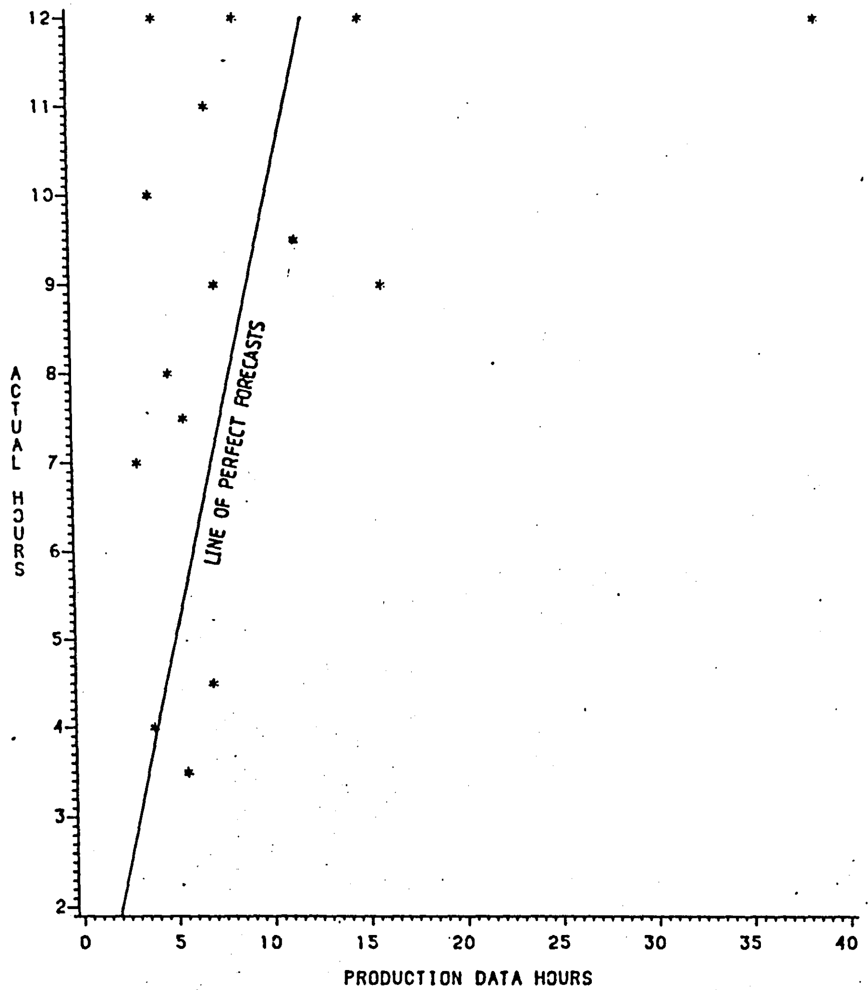


INDUSTRIAL BUILDING
CONCRETE IN FOUNDATIONS
LINE OF PERFECT FORECASTS
ACTUAL HOURS
PRODUCTION DATA HOURS

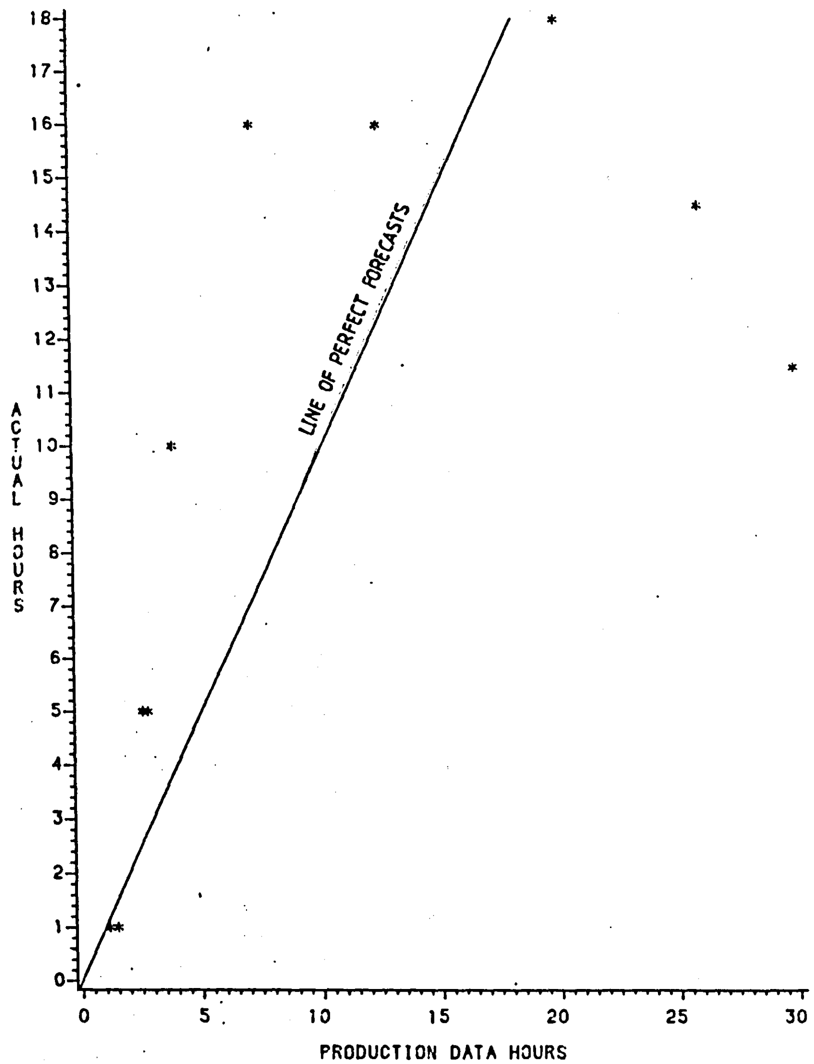


HOTEL A
CONCRETE IN FOUNDATIONS
LINE OF PERFECT FORECASTS
ACTUAL HOURS
PRODUCTION DATA HOURS

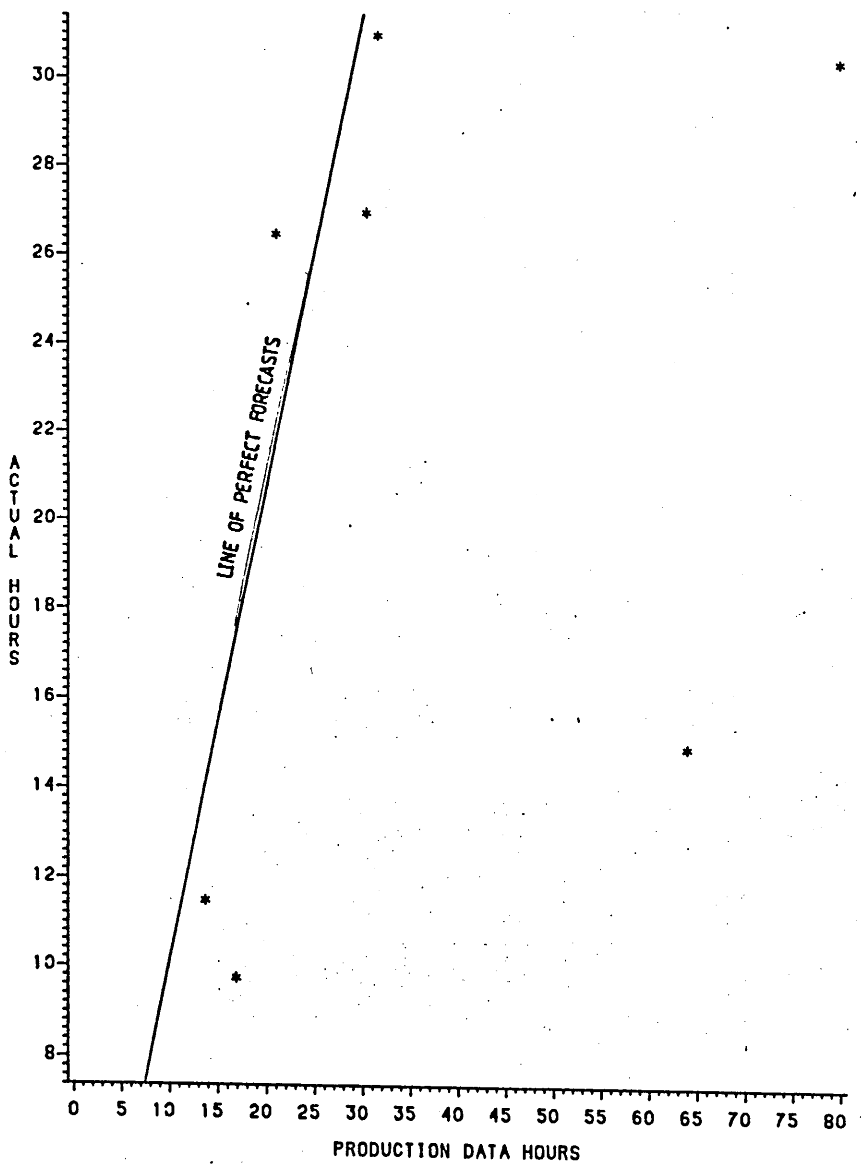
CONCRETE IN FOUNDATIONS



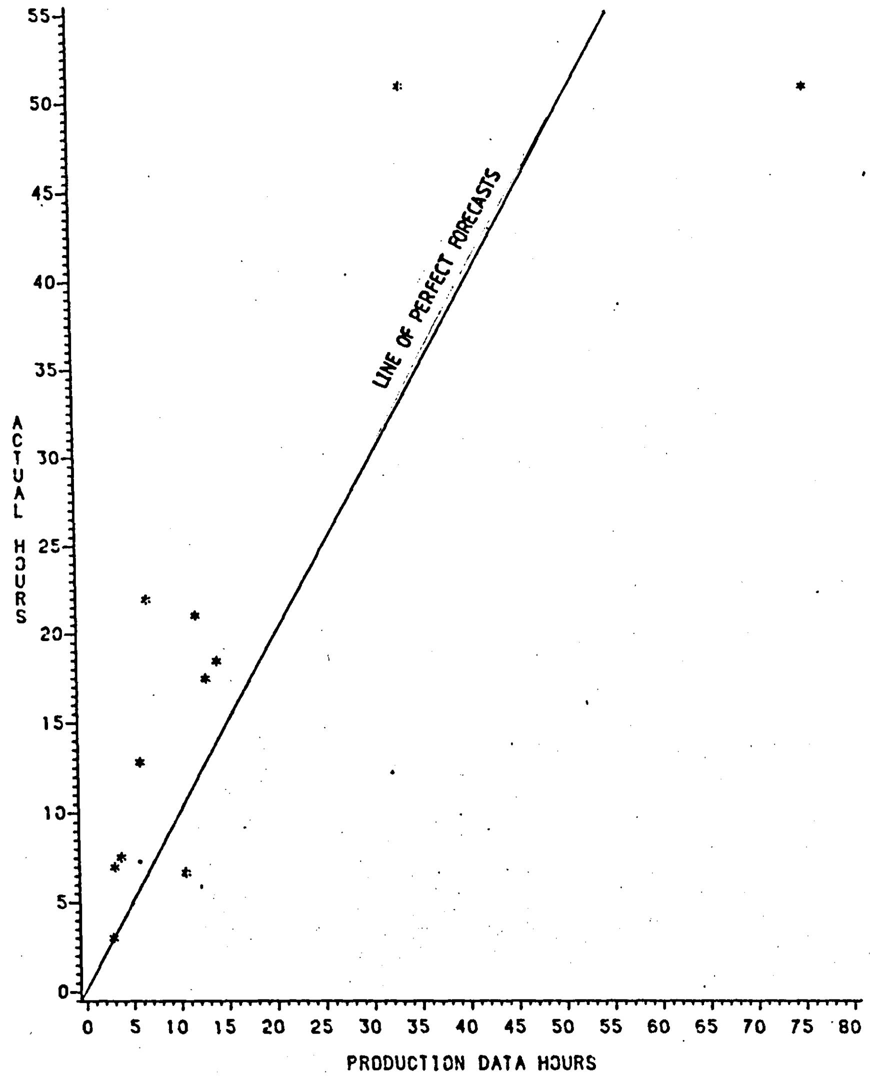
SCHOOL BUILDING
CONCRETE IN FOUNDATIONS



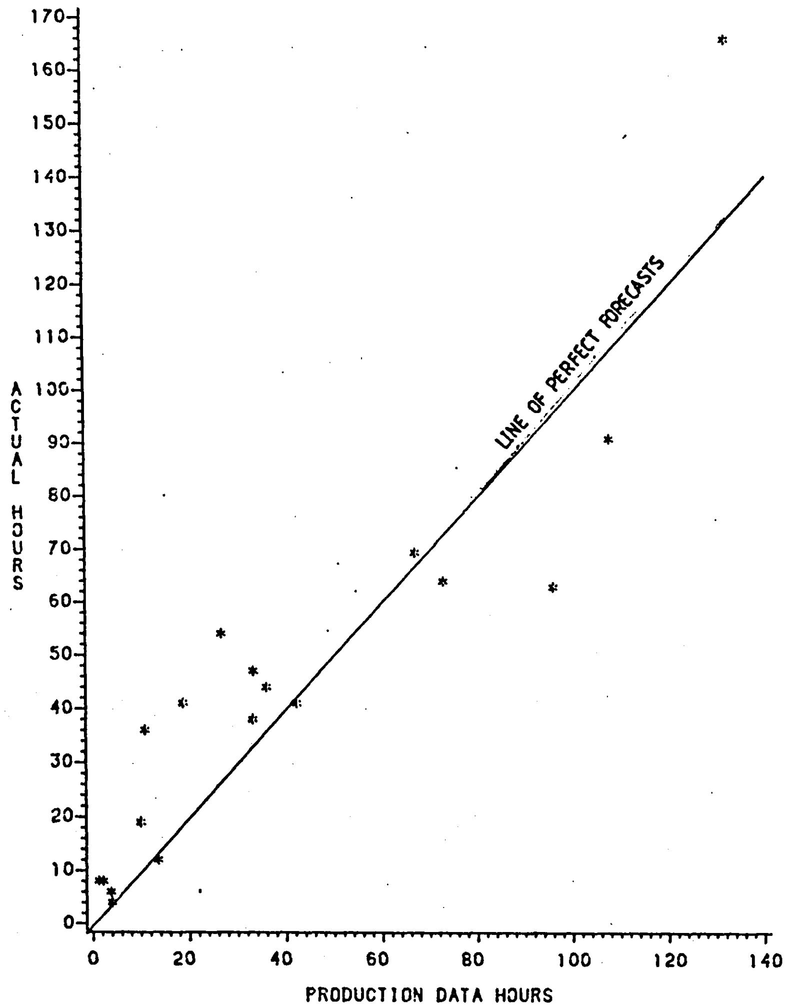
ARMY TRAINING BUILDING
CONCRETE IN FOUNDATIONS

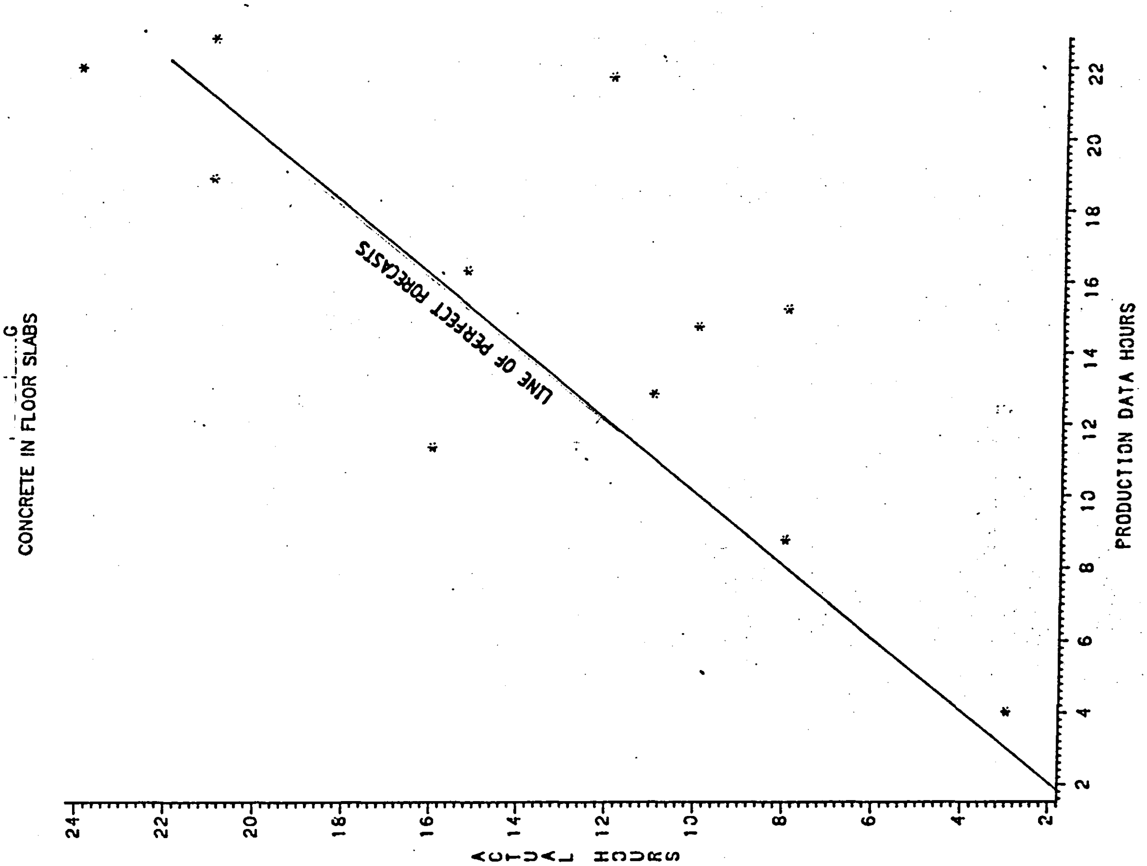


HOTEL A
CONCRETE IN FLOOR SLABS

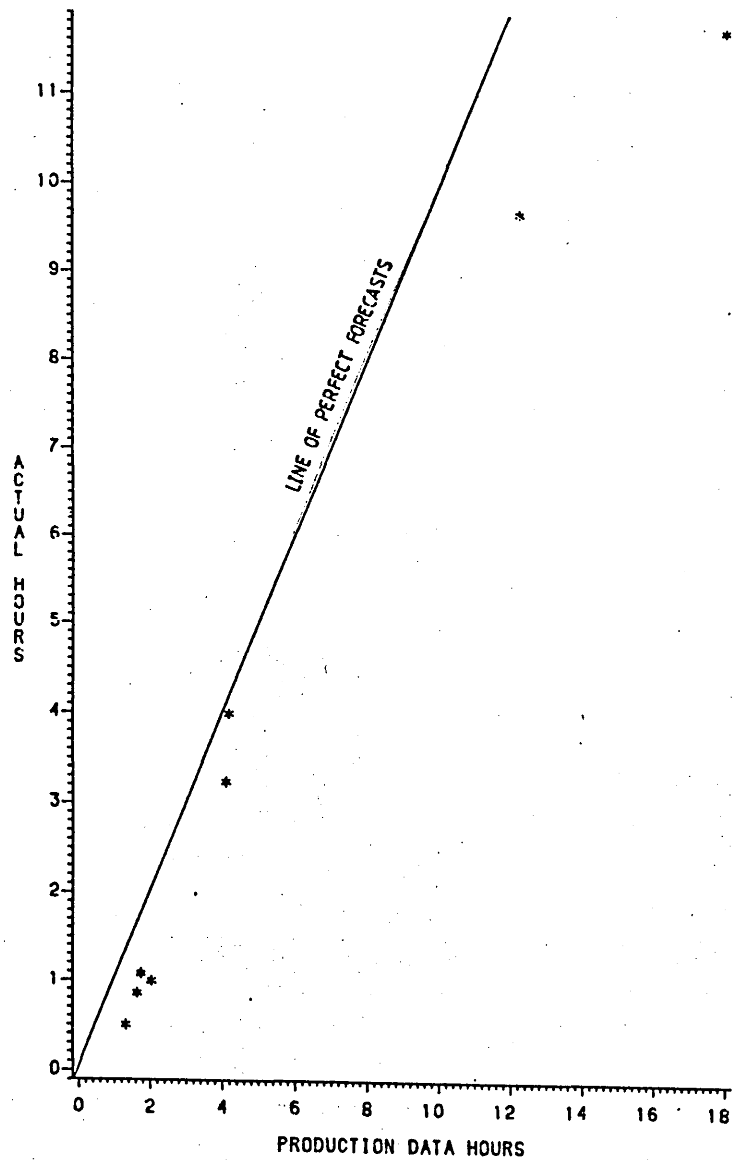


INDUSTRIAL BUILDING
CONCRETE IN FLOOR SLABS

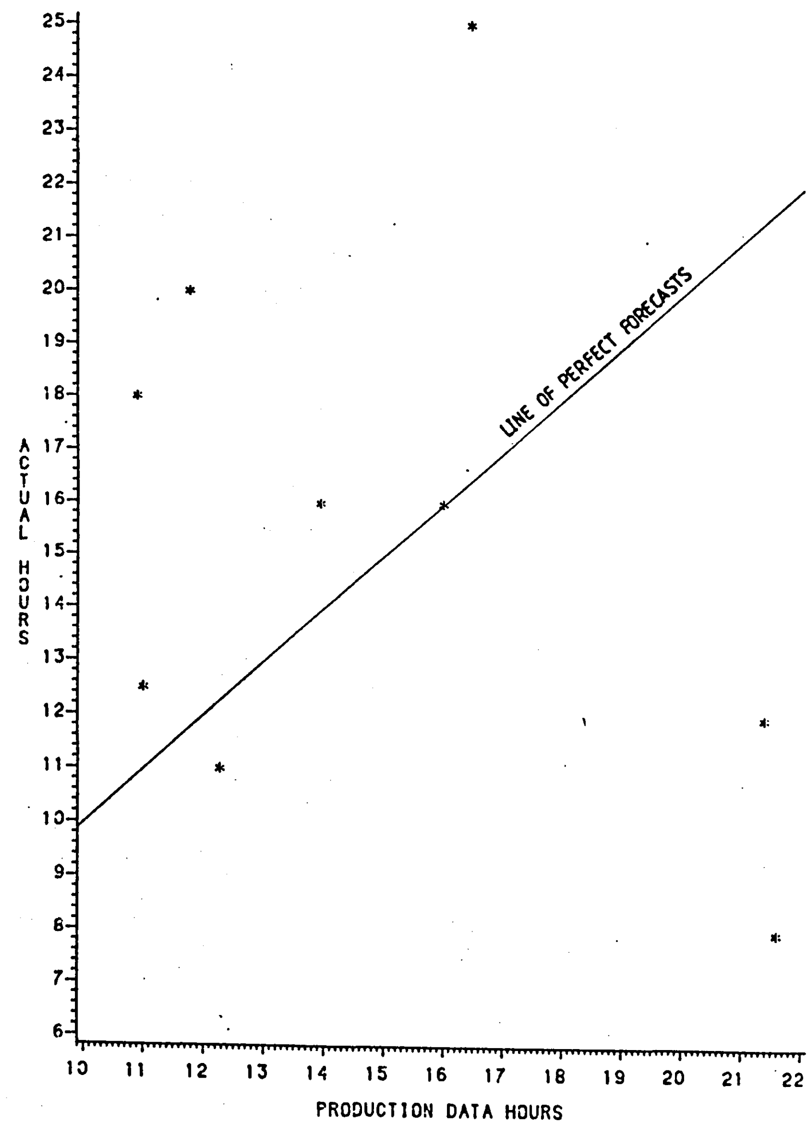



CONCRETE IN FLOOR SLABS
LINE OF PERFECT FORECASTS
ACTUAL HOURS
PRODUCTION DATA HOURS
2
4
6
8
10
12
14
16
18
20
22
24

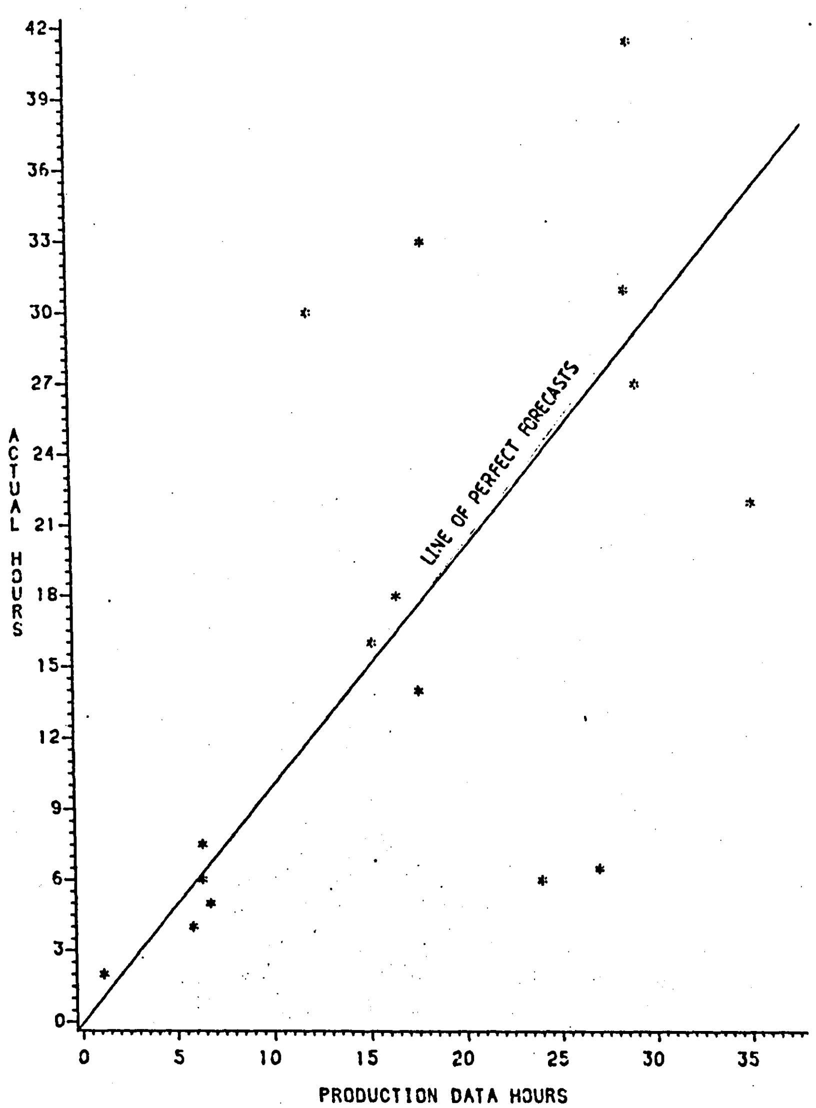
HOTEL A
CONCRETE IN SUSPENDED SLABS, STAIRS AND LANDINGS



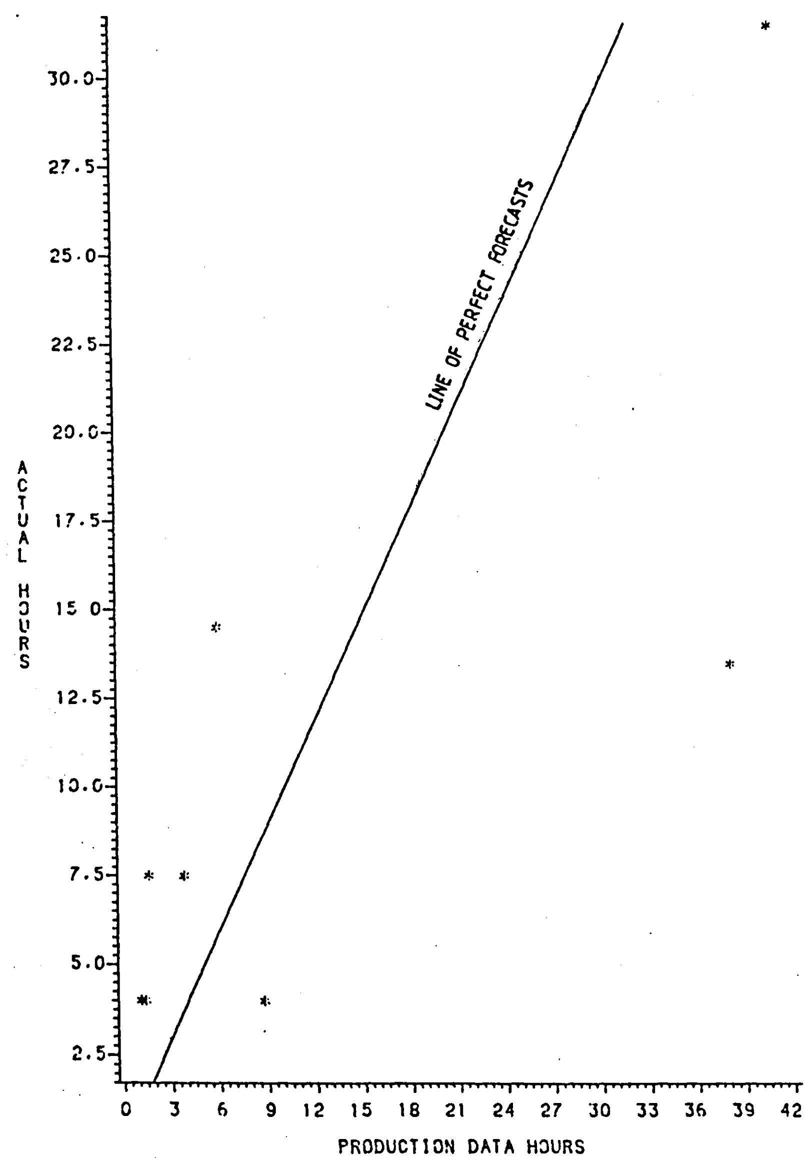
INDUSTRIAL BUILDING
CONCRETE IN SUSPENDED SLABS, STAIRS AND LANDINGS



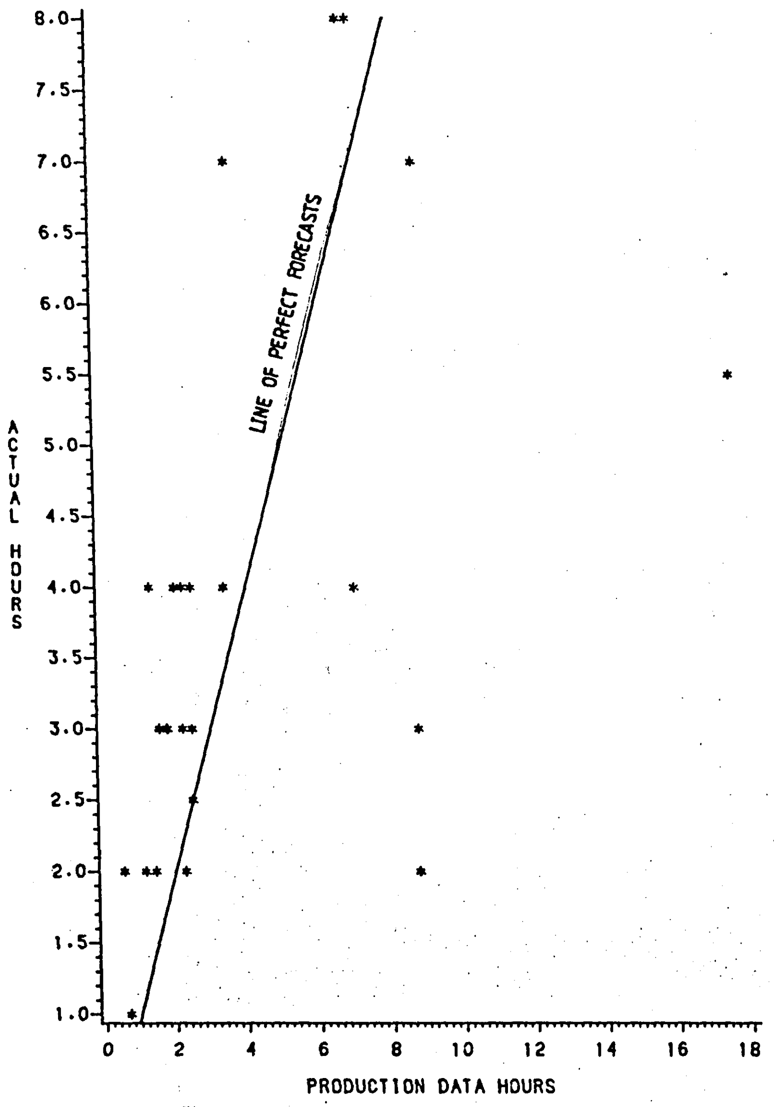
HOSPITAL A
CONCRETE IN SUSPENDED SLABS, STAIRS AND LANDINGS



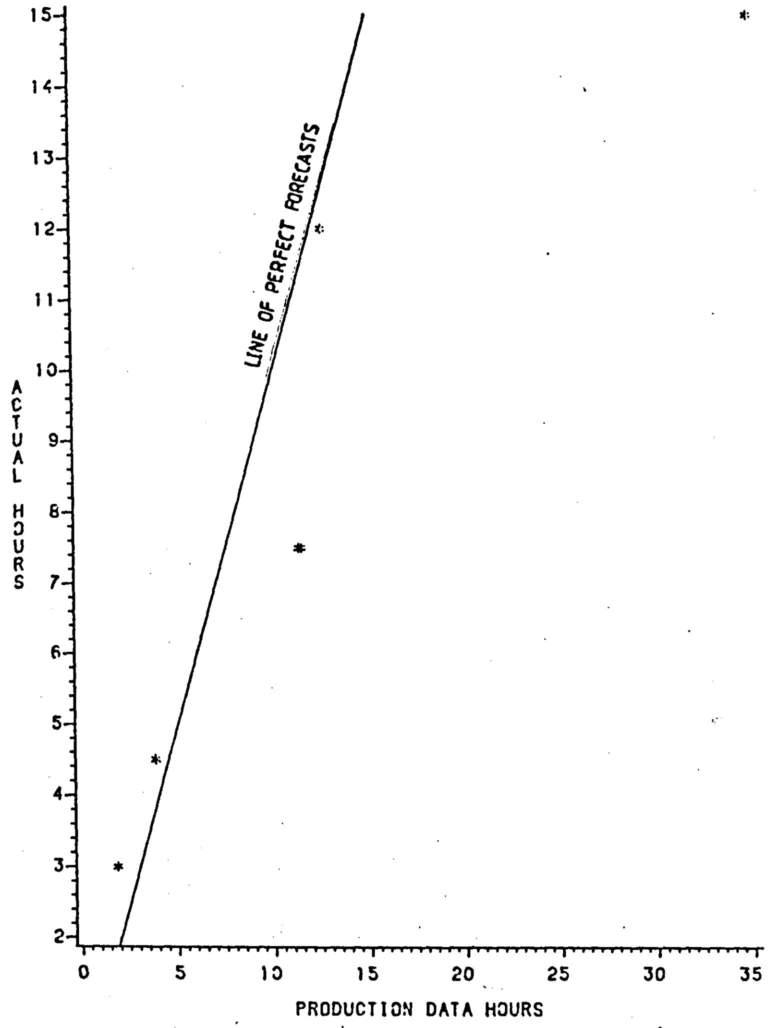
ARMY TRAINING BUILDING
CONCRETE IN SUSPENDED SLABS, STAIRS AND LANDINGS



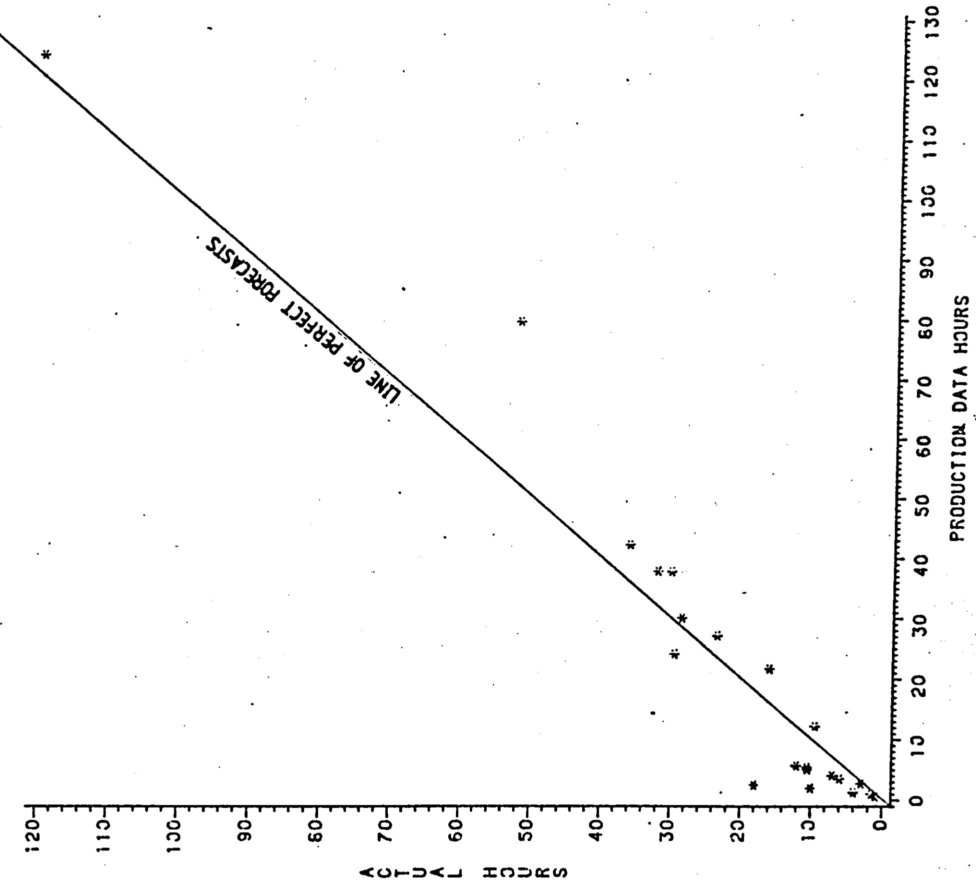
CONCRETE IN COLUMNS



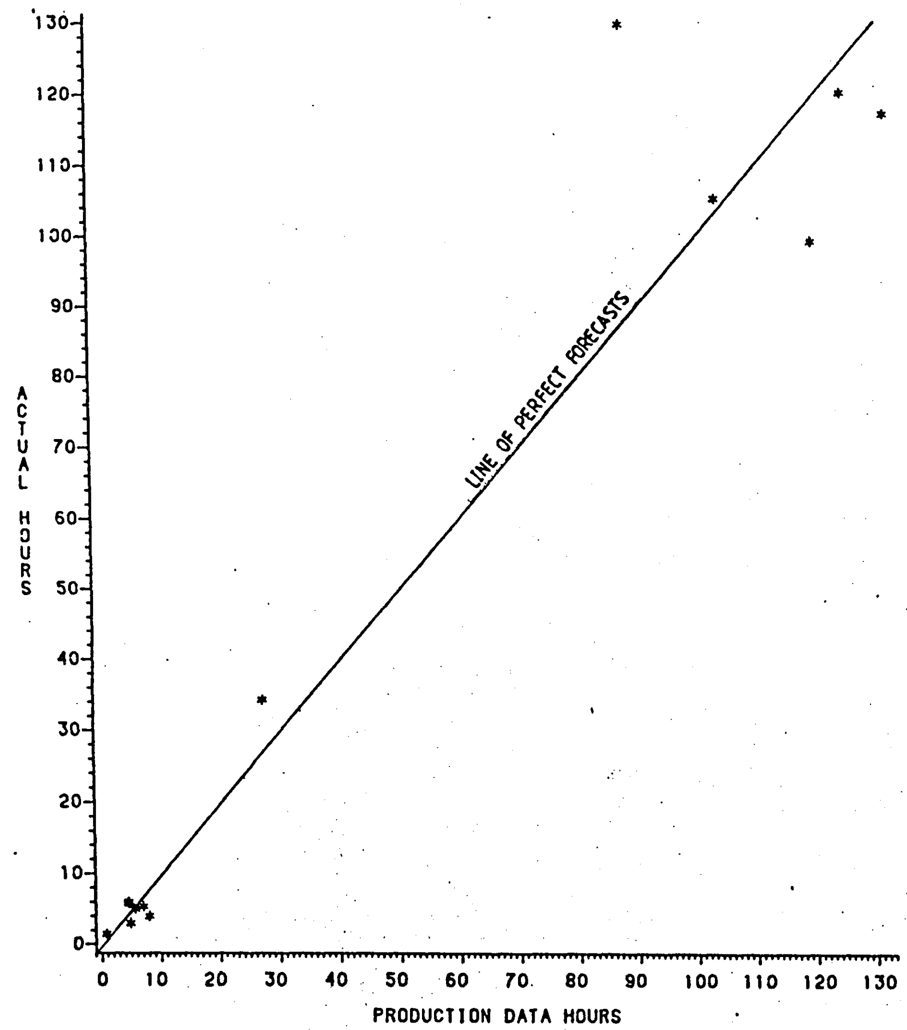
ARMY TRAINING BUILDING
CONCRETE IN COLUMNS AND BEAMS



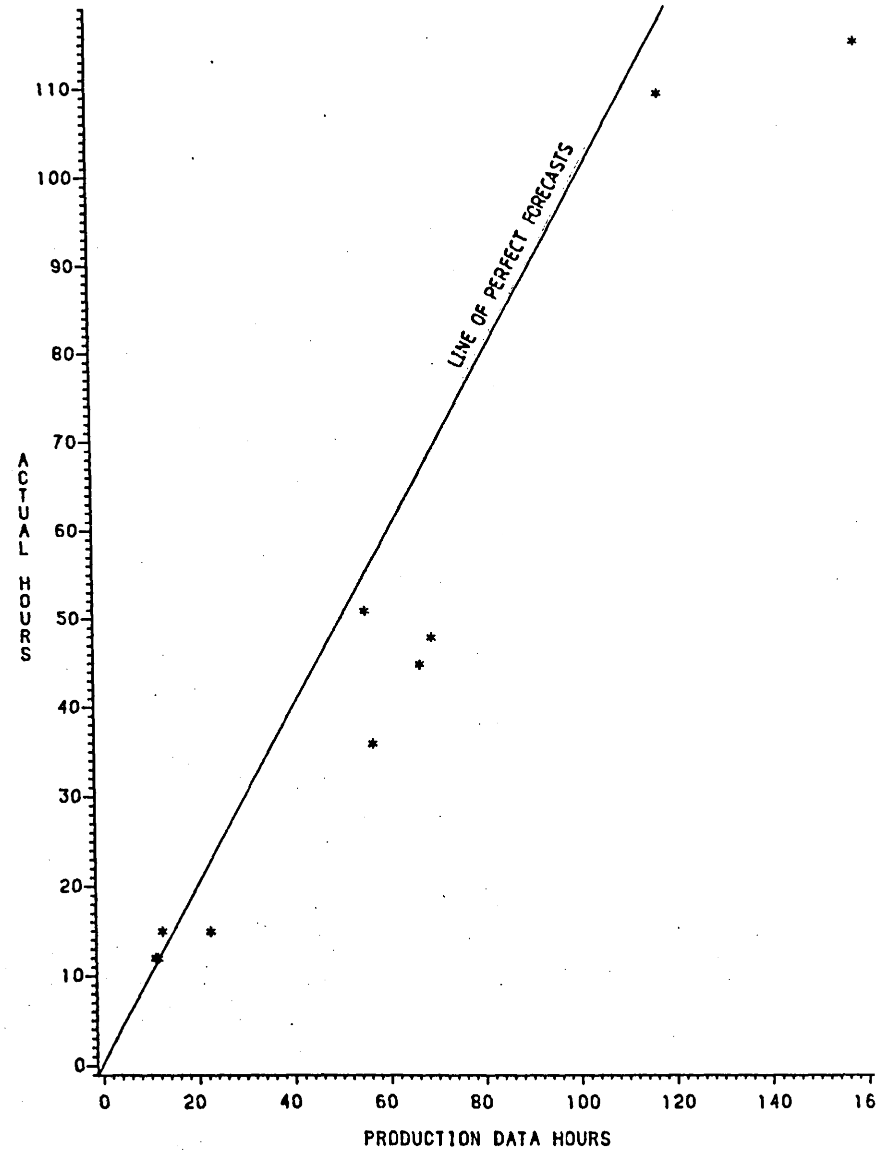
PHARMACY EXTENSION
CONCRETE – GENERALLY



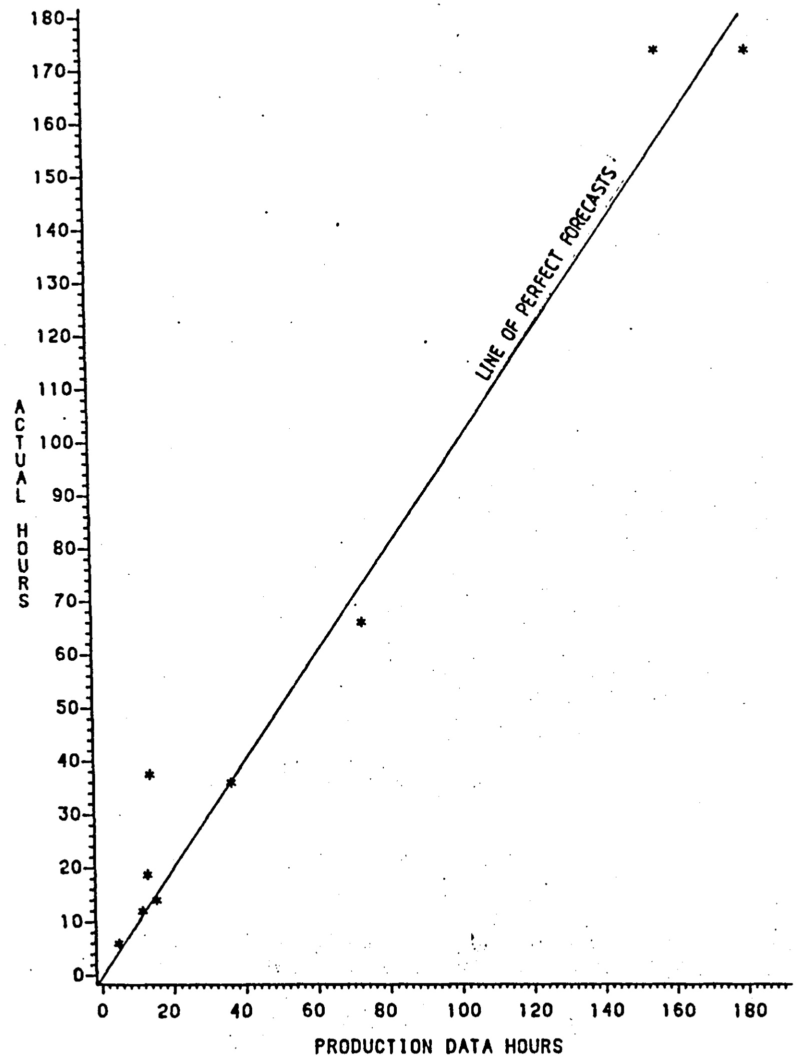
HOTEL A
BRICKWORK IN SUB-STRUCTURE



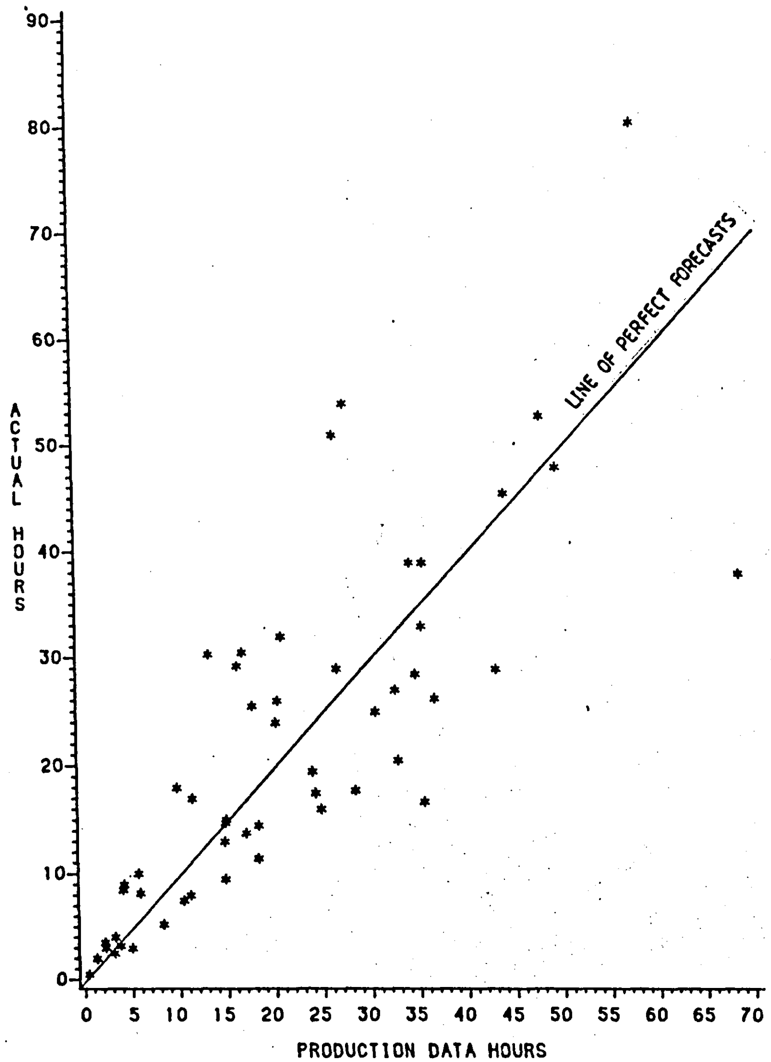
ARMY TRAINING BUILDING
BRICKWORK IN SUB-STRUCTURE



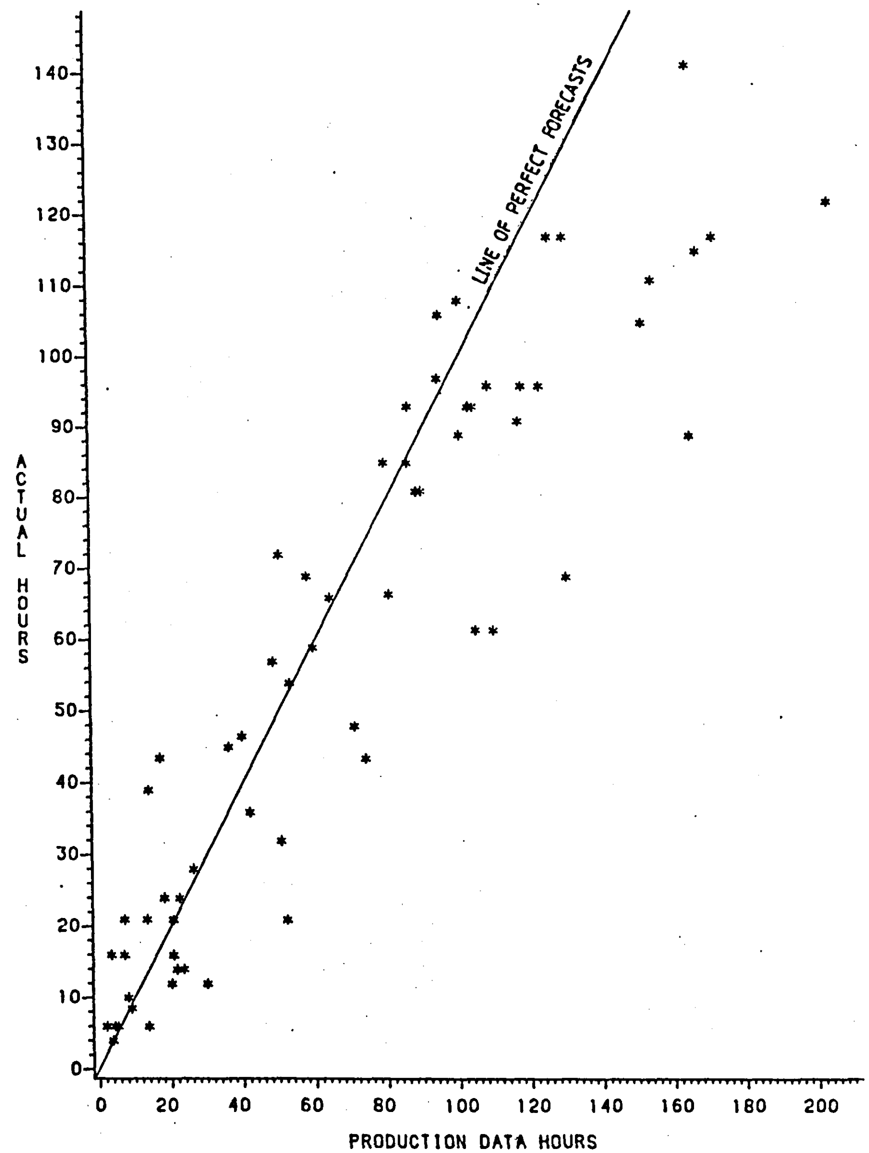
INDUSTRIAL BUILDING
BRICKWORK AND BLOCKWORK IN SUB-STRUCTURE



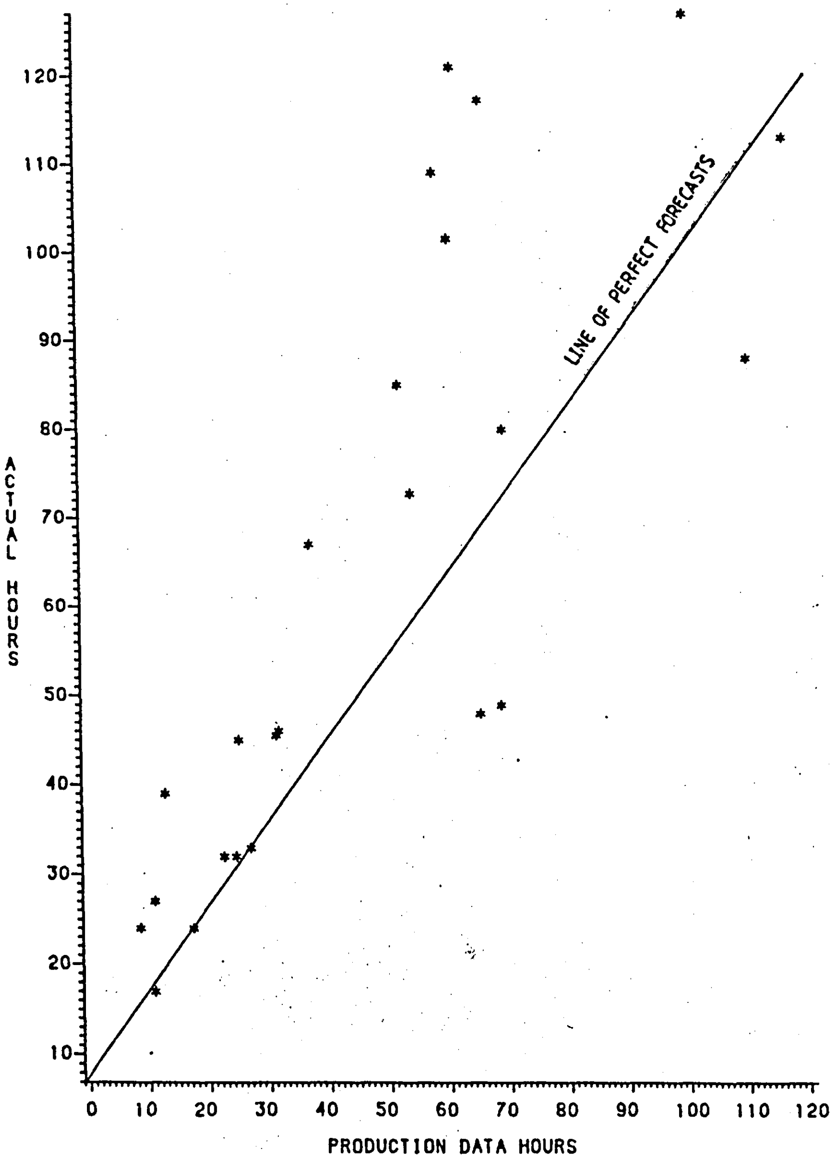
HOTEL A
BRICKWORK IN SUPERSTRUCTURE



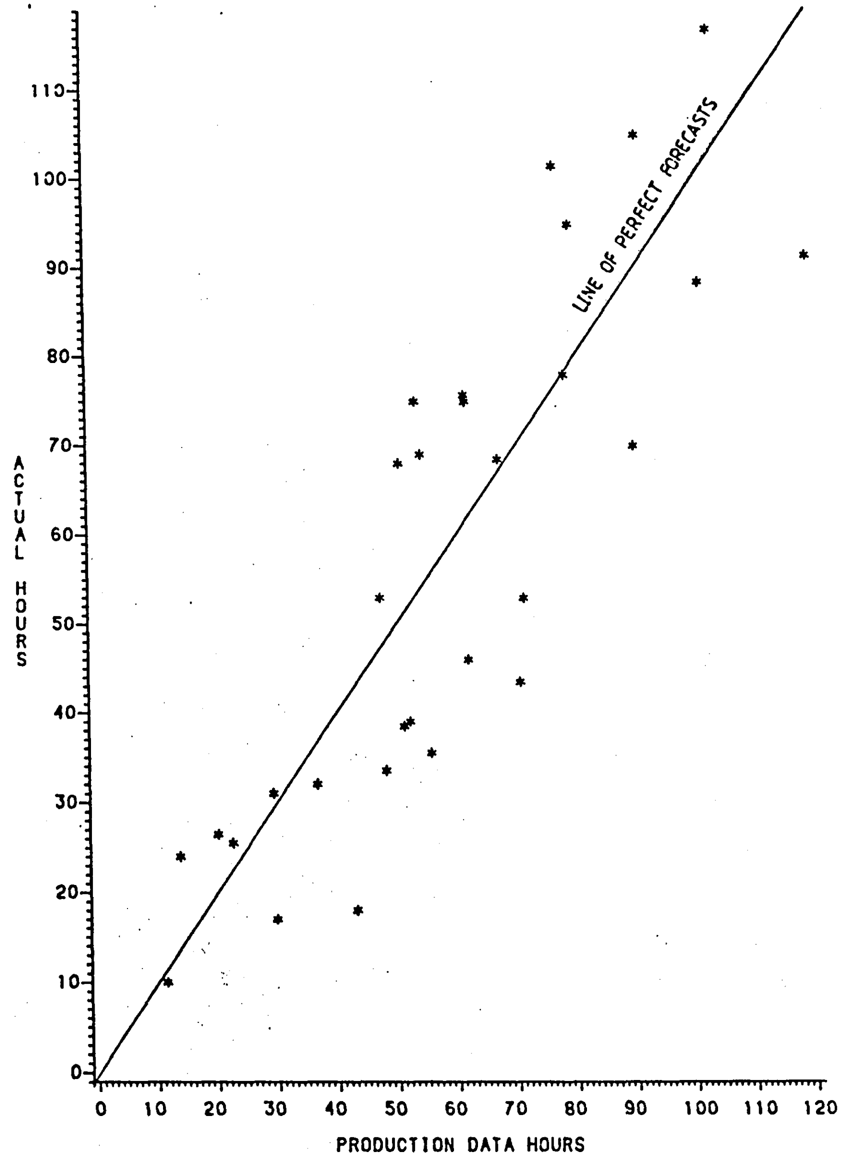
ARMY TRAINING BUILDING
BRICKWORK IN SUPERSTRUCTURE



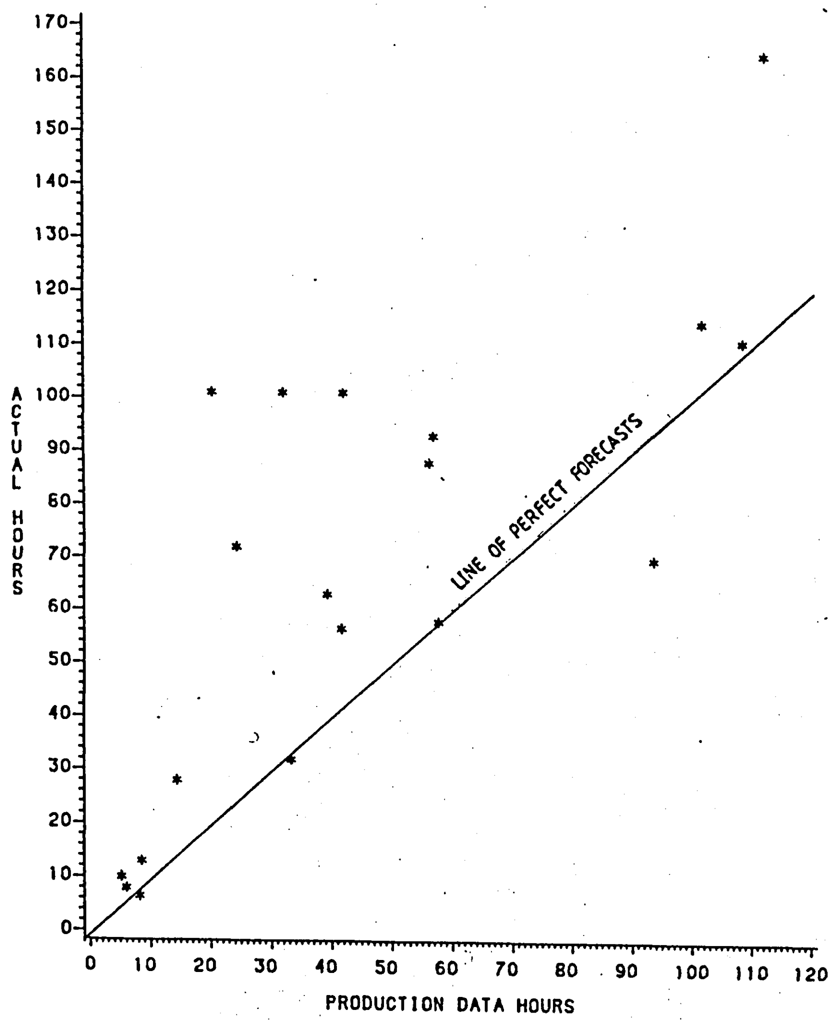
INDUSTRIAL BUILDING
BRICKWORK AND BLOCKWORK IN SUPERSTRUCTURE



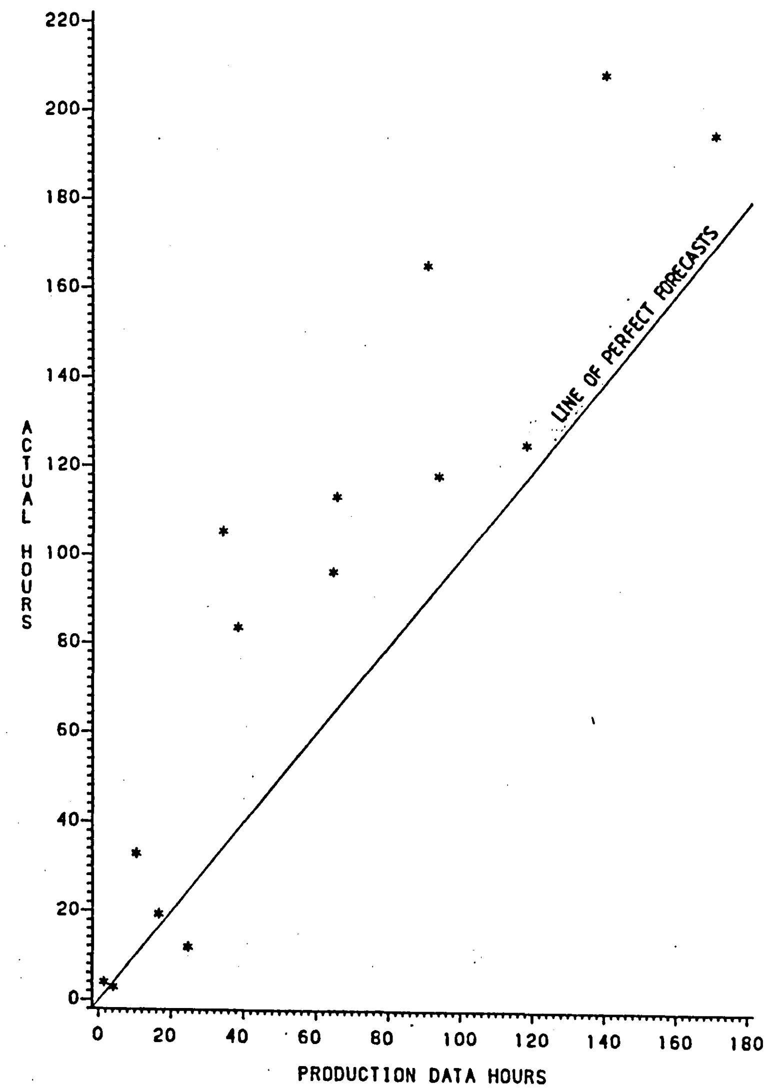
HOSPITAL A
BRICKWORK AND BLOCKWORK IN SUPERSTRUCTURE



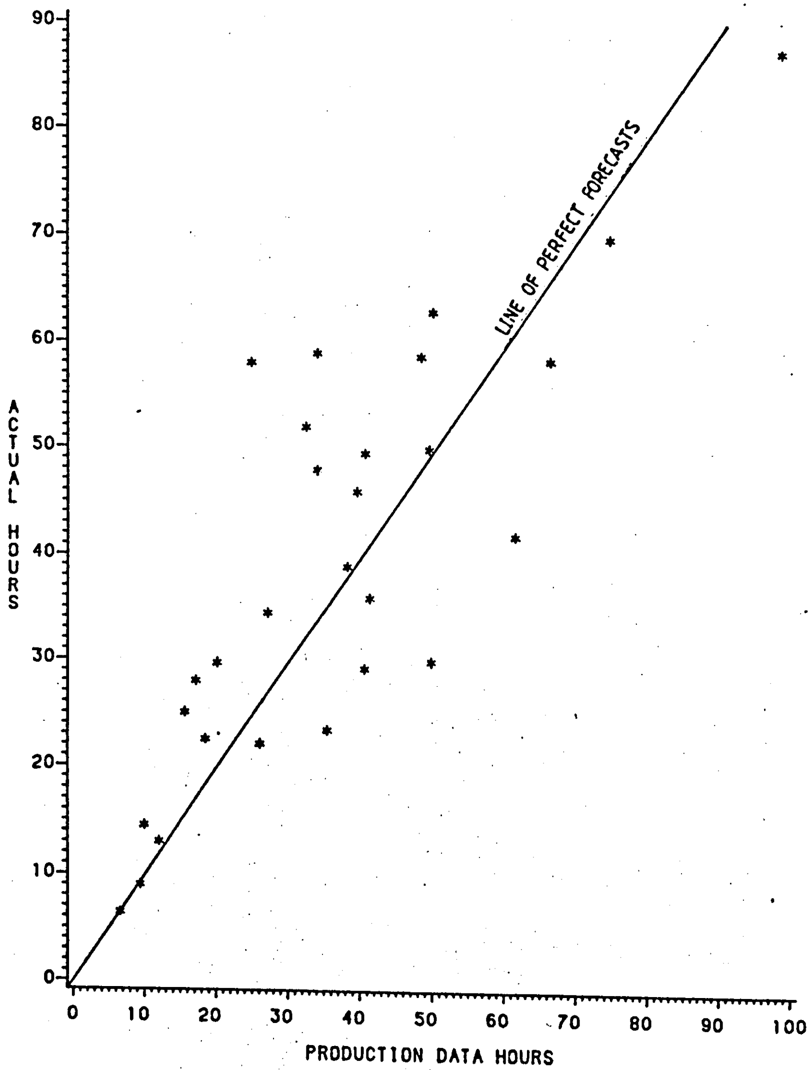
IL ING
BRICKWORK AND BLOCKWORK IN SUPERSTRUCTURE



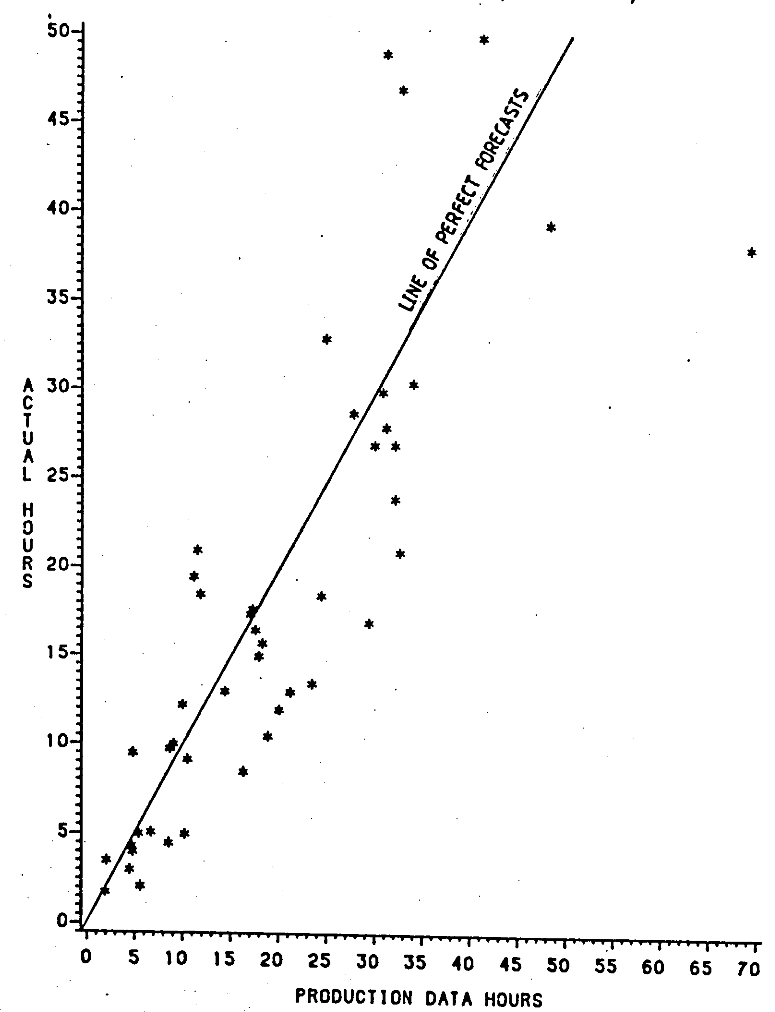
PHARMACY EXTENSION
BRICKWORK AND BLOCKWORK IN SUPERSTRUCTURE

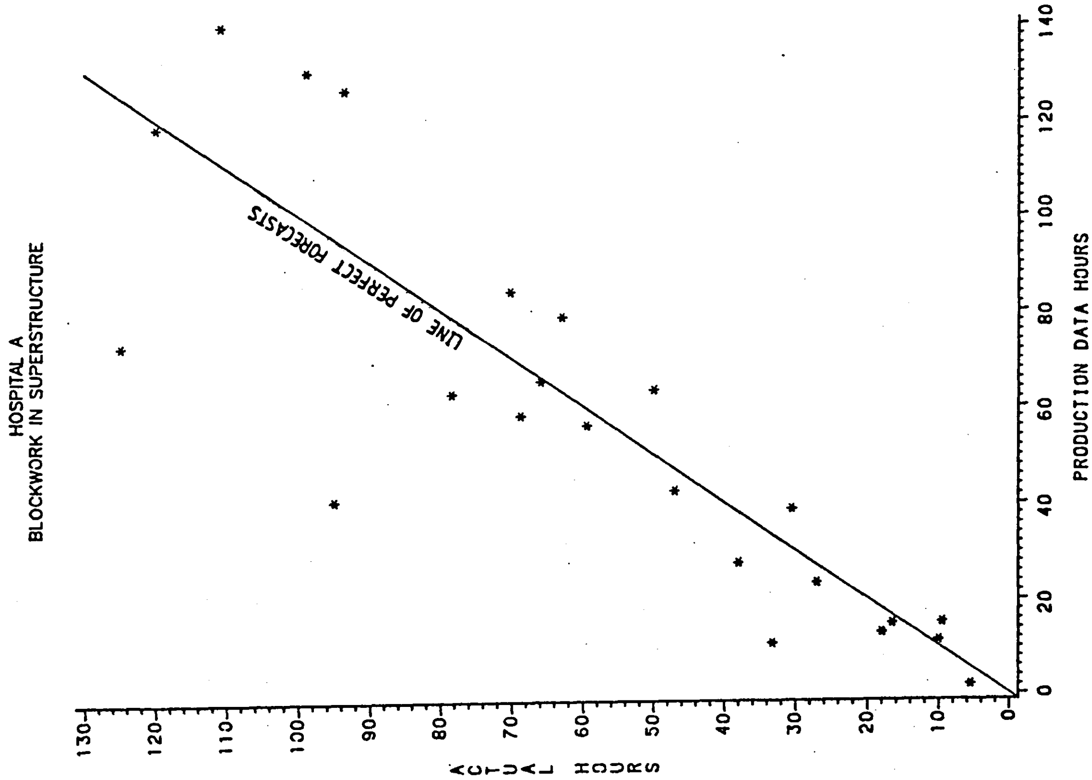


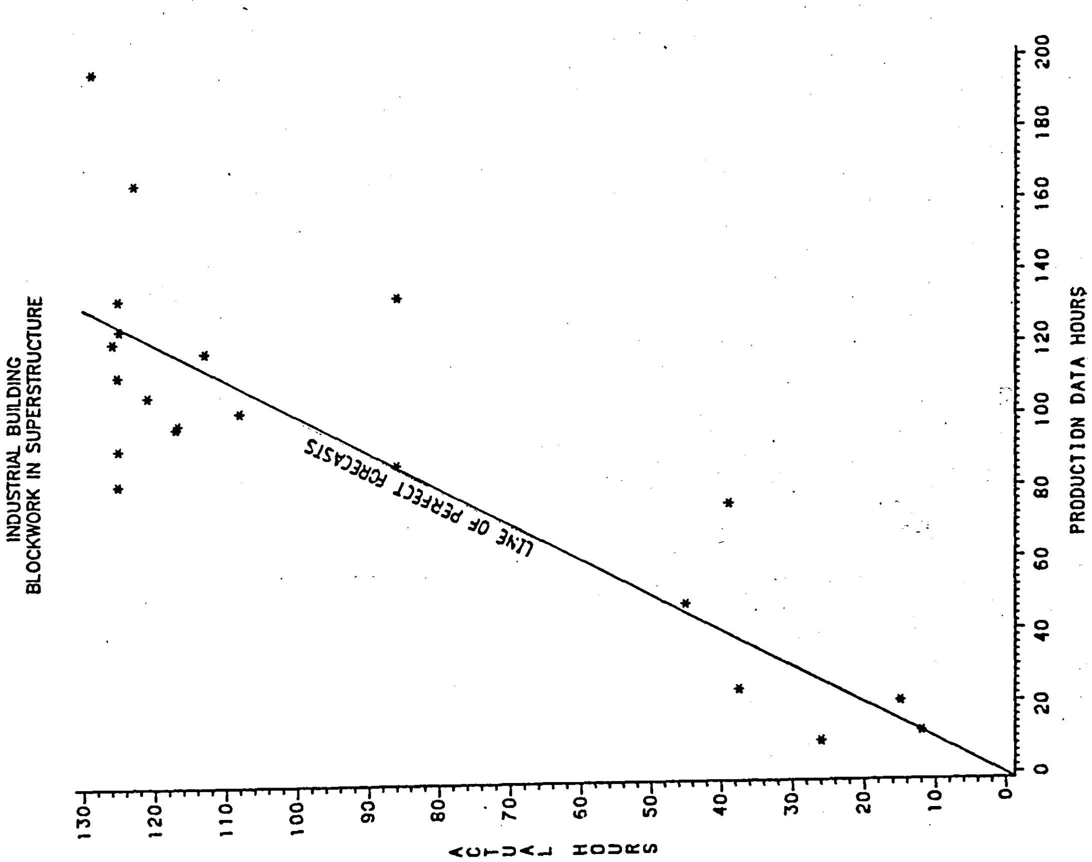
HOTEL A
BLOCKWORK IN SUPERSTRUCTURE (190mm THICK)



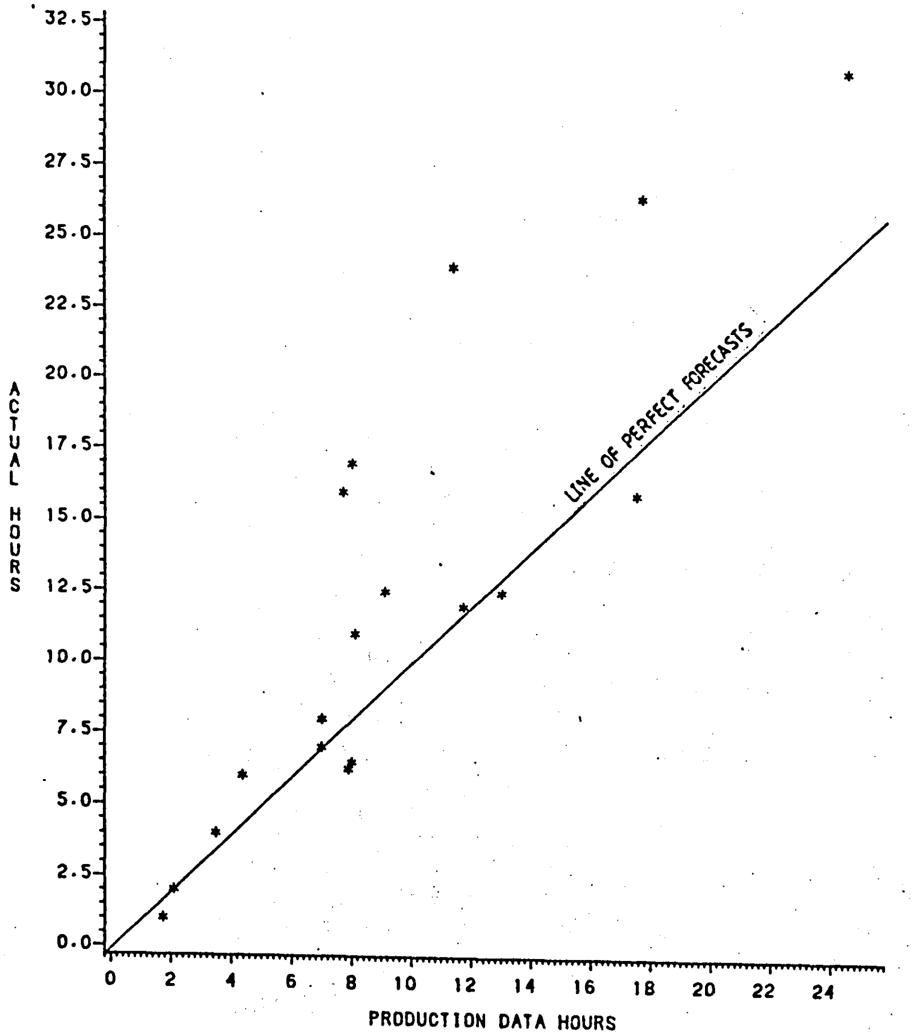
HOTEL A
BLOCKWORK IN SUPERSTRUCTURE (100mm THICK)



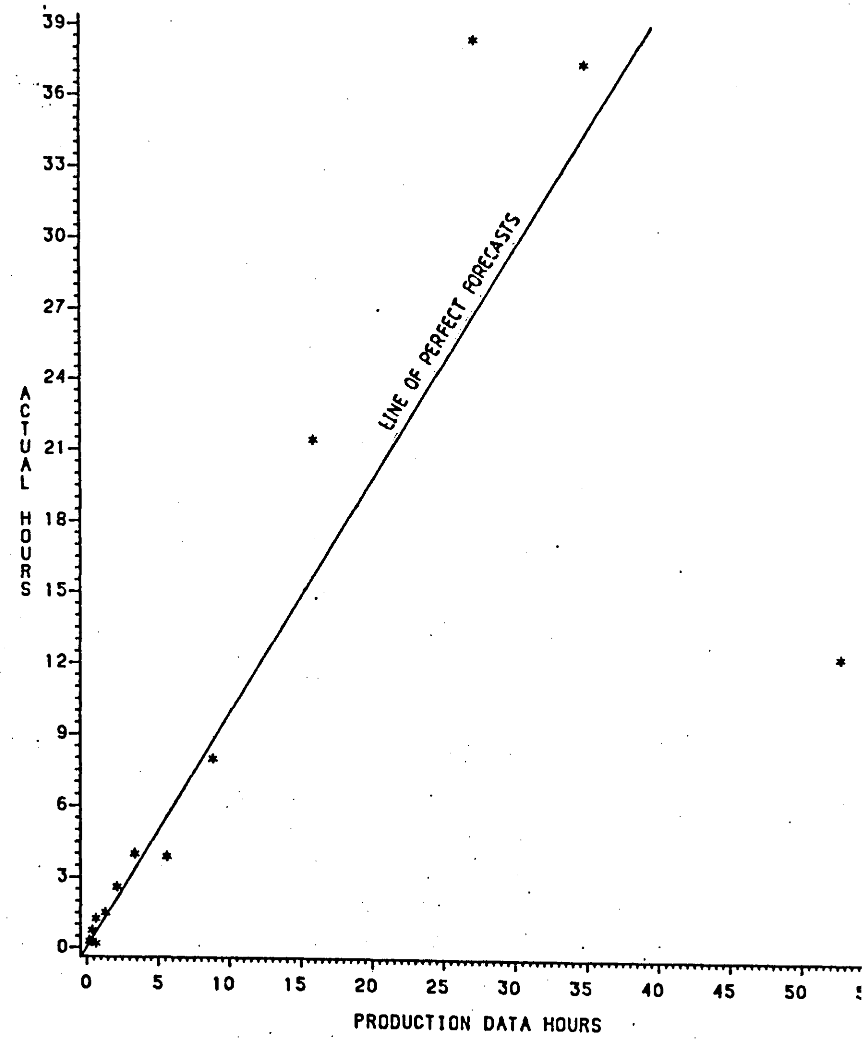

HOSPITAL A
BLOCKWORK IN SUPERSTRUCTURE
LINE OF PERFECT FORECASTS
ACTUAL HOURS
PRODUCTION DATA HOURS

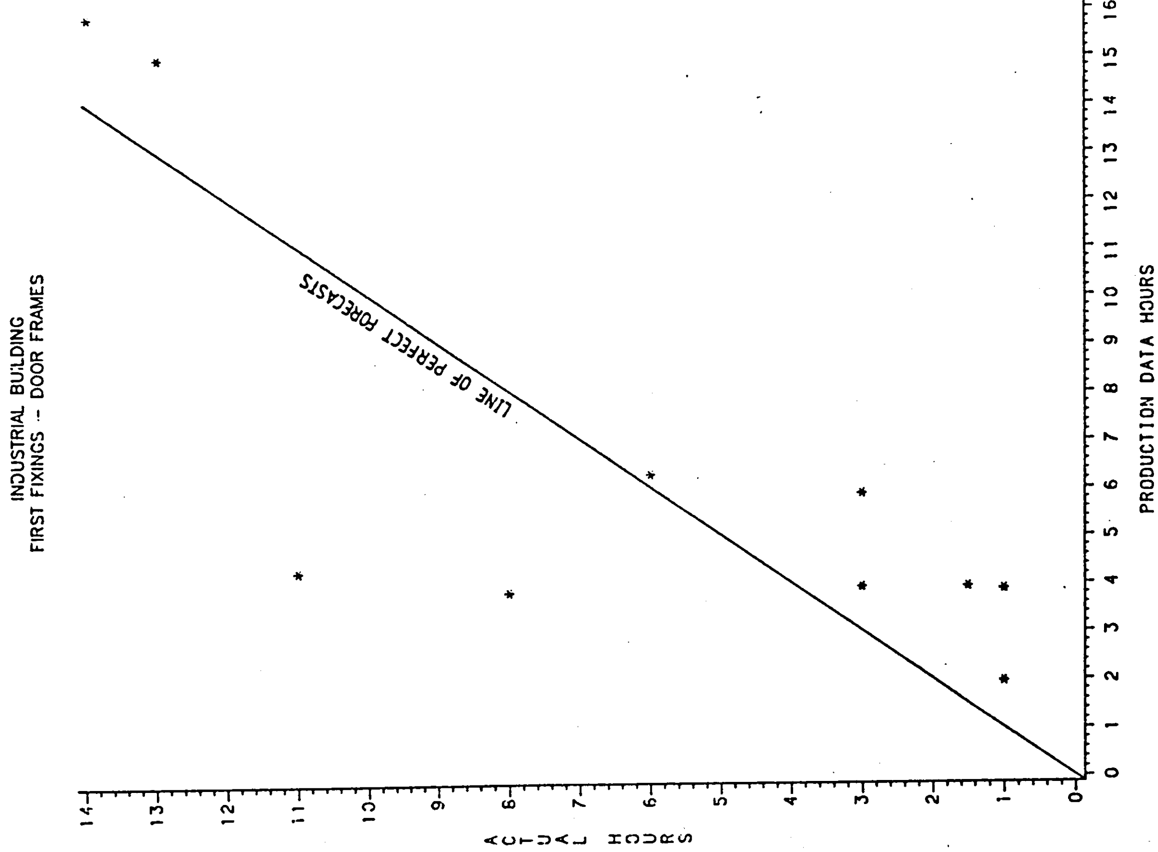

INDUSTRIAL BUILDING
BLOCKWORK IN SUPERSTRUCTURE
LINE OF PERFECT FORECASTS
ACTUAL HOURS
PRODUCTION DATA HOURS

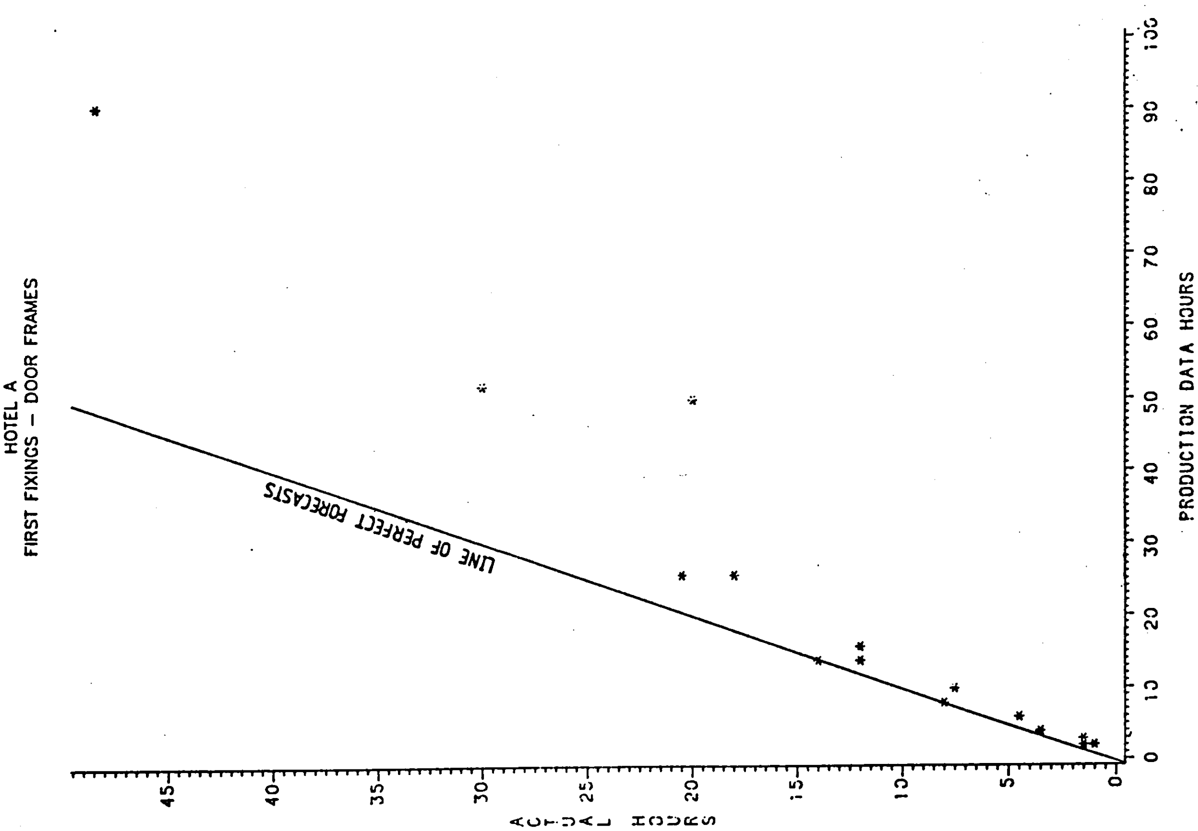
HOSPITAL A
FIRST FIXINGS – SOFTWOOD GROUNDS



HOTEL A
FIRST FIXINGS – SOFTWOOD FRAMING




INDUSTRIAL BUILDING
FIRST FIXINGS -- DOOR FRAMES
LINE OF PERFECT FORECASTS
ACTUAL HOURS
PRODUCTION DATA HOURS
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16


HOTEL A
FIRST FIXINGS – DOOR FRAMES
LINE OF PERFECT FORECASTS
ACTUAL HOURS
PRODUCTION DATA HOURS
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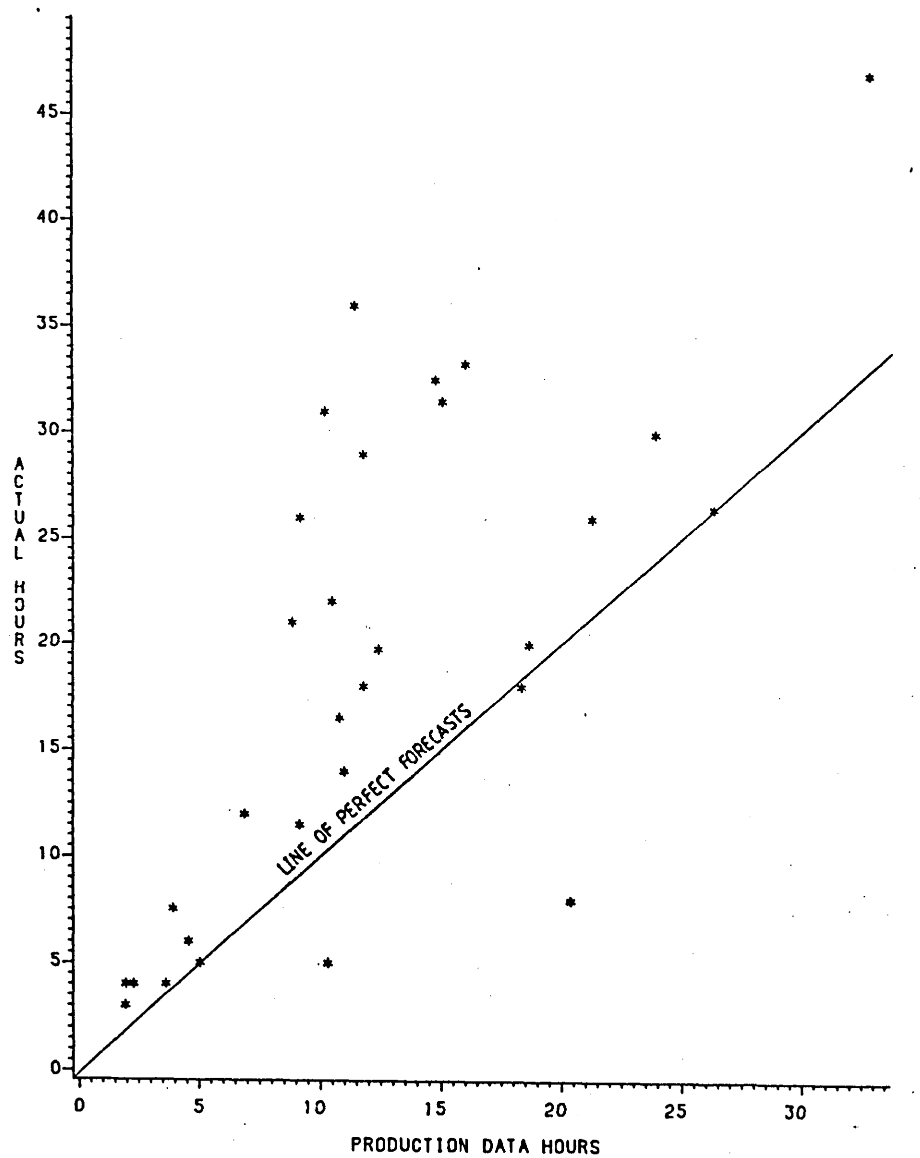
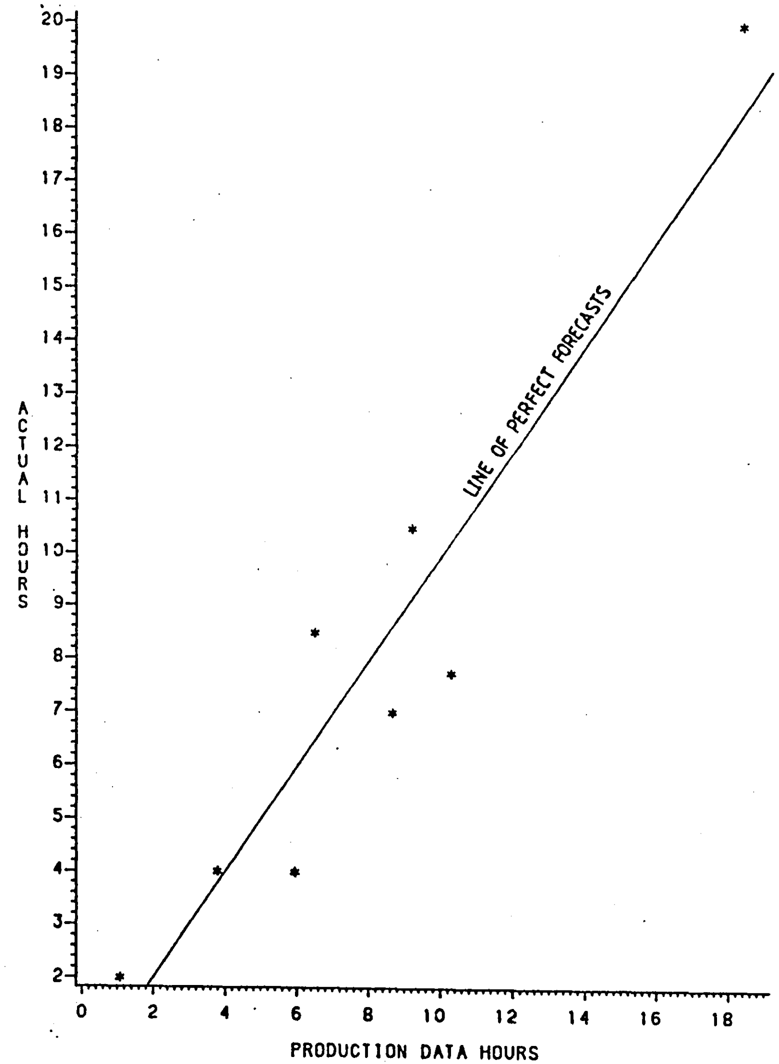
0 10 20 30 40 50 60 70 80 90 100

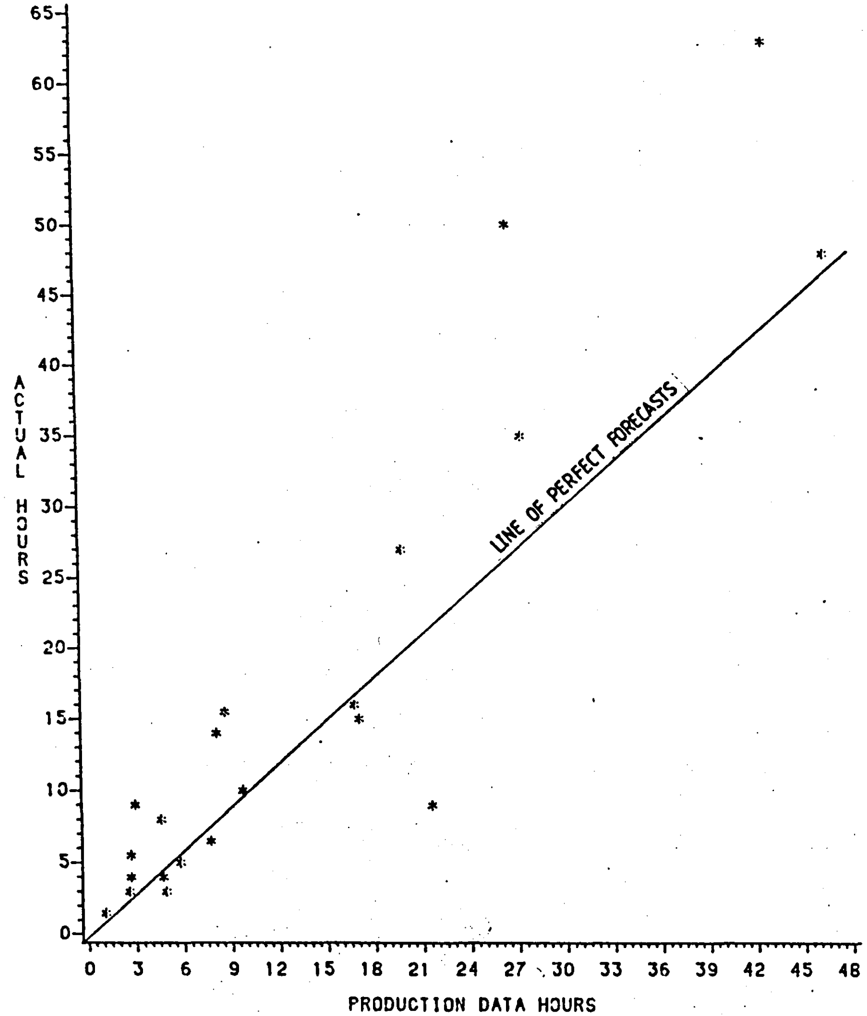
HOSPITAL A
FIRST FIXINGS – DOOR FRAMES



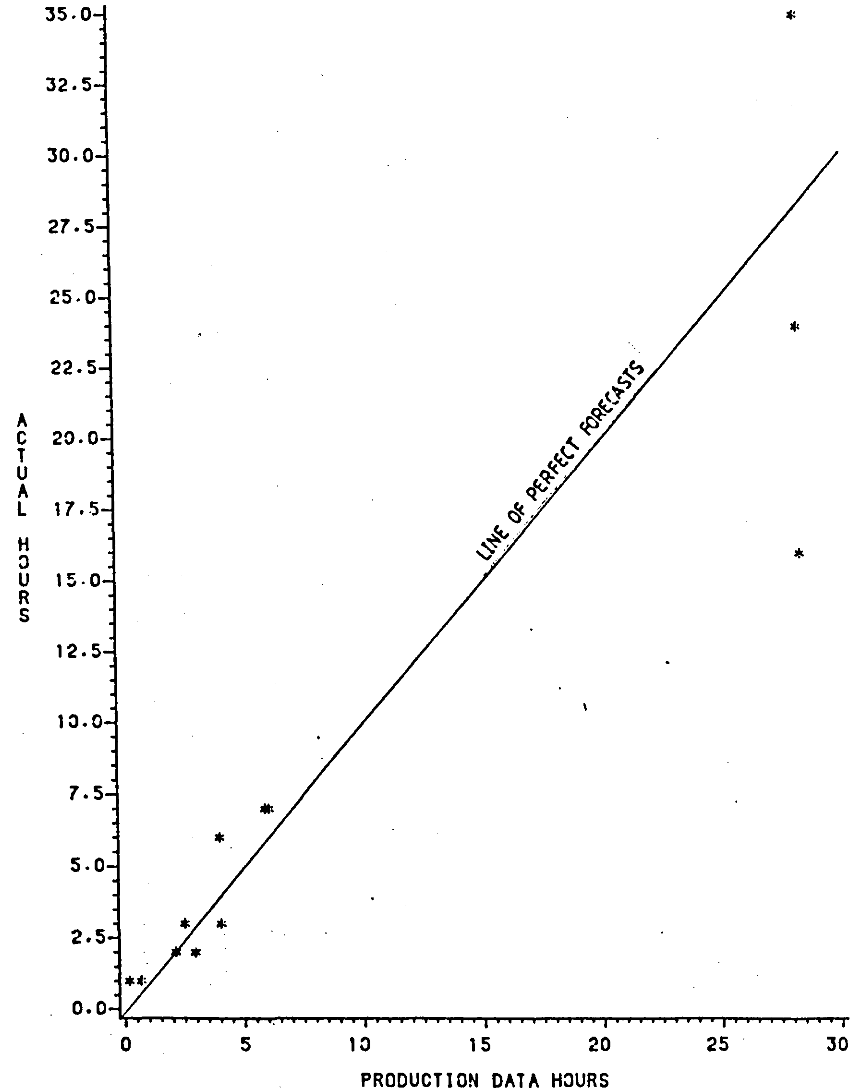
HOTEL A
FIRST FIXINGS – WINDOW FRAMES



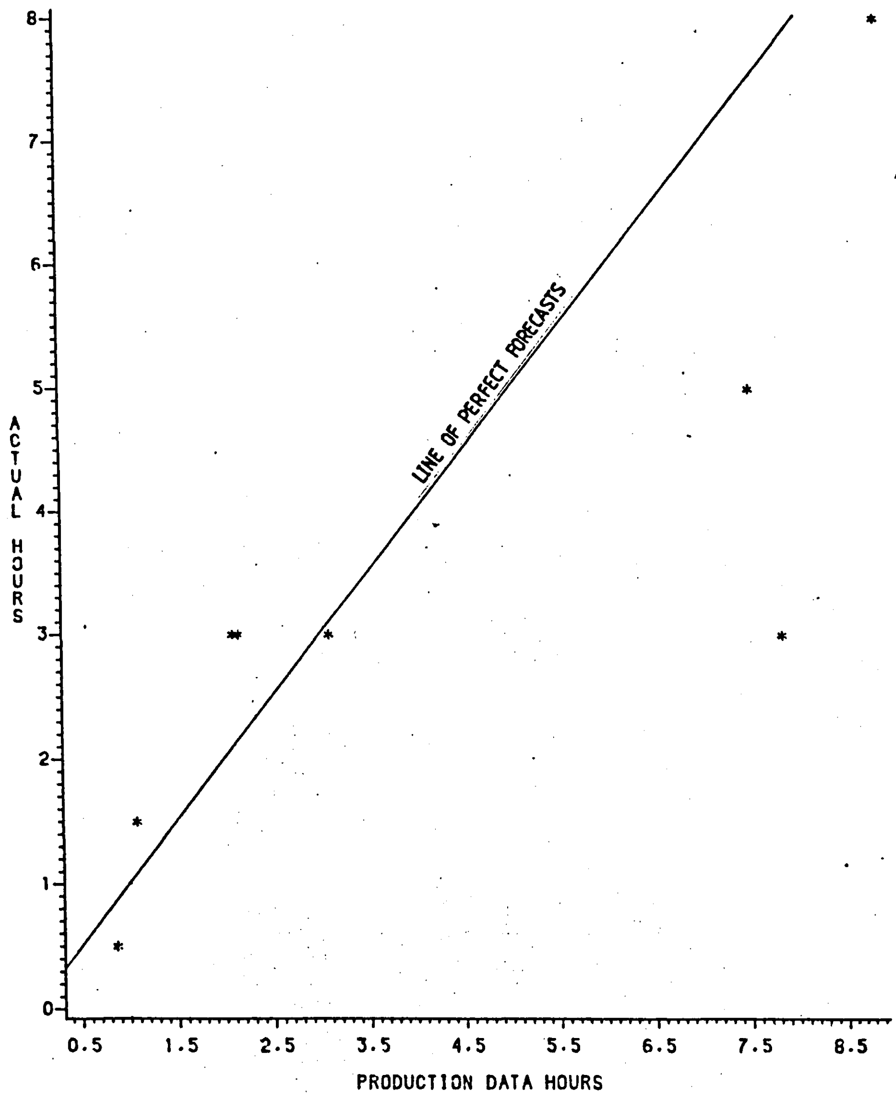
INDUSTRIAL BUILDING
FIRST FIXINGS -- GENERALLY



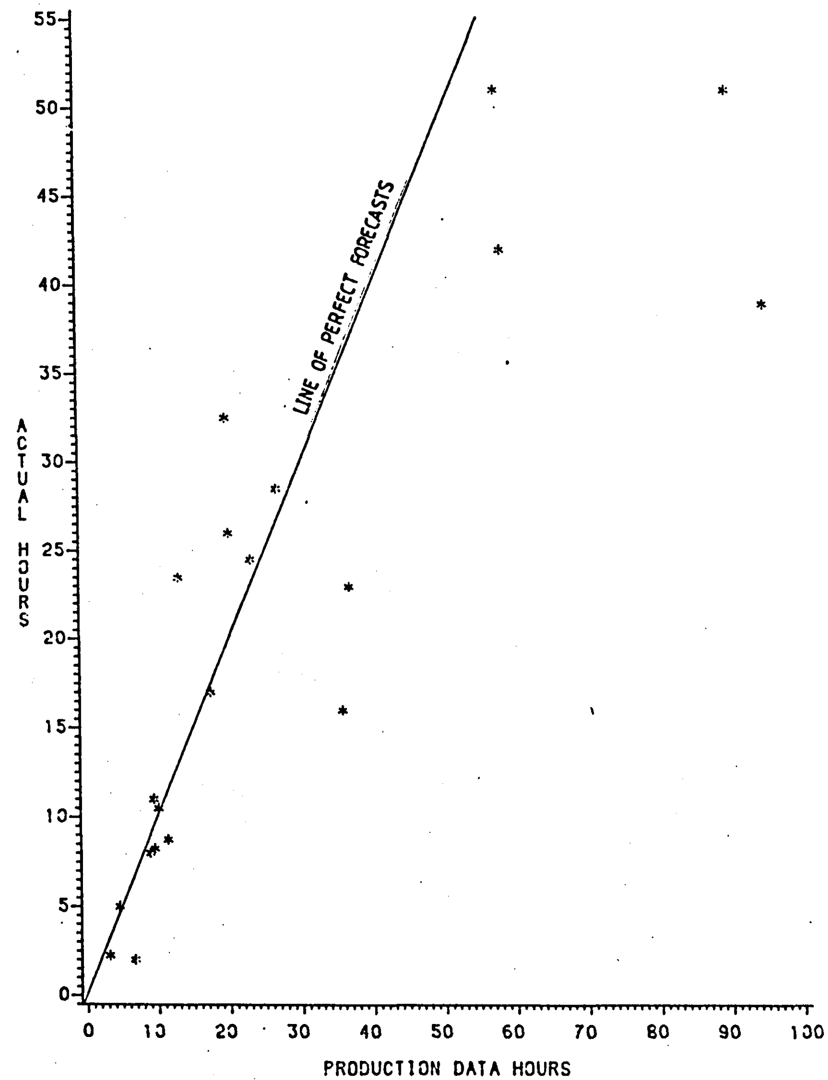
SCHOOL BUILDING
FIRST FIXINGS -- GENERALLY



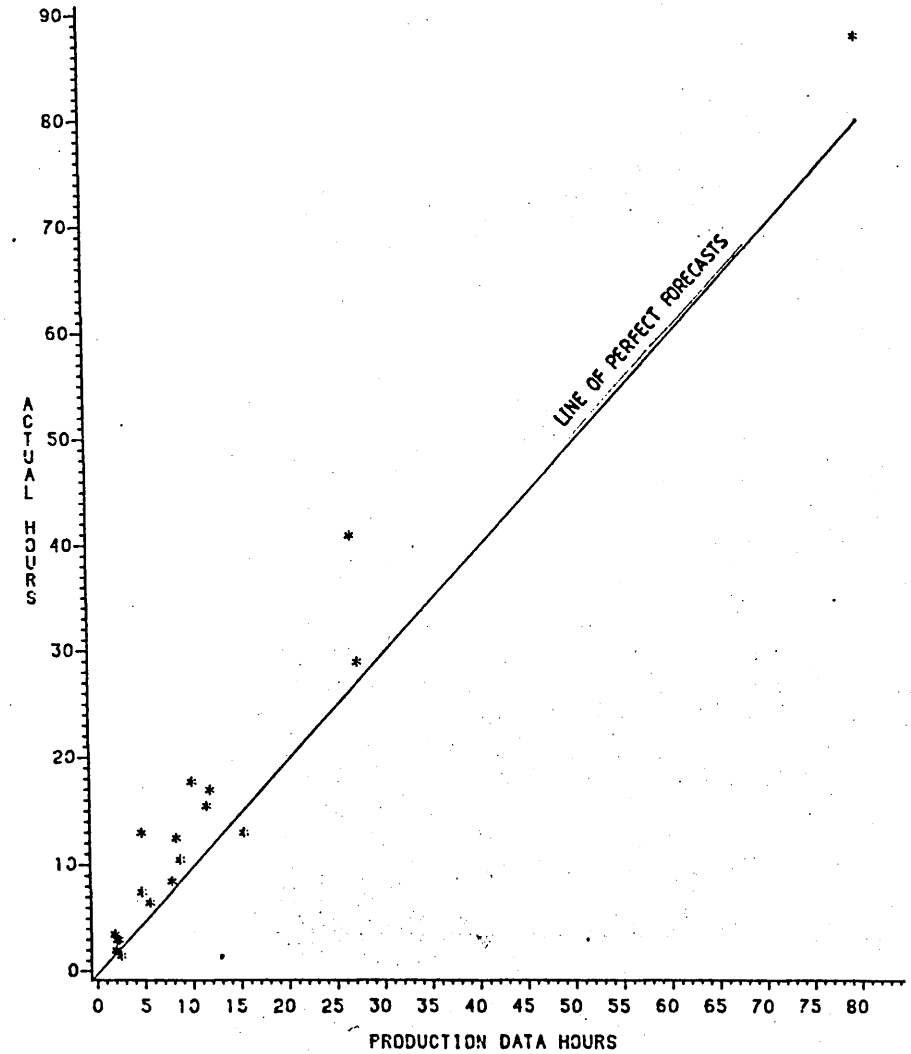
ARMY TRAINING BUILDING
FIRST FIXINGS -- GENERALLY



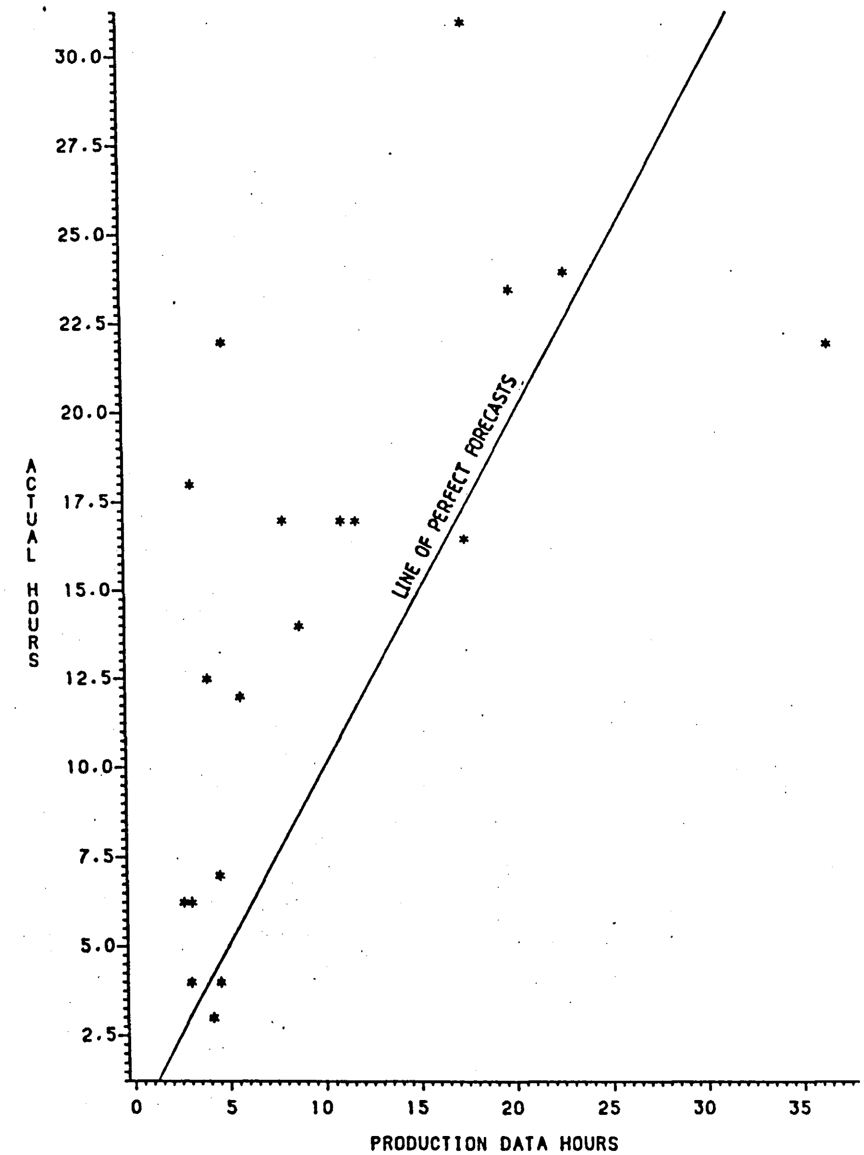
PHARMACY EXTENSION
FIRST FIXINGS -- GENERALLY



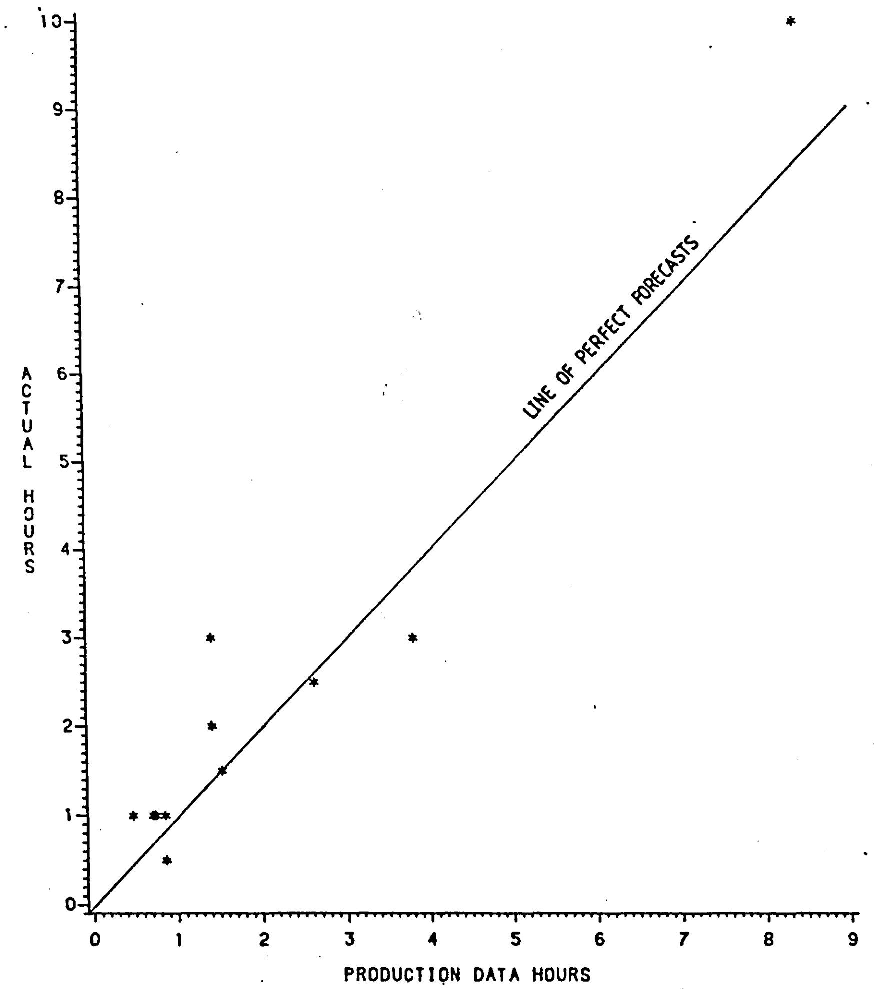
INDUSTRIAL BUILDING
SECOND FIXINGS – HANGING DOORS



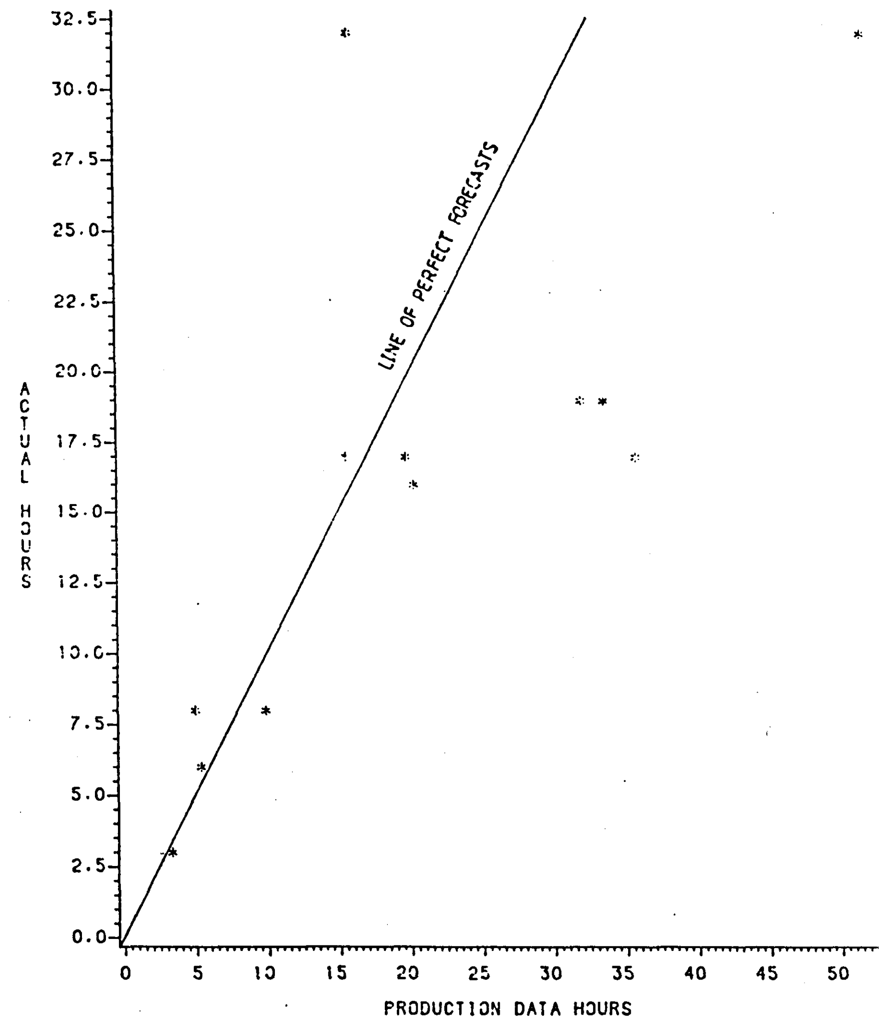
HOSPITAL A
SECOND FIXINGS – HANGING DOORS



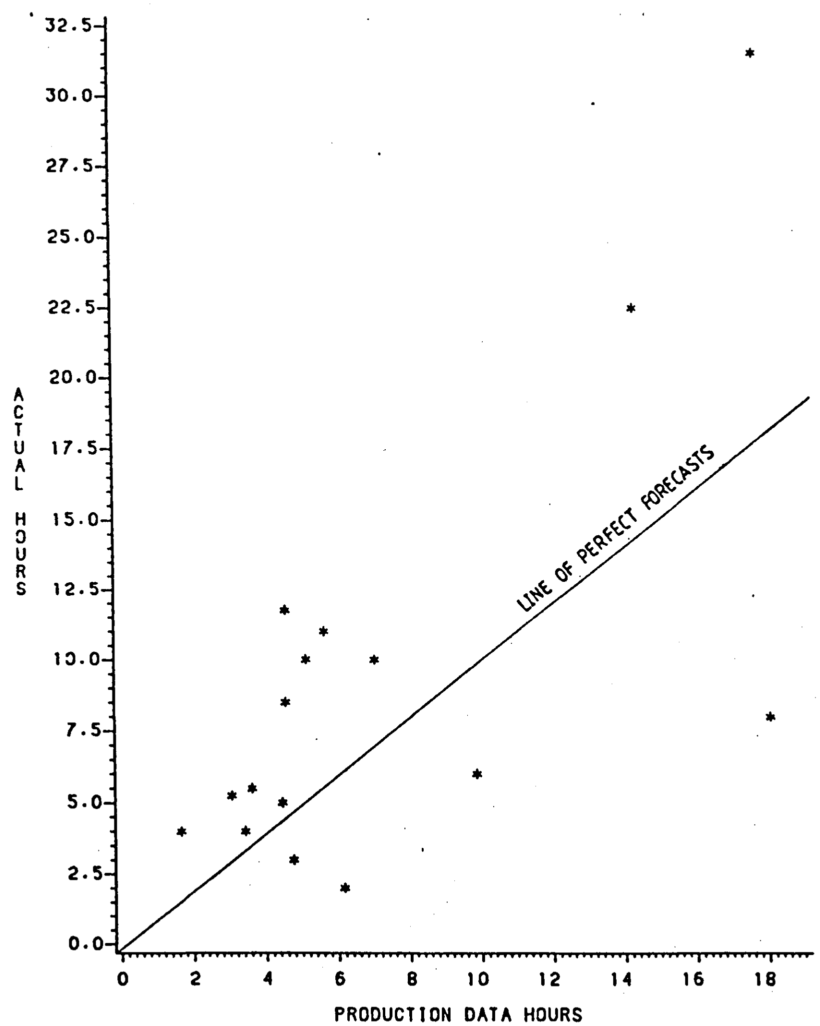
HOTEL A
SECOND FIXINGS – ARCHITRAVES AND SKIRTINGS



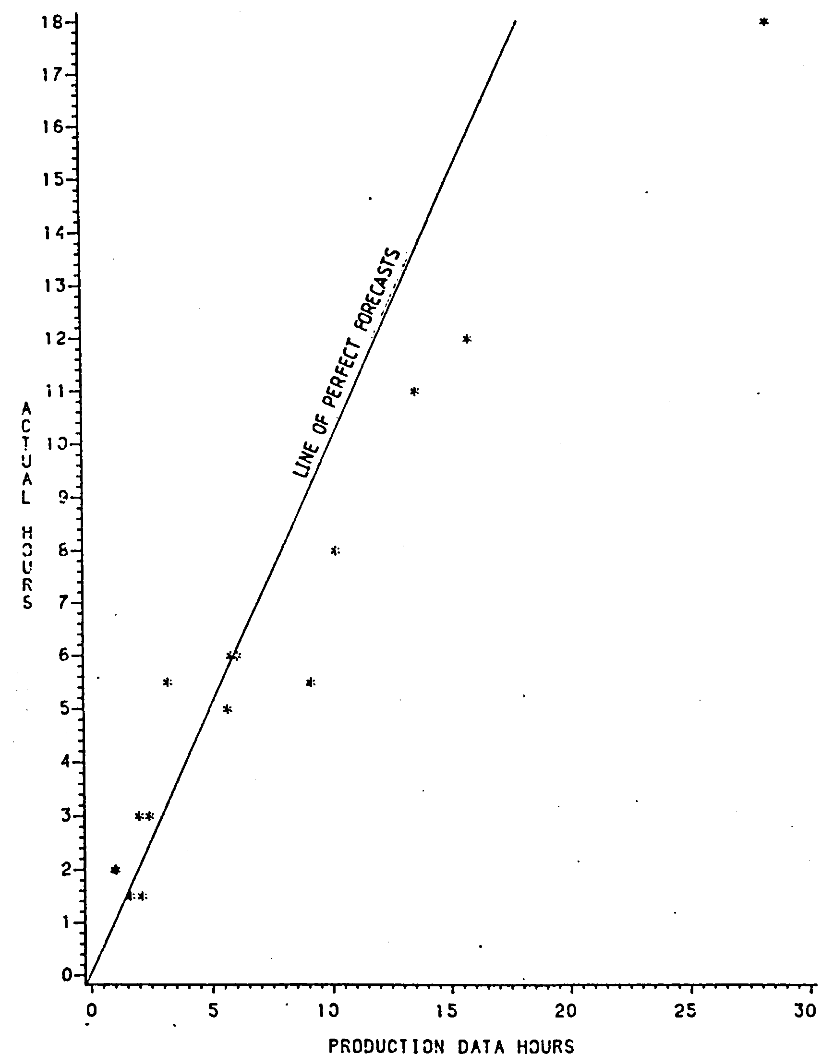
ARMY TRAINING BUILDING
SECOND FIXINGS – DOOR SETS



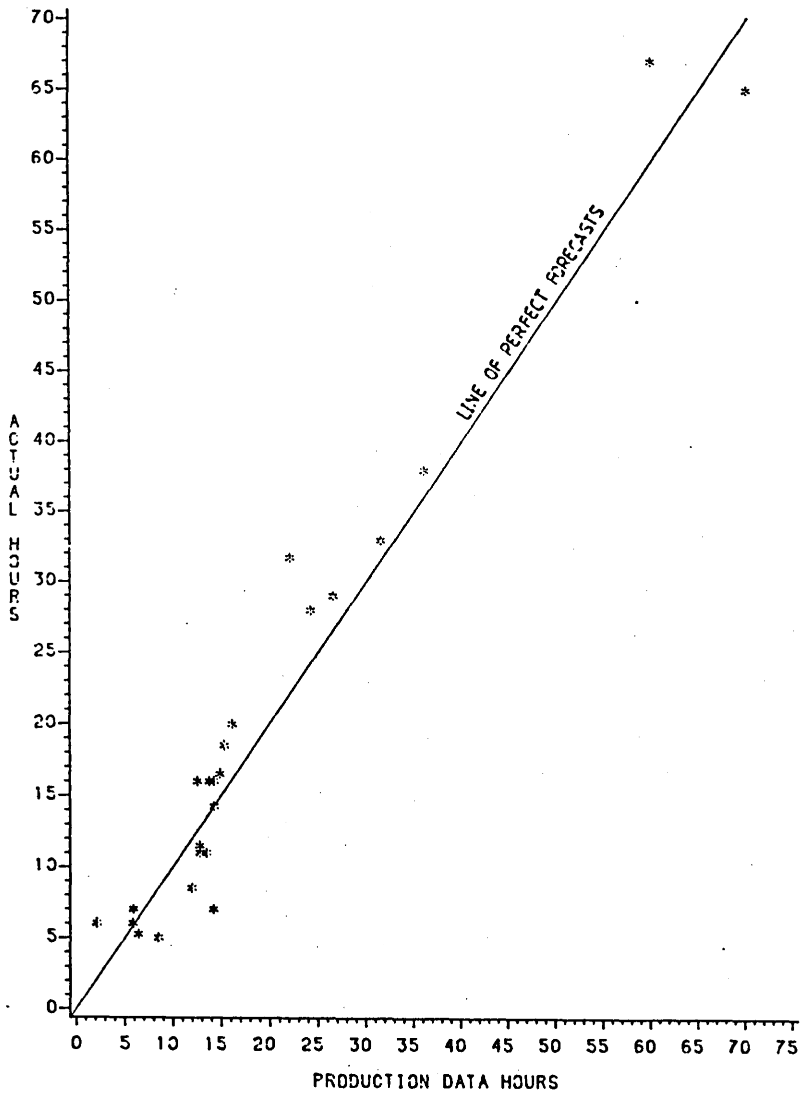
HOSPITAL A
FIXING IRONMONGERY



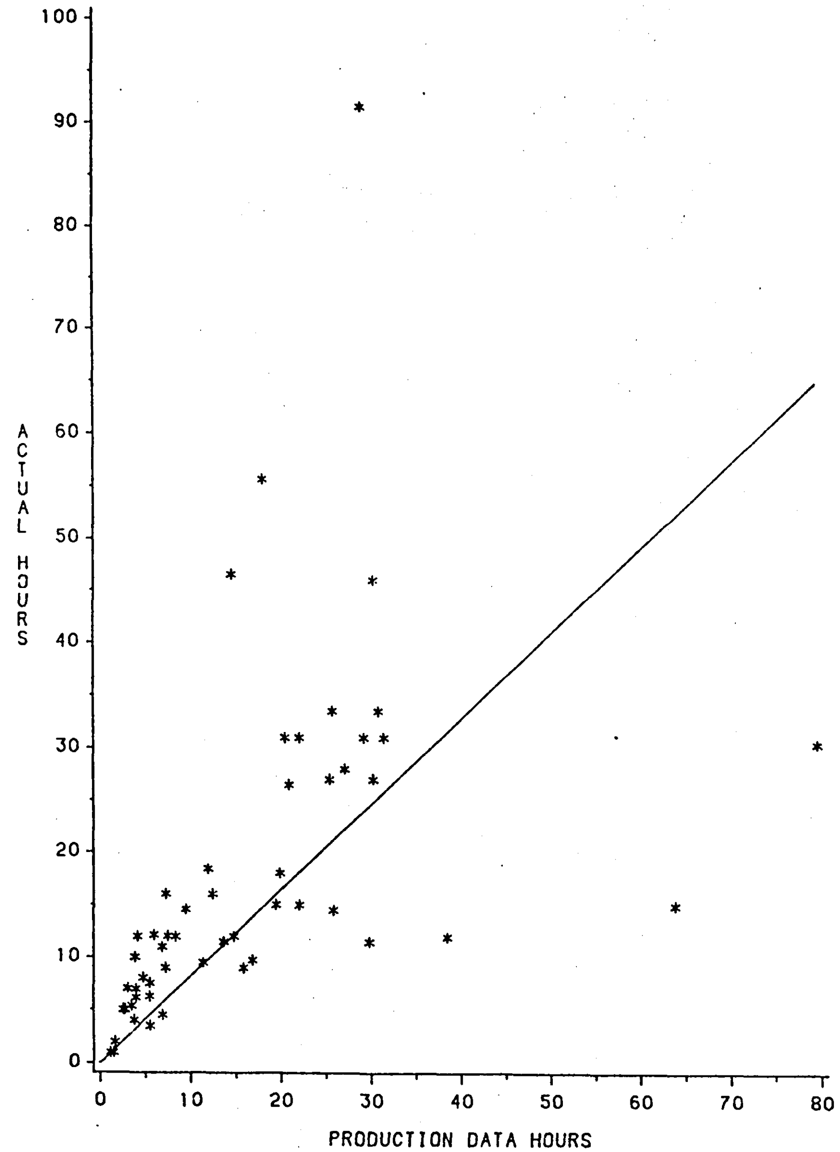
SCHOOL BUILDING
SECOND FIXINGS — GENERALLY



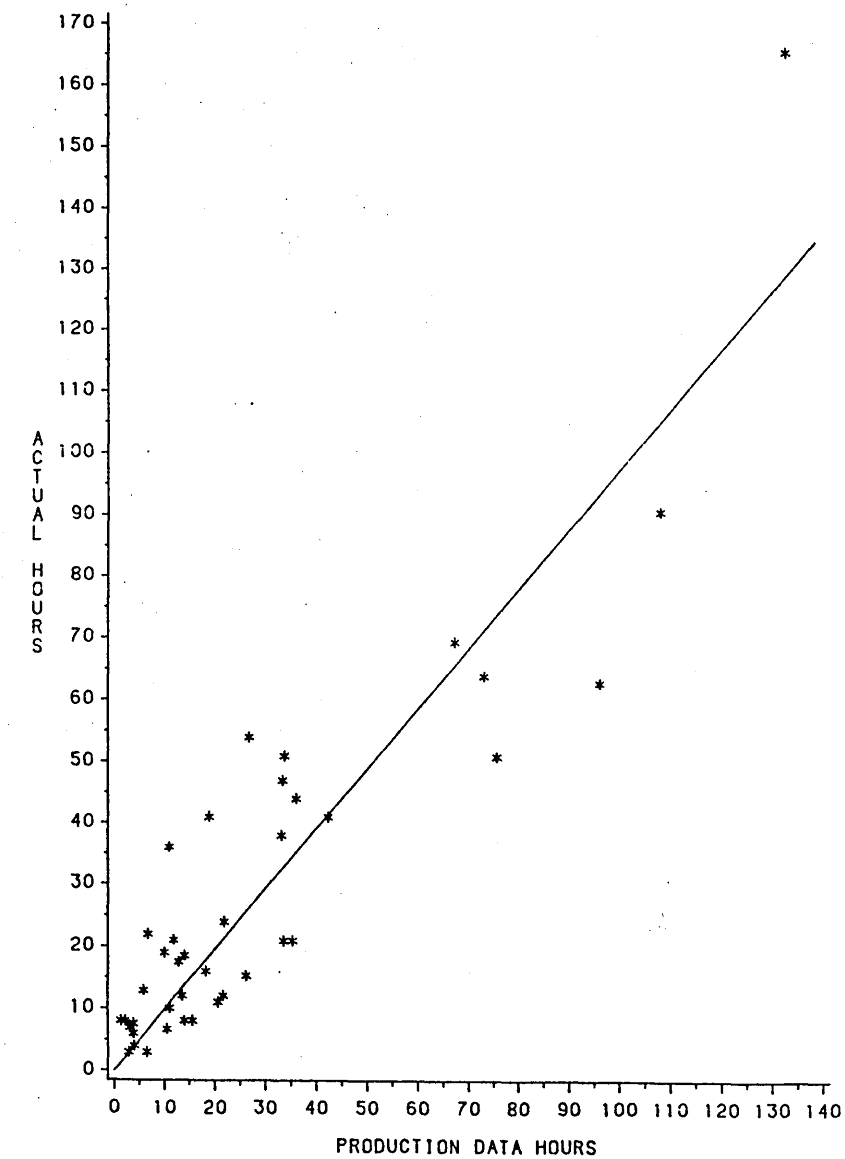
PHARMACY EXTENSION
SECOND FIXINGS -- GENERALLY



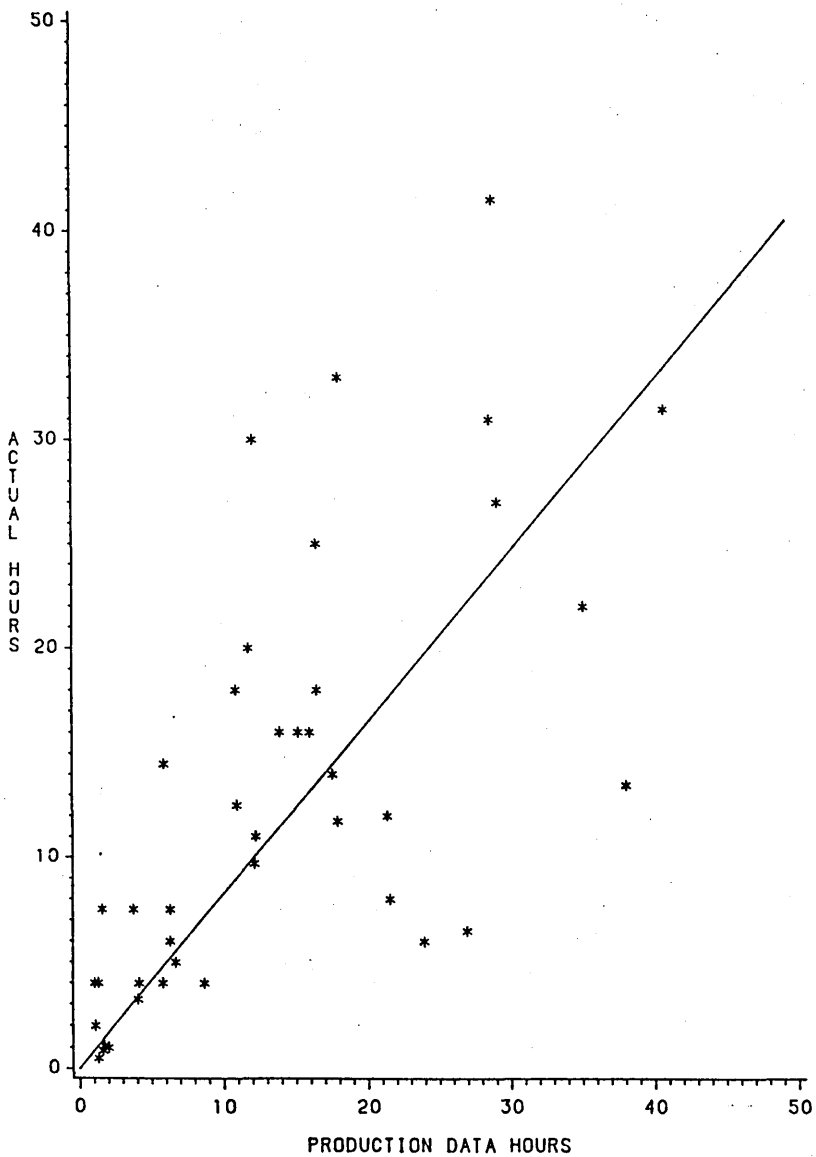
FIRST SAMPLE PROJECTS
CONCRETE IN FOUNDATIONS



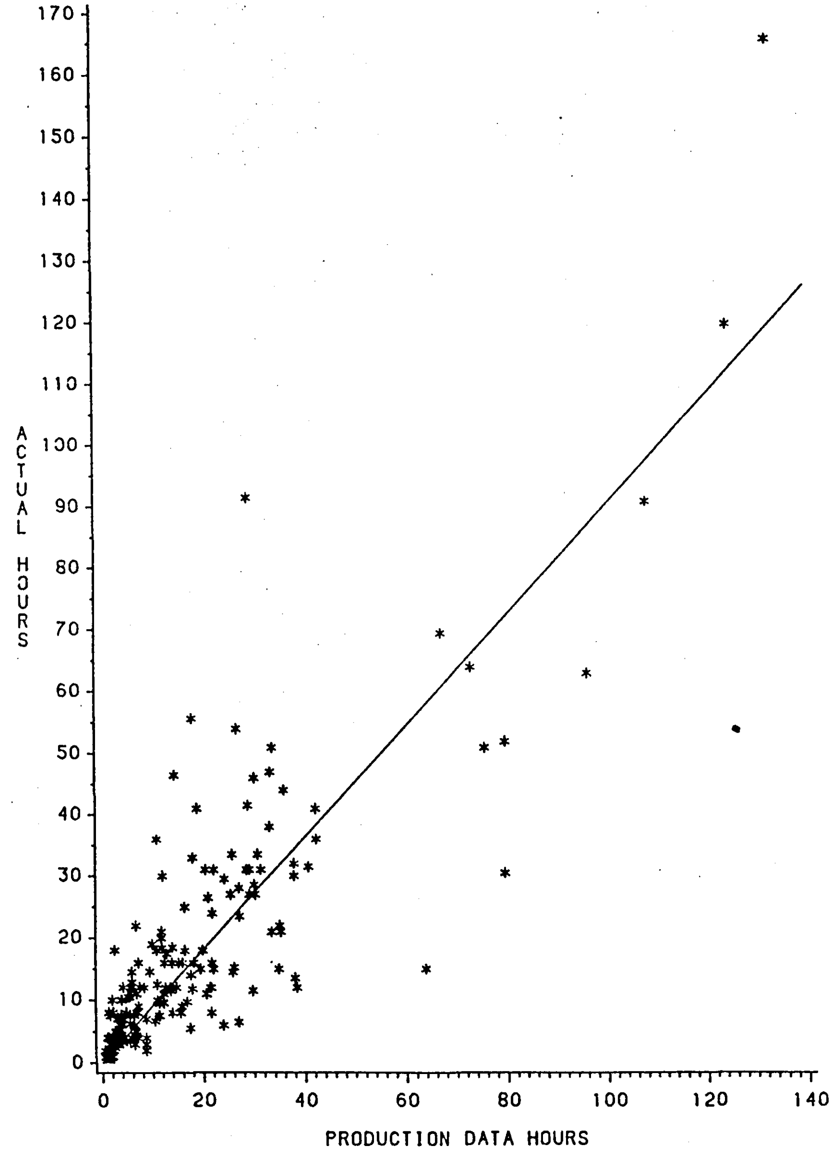
FIRST SAMPLE PROJECTS
CONCRETE IN FLOOR SLABS



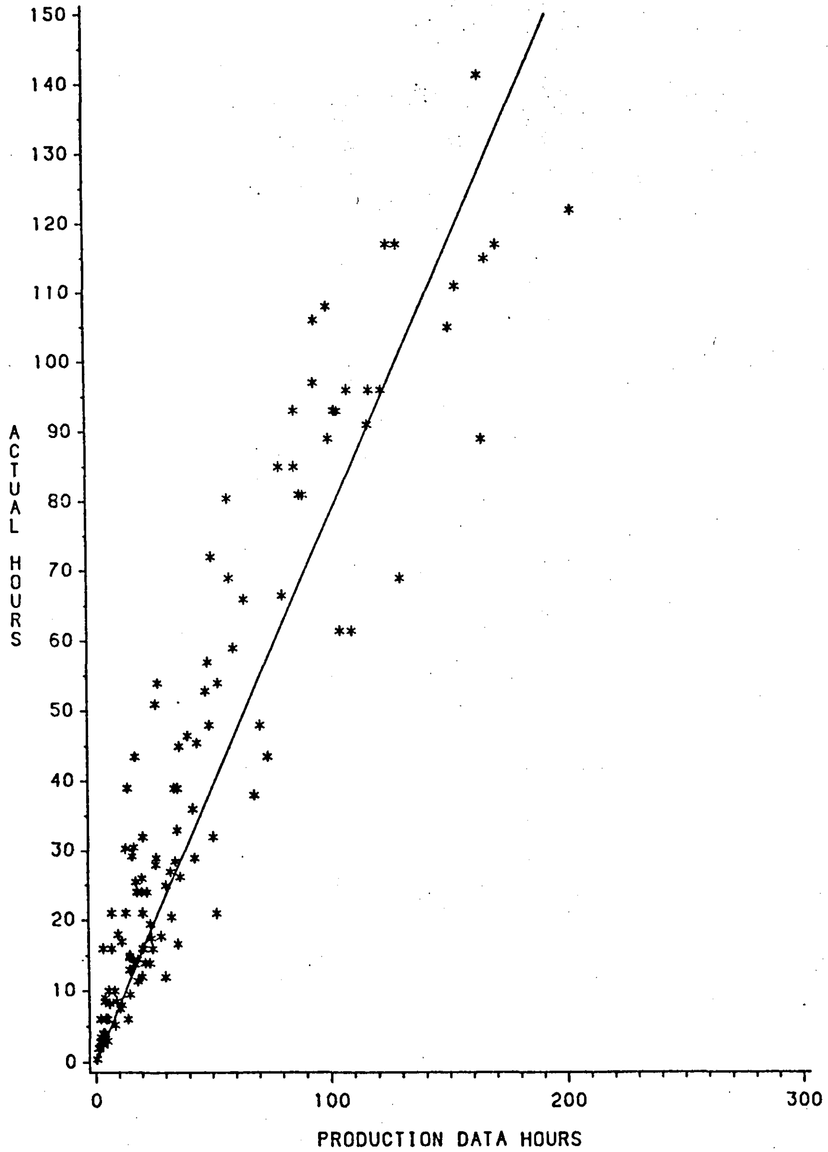
FIRST SAMPLE PROJECTS
CONCRETE IN SUSPENDED SLABS, STAIRS AND LANDINGS



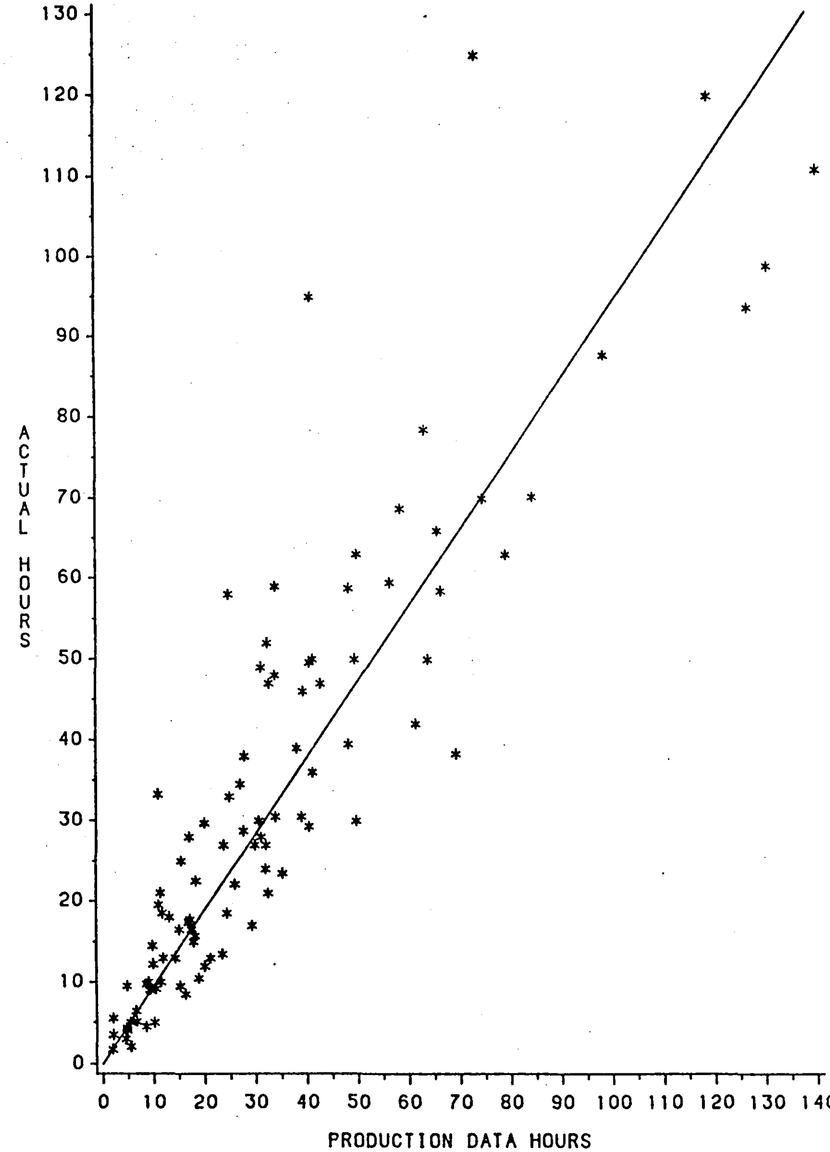
FIRST SAMPLE PROJECTS
CONCRETE WORK



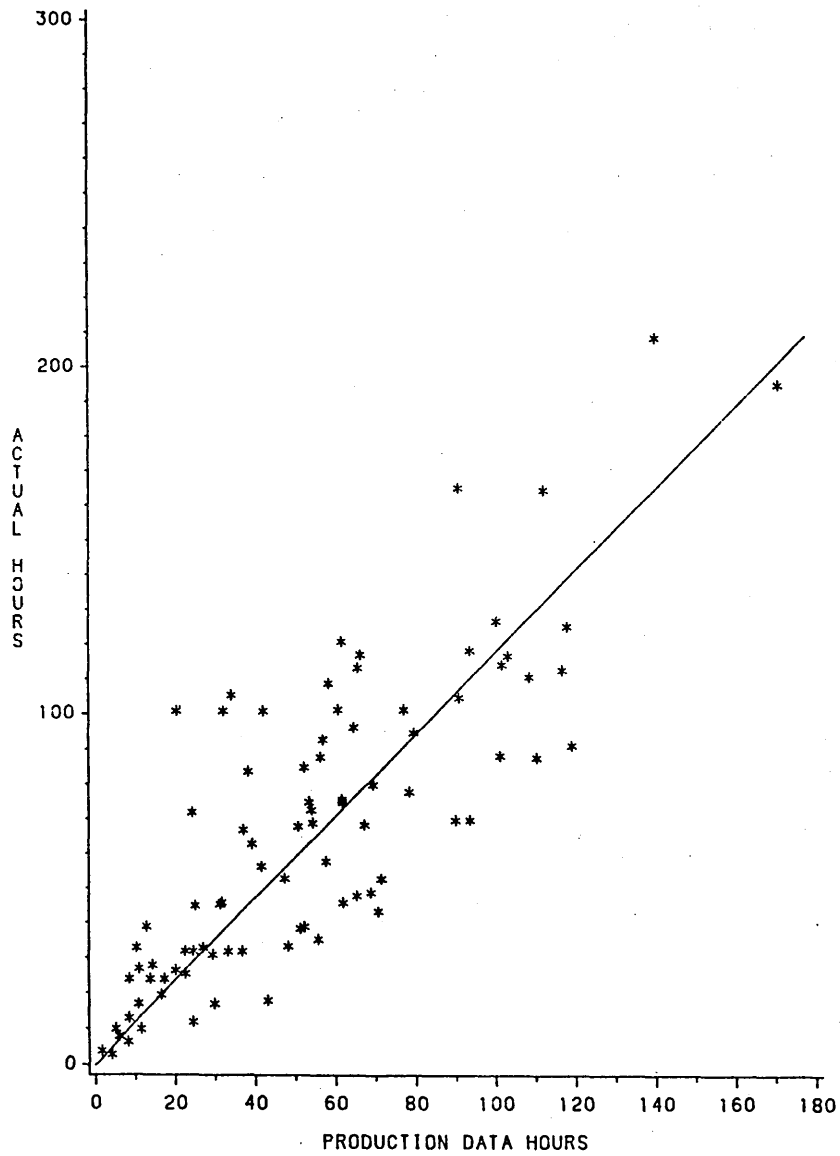
FIRST SAMPLE PROJECTS
BRICKWORK IN SUPERSTRUCTURE



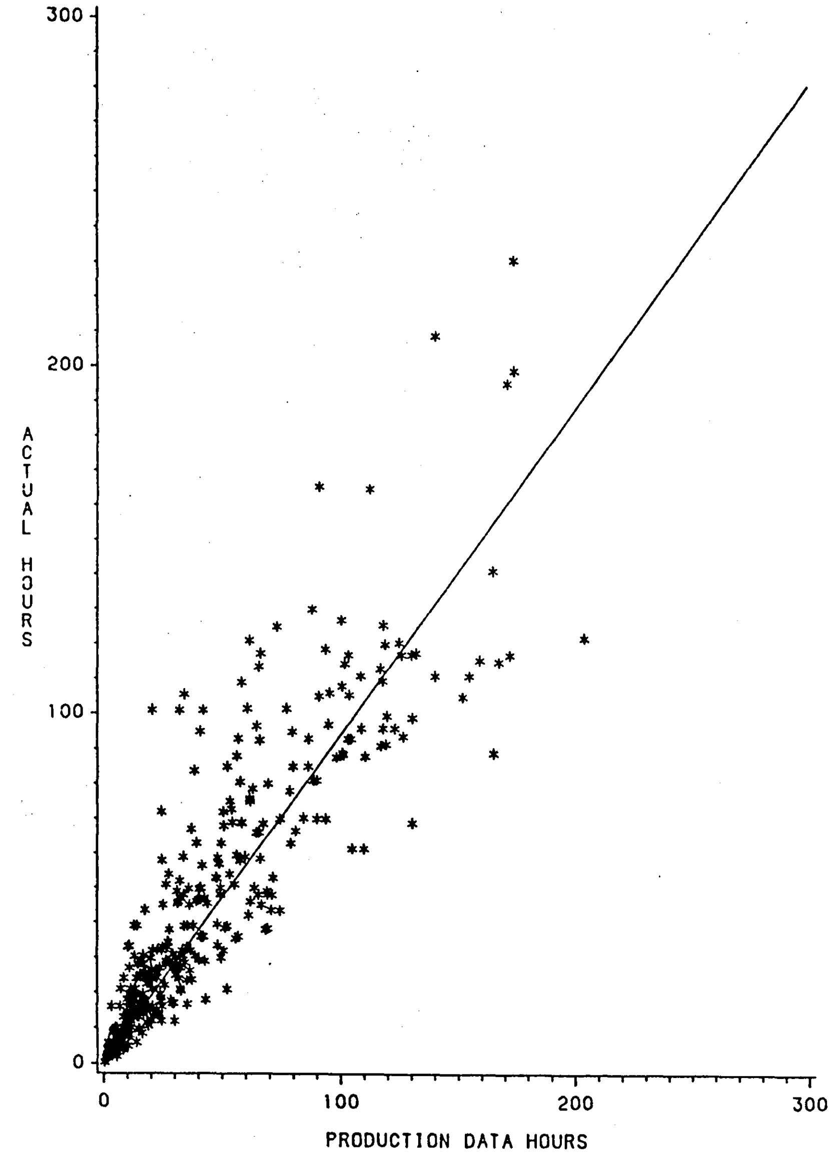
FIRST SAMPLE PROJECTS
BLOCKWORK IN SUPERSTRUCTURE



FIRST SAMPLE PROJECTS
BRICKWORK AND BLOCKWORK IN SUPERSTRUCTURE



FIRST SAMPLE PROJECTS
BRICKWORK AND BLOCKWORK



NOTATION FOR DATA STRUCTURE

[ ]	Optional structure
{ }	Alternative structure
*	Iterations of structure
(1-)	Number of occurrences of iteration

THE GLOBAL MODEL

DATA FLOWS
- Bill Items and Production Data Details
- Estimate Details
- Feedback Data
- Overall Operation Details
- Planned Work Operations
- Production Data
- Sub-operation Details
- Tender Documents
- Tender Figure
- Variations
- Work Target Details

DATA STORES
- Production Data File
- Variations Details and Outstanding Information

PROCESSES
- Overall Planning
- Prepare Estimate
- Short Term/Stage Planning
- Tender Adjudication
- Work Operations
- Work Targets

DATA FLOW: BILL ITEMS AND PRODUCTION DATA DETAILS

SOURCE REF: 1 **DESCRIPTION:** PREPARE ESTIMATE

DEST'N REF: 2, 3 **DESCRIPTION:** OVERALL PLANNING, SHORT TERM/STAGE PLANNING

EXPANDED DESCRIPTION: Bill item details, together with the appropriate labour production data allowance

INCLUDED DATA STRUCTURES: *(1-)

PAGE NUMBER
BILL ITEM REFERENCE
CLASS CODE
CATEGORY CODE
BILL ITEM DETAILS
QUANTITY
UNIT
RESOURCE DETAILS

OTHER INFORMATION:

DATA FLOW: ESTIMATE DETAILS

SOURCE REF: 1, E1 DESCRIPTION: PREPARE ESTIMATE, CONSTRUCTION MANAGEMENT

DEST'N REF: E1, 6 DESCRIPTION: CONSTRUCTION MANAGEMENT, TENDER ADJUDICATION

EXPANDED DESCRIPTION: Details of the net cost estimate for the project

INCLUDED DATA STRUCTURES:
BILL OF QUANTITIES SUMMARY:-
LABOUR, PLANT, MATERIALS
DOMESTIC SUB-CONTRACTORS,
P.C. AND PROVISIONAL SUMS,
CONTINGENCIES PROJECT OVERHEADS,
NET TOTAL

OTHER INFORMATION:

DATA FLOW: FEEDBACK DATA

SOURCE REF: 5 DESCRIPTION: WORK OPERATIONS

DEST'N REF: D1 DESCRIPTION: PRODUCTION DATA FILE

EXPANDED DESCRIPTION: Record of labour productivity performances achieved on site

INCLUDED DATA STRUCTURES:
WORK TARGET DETAILS
ACTUAL PERFORMANCE DATA *

OTHER INFORMATION:

DATA FLOW: OVERALL OPERATION DETAILS

SOURCE REF: 2 **DESCRIPTION:** OVERALL PLANNING

DEST´N REF: E3, 3 **DESCRIPTION:** SITE MANAGEMENT, SHORT TERM/STAGE PLANNING

EXPANDED DESCRIPTION: Details of operations relating to the required resources and corresponding time periods

INCLUDED DATA STRUCTURES: *

Overall operations details
Overall operations resources details

OTHER INFORMATION:

DATA FLOW: PLANNED WORK OPERATIONS

SOURCE REF: E3 **DESCRIPTION:** SITE MANAGEMENT

DEST´N REF: 5 **DESCRIPTION:** WORK OPERATIONS

EXPANDED DESCRIPTION: Details of construction work operations at various levels of detail, including durations and labour resources

INCLUDED DATA STRUCTURES: *

Overall Operations Details
Overall Operations Resouces Details
Sub-Operations Details
Sub-Operations Resources Details
Work Target Details

OTHER INFORMATION:

DATA FLOW: PRODUCTION DATA

SOURCE REF: D1 DESCRIPTION: PRODUCTION DATA FILE

DEST´N REF: 1,2,3,4 DESCRIPTION: PREPARE ESTIMATE, OVERALL PLANNING, SHORT TERM/STAGE PLANNING, WORK TARGETS

EXPANDED DESCRIPTION: Labour productivity data for measured work items

INCLUDED DATA STRUCTURES:
{STANDARD ITEM DETAILS}
{INDIVIDUAL INPUT DATA}

OTHER INFORMATION:

DATA FLOW: SUB-OPERATIONS DETAILS

SOURCE REF: 3 DESCRIPTION: SHORT TERM/STAGE PLANNING

DEST´N REF: E3, 4 DESCRIPTION: SITE MANAGEMENT, WORK TARGETS

EXPANDED DESCRIPTION: Description of sub-operations, together with labour resources and durations

INCLUDED DATA STRUCTURES: *
SUB-OPERATIONS
RESOURCES DETAILS

OTHER INFORMATION:

DATA FLOW: TENDER DOCUMENTS

SOURCE REF: E2, E1 DESCRIPTION: ARCHITECT/CLIENT, CONSTRUCTION MANAGEMENT

DEST'N REF: E1, 1, 2 DESCRIPTION: CONSTRUCTION MANAGEMENT, PREPARE ESTIMATE, OVERALL PLANNING

EXPANDED DESCRIPTION: All relevant documents relating to the proposed construction project

INCLUDED DATA STRUCTURES:

Bills Of Quantities
Drawings
Specifications
Schedules

OTHER INFORMATION:

DATA FLOW: TENDER FIGURE

SOURCE REF: 6 DESCRIPTION: TENDER ADJUDICATION

DEST'N REF: E2 DESCRIPTION: ARCHITECT/CLIENT

EXPANDED DESCRIPTION: The tender sum representing the bid for the construction project

INCLUDED DATA STRUCTURES:

Net Cost Estimate
Adjustments
Mark-Up

OTHER INFORMATION:

DATA FLOW: VARIATIONS

SOURCE REF: E2, E1, D2

DESCRIPTION: ARCHITECT/CLIENT, CONSTRUCTION MANAGEMENT, VARIATION DETAILS

DEST'N REF: E1, D2, 1, 2, 3

DESCRIPTION: CONSTRUCTION MANAGEMENT, VARIATION DETAILS AND OUTSTANDING INF., PREPARE ESTIMATE, OVERALL PLANNING, SHORT TERM/STAGE PLANNING

EXPANDED DESCRIPTION: Amendments to work content of the construction project

INCLUDED DATA STRUCTURES: *

- Additions to Bill Items
- Omissions to Bill Items
- Increases in Quantities
- Reductions in Quantities
- Description of Work Content

OTHER INFORMATION:

FREQUENCY AT THE DISCRETION OF THE ARCHITECT

DATA FLOW: WORK TARGET DETAILS

SOURCE REF: 4

DESCRIPTION: WORK TARGETS

DEST'N REF: E3, E4

DESCRIPTION: SITE MANAGEMENT
SURVEYING MANAGEMENT

EXPANDED DESCRIPTION: The details relating to a pre-measured section of work, together with resources and time periods

INCLUDED DATA STRUCTURES:

- Sub-Operation Description
- Bill Items Details *
- Resources Details

OTHER INFORMATION:

DATA STORE: PRODUCTION DATA FILE **REF:** D1

DESCRIPTION: Labour productivity data relating to measured work items

DATA FLOWS IN:

5-D1 FEEDBACK DATA

DATA FLOWS OUT:

D1-1 PREPARE ESTIMATE
D1-2 OVERALL PLANNING
D1-3 SHORT TERM/STAGE PLANNING
D1-4 WORK TARGETS

CONTENTS: *

STANDARD ITEM CODE
ITEM DETAILS
RESOURCE REFERENCE 1
RESOURCE CODE 1
RESOURCE HOURS 1
RESOURCE REFERENCE 2
RESOURCE CODE 2
RESOURCE HOURS 2

IMMEDIATE ACCESS:

SYSTEM MAINTENANCE

PHYSICAL ORGANISATION:

SEE APPENDIX 4
STDITEM.DBF

DATA STORE: Variations details and outstanding info. **REF:** D2

DESCRIPTION: Details of variations issued by architect/client, together with any outstanding information

DATA FLOWS IN:

E1-D2 VARIATIONS

DATA FLOWS OUT:

D2-1, 2, 3 VARIATIONS

CONTENTS:

ARCHITECT'S INSTRUCTIONS *
OUTSTANDING INFORMATION *

IMMEDIATE ACCESS:

MANUAL FILING SYSTEM

PHYSICAL ORGANISATION:

PROCESS: OVERALL PLANNING REF: 2

DESCRIPTION: Generations of planning information relating to overall operations

INPUTS:
E1-2 TENDER DOCUMENTS
D1-2 PRODUCTION DATA
D2-2 VARIATIONS

OUTPUTS:
2-E3, 2-3 OVERALL OPERATIONS DETAILS

LOGIC SUMMARY:

PREPARE LIST OF OVERALL OPERATIONS AND GENERATE RELEVANT DETAILS OF RESOURCES AND TIME PERIODS

PHYSICAL REF:

OVERALL PLANNING MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC APPENDIX 3.2

PROCESS: PREPARE ESTIMATE REF: 1

DESCRIPTION: Obtain the net cost estimate for the project utilising the labour production data file

INPUTS:
E1-1 TENDER DOCUMENTS
D1-1 PRODUCTION DATA
D2-1 VARIATION DETAILS AND OUTSTANDING INFO.

OUTPUTS:
1-E1 ESTIMATE DETAILS

LOGIC SUMMARY:

ESTABLISH THE COST OF LABOUR (BASED ON PRODUCTION DATA), PLANT AND MATERIALS FOR THE PROJECT.

PHYSICAL REF:

DETAILS OF LOGIC:

PROCESS: SHORT TERM/STAGE PLANNING REF: 3

DESCRIPTION: Generate short term/stage planning information relating to sub-operations

INPUTS:
2-3 OVERALL OPERATION DETAILS
D1-3 PRODUCTION DATA
D2-3 VARIATIONS

OUTPUTS:
3-E3, 4 SUB-OPERATIONS DETAILS

LOGIC SUMMARY:

PREPARE LIST OF SUB-OPERATIONS AND GENERATE RELEVANT DETAILS OF RESOURCES AND TIME PERIODS.

PHYSICAL REF:

SHORT TERM/STAGE PLANNING MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC APPENDIX 3.2

PROCESS: TENDER ADJUDICATION REF: 6

DESCRIPTION: Management evaluation and final addition

INPUTS:
E1-6 ESTIMATE DETAILS

OUTPUTS:
6-E2 TENDER FIGURE

LOGIC SUMMARY:

EVALUATE THE NET COST ESTIMATE AND CONVERT INTO A TENDER

PHYSICAL REF:

DETAILS OF LOGIC:

PROCESS: WORK OPERATIONS REF: 5

DESCRIPTION: Carry out work operations in accordance with the generated planning information

INPUTS:
E3-5 PLANNED WORK OPERATIONS

OUTPUTS:
5-D1 FEEDBACK DATA

LOGIC SUMMARY:

PHYSICAL REF:

DETAILS OF LOGIC:

PROCESS: WORK TARGETS REF: 4

DESCRIPTION: Generate work target information relating to pre-measured work items.

INPUTS:
3-4 SUB-OPERATIONS DETAILS
D1-4 PRODUCTION DATA

OUTPUTS:
4-E3, E4 WORK TARGET DETAILS

LOGIC SUMMARY:

SELECT RELEVANT ITEMS AND QUANTITIES FOR WORK TARGET AND GENERATE RELEVANT DETAILS OF RESOURCES AND TIME PERIODS

PHYSICAL REF:

DETAILS OF LOGIC:

PREPARE ESTIMATE

DATA FLOWS

- All-in Rates Details
- Bill Items and Production Data Details
- Bill of Quantities
- Estimate Details
- Labour, Plant and Materials Requirements Details
- Production Data
- Project Resource Requirements
- Site Information
- Tender Documents
- Variations

DATA STORES

- Bill Items and Production Data
- Production Data File
- Variations Details and Outstanding Information

PROCESSES

- Analyse Tender Documents
- Calculate All-in Rates for Labour, Plant and Materials
- Calculate Net Cost Estimate
- Conduct Site Visit
- Input Bill Items and Production Data Details
- Obtain Project Resource Requirements
- Overall Planning
- Short Term/Stage Planning

DATA FLOW: ALL-IN RATES DETAILS

SOURCE REF: 1.5 DESCRIPTION: CALCULATE ALL-IN RATES FOR LABOUR, PLANT AND MATERIALS

DEST´N REF: 1.4 DESCRIPTION: CALCULATE NET COST ESTIMATE

EXPANDED DESCRIPTION: All-In rate costs for labour, plant and materials

INCLUDED DATA STRUCTURES: *

ALL-IN RATE FOR LABOUR
ALL-IN RATE FOR PLANT
ALL-IN RATE FOR MATERIAL

OTHER INFORMATION:

DATA FLOW: BILL ITEMS AND PRODUCTION DATA DETAILS

SOURCE REF: D1.1 DESCRIPTION: BILL ITEMS AND PRODUCTION DATE

DEST´N REF: 1.4, 2 DESCRIPTION: CALCULATE NET COST ESTIMATE, OVERALL PLANNING

EXPANDED DESCRIPTION: Bill item details, together with the appropriate labour productivity data allowances

INCLUDED DATA STRUCTURES: *(1-)

PAGE NUMBER
BILL ITEM REFERENCE
CLASS CODE
CATEGORY CODE
BILL ITEM DETAILS
QUANTITY
UNIT
RESOURCE DETAILS

OTHER INFORMATION:

DATA FLOW: BILL OF QUANTITIES

SOURCE REF: 1.2 DESCRIPTION: ANALYSE TENDER DOCUMENTS

DEST´N REF: 1.3 DESCRIPTION: INPUT BILL ITEMS AND PRODUCTION DATA DETAILS

EXPANDED DESCRIPTION: Details of bill items and quantities

INCLUDED DATA STRUCTURES: *

PAGE NUMBER
BILL ITEM REFERENCE
BILL ITEM DETAILS
QUANTITY
UNIT

OTHER INFORMATION:

DATA FLOW: ESTIMATE DETAILS

SOURCE REF: 1.4 DESCRIPTION: CALCULATE NET COST ESTIMATE

DEST´N REF: E1 DESCRIPTION: CONSTRUCTION MANAGEMENT

EXPANDED DESCRIPTION: Details of the net cost estimate for the project

INCLUDED DATA STRUCTURES:

BILL OF QUANTITIES SUMMARY
LABOUR, PLANT, MATERIALS
DOMESTIC SUB-CONTRACTORS
P.C. AND PROVISIONAL SUMS
CONTINGENCIES
PROJECT OVERHEADS
NET TOTAL

OTHER INFORMATION:

DATA FLOW: LABOUR, PLANT AND MATERIALS REQUIREMENTS DETAILS

SOURCE REF: 1.6 DESCRIPTION: OBTAIN PROJECT RESOURCE REQUIREMENTS

DEST'N REF: 1.5 DESCRIPTION: CALCULATE ALL-IN RATES FOR LABOUR, PLANT AND MATERIAL

EXPANDED DESCRIPTION: Types of labour, plant and materials required for the project

INCLUDED DATA STRUCTURES: *

LABOUR
PLANT
MATERIALS

OTHER INFORMATION:

DATA FLOW: PRODUCTION DATA

SOURCE REF: D1 DESCRIPTION: PRODUCTION DATA FILE

DEST'N REF: 1.3 DESCRIPTION: INPUT BILL ITEMS AND PRODUCTION DATA DETAILS

EXPANDED DESCRIPTION: Labour productivity data for measured work items

INCLUDED DATA STRUCTURES:

{STANDARD ITEM DETAILS}
{INDIVIDUAL INPUT DATA}

OTHER INFORMATION:

DATA FLOW: PROJECT RESOURCE REQUIREMENTS

SOURCE REF: 1.6 **DESCRIPTION:** OBTAIN PROJECT RESOURCE REQUIREMENTS

DEST'N REF: 1.4 **DESCRIPTION:** CALCULATE NET COST ESTIMATE

EXPANDED DESCRIPTION: Details of labour, plant and materials, including quotations from sub-contractors and suppliers, etc.

INCLUDED DATA STRUCTURES: *

LABOUR
PLANT
MATERIALS
SUB-CONTRACTORS' QUOTATIONS
SUPPLIERS' QUOTATIONS

OTHER INFORMATION:

DATA FLOW: SITE INFORMATION

SOURCE REF: 1.1 **DESCRIPTION:** CONDUCT SITE VISIT

DEST'N REF: 1.3 **DESCRIPTION:** INPUT BILL ITEMS AND PRODUCTION DATA DETAILS

EXPANDED DESCRIPTION: Details of site and local conditions

INCLUDED DATA STRUCTURES: *

SITE CONDITIONS
LOCAL CONDITIONS
OTHER INFORMATION

OTHER INFORMATION:

DATA FLOW: TENDER DOCUMENTS

SOURCE REF: E1 DESCRIPTION: CONSTRUCTION MANAGEMENT

DEST'N REF: 1.1, 1.6 DESCRIPTION: CONDUCT SITE VISIT, OBTAIN PROJECT RESOURCE REQUIREMENTS

EXPANDED DESCRIPTION: All relevant documents relating to the proposed construction project

INCLUDED DATA STRUCTURES:
BILLS OF QUANTITIES
DRAWINGS
SPECIFICATIONS
SCHEDULES

OTHER INFORMATION:

DATA FLOW: VARIATIONS

SOURCE REF: D2 DESCRIPTION: VARIATIONS DETAILS AND OUTSTANDING INFORMATION

DEST'N REF: 1.3 DESCRIPTION: INPUT BILL ITEMS AND PRODUCTION DATA DETAILS

EXPANDED DESCRIPTION: Amendments to work content of the construction project

INCLUDED DATA STRUCTURES: *
ADDITIONS TO BILL ITEMS
OMISSIONS TO BILL ITEMS
INCREASES IN QUANTITIES
REDUCTIONS IN QUANTITIES
DESCRIPTIONS OF WORK CONTENT

OTHER INFORMATION:

FREQUENCY AT THE DISCRETION OF THE ARCHITECT

DATA STORE: BILL ITEMS AND PRODUCTION DATA **REF:** D1.1

DESCRIPTION: Details of all bill items and corresponding labour productivity allowances

DATA FLOWS IN:
1.3-D1.1 BILL ITEMS AND PRODUCTION DATA DETAILS

DATA FLOWS OUT:
D1.1-1.4, 2 BILL ITEMS AND PRODUCTION DATA DETAILS

CONTENTS: *
PAGE NUMBER, ITEM REFERENCE,
CLASS, CATEGORY, ITEM DETAIL,
QUANTITY, UNIT, STD. ITEM
RESOURCE REFERENCE *(1-4)
RESOURCE REFERENCE
[RESOURCE CODE] *(1-4)
{MULTIPLIER / DIVISOR} *(1-4)

IMMEDIATE ACCESS:

INPUT DATA MODULE

PHYSICAL ORGANISATION:

SEE APPENDIX 4

ITEMEST.DBF

DATA STORE: PRODUCTION DATA FILE **REF:** D1

DESCRIPTION: Labour productivity data relating to measured work items

DATA FLOWS IN:
5-D1 FEEDBACK DATA

DATA FLOWS OUT:
D1-1.3 PRODUCTION DATA

CONTENTS: *
STANDARD ITEM CODE
ITEM DETAILS
RESOURCE REFERENCE 1
RESOURCE CODE 1
RESOURCE HOURS 1
RESOURCE REFERENCE 2
RESOURCE CODE 2
RESOURCE HOURS 2

IMMEDIATE ACCESS:

SYSTEM MAINTENANCE

PHYSICAL ORGANISATION:

SEE APPENDIX 4

STDITEM.DBF

DATA STORE: VARIATIONS DETAILS AND OUTSTANDING INFO. **REF:** D2

DESCRIPTION: Details of variations issued by architect/client, together with any outstanding information

DATA FLOWS IN:
E1-D2 VARIATIONS

DATA FLOWS OUT:
D2-1.3 INPUT BILL ITEMS AND PRODUCTION DATA DETAILS

CONTENTS:
ARCHITECT'S INSTRUCTIONS *
OUTSTANDING INFORMATION *

IMMEDIATE ACCESS:

MANUAL FILING SYSTEM

PHYSICAL ORGANISATION:

PROCESS: ANALYSE TENDER DOCUMENTS REF: 1.2

DESCRIPTION: Examine the tender documents to determine the scope and nature of the work

INPUTS:
E1-1.2 TENDER DOCUMENTS

OUTPUTS:
1,2-1.3 BILL OF QUANTITIES

LOGIC SUMMARY:

Examine the drawings, specification and Bills of Quantities and determine the scope, nature and practical implications of the project.

PHYSICAL REF:

DETAILS OF LOGIC:

PROCESS: CALCULATE ALL-IN RATES FOR LABOUR, PLANT AND MATERIALS REF: 1.5

DESCRIPTION:

INPUTS:
1.6-1.5 LABOUR, PLANT AND MATERIAL REQUIREMENTS DETAILS

OUTPUTS:
1.5-1.4 ALL-IN RATES DETAILS

LOGIC SUMMARY:

PHYSICAL REF:

DETAILS OF LOGIC:

PROCESS: CALCULATE NET COST ESTIMATE REF: 1.4

DESCRIPTION: Calculate the total net cost for the project

INPUTS:
D1.1-1.4 BILL ITEMS AND PRODUCTION DATA DETAILS
1.5-1.4 ALL-IN RATES DETAILS
1.6-1.4 PROJECT RESOURCE DETAILS

OUTPUTS:
1.4-E1 ESTIMATE DETAILS

LOGIC SUMMARY:

Calculate the unit rates for Bills of Quantities items using production data and all-in rates.
Calculate the total for the Bills of Quantities.

PHYSICAL REF:

DETAILS OF LOGIC:

PROCESS: CONDUCT SITE VISIT REF: 1.1

DESCRIPTION: Carry out site visit to obtain information to assist in the preparation of the estimate

INPUTS:
D1-1.1 TENDER DOCUMENTS

OUTPUTS:
1.1-1.3 SITE INFORMATION

LOGIC SUMMARY:

PHYSICAL REF:

DETAILS OF LOGIC:

PROCESS: INPUT BILL ITEMS AND PRODUCTION DATA DETAILS REF: 1.3

DESCRIPTION: Enter bill items details and appropriate production data

INPUTS:
1.2-1.3 BILL OF QUANTITIES
1.1-1.3 SITE INFORMATION
D1-1.3 PRODUCTION DATA
D2-1.3 VARIATIONS

OUTPUTS:
1.3-D1.1 BILL ITEMS AND PRODUCTION DATA DETAILS

LOGIC SUMMARY:

Enter details of bill items including Quantities.
Enter production data using standard item codes
or individual selection of resources and outputs.

PHYSICAL REF:

INPUT MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC
APPENDIX 3.2

PROCESS: OBTAIN PROJECT RESOURCES REQUIREMENTS REF: 1.6

DESCRIPTION: Determine project resources for labour, plant, materials, sub-contractors, etc.

INPUTS:
E1-1.6 TENDER DOCUMENTS

OUTPUTS:
1.6-1.5 LABOUR, PLANT AND MATERIAL REQUIREMENTS DETAILS

LOGIC SUMMARY:

PHYSICAL REF:

DETAILS OF LOGIC:

PROCESS: OVERALL PLANNING REF: 2

DESCRIPTION: Generation of planning information relating to overall operations

INPUTS:
D1.1-2 BILL ITEMS AND PRODUCTION DATA DETAILS

OUTPUTS:
2-E3, 2-3 OVERALL OPERATIONS DETAILS

LOGIC SUMMARY:

Prepare list of overall operations and generate relevant details of resources and time periods.

PHYSICAL REF:

OVERALL PLANNING MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC
APPENDIX 3.2

PROCESS: SHORT TERM/STAGE PLANNING REF: 3

DESCRIPTION: Generate short term/stage planning information relating to sub-operations

INPUTS:
D1.1-3 BILL ITEMS AND PRODUCTION DATA DETAILS

OUTPUTS:
3-E3, 4 SUB-OPERATIONS DETAILS

LOGIC SUMMARY:

Prepare list of sub-operations and generate relevant details of resources and time periods.

PHYSICAL REF:

SHORT TERM/STAGE PLANNING MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC
APPENDIX 3.2

OVERALL PLANNING

DATA FLOWS

- Bill Items and Production Data Details
- Overall Operations, Bill Items and Quantities Details
- Overall Operations Details
- Overall Operations Resources and Durations
- Overall Operation Resources Details
- Production Data
- Tender Documents
- Resource Details
- Variations

DATA STORES

- Bill Items and Production Data
- Operations, Bill Items and Quantities
- Overall Operations
- Overall Operations Resources
- Production Data File
- Variations Details and Outstanding Information

PROCESSES

- Assign Bill Items and Quantities to Operations
- Input Resource Requirements
- Prepare Overall Operations
- Process Resources
- Short Term/Stage Planning

DATA FLOW: BILL ITEMS AND PRODUCTION DATA DETAILS

SOURCE REF: 2.1, D1.1 **DESCRIPTION:** BILL ITEMS AND PRODUCTION DATA DETAILS

DEST'N REF: 2.1 **DESCRIPTION:** ASSIGN BILL ITEMS AND QUANTITIES TO OPERATIONS

EXPANDED DESCRIPTION: Bill item details, together with the appropriate labour production data allowance

INCLUDED DATA STRUCTURES: *(1-)

PAGE NUMBER
BILL ITEM REFERENCE
CLASS CODE
CATEGORY CODE
BILL ITEM DETAILS
QUANTITY
UNIT
RESOURCE DETAILS

OTHER INFORMATION:

DATA FLOW: OVERALL OPERATIONS, BILL ITEMS AND QUANTITIES DETAILS

SOURCE REF: 2.1, D2.1 **DESCRIPTION:** ASSIGN BILL ITEMS AND QUANTITIES TO OPERATIONS, OPERATIONS BILL ITEMS AND QUANTITIES

DEST'N REF: D2.1, 2.3 **DESCRIPTION:** OPERATIONS BILL ITEMS AND QUANTITIES, PROCESS RESOURCES

EXPANDED DESCRIPTION: Overall operations together with assigned bill items, quantities and relevant production data

INCLUDED DATA STRUCTURES: *(1-)

OVERALL OPERATION
PAGE NUMBER
BILL ITEM REFERENCE
CLASS CODE
CATEGORY CODE
BILL ITEM DETAILS
QUANTITY
UNIT
RESOURCE DETAILS

OTHER INFORMATION:

DATA FLOW: OVERALL OPERATIONS DETAILS

SOURCE REF: 2.3, D2.2 **DESCRIPTION:** PREPARE OVERALL OPERATIONS, OVERALL OPERATIONS

DEST'N REF: D2.2, 2.1, 3 **DESCRIPTION:** OVERALL OPERATIONS, ASSIGN BILL ITEMS AND QUANTITIES TO OPERATIONS, SHORT TERM/STAGE PLANNING

EXPANDED DESCRIPTION: Details of operations relating to work classification and description

INCLUDED DATA STRUCTURES: *(1-)

- OPERATION NUMBER
- WORK CLASSIFICATION CODE
- OPERATION DESCRIPTION

OTHER INFORMATION:

DATA FLOW: OVERALL OPERATIONS RESOURCES AND DURATIONS

SOURCE REF: D2.3 **DESCRIPTION:** OVERALL OPERATIONS RESOURCES

DEST'N REF: E3 **DESCRIPTION:** SITE MANAGEMENT

EXPANDED DESCRIPTION: Details of resources and total time periods together with resources requirements

INCLUDED DATA STRUCTURES: * (1-)

- OPERATION NUMBER
- RESOURCE REFERENCE
- RESOURCE CODE
- RESOURCE HOURS
- PRODUCTIVITY ADJUSTMENT FACTOR
- RESOURCE NUMBER
- ACTUAL HOURS
- ACTUAL WEEKS
- FACTORED HOURS
- FACTORED WEEKS

OTHER INFORMATION:

DATA FLOW: OVERALL OPERATIONS RESOURCES DETAILS

SOURCE REF: 2.3 DESCRIPTION: PROCESS RESOURCES

DEST'N REF: D2.3, 2.4 DESCRIPTION: OVERALL OPERATIONS RESOURCES, INPUT RESOURCE REQUIREMENTS

EXPANDED DESCRIPTION: Details of resources and the total time relating to overall operations

INCLUDED DATA STRUCTURES: * (1-)

OPERATION NUMBER
RESOURCE REFERENCE
RESOURCE CODE
RESOURCE HOURS

OTHER INFORMATION:

DATA FLOW: PRODUCTION DATA

SOURCE REF: D1 DESCRIPTION: PRODUCTION DATA FILE

DEST'N REF: 2.3 DESCRIPTION: PROCESS RESOURCES

EXPANDED DESCRIPTION: Labour productivity data for measured work items

INCLUDED DATA STRUCTURES:

{STANDARD ITEM DETAILS}
{INDIVIDUAL INPUT DATA}

OTHER INFORMATION:

DATA FLOW: TENDER DOCUMENTS

SOURCE REF: E1 DESCRIPTION: CONSTRUCTION MANAGEMENT

DEST'N REF: 2.2 DESCRIPTION: PREPARE OVERALL OPERATIONS

EXPANDED DESCRIPTION: All relevant documents relating to the proposed construction project

INCLUDED DATA STRUCTURES:

BILLS OF QUANTITIES
DRAWINGS
SPECIFICATIONS
SCHEDULES

OTHER INFORMATION:

DATA FLOW: RESOURCE DETAILS

SOURCE REF: 2.4 DESCRIPTION: INPUT RESOURCE REQUIREMENTS

DEST'N REF: D2.3 DESCRIPTION: OVERALL OPERATIONS RESOURCES

EXPANDED DESCRIPTION: Details of resources allowed and corresponding time periods

INCLUDED DATA STRUCTURES: *

PRODUCTIVITY ADJUSTMENT FACTOR
NUMBER OF RESOURCES
ACTUAL HOURS
ACTUAL WEEKS
FACTORED HOURS
FACTORED WEEKS

OTHER INFORMATION:

DATA FLOW: VARIATIONS

SOURCE REF: D2

DESCRIPTION: VARIATION DETAILS AND OUTSTANDING INFORMATION

DEST'N REF: D1.1

DESCRIPTION: BILL ITEMS AND PRODUCTION DATA

EXPANDED DESCRIPTION: Amendments to work content of the construction project

INCLUDED DATA STRUCTURES:

ADDITIONS TO BILL ITEMS
OMISSIONS TO BILL ITEMS
INCREASES IN QUANTITIES
REDUCTIONS IN QUANTITIES
DESCRIPTIONS OF WORK CONTENT

OTHER INFORMATION:

FREQUENCY AT THE DISCRETION OF THE ARCHITECT.

DATA STORE: BILL ITEMS AND PRODUCTION DATA **REF:** D1.1

DESCRIPTION: Details of all bill items and corresponding labour productivity allowances

DATA FLOWS IN:
D2-D1.1 VARIATIONS

DATA FLOWS OUT:
D1.1-2.1 BILL ITEMS AND PRODUCTION DATA DETAILS

CONTENTS: *
PAGE NUMBER, ITEM REFERENCE,
CLASS, CATEGORY, ITEM DETAIL,
QUANTITY, UNIT
{STD. ITEM RESOURCE REFERENCE / RESOURCE REFERENCE} *(1-4)
[RESOURCE CODE] *(1-4)
{MULTIPLIER / DIVISOR} *(1-4)

IMMEDIATE ACCESS:

INPUT DATA MODULE

PHYSICAL ORGANISATION:

SEE APPENDIX 4
ITEMEST.DBF

DATA STORE: OPERATIONS, BILL ITEMS AND QUANTITIES **REF:** D2.1

DESCRIPTION: Operations and assigned bill items, quantities and corresponding production data allowances

DATA FLOWS IN:
2.1-D2.1 OVERALL OPERATIONS, BILL ITEMS AND QUANTITIES DETAILS

DATA FLOWS OUT:
D2.1-2.3 OVERALL OPERATIONS, BILL ITEMS AND QUANTITIES DETAILS

CONTENTS: *
OVERALL OPERATION NUMBER,
PAGE NUMBER, ITEM REFERENCE,
CLASS, CATEGORY, ITEM DETAIL,
QUANTITY, UNIT
{STD. ITEM RESOURCE REFERENCE / RESOURCE REFERENCE} *(1-4)
[RESOURCE CODE] *(1-4)
{MULTIPLIER / DIVISOR} *(1-4)

IMMEDIATE ACCESS:

OVERALL PLANNING MODULE

PHYSICAL ORGANISATION:

SEE APPENDIX 4
OALLOPS.DBF

DATA STORE: OVERALL OPERATIONS REF: D2.2

DESCRIPTION: Overall operations representing the work content of the project

DATA FLOWS IN:
2.2-D2.2 OVERALL OPERATIONS DETAILS

DATA FLOWS OUT:
D2.2-2.1, 3 OVERALL OPERATIONS DETAILS

CONTENTS: *
OPERATION NUMBER
WORK CLASSIFICATION
OPERATION DESCRIPTION

IMMEDIATE ACCESS:

OVERALL PLANNING MODULE

PHYSICAL ORGANISATION:

SEE APPENDIX 4

OPERATNS.DBF

DATA STORE: OVERALL OPERATIONS RESOURCES REF: D2.3

DESCRIPTION: Resource details and corresponding time periods relating to operations

DATA FLOWS IN:
2.3-D2.3 OVERALL OPERATIONS RESOURCES DETAILS
2.4-D2.3 RESOURCE DETAILS

DATA FLOWS OUT:
D2.3-E3 OVERALL OPERATIONS RESOURCES AND DURATIONS

CONTENTS: *
OPERATION NUMBER,
RESOURCE REFERENCE, RESOURCE CODE, RESOURCE HOURS, PRODUCTIVITY ADJUSTMENT FACTOR, RESOURCE NUMBER, ACTUAL HOURS, ACTUAL WEEKS, FACTORED HOURS, FACTORED WEEKS

IMMEDIATE ACCESS:

OVERALL PLANNING MODULE

PHYSICAL ORGANISATION:

SEE APPENDIX 4

GORES.DBF

DATA STORE: PRODUCTION DATA FILE REF: D1

DESCRIPTION: Labour productivity data relating to measured work items

DATA FLOWS IN:
5 - D1 FEEDBACK DATA

DATA FLOWS OUT:
D1 - 2.3 PRODUCTION DATA

CONTENTS: *
STANDARD ITEM CODE
ITEM DETAILS
RESOURCE REFERENCE 1
RESOURCE CODE 1
RESOURCE HOURS 1
RESOURCE REFERENCE 2
RESOURCE CODE 2
RESOURCE HOURS 2

IMMEDIATE ACCESS:

SYSTEM MAINTENANCE

PHYSICAL ORGANISATION:

SEE APPENDIX 4
STDITEM.DBF

DATA STORE: VARIATIONS DETAILS AND OUTSTANDING INFORMATION REF: D2

DESCRIPTION: Details of variations issued by architect/client, together with any outstanding information

DATA FLOWS IN:
E1 - D2 VARIATIONS

DATA FLOWS OUT:
D2 - D1.1 VARIATIONS

CONTENTS:
ARCHITECT'S INSTRUCTIONS *
OUTSTANDING INFORMATION *

IMMEDIATE ACCESS:

MANUAL FILING SYSTEM

PHYSICAL ORGANISATION:

PROCESS: ASSIGN BILL ITEMS AND QUANTITIES TO OPERATIONS **REF:** 2.1

DESCRIPTION: Assign each bill item, together with the corresponding quantities and production data details to the appropriate overall operations

INPUTS:

D1.1-2.1 BILL ITEMS AND PRODUCTION DATA DETAILS

D2.2-2.1 OVERALL OPERATIONS DETAILS

OUTPUTS:

2.1-D2.1 OVERALL OPERATIONS BILL ITEMS AND QUANTITIES DETAILS

LOGIC SUMMARY:

CHECK EACH BILL ITEM WITH EACH OPERATION
IF THE CLASS CODE IS THE SAME COMBINE
THE OPERATION DETAILS WITH THE BILL ITEM DETAILS

PHYSICAL REF:

OVERALL PLANNING MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC
APPENDIX 3.2

PROCESS: INPUT RESOURCE REQUIREMENTS **REF:** 2.4

DESCRIPTION: Select appropriate resources relating to the overall operation

INPUTS:
2.3-2.4 OVERALL OPERATIONS RESOURCES DETAILS

OUTPUTS:
2.4-D2.3 RESOURCE DETAILS

LOGIC SUMMARY:

INPUT APPROPRIATE PRODUCTIVITY ADJUSTMENT FACTOR.
INPUT THE NUMBER OF RESOURCES REQUIRED.
COMPUTE TIME PERIODS..

PHYSICAL REF:

OVERALL PLANNING MODULE

DETAILS OF LOGIC:

SEE PROCES LOGIC
APPENDIX 3.2

PROCESS: PREPARE OVERALL OPERATIONS **REF:** 2.2

DESCRIPTION: Select appropriate operations representing the construction work

INPUTS:
E1-2.2 TENDER DOCUMENTS

OUTPUTS:
2.2-D2.2 OVERALL OPERATIONS DETAILS

LOGIC SUMMARY:

INPUT OVERALL OPERATION NUMBER, WORK CLASSIFICATION
AND OPERATION DESCRIPTION

PHYSICAL REF:

OVERALL PLANNING MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC
APPENDIX 3.2

PROCESS: PROCESS RESOURCES REF: 2.3

DESCRIPTION: Compute the resources and corresponding time periods representing the overall operation

INPUTS:
D1-2.3 PRODUCTION DATA
D2.1-2.3 OVERALL OPERATIONS, BILL ITEMS AND QUANTITIES DETAILS

OUTPUTS:
2.3-D2.3, 2.3-2.4 OVERALL OPERATIONS RESOURCES DETAILS

LOGIC SUMMARY:

PROCESS THE PRODUCTION DATA FOR EACH BILL ITEM ASSIGNED TO THE OVERALL OPERATION

PHYSICAL REF:

OVERALL PLANNING MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC APPENDIX 3.2

PROCESS: SHORT TERM/STAGE PLANNING REF: 3

DESCRIPTION: Generate short term/stage planning information relating to sub-operations

INPUTS:
D2.2-3 OVERALL OPERATIONS DETAILS

OUTPUTS:

LOGIC SUMMARY:

PREPARE LIST OF SUB-OPERATIONS AND GENERATE RELEVANT DETAILS OF RESOURCES AND TIME PERIODS

PHYSICAL REF:

DETAILS OF LOGIC:

SHORT TERM/STAGE PLANNING

DATA FLOWS
- Adjustment Details
- Bill Items and Production Data Details
- Overall Operations Details
- Production Data
- Resource Details
- Sub-operations and Bill Items Details
- Sub-operations, Bill Items and Quantities Details
- Sub-operations Details
- Sub-operations Quantities Details
- Sub-operation Resources and Durations
- Sub-operations Resources Details
- Variations

DATA STORES
- Bill Items and Production Data
- Insignificant Items Adjustment
- Overall Operations
- Production Data File
- Sub-operations
- Sub-operations, Bill Items and Quantities
- Sub-operations Resources
- Variations Details and Outstanding Information

PROCESSES
- Assign Bill Items to Sub-operations
- Input Resource Requirements
- Process Adjustment for Insignificant Items
- Process Resources
- Prepare Sub-operations
- Select Sub-operations and Input Quantities
- Work Targets

DATA FLOW: ADJUSTMENT DETAILS

SOURCE REF: 3,4, D3.3 DESCRIPTION: PROCESS ADJUSTMENT FOR INSIGNIFICANT BILL ITEMS, INSIGNIFICANT ITEMS ADJUSTMENT

DEST´N REF: 3.5, D3.3, 4 DESCRIPTION: PROCESS RESOURCES, INSIGNIFICANT ITEMS ADJUSTMENT, WORK TARGETS

EXPANDED DESCRIPTION: Factors used for computing additions for insignificant bill items

INCLUDED DATA STRUCTURES:
HOURS PER UNIT

OTHER INFORMATION:

DATA FLOW: BILL ITEMS AND PRODUCTION DATA DETAILS

SOURCE REF: D2.1 DESCRIPTION: BILL ITEMS AND PRODUCTION DATA

DEST´N REF: 3.2, 3.4 DESCRIPTION: ASSIGN ITEMS TO SUB-OPERATIONS, PROCESS ADJUSTMENT FOR INSIGNIFICANT BILL ITEMS

EXPANDED DESCRIPTION: Bill items details, together with the appropriate labour production data allowance

INCLUDED DATA STRUCTURES: * (1-)
PAGE NUMBER
BILL ITEM REFERENCE
CLASS CODE
CATEGORY CODE
BILL ITEM DETAILS
QUANTITY
UNIT
RESOURCE DETAILS

OTHER INFORMATION:

DATA FLOW: OVERALL OPERATIONS DETAILS

SOURCE REF: D2.3 DESCRIPTION: OVERALL OPERATIONS

DEST'N REF: 3.1 DESCRIPTION: PREPARE SUB-OPERATIONS

EXPANDED DESCRIPTION: Details of operations relating to the required resources and corresponding time periods

INCLUDED DATA STRUCTURES: * (1-)

OPERATION NUMBER
WORK CLASSIFICATION CODE
OPERATION DESCRIPTION

OTHER INFORMATION:

DATA FLOW: PRODUCTION DATA

SOURCE REF: D1 DESCRIPTION: PRODUCTION DATA FILE

DEST'N REF: 3.4, 3.5 DESCRIPTION: PROCESS ADJUSTMENT FOR INSIGNIFICANT BILL ITEMS, PROCESS RESOURCES

EXPANDED DESCRIPTION: Labour productivity data for measured work items

INCLUDED DATA STRUCTURES:

$\left\{\begin{array}{l}\text{STANDARD ITEM DETAILS}\\\text{INDIVIDUAL INPUT DATA}\end{array}\right\}$

OTHER INFORMATION:

DATA FLOW: RESOURCE DETAILS

SOURCE REF: 3.6 DESCRIPTION: INPUT RESOURCE REQUIREMENTS

DEST´N REF: D3.4 DESCRIPTION: SUB-OPERATIONS RESOURCES

EXPANDED DESCRIPTION: Details of resources allowed and corresponding time periods

INCLUDED DATA STRUCTURES:

PRODUCTIVITY ADJUSTMENT FACTOR
NUMBER OF RESOURCES
ACTUAL HOURS
ACTUAL WEEKS
FACTORED HOURS
FACTORED WEEKS

OTHER INFORMATION:

DATA FLOW: SUB-OPERATIONS AND BILL ITEMS DETAILS

SOURCE REF: 3.2 DESCRIPTION: ASSIGN BILL ITEMS TO SUB-OPERATIONS

DEST´N REF: D3.2 DESCRIPTION: SUB-OPERATIONS BILL ITEMS AND QUANTITIES

EXPANDED DESCRIPTION: Sub-operations and assigned bill items, together with corresponding production data allowances

INCLUDED DATA STRUCTURES: * (1-)

SUB-OPERATION
PAGE NUMBER
BILL ITEM REFERENCE
CLASS CODE
CATEGORY CODE
BILL ITEM DETAILS
QUANTITY
UNIT
RESOURCE DETAILS

OTHER INFORMATION:

DATA FLOW: SUB-OPERATIONS, BILL ITEMS AND QUANTITIES DETAILS

SOURCE REF: D3.2 DESCRIPTION: SUB-OPERATIONS BILL ITEMS AND QUANTITIES

DEST'N REF: 3.5, 4 DESCRIPTION: PROCESS RESOURCES, WORK TARGETS

EXPANDED DESCRIPTION: Sub-operations and relevant items and quantities, together with corresponding production data allowances

INCLUDED DATA STRUCTURES:
SUB-OPERATION DETAILS
PAGE NUMBER
BILL ITEM REFERENCE
CLASS CODE
CATEGORY CODE
RELEVANT BILL ITEM DETAILS
SELECTED QUANTITY
UNIT
RESOURCE DETAILS

OTHER INFORMATION:

DATA FLOW: SUB-OPERATIONS DETAILS

SOURCE REF: 3.1, D3.1 DESCRIPTION: PREPARE SUB-OPERATIONS, SUB-OPERATIONS

DEST'N REF: 3.2, D3.1, 4 DESCRIPTION: ASSIGN BILL ITEMS TO SUB-OPERATIONS, SUB-OPERATIONS, WORK TARGETS

EXPANDED DESCRIPTION: Details of sub-operations relating to work classification, work category and description

INCLUDED DATA STRUCTURES: *(1-)
SUB-OPERATION NUMBER
WORK CLASSIFICATION CODE
WORK CATEGORY CODE
SUB-OPERATION DESCRIPTION

OTHER INFORMATION:

DATA FLOW: SUB-OPERATIONS QUANTITIES DETAILS

SOURCE REF: 3.3 DESCRIPTION: SELECT SUB-OPERATIONS AND INPUT QUANTITIES

DEST'N REF: D3.2 DESCRIPTION: SUB-OPERATIONS, BILL ITEMS AND QUANTITIES

EXPANDED DESCRIPTION: Quantities of Bill items representing the appropriate sub-operation

INCLUDED DATA STRUCTURES:
SUB-OPERATION NUMBER
BILL ITEM QUANTITY * (1-)

OTHER INFORMATION:

DATA FLOW: SUB-OPERATION RESOURCES AND DURATIONS

SOURCE REF: D3.4 DESCRIPTION: SUB-OPERATION RESOURCES

DEST'N REF: E3 DESCRIPTION: SITE MANAGEMENT

EXPANDED DESCRIPTION: Details of resources and total time periods together with resource requirements

INCLUDED DATA STRUCTURES: * (1-)
SUB-OPERATION NUMBER
RESOURCE REFERENCE
RESOURCE CODE
RESOURCE HOURS
PRODUCTIVITY ADJUSTMENT FACTOR
RESOURCE NUMBER
ACTUAL HOURS
ACTUAL WEEKS
FACTORED HOURS
FACTORED WEEKS

OTHER INFORMATION:

DATA FLOW: SUB-OPERATION RESOURCES DETAILS

SOURCE REF: 3.5 DESCRIPTION: PROCESS RESOURCES

DEST'N REF: D3.4, 3.6 DESCRIPTION: SUB-OPERATION RESOURCES, INPUT RESOURCE REQUIREMENTS

EXPANDED DESCRIPTION: Details of resources and the total time relating to sub-operations

INCLUDED DATA STRUCTURES: * (1-)

SUB-OPERATION NUMBER
RESOURCE REFERENCE
RESOURCE CODE
RESOURCE HOURS

OTHER INFORMATION:

DATA FLOW: VARIATIONS

SOURCE REF: D2 DESCRIPTION: VARIATIONS DETAILS AND OUTSTANDING INFORMATION

DEST'N REF: D2.1 DESCRIPTION: BILL ITEMS AND PRODUCTION DATA

EXPANDED DESCRIPTION: Amendments to work content of the construction project

INCLUDED DATA STRUCTURES:

ADDITIONS TO BILL ITEMS
OMISSIONS TO BILL ITEMS
INCREASES IN QUANTITIES
REDUCTIONS IN QUANTITIES
DESCRIPTIONS OF WORK CONTENT

OTHER INFORMATION:

FREQUENCY AT THE DISCRETION OF THE ARCHITECT

DATA STORE: BILL ITEMS AND PRODUCTION DATA REF: D2.1

DESCRIPTION: Details of all bill items and corresponding labour productivity allowances

DATA FLOWS IN:

2.1 - D2.1 BILL ITEMS AND PRODUCTION DETAILS

D2 - D2.1 -VARIATIONS

DATA FLOWS OUT:

D2.1 - 3.2, 3.4

BILL ITEMS AND PRODUCTION DATA DETAILS

CONTENTS: *

PAGE NUMBER, ITEM REFERENCE,

CLASS, CATEGORY, ITEM DETAIL,

QUANTITY, UNIT

{STANDARD ITEM RESOURCE REF / RESOURCE REFERENCE} *(1-4)

[RESOURCE CODE]* (1-4)

{MULTIPLIER / DIVISOR} * (1-4)

IMMEDIATE ACCESS:

INPUT DATA MODULE

PHYSICAL ORGANISATION:

SEE APPENDIX 4

ITEMEST.DBF

DATA STORE: INSIGNIFICANT ITEMS ADJUSTMENT REF: D3.3

DESCRIPTION: Adjustment in terms of additional hours representing insignificant bill items

DATA FLOWS IN:

3.4 - D3.3 ADJUSTMENT DETAILS

DATA FLOWS OUT:

D3.3 - 3.5, 4

ADJUSTMENT DETAILS

CONTENTS:

HOURS PER m^2

HOURS PER m^3

IMMEDIATE ACCESS:

PHYSICAL ORGANISATION:

MEMORY VARIABLE

DATA STORE: OVERALL OPERATIONS REF: D2.3

DESCRIPTION: Overall operations representing the work content of the project

DATA FLOWS IN:
2.3 - D2.3 OVERALL OPERATIONS DETAILS

DATA FLOWS OUT:
D2.3 - 3.1 OVERALL OPERATIONS DETAILS

CONTENTS: *
OPERATION NUMBER
CLASS
OPERATION DESCRIPTION

IMMEDIATE ACCESS:

OVERALL PLANNING MODULE

PHYSICAL ORGANISATION:

SEE APPENDIX 4
OPERATNS.DBF

DATA STORE: PRODUCTION DATA FILE REF: D1

DESCRIPTION: Labour productivity data relating to measured work items

DATA FLOWS IN:
5 - D1 FEEDBACK DATA

DATA FLOWS OUT:
D1 - 3,4, 3.5
PRODUCTION DATA

CONTENTS: *
STANDARD ITEM CODE
ITEM DETAILS
RESOURCE REFERENCE 1
RESOURCE CODE 1
RESOURCE HOURS 1
RESOURCE REFERENCE 2
RESOURCE CODE 2
RESOURCE HOURS 2

IMMEDIATE ACCESS:

SYSTEM MAINTENANCE

PHYSICAL ORGANISATION:

SEE APPENDIX 5
STDITEM.DBF

DATA STORE: SUB-OPERATIONS **REF:** D3.1

DESCRIPTION: Sub-operations representing sub-divisions of the overall operations

DATA FLOWS IN:

3.1 - D3.1 SUB-OPERATIONS DETAILS

DATA FLOWS OUT:

D3.1 - 3.2 SUB-OPERATIONS DETAILS

CONTENTS: *

SUB-OPERATION NUMBER
WORK CLASSIFICATION
WORK CATEGORY
SUB-OPERATION DESCRIPTION

IMMEDIATE ACCESS:

SHORT TERM/STAGE PLANNING MODULE

PHYSICAL ORGANISATION:

SEE APPENDIX 4

SUBOPS.DBF

DATA STORE: SUB-OPERATIONS, BILL ITEMS AND QUANTITIES **REF:** D3.2

DESCRIPTION: Sub-operations and assigned bill items, quantities and corresponding production data allowances

DATA FLOWS IN:

3.2 - D3.2 SUB-OPERATIONS AND BILL ITEMS DETAILS
3.3 - D3.2 SUB-OPERATIONS QUANTITIES DETAILS

DATA FLOWS OUT:

D3.2 - 3.5, 4 SUB-OPERATIONS, BILL ITEMS AND QUANTITIES DETAILS

CONTENTS: *

SUB-OPERATION NUMBER
PAGE NUMBER, ITEM REFERENCE
CLASS, CATEGORY, ITEM DETAIL
QUANTITY, UNIT
{STD. ITEM RESOURCE REFERENCE / RESOURCE REFERENCE} *(1-4)
[RESOURCE CODE]* (1-4)
{MULTIPLIER / DIVISOR} * (1-4)

IMMEDIATE ACCESS:

SHORT TERM/STAGE PLANNING MODULE

PHYSICAL ORGANISATION:

SEE APPENDIX 4

BISUBOPS. DBF

DATA STORE: SUB-OPERATIONS RESOURCES **REF:** D3.4

DESCRIPTION: Resource details and corresponding time periods relating to sub-operations

DATA FLOWS IN:

3.5 - D3.4 SUB-OPERATIONS RESOURCES DETAILS

3.6 - D3.4 RESOURCE DETAILS

DATA FLOWS OUT:

D3.4 - E3 SUB-OPERATION RESOURCES AND DURATIONS

CONTENTS: *

SUB-OPERATION NUMBER

RESOURCE REFERENCE, RESOURCE CODE, RESOURCE HOURS, PRODUCTIVITY ADJUSTMENT FACTOR, RESOURCE NUMBER, ACTUAL HOURS, ACTUAL WEEKS, FACTORED HOURS, FACTORED WEEKS

IMMEDIATE ACCESS:

SHORT TERM/STAGE PLANNING MODULE

PHYSICAL ORGANISATION:

SEE APPENDIX 4

GSRES. DBF

DATA STORE: VARIATIONS DETAILS AND OUTSTANDING INFORMATION **REF:** D2

DESCRIPTION: Details of variations issued by architect/client, together with any outstanding information

DATA FLOWS IN:

E1 - D2 VARIATIONS

DATA FLOWS OUT:

D2 - D2.1 VARIATIONS

CONTENTS:

ARCHITECT'S INSTRUCTIONS *

OUTSTANDING INFORMATION *

IMMEDIATE ACCESS:

MANUAL FILING SYSTEM

PHYSICAL ORGANISATION:

PROCESS: ASSIGN BILL ITEMS TO SUB-OPERATIONS **REF:** 3.2

DESCRIPTION: Assign each bill item together with the corresponding quantities and production data details to the appropriate sub-operations

INPUTS:
D2.1 - 3.2 BILL ITEMS AND PRODUCTION DATA DETAILS
D3.1 - 3.2 SUB-OPERATIONS DETAILS

OUTPUTS:
3.2 - D3.2 SUB-OPERATIONS AND BILL ITEMS DETAILS

LOGIC SUMMARY:

CHECK EACH BILL ITEM WITH EACH SUB-OPERATION
IF THE CLASS AND CATEGORY CODES ARE THE SAME
COMBINE THE SUB-OPERATION DETAILS WITH THE
BILL ITEM DETAILS

PHYSICAL REF:

SHORT TERM/STAGE PLANNING
MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC
APPENDIX 3.2

PROCESS: INPUT RESOURCE REQUIREMENTS **REF:** 3.6

DESCRIPTION: Select appropriate resources relating to the sub-operation

INPUTS:
3.5 - 3.6 SUB-OPERATION RESOURCES DETAILS

OUTPUTS:
3.6 - D3.4 RESOURCE DETAILS

LOGIC SUMMARY:

INPUT APPROPRIATE PRODUCTIVITY ADJUSTMENT FACTOR
INPUT THE NUMBER OF RESOURCES REQUIRED
COMPUTE TIME PERIODS

PHYSICAL REF:

SHORT TERM/STAGE PLANNING
MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC
APPENDIX 3.2

PROCESS: PROCESS ADJUSTMENT FOR INSIGNIFICANT BILL ITEMS **REF:** 3.4

DESCRIPTION: Process additional hours adjustment representing insignificant bill items in hours per unit

INPUTS:
D1-3.4 PRODUCTION DATA
D2.1-3.4 BILL ITEMS AND PRODUCTION DATA DETAILS

OUTPUTS:
3.4-D3.3 ADJUSTMENT DETAILS

LOGIC SUMMARY:

OBTAIN TOTAL MEASURE FOR BRICKWORK AND BLOCKWORK AND CONCRETE ITEMS.
OBTAIN TOTAL HOURS FOR INSIGNIFICANT ITEMS FOR BRICKWORK AND BLOCKWORK AND CONCRETE.
COMPUTE FACTORS IN TERMS OF HOURS/m^2 AND HOURS/m^3

PHYSICAL REF:

SHORT TERM/STAGE PLANNING MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC APPENDIX 3.2

PROCESS: PROCESS RESOURCES **REF:** 3.5

DESCRIPTION: Compute the resources and corresponding time periods representing the sub-operation

INPUTS:
D1-3.5 PRODUCTION DATA
D3.2-3.5 SUB-OPERATIONS, BILL ITEMS AND QUANTITIES DETAILS
D3.3-3.5 ADJUSTMENT DETAILS

OUTPUTS:
3.5-D3.4, 3.6
SUB-OPERATIONS RESOURCES DETAILS

LOGIC SUMMARY:

PROCESS THE PRODUCTION DATA FOR EACH BILL ITEM ASSIGNED TO THE SUB-OPERATION.
SELECT RESOURCES AND OBTAIN CORRESPONDING TIME PERIODS.

PHYSICAL REF:

SHORT TERM/STAGE PLANNING MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC APPENDIX 3.2

PROCESS: PREPARE SUB-OPERATIONS REF: 3.1

DESCRIPTION: Select appropriate sub-operations representing a sub-division of the overall operations

INPUTS:
D2.3 - 3.1 OVERALL OPERATIONS DETAILS

OUTPUTS:
3.1 - D3.1 SUB-OPERATIONS DETAILS

LOGIC SUMMARY:

INPUT SUB-OPERATION NUMBER, WORK CLASSIFICATION, WORK CATEGORY AND OPERATION DESCRIPTION

PHYSICAL REF:

SHORT TERM/STAGE PLANNING MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC APPENDIX 3.2

PROCESS: SELECT SUB-OPERATIONS AND INPUT QUANTITIES REF: 3.3

DESCRIPTION: Select appropriate sub-operation and input quantities for relevant items representing the work

INPUTS:
D3.2 - 3.3 SUB-OPERATIONS QUANTITIES DETAILS

OUTPUTS:
3.3 - D3.2 - SUB-OPERATIONS QUANTITIES DETAILS

LOGIC SUMMARY:

SELECT APPROPRIATE SUB-OPERATIONS
INPUT QUANTITIES AGAINST BILL ITEMS REPRESENTING THE SUB-OPERATION

PHYSICAL REF:

SHORT TERM/STAGE PLANNING MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC APPENDIX 3.2

PROCESS: WORK TARGETS REF: 4

DESCRIPTION: Generate work target information relating to pre-measured work item

INPUTS:

D3.2-4 SUB-OPERATIONS, BILL ITEMS AND QUANTITIES DETAILS

D3.3-4 ADJUSTMENT DETAILS

OUTPUTS:

LOGIC SUMMARY:

SELECT RELEVANT ITEMS AND QUANTITIES FOR WORK TARGET AND GENERATE RELEVANT DETAILS OF RESOURCES AND TIME PERIODS.

PHYSICAL REF:

DETAILS OF LOGIC:

WORK TARGETS

DATA FLOWS

- Adjustment Details
- Production Data
- Sub-operation and Assigned Bill Items
- Sub-operation and Work Target Bill Items Details
- Sub-operations Details
- Sub-operation Number
- Work Target Bill Items Quantities Details
- Work Target Report
- Work Target Resources Details

DATA STORES

- Insignificant Items Adjustment
- Production Data File
- Sub-operations
- Sub-operations, Bill Items and Quantities
- Sub-operation Resources

PROCESSES

- Generate Work Target Item
- Prepare Work Target Report
- Select Sub-operation for Targetting
- Select Work Target Bill Items and Input Quantities

DATA FLOW: ADJUSTMENT DETAILS

SOURCE REF: D3.3 DESCRIPTION: INSIGNIFICANT ITEMS ADJUSTMENT

DEST'N REF: 4.3 DESCRIPTION: GENERATE WORK TARGET ITEM

EXPANDED DESCRIPTION: Factors used for computing additions for insignificant bill items

INCLUDED DATA STRUCTURES:
HOURS PER UNIT

OTHER INFORMATION:

DATA FLOW: PRODUCTION DATA

SOURCE REF: D1 DESCRIPTION: PRODUCTION DATA FILE

DEST'N REF: 4.3 DESCRIPTION: GENERATE WORK TARGET ITEM

EXPANDED DESCRIPTION: Labour productivity data for measured work items

INCLUDED DATA STRUCTURES:
{STANDARD ITEM DETAILS}
{INDIVIDUAL INPUT DATA}

OTHER INFORMATION:

DATA FLOW: SUB-OPERATION AND ASSIGNED BILL ITEMS

SOURCE REF: D3.2 DESCRIPTION: SUB-OPERATIONS BILL ITEMS AND QUANTITIES

DEST´N REF: 4.2 DESCRIPTION: SELECT WORK TARGET BILL ITEMS AND INPUT QUANTITIES

EXPANDED DESCRIPTION: The bill items assigned to the particular sub-operation

INCLUDED DATA STRUCTURES: * (1-)

SUB-OPERATION
PAGE NUMBER
BILL ITEM REFERENCE
CLASS CODE
CATEGORY CODE
BILL ITEM DETAILS
QUANTITY

OTHER INFORMATION:

DATA FLOW: SUB-OPERATION AND WORK TARGET BILL ITEMS DETAILS

SOURCE REF: D3.2 DESCRIPTION: SUB-OPERATION BILL ITEMS AND QUANTITIES

DEST´N REF: 4.4 DESCRIPTION: PREPARE WORK TARGET REPORT

EXPANDED DESCRIPTION: Work target bill items from sub-operation together with quantities and production data allowances

INCLUDED DATA STRUCTURES: *(1-)

SUB-OPERATION
PAGE NUMBER
BILL ITEM REFERENCE
CLASS CODE
CATEGORY CODE
BILL ITEM DETAILS
QUANTITY
UNIT
RESOURCE DETAILS

OTHER INFORMATION:

DATA FLOW: SUB-OPERATION DETAILS

SOURCE REF: D3.1 **DESCRIPTION:** SUB-OPERATIONS

DEST'N REF: 4.1 **DESCRIPTION:** SELECT SUB-OPERATION FOR TARGETTING

EXPANDED DESCRIPTION: Details of sub-operations relating to work classification, work category and description

INCLUDED DATA STRUCTURES: * (1-)

SUB-OPERATION NUMBER
WORK CLASSIFICATION CODE
WORK CATEGORY CODE
SUB-OPERATION DESCRIPTION

OTHER INFORMATION:

DATA FLOW: SUB-OPERATION NUMBER

SOURCE REF: 4.1 **DESCRIPTION:** SELECT SUB-OPERATION FOR TARGETTING

DEST'N REF: 4.2 **DESCRIPTION:** SELECT WORK TARGET BILL ITEMS AND INPUT QUANTITIES

EXPANDED DESCRIPTION: Number given to sub-operation description

INCLUDED DATA STRUCTURES:

SUB-OPERATION NUMBER

OTHER INFORMATION:

DATA FLOW: WORK TARGET BILL ITEMS QUANTITIES DETAILS

SOURCE REF: 4.2 **DESCRIPTION:** SELECT WORK TARGET BILL ITEMS AND INPUT QUANTITIES

DEST'N REF: D3.2, 4.3 **DESCRIPTION:** SUB-OPERATIONS BILL ITEMS AND QUANTITIES, GENERATE WORK TARGET ITEM

EXPANDED DESCRIPTION: Quantities of bill items representing the appropriate work target from the sub-operation

INCLUDED DATA STRUCTURES:
BILL ITEM QUANTITY * (1-)

OTHER INFORMATION:

DATA FLOW: WORK TARGET REPORT

SOURCE REF: 4.4 **DESCRIPTION:** PREPARE WORK TARGET REPORT

DEST'N REF: E3, E4 **DESCRIPTION:** SITE MANAGEMENT, SURVEYING MANAGEMENT

EXPANDED DESCRIPTION: Print-out of work target details, including provision for the recording of feedback data

INCLUDED DATA STRUCTURES:
SUB-OPERATION NUMBER
SUB-OPERATION DESCRIPTION
(PAGE NUMBER, BILL ITEM REFERENCE, CLASS CODE, CATEGORY CODE, BILL ITEM DETAILS, QUANTITY, UNIT, RESOURCE PRODUCTION HOURS, PRODUCTIVITY ADJUSTMENT FACTOR, ADJUSTED HOURS, BONUS PERCENTAGE, TARGET HOURS) * (1-)

OTHER INFORMATION:

DATA FLOW: WORK TARGET RESOURCES DETAILS

SOURCE REF: 4.3 **DESCRIPTION:** GENERATE WORK TARGET ITEM

DEST'N REF: D3.4 **DESCRIPTION:** SUB-OPERATION RESOURCES

EXPANDED DESCRIPTION: Details of resources and time periods relating to the work target

INCLUDED DATA STRUCTURES:

SUB-OPERATION NUMBER

{RESOURCE REFERENCE
{RESOURCE CODE } ~~* (1-)~~

RESOURCE PRODUCTION HOURS

PRODUCTIVITY ADJUSTMENT FACTOR

ADJUSTED HOURS

BONUS PERCENTAGE

TARGET HOURS

OTHER INFORMATION:

DATA STORE: INSIGNIFICANT ITEMS ADJUSTMENT **REF:** D3.3

DESCRIPTION: Adjustment in terms of additional hours representing insignificant bill items

DATA FLOWS IN:
3.4 - D3.3 ADJUSTMENT DETAILS

DATA FLOWS OUT:
D3.3 - 4.2 ADJUSTMENT DETAILS

CONTENTS:
HOURS PER m^2
HOURS PER m^3

IMMEDIATE ACCESS:

PHYSICAL ORGANISATION:

MEMORY VARIABLE

DATA STORE: PRODUCTION DATA FILE **REF:** D1

DESCRIPTION: Labour productivity data relating to measured work items

DATA FLOWS IN:
5 - D1 FEEDBACK DATA

DATA FLOWS OUT:
D1 - 4.3 PRODUCTION DATA

CONTENTS: *
STANDARD ITEM CODE
ITEM DETAILS
RESOURCE REFERENCE 1
RESOURCE CODE 1
RESOURCE HOURS 1
RESOURCE REFERENCE 2
RESOURCE CODE 2
RESOURCE HOURS 2

IMMEDIATE ACCESS:

SYSTEM MAINTENANCE

PHYSICAL ORGANISATION:

SEE APPENDIX 4

STDITEM.DBF

DATA STORE: SUB-OPERATIONS REF: D3.1

DESCRIPTION: Sub-Operations representing sub-division of the overall operations

DATA FLOWS IN:
3.1 - D3.1 SUB-OPERATIONS DETAILS

DATA FLOWS OUT:
D3.1 - 4.1 SUB-OPERATIONS DETAILS

CONTENTS: *
SUB-OPERATION NUMBER
WORK CLASSIFICATION
WORK CATEGORY
SUB-OPERATION DESCRIPTION

IMMEDIATE ACCESS:

SHORT TERM/STAGE PLANNING MODULE

PHYSICAL ORGANISATION:

SEE APPENDIX 4
SUBOPS. DBF

DATA STORE: SUB-OPERATIONS, BILL ITEMS AND QUANTITIES REF: D3.2

DESCRIPTION: Sub-operations and assigned bill items, quantities and corresponding production data allowances

DATA FLOWS IN:
4.2 - D3.2 WORK TARGET BILL ITEMS QUANTITIES DETAILS

DATA FLOWS OUT:
D3.2 - 4.2 SUB-OPERATION AND ASSIGNED BILL ITEMS
D3.2 - 4.4 SUB-OPERATION AND WORK TARGET BILL ITEMS DETAILS

CONTENTS: *
SUB-OPERATION NUMBER
PAGE NUMBER, ITEM REFERENCE
CLASS, CATEGORY, ITEM DETAIL
QUANTITY, UNIT
$\left\{\begin{array}{l}\text{STD. ITEM RESOURCE REFERENCE}\\ \text{RESOURCE REFERENCE}\end{array}\right\}$ *(1-4)
[RESOURCE CODE] *(1-4)
$\left\{\begin{array}{l}\text{MULTIPLIER}\\ \text{DIVISOR}\end{array}\right\}$ *(1-4)

IMMEDIATE ACCESS:

WORK TARGET MODULE

PHYSICAL ORGANISATION:

SEE APPENDIX 4

BISUBOPS. DBF

DATA STORE: SUB-OPERATIONS RESOURCES **REF:** D3.4

DESCRIPTION: Resource details and corresponding time periods relating to sub-operations

DATA FLOWS IN:

4.3 - D3.4 WORK TARGET RESOURCES DETAILS

DATA FLOWS OUT:

D3.4 - 4.4 WORK TARGET RESOURCES DETAILS

CONTENTS: *

SUB-OPERATION NUMBER
RESOURCE REFERENCE, RESOURCE CODE, RESOURCE HOURS, PRODUCTIVITY ADJUSTMENT FACTOR, RESOURCE NUMBER, ACTUAL HOURS, ACTUAL WEEKS, FACTORED HOURS, FACTORED WEEKS

IMMEDIATE ACCESS:

WORK TARGET MODULE

PHYSICAL ORGANISATION:

SEE APPENDIX 4

GSRES. DBF

PROCESS: GENERATE WORK TARGET ITEM **REF:** 4.3

DESCRIPTION: Establish the target time from the selected bill items and quantities

INPUTS:

4.2 - 4.3 WORK TARGET BILL ITEMS QUANTITIES DETAILS
D1 - 4.3 PRODUCTION DATA
D3.3 - 4.3 ADJUSTMENT DETAILS

OUTPUTS:

4.3 - D3.4 WORK TARGETS RESOURCES DETAILS

LOGIC SUMMARY:

PROCESS THE PRODUCTION DATA FOR EACH BILL ITEM ASSIGNED TO THE WORK TARGET TO OBTAIN THE TOTAL TIME

PHYSICAL REF:

WORK TARGET MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC
APPENDIX 3.2

PROCESS: PREPARE WORK TARGET REPORT **REF:** 4.4

DESCRIPTION: Prepare in report format the work target data, including the provision for the recording of feedback data

INPUTS:

D3.2 - 4.4 SUB-OPERATION AND WORK TARGET BILL ITEMS DETAILS
D3.4 - 4.4 WORK TARGET RESOURCES DETAILS

OUTPUTS:

4.4 - E3, E4 WORK TARGET REPORT

LOGIC SUMMARY:

PRINT RELEVANT ITEMS AND RESOURCE DETAILS REPRESENTING THE WORK TARGET

PHYSICAL REF:

WORK TARGET MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC
APPENDIX 3.2

PROCESS: SELECT SUB-OPERATION FOR TARGETTING **REF:** 4.1

DESCRIPTION: Decide on the relevant sub-operation for targetting purposes

INPUTS:
D3.1 - 4.1 SUB-OPERATION DETAILS

OUTPUTS:
4.1 - 4.2 SUB-OPERATION NUMBER

LOGIC SUMMARY:

DECIDE ON THE APPROPRIATE SUB-OPERATION AND SELECT THE CORRESPONDING SUB-OPERATION NUMBER

PHYSICAL REF:

WORK TARGET MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC
APPENDIX 3.2

PROCESS: SELECT WORK TARGET BILL ITEMS AND INPUT QUANTITIES **REF:** 4.2

DESCRIPTION: Select appropriate bill items from the sub-operation and input the required quantities representing the work

INPUTS:
4.1 - 4.2 SUB-OPERATION NUMBER
D3.2 - 4.2 SUB-OPERATION AND ASSIGNED BILL ITEMS

OUTPUTS:
4.2 - D3.2, 4.3 WORK TARGET BILL ITEMS QUANTITIES DETAILS

LOGIC SUMMARY:

INPUT QUANTITIES AGAINST BILL ITEMS REPRESENTING THE WORK TARGET

PHYSICAL REF:

WORK TARGET MODULE

DETAILS OF LOGIC:

SEE PROCESS LOGIC
APPENDIX 3.2

<u>Input Bill Items and Production Data Details</u> (Ref. 1.3)

1. Enter bill items and production data details.

    1.1 Access the bill item and production data file.

    1.2 Enter details of bill items.

        1.2.1 Enter bill page number.

        1.2.2 Enter item reference.

        1.2.3 Enter classification code.

        1.2.4 Enter category code.

        1.2.5 Enter item description.

        1.2.6 Enter item quantity.

        1.2.7 Enter item unit.

2. Enter production data.

    2.1 Access production data file.

    2.2 If item relates to a data base item, enter data base item code.

    2.4 If item does not relate to a data base item:

        2.4.1 Enter resource reference;

        2.4.2 Enter resource code;

        2.4.3 Enter resource hours.

Assign Bill Items and Quantities to Operations (Ref. 2.1)

1. Check each bill item with each operation.

    1.1 Access the overall operations file.

    1.2 Access the bill items and production data file.

    1.3 Using the class code as the key, check each bill item with each operation.

2. Combine the overall operations details with the bill items details.

    2.1 If the class code is the same in each case combine the data from both files.

    2.2 Store the data to a combined data file.

Input Resources Requirements (Ref. 2.4)

1. Select appropriate resources relating to the overall operation.

    1.1 Access the overall operation resources file.

    1.2 Input the productivity adjustment factor relating to the operation and building type.

    1.3 Input the resource requirements representing the gang size for the trade.

2. Multiply the resource hours by the productivity adjustment factor.

3. Divide the adjusted resource hours by the resource number.

4. Calculate the resource requirements time periods.

    4.1 Calculate resource hours.

    4.2 Calculate resource weeks.

    4.3 Calculate adjusted resource hours.

    4.4 Calculate adjusted resource weeks.

Prepare Overall Operations (Ref. 2.2)

1. Obtain tender documents.

   1.1 Inspect tender drawings.

   1.2 Inspect bills of quantities.

   1.3 Inspect specification.

2. Using the tender documents determine the major operations of the project.

3. Enter operations in approximate work order.

   3.1 Enter operation number.

   3.2 Enter operation classification code.

   3.3 Enter operation description.

Process Resources (Ref. 2.3)

1. Process the production data for each item assigned to the overall operation.

   1.1 Access operation, bill items and quantities file.

   1.2 Access production data file.

   1.3 Access overall operations resources file.

2. Check production data for each bill item.

   2.1 If the resource reference is a standard item code:

      2.1.1 obtain the resource details from the production data file;

      2.1.2 multiply the resource hours by the bill item quantity and store in the overall operations file along with the corresponding resource references and resource codes.

   2.2 If the resource reference is not a standard item code:

      2.2.1 apply the multiplication and division factors to the bill item quantity to obtain the time period and store in the overall operations file along with the corresponding resource references and resource codes;

2.3 Display the resource details for the overall operation.

<u>Assign Bill Items to Sub-operations</u> (Ref. 3.2)

1. Check each bill item with each sub-operation.

    1.1 Access the sub-operations file.

    1.2 Access the bill items and production data file.

    1.3 Using the class code and category code as the keys, check each bill item with each sub-operation.

2. Combine the sub-operations details with the bill items details.

    2.1 If the class code and the category code are the same in each case combine the data from both files.

    2.2 Store the data to the sub-operations, bill items and quantities data file.

<u>Input Resource Requirements</u> (Ref. 3.6)

1. Select appropriate resources relating to the sub-operation.

    1.1 Access the sub-operation resources file.

    1.2 Input the productivity adjustment factor relating to the sub-operation and building type.

    1.3 Input the resource requirements representing the gang size for the trade.

2. Multiply the resource hours by the productivity adjustment factor.

3. Divide the adjusted resource hours by the resource number.

4. Calculate the resource requirements time periods.

    4.1 Calculate resource hours.

    4.2 Calculate resource weeks.

    4.3 Calculate adjusted resource hours.

    4.4 Calculate adjusted resource weeks.

Process Adjustments for Insignificant Items (Ref. 3.4)

1. Obtain the insignificant items adjustment for concrete work, and brickwork and blockwork.

    1.1 Access bill items and production data file.

    1.2 Check the item classification code and the unit.

        1.2.1 If the item classification relates to concrete work and the unit is m3, store the quantity value.

        1.2.2 If the item classification relates to concrete work and the unit is not m3, calculate and store the resource hours for the bill item.

        1.2.3 Calculate the adjustment figure for concrete work.

            1.2.3.1 Access the total m3 for all bill items.

            1.2.3.2 Access the total hours for insignificant items in concrete work.

            1.2.3.3 Divide the total hours by the total m3 and store the hours/m3 value.

        1.2.4 If the item classification relates to brickwork and blockwork and the unit is m2, store the quantity value.

        1.2.5 If the item classification relates to brickwork and blockwork and the unit is not m2, calculate and store the resource hours for the bill item.

        1.2.6 Calculate the adjustment figure for brickwork and blockwork.

            1.2.6.1 Access the total m2 for all bill items.

            1.2.6.2 Access the total hours for insignificant items in concrete work.

1.2.6.3 Divide the total hours by the total m2 and store the hours/m2 value.

Process Resources (Ref. 3.5)

1. Process the production data for each item assigned to the sub-operation.

   1.1 Access sub-operation, bill items and quantities file.

   1.2 Access production data file.

   1.3 Access sub-operations resources file.

2. Check production data for each bill item.

   2.1 If the resource reference is a standard item code:

      2.1.1 obtain the resource details from the production data file;

      2.1.2 multiply the resource hours by the bill item quantity and store in the sub-operations file along with the corresponding resource references and resource codes.

   2.2 If the resource reference is not a standard item code, apply the multiplication and division factors to the bill item quantity to obtain the time period and store in the sub-operations file along with the corresponding resource references and resource codes.

   2.3 Add adjustment for insignificant bill items.

      2.3.1 If the sub-operation is concrete work:

         2.3.1.1 Access the hours/m3 figure and multiply by the m3 figure for the sub-operation.

         2.3.1.2 Divide the total by the number of resources used in the operation.

         2.3.1.3 Add the calculated figure to each of the total resource hours.

2.3.2 If the sub-operation is brickwork or blockwork:

2.3.2.1 Access the hours/m2 figure and multiply by the m2 figure for the sub-operation.

2.3.2.2 Divide the total by the number of resources used in the operation.

2.3.3.3 Add the calculated figure to each of the total resource hours.

2.4 Display the resource details for the sub-operation.

<u>Prepare Sub-operations</u> (Ref. 3.1)

1. Access the overall operations file.

2. Select appropriate sub-operations from the sub-division of the overall operations.

3. Enter sub-operations in approximate work order.

   3.1 Enter sub-operation number.

   3.2 Enter sub-operation classification code.

   3.3 Enter sub-operation category code.

   3.4 Enter sub-operation description.

<u>Select Sub-operations and Input Quantities</u> (Ref. 3.3)

1. Access the sub-operations file.

2. Access the sub-operations, bill items and quantities file.

3. Select the appropriate operation and assigned bill items.

4. Enter quantities against the relevant items representing the sub-operation.

5. Store the sub-operation and the quantities details.

Generate Work Target Item (Ref. 4.3)

1. Process the production data for each item assigned to the sub-operation.

    1.1 Access sub-operation, bill items and quantities file.

    1.2 Access production data file.

    1.3 Access sub-operations resources file.

2. Check production data for each bill item.

    2.1 If the resource reference is a standard item code:

        2.1.1 obtain the resource details from the production data file;

        2.1.2 multiply the resource hours by the bill item quantity and store in the sub-operations file along with the corresponding resource references and resource codes.

    2.2 If the resource reference is not a standard item code, apply the multiplication and division factors to the bill item quantity to obtain the time period and store in the sub-operations file along with the corresponding resource references and resource codes.

    2.3 Add adjustment for insignificant bill items.

        2.3.1 If the sub-operation is concrete work:

            2.3.1.1 Access the hours/m3 figure and multiply by the m3 figure for the sub-operation.

            2.3.1.2 Divide the total by the number of resources used in the operation.

            2.3.1.3 Add the calculated figure to each of the total resource hours.

        2.3.2 If the sub-operation is brickwork or blockwork:

2.3.2.1 Access the hours/m2 figure and multiply by the m2 figure for the sub-operation.

2.3.2.2 Divide the total by the number of resources used in the operation.

2.3.3.3 Add the calculated figure to each of the total resource hours.

2.4 Display the resource details for the sub-operation.

3. Enter the productivity adjustment factor

4. Calculate the adjusted production data hours.

5. Enter the bonus increment percentage.

6. Calculate the target hours.

<u>Prepare Work Target Report</u> (Ref. 4.4)

1. Access the sub-operations, bill items and quantities file.

2. Access the sub-operations resources file.

3. Enter the sub-operation relating to the work target.

4. Print work target data in report format.

   4.1 Print sub-operation number and description.

   4.2 Print relevant bill items details and quantities.

   4.3 Print report format headings.

   4.4 Print work target resources details.

   4.5 Print productivity adjustment factor.

   4.6 Print adjusted production hours.

   4.7 Print bonus percentage.

   4.8 Print target hours.

Select Sub-operation for targetting (Ref. 4.1)

1. Access the sub-operation file.

2. Select the appropriate sub-operation relating to the work target.

Select Work Target Bill Items and Input Quantities (Ref. 4.2

1. Access the sub-operations, bill items and quantities file.

2. Select the appropriate sub-operation and assigned bill items relating to the work target.

3. Enter quantities against the relevant items representing the work target.

4. Store the sub-operation and the work target quantities details.

PLANNING SYSTEM FILES

Data Base Files	Index Files
OPERATNS.DBF	OPNOIND.NDX
ITEMEST.DBF	ITEMIND.NDX
OALLOPS.DBF	OALLOIND.NDX
GORES.DBF	GORESIND.NDX
STDITEM.DBF	SITMIND.NDX
SUBOPS.DBF	SOPNOIND.NDX
BISUBOPS.DBF	BSBOPIND.NDX
GSRES.DBF	GSRESIND.NDX

OVERALL OPERATIONS DATA BASE (OPERATNS.DBF)

Field Name	Field Type	Field Description	Field Width	Decimal Places
NO	Numeric	Operation Number	003	0
CLASS	Character	Work Classification	006	-
OPERATION	Character	Operation Description	030	-

BILL ITEMS AND ESTIMATE DETAILS DATA BASE (ITEMEST.DBF)

Field Name	Field Type	Field Description	Field Width	Decimal Places
PAGE	Numeric	BQ Page Number	004	0
REF	Character	BQ Item Reference	001	-
CLASS	Character	Work Classification	006	-
CAT	Character	Work Category	006	-
ITEMDETAIL	Character	BQ Item Description	030	-
QUANT	Numeric	Bill Item Quantity	008	002
UNIT	Character	Unit of Measure	002	-
REF1	Numeric	Resource Reference 1	004	-
RES1	Character	Resource Code	005	-

MUL1	Numeric	Multiplication Field 1	006	002
DIV1	Numeric	Division Field 1	006	002
REF2	Numeric	Resource Reference 2	004	0
RES2	Character	Resource Code	005	-
MUL2	Numeric	Multiplication Field 2	006	002
DIV2	Numeric	Division Field 2	006	002
REF3	Numeric	Resource Reference 3	004	0
RES3	Character	Resource Code	005	-
MUL3	Numeric	Multiplication Field 3	006	002
DIV3	Numeric	Division Field 3	006	002
REF4	Numeric	Resource Reference 4	004	0
RES4	Character	Resource Code	005	-
MUL4	Numeric	Multiplication Field 4	006	002
DIV4	Numeric	Division Field 4	006	002

OVERALL OPERATIONS AND BILL ITEMS DATA BASE (OALLOPS.DBF)

Field Name	Field Type	Field Description	Field Width	Decimal Places
NO	Numeric	Operation Number	003	0
CLASS	Character	Work Classification	006	-
OPERATION	Character	Operation Description	030	-
PAGE	Numeric	BQ Page Number	004	0
REF	Character	BQ Item Reference	001	-
CLASS	Character	Work Classification	006	-
CAT	Character	Work Category	006	-
ITEMDETAIL	Character	BQ Item Description	030	-
QUANT	Numeric	Bill Item Quantity	008	002
UNIT	Character	Unit of Measure	002	-
REF1	Numeric	Resource Reference 1	004	-
RES1	Character	Resource Code	005	-
MUL1	Numeric	Multiplication Field 1	006	002
DIV1	Numeric	Division Field 1	006	002
REF2	Numeric	Resource Reference 2	004	-
RES2	Character	Resource Code	005	-

MUL2	Numeric	Multiplication Field 2	006	002
DIV2	Numeric	Division Field 2	006	002
REF3	Numeric	Resource Reference 3	004	0
RES3	Character	Resource Code	005	-
MUL3	Numeric	Multiplication Field 3	006	002
DIV3	Numeric	Division Field 3	006	002
REF4	Numeric	Resource Reference 4	004	0
RES4	Character	Resource Code	005	-
MUL4	Numeric	Multiplication Field 4	006	002
DIV4	Numeric	Division Field 4	006	002

OVERALL OPERATIONS RESOURCES DATA BASE (GORES.DBF)

Field Name	Field Type	Field Description	Field Width	Decimal Places
OPNO	Numeric	Operation Number	003	0
REFGEN	Numeric	Resource Reference	004	0
RES	Character	Resource Code	005	-
HOURS	Numeric	Resource Hours	008	002

ADJF	Numeric	Adjustment Factor	012	002
RESNO	Numeric	Resource Number	012	0
ACTHRS	Numeric	Actual Hours	012	002
ACTWKS	Numeric	Actual Weeks	012	001
FHRS	Numeric	Factored Hours	012	002
FWKS	Numeric	Factored Weeks	012	001

STANDARD ITEM DATA BASE (STDITEM.DBF)

Field Name	Field Type	Field Description	Field Width	Decimal Places
CODE	Numeric	Standard Item Code	004	0
ITEMDETAIL	Character	Standard Item Details	030	-
REF1	Numeric	Resource Reference 1	004	0
RES1	Character	Resource Code 1	005	-
HOURS1	Numeric	Resource 1 Hours	005	002
REF2	Numeric	Resource Reference 2	004	0
RES2	Character	Resource Code 2	005	-
HOURS2	Numeric	Resource 2 Hours	005	002

SUB-OPERATIONS DATA BASE (SUBOPS.DBF)

Field Name	Field Type	Field Description	Field Width	Decimal Places
SUBOPNO	Numeric	Sub-operation Number	003	0
CLASS	Character	Work Classification	006	-
CAT	Character	Work Category	006	-
SUBOP	Character	Sub-operation Description	030	-

SUB-OPERATIONS AND BILL ITEMS DATA BASE (BISUBOPS.DBF)

Field Name	Field Type	Field Description	Field Width	Decimal Places
SUBOPNO	Numeric	Sub-operation Number	003	0
CLASS	Character	Work Classification	006	-
CAT	Character	Work Category	006	-
SUBOP	Character	Sub-operation Description	030	-
PAGE	Numeric	BQ Page Number	004	0
REF	Character	BQ Item Reference	001	-
CLASS	Character	Work Classification	006	-
CAT	Character	Work Category	006	-
ITEMDETAIL	Character	BQ Item Description	030	-

QUANT	Numeric	Bill Item Quantity	008	002
UNIT	Character	Unit of Measure	002	-
REF1	Numeric	Resource Reference 1	004	0
RES1	Character	Resource Code	005	-
MUL1	Numeric	Multiplication Field 1	006	002
DIV1	Numeric	Division Field 1	006	002
REF2	Numeric	Resource Reference 2	004	0
RES2	Character	Resource Code	005	-
MUL2	Numeric	Multiplication Field 2	006	002
DIV2	Numeric	Division Field 2	006	002
REF3	Numeric	Resource Reference 3	004	0
RES3	Character	Resource Code	005	-
MUL3	Numeric	Multiplication Field 3	006	002
DIV3	Numeric	Division Field 3	006	002
REF4	Numeric	Resource Reference 4	004	0
RES4	Character	Resource Code	005	-
MUL4	Numeric	Multiplication Field 4	006	002
DIV4	Numeric	Division Field 4	006	002

SUB-OPERATIONS RESOURCES DATA BASE (GSRES.DBF)

Field Name	Field Type	Field Description	Field Width	Decimal Places
SUBOPNO	Numeric	Sub-operation Number	003	0
REFGEN	Numeric	Resource Reference	004	0
RES	Character	Resource Code	005	-
HOURS	Numeric	Resource Hours	008	002
ADJF	Numeric	Adjustment Factor	012	002
RESNO	Numeric	Resource Number	012	0
ACTHRS	Numeric	Actual Hours	012	002
ACTWKS	Numeric	Actual Weeks	012	001
FHRS	Numeric	Factored Hours	012	002
FWKS	Numeric	Factored Weeks	012	001
PRODADJ	Numeric	Production Data Adjustment	012	002
PRODBONUS	Numeric	Production Bonus	012	0

PLANNING SYSTEM PROGRAMS

PAC.PRG
MMENU.PRG
IEMENU.PRG
OAMENU.PRG
OPSMENU.PRG
AITMMENU.PRG
GOAOMENU.PRG
STMENU.PRG
SBMENU.PRG
ASSBMENU.PRG
GSTOMENU.PRG
WTMENU.PRG
SMMENU.PRG
IPITMEST.PRG
LISTITM.PRG
ITMESTA.PRG
DELITEM.PRG
PRINTIE.PRG
PREPOPS.PRG
LISTOPS.PRG
AMNDOPS.PRG
DELOPS.PRG
PRINTOPS.PRG
ASBIQNTS.PRG
LISTOPIT.PRG
PRINTOAO.PRG

GENOARES.PRG
AOAOPSR.PRG
LOAOPSR.PRG
POAOPSR.PRG
SELSBOPS.PRG
LSTSBOPS.PRG
AMDSBOPS.PRG
DELSBOPS.PRG
PRTSBOPS.PRG
ASBISBOP.PRG
SSBOPIT.PRG
AMSBOPIT.PRG
PSBOPIT.PRG
GENSBRES.PRG
AMSBOPSR.PRG
LSBOPSR.PRG
PSBOPSR.PRG
STARGITM.PRG
ATARGITM.PRG
GTARGITM.PRG
PTARGITM.PRG
ADSITM.PRG
AMSITM.PRG
DELSITM.PRG
LSITM.PRG
PSITM.PRG

LIST OF STANDARD ITEMS

CODE	ITEM DETAILS		REF	RES	HOURS	REF	RES	HOURS
2805	conc. foundations (d)	m3	661	GLAB	0.24	0		0.00
2810	conc. foundations (h)	m3	661	GLAB	0.76	0		0.00
2815	conc. bases (d)	m3	661	GLAB	0.38	0		0.00
2820	conc. bases (h)	m3	661	GLAB	0.88	0		0.00
2825	conc. grnd beams (h)	m3	661	GLAB	0.77	0		0.00
2830	conc. flr. slabs 100th (h)	m3	661	GLAB	0.90	0		0.00
2835	conc. flr. slabs 150th (d)	m3	661	GLAB	0.29	0		0.00
2840	conc. flr. slabs 150th (h)	m3	661	GLAB	0.75	0		0.00
2845	conc. flr. slabs 200th (d)	m3	661	GLAB	0.26	0		0.00
2850	conc. flr. slabs 200th (h)	m3	661	GLAB	0.66	0		0.00
2855	conc. susp. slabs 150th (h)	m3	661	GLAB	2.25	0		0.00
2860	conc. susp. slabs 150th (c)	m3	661	GLAB	0.53	0		0.00
2865	conc. stairs (h)	m3	661	GLAB	6.00	0		0.00
2870	conc. stairs (c)	m3	661	GLAB	1.67	0		0.00
2875	conc. landings (h)	m3	661	GLAB	5.63	0		0.00
2880	conc. landings (c)	m3	661	GLAB	1.34	0		0.00
2885	conc. columns (h)	m3	661	GLAB	4.50	0		0.00
2890	conc. columns (c)	m3	661	GLAB	1.75	0		0.00
2895	conc. stub columns (h)	m3	661	GLAB	4.50	0		0.00
2900	conc. col. enclosure (h)	m3	661	GLAB	6.00	0		0.00
2905	conc. upstands (h)	m3	661	GLAB	1.20	0		0.00
2910	conc. plinths (h)	m3	661	GLAB	0.84	0		0.00
2915	conc. padstones (h)	m3	661	GLAB	1.10	0		0.00
2920	conc. beams (h)	m3	661	GLAB	2.30	0		0.00
2925	conc. beams (c)	m3	661	GLAB	0.78	0		0.00
2930	conc. beam enclosure (h)	m3	661	GLAB	4.38	0		0.00
2935	conc. cavity fill (h)	m3	661	GLAB	2.33	0		0.00
2940	visqueen/poly dpm	m2	661	GLAB	0.02	0		0.00
2950	mesh reinf.	m2	661	GLAB	0.04	0		0.00
2955	steel trowel finish	m2	661	GLAB	0.07	0		0.00
2960	wood float finish	m2	661	GLAB	0.06	0		0.00
2965	bit. sheet flr cover	m2	661	GLAB	0.07	0		0.00
2970	exp. poly edge board 25th	m2	661	GLAB	0.03	0		0.00
2975	exp. poly board - slab	m2	661	GLAB	0.02	0		0.00
2980	power float	m2	661	GLAB	0.14	0		0.00
2985	flexcell exp. jnt.	m	661	GLAB	0.03	0		0.00
2990	bit. sheet turned up wall	m	661	GLAB	0.15	0		0.00

LIST OF STANDARD ITEMS

CODE	ITEM DETAILS		REF	RES	HOURS	REF	RES	HOURS
6800	hb wall, commons	m2	602	BL	0.67	663	BLLAB	0.33
6805	1b wall, commons	m2	602	BL	1.17	663	BLLAB	0.59
6810	1.5b wall, commons	m2	602	BL	1.46	663	BLLAB	0.73
6815	hb wall, facings	m2	602	BL	0.95	663	BLLAB	0.48
6820	1b wall, facings	m2	602	BL	2.52	663	BLLAB	1.26
6825	1.5b wall, facings	m2	602	BL	2.93	663	BLLAB	1.47
6830	hb wall, engineering	m2	602	BL	0.78	663	BLLAB	0.39
6835	1b wall, engineering	m2	602	BL	0.95	663	BLLAB	0.48
6840	1.5b wall, engineering	m2	602	BL	1.25	663	BLLAB	0.63
6845	100th blocks	m2	602	BL	0.47	663	BLLAB	0.24
6850	100th blocks, P2S	m2	602	BL	0.49	663	BLLAB	0.24
6855	140th blocks	m2	602	BL	0.57	663	BLLAB	0.29
6860	140th blocks, P2S	m2	602	BL	0.65	663	BLLAB	0.33
6865	190th blocks	m2	602	BL	0.57	663	BLLAB	0.29
6870	190th blocks, P2S	m2	602	BL	0.77	663	BLLAB	0.39
6875	cavity insulation	m2	602	BL	0.07	663	BLLAB	0.03
6880	DPC cavity tray	m2	602	BL	0.21	663	BLLAB	0.11
6890	boe facings	m	602	BL	0.38	663	BLLAB	0.20
6895	close cavity with bwk	m	602	BL	0.13	663	BLLAB	0.07
6900	lintels 1200-2400m	m	602	BL	0.20	663	BLLAB	0.10
6910	vertical joints in bwk	m	602	BL	0.10	663	BLLAB	0.05
6915	sill blocks	m	602	BL	0.45	663	BLLAB	0.23
6920	raking cutting bwk	m	602	BL	0.12	663	BLLAB	0.06
6925	cutting blocks	m	602	BL	0.13	663	BLLAB	0.06
6930	hb proj. bands 300 wide	m	602	BL	0.29	663	BLLAB	0.14
6935	hb proj. boe	m	602	BL	0.52	663	BLLAB	0.26
6940	close cavity wi. asb. slate	m	602	BL	0.04	663	BLLAB	0.02
6945	bed plate & frame in mortar	m	602	BL	0.02	663	BLLAB	0.01
6950	rake out jnts for flashing	m	602	BL	0.03	663	BLLAB	0.01
6955	cut back lintel	m	602	BL	0.27	663	BLLAB	0.14
6960	bituthene layer	m	602	BL	0.18	663	BLLAB	0.09
6965	cut out and tooth	m	602	BL	0.40	663	BLLAB	0.20
6970	fix anchors	nr	602	BL	0.08	663	BLLAB	0.04
6975	cut bricks	nr	602	BL	0.03	663	BLLAB	0.02
6980	clearing slots	nr	602	BL	0.04	663	BLLAB	0.02
6985	shot fixings to steel	nr	602	BL	0.04	663	BLLAB	0.02

LIST OF STANDARD ITEMS

CODE	ITEM DETAILS		REF	RES	HOURS	REF	RES	HOURS
8640	12.5 ply fascia	m2	601	CJ	0.17	0		0.00
8645	chipboard	m2	601	CJ	0.36	0		0.00
8650	12.5 ply soffit	m2	601	CJ	0.35	0		0.00
8655	t+g floor boarding	m2	601	CJ	0.25	0		0.00
8660	50x50 sw framing	m	601	CJ	0.07	0		0.00
8665	50x50 sw framing p+s	m	601	CJ	0.12	0		0.00
8670	50x75 sw framing	m	601	CJ	0.10	0		0.00
8675	63x132 sw door linings	m	601	CJ	0.20	0		0.00
8680	sw door frames p+s	m	601	CJ	0.42	0		0.00
8685	sw door frames built in	m	601	CJ	0.17	0		0.00
8695	900x1200 sw window frame	m	601	CJ	0.42	0		0.00
8700	1200x1500 sw window frame	m	601	CJ	0.54	0		0.00
8705	50x50 noggings	m	601	CJ	0.11	0		0.00
8710	shaddow battens	m	601	CJ	0.20	0		0.00
8715	grounds, nailed	m	601	CJ	0.11	0		0.00
8720	grounds, plugged	m	601	CJ	0.12	0		0.00
8730	50x50 sw bearers	m	601	CJ	0.12	0		0.00
8735	25x100 sw bearers	m	601	CJ	0.16	0		0.00
8740	38x100 sw bearers	m	601	CJ	0.16	0		0.00
8745	50x150 sw bearers	m	601	CJ	0.21	0		0.00
8750	50x200 sw bearers	m	601	CJ	0.31	0		0.00
8755	25X38 head plate	m	601	CJ	0.08	0		0.00
8760	25X38 sole plate	m	601	CJ	0.07	0		0.00
8765	25x50 base plate	m	601	CJ	0.10	0		0.00
8770	door batten	m	601	CJ	0.07	0		0.00
8775	vee jntd. boards 100 wide	m	601	CJ	0.44	0		0.00

LIST OF STANDARD ITEMS

CODE	ITEM DETAILS		REF	RES	HOURS	REF	RES	HOURS
8805	angle fillet	m	601	CJ	0.06	0		0.00
8810	19x50 sw architraves	m	601	CJ	0.08	0		0.00
8815	19x100 sw architraves	m	601	CJ	0.21	0		0.00
8820	14x70 sw skirtings	m	601	CJ	0.07	0		0.00
8825	14x70 sw skirtings p+s	m	601	CJ	0.12	0		0.00
8830	19x100 sw skirtings	m	601	CJ	0.20	0		0.00
8835	window board	m	601	CJ	0.34	0		0.00
8845	handrail	m	601	CJ	0.54	0		0.00
8850	quadrant bead	m	601	CJ	0.05	0		0.00
8855	hat+coat rail, plugged	m	601	CJ	0.12	0		0.00
8860	curtain rail	m	601	CJ	0.07	0		0.00
8865	slatted shelving	m	601	CJ	0.22	0		0.00
8870	blockboard shelving	m	601	CJ	0.17	0		0.00
8875	capping to balustrade	m	601	CJ	0.05	0		0.00
8880	hw handrail	m	601	CJ	0.20	0		0.00
8885	doors, single	nr	601	CJ	0.99	0		0.00
8890	doors, double	nr	601	CJ	2.12	0		0.00
8895	doors, panelled	nr	601	CJ	0.67	0		0.00
8900	doors, int. flush	nr	601	CJ	0.51	0		0.00
8905	hw door	nr	601	CJ	1.84	0		0.00
8910	int/ext door sets, single	nr	601	CJ	1.26	0		0.00
8915	int/ext door sets, double	nr	601	CJ	1.80	0		0.00
8920	bath panel	nr	601	CJ	0.60	0		0.00
8925	sink base unit	nr	601	CJ	0.34	0		0.00
8930	cupbd/drainer unit	nr	601	CJ	0.34	0		0.00
8935	wall unit	nr	601	CJ	0.50	0		0.00
8940	worktop 600x1000	nr	601	CJ	0.34	0		0.00
8945	worktop, L shaped	nr	601	CJ	0.40	0		0.00
8950	flush bolts	nr	601	CJ	0.76	0		0.00
8955	transome bolts	nr	601	CJ	0.34	0		0.00
8960	100mm butt hinges	nr	601	CJ	0.53	0		0.00
8965	pull handles	nr	601	CJ	0.13	0		0.00
8970	door closer	nr	601	CJ	1.06	0		0.00
8975	door stop	nr	601	CJ	0.23	0		0.00
8980	escutcheon	nr	601	CJ	0.13	0		0.00
8985	limiting stay	nr	601	CJ	0.31	0		0.00
8990	panic bolt	nr	601	CJ	1.75	0		0.00
8995	mortice lock	nr	601	CJ	0.40	0		0.00
9000	kicking plates	nr	601	CJ	0.28	0		0.00
9005	door holder	nr	601	CJ	0.23	0		0.00
9010	metal stop	nr	601	CJ	0.93	0		0.00
9015	push plates	nr	601	CJ	0.11	0		0.00
9020	auto alarm	nr	601	CJ	0.35	0		0.00
9025	cabin hooks	nr	601	CJ	0.35	0		0.00
9030	door selector	nr	601	CJ	0.70	0		0.00
9035	indicator bolt	nr	601	CJ	0.42	0		0.00
9040	lever handle	nr	601	CJ	0.13	0		0.00
9045	norfolk latch	nr	601	CJ	0.30	0		0.00
9050	backing plate	nr	601	CJ	0.08	0		0.00
9055	night latch	nr	601	CJ	0.58	0		0.00
9060	dead lock	nr	601	CJ	0.66	0		0.00
9065	brass ball catch	nr	601	CJ	0.27	0		0.00
9070	number plate	nr	601	CJ	0.10	0		0.00
9075	letter plate	nr	601	CJ	0.32	0		0.00
9080	hat+coat hooks	nr	601	CJ	0.06	0		0.00
9085	magnetic catch	nr	601	CJ	0.08	0		0.00
9090	barrel bolt	nr	601	CJ	0.14	0		0.00
9095	handrail brackets	nr	601	CJ	0.15	0		0.00
9100	chubb window lock	nr	601	CJ	0.20	0		0.00
9105	door sign	nr	601	CJ	0.07	0		0.00