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HOUSE BUILDING PRODUCTIVITY : A Study of labour requirements on Scottish house building sites using activity sampling methods

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SUMMARY

This study is concerned with labour productivity in traditional house building in Scotland. Productivity is a measure of the effective use of resources and provides vital benefits that can be combined in a number of ways.

The introduction gives the background to two Scottish house building sites (Blantyre and Greenfield) that were surveyed by the Building Research Establishment (BRE) activity sampling method to provide the data for the study. The study had two main objectives : (1) summary data analysis in average manhours per house between all the houses on the site, and (2) detailed data analysis in average manhours for each house block on the site. The introduction also provides a literature review related to the objectives.

The method is outlined in Chapter 2, the sites are discussed in Chapter 3, and Chapter 4 covers the method application on each site and a method development made in the study.

The summary data analysis (Chapter 5) compares Blantyre and Greenfield, and two previous BRE surveys in England. The main detailed data analysis consisted of three forms, (Chapters 6, 7 and 8) each applied to a set of operations. The three forms of analysis were variations in average manhours per house for each house block on the site compared with : (1) block construction order, (2) average number of separate visits per house made by operatives to each block to complete an operation, and (3) average number of different operatives per house employed on an operation in each block. Three miscellaneous items of detail data analysis are discussed in Chapter 9.

The conclusions to the whole study state that considerable variations in manhours for repeated operations were discovered, that the numbers of visits by operatives to complete operations were large and that the numbers of different operatives employed in some operations were a factor related to productivity.

A critique of the activity sampling method suggests that the data produced is reliable in summary form and can give a good context for more detailed data collection. For future work, this could take the form of selected operations, with the context of an activity sampling survey, that would be intensively surveyed by other methods.

Key words:

PRODUCTIVITY HOUSE BUILDING ACTIVITY SAMPLING
LABOUR REQUIREMENTS BUILDING OPERATIONS

PREFACE

> Productivity is concerned with the effective use of resources.
>
> Productivity is an abstract concept, and is essentially in output/input relationship, analogous to the efficiency of an engine. Just as in an engine one may measure the constituent factors affecting overall output, such as thermal efficiency or mechanical efficiency, so with industry one may measure the productivity of the constituent resources used to create wealth, namely land, capital, and labour. (R R Gilchrist, 1970)

This study is concerned with the effective use of labour resources in the creation of houses measured in relation to work on building sites. The standard industrial measure of productivity in the study will be the number of manhours required for a given output e.g. the plumber work in a 5-person house.

This application of labour productivity is to a particular product, namely, Scottish house building using traditional methods. As with most traditional house building the Scottish methods have a significant labour content involving a large amount of work taking place on the building site.[A] Research into labour requirements on the site is therefore of first importance if the productivity of traditional house building is to be improved.

Improving productivity in traditional house building can have many beneficial effects, appropriate even in recessive economic conditions. When related to house building these benefits could produce any of

---

[A] An average of 743 and 321 manhours per house on the Blantyre house building site surveyed in this study, for the house construction and external works, respectively.

the following alternative policies:

1

The current low monetary investment in house building could achieve more houses if productivity were improved to lower the cost per unit.

2

Employing the same monetary investment, better quality building materials could be afforded with improved labour productivity, which would reduce house maintenance costs.

3

Improved productivity could be used to increase pay or decrease working hours for the same pay, while holding costs constant.

Improved productivity can only be gained by careful, and continuous analysis. The research programme in which this study is based, is a contribution to such analysis. This programme was begun in 1970 by the Scottish Development Department (SDD). The SDD, as the central government department in Scotland with overall responsibility for physical development, has an overall public interest to control house costs, while at the same time maintaining and improving housing standards.

> In the ideal world, management, unions, and employees would all play their part in the drive for labour productivity. Without increases in labour productivity there can be no appreciable increase in the standard of living (or more leisure for the same standard of living) or a combination of both.
>
> Since it is not an ideal world, management, who alone must decide on the steps which must be taken to improve the use of resources, has an inescapable duty to the nation, ... and to the employees to ensure that the most efficient use is being made of the factors of production. Without suitable measurement of performance such a duty cannot be fulfilled. (R R Gilchrist, 1970)

One aim of the SDD research programme was to control and, if possible,

lower building costs by reducing labour requirements and then to encourage local authorities to use the findings in future traditional house building projects. The work was initiated at a time when there was a growing shortage of on the site building labour.

Since the inception of the SDD work and this study, the labour supply situation has changed dramatically in the construction industry, from an under to an over supply in relation to building investment. The decline in the industry has understandably led to Government pressure to try to keep all people employed. It would be unfortunate if this were to have a permanent effect on productivity since its benefits must in the long term take precedence over short term measures to protect employment. In the long term, more flexible policies to develop productive capacity or to reduce working time should be followed. Improved productivity often involves the need of progressively more skills. In this area, Government can approach the employment problem by offering many more training opportunities.

Two additional points need to be mentioned:

1

The study is concerned only with on the site building work. It might be though that as conditions in an off the site factory are more productive than average conditions on a building site, progressively more work should be removed from the site. However, this progression does tend to lead to more transport costs and for hard evidence, the movement of work off the site needs to be studied in relation to on the site work. One solution would be that building work on the site must conform to factory conditions

more closely (which could achieve greatly increased productivity) as an alternative to progressively moving more work off the site.

2

The relationship between cost and price often appears in association with productivity, for example, in formulating incentive schemes. But price is artificial if it has no basis in real costs of materials, plant, particularly labour actually used, necessary overheads (which could be itemised) and profits to the contractor. With the present lack of knowledge about actual labour requirements, this must often be the case in a priced Bill of Quantities. Few accurate common time standards for building work are available.

It was partly the need to know more of such issues, and the actual labour requirements in Scottish traditional house building, that led SDD into a productivity research programme. The SDD supported this study through an external research contract with Aston University.

For overall supervision, particular acknowledgement is due to my internal supervisor, Professor D J Hinton and to two external SDD advisors, Dr J Gibbons and Miss M J Blanco White. Other acknowledgements must be made to A J Stevens, T Paterson, K MacDonald, W S Forbes, D Gray and Miss P Miller. Each of these people gave particular advice or assistance at various stages in the process of the study.

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CHAPTER 1

INTRODUCTION

THE BACKGROUND TO THE STUDY

The relationship between costs and standards of houses is a vital issue for a society and one that is the subject of continuous public debate. Labour productivity in house building is closely related to costs and standards. The house design and site layout, as well as the way the building work is organised, can have an important effect on the labour productivity achieved.

This study looks at labour productivity through the influence both of the design (design being defined as all pre-determined aspects of the building project from the overall site layout down to the details of the construction) and of the organisation of the work on the building site. The detail of the activity sampling data on which the study was based can be related to separate parts of the design e.g. the external walls of the houses, and the study data describes the way the work was actually organised on the site by the main contractor and the sub-contractors.

The study data was derived from a Building Research Establishment (BRE) activity sampling survey method (the method measures the on the site labour requirements in building) carried out on two Scottish Local Authority traditional house building projects. The BRE activity sampling method used in the surveys is outlined in chapter 2. Both site surveys were carried out by the Scottish Development Department (SDD) in collaboration with BRE, as part of a SDD productivity programme, which began in 1970.

The first site to be surveyed was at Blantyre (near Glasgow, involving 132 single and two storey houses), a project in which the National Building Agency (NBA) employed their best design rationalisation ideas for good productivity in collaboration with the Local Authority (Lanarkshire County Council) building the project. The Blantyre site was completed in June 1972, after which the BRE processed the data by computer and subsequently provided SDD with summary table results of labour requirements at Blantyre, produced by hand working from the computer output tables.

By October 1973, when this study began, SDD had produced an Interim Report on Blantyre, using the BRE summary tables, which generally discussed the Blantyre data in terms of average manhours per house on the site e.g. an average of 149 manhours per house were required in the substructure for all the houses at Blantyre. The average manhours per house used in the BRE summary tables were derived by dividing the total number of manhours for an item of work, referred to as an operation, by the total number of houses on the site. To these productive manhours, a proportional addition of all the non-productive manhours collected in the survey was made to provide an all inclusive notional figure of average manhours per house for each operation. Analysis of data in this form is general, and any comparisons between one site and another, using the data handled in this manageable way, must necessarily take account of the individual characteristics of each of the sites e.g. the distribution of house sizes.

The SDD Blantyre Interim Report and two previous BRE house building surveys (at Finchampstead and Crawley in England), which are all based on using the data in the summary form just described, are

compared in chapter 5, together with the second Scottish SDD activity sampling survey at Greenfield (in Glasgow, involving 131 two-storey houses and including 218 flats). All the Greenfield data analysis, and the work involved in organising the method to manipulate the collected data, were an important part of this study; together with further analysis made on the Blantyre data that went beyond the SDD Interim Report. The Greenfield project was a part timber system designed by the building contractor and of particular interest to SDD to investigate any significant productivity advantages of that method compared to the all brick construction at Blantyre.

As well as looking at the Blantyre and Greenfield data in the BRE summary form described, the study concentrated on making more use of all the details in activity sampling data. The BRE have used activity sampling data in more detail, but they have found it largely unmanageable, based on the relative unsophistication of the computer application achieved in their method. To overcome the problem, this study included development of the computer application on the Blantyre data, and this is discussed in chapter 4. The BRE have, nonetheless made some progress towards detailed use of the data. This work was freely discussed with BRE during the early part of this study. Looking at some operations e.g. at Finchampstead, the BRE have found further evidence of wide variation in manhours for similar work in different workplaces on the site and some evidence relating variation in manhours for an operation and the number of distinct visits, for various periods of time, made by operatives to complete the work content of the same operation in each workplace. The wide variation in manhours for similar work had been reported, previously, from activity sampling data by Clapp, in 1965. None of this limited work on the detailed use

of activity sampling data since 1965 has been published by BRE, with the exception of a similar form of pattern making analysis which appears in the first section of chapter 9. This analysis illustrates the number of productive manhours spent in the construction of a house block, for each operation of work in the block through the construction period, in weeks.

THE OBJECTIVES OF THE STUDY

This study contains two objectives for analysis based on the two activity sampling surveys carried out at Blantyre and Greenfield. The two objectives are as follows:

1

To extend the summary data type of analysis made by the BRE on their Finchampstead and Crawley activity sampling site surveys, and by SDD on the Blantyre survey, by further similar analysis of Blantyre and similar analysis of Greenfield.

The type of analysis largely involves expressing results in terms of average manhour per house on each site as defined in the previous section. With care in assessing the validity of this measure, due to the individual characteristics of each site, comparisons can be made between the two Scottish sites only, and between all four sites. The results for each site can be related to the detail of the construction, and the sites compared (where valid) to produce conclusions useful to the development of labour productivity, through changes in design or the organisation of the work. The analysis would also provide indicators for the detailed data analysis defined in the second objective.

Following on from initial, limited and unpublished, work by the BRE, this study examines the value of activity sampling data (from Blantyre and Greenfield) for detailed analysis of the relationship between design and organisation of work, and labour productivity.

The detailed data analysis selected for this study are outlined in the next section. Much of the detailed analysis broadly involved expressing the data in terms of average productive manhours per house for each block on the site for any selected operation. An average per block was chosen to improve accuracy, as it involved a larger section of the sample. For many operations selection of the data by house would have been too inaccurate. As far as could be discovered, the main contractors treated each block as the unit of production.

THE GENERAL LAYOUT AND CONTENTS OF THE STUDY

The two following sections of this introduction divide recent literature into selected references (underlined in the bibliography) that provide support for labour productivity analysis using activity sampling data and the very few references on the previous use of activity sampling data for analysis.

Chapters 2, 3 and 4 describe the BRE activity sampling method, the principal details of the two sites surveyed by the method, namely Blantyre and Greenfield, and the relevant details of the actual surveys made at Blantyre and Greenfield, respectively. Particular emphasis is given in chapter 4 to the computer programme developments made in this study for the extended detailed analysis of the Blantyre data.

In summary form, in notional terms of average manhours per house for the whole site, chapter 5 discusses comparative results for Blantyre and Greenfield and to a lesser extent between both these sites and similar results from the two English surveys at Finchampstead and Crawley. The content of the chapter covers objective one stated in the previous section.

The second objective of the study is discussed in chapters 6, 7, 8 and 9, which contain the detailed analysis made on the Blantyre and Greenfield data. The main detailed data analysis is presented in chapters 6, 7 and 8, which are similar chapters in the sense that the same number of operations are analysed in three separate forms in each of the chapters, respectively. Briefly, the three forms of analysis are as follows:

1

Chapter 6 discusses a number of operations in which the average manhours per house for each block on the site are compared with the order in which the blocks were built.

2

Chapter 7 discusses the same operations, but compares average manhours per house with an assessment of the average number of separate visits per house, for whatever length of time, made by any operative to each block to complete the work of an operation.

3

Chapter 8 discusses the same operations again, but this time compares average manhours per house with the average number of operatives per house employed on each block to complete the work of an operation.

The main reasons behind these three forms of analysis are discussed at the beginning of each chapter, respectively, together with a

detailed definition of each of the forms.

The remaining detailed analysis chapter describes three items of other analysis carried out during the study, that are worthy of inclusion here, and are referred to as miscellaneous detailed analysis. The three items of miscellaneous analysis are as follows:

1

The first analysis shows an example, from Blantyre and Greenfield, of the general pattern of construction, in manhours, of a house block, comparing the approximate sequence of operations in building the block with the construction period, in weeks.

2

The second analysis compares the relative performance of the bricklayer gangs at Blantyre, by relating manhours per metre square of single skin brickwork in the superstructure of each house block, with an estimate of an order in which the blocks were built.

3

The final analysis tries to relate the productive and non-productive manhours of bricklayers as a whole trade at Greenfield.

The reasons for each analysis, and a detailed definition of each analysis, are stated at the beginning of each of the three chapter 9 sections, respectively.

Chapter 10 contains the main conclusions from the work of the study. The last section provides a 'critique' of the BRE activity sampling method and suggests future work.

The bibliography to the study is a selected one, with the references listed in alphabetical order. Those references referred to in the text have the author's name underlined.

The appendices contain two types of table. They are:

1

Coding Lists containing each work operation (predetermined by BRE and SDD before the activity sampling surveys began) at Blantyre and Greenfield, which are referred to in the graphs contained in the analysis chapters and by the text.

2

Simple one page examples of data tables produced by computer application, that have been used in the analysis. The text refers to many of these example tables, only to show the form of the data that had to be utilised in each analysis.

SELECTED RELEVANT GENERAL BUILDING LITERATURE RELATED TO THE OBJECTIVES OF THE STUDY

The references used in this section have been selected from the limited amount of material published in the field since the end of World War 2. They were chosen from references on all building, specifically to provide the best indicators that could be found of detailed analysis of labour productivity within the scope of activity sampling data.

In 1949, a British productivity development team was sent to the USA to study methods of improving productivity in the American building industry. The team tried to isolate the factors which gave the high level of productivity observed. Of significance to the data in this study, the team reported the following factors as important to good productivity:

1

The complete pre-planning of the job by building owner, architect

and contractor

2

The proper co-ordination of the sub-contractor's work and the effective collaboration between them and the general contractor

3

The recognition of the importance of continuous research ... into building techniques (HMSO, 1949).

In 1955, Rosner reported on current experience in West Germany, a country then involved in massive re-building on limited resources, where work had concentrated on two aspects, applicable to activity sampling data, which could improve general building, including house building, site productivity. The two aspects were as follows:

1

The analysis of site operations

2

The rationalisation of site operations (Rosner, 1955).

In 1957, Kaplan identified the main factors that had contributed to the high growth in improved productivity in house building in the USA since World War 2. The main factors, again related to activity sampling data, were:

1

The increased scale of operations

2

The better organisation of the production process.

Kaplan concluded by emphasising further productivity improvement through the simplification of individual operations, minimising handling and further improvements in site organisation. Productivity

improvements could be expected through

> job specialisation and the organisation of work into a series of simple operations that enables workers as individuals and as a team to become thoroughly proficient in carrying out their assignments.

Kaplan finally added that

> simplification of the entire production process presents an even more important possibility for progress (Kaplan, 1957).

In 1965, the United Nations produced a survey co-ordinating research on the beneficial effect of repetition on the building site on productivity, in all the member countries. In a selection of the summary and conclusions, this UN report stated that,

> in summary, the following factors contribute to a maximum favourable effect of repetition on the building site:
> 1
> Architectural and structural plans ensuring maximum identity of operations
> 2
> Adequate size of projects allowing for suffieient specialisation as well as sufficient space for each of the work gangs involved
> 3
> Proper pre-planning and organisation of site works
> 4
> Adequate day-to-day management and supervision of site work.

Of particular significance to activity sampling data, which can provide reliable data on the variation in manhours for a repeated operation, the 1965 UN report stressed three aspects of variation in productivity for the successive repetition of the same operation. The three aspects were:

> 1
> An operation-learning phase, during which the workers acquire sufficient knowledge of the task to be performed and when labour productivity increases rapidly
> 2
> A routine-acquiring phase, during which a gradual improvement of labour productivity is attained through a growing familiarity with the job and through small changes in work method and organisation. In most cases an approximately

stable operation time is ultimately achieved

3 The increase in operational time often observed at the end phase of repetitive work sequences seems in most cases to be due to modifications and additions of operations which are called for in the end phase, i.e. operational discontinuity. Sometimes, however, the end effect has been found to be due to lack of planning and management (United Nations, 1965).

Each of these aspects can be tested with repeated operations on the activity sampling data for Greenfield and Blantyre. An appropriate form of analysis is discussed for a number of Greenfield and Blantyre operations in chapter 6.

The National Building Agency (NBA) have been involved in similar rationalisation in house building for many years. Except for the limited statements in the Arbroath Study (NBA, 1971), the NBA have produced a number of unpublished reports on house building productivity since their 1966 book of Generic plans: Scotland - one and two storey houses. The Blantyre project, that provided data for this study, and on which the NBA were consultants, was a concentration of NBA experience towards the development of house building productivity. The important design rationalisations made by the NBA at Blantyre are discussed in detail in chapter 3.

In 1966, Bishop wrote supporting activity sampling as a method of generating the detailed data necessary to develop productivity.

> One important feature, frequently overlooked, is observation of production and of construction in the field. Direct observation by well-established activity sampling methods is essential if production costs are to be correctly allocated and the operation consequences of design and management known (Bishop (1), 1966).

Bishop also maintained that productivity development must be a continuous process.

> The cycle, production, appraisal, experimental development and redesign is a continuous and continuing process and one important characteristic of industrialised processes. Important because it alone is likely to realise the substantial improvement in productivity recorded in other industrialised sectors of the economy. At present much house building 'design' is divorced from production in a way that makes it difficult, if not impossible, to establish the continuing development process described here.

In the same paper, Bishop reported current ideas thought important to productivity development, that were gaining credibility based on the small amount of hard data available.

> At a tactical level thoughtful design can create operations which are discrete and extensive and therefore likely to lead to building that is easy to build. Deliberate attempts to increase productivity, including mechanising individual operations, introducing components to eliminate in situ work, developing industrialised building, always disturb an existing situation and demand study and appraisal during construction and systematic development in the light of the experience gained. Effective control and systematic development are necessary conditions if higher productivity is to be obtained from the building industry - whether conventional or industrialised. Neither condition is readily obtained in the present industry which is adapted to bespoke construction based on craft practice (Bishop (1), 1966).

Recently, the idea that operations should be 'discrete and extensive' for good productivity has received much attention, particularly by BRE in unpublished work. The analysis of the data in this study attempts to provide some support for the idea, but what is really needed, is far more extensive hard data than is currently available. In another paper in 1966, Bishop discussed three important aspects of productivity in building operations. The three aspects were:

1

Variation

In the building industry in the UK there is

> comparatively little information about the relative performance of operatives in terms of labour requirements for specific operations. The labour requirements for any repetitive operation on any site will under normal circumstances be in the range of roughly 1:4 and variations of the order of 1:10 are not uncommon.

Again, variation in manhours for a repeated operation can be assessed by activity sampling data. Some Blantyre and Greenfield operation variations are discussed in chapter 6.

2

Interruptions

> Operations may be divided into three phases; setting-up, working and clearing away. There is also an element of secondary setting-up whenever work commences at a work-place, or after an interval (new day, tea break, etc.). Work then ensues (unless interrupted) until the end of the working period when, depending upon the craft involved, there is some work entailed in collecting tools, clearing-up, sweeping out. It follows that as much work as possible should be done at each workplace; alternatively, small operations should be tackled by specialist sub-gangs able to move rapidly from workplace to workplace, in effect treating all workplaces as a single workplace. Very small operation building must result in low productivity unless the site is sufficiently large to permit a considerable degree of gang specialisation.

Interruptions for a repeated operation can be assessed using activity sampling data and compared with variation in manhours. The Blantyre and Greenfield data has been applied to this form of analysis. The analysis is discussed in chapter 7, in which interruptions are amended in favour of a measure of the number of separate visits made by operatives to complete an operation in each workplace. Once again, Bishop implies the benefit to productivity of discrete and extensive operations, which should have the least number of wasteful interruptions.

3

Site Organisation

> If there is no particular necessity to build quickly, the difficult organisational problems implicit in this situation may be solved by creating a large number of possible workplaces for each gang, so that each gang will be able to find a job somewhere in the site on completion of a task. Building slowly makes fewer demands on management and nearly always leads to lower non-productive time but increases overheads and funding costs (Bishop (2), 1966).

Better organisation than that suggested by Bishop may involve creating as few interruptions as possible, again with operations as discrete and extensive as possible, to produce houses on a site, say, in phases to reduce funding costs, at least.

As an introduction to the last section on the use of activity sampling data, a report produced by An Foras Forbartha on house building productivity was based on building contractors' own labour time records. Although the data is not as detailed or reliable as activity sampling, nonetheless, the report represents an important and rare recent contribution to the field. The An Foras Forbartha study identified two aspects of interruption to work that influenced productivity. The two aspects were:

1

Productivity advantages in the use of serial tendering, concluded from projects using similar house designs in different locations

2

A productivity relationship between specific interruptions by operatives on a particular site and the variation in output achieved. The planning and programming of the work was blamed for the disadvantageous interruption record.

Two other factors, important to productivity development, were identified in the An Foras Forbartha study. They were:

1

A relationship between gang size, in particular trades for which there was adequate data, and the levels of productivity achieved

2

A relationship between the size of the building contract and the levels of productivity achieved. From the Blantyre data, a detailed analysis of the bricklaying gangs working on the superstructure of each house block was possible. The analysis compared the performance, in manhours, of each gang involved in the construction of the blocks. The results are discussed in ITEM 2 of chapter 9 (Pigott, 1972).

Despite the lack of evidence, a recent BRE report has tried to show (based on contractor supplied data) that good progress in reducing labour requirements in house building has been made since World War 2. The report stated an average reduction from a generally held 2665 man-hours per house in 1949 to 2000 hanhours in 1969, but around 1200 man-hours from these contractors contributing to the BRE report (Forbes, 1969).

THE LITERATURE ON THE PREVIOUS USE OF ACTIVITY SAMPLING DATA

Pressure for the detailed data necessary to develop productivity, began with the slow development of techniques to handle large amounts of data and expanded rapidly with the advancement of the computer. Fjosne, reporting in 1961 on the outlook in the Swedish industry, stated that

> there are several reasons for expecting a rapid evolution. Increasingly efficient electronic computers are at our disposal for handling and analysing vast quantities of numerical data. Thus, there are almost unlimited possibilities for making accurate and complete analyses

> with a minimum of human effort. This will no doubt have a decisive influence of the future outlook and methodology used in productivity measurement in the building industry.

Fjosne continued by stating that

> the development of useful techniques of analysis and practical analyses of building sites, for the purpose of providing the building industry with trustworthy data from actual examples, should be given priority within building research (Fjosne, 1961).

The recent An Foras Forbartha study, the BRE survey of progress in productivity in housing since World War 2 (Forbes, 1969) and some other early studies of labour requirements used data for the whole of each trade on site. Much of this data was taken from the building contractor's own labour time sheets and was not very detailed or necessarily independent.

> However, if it is required to apportion the men's time to particular parts of the work, or to different activities, or both, then special arrangements will have to be made to collect the information by direct observation using one or other of the recognised work study techniques. The finer the level of detail required, the greater will be the effort to collect the data - and the expense (Forbes, 1966).

The work study technique that has received much attention in recent years, especially by the BRE, for productivity development work, has been the activity sampling method already mentioned.

However, even now, sixteen years after Fjosne speculated on the future of computers in productivity development work, the use of activity sampling data has been slight, principally because of the unsophisticated handling by computer, so far achieved, of the vast amount of data collected in each survey. Site survey data in summary form e.g. expressing the data in terms of average manhours per house for the roof construction of all houses on a site, has been collated

by computer, further manipulated by arduous hand working and published in two particular BRE publications. These publications reported on the Finchampstead site survey, a project of timber pre-fabricated houses on which the BRE contributed productivity advice, and the Crawley site survey, a project which was an early metric design in England, employing metric bricks. Both of these surveys are considered in the comparative analysis discussed in chapter 5.

Only one published report on the detailed use of activity sampling data could be found; although, as previously mentioned, the BRE have made some, unpublished, detailed data analyses on their own recent activity sampling surveys, particularly Finchampstead and Crawley. The one published report was made by Clapp as long ago as 1965, on activity sampling data that was ten years old. Neither the data collection, nor the detailed analysis achieved by Clapp, had the benefit of any computer application. The analysis had to rely on earlier, and extensive, handworking methods. The data was simplified however, in covering groups of similar semi-detached houses.

In the report, Clapp commented on the pressing need to know more about labour requirements in house building and stated that there was a dearth of factual information in the field. Despite the small number of activity sampling surveys that have been done since then, this lack of factual information remains generally the same.

In the same report Clapp concluded that two of the main causes of variation in manhours for a repeated operation within a site are:

1

A marked improvement in productivity during the first few operations of a repeated operation

2

Differences between gangs of operatives which influence productivity.

As evidence for the first cause, Clapp reported, for a repeated operation, based on a series of similar semi-detached houses, that manhours fell for the first pairs of houses and then, subsequently, manhours varied around an improved average value. These findings had been reported in the UN report of the same year, although that report referred to an end phase, in which the last few operations increased in manhours again. This end phase was not reported by Clapp.

For the second cause of variation in manhours for a repeated operation, Clapp asserted that

> if more than one gang is employed on an operation, the differences in productivity between the gangs often has more effect on the manhours than any other factor.

Incidently, Clapp found that the greatest amount of variation in manhours for a repeated operation was in miscellaneous joinery, an operation involving many small items of work. This finding can be compared with the amount of variation in operations at Blantyre and Greenfield discussed in chapter 6.

Lastly, she reported that sub-contractors generally had a higher level of productivity than main contractors (Clapp, 1965). A conclusion from this finding could be that sub-contractors demand, and achieve, generally more discrete and extensive trade operation work than main contractors.

CHAPTER 2

THE BUILDING RESEARCH ESTABLISHMENT (BRE) ACTIVITY SAMPLING METHOD

The BRE activity sampling method for assessing labour requirements on building sites has been developed over many years. In recent years, an increasing computer application, to help in efficiently handling the vast amounts of data generated in most site surveys, has been introduced. In 1971, when the Blantyre site survey began, specially designed site data sheets were used capable of relatively fast reading in an optically controlled machine. The method included a newly developed computer programmed package that manipulated the data into two sets of predetermined tables of a variety of forms (see appendices 4 to 7 inclusive). Both the Blantyre and Greenfield surveys made by SDD with BRE assistance, were completed using the then current 1971 method. An outline of that method is discussed in the following two sections, with the description divided between the collection and computer manipulation of the data, and the statistical accuracy of the data derived from the method. This chapter is concluded with a broad comparison between the quality and quantity of activity sampling data and other methods of providing information on labour requirements on building sites.

AN OUTLINE OF THE BRE ACTIVITY SAMPLING METHOD

The current details of the activity sampling method used for the Blantyre and Greenfield site surveys are fully described by the BRE in their publication, Current Paper 16/1969 (Stevens, 1969). To summarise, the following main components of the method can be

identified. Site observers make detailed observations following a carefully prepared coding system, at regular time intervals of the work in progress, on each operative on the site. Each observation is made on a specially designed site observation data sheet, to form a work activity sample for the whole site works. Each observation coded by the site observers on to the data sheets contains eleven attributes i.e. seperate items of data. The eleven attributes coded by the observers contain the following details from each operative observation:

1

The week number in the construction period

2

The date involving the day and month

3

The site observer's own code number

4

The round time in which the observation was made

5

The operative's code number which revealed his trade e.g. bricklayer or carpenter

6

The operative's status in his trade e.g. apprentice or foreman

7

The house block number e.g. there were twenty-two separate house blocks at Blantyre

8

The individual house number within each house block

9

The stage of work in progress e.g. the roof covering work or the electrical work (a complete Coding List of the stages describing the Blantyre and Greenfield constructions are given in appendices 1 and 2 respectively)

10

The operation within the stage of work in progress e.g. the roof tiling as part of the roof covering work or the wiring and outlet boxes as part of the electrical work (the Coding Lists giving the stages of work included the operations within each stage and can be referred to in appendices 1 and 2)

11

The activity within the operation e.g. preparing a door to be hinged or fixing a hinged door into an opening frame (Coding Lists of the separate activities collected in the activity sample for Blantyre and Greenfield are given in appendix 3).

The site observers begin rounds, in which observations are made, at regular intervals e.g. one hourly intervals for the Blantyre site survey. To ensure that observations are as random as possible, the exact round times are begun at slightly altered intervals, usually by adding ten minutes from day to day, including further adjustments to allow for regular lunch and teabreaks, on a twelve day cycle.

> To randomise further the pattern of observation start times it is suggested that the first day in the twelve day cycle of observation round times should also be randomly chosen i.e. having completed day twelve of the cycle one should not automatically restart at day 1. As a further assurance of randomness, whenever possible the observer should start each round from a different position on the site and take different routes around the site (Stevens, 1969).

The Blantyre and Greenfield site surveys employed three site observers rather than the two observers commonly used by the BRE on English surveys. The reason for the third observer was due to longer working hours during the summer months and frequent weekend working on Sundays. The observation sheets, designed by BRE, contain the data of seven separate observations. The observers number the data sheets consecutively for each working day. The sheets are collected together by week for the next stage in the data handling process. This next stage is the fast reading, by an optical reader, of the sheets for each week on site, to convert the data to binary code on punched paper tape.

In order to prepare the data for computer processing, the BRE first convert the raw data on paper tape directly to magnetic tape. The data for each week is then processed by a BRE computer programme to produce a set of weekly tables. Normally the first table in the set (e.g. appendix 4, table 4.1), lists any faults found in each observation by the programme and states what correction the programme was able to make or if no correction was possible. The table provides a continuous check on the data, which must be monitored each week. The next table in the weekly set (e.g. appendix 4, table 4.2), by far the largest and most important, provides an ordered list of all the observations made (a substantial rearrangement of the order in which the data was collected by the site observers) including all the attributes with each observation. Simply, the table lists observation attributes in separate sub-tables for each day, placing operative code numbers, his trade and status, against each round time for the day. The weekly table set also includes a number of much smaller tables which summarise the data for the week. A complete

list of the BRE weekly tables (with illustrated examples from the Blantyre data) is given in appendix 4.

Under the BRE method of handling the data, any detailed analysis largely depends on the second table, in which the mass of the data is simply ordered day by day throughout the construction period, with the data otherwise remaining in near raw form.

As the BRE computer programme produces each set of weekly tables, the programme stores the processed data successively on magnetic tape, which is subsequently processed by a further BRE computer programme that produces a final set of total data summary tables. An example list of the total data summary tables for Blantyre is given in appendix 5.

THE ACCURACY OF THE ACTIVITY SAMPLING DATA

The labour requirements in manhours measured in activity sampling surveys are based on the laws of probability. It is assumed that a random sample of the work on the site will tend to have the same distribution pattern as the actual, or real, work pattern on the site. The more numerous the observations in the sample the better the estimate. The accuracy of the estimate for any part of the sample survey, for example in an operation, can be calculated from the following formula assumed in the method.

The formula giving the relationship between the degree of accuracy and the number of observations is:

$$A = 2\sqrt{\frac{(1-P)}{NP}}$$

where N = total number of observations
A = degree of accuracy
P = percentage occurence of operation

The values of A and P must be expressed in decimal form i.e.
5 per cent = 0.05

Three example calculations are illustrated below based on the Blantyre activity sampling survey:

	SAMPLE OBSERVATIONS	PERCENTAGE ACCURACY	FULL RANGE IN MANHOURS
1	30	± 36.5	19 - 41
2	200	± 14	172 - 228
3	1800	± 4.5	1716 - 1884

In the Blantyre survey, observations were made at hourly intervals, in which case 30 observations collected for an operation represents 30 manhours. According to the stated accuracy formula, the operation observed may actually have taken between 19 and 41 manhours i.e. 30 manhours at a ± 36.5 per cent accuracy.

THE RELATIONSHIP BETWEEN THE ACTIVITY SAMPLING METHOD AND OTHER METHODS PROVIDING SIMILAR DATA

The scale of detail in methods of assessing labour requirements in building are related to the quality of the resulting data required. If, for example, manhours by trade for a whole house building site are sufficient, then suitable data can be obtained with the aid of the building contractors. The data is not, necessarily, independent. The significant advantage of data collected at this level is that it is feasible to cover a number of sites within a reasonable time period and expense. The BRE report (a survey of progress in house building) made use of data from 48 sites, collected in this general way. The spread of the data was such that average requirements for speculative development, local authority tradition and local authority system building, at 1,030, 1,200 and 1,070 manhours per dwelling, respectively, were concluded from the 48 sites used in the

report (Forbes, 1969).

If manhours are to be divided between operatives in each trade, and related to particular parts of the work, then a direct observation work study technique is needed. The technique that has received much attention in recent years, especially by the BRE, has been the activity sampling mehtod outlined in this chapter. Referring to the advantages of activity sampling, Stevens stated:

> Activity sampling has been found to be particularly suitable for detailed studies on site since, as few as two observers can study about 100 operatives, it is possible to estimate the accuracy of the results, and little or no continuous close contact between the operatives and the observers is involved (Stevens, 1969).

Recent BRE activity sampling surveys of house building have collected data for the whole site i.e. the house construction and the external works. This has been possible (at reasonable expense) as computers have been used to manipulate the large amount of data generated in a survey. The Blantyre survey involved about 140,000 separate site observations, that together contained more than 1.25 million items of data.

However, activity sampling is but a series of regular observations on what each operative is doing on the site, which are usually at one hourly intervals in BRE surveys. If yet more detailed data is required, a decision has to be made between an enormous increase in data that follows from increasing the accuracy and detail of activity sampling by reducing observations to half-hourly or quarter-hourly, and still covering all the site works; or, being forced, through expense and the sheer weight of data, to be selective in which items of work and workplaces are covered by the survey.

The level of detail achieved can increase to continuous observation e.g. in taking video-tape recordings of work at a particular workplace, but necessarily, the coverage of the site work will be limited compared to activity sampling at one observation per hour, for a similar expense. The significant disadvantages of the continuous observation of work are that the work can be influenced by the close observation and that the data produced by the method has no general context in data from the whole site work or even any relationship to repeated work, such as on a house building site, in other work-places, unless specific arrangements have been made to survey a particular item of work in all workplaces, but this may be expensive.

CHAPTER 3

THE BLANTYRE AND GREENFIELD SITE DESCRIPTIONS

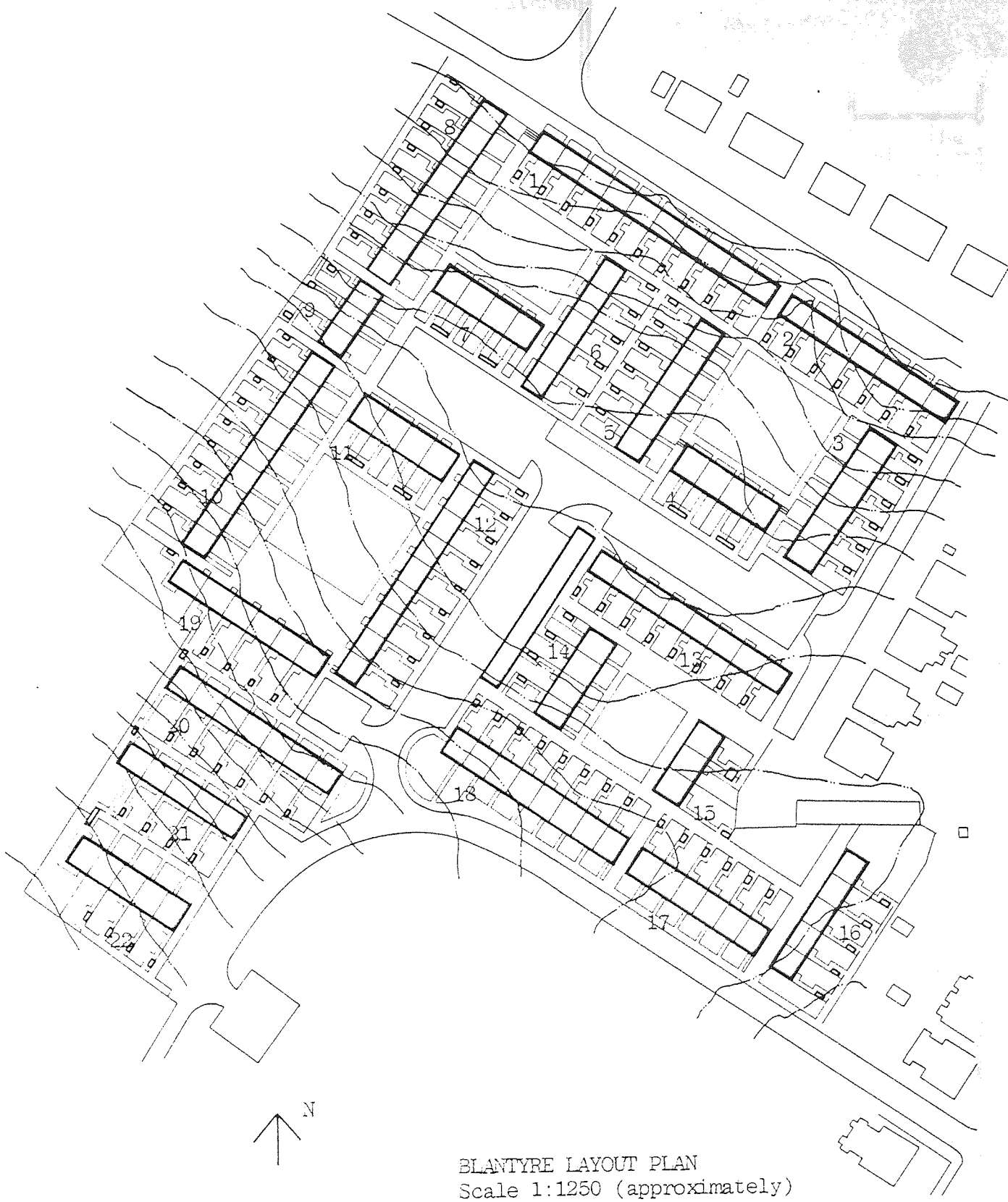
As indicated in the introduction, the data for this study consisted of two BRE activity sampling surveys made by SDD in collaboration with BRE on the Blantyre and Greenfield house building sites. This chapter provides a description of the two projects.

THE BACKGROUND TO THE BLANTYRE PROJECT

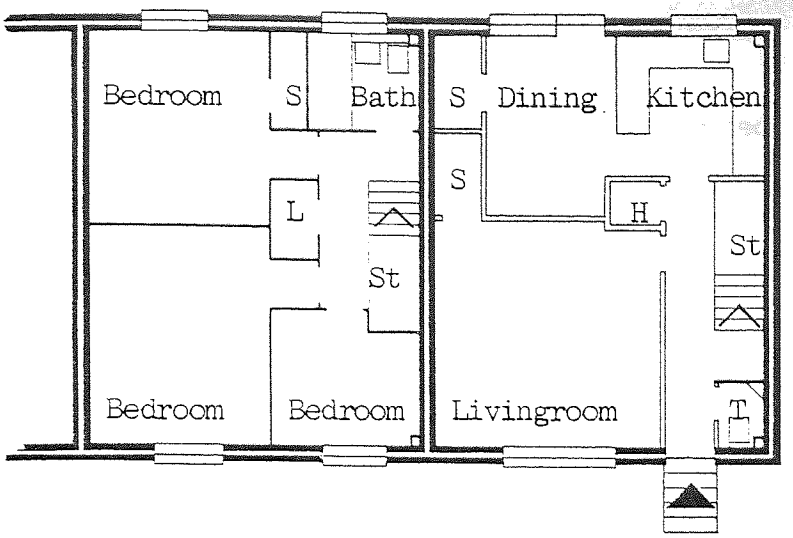
To Lanarkshire County Council, the Local Authority client, the houses built in 1971-72 at the Blantyre site were a normal part of the planned new house provision in Lanark County. The unusual aspect of the project for the Lanark County Architect's Department (LCAD) was that Blantyre became the first houses to be built to metric dimensions in the County. LCAD collaborated with the National Building Agency (NBA) on the metric layout and house plans design and on preparing full metric working drawings. The NBA designed the layout and the house plans in consultation with LCAD, while LCAD developed special interest in Scotland and elsewhere from the further interests of the NBA in developing productivity in traditional house building. The Blantyre project contained 132 single and two storey houses of traditional construction. The construction was supervised on the site by the Lanark County Architects.

THE BLANTYRE SITE LAYOUT

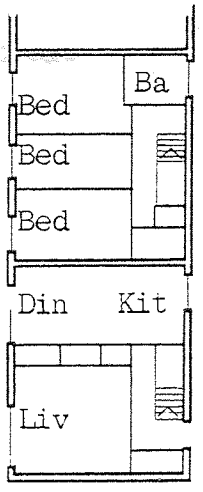
The Blantyre project was a redevelopment of a central part of Blantyre, a small town just outside the old confines of Greater Glasgow. The 3.0 hectare site is surrounded by existing roads and stone built houses to the north-east and south-east; a redeveloped



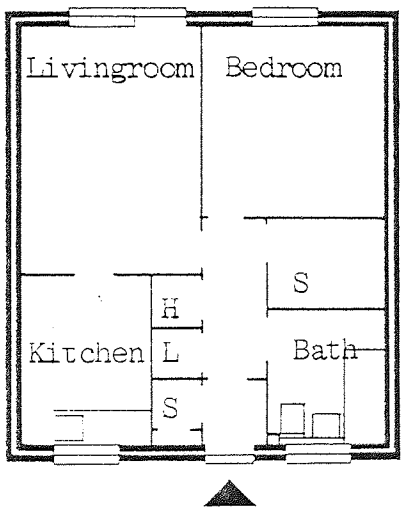
BLANTYRE LAYOUT PLAN
Scale 1:1250 (approximately)



5-person
dual aspect



5-person
controlled aspect
(shell rotated 90)



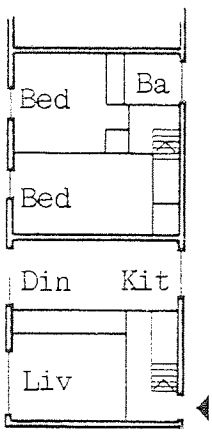
2-person
dual aspect

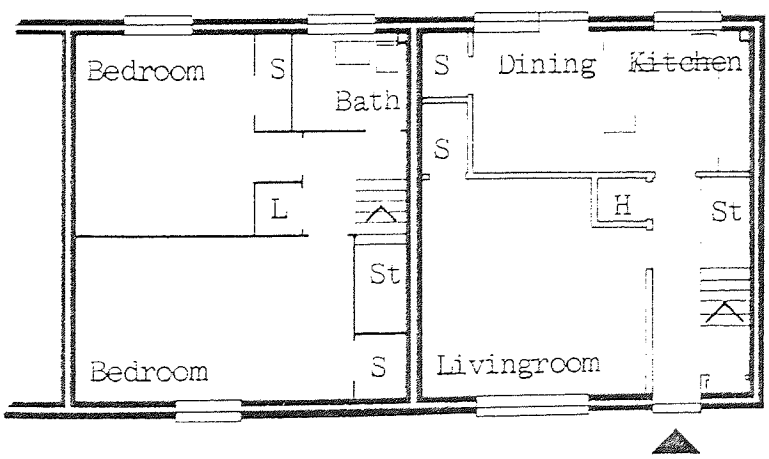
BLANTYRE HOUSE PLANS
Scale 1:150 (approximately)

KEY

S Store
L Linen cupboard
H Heater cupboard
St Staircase
T Toilet

4-person
controlled aspect
(shell rotated 90)





4-person
dual aspect

road, giving the main access to the project, and an open grassed area to the south-west, and finally, a double bank of mature trees along an old footpath to the north-west. The site slopes on average by 1 in 24 to the north-east and the designed population density is 177 persons per hectare. From the existing surrounding roads, the site layout design extends road access into the centre of layout, providing overall a parking place for 90 per cent of the houses and garages for only 11 per cent. Another main element in the layout design was the formation of four pedestrian courts by arranging the houses in simple blocks, three to ten houses long, at right angles and parallel to the site contours. Each house has a small garden, with the provision of a garden shed, and a screened area on the front of the house as a dustbin store. Footpath access was provided on both sides of each house and vehicular access is achieved for 60 per cent of the houses. The landscaping is exceedingly simple and bare. While the houses look well constructed, and of good quality, the overall impression is of a rather formal and colourless layout.

THE BLANTYRE HOUSE PLANS

The house provision in the Blantyre project comprised 15 two-person single storey houses, 82 four-person two storey houses, and 35 five-person two storey houses. The accommodation schedule provides details of both the house block numbers (see also Blantyre layout plan) and the total number of houses in each of the five house types (each block contains only one house type, except blocks 6 and 19). The schedule also includes the frontage, depth and floor area (measured between internal finished surfaces) for each house type.

ACCOMMODATION SCHEDULE: BLANTYRE

HOUSE TYPE (BLOCK NUMBERS FROM THE LAYOUT PLAN)	NUMBER	FRONTAGE (m)	DEPTH (m)	FLOOR AREA (m^2)
2-person (4, 7, 11, 15)	15	6.6	7.5	49.5
4-person dual aspect (5, 8, 9, 10)	26	6.0	6.6	79.0
4-person controlled aspect (1, 2, 6 (1 house) 12, 13, 16, 19 (4 houses), 20, 21)	56	6.6	6.0	79.0
5-person dual aspect (3, 14, 17, 18, 22)	29	6.0	7.5	90.0
5-person controlled aspect (6 (4 houses), 19 (2 houses))	6	7.5	6.0	90.0
Total	132			

In general, the standard of provision in the Blantyre houses was high compared to the norm for local authority houses in Scotland. The most obvious indicators of a good standard of provision relate to storage and services. Overall, the number of kitchen storage fitments, the kitchen to dining room divider, and the outside garden and dustbin stores combined to provide a store area well above minimum requirements. On services provision, each house was designed with a high standard of provision in electrical outlets, the five-person house types included a separate ground floor wc and whb compartment and all the house windows were fitted with double glazing.

DESIGN RATIONALISATION ON THE BLANTYRE PROJECT

The range of house plans used at Blantyre were derived from the Scottish Local Authorities Special Housing (SLASH) common plans. The common plans, called SLASH plans, were developed to introduce, efficiently, metric dimensions into Scottish local authority house design in general and were designed through collaboration between SLASH, the NBA and SDD. The SLASH common plans are supposed to try to harness the beneficial effect on costs and productivity, of repetition; the main strategic method to achieve this is to co-ordinate overall shell (house) sizes. At Blantyre, only three shell sizes were employed. In co-ordinating overall shell sizes, the SLASH methods develop critical dimensions, which are used to extend repetition into the detailed elements of the shells used throughout a site construction. At Blantyre, the main elements to be repeated where feasible throughout the site were:

1

The span and depth of the first floor joists

2

The first floor construction around the plumbing stack, the heating unit and the staircase

3

The bathroom layout

4

The plumbed part of the kitchen layout

5

The heating unit

6

The staircase.

The other important aspect of SLASH common plans is the application of a metricated system of dimensional co-ordination. The common plans and their eventual construction should adhere to the conventions of the dimensional system adopted. Three main aims of dimensional co-ordination, again to reduce costs and improve productivity, are:

1

The avoidance of cutting to waste any material, particularly sheet material

2

To ensure a better fit for similarly dimensionally co-ordinated components and materials

3

To improve the general clarity of information for setting-out work at all stages.

These aims were inherent in the early application of the metric common plans at Blantyre.

To summarise, the accommodation schedule shows that in the Blantyre project only three overall shell dimensions of 6.0 metres and 7.5 metres were used in the house designs. Five house types were designed from the three shell dimensions. The 2-person house type and one each of the 4-person and 5-person house types were dual aspect [A]. The two remaining house types, one 4-person and one 5-person, were controlled aspect. These two controlled aspect[B] types were achieved within the simple expedient of rotating the two 4-person and 5-person dual aspect house shells through 90 degrees,

---

[A] There is no restriction in placing any room window in the front or back side of a terraced house.

[B] Certain windows, usually to the living room and bedrooms, are restricted to one side of a terraced house only.

GENERAL HOUSE CONSTRUCTION

BLANTYRE	GREENFIELD
SUBSTRUCTURE	SUBSTRUCTURE
Strip concrete foundation	Concrete raft foundation
Cavity brickwork to damp proof course (dpc) level including party walls	Same as at Blantyre
Honeycomb sleeper walls supporting ground floor	Solid sleeper wall supporting ground floor
Blaes underfloor filling, ash binding and pitch damp proof membrane (dpm)	Same as at Blantyre
Suspended timber joist and board ground floor	Suspended timber joist and sheet ground floor
Concrete steps, outside ground level to ground floor	Same as at Blantyre
SUPERSTRUCTURE	SUPERSTRUCTURE
Cavity brickwork external and party walls, timber windows and doors, concrete cills and lintols	Timber frame inner wall panels timber windows and doors Single skin brickwork outer and party wall, pre-stressed concrete lintols, concrete cills, scaffolding
Suspended timber joists and board first floor	Suspended timber joists and sheet first floor
Pre-formed timber roof trusses	Same as at Blantyre
Plasterboard sarking, felt, battens and concrete interlocking tiles	Timber board sarking, otherwise the same as at Blantyre
Single and double glazing	Single glazing only
Roughcast rendering to brickwork	Same as at Blantyre
Scaffolding	Same as at Blantyre
Timber staircase	Same as at Blantyre

BLANTYRE	GREENFIELD
SERVICES AND FINISHES	SERVICES AND FINISHES
Plasterboard linings to ceilings and walls	Same as at Blantyre
Honeycomb plasterboard partitions, door sets	Same as at Blantyre except door frames only
Plumber: pvc rainwater goods, h/c water supply and waste pipework to bathroom/kitchen, 5-person house ground floor wc/whb compartment	Similar to Blantyre, except no separate ground floor wc/whb compartment 5 or 7-person houses
Electrician: pre-fabricated wiring trees, organised and pre-packaged fittings	Similar to Blantyre, except all work prepared on site
Electric warm air heating unit	Similar to Blantyre, gas fired
Final joinery: timber skirtings architraves, etc., iron-mongery, kitchen storage units kitchen to dining room divider	Doors; otherwise similar, except less kitchen storage and no kitchen to dining room divider
Jointing plasterboard lining/ honeycomb partitions	Same as at Blantyre
Artex textured paint to ceilings	Same as at Blantyre
Emulsion paint walls/ceilings	Same as at Blantyre
Gloss paint internal and external timber	Same as at Blantyre

preserving an overall use of only three shell sizes. The 4-person and 5-person controlled aspect house types are illustrated to a smaller scale, in the house plans drawing.

A GENERAL DESCRIPTION OF THE BLANTYRE CONSTRUCTION

The first column of the comparative construction table briefly describes the Blantyre house construction. The table compares the Blantyre construction with that at Greenfield to illustrate the broad similarities between the two projects. The Blantyre construction will be discussed in the total data summary tables analysis given in chapter 5. The Blantyre construction is given in further detail in the activity sampling Code List in appendix 1.

THE BLANTYRE MAIN CONTRACTOR

The Blantyre main contractor had much experience from previous traditional house building contracts. For Blantyre, the contractor employed his own men, and sub-contractors for some of the specialist operations. The contractor's site management staff had a settled workforce throughout the contract and they easily achieved the 18 months construction period planned for the project. The NBA produced a sequence diagram of operations for the work on Blantyre, related to the detail drawings supplied to the contractor. During construction the NBA kept a 'line of balance' graph that contained each operation in the sequence diagram. The overall conclusions of the diagram seemed to be that management control was well balanced in the substructure, brickwork and roof construction and then fell out of balance in the following services and finishes work. The services and finishes work will be discussed in more detail in the overall analysis chapter 5, and again in the detailed analysis

chapters 6, 7 and 8, and particularly in chapter 9.

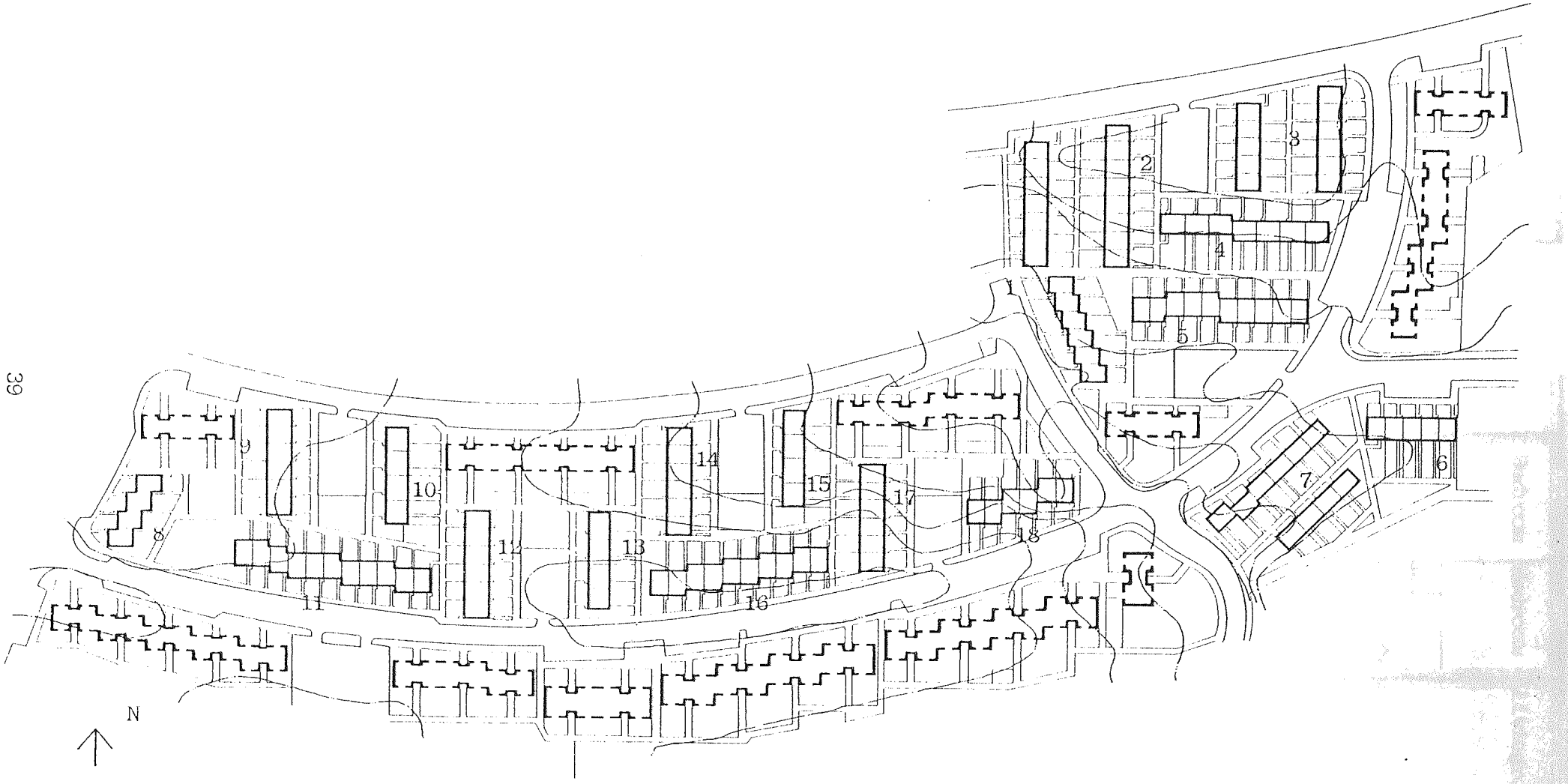
THE BACKGROUND TO THE GREENFIELD PROJECT

The Greenfield project, built between 1972-74, contained 131 two storey houses and 218 flats in two and four storey blocks, and was part of Glasgow Corporation's new building programme. An important aspect of the project was that the main contractor used his own house building system as the construction for the 131 houses on the site. The contractor also provided Glasgow Corporation with the layout design and the house type designs. This study deals only with the data on the 131 houses at Greenfield (which employed the main contractor's building system), for comparison with Blantyre and the BRE surveys at Finchampstead and Crawley in England.

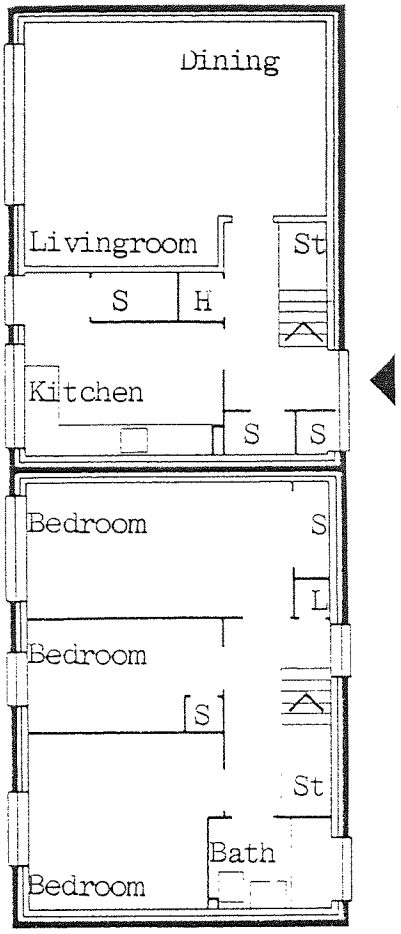
THE GREENFIELD SITE LAYOUT

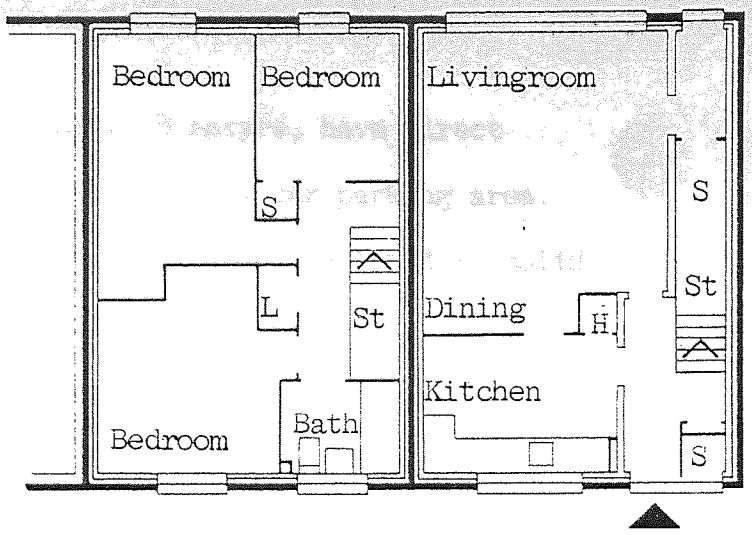
The Greenfield project was a redevelopment of part of Shettleston, in Greater Glasgow. The 6.4 hectare site is set against a massive railway embankment (with an operating factory on the other side) to the south; further building sites open for redevelopment to the west, east and north-east corner, and a primary school and a broad grass area to the north. The site slopes on average 1 in 90 to the south and the designed population density is 205 persons per hectare, rather more than the 177 persons per hectare at Blantyre because of the 218 flats.

Broadly, the layout design makes use of the existing (rather linear) road pattern and simply distributes the house blocks along the roadside. Some house terraces are placed at right angles to the road to allow for off-street car parking areas. The layout provides no garages, but, including the roadside, caters for more than one car parking place per house and flat. About 86 percent of the



GREENFIELD LAYOUT PLAN
Scale 1:2000 (approximately)



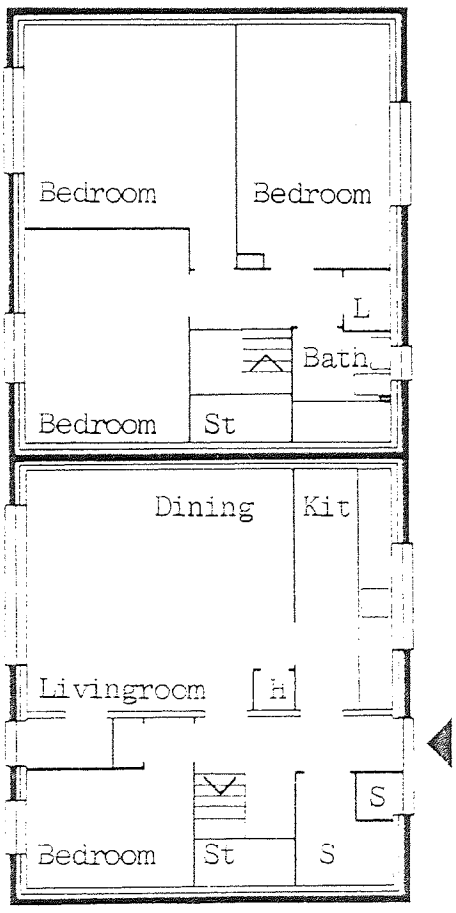


5-person
dual aspect
(north access)

5-person
controlled aspect

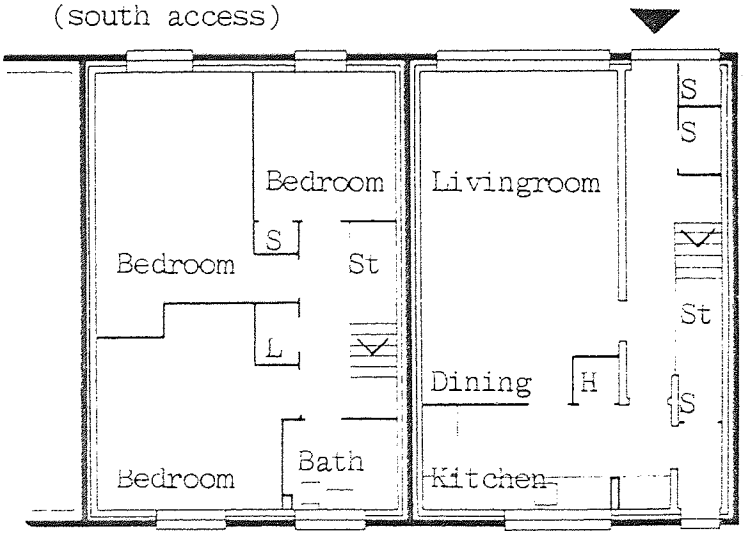
KEY
See Blantyre plans

GREENFIELD HOUSE PLANS
Scale 1:150 (approximately)



7-person
dual aspect

5-person
dual aspect
(south access)



houses, compared to only 60 per cent at Blantyre, have direct vehicular access from either the roadside or a car parking area. On the site layout drawing, the house blocks are outlined in solid line and the flat blocks in dashed line. The flat blocks on the south side of the site are four storeys and so form a barrier for the house blocks against the embankment and factory beyond. A large number of footpaths run through the layout, giving pedestrian access to both sides of each block. Typical of many Scottish local authority housing projects, the landscaping is, as at Blantyre, very simple. The overall impression of the layout design is bare and colourless, and the line of four storey flat blocks on the south side formidable, but then so is the embankment that the flat blocks hide.

THE GREENFIELD HOUSE PLANS

The house and flat provision in the Greenfield project comprised 112 five-person two storey houses, 19 seven-person two storey houses, 88 flats in four storey blocks and 130 flats in two storey blocks for old people. Considering the houses only, the accommodation schedule provides details, the number, overall size and floor area of both the house block numbers (see also Greenfield layout plan) and the total number of houses in each of the four house types (each block contains only one house type). The schedule also includes the frontage, depth and floor area (measured between internal finished surfaces) for each house type.

ACCOMMODATION SCHEDULE: GREENFIELD

HOUSE TYPE (BLOCK NUMBERS FROM THE LAYOUT PLAN)	NUMBER	FRONTAGE (m)	DEPTH (m)	FLOOR AREA (m^2)
5-person dual aspect north access (1, 2, 3, 6, 8, 9, 12, 14, 17)	65	5.5	7.9	87.0
5-person dual aspect south access (5, 11, 16, 18)	37	5.5	7.9	87.0
5-person controlled aspect (7)	10	7.9	5.5	87.0
7-person dual aspect (4, 10, 13, 15)	19	7.9	6.7	106.0
Total	131			

In general, the standard of provision in the Greenfield houses was the bare statutory minimum. For example, none of the large 5-person and 7-person house types involved had a separate wc and whb compartment on the ground floor.

DESIGN RATIONALISATION ON THE GREENFIELD PROJECT

The house plans used by the contractor at Greenfield were based on SLASH common plans. For the four house types, only two shell sizes were employed and both of the shells had one common dimension, namely 7.9 m. Two 5-person house types were designed within one shell size to provide plans with either main access from the north, or the south. The same shell size was turned through 90 degrees to form the controlled aspect, third, 5-person type. The second shell size, with one dimension in common, provided the larger, single, 7-person house type. The contractor designed the four house types

GENERAL HOUSE CONSTRUCTION

BLANTYRE	GREENFIELD
SUBSTRUCTURE	SUBSTRUCTURE
Strip concrete foundation	Concrete raft foundation
cavity brickwork to damp proof course (dpc) level including party walls	Same as at Blantyre
Honeycomb sleeper walls supporting ground floor	Solid sleeper wall supporting ground floor
Blaes underfloor filling, ash binding and pitch damp proof membrane (dpm)	Same as at Blantyre
Suspended timber joist and board ground floor	Suspended timber joist and sheet ground floor
Concrete steps, outside ground level to ground floor	Same as at Blantyre
SUPERSTRUCTURE	SUPERSTRUCTURE
Cavity brickwork external and party-walls, timber windows and doors, concrete cills and lintols	Timber frame inner wall panels timber windows and doors Single skin brickwork outer and party-wall, pre-stressed concrete lintols, concrete cills, scaffolding
Suspended timber joists and board first floor	Suspended timber joists and sheet first floor
Pre-formed timber roof trusses	Same as at Blantyre
Plasterboard sarking, felt, battens and concrete interlocking tiles	Timber board sarking, otherwise the same as at Blantyre
Single and double glazing	Single glazing only
Roughcast rendering to brickwork	Same as at Blantyre
Scaffolding	Same as at Blantyre
Timber staircase	Same as at Blantyre

BLANTYRE	GREENFIELD
SERVICES AND FINISHES	SERVICES AND FINISHES
Plasterboard linings to ceilings and walls	Same as at Blantyre
Honeycomb plasterboard partitions, door sets	Same as at Blantyre except door frames only
Plumber: pvc rainwater goods, h/c water supply and waste pipework to bathroom/kitchen, 5-person house ground floor wc/whb compartment	Similar to Blantyre, except no separate ground floor wc/whb compartment 5 or 7-person houses
Electrician: pre-fabricated wiring trees, organised and pre-packaged fittings	Similar to Blantyre, except all work prepared on site
Electric warm air heating unit	Similar to Blantyre, gas fired
Final joinery: timber skirtings architraves, etc., iron-mongery, kitchen storage units kitchen to dining room divider	Doors; otherwise similar, except less kitchen storage and no kitchen to dining room divider
Jointing plasterboard lining/ honeycomb partitions	Same as at Blantyre
Artex textured paint to ceilings	Same as at Blantyre
Emulsion paint walls/ceilings	Same as at Blantyre
Gloss paint internal and external timber	Same as at Blantyre

in imperial dimensions without following any dimensional co-ordination system. The main rationalisation in the contractor's construction system appears in the dimensioning of the timber prefabricated panels which formed the floors and part of the external and party walls. The prefabricated panels (made off the site by the contractor), were the only industrialised part of the 'system building' offered by the contractor. As a credit to the contractor, the prefabricated panels were erected very efficiently, in part because the operations involved were carefully planned (see ITEM 1, chapter 9).

A GENERAL DESCRIPTION OF THE GREENFIELD CONSTRUCTION

The second column of the comparative construction table briefly describes the main differences between the Greenfield and Blantyre constructions. The Greenfield construction will be discussed in the total data summary tables analysis given in chapter 5, and is given in further detail in the Greenfield Coding List in appendix 2.

THE GREENFIELD MAIN CONTRACTOR

As at Blantyre, the Greenfield main contractor was an experienced house builder, the experience being derived from his own house building system, and from previous traditional house building contracts. For Greenfield, the contractor employed sub-contractors and self-employed men (particularly bricklayers and labourers) to do most of the work.

Only the contractor's site management was in any way familiar with the house building system. The sub-contractors and the self-employed men were unsettled while working on the site. The contract included the building workers' strike of 1972 and finally finished 6 months

beyond the planned 18 months construction period. A significant problem in programming the construction of the houses was the need to construct, concurrently as part of the contract, the 218 traditionally built brick cavity and heavy concrete floor flats. For example, on one occassion, many operatives were transferred from working on the flats to working on the houses, where they temporarily destroyed the balance of the trades working there, because many concrete stair units in the flats had to be replaced, so preventing access.

CHAPTER 4

THE BLANTYRE AND GREENFIELD ACTIVITY SAMPLING METHOD APPLICATION AND DEVELOPMENT

This chapter deals breifly with the application of the BRE activity sampling method to each of the Blantyre and Greenfield house building sites. The Blantyre survey is discussed first, together with a description of the work done in this study in developing the BRE method for the purposes of detailed data analysis, using the Blantyre data. The Blantyre survey was complete, including computer processing, when this study began in October 1973. The Greenfield survey, on the other hand, was still being carried out on the site in October 1973 and only a small proportion of the data processing had been done. Thus, Blantyre became the more important survey in the study, as most of the necessary method development work was possible during the time interval in which the Greenfield survey was completed, including computer processing, by February 1975.

THE BLANTYRE ACTIVITY SAMPLING METHOD APPLICATION

The Blantyre activity sampling survey was carried out by three site observers, under the joint supervision of SDD and BRE, during the site construction period that ran from January 1971 to June 1972. The details of the survey at Blantyre are described in chapter 2 on the method. With the exception of the work in converting the data on the Blantyre site observer sheets to binary code on punched paper tape (work that involved optical reading machines), the data processing was carried out by BRE themselves. Following the data handling procedures in their method, BRE subsequently converted the raw Blantyre data on punched paper tape directly to magnetic tape.

Using the magnetic tape, the data for each site week at Blantyre was processed together with a BRE computer programme that produced the set of data tables discussed in chapter 2. As the data for each week was processed, the programme successively stored the data on a further magnetic tape. Finally, this magnetic tape was processed together with a further BRE programme that produced a set of total data summary tables. These summary tables were used as the basis for overall data analysis on Blantyre discussed in chapter 5. The set of Blantyre total data summary tables are listed in appendix 5. For the analysis discussed in chapter 5, BRE created some further tables, produced by hand methods, indicating that the computer-produced summary tables had not been well enough developed.

THE ACCURACY OF THE BLANTYRE ACTIVITY SAMPLING DATA

Using the data accuracy formula given in chapter 2 on the BRE activity sampling method, the table below shows the range of accuracy in five samples from the Blantyre data:

	SAMPLE OBSERVATIONS	PERCENTAGE ACCURACY	FULL RANGE IN MANHOURS
1	30	$\pm$36.5	19 - 41
2	80	$\pm$22.5	62 - 98
3	200	$\pm$14	172 - 228
4	600	$\pm$8	552 - 648
5	1800	$\pm$4.5	1716 - 1884

An important point to make for the datailed analysis is that the results are given in terms of average manhours per house for each

house block on site. So the accuracy of 20 manhours per house for an operation in a block of six houses is derived from a much higher accuracy of 120 observations than a single part of the sample of only 20 observations. For this reason the detailed analysis handles average manhours per house per block, as for many operations the hourly observation sample by individual house at Blantyre is too inaccurate.

THE BLANTYRE ACTIVITY SAMPLING DATA DEVELOPMENT MADE IN THE STUDY

An investigation was made early in the study to evaluate available BRE sets of weekly data tables on Blantyre for the purpose of making detailed data analysis. A list of the BRE set of weekly tables, together with an illustrated example of each table, is given in appendix 4. Among the lists of weekly tables, only table 4.2 provides a record of all the Blantyre data for possible detailed analysis. Table 4.2 simply lists in rows each activity sampling observation collected by the site observers for each operative on every working day from week to week in the construction period. The Blantyre data contained about 140,000 such observations.

It was soon realised that detailed analysis from the table 4.2 of the 140,000 Blantyre observations would only be practical, on a very limited scale, by hand methods. If substantial analysis were to be achieved in the study, then the data in table 4.2 would have to be processed again on a computer by rather more sophisticated methods. In other words, the original BRE programme had not been developed far enough to suit the possible requirements of sorting and tabulating the data to suit detailed analysis. In support of this conclusion, the Blantyre set of total data summary tables,

produced by the second BRE programme, had not been developed far enough to suit overall data analysis either. The evidence being a further set of summary tables produced (using hand methods) by BRE on the Blantyre data for overall analysis. (As part of the work in this study, other similar summary tables had to be made by hand methods from total data summary tables produced by the BRE programme on the Greenfield data).

New computer programmes were needed to extend the BRE method to achieve a flexible sorting facility for the Blantyre data to suit possible detailed analysis. The programme requirements were discussed with the BRE and the Scottish Office Computer Service (SOCS). SOCS suggested that their standard set of programmes called the Scottish Office Computer Service Information Retrieval (SOCSIR) system could be a practical proposition. SOCSIR is simply a standard information retrieval system developed by SOCS to achieve a variety of tabulations from data in a common form holding a number of variables. The only significant problem would be to achieve a common form of the Blantyre data suitable for computer processing with SOCSIR. The BRE were asked to assist in creating a new magnetic tape-file of the Blantyre data in a form suitable to SOCSIR. To achieve this the BRE had to make two main amendments to their original programmes. The first amendment would mean that the programmes produced only table 4.1 (illustrated in appendix 4) from the data of each week. Table 4.1 lists each correct data sheet in sequence and the results of faulty sheets that required any of a number of observation accuracy checks performed by the programme on the data. The data included about 140,000 observations, each observation having 11 attributes, or seperate items of information. Table 4.1 was

necessary as the data for each week had to be monitored to ensure a high level of accuracy. The second amendment would mean that the programmes completed operation by storing the observations for each week on a magnetic tape, but this time retaining all the attributes of each observation. In the original programmes the attributes of observation round time, date and week number were not stored on magnetic tape on completion of the data processing for each week.

On completion of the method development work, an accurate full data file for the Blantyre activity sampling survey was available for use with SOCSIR to sort the data into tabulations to suit detailed analysis. Six requests of SOCSIR were origninally programmed during discussions with SOCS, and six requests have been made, involving three basic variations in sorting the Blantyre data into table form. A sample from each of the new tables requested of SOCSIR is illustrated in appendix 8.

A discussion of each SOCSIR table requested to suit the detailed analysis is purposefully deferred until the appropriate context of the detailed analysis chapters, 6, 7, 8 and 9.

THE GREENFIELD ACTIVITY SAMPLING METHOD APPLICATION

The SDD, with assistance from the BRE, carried out a second site survey on Greenfield between June 1972 and March 1974, using the same three site observers that they had employed to carry out the Blantyre survey. The Greenfield survey included virtually the same number of dwellings as the Blantyre survey, but in addition contained a large number of flats (132 houses at Blantyre, 131 houses and 218 flats at Greenfield). This increased the size of the survey

and so the interval between observations made by the site observers was increased from one hour at Blantyre to one and a half hours at Greenfield, so that the three site observers could cope with the work load. Otherwise the Greenfield survey was carried out in the same method as at Blantyre.

As in the Blantyre survey, the conversion to paper tape of the Greenfield data sheets for each week on site was done in Edinburgh. On this occassion, however, the computer processing was also done in Scotland on the SOCS computing facilities. SOCS used the BRE computer programmes to process the Greenfield data, after first testing the programmes on their facilities. SOCS began data conversion from paper tape to magnetic tape and processing in May 1973, and finally completed the work in February 1975. Part of the work in this study was involved in helping SOCS to produce the Greenfield data, accurately processed by their computer. The work involved careful co-ordination of the efforts of BRE, SOCS and Edinburgh Corporation who did the site sheets to paper tape conversion work.

Once the weekly tables for Greenfield were complete, SOCS merged all the data on to one magnetic tape. The tape containing all the Greenfield data was then processed by SOCS using the BRE devised computer programme, to produce the BRE designed set of total data summary tables. A list of these summary tables, processed by SOCS for Greenfield, is given in appendix 7. As a first step for overall analysis, a set of further summary tables were produced by hand methods for the Greenfield data from the computer produced summary tables. A detailed discussion of these further summary tables is given in chapter 5, together with those tables devised for Blantyre.

THE ACCURACY OF THE GREENFIELD ACTIVITY SAMPLING DATA

The same accuracy formula described for Blantyre applies in the Greenfield survey. The only difference between the surveys is that the observation interval at Greenfield had to be one and a half hours rather than one hour at Blantyre, because of the large increase in work covered by the survey (218 flats included with the 131 houses). This alternative observation interval is reflected in the three similar examples (as those given for Blantyre) of assumed accuracy calculated from the previously described formula.

	SAMPLE OBSERVATIONS	PERCENTAGE ACCURACY	FULL RANGE IN MANHOURS
1	20	±44.5	17 - 43
2	50	±28	54 - 96
3	140	±17	175 - 245
4	400	±10	540 - 660
5	1200	±5.5	1697 - 1903

As with the Blantyre data, the accuracy of the number of manhours per block for any operation in the detailed analysis, before division by houses per block, is preserved in the manhours per house results indicated.

GREENFIELD DETAILED ANALYSIS FROM HAND SORTING THE DATA

During the final period that the study was involved in the work of developing the BRE method for the further computer processing of the Blantyre data to suit detailed analysis, some detailed analysis

(based on the BRE weekly table, Table 2) was made, by hand methods, on the Greenfield data. This work was initiated for three reasons:

1

The delay in achieving a new Blantyre data file for use with SOCSIR in detailed analysis.

2

To explore the data, even on limited basis, and to provide a guide to possible following detailed analysis on the Blantyre data using SOCSIR.

3

To extend further computer application with SOCSIR in the detailed analysis of the Greenfield data was not possible within the available resources.

CHAPTER 5

MANHOURS PER HOUSE OBTAINED FROM THE BLANTYRE AND GREENFIELD ACTIVITY SAMPLING DATA: SUMMARY DATA ANALYSIS

This chapter compares the activity sampling data on Blantyre with that on Greenfield, in terms of the average number of manhours for an operation, per house, for all the houses on the site. The analysis also includes data in similar form from two recent surveys of house building sites in England, at Finchampstead and Crawley, made by BRE themselves. The analysis recognises the inherent differences between the four sites discussed (no two sites are the same) and emphasises significant differences in the data where this accounts for major variations in work content.

Although Greenfield involved about 15 percent more built area per house than Blantyre, due to a distribution containing more larger houses (see accommodation schedules in chapter 3), this is not reflected uniformly in the building work. For example, a 15 percent increase in the external wall built at Greenfield was not involved, nor was 15 percent more plumbing work required. For the latter the reverse was the case because the large Blantyre houses had a separate ground floor toilet compartment that was not provided at Greenfield.

This general form of total data analysis of the Blantyre and Greenfield surveys was made a part of this study for three reasons:

1

For comparison with most of the previous work in this field (using activity sampling data in a similar form) by BRE, and some by SDD on Blantyre before this study began

2

To identify changes in specification or work organisation in Scottish traditional house building that could be made to improve productivity

3

To provide some guidance to work operations worth subjecting to much more detailed analysis within the maximum capabilities of the activity sampling data.

The Blantyre survey data, completed before this study began, will be discussed first, including some comparative references to Greenfield, Finchampstead and Crawley. The BRE kindly provided un-published data in the form of average manhours per house for the Finchampstead and Crawley sites, for application in the comparative analysis.

The houses at Crawley were of traditional construction including cavity brickwork designed to metric dimensional co-ordination as at Blantyre; while at Finchampstead a prefabricated timber panel and part prefabricated concrete foundation system were used.

The SDD had just completed an interim report on the Blantyre data when this study began, in generally the same form of analysis used in this chapter and based on tables produced by BRE. Overall comparisons were drawn in the interim report between Blantyre and Finchampstead. This chapter briefly reviews and extends this analysis on Blantyre and Finchampstead and includes Greenfield and Crawley for the first time.

The Greenfield survey data discussion follows that on Blantyre and to a similar format makes comparative references to Blantyre, Finchampstead and Crawley.

For each section of the analysis, a numbered table (referred to in the text as required) illustrates the average manhours per house results for each site, for selected operations. These numbered tables (six in all) are illustrated on the next three pages, making one place of reference to them only.

TABLE 1

AVERAGE MANHOURS PER HOUSE SUMMARY FOR ALL WORK

	Blantyre	Green-field	Finchamp-stead	Crawley
Substructure	149	123	70	107
Superstructure	253	254	90	344
Services	76	133	145	101
Finishes	256	218	255	267
House Total	743	728	560	819
External Works	321	-[A]	370	-[B]
Total	1064	-	930	-

TABLE 2

AVERAGE MANHOURS PER HOUSE FOR THE SUBSTRUCTURE

	Blantyre	Green-field	Finchamp-stead	Crawley
Excavate foundations	18	20	7	14
Concrete foundations	12	15	-	11
Brickwork to dpc	78	65	-	29
Underfloor filling	23	12	9	15
Suspended grd floor	15	11	-	-
Concrete pads/beams	-	-	15	-
Concrete floor slab	-	-	27	19

[A] External works results confused with 218 flats at Greenfield

[B] External works results not available for Crawley

TABLE 3

AVERAGE MANHOURS PER HOUSE FOR THE SUPERSTRUCTURE

	Blantyre	Green-field	Finchamp-stead	Crawley
Scaffolding	7	24	3	16
External/party walls	154	111	26	231
Roughcast	20	43	-	-
Roof	24	28	29	35
Glazing	5	6	-[A]	7
First floor/stairs	19	12	19	36
Partitions	15	30	20	19

TABLE 4

AVERAGE MANHOURS PER HOUSE FOR THE SERVICES

	Blantyre	Green-field	Finchamp-stead	Crawley
Plumber work	35	79	73	41
Electrical work	34	41	72	33
Heating work	7	10	-[C]	-[D]
Gas	-[B]	3	-[B]	27

[A] Glazing at Finchampstead included in prefabricated wall panels

[B] Blantyre and Finchampstead had electric heating and no gas service supply at all

[C] The Finchampstead heating work was included with electrical work in this survey

[D] The Crawley heating work was included under gas work

TABLE 5

AVERAGE MANHOURS PER HOUSE FOR THE FINISHES

	Blantyre	Green-field	Finchamp-stead	Crawley
Drylinings	56	46	28	45
Lining joints	18	23	31	48
Final joinery	84	73	61	64
Snagging	11	16	-[A]	-[A]
Decoration	89	60	113	97
(Internal gloss)	(49)	(33)	(40)	-[B]

TABLE 6

AVERAGE MANHOURS PER HOUSE FOR THE EXTERNAL WORKS

	Blantyre	Green-field[C]	Finchamp-stead	Crawley[D]
Draining Services	76		106	
Welfare etc	81		77	
Landscaping	164		188	
(Paving)	(97)		(45)	

A Not a recognised operation in England

B No separate figure for internal gloss painting was available from BRE unpublished data on Crawley

C External works results confused with 218 flats at Greenfield

D External works results were not available for Crawley from BRE data

THE BLANTYRE ALL WORK SUMMARY MANHOURS COMPARED WITH GREENFIELD, FINCHAMPSTEAD AND CRAWLEY

The all work summary manhours for Blantyre, Greenfield, Finchampstead and Crawley illustrated in Table 1, show how favourable the Blantyre result was for a traditional building design solution. The Blantyre result was only an average 1064 manhours per house including the external works. This compares well with a survey by BRE that gave 1200 manhours per house as the average labour requirements for traditional local authority house building (Forbes 1969). The Blantyre result compares particularly favourable with the 930 average manhours per house measured for Finchampstead. The difference between the two sites would be reduced if, in a comprehensive measurement of labour requirements, the off the site manhours in prefabricating the timber panels and parts of the concrete foundation in the Finchampstead house construction could be included.

THE BLANTYRE SUBSTRUCTURE MANHOURS COMPARED

As in many Scottish house building sites, the Blantyre site was sloping with an average fall of 1 in 24. In comparison, both the Crawley and Finchampstead sites were flat. The Blantyre house designs made no special provision for the site slope and the layout design provided few steps between houses in blocks at right angles to the site contours. As a result, the amount of building work in most of the operations below the damp proof course (dpc) in the Blantyre construction were excessive. The substructure results at Blantyre are given in Table 2.

An additional problem was that the layout design set the house floor levels unnecessarily high and during construction the actual built

floor levels were made higher than those of the design. As a point of comparison within the construction, the average substructure brick work manhours were slightly more than the superstructure brickwork manhours from dpc to the first floor level, or, more than 50 percent of all the superstructure manhours. The average manhours required for underfloor filling reflected the excessive brickwork below the dpc. A further outcome of this lack of control with the substructure, was that the entrances to houses had to have many concrete steps built up from the finished outside ground level. In the worst conditions, as many as seven concrete steps and a concrete platt immediately outside the entrance door had to be constructed with brickwork support, and the finished steps had specially constructed mild steel railings on the outside edge of the steps and platts.

The average substructure manhours at Blantyre were 14 percent of the total average manhours per house. As a point of comparison, the average substructure manhours at Finchampstead were more than 50 percent lower than at Blantyre and represented only 8 percent of the Finchampstead total average manhours requirement per house.

THE BLANTYRE SUPERSTRUCTURE MANHOURS COMPARED

At Blantyre, the average manhours per house for the superstructure (given in detail in Table 3) was 24 percent; 60 percent of the manhours were spent on the brick cavity external and party walls and brickwork sundries including cills, lintols, windows and doors.

The figures for the external and party walls and sundries at Crawley appear poor in comparison because of the unfamiliar dimensional co-ordination of the facing bricks specified, combined with the large light weight concrete blocks that formed the inner wall of the cavity

construction. Also, some extra walling was required at Crawley as the houses were semi-detached or in short blocks.

The roughcast finish, including the scaffolding used at Blantyre, required 11 percent of the superstructure manhours and the roof construction only 10 percent.

Compared to the external and party walls at Finchampstead, the Blantyre performance in terms of on the site labour requirements is poor. However, the measurement of on the site manhours for the sophisticated prefabrication of the superstructure at Finchampstead, does not include the necessary off the site manhours to fabricate the wall panels from the commonly supplied materials and components. Nonetheless, the on the site performance at Finchampstead was impressive, and the average difference in manhours between Blantyre and Finchampstead for the external and party walls (complete with the external but not the internal finish) was a full 160 manhours per house. For this reason, efforts to improve labour requirements in masonry wall construction in traditional building would be well worth while, and would help to improve the on the site competitive position of traditional building with other house building systems e.g. complete timber systems like that used at Finchampstead.

THE BLANTYRE SERVICES AND FINISHES COMPARED

Once the substructure and superstructure had been built, all four projects discussed, namely, Blantyre, Greenfield, Crawley and Finchampstead, adopted very similar specifications for services and finishes. Nonetheless some variations in specification occurred, and some of these will be discussed, but broadly the provisions for services and finishes in the projects were the same. Also, some

variations in average manhours per house for similar operations occurred, and some of these will be discussed too. Most of the work in services and finishes was completed on the site in all four projects. Referring to Table 1 again, services and finishes at Blantyre absorbed nearly a third of the average manhours requirement per house (including external works).

At Blantyre, services i.e. electrics, plumbing and heating, were 22 percent of the average manhours per house in services and finishes as a whole. The electrical and plumbing systems were 10 percent each and the heating system a mere 2 percent. The average manhours per house in services are given in Table 4.

The plumbing system layout was carefully designed and standardised in the house types at Blantyre, which helped to produce the good average result of 35 manhours per house. Good design efforts at Crawley produced a similar average plumbing system result of 41 manhours per house. Similar good results were made at Blantyre and Crawley for the electrical system, 34 and 33 manhours on average per house, respectively.

Finishes can be divided into three main groups, which together with services, each take approximately 25 percent of the manhours in services and finishes as a whole. The three groups are:

1

Plasterboard drylining and jointing

2

Final joinery together with snagging

3

Decoration.

Table 5 gives the average manhours per house at Blantyre for finishes.

The joiner trade contributes more manhours than any other trade to finishes, followed by the painter and to a varying degree between the sites, the plasterer. At Blantyre, snagging was significant at 11 manhours per house, which suggests that labour requirement reductions are possible from the better organisation of joiner work.

The drylining work at Blantyre was divided between plasterers and joiners. The plasterers fixed only the plasterboard lining to the masonry walls with plaster dabs. This division reduced the drylining work for each trade, complicated the programming of the work and contributed to the poor performance of 74 manhours per house. The same division of drylining work, and an even worse performance at 92 manhours per house, occurred at Crawley. Lastly, in decoration, internal gloss painting absorbed the largest proportion of the manhours per house at Blantyre (a full 49 manhours shown in brackets in Table 5).

THE BLANTYRE EXTERNAL WORKS COMPARED

The Blantyre project was a redevelopment with many existing roads and underground services which could continue to be used, making the project quite different from the virgin site development at Finchampstead or any other house building site. These common differences between sites make rationalisation difficult, which explains the poor attention external works has received towards reducing labour requirements, and is the reason why most sites are worked and finished externally simply to complete the site somehow. In one group of external works, underground services, attempts have been made at work co-ordination. At Finchampstead co-ordinated

underground services were tried, but the result was poor due to a common failure to achieve good working co-operation between the utility boards involved.

At Blantyre, the external work required 30 percent of the total average manhours per house, nearly equal to substructure and superstructure at 38 percent, or services and finishes at 32 percent.

Within the Blantyre external works (listed in Table 6) services and drainage were 24 percent of average manhours per house. This result was generally better than at Finchampstead, which employed a co-ordinated services trench, because of the higher density and existing services and drainage at Blantyre. Another large item of external works manhours was the contractor's site establishment, welfare facilities, site management and plant maintenance, which together were 25 percent of average external works manhours at Blantyre. The hard and soft landscaping at Blantyre was the third large external works item at 42 percent of the average manhours per house. Within the landscaping, footpaths and car parking absorbed 70 percent of the manhours. A change in the layout form could reduce footpaths to serving one side of the houses only and limit the area, and impact, of car parking places; thereby eliminating a proportion of the work to be done, which should lower the manhour requirements.

THE GREENFIELD ALL WORK SUMMARY MANHOURS COMPARED WITH BLANTYRE, FINCHAMPSTEAD AND CRAWLEY

Referring again to Table 1, the average manhours per house at Greenfield were 728, only 15 manhours less than at Blantyre and far more than the 560 average manhours at Finchampstead. This suggests that the part timber construction system provided by the contractor for Greenfield gave no real advantages over the entirely brick traditional constrction at Blantyre. The external wall, the only industrialised part of the system building, will be discussed in more detail under the superstructure heading. However, the Greenfield result is improved by one factor, and that is the larger house types distribution at Greenfield entailed 15 percent more area to construct that at Blantyre (measured between internal finished faces).

THE GREENFIELD SUBSTRUCTURE MANHOURS COMPARED

Although Blantyre had a slightly steeper average site slope, the Greenfield substructure was more successful in requiring 26 fewer average manhours per house. However, Greenfield had several staggered house blocks, producing complicated foundations; while Blantyre had only simple, straight, blocks. Both substructures required substantially more on the site manhours than the solid floor construction at Finchampstead, which had the advantage of a flat site.

With reference again to Table 2, the alternative substructure at Greenfield was measured as 5 manhours per house more than Blantyre, for the whole house excavation and steel mesh re-inforced concrete slab, rather than the Blantyre trench and concrete strip foundations. This extra Greenfield labour requirement was reversed by an average of 24 manhours for the following work in brickwork below dpc and

and the underfloor filling. Principally, although the Greenfield site was less steep, the concrete slab permitted by 'cut and fill' a shallower excavation, and the floor levels were not, as at Blantyre, built unnecessarily high which eliminated many possible steps to entrances at Greenfield.

The average substructure manhours at Greenfield were 16 percent of the total average manhours required on each house (excluding external works which could not be covered). As a point of comparison in the house walls at Greenfield, the substructure brickwork manhours were equal to 60 percent of the manhours measured for the brickwork and timber panels of the superstructure.

THE GREENFIELD SUPERSTRUCTURE MANHOURS COMPARED

The brickwork and timber panel type of superstructure specification at Greenfield has been widely used in Scotland in recent years, making the survey at Greenfield particularly important. Many local authorities and contractors in Scotland seem to favour the durability and traditional outward appearance of the roughcast outer leaf of brickwork specified for Greenfield. The Greenfield specification also included a brickwork wall constructed between the double party wall timber panels, this forms a good fire stop as well as adding mass to the party wall to improve sound insulation.

Referring to Table 1, the superstructure average manhours per house were only 12 less than the all brick cavity wall Blantyre construction. With reference to Table 3, the average manhours spent on the timber prefabricated panels on the site were a mere, and very impressive, 11. However, this advantage was not consolidated. One reason appears to be some work quantity disadvantages for Greenfield. These

disadvantages were that Greenfield involved 15 percent more area to construct on average per house than Blantyre (requiring a smaller percentage increase in wall construction work) and that Greenfield had 30 percent of the houses staggered by half the house depth which further increased the external walling to be built.

However, much of the advantage of the timber panels seems to have been lost on the following brickwork at Greenfield. The external and party wall brickwork had been divided into smaller quantities of work than is normal for tradition building (e.g. as at Blantyre) and this may have led to less efficient working. What is more certain is that the external brickwork required a bricklayer scaffold, as the wall could not be built over-arm from inside the house as is normal Scottish practice, which may have added 17 manhours per house (obtained by subtracting the roughcaster scaffold manhours from the roughcaster and bricklayer scaffold manhours at Greenfield).

Excluding unknown factors, and excepting the extra work entailed at Greenfield, the roughcasting required more than twice the number of manhours used at Blantyre.

In the party wall, the single skin of brickwork, serving as a fire stop, was difficult to construct through the timber panels and seemed very inefficient in requiring 37 manhours per house. The party wall brickwork seems to have further eroded the advantages of the timber panels by impeding the roof construction.

The management of the bricklayers at Greenfield seems to have been further complicated by the continual movement of men between the construction of the houses and the 218 traditionally-built flats on the site. Finally, the timber at Greenfield, typifying the system,

brought the superstructure manhour requirements of 255 nowhere near the 97 superstructure manhours at Finchampstead. However, the durability of resin based finish on the plywood outer panels at Finchampstead has been questioned, as it has delaminated after only a few years on a very sheltered site, quite unlike most sites in Scotland.

THE GREENFIELD SERVICES AND FINISHES MANHOURS COMPARED

Illustrated in Table 4, the plumber work result at Greenfield was particularly poor at 79 manhours per house. Precise reasons for this poor result are difficult to give except that, in general, interference to plumbing work progress by other trades may have been a substantial cuase of inefficiency. Frost damage to completed plumbing systems filled carelessly with water caused extra work, but overall it amounted to an increase of only approximately 4 percent in average manhours per house. Compared to the Blantyre plumbing result, the Greenfield performance is even worse, because the 5-person houses at Blantyre had separate wc and whb compartments on the ground floor, while neither the 7-person nor the 5-person houses at Greenfield had this additional plumbing work. Relatively high results, for average manhours per house, were recorded for both plumber and electrical work at Finchampstead. The Finchampstead 68 manhours per house for plumber work can be partially explained by a complex plumbing layout, which tends to support the plumbing rationalisation at Blantyre.

The poor Finchampstead electrical work result is more difficult to explain, but, in part, it has been attributed to the inefficient working practices of the electrical sub-contractor, which severely

interrupted work progress for other services and finishes trades.

The joiner trade completed all the plasterboard drylining at Greenfield, with the result that drylining to walls was 10 manhours per house better than at Blantyre, where the lining work was divided between the joiner and plasterer trades.

The Greenfield performance was better on all aspects of decoration work than at Blantyre. Internal gloss painting continuing to take the highest proportion of the manhours required, at more than 60 percent.

The 16 snagging manhours per house at Greenfield were high, and when added to the 73 manhours per house for final joinery, make the overall joiner finishing work manhours much higher than at Finchampstead or Crawley. The Blantyre final joinery result was similar to that at Greenfield, which suggests that Scottish final joinery practice would benefit from development work to reduce labour requirements.

PRELIMINARY CONCLUSIONS

Some valid general comparisons between the Scottish sites at Blantyre and Greenfield, and with the English sites at Finchampstead and Crawley, were possible. These four sites represent the majority of the recent activity sampling data on house building in Britain. Some possible changes in construction specification or work organisation from that at Blantyre or Greenfield could be drawn fron the form of analysis, for the purposes of productivity development work in traditional house building.

Lastly, the analysis identified the large operations on both sites

that could be analysed in further detail. The following detailed data analysis in chapters 6, 7, 8 and 9 researches into the substructure and superstructure brickwork at Blantyre (for which processed data was available, see chapter 4), which were large bricklayer operations. Otherwise, most of the researches were confined to services and finishes operations at Blantyre and to a smaller extent at Greenfield (for which much less processed data was possible, see chapter 4). Particular emphasis was placed on services and finishes operations as they account for nearly half the required manhours at Blantyre and Greenfield, excluding the external works. Significant productivity improvements could be made in these operations. This is especially important as they require the attention and good practice of skilled men.

CHAPTER 6

BLANTYRE AND GREENFIELD DETAILED DATA ANALYSIS : MANHOURS COMPARED WITH CONSTRUCTION ORDER

This chapter is the first of three that contain the main work on detailed data analysis made in this study. The chapters, numbers 6, 7 and 8, have the same general format, in that they each contain a different form of analysis applied to the same selected number of trade operations from Greenfield and Blantyre.

THE DEFINITION OF THE FORM OF ANALYSIS

The first form applied, was the detailed analysis of the variation in manhours for work operations, in terms of the average number of man-hours per house for each block on the site, compared with an estimate of order in construction of the house blocks, at Greenfield and Blantyre.

THE OBJECTIVES OF THE FORM OF ANALYSIS

This form of detailed data analysis is intended to provide answers to the following key questions:

1

For more or less the same operation, carried out in the houses of each block, for either site separately, how much variation in average manhours per house was there between the blocks?

2

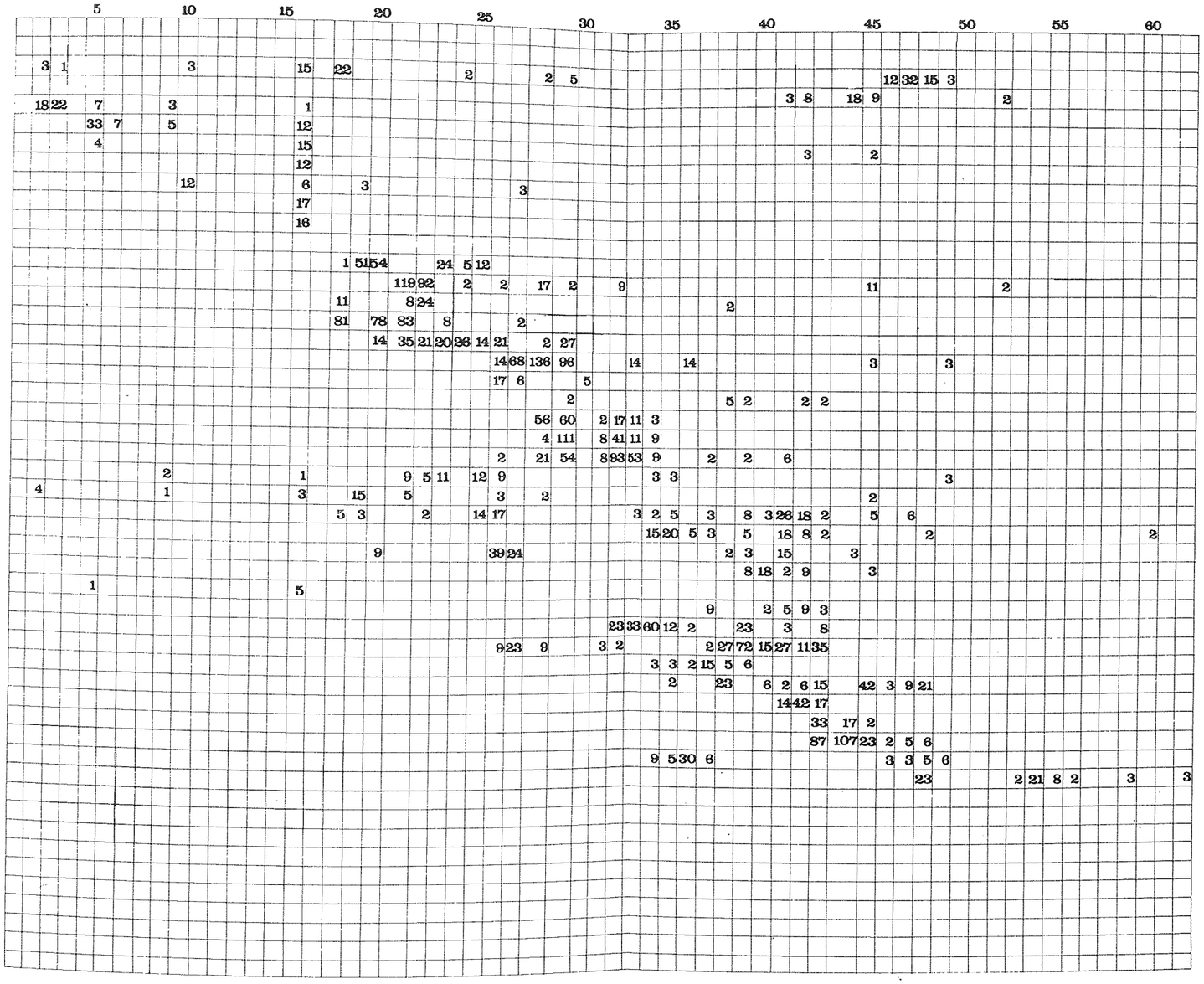
Within the variation calculated was there any form of relationship between manhours per house (averaged for each block) and the order in which the blocks were worked on, for any operation, by the main contractor or a sub-contractor?

GREENFIELD

Block 3 — 11 houses — Productive manhours only

Operations

Weeks



As an important common question, was there any learning improvement apparent in a pattern of reducing nanhours from the repetition of any operation; or what the United Nations study (UN 1965) called the early routine acquiring stage.

THREE GREENFIELD OPERATION GRAPHS

In the graphs that follow, average manhours per house for each block on the site are always shown on the vertical axis and the manhours are those derived from the activities F, N and P only (the activities are defined in appendix 3.2). These activities are those at the workplace involving operatives in actually constructing the work in each operation.

To calculate the average manhours arranged on the vertical axis in the graphs, the BRE computer-produced total data summary tables (discussed in chapter 4) were converted by hand methods into further tables. These tables provided results (in terms of average manhours per house for each house block on the site, for each operation analysed) that could be directly transferred to the graphs.

For the block order horizontal axis on the graphs a more complicated calculation was necessary. Independently, tables had been made for each block at Greenfield comparing each operation listed in approximate building sequence in the first column, against the production weeks of the block in subsequent columns, giving a table of manhours per operation per week. A typical example from this work is illustrated here for a block from Greenfield. This table is discussed in detail in chapter 9. As an example, the operation of completing all the work on doors at Greenfield could be extracted from the 18 block tables

just mentioned as a series of manhours per week through a number of weeks for each block. These series of manhours per week can order the blocks by the first or last week in which manhours were recorded for the doors operations. However, a block that begins first may not end first, or vice versa. The measure chosen selects the week for ordering purposes when 50 percent of the work on the doors operation was reached (usually this falls within the most concentrated period of work on each block i.e. small numbers of manhours per week tend to lead into and end the work on most operations).

Handling all the BRE computer-produced weekly and summary data tables by hand working for the Greenfield operations was complicated and very time consuming to achieve by the two methods just described. As a result, in all, only three separate Greenfield operations were hand worked through this and the other two main forms of detailed analysis chosen (discussed in the following two chapters).

A key that separates the Greenfield 5-person and 7-person house block results in the graphs is given below:

- ● 5-person house blocks
- ◑ 7-person house blocks.

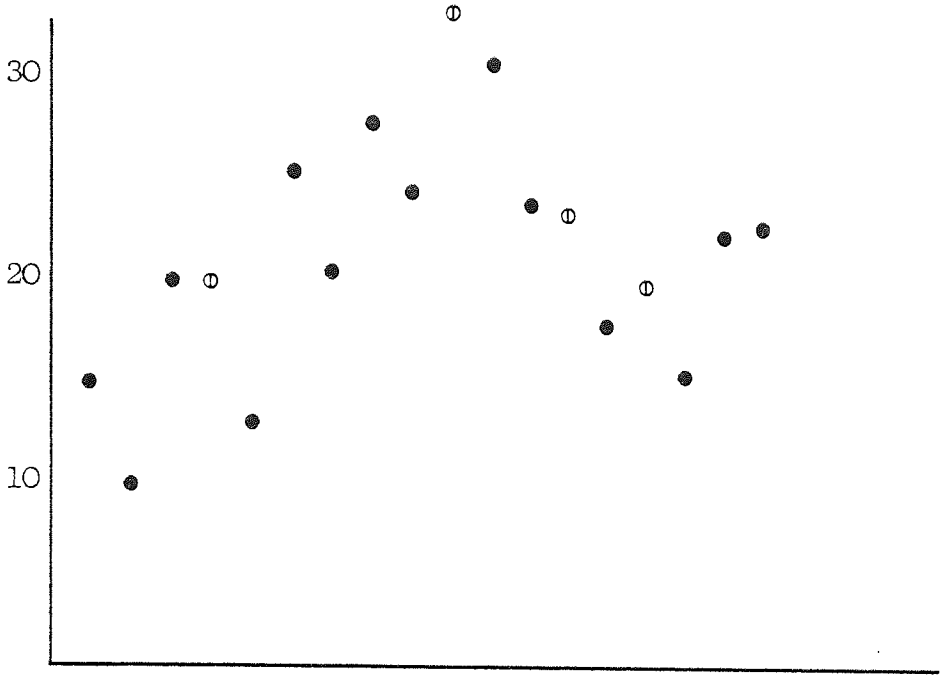
ANALYSIS OF THE GREENFIELD GRAPHS

The three Greenfield operation graph pages each contain the following headings under the graph, which provide selected facts or results on each operation, that can then be referred to in the analysis text. The headings selected are as follows:

1 : GREENFIELD SURVEY OPERATION CODE

The operation code number (usually a group of operations that are defined

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

GREENFIELD SURVEY OPERATION CODE : 10C

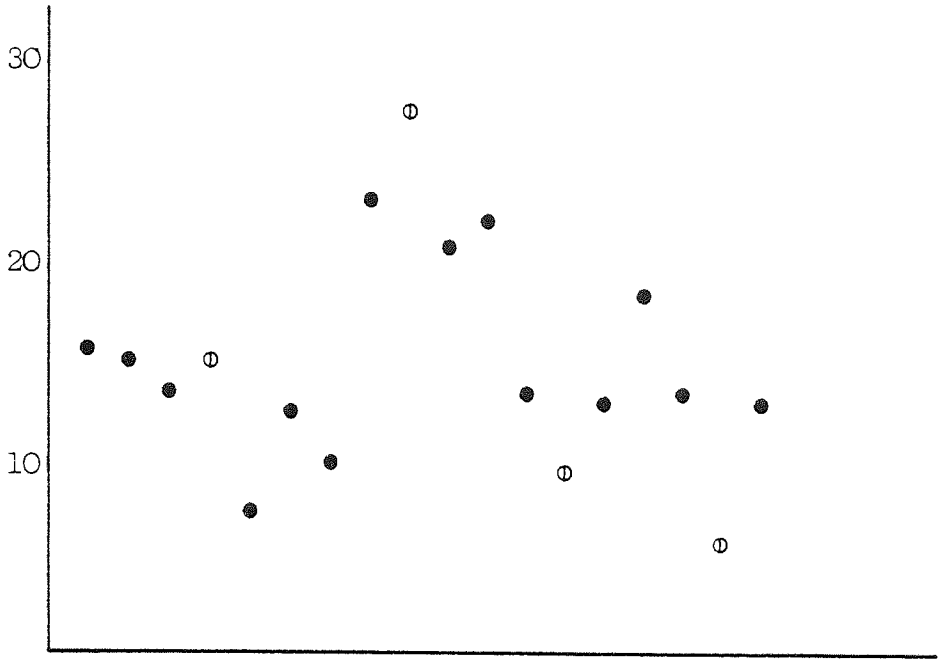
OPERATION WORK : INTERNAL PLUMBER CARCASSING

VARIATION IN MANHOURS : MORE THAN 3 : 1

GRAPH RELATIONSHIP : RANDOM

AVERAGE MANHOURS

PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

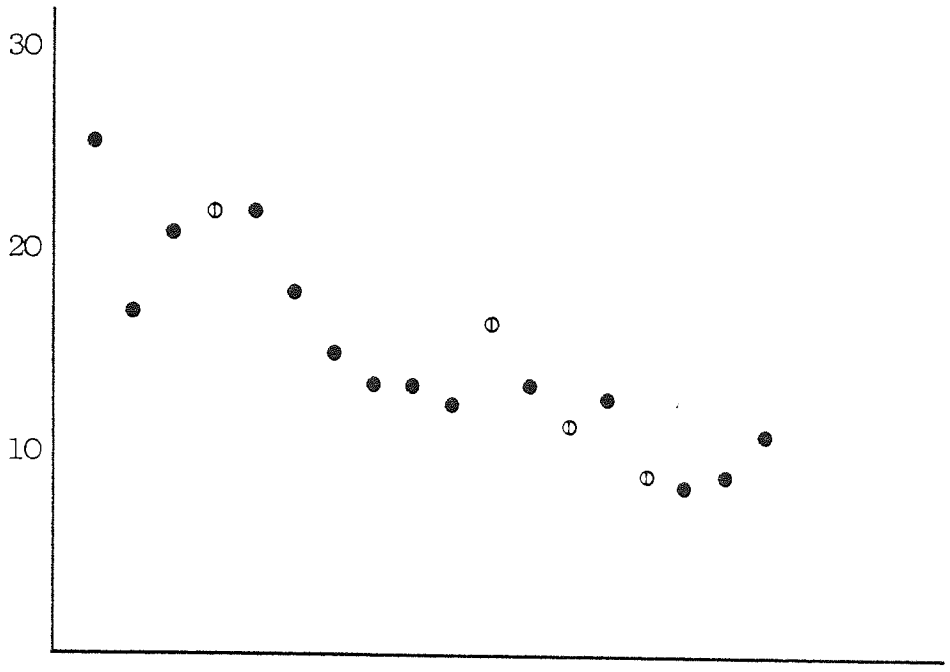
GREENFIELD SURVEY OPERATION CODE : 14D

OPERATION WORK : PLASTERBOARD LINING JOINTS

VARIATION IN MANHOURS : MORE THAN 3 : 1

GRAPH RELATIONSHIP : RANDOM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

GREENFIELD SURVEY OPERATION CODE : 16A

OPERATION WORK : ALL WORK ON INTERNAL AND EXTERNAL DOORS

VARIATION IN MANHOURS : MORE THAN 3 : 1

GRAPH RELATIONSHIP : LINEAR

by code letters in appendix 1)

2 : OPERATION WORK

The work content of the operation

3 : VARIATION IN MANHOURS

The general ratio of variation in manhours for the operation

4 : GRAPH RELATIONSHIP

The general graph line form of any relationship between manhours and block construction order.

The graphs for operations 10C and 14D both suggested, graphically, a peak line shape, that seems to indicate less efficient working in the middle of the block construction order, when the most blocks were being built at one time. However, this graphical shape is not significant statistically. Statistical tests show only an essentially random distribution, forming no firm relationship between manhours and block construction order.

However, the work on internal and external doors (operation code 16A) does form a statistically significant linear decrease in manhours with the block order, shown clearly on the graph. A special influence, that is known from non-activity sampling records in the survey, that may have sharply increased manhours spent on doors in the first blocks constructed, was the employment of far too many joiners due to access problems for the trade in working on the flat blocks built on the Greenfield site, at the same time as the house blocks. There seems to be many other special influences of this kind, that the activity sampling method does not account for, which could add explanation to the results found on all operations. Overall, the variation in manhours was more than 3 : 1, for each of these Greenfield operations. This indicates that considerable improvements in productivity could

be made if the conditions that create the variation in manhours were better known.

SIXTEEN BLANTYRE WORK OPERATION GRAPHS

The results at Greenfield gave some encouragement to the development (described in chapter 4) of computer application on the Blantyre data, to make possible the study of a much wider number of trade operations to further test the analysis. The computer output had to be equivalent to the hand produced tables on each block at Greenfield, showing manhours against each operation in approximate building sequence for each site working week. The table was finally constructed on two computer line-printer outputs containing site weeks 3 to 41 and 42 to 76, respectively. These output tables were used to calculate block order by 50 percent of the work done on an operation, in the same way as described for Greenfield.

The BRE computer-produced summary tables for Blantyre were converted by hand methods (the same work that had been done for Greenfield) into further tables giving the variation in labour requirements in terms of average manhours per house for each block on the site for each Blantyre operation discussed.

As previously described for Greenfield, in the Blantyre graphs that follow average manhours per house for each block on the site are always shown on the vertical axis and block construction order on the horizontal axis. The manhours given are those derived from the activities F, N and P only (the activities are defined in appendix 3.1).

The development of computer application on the Blantyre data, to suit the detailed analysis, made it possible to attempt sixteen separate

operations in the form of analysis discussed in this chapter and also in each of the two analysis forms discussed in the next two chapters.

A key that separates the Blantyre 2-person, 4-person and 5-person house block results in the graphs is given below:

⊖ 2-person house blocks

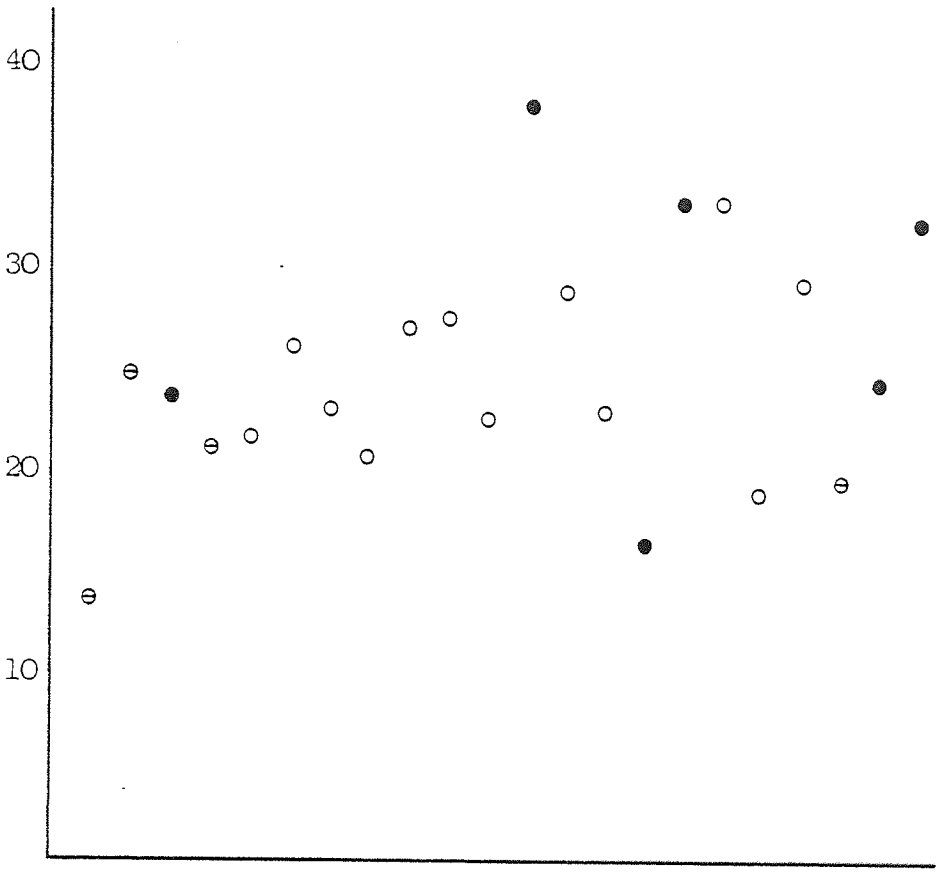
○ 4-person house blocks

● 5-person house blocks.

ANALYSIS OF THE BLANTYRE GRAPHS

Each graph page illustrating the sixteen Blantyre operations analysed in the study, contains the same information about the graph previously described for the Greenfield operations, with the addition of a statement, where appropriate, excluding the 2-person house block results from many of the operations as they concern houses containing significantly less work for reasonable comparison with the other house types on the site. The Blantyre operation code letters in each graph are defined in appendix 2. Comparing the results of variation in manhours from the operation graphs, the Blantyre operations tended to vary less than the common 3 : 1 variation found for the three operations analysed at Greenfield. Comparing the same operations from Greenfield and Blantyre, the lower variation in man-hours is confirmed with operations 28E,F and 33A,B,C,D at around 2 : 1 and operation 31A,B,C at around 3 : 2, compared to the general 3 : 1 variation at Greenfield. However, some other trade operations at Blantyre had the same order of 3 : 1 variation in man-hours discovered at Greenfield.

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 5A,B,C,D,E,F,G,J

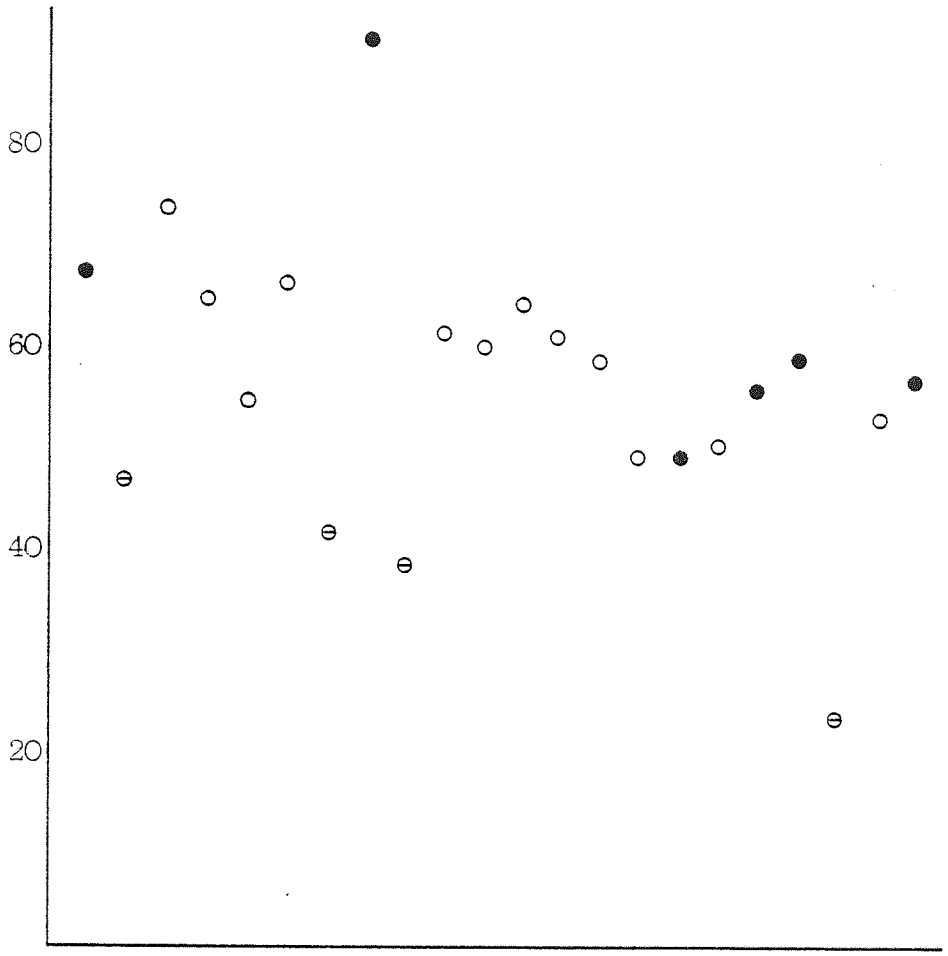
OPERATION WORK : BRICKWORK SUBSTRUCTURE

TWO-PERSON HOUSE BLOCKS : INCLUDED

VARIATION IN MANHOURS : MORE THAN 2 : 1

GRAPH RELATIONSHIP : RANDOM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 16, 18, 20

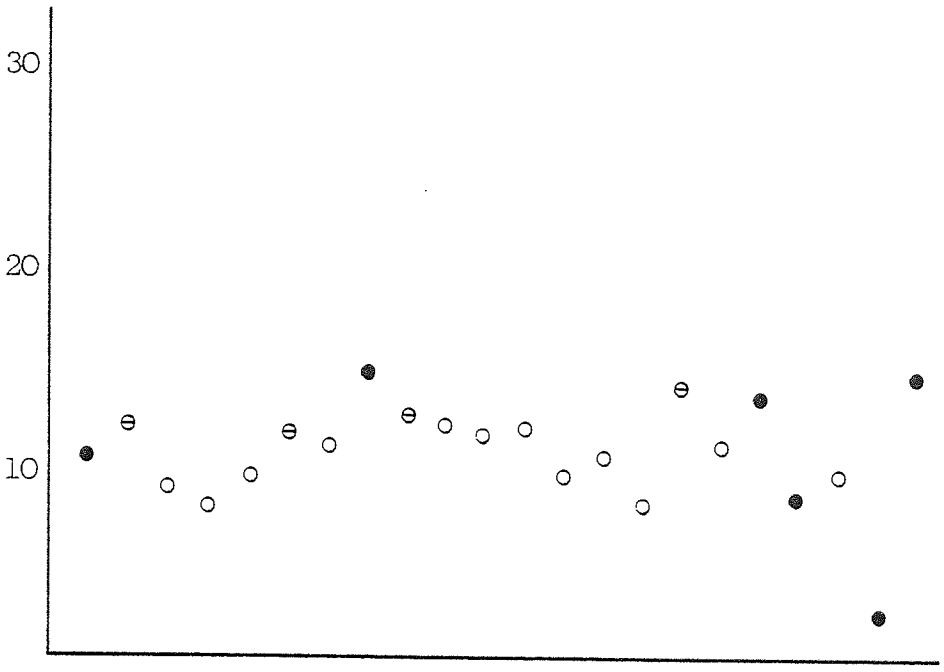
OPERATION WORK : BRICKWORK SUPERSTRUCTURE

TWO-PERSON HOUSE BLOCKS : EXCLUDED

VARIATION IN MANHOURS : MORE THAN 3 : 2

GRAPH RELATIONSHIP : RANDOM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 22A,B,C,D

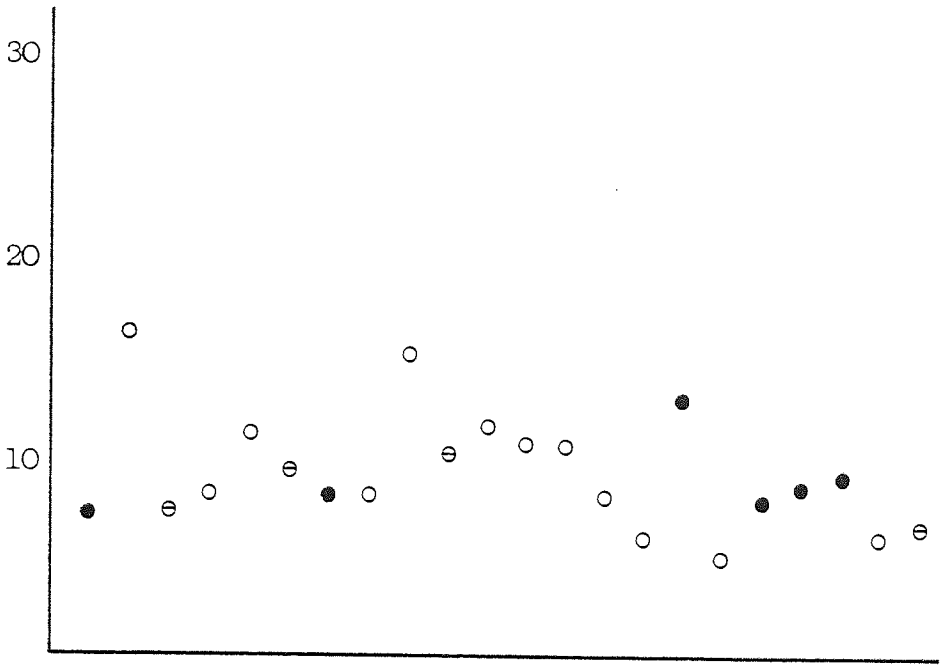
OPERATION WORK : ROOF COVERING INCLUDING TILES

TWO-PERSON HOUSE BLOCKS : INCLUDED

VARIATION IN MANHOURS : MORE THAN 3 : 2

GRAPH RELATIONSHIP : RANDOM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 24B

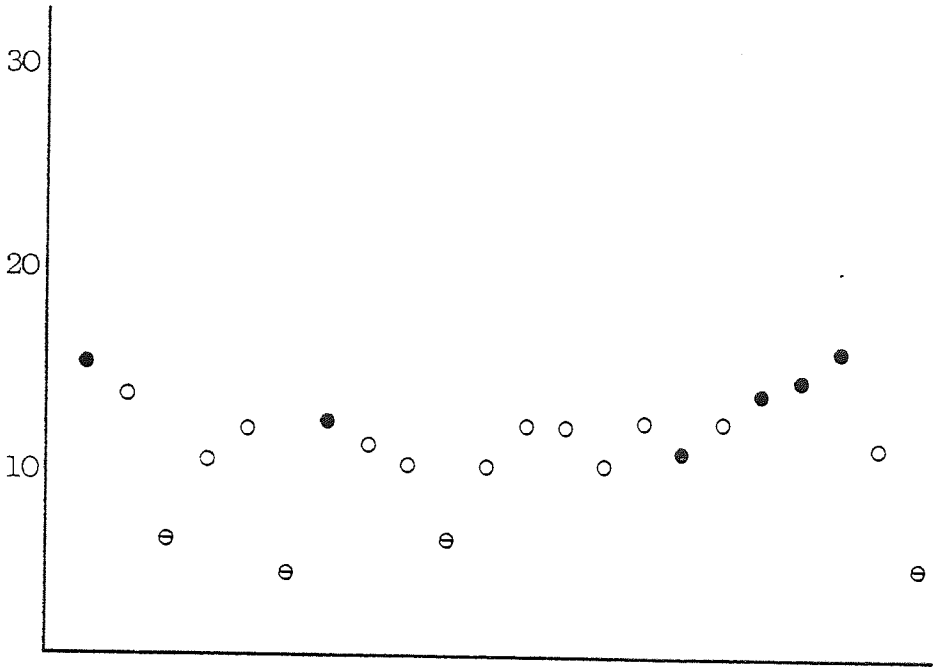
OPERATION WORK : PLASTERBOARD (PARAMOUNT) ROOM PARTITIONS

TWO-PERSON HOUSE BLOCKS : INCLUDED

VARIATION IN MANHOURS : MORE THAN 3 TO 1

GRAPH RELATIONSHIP : RANDOM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 27A,B,C

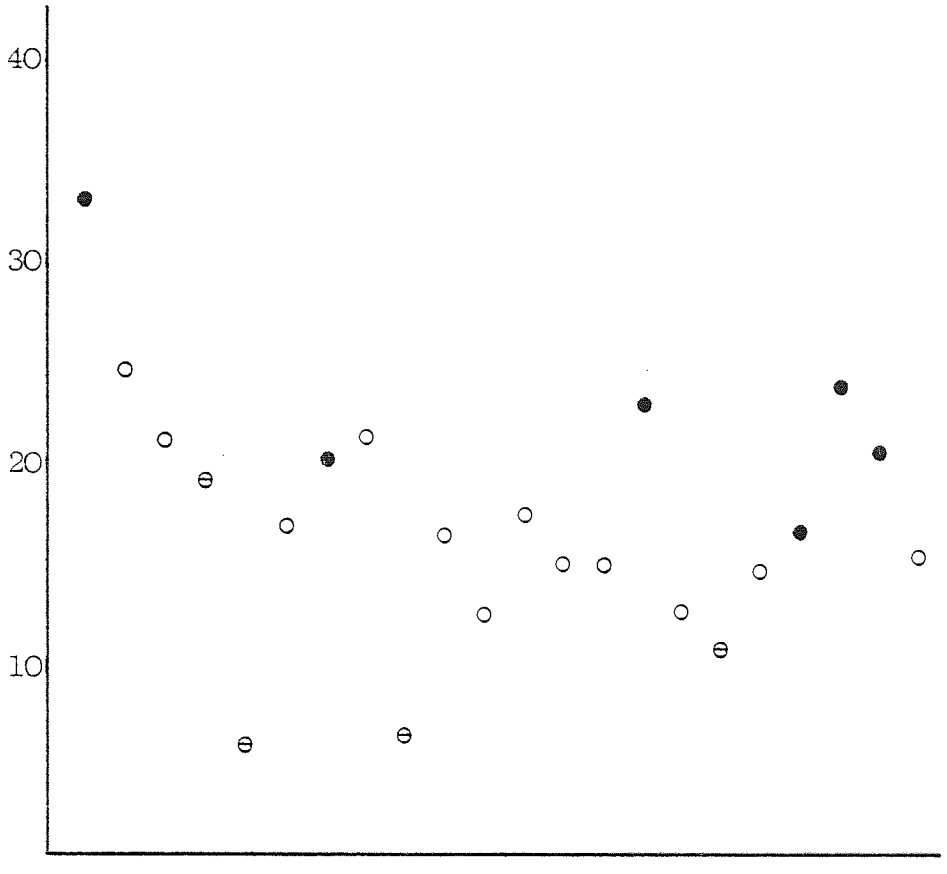
OPERATION WORK : PLASTERBOARD LININGS TO BRICK WALLS

TWO-PERSON HOUSE BLOCKS : EXCLUDED

VARIATION IN MANHOURS : MORE THAN 3 : 2

GRAPH RELATIONSHIP : RANDOM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 27D,E

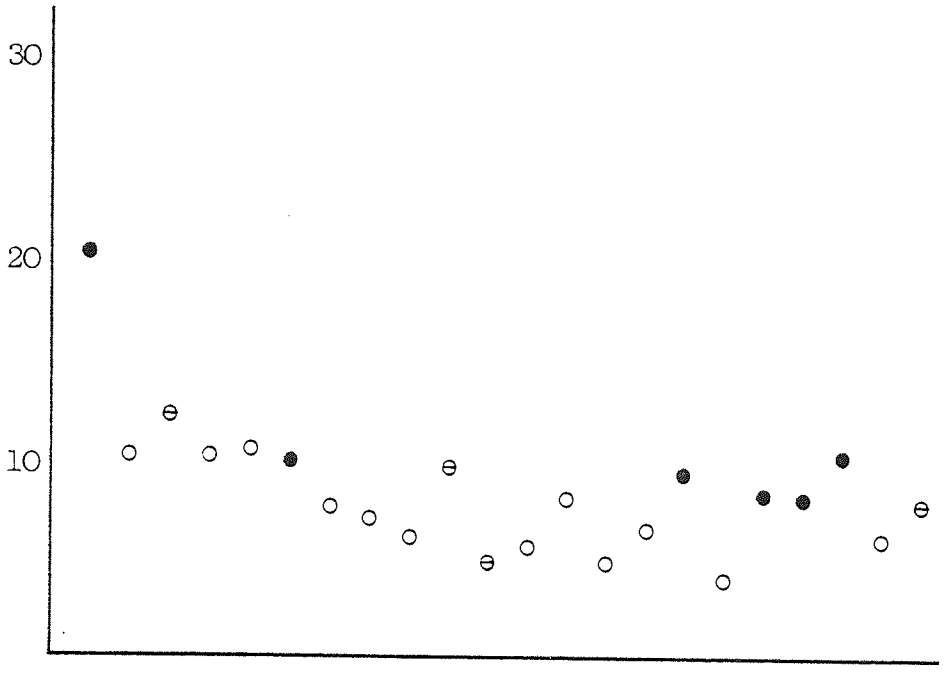
OPERATION WORK : PLASTERBOARD LININGS TO CEILINGS AND TIMBER STUD PARTITION

TWO-PERSON HOUSE BLOCKS : EXCLUDED

VARIATION IN MANHOURS : MORE THAN 2 : 1

GRAPH RELATIONSHIP : RANDOM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 28E,F

OPERATION WORK : ALL PLUMBING WORK

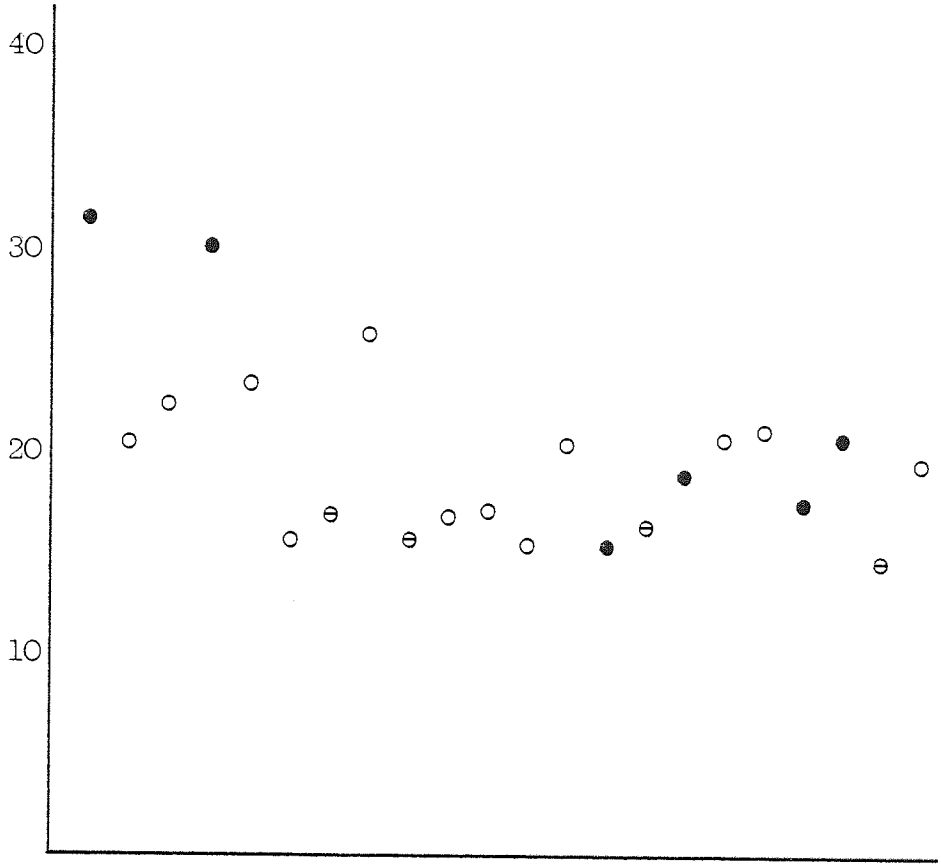
TWO-PERSON HOUSE BLOCKS : INCLUDED

VARIATION IN MANHOURS : MORE THAN 2 : 1

GRAPH RELATIONSHIP : LINEAR

AVERAGE MANHOURS

PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 29A,B

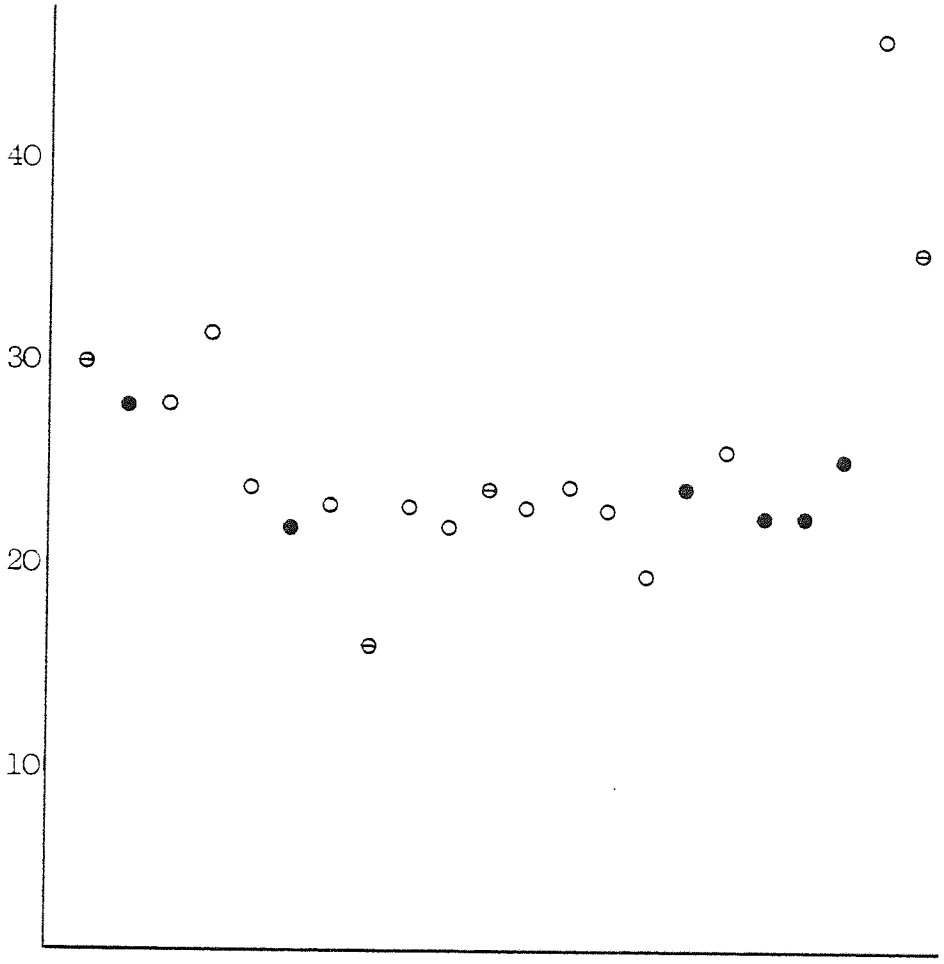
OPERATION WORK : ALL ELECTRICAL WORK

TWO-PERSON HOUSE BLOCKS : EXCLUDED

VARIATION IN MANHOURS : MORE THAN 3 : 2

GRAPH RELATIONSHIP : RANDOM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 31A,B,C

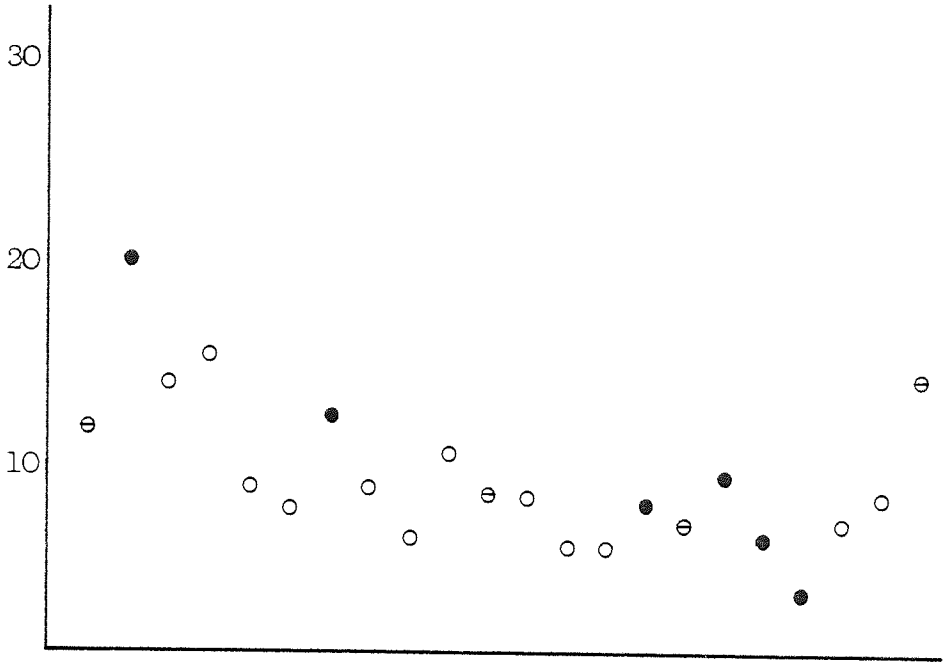
OPERATION WORK : ALL WORK ON INTERNAL AND EXTERNAL DOORS

TWO-PERSON HOUSE BLOCKS : EXCLUDED

VARIATION IN MANHOURS : MORE THAN 3 : 2

GRAPH RELATIONSHIP : RANDOM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 31D

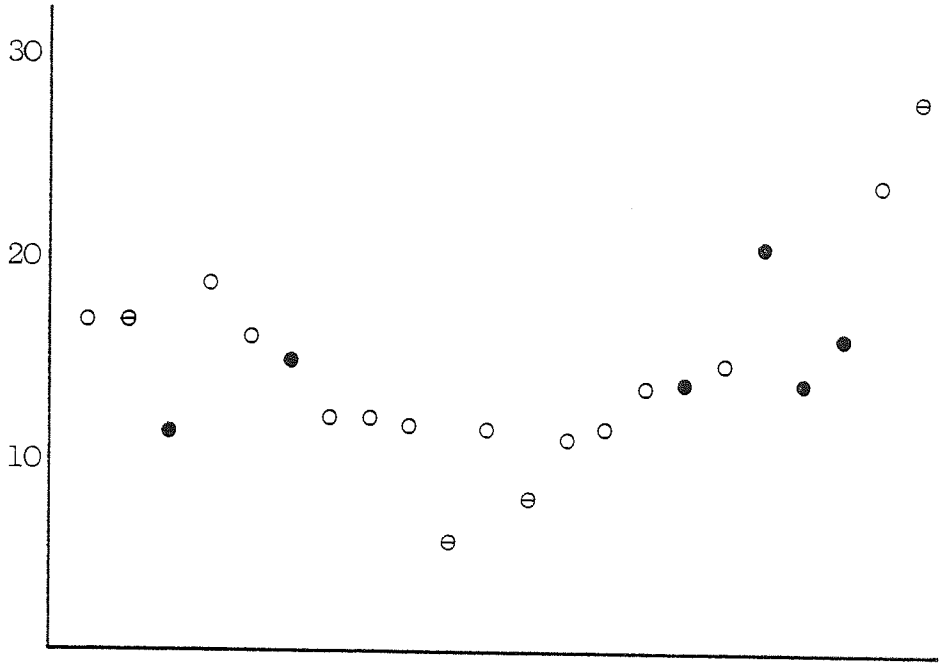
OPERATION WORK : KITCHEN FITTINGS

TWO-PERSON HOUSE BLOCKS : INCLUDED

VARIATION IN MANHOURS : MORE THAN 3 : 1

GRAPH RELATIONSHIP : LINEAR

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 31F,G,H,J

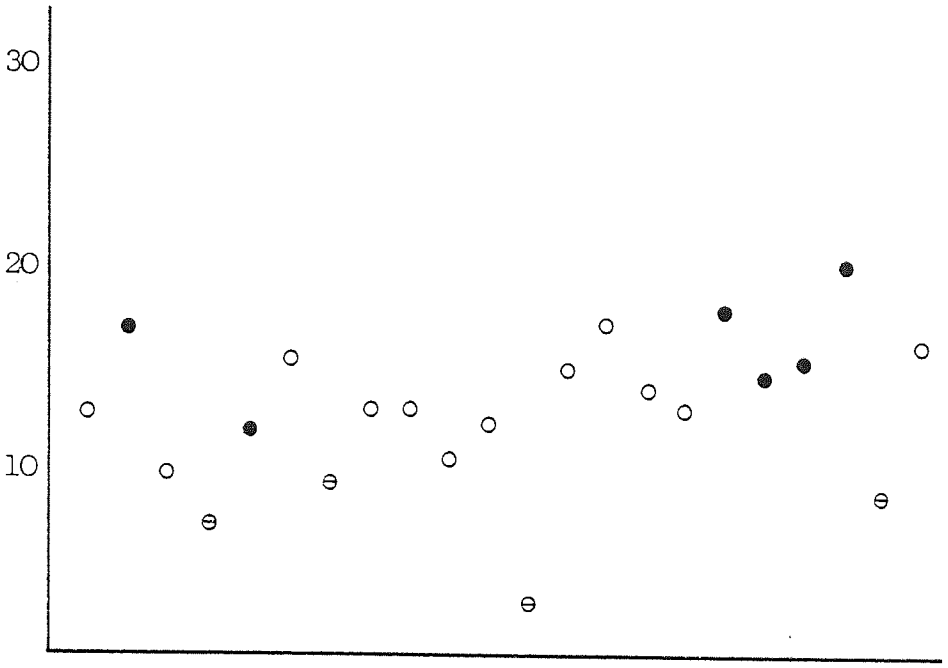
OPERATION WORK : FINAL INTERNAL JOINERY

TWO-PERSON HOUSE BLOCKS : EXCLUDED

VARIATION IN MANHOURS : MORE THAN 2 : 1

GRAPH RELATIONSHIP : CURVE FORM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 33A,B,C,D

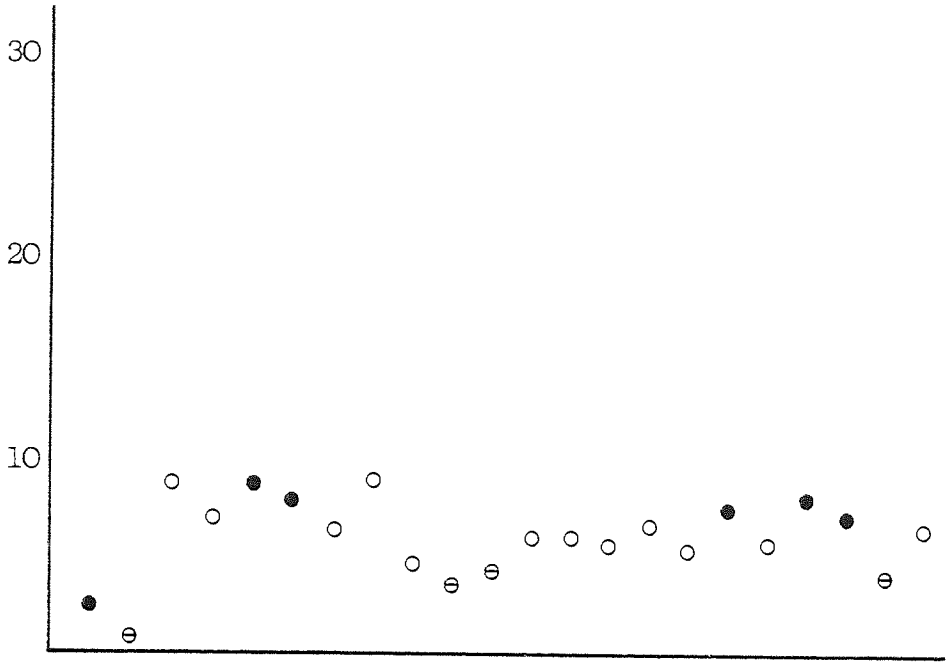
OPERATION WORK : PLASTERBOARD LINING JOINTS

TWO-PERSON HOUSE BLOCKS : EXCLUDED

VARIATION IN MANHOURS : MORE THAN 3 : 2

GRAPH RELATIONSHIP : RANDOM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 33E

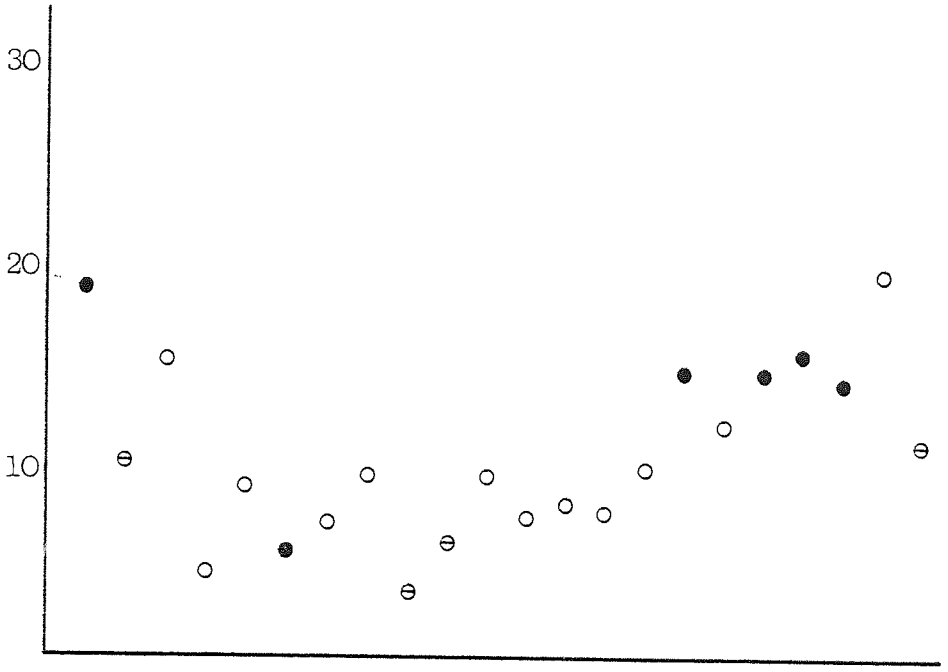
OPERATION WORK : (ARTEX) CEILING FINISH

TWO-PERSON HOUSE BLOCKS : EXCLUDED

VARIATION IN MANHOURS : MORE THAN 3 : 2

GRAPH RELATIONSHIP : RANDOM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 34A

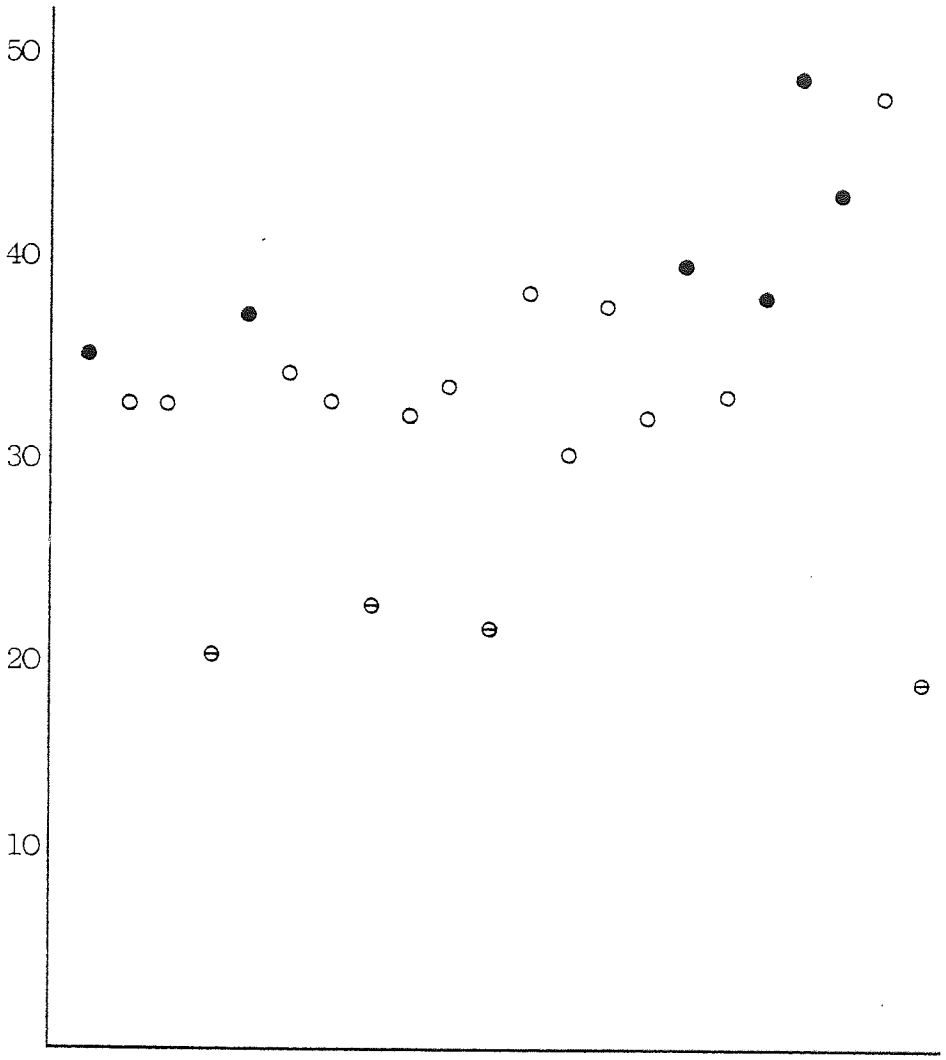
OPERATION WORK : INTERNAL EMULSION PAINTING

TWO-PERSON HOUSE BLOCKS : EXCLUDED

VARIATION IN MANHOURS : MORE THAN 3 : 1

GRAPH RELATIONSHIP : CURVE FORM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 34B

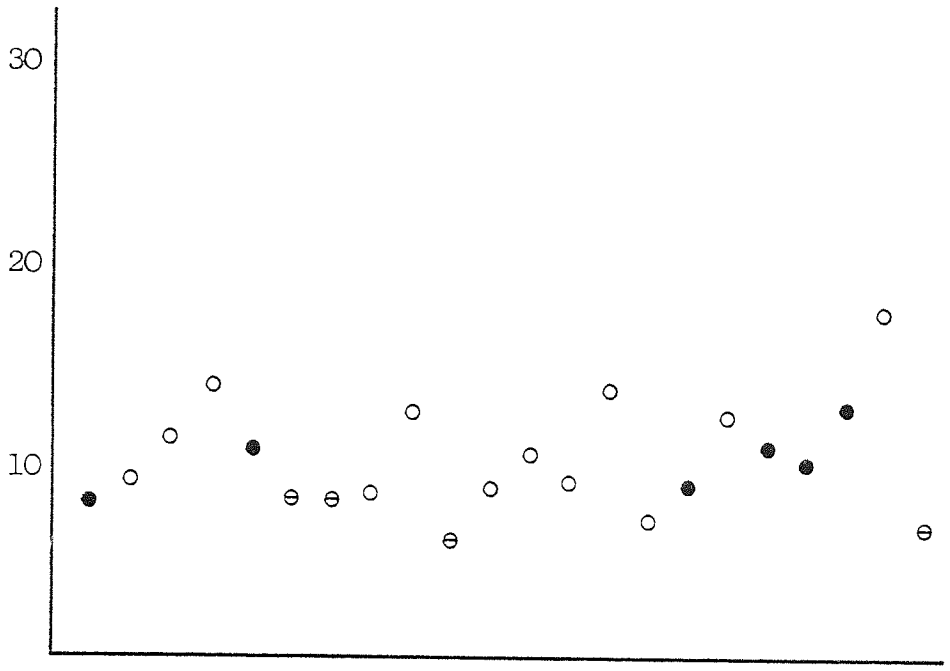
OPERATION WORK : INTERNAL GLOSS PAINTING

TWO-PERSON HOUSE BLOCKS : EXCLUDED

VARIATION IN MANHOURS : MORE THAN 3 : 2

GRAPH RELATIONSHIP : RANDOM

AVERAGE MANHOURS
PER HOUSE



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 34C

OPERATION WORK : EXTERNAL GLOSS PAINTING

TWO-PERSON HOUSE BLOCKS : EXCLUDED

VARIATION IN MANHOURS : MORE THAN 2 : 1

GRAPH RELATIONSHIP : RANDOM

Each Blantyre operation graph was systematically tested for any clear statistical relationship between manhours and the order of construction of the blocks. For twelve of the sixteen operations, the results of the tests were negative, in that the relationship between manhours and order was random, thus proving no significant effect of construction order on manhours. However, the remaining four operations provided two different conclusions from the test. These conclusions were:

1

Operations 28E,F and 31D which both show a general downward trend of improvement in manhours with order, that is statistically confirmed as a significant linear relationship.

2

Operations 31F,G,H,J and 34A both show a curved graph shape, that first improves gradually in manhours, then follows a particularly low variaton period in the centre of the graph and finishes with a marked deterioration in manhours for blocks at the end of the order. Together with operations 31A,B,C and 27D,E, whose early blocks showed a marked general improvement in manhours, these results generally agree with the early learning phase (called the routine acquiring stage), identified by the UN Report for repeated work operations (UN, 1965). However, most of the other Blantyre operations do not show this early effect, which suggests that learning is not an important factor in these operations, principally because the work involved is so well known to the trades involved, from one traditional house building project to the next.

At least one of the operations with a statistically significant shape, namely 16A at Greenfield, has a known explanation for the

particularly high manhours in early blocks (discussed in the Greenfield analysis section earlier in this chapter) that does not involve learning as a significant influence on manhours. If more were known of the other operations with a non-random relationship, they too may be largely explained without reference to learning as a significant influence.

STATISTICS TESTS APPLIED

The statistic tests employed on the results shown in the operation graphs discussed in this chapter, were standard statistical techniques embodied in SOCS computer programmes, into which the results for each operation were fed through a remote computer terminal. The techniques used were auto-correlation methods to test for randomness in time and for the few non-random results, regression analysis was used to determine the form of the graph pattern found.

SUMMARY

Overall, and to provide a brief summary of this chapter, the operation graphs show that manhours in the operations analysed for Greenfield and Blantyre varied by ratios of 3 : 2 to 4 : 1 or more. For most of the operations analysed, the manhour variation formed a random relationship with house block order in construction. Only a few operations formed any recognisable relationship with construction order e.g. when manhours fell for the first few house blocks indicating a possible effect of learning to do the work in a repeated operation. For many operations, however, learning does not appear to be a significant factor in the variation in manhours discovered by the analysis.

CHAPTER 7

BLANTYRE AND GREENFIELD DETAILED DATA ANALYSIS : MANHOURS COMPARED WITH SEPARATE OPERATIVE VISITS

The analysis in this chapter covers the same set of work operations from Greenfield and Blantyre, that were discussed in chapter 6. The chapter represents the second of three forms of analysis made in the study on each of the selected operations from the two sites.

THE DEFINITION OF THE FORM OF ANALYSIS

The detailed analysis of the variation in manhours, in terms of average manhours per house, compared with an estimate of the average number of separate operative visits per house, to complete a similar operation, for each house block on the site.

THE OBJECTIVES OF THE FORM OF ANALYSIS

This form of detailed data analysis, that compares average manhours with visits, was developed for three diverse reasons:

1

Random inspection of the computer-produced BRE weekly data tables (appendices 4 and 6, tables 4.1 and 6.1 respectively) confirmed that operative work in many operations was not continuous from observation to observation. The work on an operation was too often divided between a number of days in any number of weeks and appeared, overall, to be highly disorganised. Interruptions to work on an operation by an operative are numerous in character but, as previously stated, the activity sampling data provides little information on the causes of interrruptions, which necessitate further visits to complete the work.

Two causes of interruptions which could be explored with future applications of activity sampling, on development projects, to produce comparable results to those that follow in this study, are the main contractor's organisation of the work and the overall, and detailed design.

In the production of Blantyre and Greenfield, the contractors seem to have caused numerous interruptions (see example block tables from Blantyre and Greenfield in chapter 9) by poor work organisation. Other interruptions may have been necessary because of the nature of the design, and yet other interruptions may have been caused by many factors not related to the design or the contractor's organisation. Nonetheless, the design and the contractor's organisation could, even for special factors such as the weather, plan to reduce or eliminate the detrimental effect of interruptions. Interruptions are assumed to cause inefficient working by, for example, increasing preparation for working, clearing-up after work stops, the disruption of a working rhythm and introducing a new operative to an operation who is unfamiliar with what has happened in the work so far.

An important aim of traditional house building projects should be to produce a design that is simple to build and that allows a series of large, independent, trade operations, making the problem of site work organisation simple too. In this effort to eliminate interruptions caused by work organisation and design, the other factors causing interruptions should become isolated and the particular effect of say an incentive scheme more recognisable. The effort should focus attention, continuously, on factors that help or hinder efficiency.

2

The activity sampling data is capable of giving a form of visits measurement. The BRE computer programme provide an ordered weekly list of the activity sampling observations by operative day i.e. the recorded observations on each operative on each day in the week. As a preliminary caution that will be discussed again later, the estimation of visits by the definition given means that the minimum measurable visit by the method is one observation, which in the activity sampling method is considered as one manhour..

3

A visits estimation has been made before by the BRE (internal work, unpublished), in which they found a good linear relationship between manhours and visits, but only on a limited scale for which no conclusions have been published. Therefore, further attempts at exploring visits and manhours seemed worthwhile. The exploration would cover new data to see if similar results were found and the data would be on Scottish house building rather than English. In addition, the scale of work covered could be much wider as the Blantyre data would be handled by computer directly to suit the analysis. This would have two advantages:

1

Many different operations could be tested to discover any variation in results from one operation to the next, within or between trades

2

The average number of manhours per visit could be calculated and compared between operations. For example, the brickwork in the superstructure of the houses at Blantyre may be historically better organised and contain more continuous working than the final joinery work.

THREE GREENFIELD WORK OPERATION GRAPHS

For each operation, the graphs in this chapter use the same average manhours per house for each block at Greenfield as were previously calculated for the graphs of the same operations in chapter 6. The average manhour results are, similarly, always shown on the vertical axis of the graphs in this chapter.

Separate operative visits were derived on the definition that a visit was one of a number of consecutive observations in the activity sampling survey data on a work operation and house block which was not interrupted by a non-productive observation (see appendix 3.2 for non-productive activities) included in any consecutive number of observations; confined within the maximum of one operative working day usually represented, at Blantyre for example, by eight observations at hourly intervals. This definition represents the most detail in which the activity sampling method data can estimate separate operative visits to complete an operation.

Briefly, the average number of visits per house for each block were calculated by the following method. Detailed hand analysis on the Greenfield computer-produced weekly tables began by the making of eighteen house block tables (these tables were used in the chapter 6 analysis to calculate house block order) which gave the productive manhours on each operation in each site construction week for each block. An example house block from Greenfield will be discussed in chapter 9. To calculate visits, a further table had to be made by hand methods for each separate operation considered, for each of the eighteen blocks. The manhours for a chosen operation could be withdrawn from the eighteen block tables and this would give the

week numbers in which the operation data could be found for each block. This entirely hand sorting device simplified the search problem of taking data from ninety separate week tables for each operation and block considered. The computer-produced weekly tables provided operative working days (in order), in which observations were contributed to work on the particular operation and block under consideration. From these new operative working day tables the visits were counted, following the previously described definition, from the observations listed. Finally, the number of visits obtained for each block were divided by the number of houses per block to make a feasible application of the analysis. The visits for only three operations were calculated from the Greenfield data, because of the lengthy process just described in brief. They are the same three operations discussed in chapter 6.

In the graphs of the three Greenfield operations, average visits per house for each block on the site are always shown on the horizontal axis and the visits are calculated from consecutive observations in the data of the activities F, N and P only (defined in appendix 3.2).

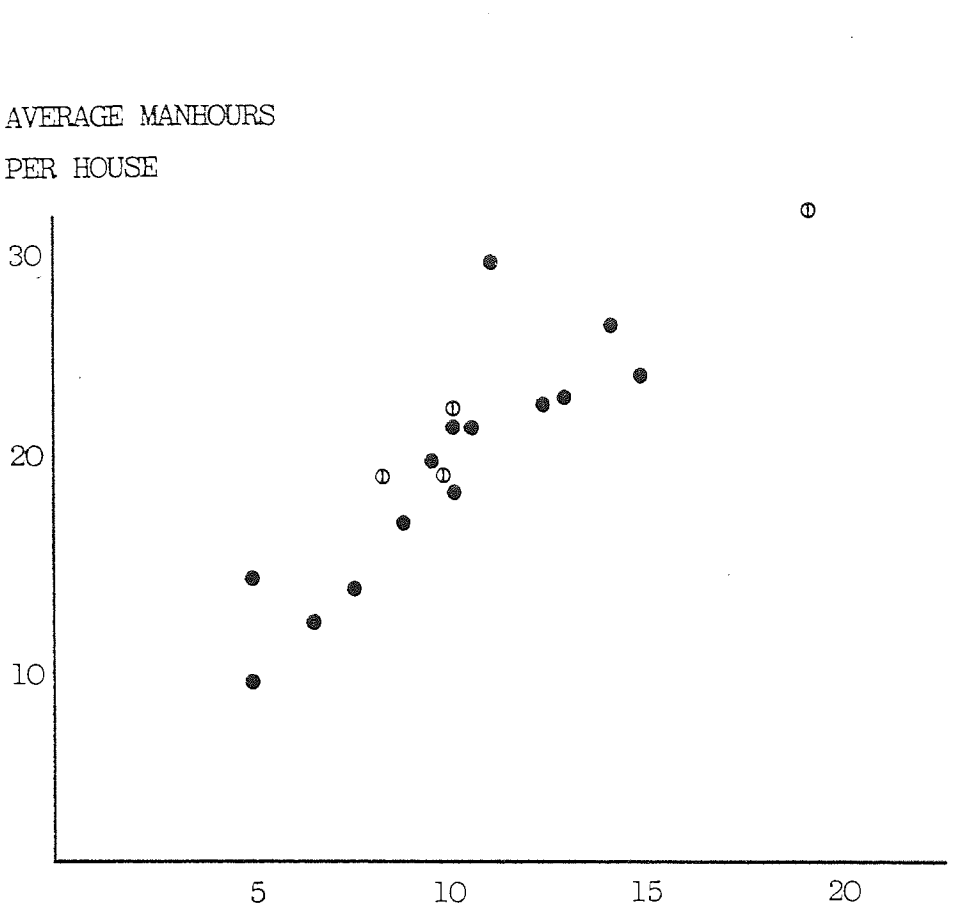
A key that separates the Greenfield 5-person and 7-person house block results in the graphs is given below:

● 5-person house blocks

⏀ 7-person house blocks.

ANALYSIS OF THE GREENFIELD GRAPHS

Following the example of the previous chapter, each graph page states selected facts and results about the graph (this applies to the Blantyre operation graphs as well) that can be referred to in the analysis text. The two new selected results shown under the graphs



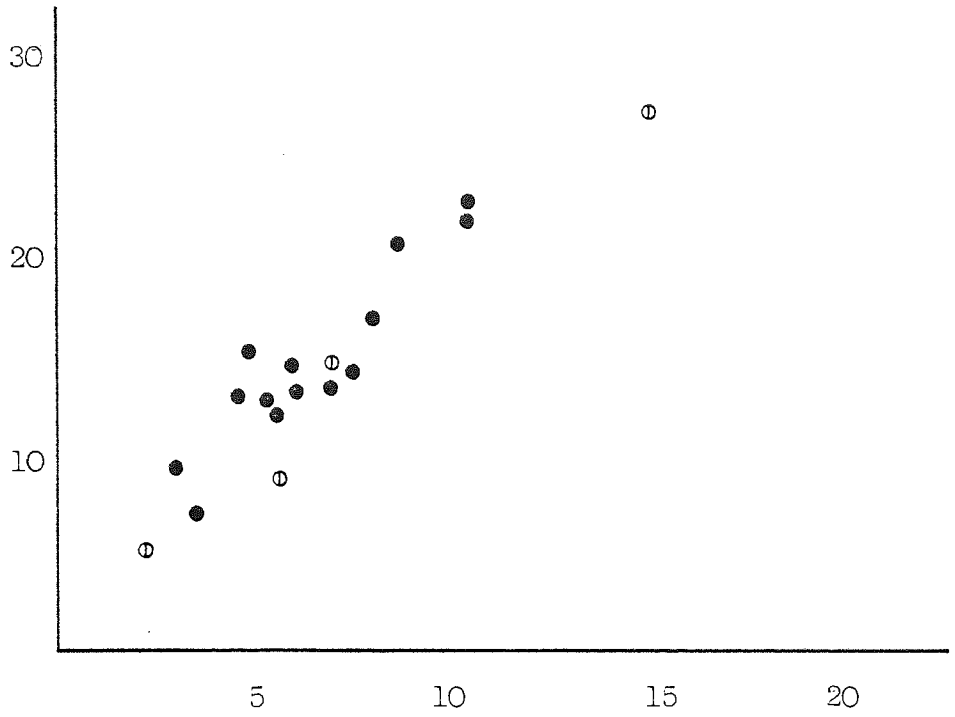
GREENFIELD SURVEY OPERATION CODE : 10C

OPERATION WORK : INTERNAL PLUMBER CARCASSING

CORRELATION COEFFICIENT : 0.887

AVERAGE NUMBER OF MANHOURS PER VISIT : 2.0

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF VISITS PER HOUSE

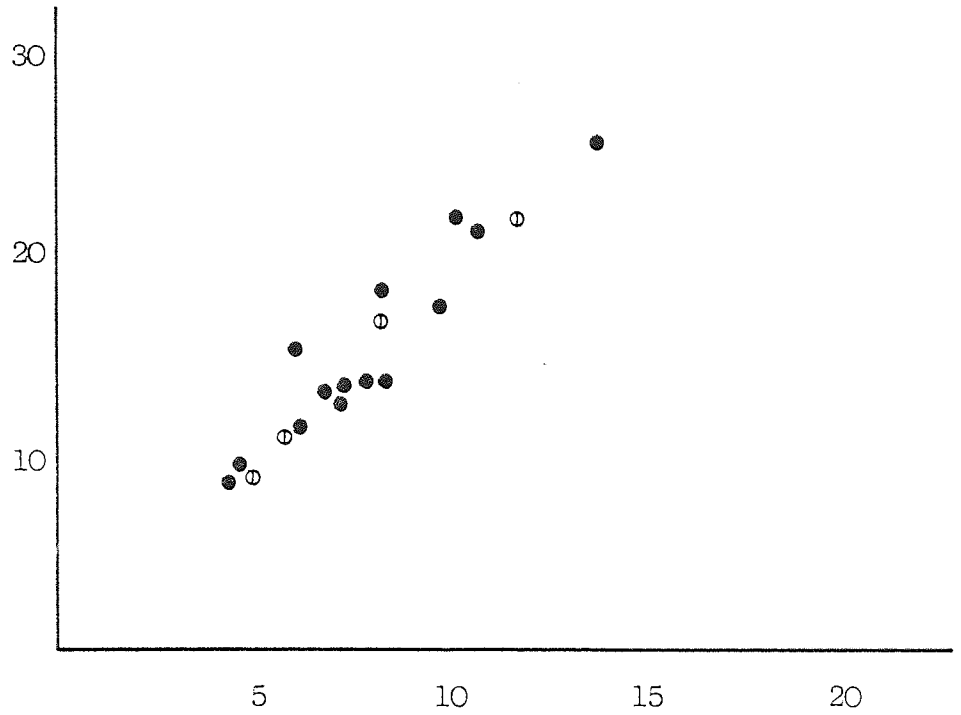
GREENFIELD SURVEY OPERATION CODE : 14D

OPERATION WORK : PLASTERBOARD LINING JOINTS

CORRELATION COEFFICIENT : 0.995

AVERAGE NUMBER OF MANHOURS PER VISIT : 2.14

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF VISITS PER HOUSE

GREENFIELD SURVEY OPERATION CODE : 16A

OPERATION WORK : ALL WORK ON INTERNAL AND EXTERNAL DOORS

CORRELATION COEFFICIENT : 0.932

AVERAGE NUMBER OF MANHOURS PER VISIT : 1.96

in this chapter are as follows:

1: CORRELATION COEFFICIENT

The correlation coefficient at unity would describe a perfect line, representing a form of exact relationship between average manhours and visits in a graph in this chapter. The quality of the relationship between results (manhours and visits in this case) fades from any real significance below a measured coefficient of 0.5.

2: AVERAGE NUMBER OF MANHOURS PER VISIT

The average number of manhours per visit represents an average result between all the house blocks on the site.

All three Greenfield operation graphs easily show a good linear relationship between average manhours and the average number of separate operative visits made per house to each block to complete similar work. The relationship is confirmed by strong correlation coefficients.

However, an early conclusion to these findings, was to suspect the real independence of manhours and visits, which are calculated in a different way from the same activity sampling data source. If all visits were only one observation then the correspondance with man-hours (which are converted directly from separate observations e.g. observations at hourly intervals are one manhour for each observation) would be one to one. For these three Greenfield operations, the average visit lengths were around two manhours per visit (range 1.96 to 2.14). These results are close to a one to one correspondance with the 1½ hourly observation interval in the Greenfield activity sampling survey.

SIXTEEN BLANTYRE WORK OPERATION GRAPHS

For the three Greenfield operations analysed, the relationship between average manhours and visits was strong, but necessarily requires cautious interpretation due to the common data source for assessing both manhours and visits. The analysis seems to have proved limitations on the use of activity sampling data because it can only make a relatively crude measure of the number of actual visits to complete operation work.

However, the limitations were not sufficient to deter further testing of the relationship between manhours and visits for a much wider number of trade operations at Blantyre; especially as the Blantyre activity sampling data contained many more observations that were made at hourly intervals instead of 1½ hourly at Greenfield.

SOCS produced three computer outputs, covering all the operations at Blantyre, for the calculation of visits. Repeating the tables made by hand methods for Greenfield, the SOCS computer outputs listed each observation, of each operative by day, that contributed to each operation. The outputs were a series of house block tables for each operation in sequence. An example of the output is illustrated in appendix 8, table 8.2. Related non-productive observations were shown in each table (as they were in the Greenfield tables produced by hand methods) because, by the stated definition, non-productive observations were not taken as the cause of a new visit and thus they needed to be differentiated from productive observations (not shown on the table) on other operations or blocks. A significant amount of handworking was still required on the computer output to calculate average visits per house for each block on an operation but the same

sixteen operations discussed in chapter 6 were eventually covered.

In the sixteen Blantyre operation graphs, average visits per house for each block on the site are always shown on the horizontal axis. The visits for each operation are calculated from consecutive observations in the Blantyre data of the activities F, N and P only (defined in appendix 3.1).

The average manhours per house for each block in the sixteen Blantyre operation graphs are the same as those calculated for chapter 6. In the operation graphs, average manhours per house for each block on the site are always shown on the vertical axis and the manhours are again those derived from the activities F, N and P only.

A key that separates the Blantyre 2-person, 4-person and 5-person house block results in the graphs is given below:

⊖ 2-person house blocks

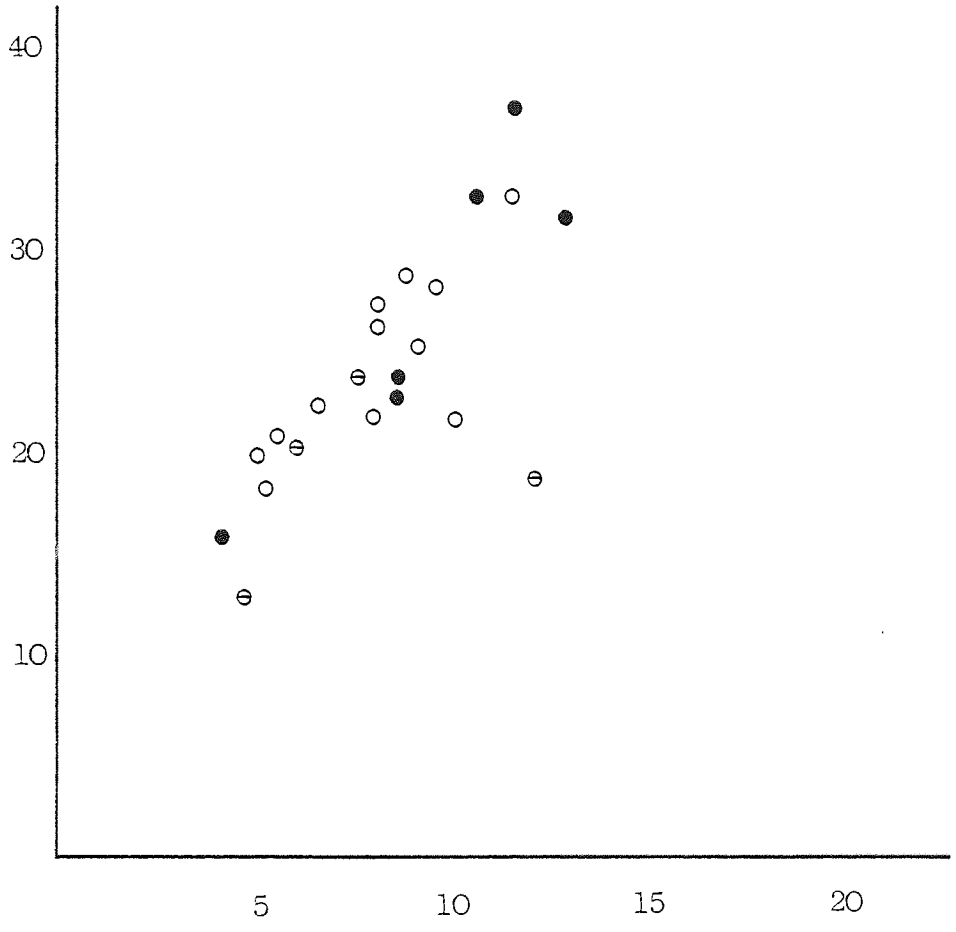
○ 4-person house blocks

● 5-person house blocks.

ANALYSIS OF THE BLANTYRE GRAPHS

Under each Blantyre operation graph, the same list of facts and results about the graph, are listed as previously described for the Greenfield operations analysed in this chapter. In addition, the list indicates whether the 2-person house block results have been excluded from each operation analysis, for involving significantly less work, or not.

In general, a similar linear relationship between average manhours and visits was found for most of the sixteen Blantyre operations analysed (two operations had correlation coefficients of only 0.446



BLANTYRE SURVEY OPERATION CODE : 5A,B,C,D,E,F,G

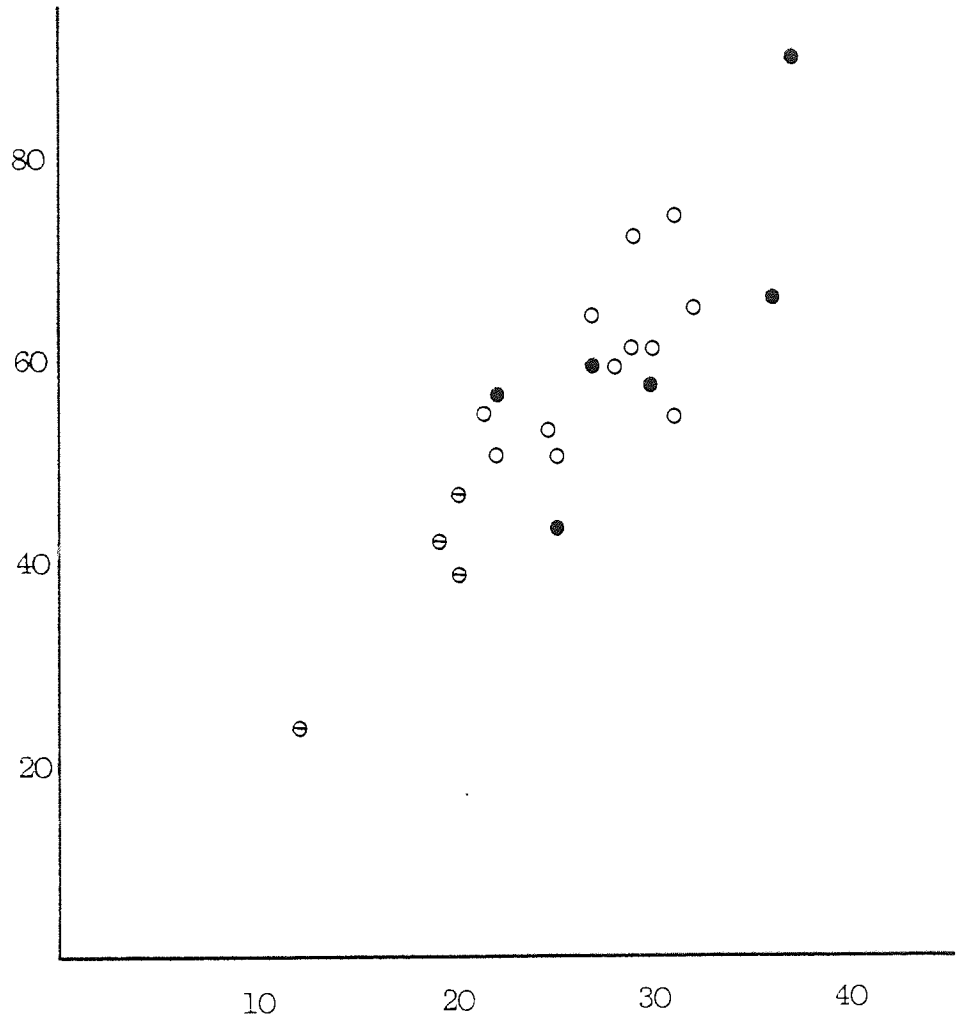
OPERATION WORK : BRICKWORK SUBSTRUCTURE

TWO-PERSON HOUSE BLOCKS : INCLUDED

CORRELATION COEFFICIENT : 0.747

AVERAGE NUMBER OF MANHOURS PER VISIT : 2.98

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF VISITS PER HOUSE

BLANTYRE SURVEY OPERATION CODE : 16, 18, 20

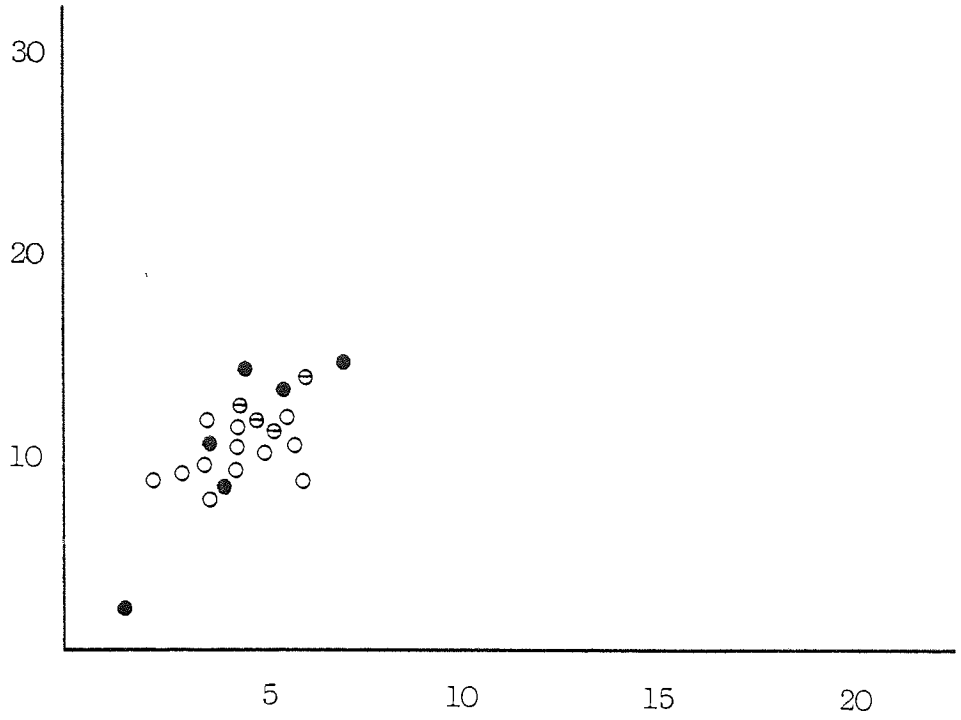
OPERATION WORK : BRICKWORK SUPERSTRUCTURE

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : 0.833

AVERAGE NUMBER OF MANHOURS PER VISIT : 2.15

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF VISITS PER HOUSE

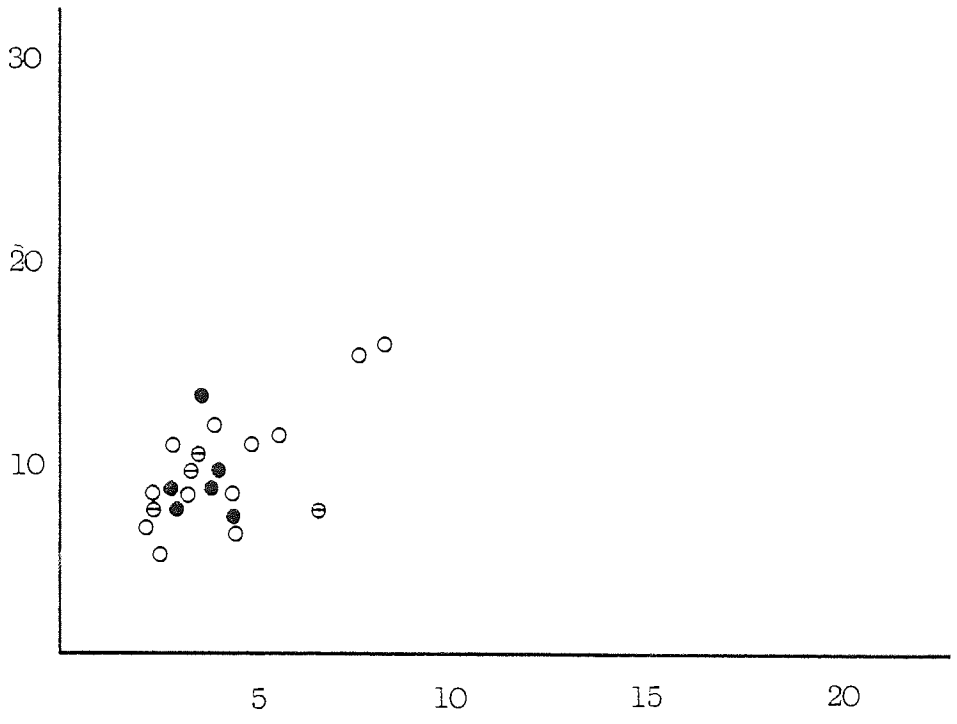
BLANTYRE SURVEY OPERATION CODE : 22A,B,C,D

OPERATION WORK : ROOF COVERING INCLUDING TILES

TWO-PERSON HOUSE BLOCKS : INCLUDED

CORRELATION COEFFICIENT : 0.716

AVERAGE NUMBER OF MANHOURS PER VISIT : 2.33



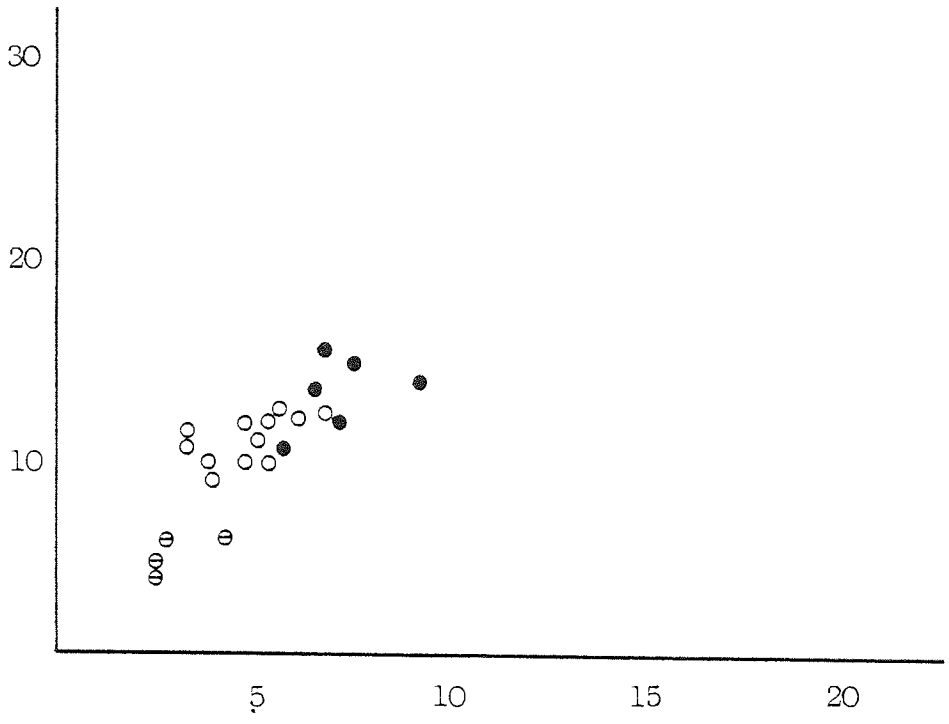
BLANTYRE SURVEY OPERATION CODE : 24B

OPERATION WORK : PLASTERBOARD (PARAMOUNT) ROOM PARTITIONS

TWO-PERSON HOUSE BLOCKS : INCLUDED

CORRELATION COEFFICIENT : 0.763

AVERAGE NUMBER OF MANHOURS PER VISIT : 2.29



BLANTYRE SURVEY OPERATION CODE : 27A,B,C

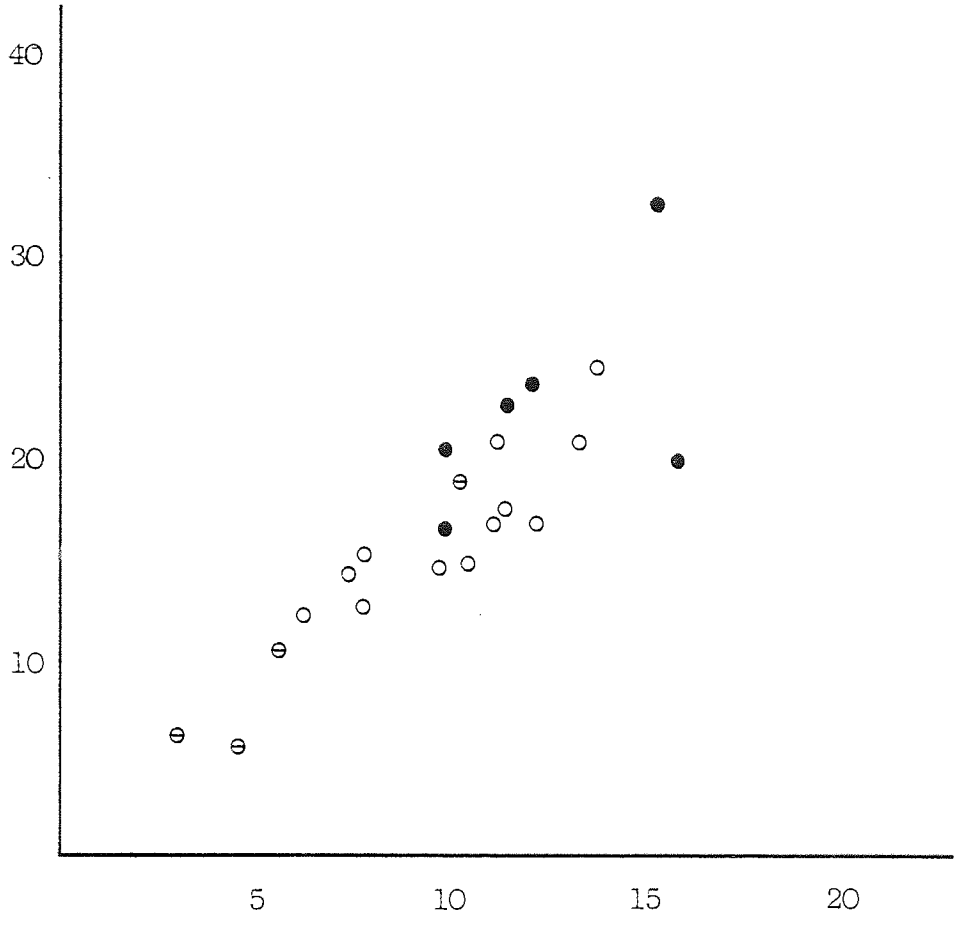
OPERATION WORK : PLASTERBOARD LININGS TO BRICK WALLS

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : INSUFFICIENT DATA DUE TO SEPARATION INTO HOUSE TYPES

AVERAGE NUMBER OF MANHOURS PER VISIT : 2.03

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF VISITS PER HOUSE

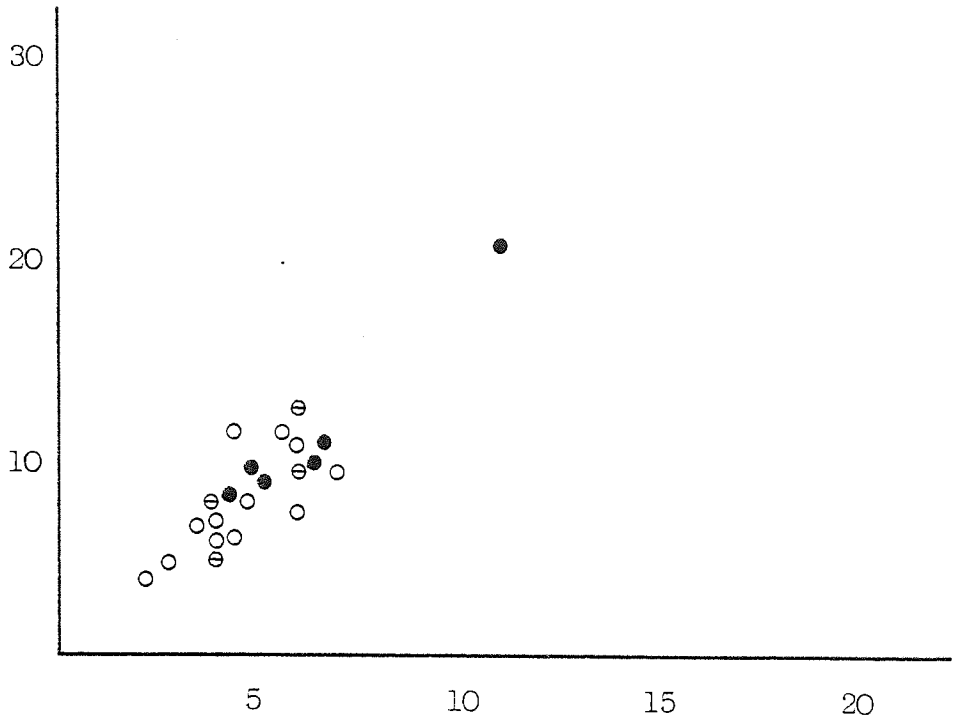
BLANTYRE SURVEY OPERATION CODE : 27D,E

OPERATION WORK : PLASTERBOARD LININGS TO CEILINGS AND TIMBER STUD PARTITION

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : 0.77

AVERAGE NUMBER OF MANHOURS PER VISIT : 1.73



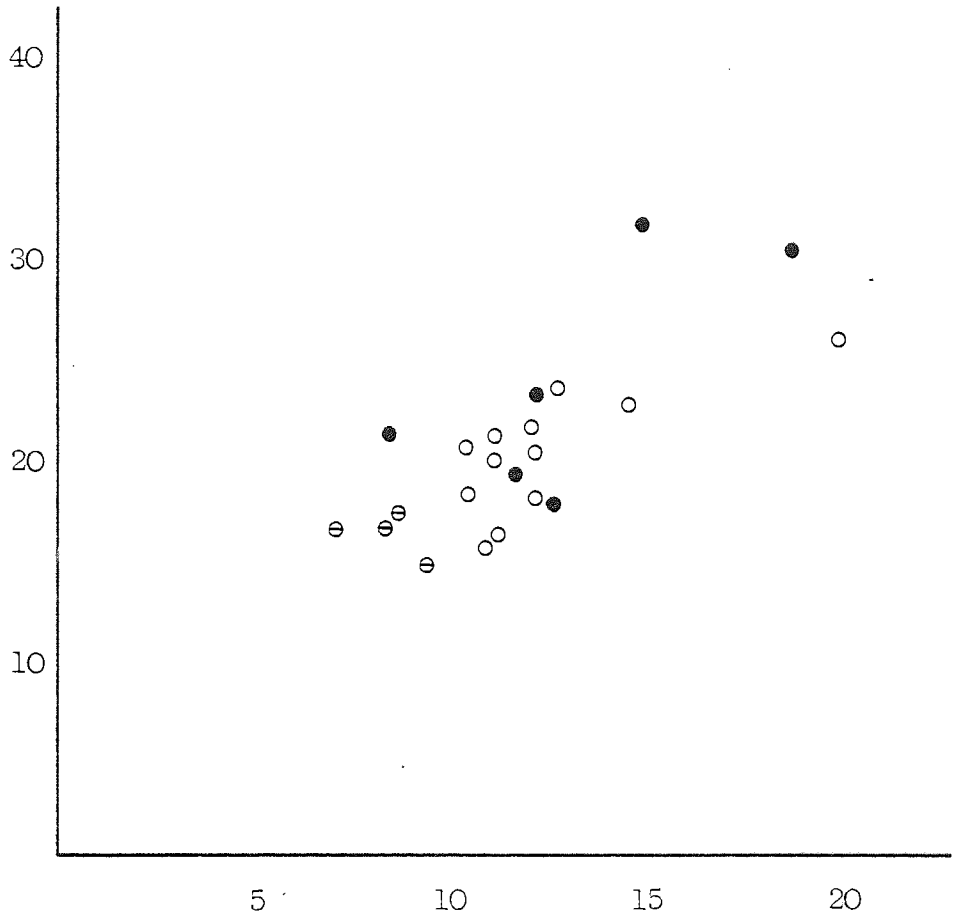
BLANTYRE SURVEY OPERATION CODE : 28E,F

OPERATION WORK : ALL PLUMBING WORK

TWO-PERSON HOUSE BLOCKS : INCLUDED

CORRELATION COEFFICIENT : 0.773

AVERAGE NUMBER OF MANHOURS PER VISIT : 1.74



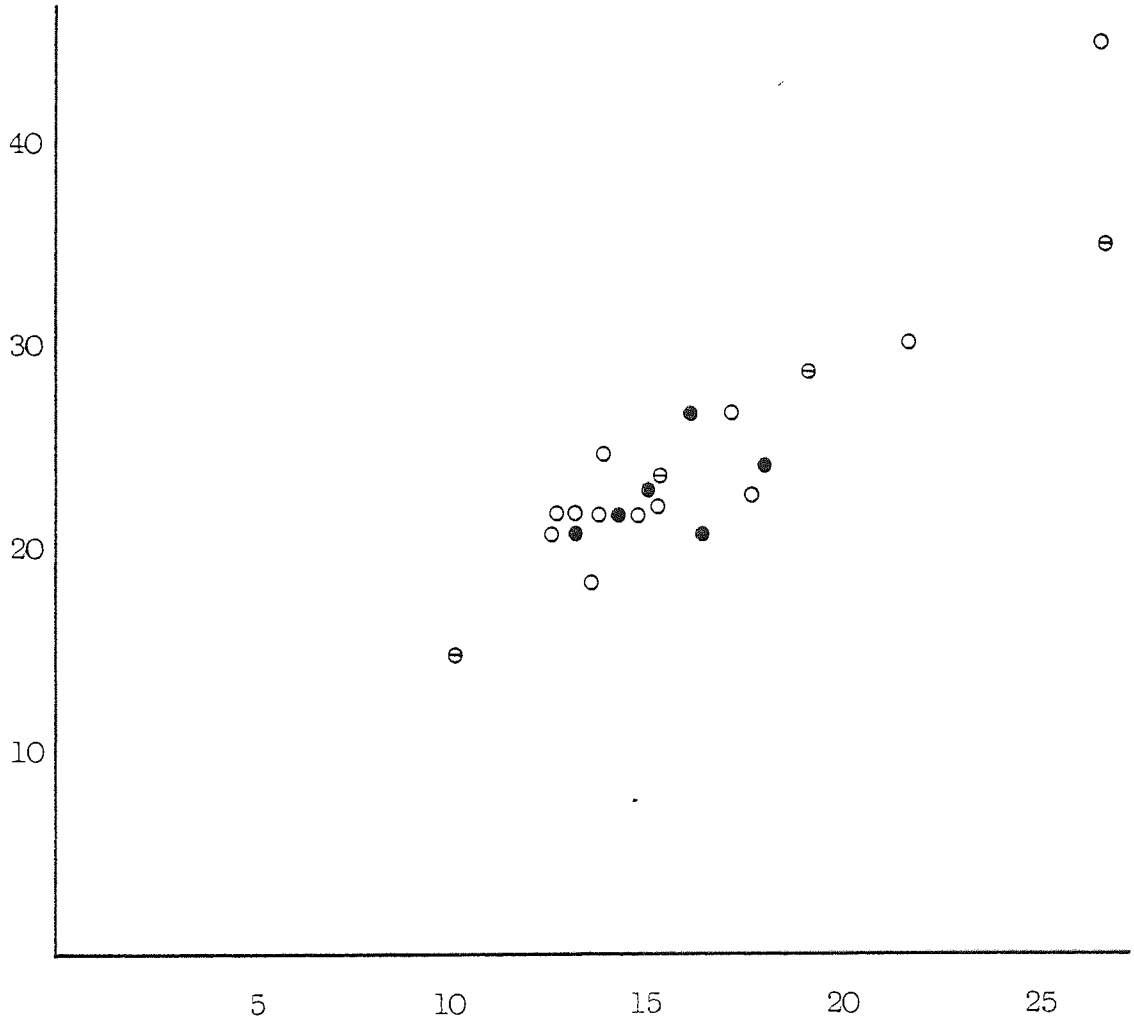
BLANTYRE SURVEY OPERATION CODE : 29A,B

OPERATION WORK : ALL ELECTRICAL WORK

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : 0.705

AVERAGE NUMBER OF MANHOURS PER VISIT : 1.75



BLANTYRE SURVEY OPERATION CODE : 31A,B,C

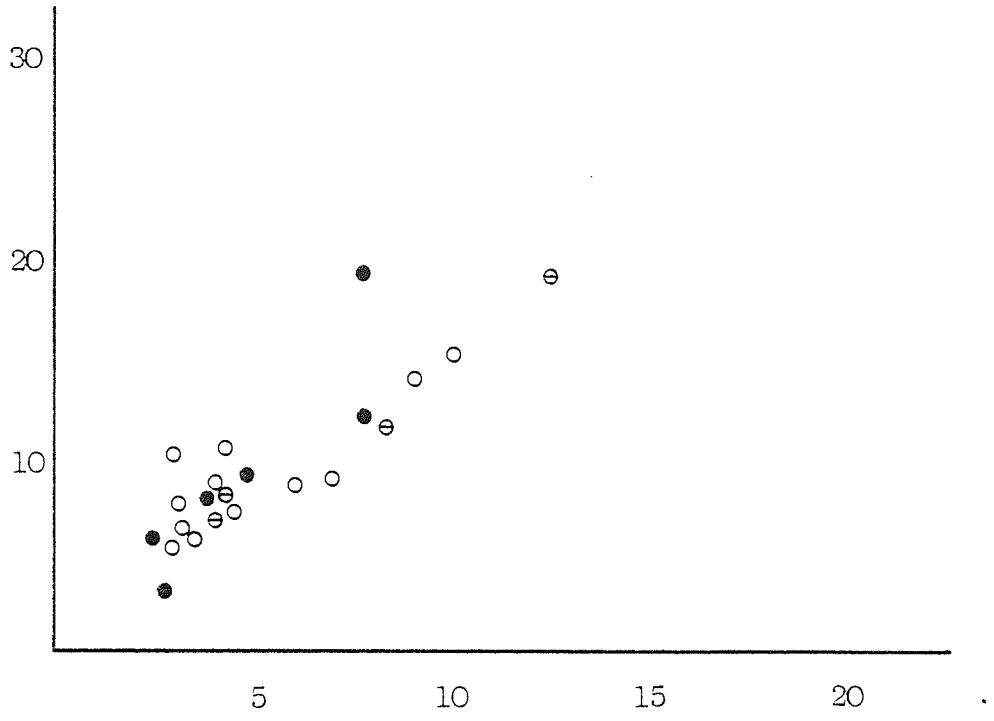
OPERATION WORK : ALL WORK ON INTERNAL AND EXTERNAL DOORS

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : 0.906

AVERAGE NUMBER OF MANHOURS PER VISIT : 1.54

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF VISITS PER HOUSE

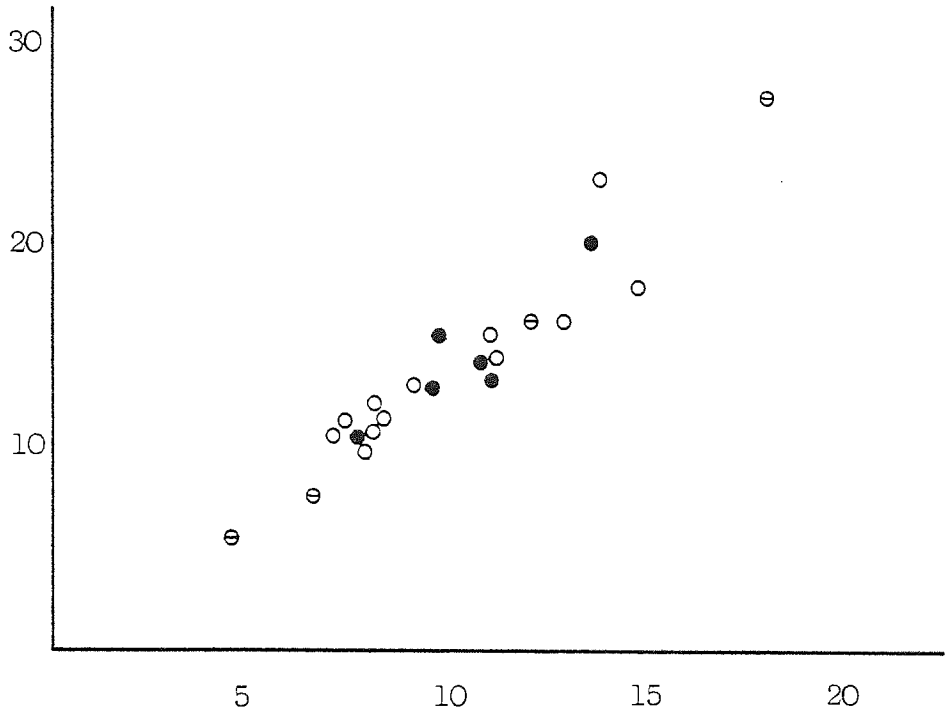
BLANTYRE SURVEY OPERATION CODE : 31D

OPERATION WORK : KITCHEN FITTINGS

TWO-PERSON HOUSE BLOCKS : INCLUDED

CORRELATION COEFFICIENT : 0.858

AVERAGE NUMBER OF MANHOURS PER VISIT : 1.72



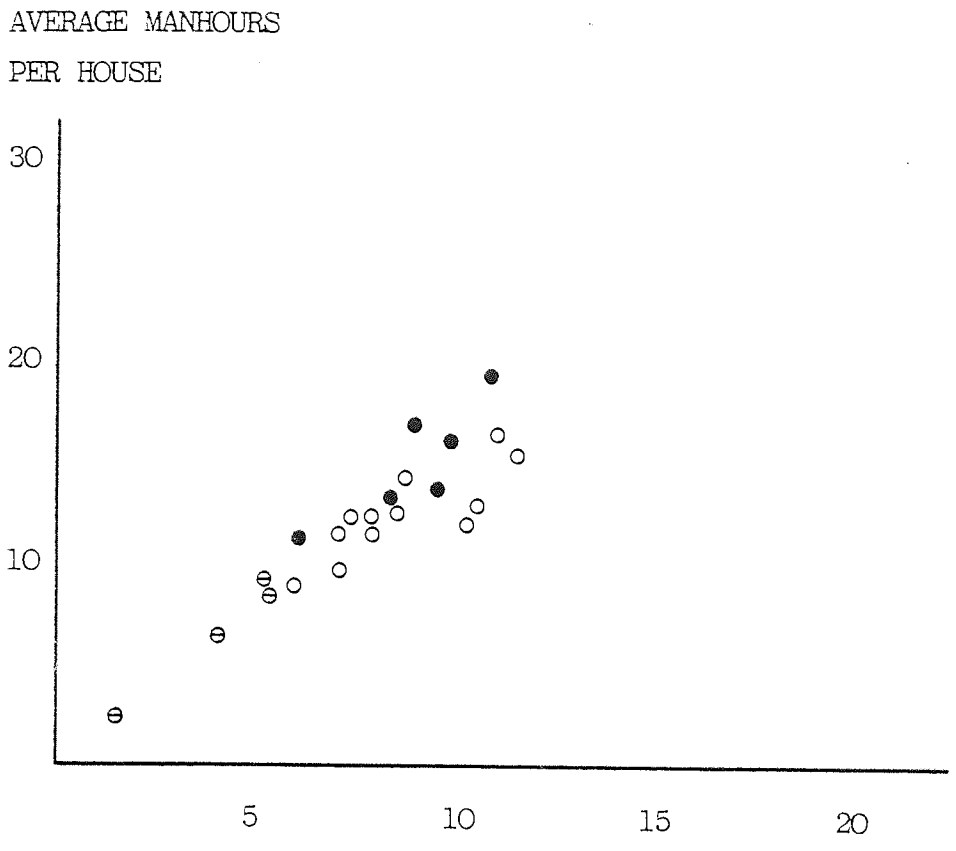
BLANTYRE SURVEY OPERATION CODE : 31F,G,H,J

OPERATION WORK : FINAL INTERNAL JOINERY WORK

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : 0.855

AVERAGE NUMBER OF MANHOURS PER VISIT : 1.41



BLANTYRE SURVEY OPERATION CODE : 33A,B,C,D

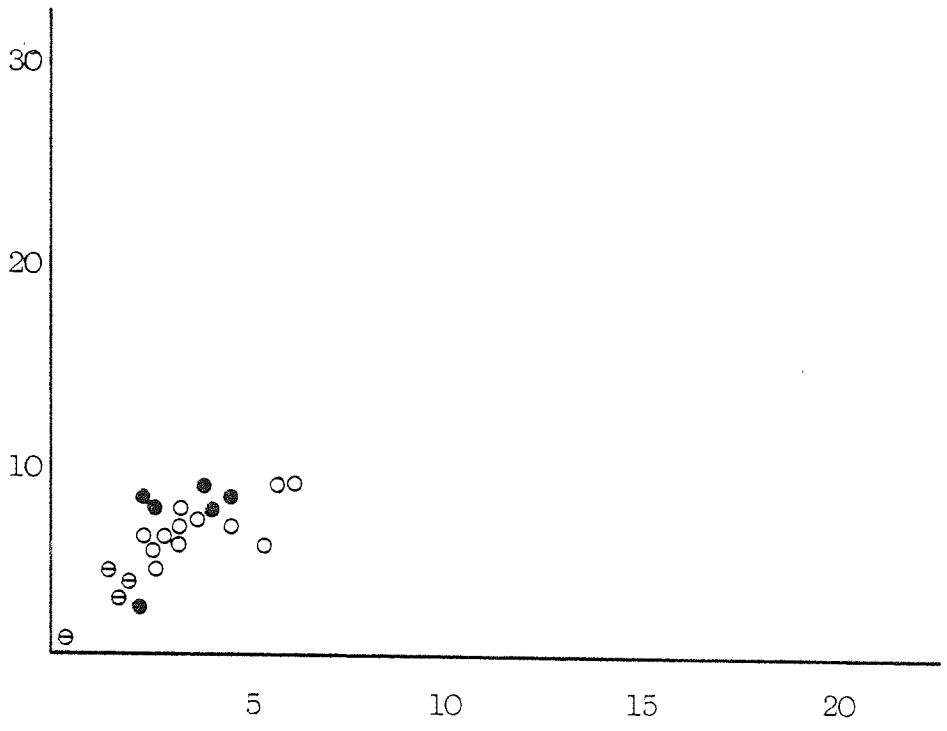
OPERATION WORK : PLASTERBOARD LINING JOINTS

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : 0.698

AVERAGE NUMBER OF MANHOURS PER VISIT : 1.55

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF VISITS PER HOUSE

BLANTYRE SURVEY OPERATION CODE : 33E

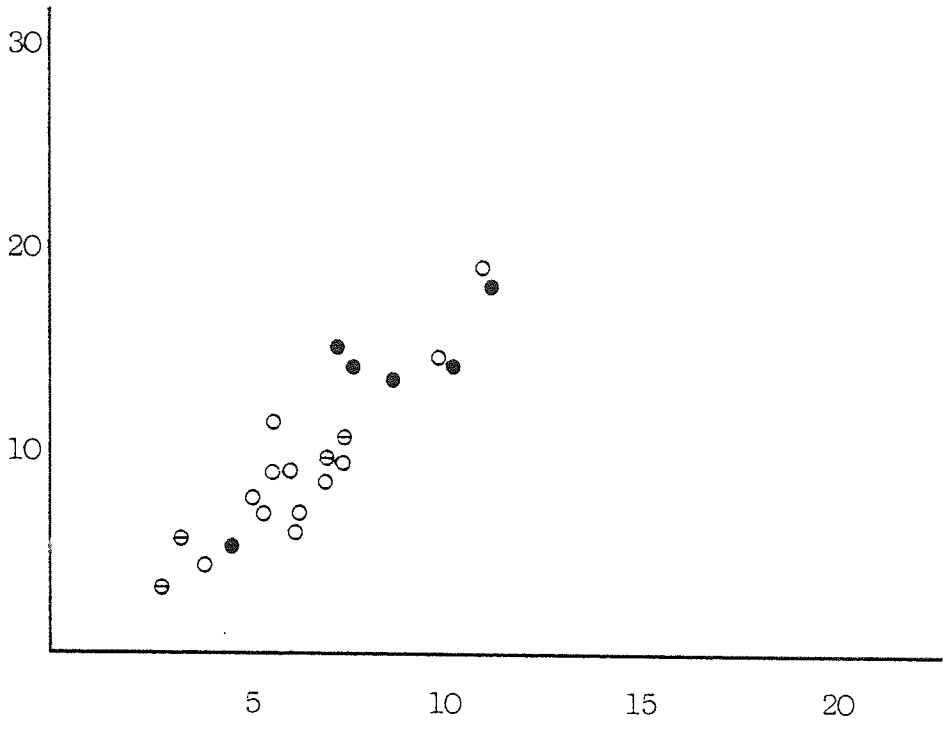
OPERATION WORK : (ARTEX) CEILING FINISH

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : 0.544

AVERAGE NUMBER OF MANHOURS PER VISIT : 2.29

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF VISITS PER HOUSE

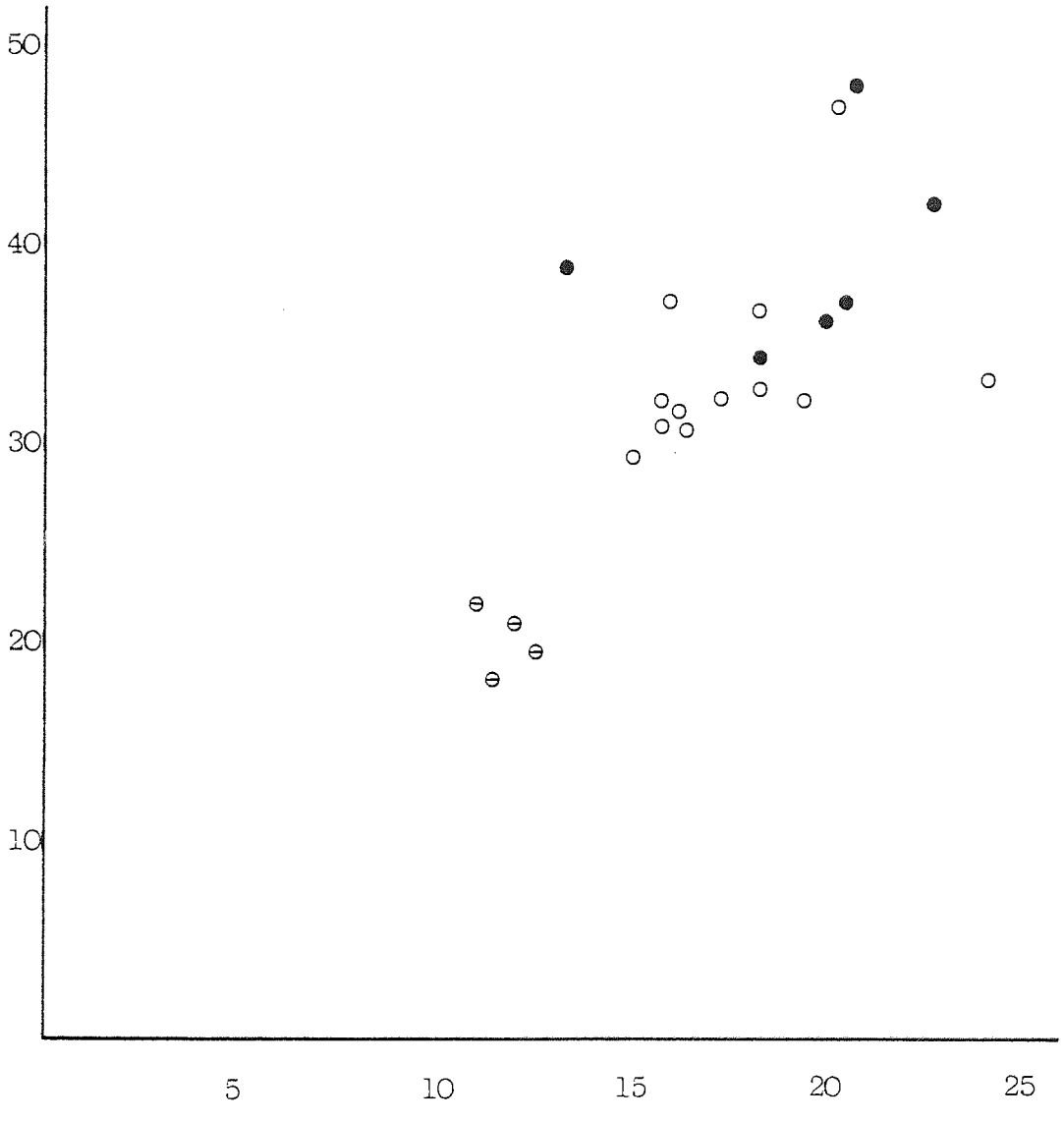
BLANTYRE SURVEY OPERATION CODE : 34A

OPERATION WORK : INTERNAL EMULSION PAINTING

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : 0.949

AVERAGE NUMBER OF MANHOURS PER VISIT : 2.29



BLANTYRE SURVEY OPERATION CODE : 34B

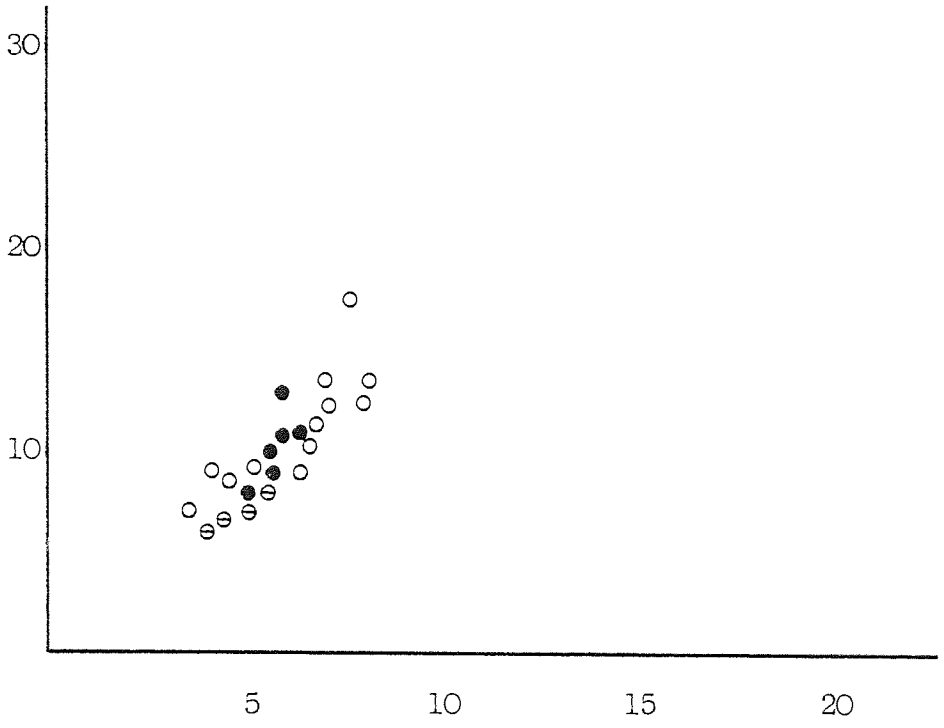
OPERATION WORK : INTERNAL GLOSS PAINTING

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : 0.446

AVERAGE NUMBER OF MANHOURS PER VISIT : 1.93

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF VISITS PER HOUSE

BLANTYRE SURVEY OPERATION CODE : 34C

OPERATION WORK : EXTERNAL GLOSS PAINTING

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : 0.814

AVERAGE NUMBER OF MANHOURS PER VISIT : 1.73

(operation 34B) and 0.544 (operation 33E)), as had been discovered for all three Greenfield operations previously discussed.

The range of results in terms of correlations coefficients confirming the linear relationship between manhours and visits was 0.446 to 0.949. The range of average manhours per visit was 1.41 to 2.98 for the same operations. The table below briefly compares these two results (in appropriate construction order) for each of the sixteen operations.

BLANTYRE OPERATIONS

OPERATION CODE	5A+	16+	22A+	24B	27A+	27D+
CORRELATION COEFFICIENT	0.747	0.833	0.716	0.763	-	0.77
MANHOURS PER VISIT	2.98	2.15	2.33	2.29	2.03	1.73

OPERATION CODE	28E+	29A+	31A+	31D	31F+	33A+
CORRELATION COEFFICIENT	0.773	0.705	0.906	0.858	0.855	0.698
MANHOURS PER VISIT	1.74	1.75	1.54	1.72	1.41	1.55

OPERATION CODE	33E	34A	34B	34C
CORRELATION COEFFICIENT	0.554	0.949	0.446	0.814
MANHOURS PER VISIT	1.84	1.5	1.93	1.73

The first four operations in the above table (from the substructure and superstructure), had relatively higher results in terms of average manhours per visit (range 2.15 - 2.98) than the remaining

services and finishes operations (range 1.41 - 1.93) which were all less than two manhours per visit. The four superstructure operations (all of more than two manhours per visit, which is well above the one observation equal one visit and one manhour level) nonetheless had good correlation coefficient results of 0.747, 0.833, 0.716 and 0.763, respectively. Alternatively, the lowest result for average manhours per visit, among the services and finishes operations, was 1.41 for all the work in final joinery and yet, the accompanying high correlation coefficient was far from perfect at 0.855.

Of least significance in terms of correlation coefficients were operations 33E at 0.544 and 34B at 0.446 with averages of 1.84 and 1.93 manhours per visit, respectively; but both these averages were near the middle of the range of manhours per visit found in the analysis and were not in any way unusual to reflect the low coefficient results.

Generally then, the smallest results in terms of manhours per visit (i.e. those operations closest to one observation equals one visit equals one manhour) were not accompanied by near perfect correlations. The operations with the highest manhours per visit (i.e. the non-services and finishes operations selected for analysis) were accompanied by good correlations (excluding operation 27A,B,C), that confirm a firm relationship between manhours and number of visits.

Compared to the brickwork operations, the services and finishes operations analysed involved shorter, less continuous, working periods e.g. operation 31F,G,H,J (all internal final joinery) involved more than twice as many separate operative visits than 5A,B,C,D,E,F,G,J (brickwork substructure) for the same number of

manhours of completed work.

STATISTICS TEST APPLIED

The statistics test employed on the results shown in the operation graphs discussed in this chapter, was a standard statistical technique embodied in a SOCS computer programme, into which the results for each operation were fed through a remote computer terminal. The technique used was a sample correlation coefficient calculation, with significant deviations from zero detected using approximately 95 percent confidence limits.

SUMMARY

As a brief summary of this chapter, a good linear relationship was in evidence in most of the operation graphs relating manhours to the number of separate operative visits in the operations analysed for Greenfield and Blantyre. However, cautious interpretation is required as the shortest separate operative visit that could be measured from the activity sampling data also represents one manhour in the data.

CHAPTER 8

BLANTYRE AND GREENFIELD DETAILED DATA ANALYSIS : MANHOURS COMPARED WITH NUMBER OF DIFFERENT OPERATIVES

This chapter describes the third of the three forms of detailed data analysis made in the study on nineteen selected operations from Greenfield and Blantyre. The two other forms of analysis (applied to the same set of operations) were discussed in the previous chapters 6 and 7.

THE DEFINITION OF THE FORM OF ANALYSIS

The detailed analysis of the variation in manhours of work operations, in terms of average manhours per house, compared with an estimate of the average number of different operatives employed per house to complete a similar operation for each house block on the site.

THE OBJECTIVES OF THE FORM OF ANALYSIS

This particular form of detailed data analysis, that compares average manhours with the number of different operatives employed, was developed for three reasons:

1

Early work in the study on the Greenfield data, produced tables (made by hand methods) for each of the eighteen house blocks on the site comparing operations with site weeks, which showed that the site work on many operations was scattered over a large number of weeks. An example table describing a house block at Greenfield will be discussed in the next chapter, together with a later computer-produced table of a house block at Blantyre. In studying these house block tables it seemed possible that over the long period that

many operations lasted many new operatives could be involved in the work of completing any operation. Even within a short period, for example a week, the number of visits to complete operations was found to be large and this could also allow the possibility of the employment of several different operatives on any operation. The principal question to be answered by this part of the study was that if so many new operatives were found employed on an operation in each block (each operative successively unfamiliar with the work if he had not been involved in the operation before, and certainly not familiar with each particular block and the current position, and possible problems, in completing the operation): what relationship was there between the variation in labour requirements in terms of manhours for an operation and the number of different operatives employed? The study eventually concentrated on proving the following hypothesis as true: that as the number of different operatives employed on an operation are increased, the efficiency in completing the work of the operation falls i.e. the required number of manhours for an operation increases.

2

The data obtained from activity sampling provides observations on each operative on the site, and thus allows a form of measurement of the way different operatives were employed on operations by the main contractor and for some operations by the sub-contractors.

3

Although work study in general contains previous research on optimum operative gang sizes for certain operations (An Foras, 1972), no previous work was found on the actual number of operatives employed to complete operations, and thus, in this use of activity sampling data.

If the hypothesis described is true, then, from a practical point of view the contractor must control the number of operatives employed on operations in each block to improve labour requirements. In other words, for the effect on labour requirements of the employment of different operatives on an operation, the best advantage would be gained from the employment of just the minimum efficient operative gang size. Variations in productivity would remain as the hypothesis assumes that all operatives perform equally, which they do not (not even for one man from one day to the next).

THREE GREENFIELD WORK OPERATION GRAPHS

The average manhours per house for each block in the three Greenfield operation graphs are the same as those calculated for chapter 6, and in the graphs the manhour results are always shown on the vertical axis.

The estimate of the average number of different operatives employed in each operation considered was derived from the tables (produced by hand methods) discussed in chapter 7 for estimating visits, in which the observations for each operative working on an operation and block were recorded by day. Using the same tables in a different way, each successive new operative (the table lists the work on an operation and block in day order) was logged for each operation in each block on the site. The number of different operatives calculated for each operation in each block were subsequently divided by houses per block, to give the average number of different operatives employed per house. The calculation procedure was involved and so the test was restricted to the three operations described below, so completing the same set of operations discussed for manhours compared to a block order and

manhours compared to separate operative visits in chapters 6 and 7, respectively.

In the graphs of the three Greenfield operations the average number of different operatives employed per house for each block on site are always shown on the horizontal axis and the number of different operatives are calculated from operatives contributing work under the activities F, N and P only (defined in appendix 3.2).

A key that separates the Greenfield 5-person and 7-person house block results in the graphs is given below:

● 5-person house blocks

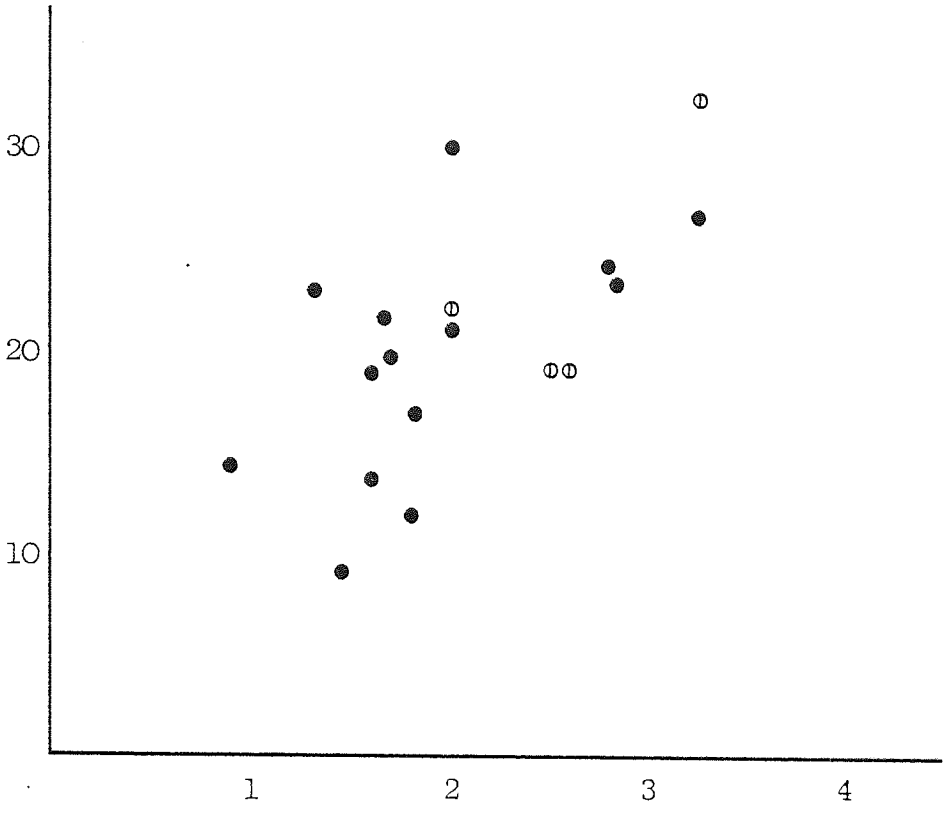
⦶ 7-person house blocks.

ANALYSIS OF THE GREENFIELD GRAPHS

The selected facts and result shown under each Greenfield graph have been discussed previously in chapters 6 and 7.

The results in operations 10C and 14D both suggest, graphically, a general linear relationship between manhours and the number of different operatives employed. This conclusion is confirmed by correlation coefficients of 0.636 for operation 10C and 0.576 for 14D. However, the graph on operation 16A (which produced such positive results to the two previous forms of analysis) indicates no positive relationship between manhours and the number of different operatives, and the correlation test confirmed this conclusion. More detailed information about each block result is required to explain this apparently special outcome of the three operations analysed.

AVERAGE MANHOURS
PER HOUSE



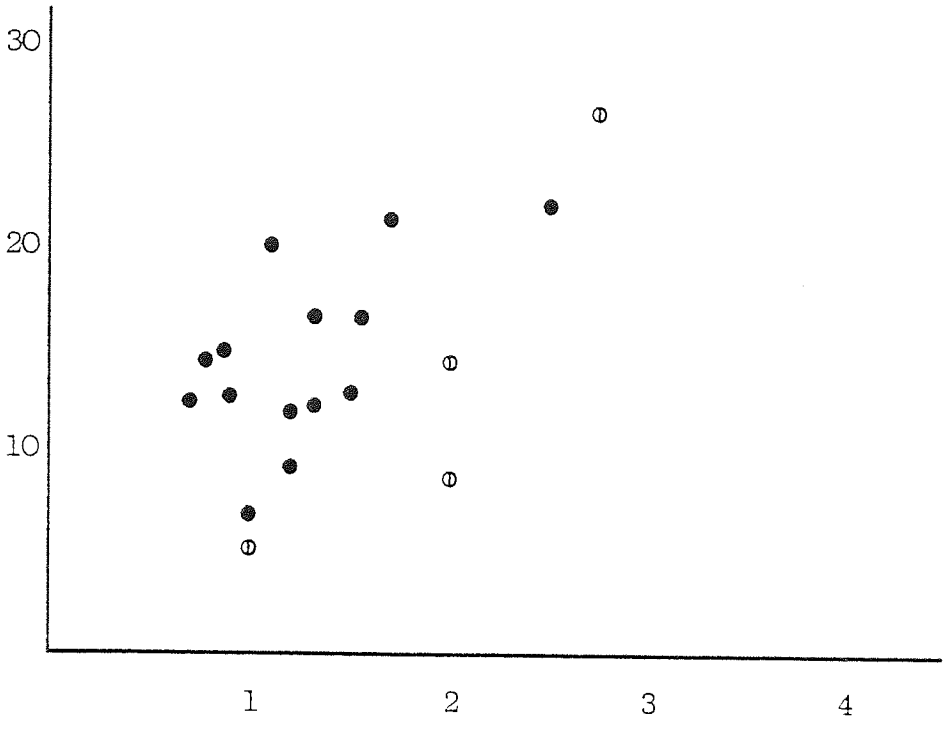
AVERAGE NUMBER OF OPERATIVES PER HOUSE

GREENFIELD SURVEY OPERATION CODE : 1OC

OPERATION WORK : INTERNAL PLUMBER CARCASSING

CORRELATION COEFFICIENT : 0.636

AVERAGE MANHOURS
PER HOUSE



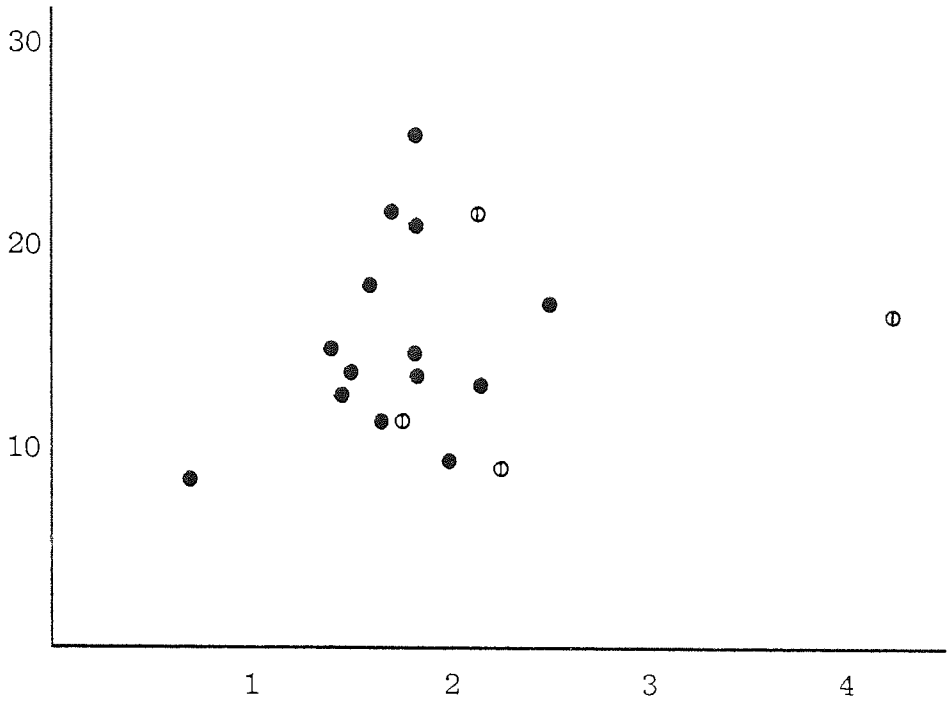
AVERAGE NUMBER OF OPERATIVES PER HOUSE

GREENFIELD SURVEY OPERATION CODE : 14D

OPERATION WORK : PLASTERBOARD LINING JOINTS

CORRELATION COEFFICIENT : 0.576

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

GREENFIELD SURVEY OPERATION CODE : 16A

OPERATION WORK : ALL WORK ON INTERNAL AND EXTERNAL DOORS

CORRELATION COEFFICIENT : NO CORRELATION

SIXTEEN BLANTYRE WORK OPERATION GRAPHS

Although only three operations from Greenfield were calculated for a comparison between manhours and operatives, two appeared to show a firm relationship and so the analysis of many further operations at Blantyre was considered worthwhile. The case was assisted by the fact that activity sampling could provide useful data for comparison and that the further application of a computer on the Blantyre data would cover most of the work involved with relative ease, compared to the hand work efforts required on the Greenfield data.

For this analysis a table listing operatives contributing work in each block for every operation at Blantyre was produced by SOCS (appendix 8, table 8.3). The table contained the number of productive manhours contributed by each operative working on an operation in each block. However, in the final analysis, the activities F, N and P only were used and so this table (table 8.3), which contained combined productive manhours of all activities, gave way to the SOCS produced table used to calculate visits (appendix 8, table 8.2). This table lists each activity separately and allowed the counting of the number of different operatives working on an operation and block who contributed the F, N and P activities only to be made. The calculation procedure for number of different operatives thus became the same as at Greenfield. The table (table 8.3) listing operatives in each block for every operation could have been designed to restrict manhours to the activities F, N and P and this would have made calculation simpler, but further computer application was not possible. As before, sixteen separate Blantyre operations were tested.

In the sixteen Blantyre operation graphs the average number of different operatives employed per house for each block on site are always shown on the horizontal axis and as for Greenfield, the number of different operatives are calculated from operatives contributing work under the activities F, N and P only (defined in Appendix 3.1).

The average manhours per house for each block in the graphs were calculated as before, and represent a repeat use of the data from chapters 6 and 7.

The key that separates the Blantyre 2-person, 4-person and 5-person house block results in the graphs is given again below:

⊖ 2-person house blocks

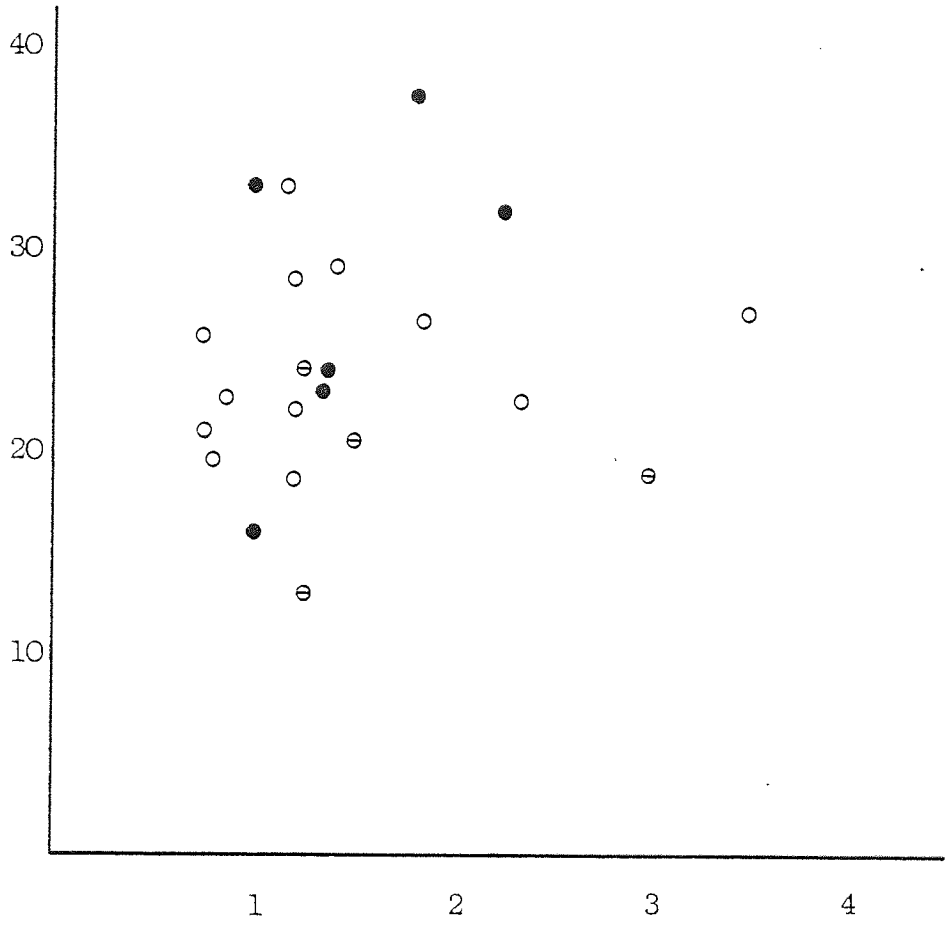
○ 4-person house blocks

● 5-person house blocks

ANALYSIS OF THE BLANTYRE GRAPHS

The selected facts and results stated under each Blantyre graph were defined in chapters 6 and 7. The graph for operation 22A,B,C,D suggests a general relationship of increasing manhours with a growth in the number of different operatives employed in constructing the roofs of each block. The relationship is supported by a relatively weak linear correlation coefficient of only 0.482. Similarly, operation 28E,F suggests a linear relationship that is confirmed by another weak, but positive, 0.484 correlation coefficient. The finding for this operation agrees with the similar operation analysed at Greenfield. the majority of the block results in operation 31D also form an identifiable linear relationship between average manhours and the average number of different operatives employed on installing

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

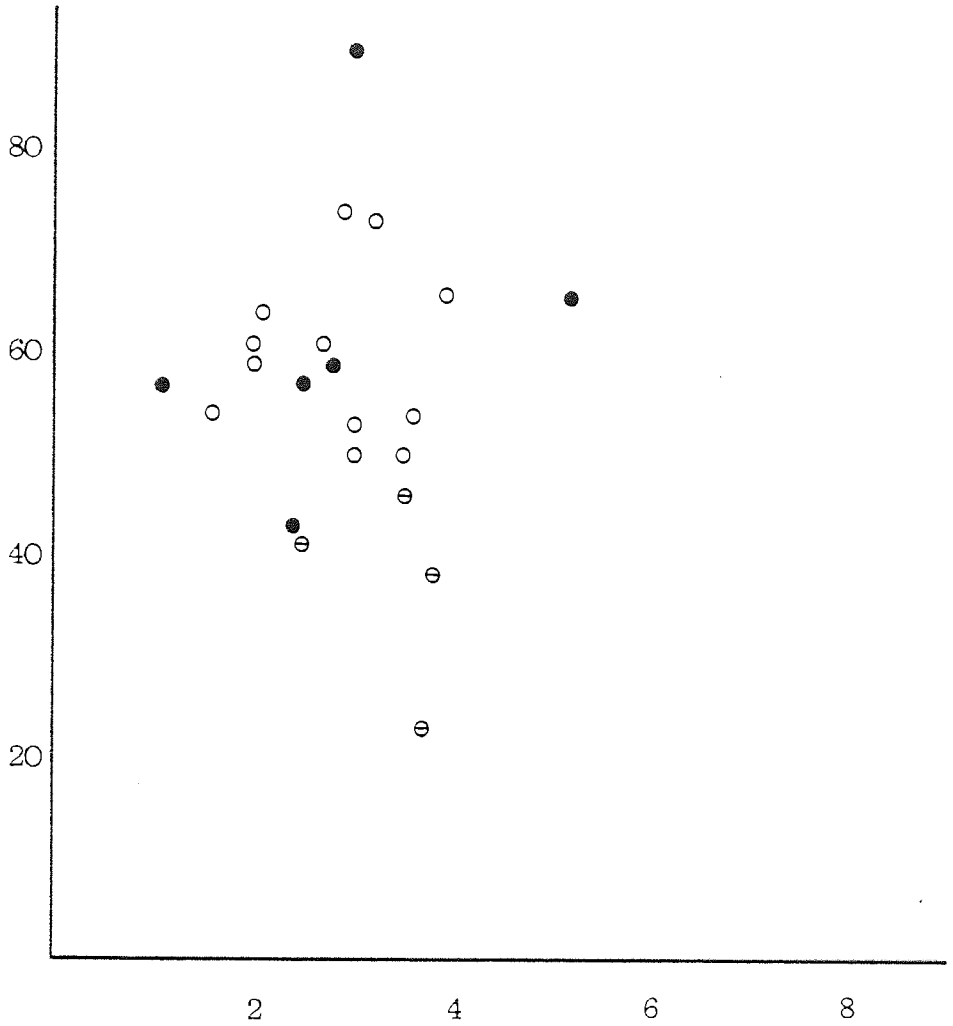
BLANTYRE SURVEY OPERATION CODE : 5A,B,C,D,E,F,G,J

OPERATION WORK : BRICK SUBSTRUCTURE

TWO-PERSON HOUSE BLOCKS : INCLUDED

CORRELATION COEFFICIENT : NO CORRELATION

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

BLANTYRE SURVEY OPERATION CODE :- 16, 18, 20

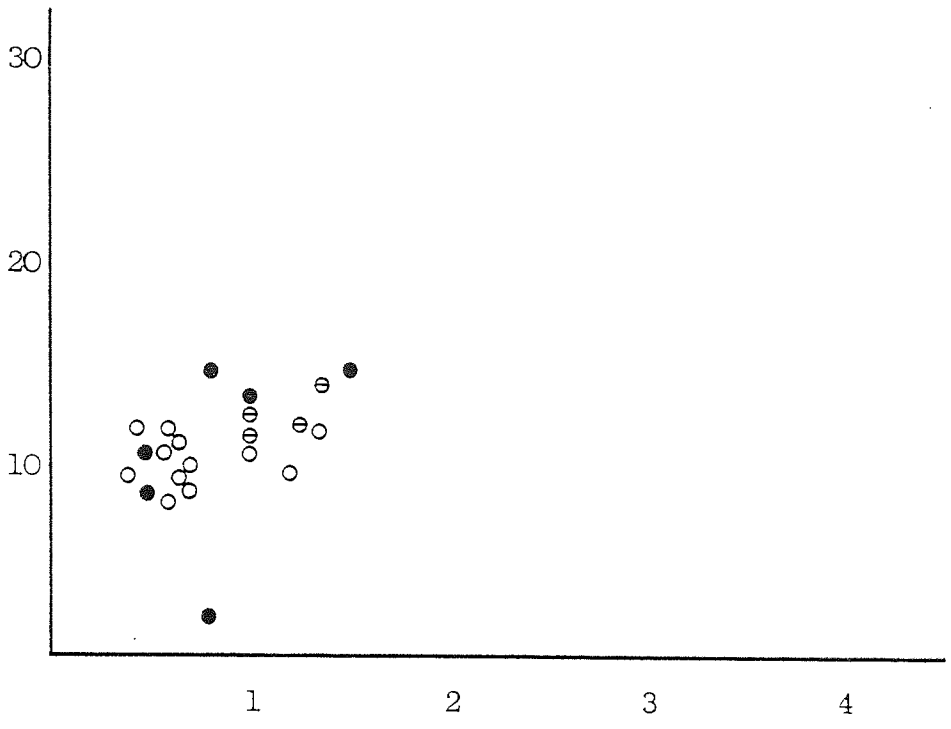
OPERATION WORK : BRICKWORK SU PER STRUCTURE

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : NO CORRELATION

AVERAGE MANHOURS

PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

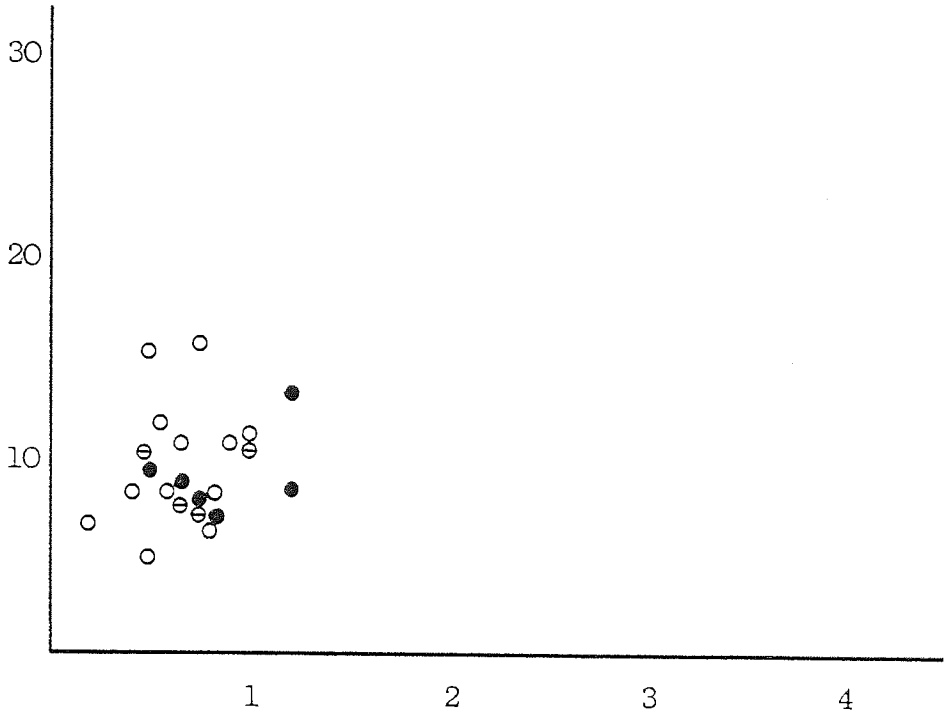
BLANTYRE SURVEY OPERATION CODE : 22A,B,C,D

OPERATION WORK : ROOF COVERING INCLUDING TILES

TWO-PERSON HOUSE BLOCKS : INCLUDED

CORRELATION COEFFICIENT : 0.482

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

BLANTYRE SURVEY OPERATION CODE : 24B

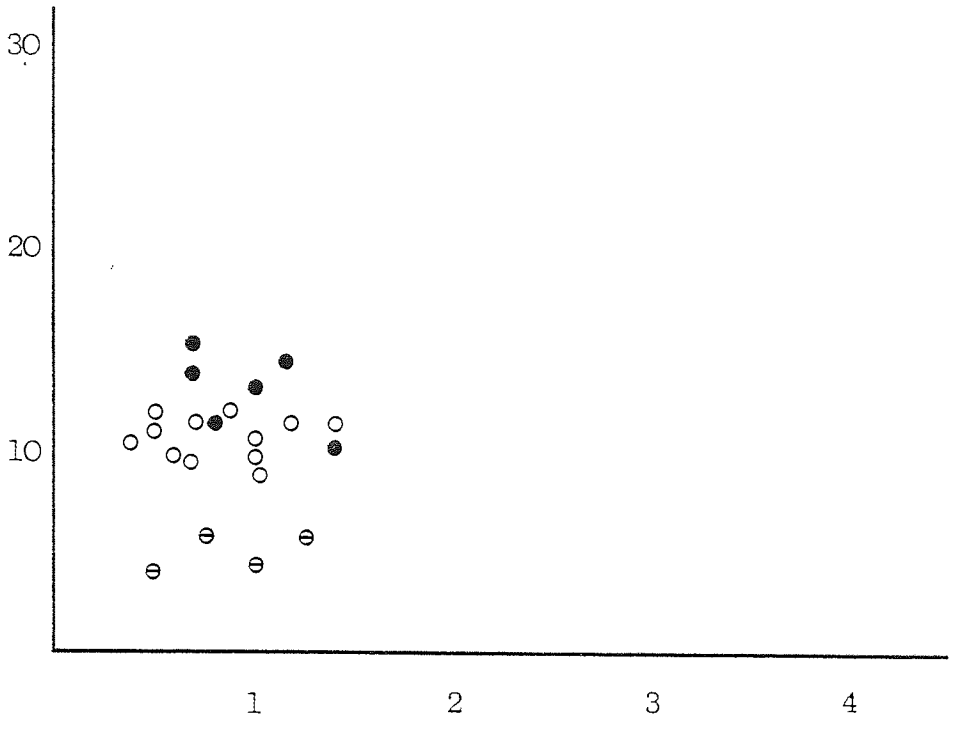
OPERATION WORK : PLASTERBOARD (PARAMOUNT) ROOM PARTITIONS

TWO-PERSON HOUSE BLOCKS : INCLUDED

CORRELATION COEFFICIENT : NO CORRELATION

AVERAGE MANHOURS

PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

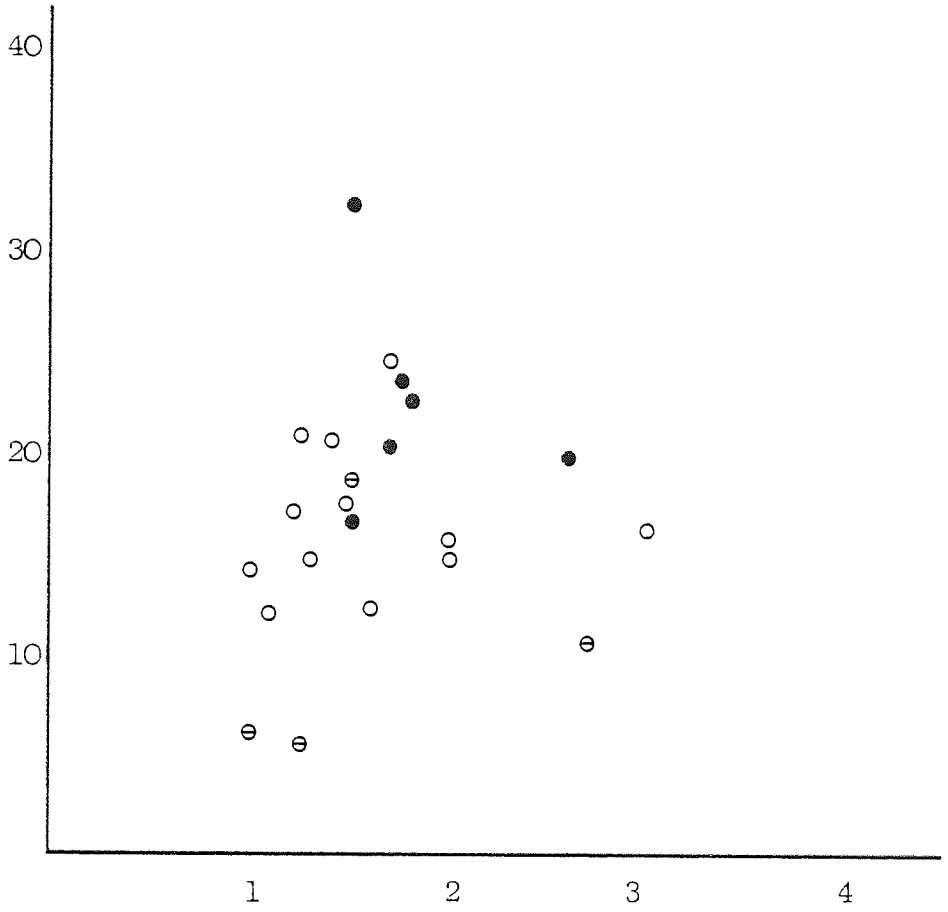
BLANTYRE SURVEY OPERATION CODE : 27A,B,C

OPERATION WORK : PLASTERBOARD LININGS TO BRICK WALLS

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : NO CORRELATION

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

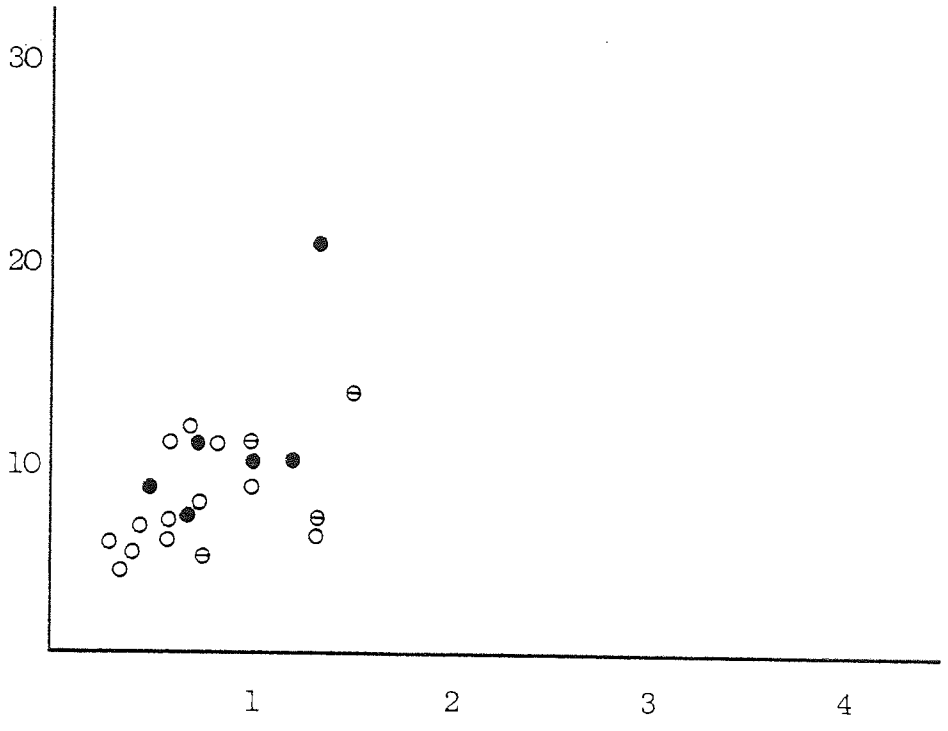
BLANTYRE SURVEY OPERATION CODE : 27D,E

OPERATION WORK : PLASTERBOARD LININGS TO CEILINGS AND TIMBER STUD PARTITION

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : NO CORRELATION

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

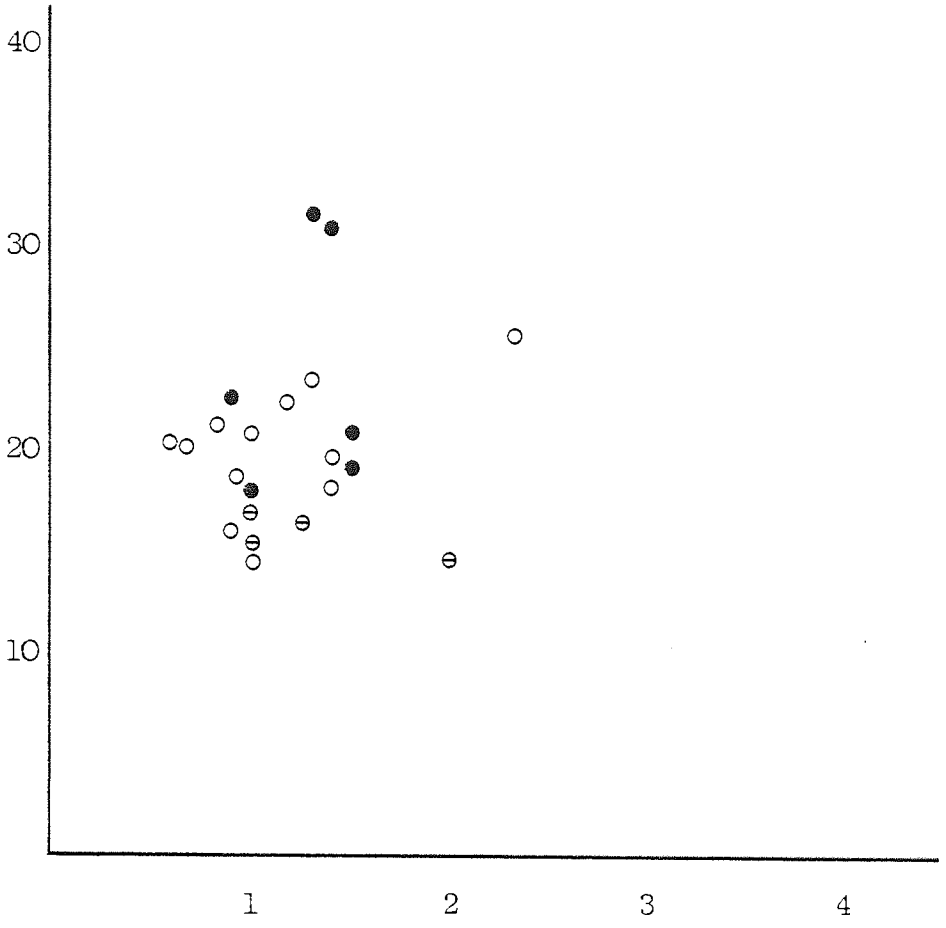
BLANTYRE SURVEY OPERATION CODE : 28E,F

OPERATION WORK : ALL PLUMBING WORK

TWO-PERSON HOUSE BLOCKS : INCLUDED

CORRELATION COEFFICIENT : 0.484

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

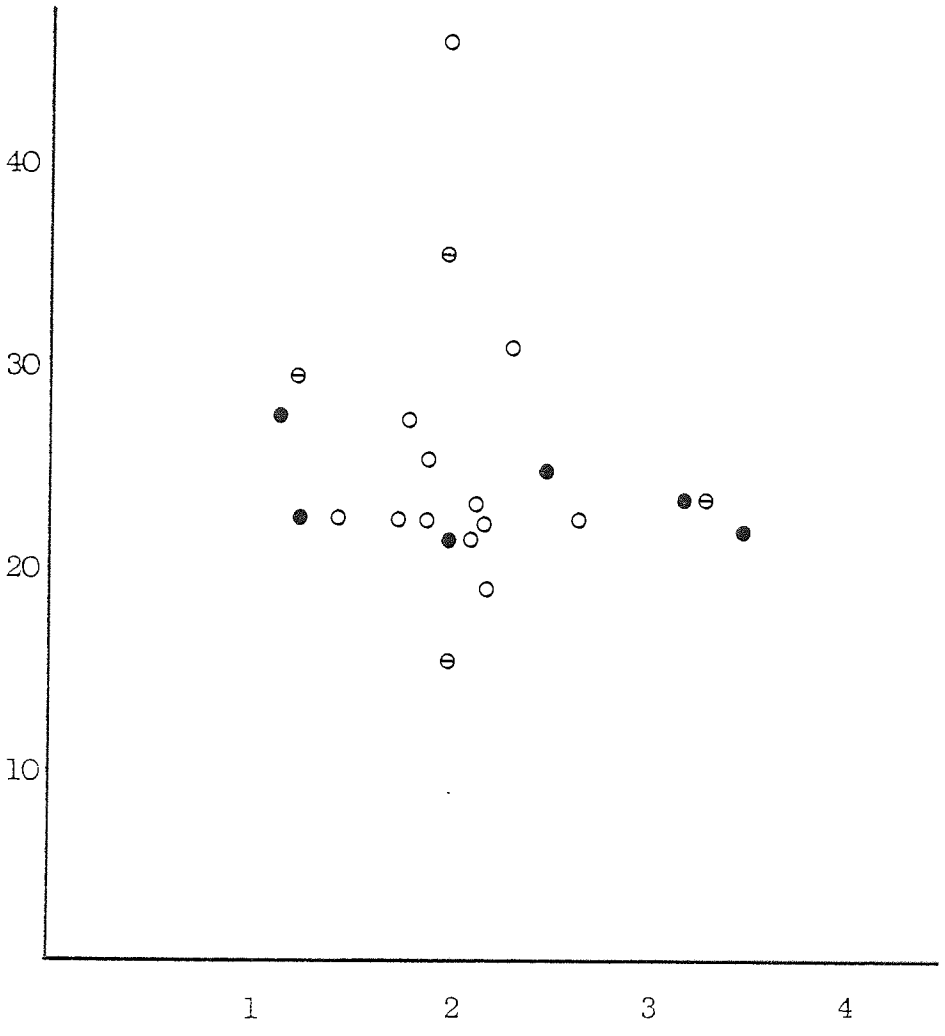
BLANTYRE SURVEY OPERATION CODE : 29A,B

OPERATION WORK : ALL ELECTRICAL WORK

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : 0.395

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

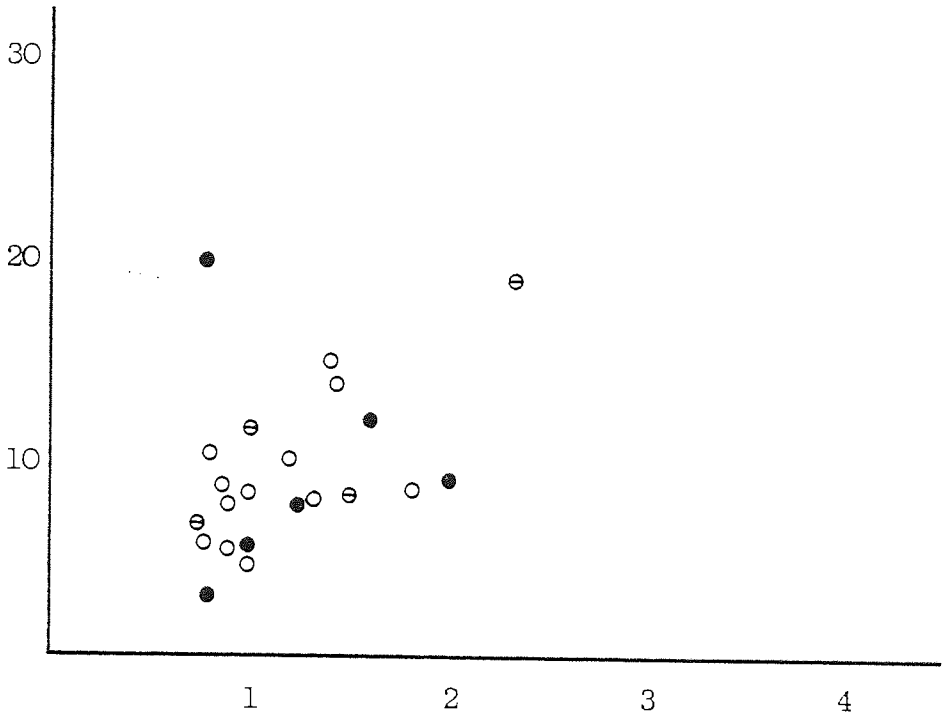
BLANTYRE SURVEY OPERATION CODE : 31A,B,C

OPERATION WORK : ALL WORK ON INTERNAL AND EXTERNAL DOORS

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : NO CORRELATION

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

BLANTYRE SURVEY OPERATION CODE : 31D

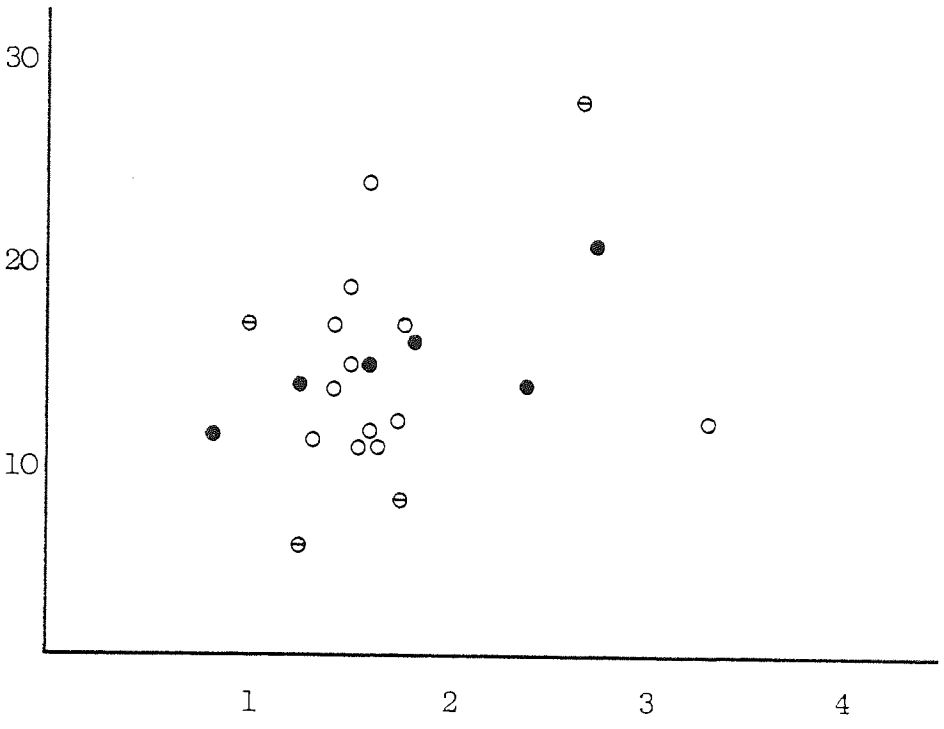
OPERATION WORK : KITCHEN FITTINGS

TWO-PERSON HOUSE BLOCKS : INCLUDED

CORRELATION COEFFICIENT : 0.434

AVERAGE MANHOURS

PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

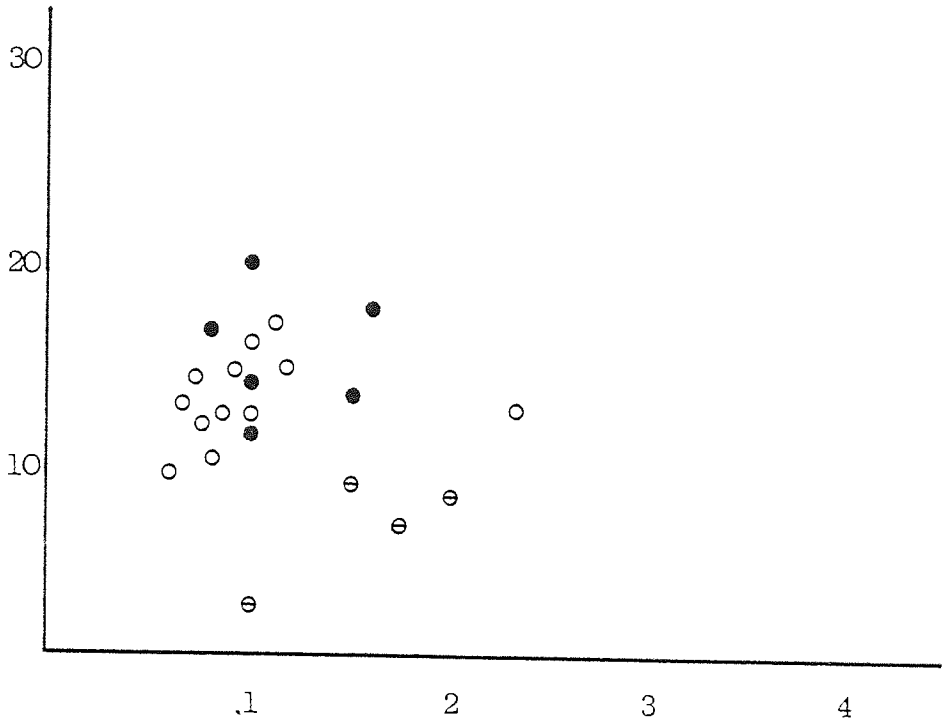
BLANTYRE SURVEY OPERATION CODE : 31F,G,H,J

OPERATION WORK : FINAL INTERNAL JOINERY

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : 0.332

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

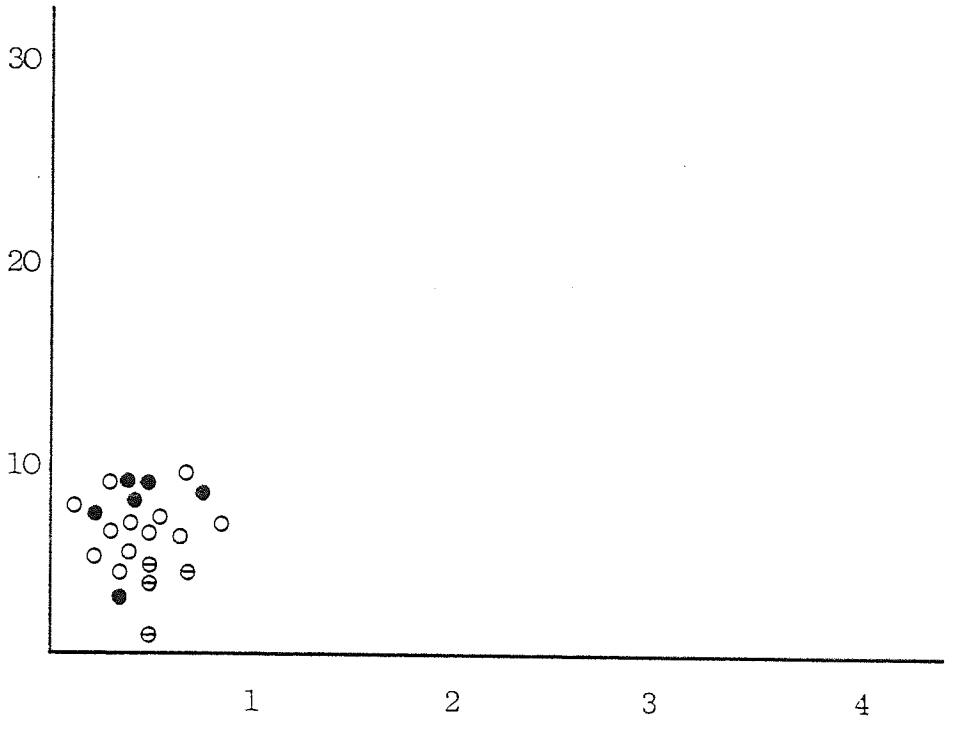
BLANTYRE SURVEY OPERATION CODE : 33A,B,C,D

OPERATION WORK : PLASTERBOARD LINING JOINTS

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : NO CORRELATION

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

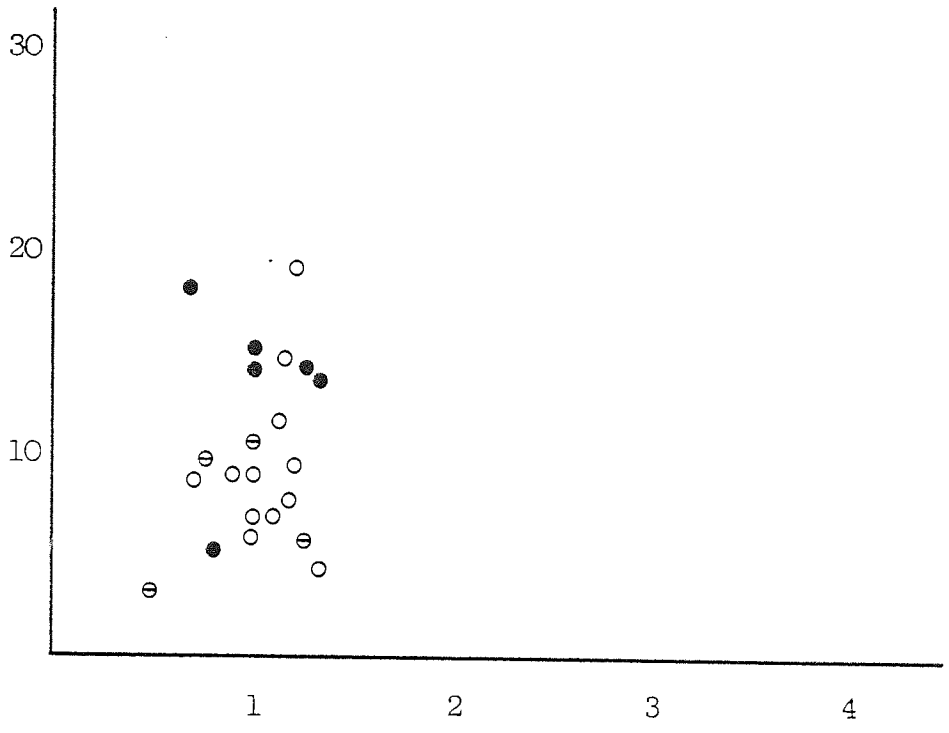
BLANTYRE SURVEY OPERATION CODE : 33E

OPERATION SURVEY : (ARTEX) CEILING FINISH

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : NO CORRELATION

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

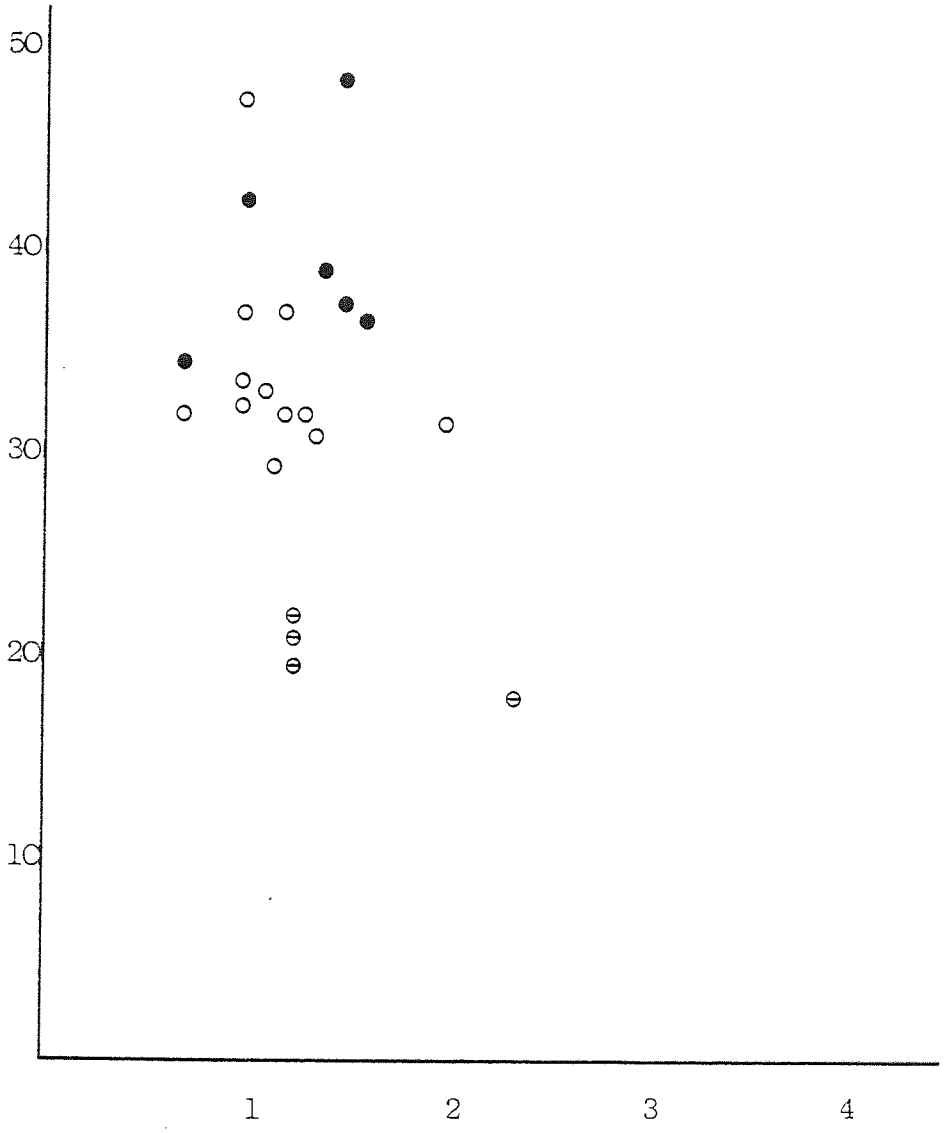
BLANTYRE SURVEY OPERATION CODE : 34A

OPERATION SURVEY : INTERNAL EMULSION PAINTING

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : NO CORRELATION

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

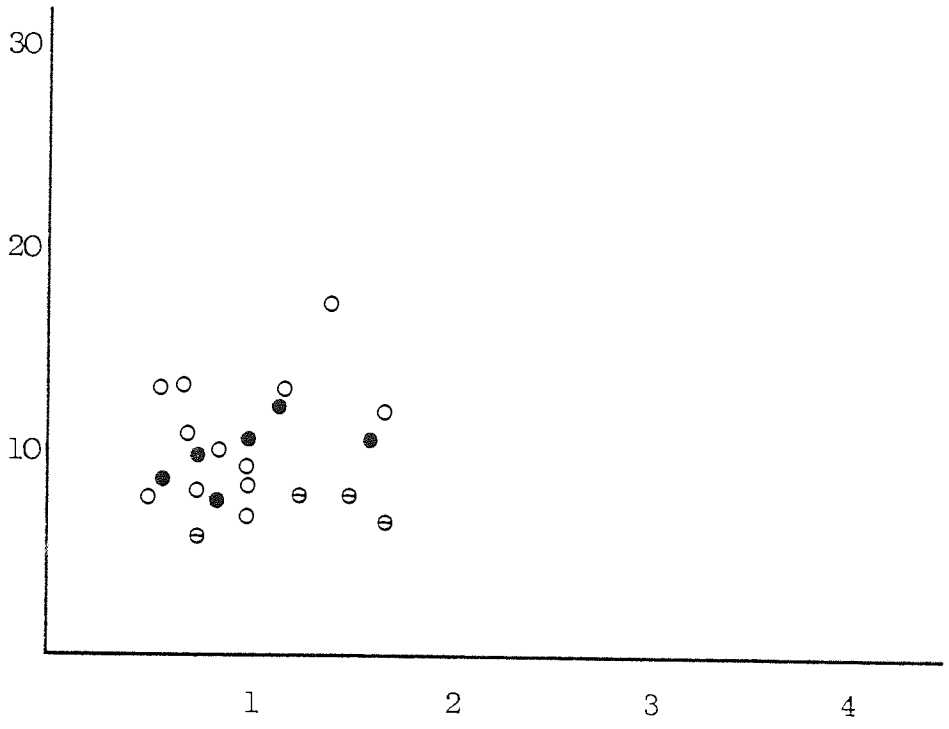
BLANTYRE SURVEY OPERATION CODE : 34B

OPERATION SURVEY : INTERNAL GLOSS PAINTING

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : NO CORRELATION

AVERAGE MANHOURS
PER HOUSE



AVERAGE NUMBER OF OPERATIVES PER HOUSE

BLANTYRE SURVEY OPERATION CODE : 34C

OPERATION SURVEY : EXTERNAL GLOSS PAINTING

TWO-PERSON HOUSE BLOCKS : EXCLUDED

CORRELATION COEFFICIENT : 0.371

kitchen fittings, which is confirmed by a weak, but positive, 0.434 correlation coefficient.

Three operation graphs, namely 29A,B, 31F,G,H,J and 34C, all illustrate scattered block results which nonetheless show a vague general relationship between increasing manhours and the number of different operatives employed. This linear relationship is confirmed by very weak correlation coefficients of 0.395, 0.332 and 0.371, respectively.

The remaining ten operation graphs analysed, each suggest no identifiable relationship between average manhours per house and the number of different operatives employed per house to complete the work of the operation. However, certain other observations were possible from these graphs e.g. in operation 27A,B,C average manhours per house remained reasonably constant for blocks of the same house size (that seems to suggest efficient working on plasterboard linings), while the average number of different operatives per house employed on blocks of each house size varied by more than 2:1. The number of different operatives employed clearly seems to have had no real influence on the average manhour results between blocks for this particular operation. Similarly, for operation 31A,B,C, while more than 50 percent of the block results were around 22 manhours per house, the average number of different operatives employed per house varied by a ratio of more than 3:1. Alternatively, operation 34A illustrates (particularly for the 4-person house block results) a vertical distribution in which the average number of operatives remained close to one operative per house while average manhour per house varied by more than 3:1.

STATISTICS TEST APPLIED

The statistics test employed on the results shown in the operation graphs discussed in this chapter, was the same standard statistical technique used in chapter 7, embodied in a SOCS computer programme into which the results for each operation were fed through a remote computer terminal. The technique used was a sample correlation coefficient calculation, with significant deviations from zero detected using approximately 95 percent confidence limits.

SUMMARY

Based on the operation graphs, and as a brief summary of this chapter, a few of the operations analysed for Greenfield and Blantyre show a recognisable general relationship between manhours and the number of different operatives employed. However, the rest of the operation graphs indicate only a random distribution proving no recognisable relationship.

CHAPTER 9

THREE ITEMS OF MISCELLANEOUS DETAILED DATA ANALYSIS FROM GREENFIELD AND BLANTYRE

This final detailed analysis chapter discussed three miscellaneous items of work carried out during the process of the study. Each item was related in some way to the work of the three previous detailed analysis chapters. The subject for each item was intimated in chapter 1.

ITEM ONE

THE DISTRIBUTION OF MANHOURS IN THE BUILDING OF A HOUSE BLOCK AT GREENFIELD AND BLANTYRE

The activity sampling data available in the study describes, in sample form, the way the building work on either the Blantyre or Greenfield site was organised through the construction period between the main contractor and all the sub-contractors. Early work in this study sought to examine the organisation of block construction at Greenfield to see what sort of construction patterns were developed on site, what sort of work operation sequence was actually followed in the construction and how concentrated was the work in any operation?

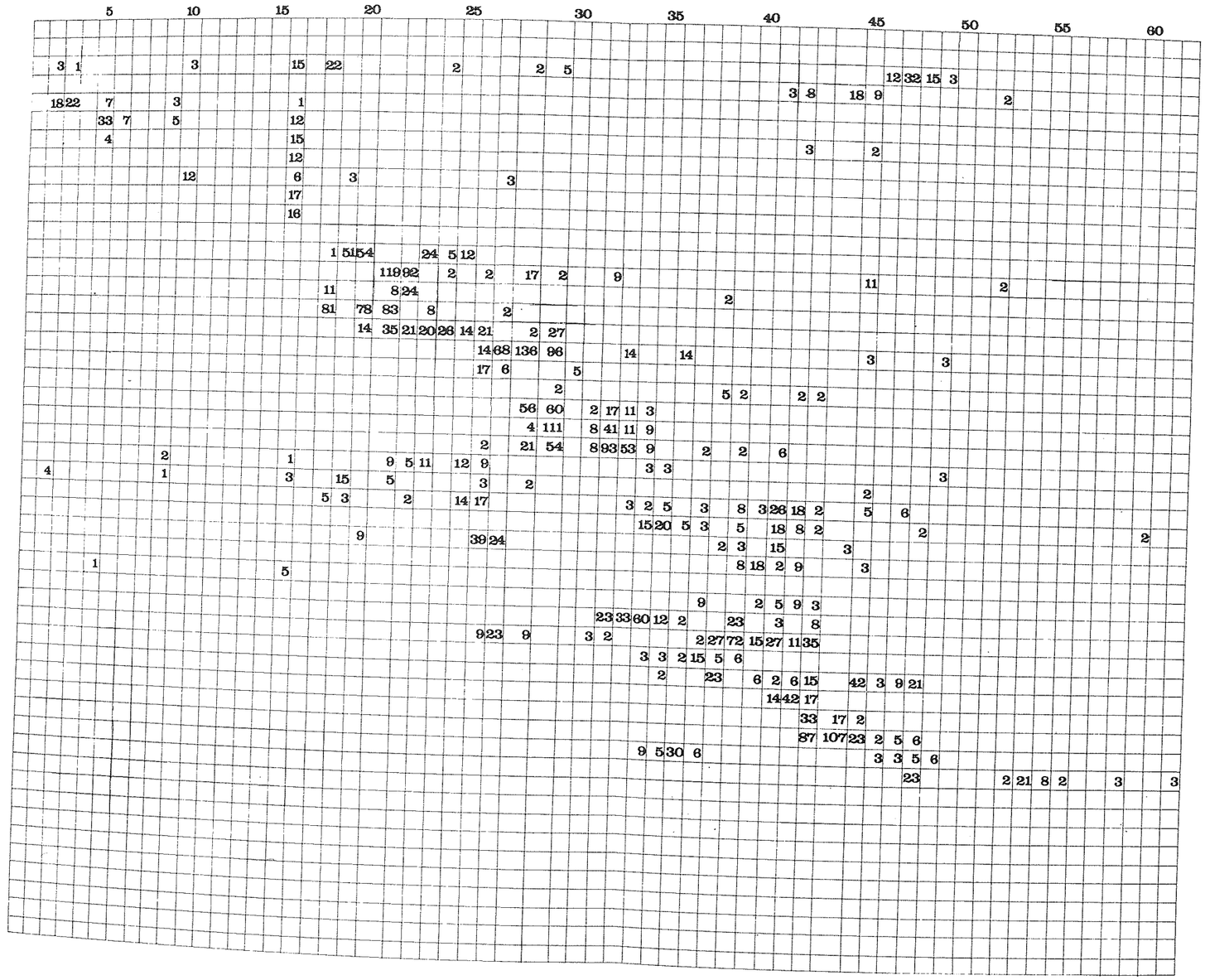
The analysis would have examined the on the site labour requirements in the construction of a house rather than a block; but the activity sampling observations at hour intervals for Blantyre or 1½ hour intervals for Greenfield mean that the sample for one house is often too small for many operations, to be an acceptable measure of accuracy in manhours actually worked e.g. floor boards in a house may have registered observations when the joists did not. Instead, the house block was chosen for detailed analysis purposes. In general, the

GREENFIELD

Block 3 11 houses Productive manhours only

Operations

Weeks



main contractor treated a house block as the unit of production.

An example house block table will now be discussed, first for Greenfield and then for Blantyre. The discussions will be preceded by a brief description of the method of derivation of the data in the tables.

GREENFIELD HOUSE BLOCK NUMBER 3

An early review of the Greenfield data suggested complicated site working. Selecting the data for each block would be a way of simplifying the data for initial analysis. To this end, a table for each of the eighteen blocks at Greenfield was finally developed. The block 3 table illustrated is a typical example from the eighteen blocks. The production of the block tables involved searching by hand methods the eighty-four sets of weekly tables produced by computer for Greenfield. Table 6.4 (illustrated in appendix 6) was used in the search. Table 6.4 lists any productive manhours by trade for each operation worked on each block during each of the eighty-four weeks. Basically, for each separate operation, table 6.4 was hand searched for productive manhours in any week for each of the eighteen blocks. In this way, a full set of operation tables containing productive manhours, setting a list containing each block against the site survey weeks, was produced by hand methods. The process was time consuming, rather than difficult, and not to be repeated.

A table for each block (produced by further hand working) setting each operation against the survey weeks, could easily be formed by selecting each block row of manhours from the operation tables in sequence. The block tables were more easily made this way, as searching

for the relevant data in table 6.4 by operation was simpler. In any case, each operation table could be used for further analysis. All this hand searching to produce the block tables would be replaced by computer work for the far more complex, in terms of the number of separate operations, Code List for Blantyre (see appendix 1). This analysis for Blantyre will be discussed next in this chapter. The general organisation of the work within each block at Greenfield could be examined by the method of tabling the data described for each of the eighteen blocks. As has already been mentioned, the hand searching work was time consuming, and should not be repeated, but nevertheless it did give a good working knowledge of the Greenfield data with which to begin this study.

The illustrated table of block 3 at Greenfield shows a typical example of the distribution of productive manhours in the eighteen block tables produced. The first column in the table lists the main operations from the Greenfield Code List (see appendix 2) in the general sequence of construction, set against the first row in the table which gives the construction period in week intervals.

If the pattern in the block 3 table is simplified by ignoring weeks containing only a small number of manhours for an operation, (say 5 manhours per week) two factors seem apparent from the changed table:

1

The table shows a more orderly sequence of operation work that is nevertheless spread over a long period

2

However, even when this simplified view of excluding operation weeks with small manhours is made on the table, there are many major interruptions of the work for the main trades e.g. the plumber and

electrician trades working on services or the joiner trade working on linings or finishings.

If now all the manhours in the table are considered, the pattern tends to show a wide scatter of work and seems to indicate disorganised working. The exception to this observation is the single column of manhours under week 16, set against the operations for the pre-fabricated timber superstructure in the Greenfield construction. This part of the superstructure involved considerable planning for manufacture in off the site factory conditions and for erection on the site by the main contractor. The result was the construction of the timber superstructure in less than a week, which seems to support possible on the site labour requirement reductions from further rationalisation of the whole house construction. Of course, no account has been take of the off the site labour requirements in manufacture of the timber superstructure that could have occurred on the site or any increased transport requirements of the prefabricated material. The traditional on the site construction that followed the timber superstructure spread out over many weeks for block 3, showing a general pattern that is typical in all the eighteen block tables. Many operations lasted more than three or four months e.g. the main part of the plumber carcassing and fittings was spread over three months or so. In total, the table shows the plumber carcassing and fittings work required 202 productive manhours for block 3. This is approximately equivalent to two plumbers working for three weeks, if some additional manhours allowance is made for a normal non-productive manhours content. This is much less than three months (the time span actually taken for the majority of the work, with the weeks containing only a small number of manhours excluded), and far less than seven or so months over which some work was done to complete the total in

the table of 202 productive manhours.

An important point should be raised here concerning all the block tables on Greenfield, and that is the spread of work, for example in services, is not constant between blocks, but varies greatly. However, in analysis of this variation no simple relationship was found to exist between the spread of working and the manhours required by an operation for each of the blocks. Therefore, there was no crude proof that minimising the spread of working would cause a decrease in manhours.

Overall, the total construction time for block 3 was more than a year, a very long time in view of the relatively small on the site manhours actually required. The same construction period was generally true for the other seventeen blocks at Greenfield.

BLANTYRE HOUSE BLOCK NUMBER 12

The Greenfield house block tables were followed by similar tables produced by computer from the SCCS Blantyre data file for each of the twenty-two Blantyre blocks. The tables were made from the application of the SCCSIR system (discussed in chapter 3) to the SCCS Blantyre data file that contained all the observation attributes, and in particular, included the attributes related to time (see chapter 2) that had been excluded from previous BRE data files.

A request of the SCCSIR system is made on two standard forms. On the first form the user follows a sequence of questions in specifying the request. Two main questions need to be answered:

1

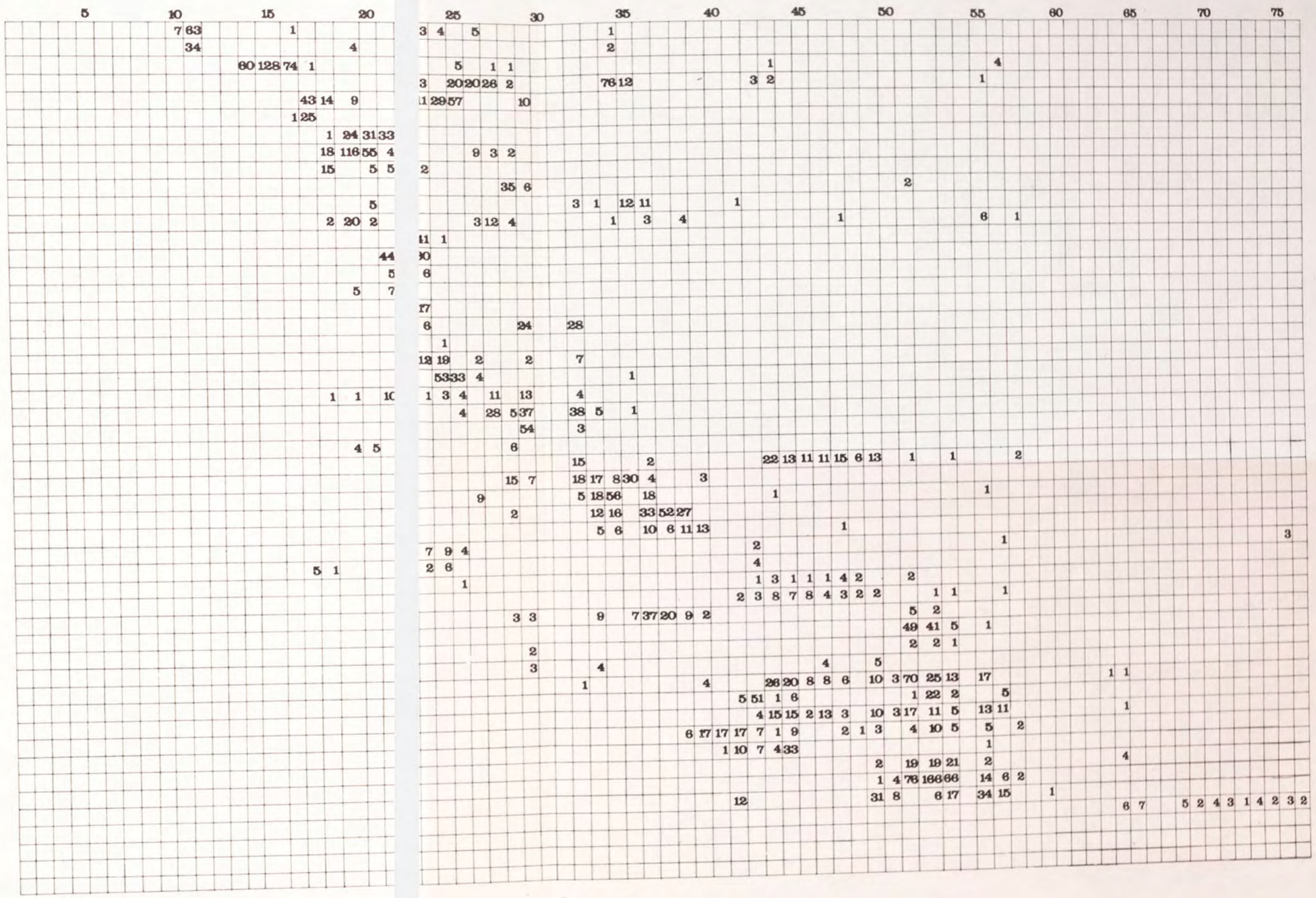
Which data in the whole data file will be required for the request?

BLANTYRE Block 12 9 houses Prod tive manhours only

Operations

Excavate foundations
Concrete foundations
Brickwork to dpc
Steps
Blaes filling
Wallplates and ground floor joists
Party wall brickwork dpc to first floor
Outside wall brickwork dpc to first floor
Gable wall brickwork dpc to first floor
First floor joists
Timber ground floor stud partition
Sundries dpc to first floor
Party wall brickwork first floor to eaves
Outside wall brickwork first floor to eaves
Gable wall brickwork first floor to eaves
Sundries first floor to eaves
Party wall brickwork eaves to apex
Gable wall brickwork eaves to apex
Beamfilling
Roof construction
Roof covering
Scaffolding
Roughcasting
Ground floor boarding
First floor boarding
Stairflights
Drylining to ceilings
Paramount partitions
Drylining to walls
Drylining to partitions
Rainwater goods
Soil and vent pipe
Carcassing h/c services
Plumber fittings
Wiring and outlet boxes
Electrical fittings
Carcassing electrical heating service
Electrical warm air heating unit
Doors
Kitchen units
Miscellaneous joinery
Jointing to drylinings
Artex
Emulsion paint to internal walls
Internal gloss painting
External gloss painting
Snagging

Weeks



In this case, only data describing the productive manhours used in the construction of the substructure, superstructure and finishings of each block would be selected.

2

How exactly will the selected data be sorted? Again in this case, the data would be sorted principally by block number, to form separate block tables listing each operation in general building sequence against the site construction period week numbers.

The second form requires the user to fill in on a grided sheet of line-printer page size (in defined areas of the page) the headings, column and row setting-out of the tables requested. This sample table must be carefully set-out, and thought must be given to recurring pages of each table in the line-printer output. In this request, the layout of the table had to be spread over two line-printer pages because of the number of columns required for the seventy-two site weeks. This necessitated two requests of the SOCSIR system to produce the block tables. The first request contained the data for weeks 3 to 41 and the second, weeks 42 to 76 (see appendix 8, tables 8.1). Overall, these first two requests produced twenty-two block tables containing the substructure, superstructure and finishings operations listed in general building sequence against the weeks of the construction period. The SOCSIR system requests were simply and quickly done. SOCS produced the requests in a matter of days, producing work that would have taken months by hand methods from the seventy-two sets of weekly tables on Blantyre (see appendix 4), and would not have been considered.

Block 12 is reproduced as an example from the twenty-two tables computer-sorted for Blantyre. The table has been simplified by

combining some operations to make for easier comparison with Greenfield.

The general pattern of manhours shown in the block 12 table is very similar to that of the block 3 table from Greenfield. In general terms there are a few differences in construction between the two sites, once the stage of the prefabricated timber superstructure at Greenfield is passed (the constructions are compared operation for operation in chapter 4).

The seemingly disorganised working represented in the block 12 table, like the block 3 table from Greenfield, tends to support the idea that further rationalisation of the sequence of construction may reduce labour requirements i.e. a tidy and compact flow of work may be accompanied by fewer manhours. However, as mentioned for Greenfield operations, no crude proof could be found of a relationship between the spread of work and the manhours required for an operation, and so a tidy and compact sequence of construction shown on a block table for a future site may show no reduction in labour requirements (all other things being equal) but this seems unlikely. Further rationalisation of the construction sequence needs to be tested through several development projects aimed at reducing on the site labour requirements in traditional construction.

ITEM TWO

THE BLANTYRE HOUSE SUPERSTRUCTURE BRICKLAYING GANGS

Following the detailed data analysis in chapter 8, that compared the average number of different operatives per house with the average manhours per house for each block on several operations, the activity sampling data can provide the number of manhours contributed by

each operative on any operation in each block. If the set of operatives employed on an operation in each block can be related together, then any identifiable operative gang structure can be compared with the variation in manhours for the same operation in each block. By this comparison the possible influence of different gangs can be tested against the measured variation in manhours between blocks.

To control the amount of hand working necessary to identify gang structures in an operation, table 8.3 (illustrated in appendix 8), that lists the manhours contributed by each operative by house block for each operation at Blantyre, was used in this analysis.

A work operation from the bricklayer, joiner, plumber, electrician, plasterer and painter trades were tested for an identifiable gang structure. From the operations tested, the only clear gang structure was for bricklayers working on the superstructure brickwork operations at Blantyre. Four main bricklayer gangs were found, marked as gangs A, B, C and F in the following graph that illustrates the results. Membership of gang C changed during the construction period, eventually forming a new gang, gang D. A sixth gang, gang E, completed only one block superstructure.

The manhours per block for the superstructure brickwork, were calculated as in the previous analysis in chapters 6, 7 and 8 from the BRE computer produced total data summary tables for Blantyre (see table 5.4, appendix 5).

As a more accurate method of comparing the Blantyre blocks, the quantity of brickwork in terms of square metres of half-brick walling in each block, was calculated from the Bill of Quantities.

This calculation would account for the different house sizes between blocks (particularly the 2-person house blocks), a number of brick wall steps between houses in some blocks and the quantity of gable wall per house in blocks with different numbers of houses.

For each block, the number of manhours per square metre of half-brick walling was calculated. The results of the calculations are given on the vertical axis of the graph illustrated. The horizontal axis in the graph shows the block construction order, derived from the Blantyre data when 50 percent of the superstructure bricklaying had been completed in each block (previously used in the superstructure brickwork analysis in chapter 6). A key to the Blantyre block house sizes in the graph is given below:

⊖ 2-person houses

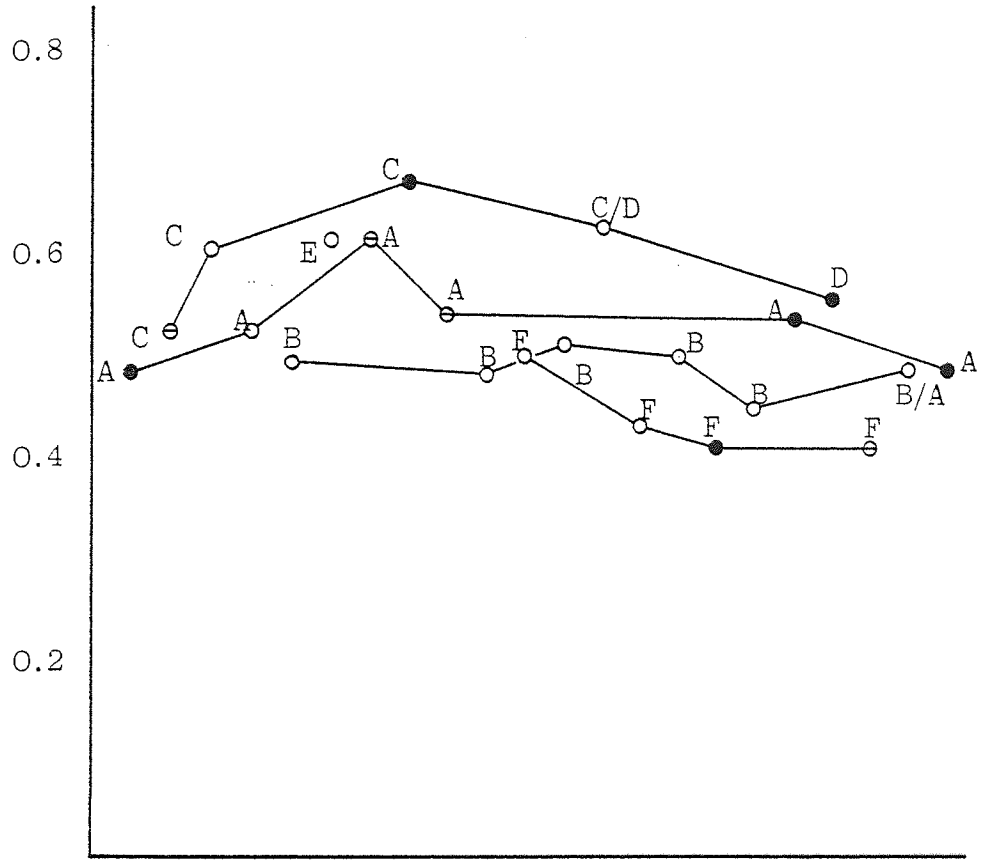
○ 4-person houses

● 5-person houses.

The results for the first blocks completed by each of the main four gangs (A, B, C and F) were remarkably close at 0.5 manhours per square metre of half-brick walling. Subsequently, the results for other blocks completed by each gang varied in different ways, which seems to suggest that the operatives in each particular gang have an influence on labour requirements for the operation.

In general, gang C required more manhours than the other gangs to complete a square metre of half-brick walling; in part, because the gang worked on a house block of an alternative house size each time it changed to a new block, and the gang operative membership changed from C to another composition of operatives, called gang D. Gang F produced lower results in terms of manhours per square metre of half-

AVERAGE MANHOURS PER SQUARE METRE
OF HALF-BRICK WALLING



HOUSE BLOCKS IN ORDER OF 50 PERCENT WORK DONE

BLANTYRE SURVEY OPERATION CODE : 16, 18, 20

OPERATION WORK : BRICKWORK SUPERSTRUCTURE

brick walling than gang B, which in turn had lower results than gang A. In general, if the next block that either gang A, B or F moved to work on had the same house size as the last block, then the results in terms of manhours per square metre of half-brick walling tended to be reduced. This observation seems to indicate that the repetition of a familiar operation produces a beneficial reduction in labour requirements.

ITEM THREE

THE GREENFIELD BRICKLAYER NON-PRODUCTIVE MANHOURS COMPARED WITH PRODUCTIVE MANHOURS

A part of the Blantyre and Greenfield activity sampling data that has not been discussed in this study so far is the large non-productive manhours element in the total number of manhours that are divided between the trades on either site (the total data summary analysis discussed in chapter 5 includes the non-productive manhours element in the data). Non-productive manhours were 23 percent and 27 percent of total manhours at Blantyre and Greenfield respectively.

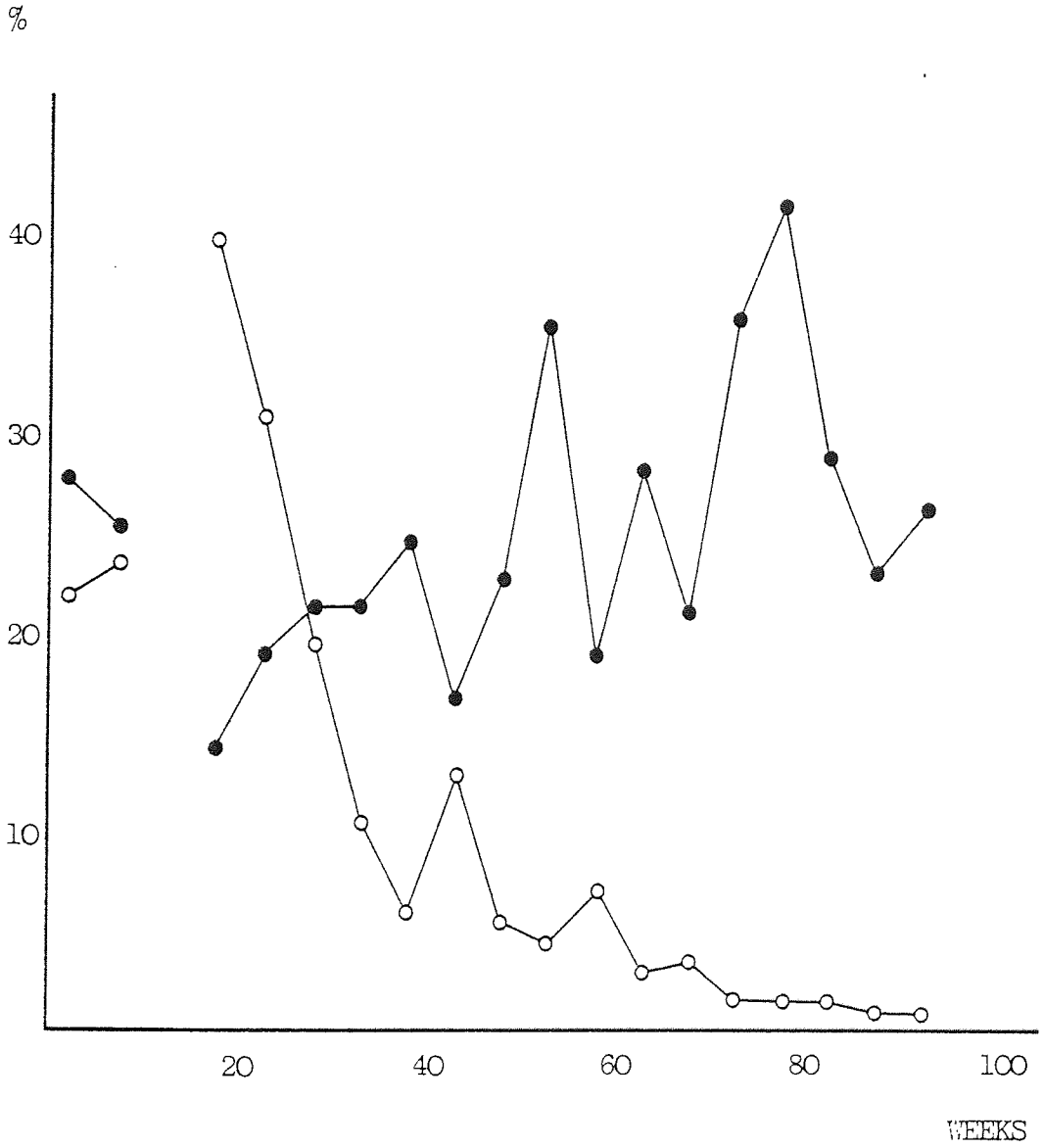
The detailed data analysis in this study has concentrated attention on the variation in manhours on operations repeated in each block on site for the productive activities F, N and P (defined in appendix 3). The non-productive manhours are derived from other activities in the activity sampling data (listed and defined in appendix 3 as S, I, RO and A).

For detailed data analysis, what relationship exists between the variation in productive manhours and non-productive manhours for operatives working on an operation repeated in each block on the site? Is the hypothesis true that the proportion of non-productive

manhours increases coincidently with increasing manhours, in the range of variation in manhours for a repeated operation? If the hypothesis is true, controlling the factors that cause interruptions to work that probably increase the number of non-productive manhours in an operation, may reduce the total labour requirements in terms of non-productive and productive manhours.

The problem in analysing this hypothesis in this study is that in the activity sampling data for Blantyre and Greenfield the non-productive manhours are related to operatives, but not to each operation or block. Put another way, a site observer making an observation in the surveys was not able to record in which block and on what operation an operative was working when he observed the operative, say, walking around the site. Simplified methods of proportioning non-productive manhours between productive manhours, for each operative working on an operation in a block and other operations and blocks on the same working days, were carried out in the study, but without any convincing result.

In examining non-productive manhours during the study, only one form of useful detailed data analysis was found that could be derived directly from the activity sampling data. The analysis involved comparing the productive and non-productive manhours of the bricklayer trade at Greenfield, in terms of the proportion of non-productive manhours in the total manhours by week during the construction period. A different hypothesis was that the percentage of non-productive in all manhours would be lowest when production (measured in manhours) was highest i.e. when there was plenty of work on the site the non-productive manhours percentage would be low, and vice versa. The results of this analysis on the bricklayers at Green-



BRICKLAYER TRADE : PERCENTAGE NON-PRODUCTIVE TO ALL MANHOURS
AVERAGED EACH 5 WEEKS

field are illustrated in the graph.

The horizontal axis in the graph represents weeks in the Greenfield construction period. The manhour results used in the graph were calculated from the Greenfield sets of computer-produced weekly tables (listed in appendix 6), as a weekly average per five weeks of the construction period. The solid circles line in the graph represents to a convenient scale the variation in average total manhours per five weeks. These total manhour results are compared with the variation in the percentage of non-productive manhours in the total manhours (productive and non-productive manhours combined) for the same 5 week periods, represented by the open circles line in the graph (the vertical axis shows the percentage of non-productive manhours). The comparison seems to support the stated hypothesis, but the peak shown on the graph represents the large amount of brickwork done after the 1972 general building strike, and so the incentive to earn money again may have extraordinarily reduced the percentage of non-productive manhours. Nevertheless, the two following peaks in the graph, around weeks 40 and 60 in the construction period, are also accompanied by low percentages of non-productive manhours.

CHAPTER 10

CONCLUSIONS

This final chapter contains the main conclusions drawn seriatim from chapters 5 to 9, that cover the analysis work in the study. The chapter concludes with suggestions for future work in this field. The contents of the chapter are divided into three sections:

1

Conclusions from the total data summary tables analysis described in chapter 5, divided under the following headings:

1.1 Substructure

1.2 Superstructure

1.3 Services and Finishes

1.4 External works.

2

Conclusions from the main detailed data analysis described in chapters 6, 7 and 8, dealing with each chapter in order. A further part of the section covers the conclusions derived from the miscellaneous detailed data analysis discussed in chapter 9. Based on these detailed data analysis conclusions, the final part of the section makes recommendations on ways to reduce labour requirements in traditional house building.

3

A critique on the BRE activity sampling method employed on the Blantyre and Greenfield sites, and also on the extension to the method introduced in this study. The final part of the section concludes with a recommendation of combining more detailed methods with the activity sampling method used in the study, for the purposes of future work in this field.

1

SUMMARY DATA ANALYSIS

The summary data analysis indicated operations in which possible reductions in labour requirements could be made for the development of labour productivity.

1.1

SUBSTRUCTURE

The analysis of Blantyre shows that the average labour requirements for the house substructure were significant (149 manhours compared wtih only 70 manhours at Finchampstead) and in need of special attention. The labour requirements for the Greenfield substructure (123 manhours) were less than at Blantyre, but because the construction also used a suspended timber floor, the manhours for brickwork below dpc were still relatively large. The Crawley and Finchampstead substructures had fewer labour requirements than either Blantyre or Greenfield, partly explained by the employment of solid concrete floors on the English sites. A solid concrete floor construction would have reduced requirements at Blantyre and Greenfield, especially if the house blocks had been:

1

Placed parallel to the site contours

2

Divided into blocks of only two or three houses, or given adequate steps between houses for blocks placed at right angles to the contours

3

Given foundations formed by cutting and filling the site slope to minimise excavation, masonry work below dpc and following external

works in making banks or retaining walls.

1.2

SUPERSTRUCTURE

The cavity brickwork superstructure at Blantyre represented 20 percent of the labour requirements on the house construction (excluding the external site works). Therefore, even a small percentage reduction in labour requirements would make a significant overall contribution. One way to reduce the labour requirements in the Blantyre house walls would have been to design the walls for larger masonry units e.g. light-weight concrete blocks. This suggestion is derived from recent research relating improved bricklayer productivity to masonry unit size (Kinninburgh, 1968).

1.3

SERVICES AND FINISHES

The services and finishes work took almost 50 percent of the labour requirements on the houses at Blantyre and Greenfield. However, the summary data analysis could only suggest a number of small reductions in labour requirements that could be made. For example the plasterboard drylining work at Blantyre was carried out by the plasterer and the joiner trades. However, the labour requirements for the operation were more than at Greenfield, where the work was done by the joiner trade only. Thus, the benefit at Greenfield seems to have been gained by the fact that the lining work was done as a larger, single, trade item of work.

The work in plumbing at Greenfield (79 manhours) had particularly high labour requirements that may have been due, in part, to interference from other trades. Other trade interference may also have contributed to the high labour requirements at both Blantyre

and Greenfield for final joinery and snagging (95 and 89 manhours, respectively), and decoration at Blantyre (89 manhours), particularly internal gloss painting (49 manhours). Organisation of the work of these operations into larger, independent, trade divisions (as in the case of drylinings work at Greenfield) should improve labour productivity.

1.4

EXTERNAL WORKS

The external works at Blantyre absorbed 30 percent of the labour requirements overall. This proportion was even higher at Finchampstead, distorted by the exceptionally low on the site labour requirements in the substructure and superstructure (Greenfield probably has similar external works labour requirements to Blantyre). Much more research and development work needs to be applied on external works, particularly in services co-ordination and on the site layout in relation to hard surfacing i.e. roads and footpaths.

2

DETAILED DATA ANALYSIS

An important fact developed from the detailed data analysis is that the labour requirements for a repeated operation through the house blocks at Blantyre or Greenfield can vary by 3 : 1 or more e.g. internal plumber carcassing work at Greenfield or internal emulsion painting at Blantyre. In which case, the most important question to answer is what particular conditions produced the lowest manhours on an operation, or conversely, what other conditions produced the highest manhours on exactly the same operation in another house block?

MANHOURS V BLOCK ORDER, CHAPTER 6

The operation analysis discussed in chapter 6 was carried out to reveal any relationship between variations in manhours and order in construction of similar, repeated, operations. The overall conclusions of the analysis are that some of the operations investigated produced simple relationships, but the majority revealed only a random relationship between manhours and block order. The operations showing a random relationship could only have each result explained in detail, by more data on each block than could be provided by the BRE activity sampling method. The few operations for which simple relationships were found (e.g. the linear fall in manhours with order for all the work on doors at Greenfield or the kitchen fittings at Blantyre) cannot be fully explained either, without further data about each block.

Learning the operation may have had some influence on lowering manhours in most of the operations in which a relationship was found between manhours and block order. However, for the remaining operations analysed, learning to do the work seems not to appear as a significant factor affecting variations in manhours.

MANHOURS V SEPARATE VISITS, CHAPTER 7

The hypothesis that interruptions to work on an operation may increase manhours, created the operation analysis discussed in chapter 7, in which BRE activity sampling data was used to calculate visits for comparison with manhours. The overall conclusion from the operation analysis was that for most operations a good linear relationship was found to exist between manhours and visits. However, manhours and visits were calculated from the same observations on

each operation. This is important for the three Greenfield operations, as the average numbers of manhours per visit were in the range from 1.96 to 2.14 (manhours), close to the observation interval (Greenfield activity sampling survey) of 1.5 hours. The position was less critical for most of the Blantyre operations analysed, especially as the observation interval was shorter at 1 hour. The Blantyre superstructure operations were well above the one observation equals one visit level, with a range of 2.15 to 2.98 manhours per visit, and yet these operations had good correlation coefficients confirming a firm relationship between manhours and visits.

Nonetheless, a large number of visits do take place within most of the operations investigated and if these visits could be reduced, then savings in labour requirements would follow. The large number of visits is probably the result of many factors which the BRE activity sampling method does not document. A fact which the Blantyre analysis shows clearly, is that the bricklayer operations involve longer visits on average (i.e. more continuous working) than in the services and finishes operations.

MANHOURS V NUMBER OF OPERATIVES, CHAPTER 8

Early analysis in this study found that work in many operations was spread over numerous weeks for most blocks. This spread of work could be accompanied by the successive employment of new operatives to complete any operation. The hypothesis that successive new operatives put to work on an operation may increase manhours, led to the operation analysis discussed in chapter 8, that compares for selected operations the number of different operatives employed with variation in manhours. The overall conclusions from the operation analysis are that a few of the operations investigated show a

general relationship between number of different operatives and manhours, which supports the hypothesis that controlling the number of operatives employed on an operation down to the optimum number for trade working would reduce labour requirements (e.g. joiners working in pairs on plasterboard dry linings). The remainder of the operations show a random distribution about which more could be discovered only if additional data on the factors affecting the labour requirements in each block were known.

MISCELLANEOUS DETAILED ANALYSIS, CHAPTER 9

The two house block tables given as typical examples of the sequence of work in the construction of blocks at Blantyre and Greenfield show a wide scatter of work over many weeks for most operations (particularly those operations in services and finishes). Even if the site construction weeks containing only a few manhours on an operation are ignored, the work on most services and finishes operations is divided between many weeks. This seems to support the hypothesis that the operations are disorganised and yet no relationship could be found between the spread of work through many weeks and the manhours on an operation for each block.

The bricklayer gang analysis for the Blantyre superstructure operation showed that the operative composition of each gang was a factor affecting productivity. Also the productivity of a gang did appear to improve, through learning the operation, if the next house block that the gang constructed was composed of exactly the same house type.

The third item in chapter 9 discussed the analysis work in the study directed towards finding any relationship between productive and non-productive manhours in operations. This relationship is important

as non-productive manhours are significant e.g. 23 percent and 27 percent of total manhours at Blantyre and Greenfield, respectively. The analysis covered the Greenfield bricklayer work as a whole and suggests that the proportion of non-productive manhours in the total manhours (productive and non-productive manhours combined) tends to fall as the volume of work rises, and vice-versa. The activity sampling data does not relate non-productive manhours to particular work but only to individuals, and this limited the analysis. Future work would require more detailed data, so that non-productive and productive manhours can be closely related.

GENERAL RECOMMENDATIONS

Interruptions to work were found in plenty through the detailed analysis, most particularly in the typical house block tables from Blantyre and Greenfield and in the large numbers of visits estimated. For the purposes of future development work this emphasis gives some support to the hypothesis that larger, more independent, trade operations should be organised to reduce labour requirements as this should reduce conflict between trades, and thus interruptions. This hypothesis applied particularly to the operations in services and finishes on which much of the analysis in this study has concentrated.

In detail, the main service operations i.e. plumbing and electrics could each be organised as one operation. The joiner work could be simplified into two main operations i.e. drylinings, flooring and joinery work for services and later, the final finishing joinery. The remaining principal items of work could be amalgamated into one painter trade operation that includes the plasterboard jointing together with the normal internal and external painting work.

This simplication of the way the house construction is organised can only be achieved by design which recognises the special needs of simplification for efficient production e.g. by careful planning for floor access panels to facilitate the single electrics operation (beneficial for future renewal of wiring) and in construction if contractors can be encouraged to see the benefits of simpler site management in larger, more independent, trade work operations. Recent work by the National Building Agency expresses confidence in rationalising house design to obtain fewer separate operations in a common building sequence throughout a site as a method of reducing labour requirements in house building. The work seems to place less emphasis on rationalising the physical design which can easily compromise the needs and attitudes of users.

Any rationalisation of the design of houses to simplify production must involve the architect. The analysis in this study tended towards simpler work organisation on the site, rather than specific analysis of use to the architect. However, some design implications do follow from simplifying the organisation of building operation work e.g. a two-storey house design must cater for screwed down access panels in the first floor to allow the electrical work (mentioned above) to be completed as one operation. Future work would require more detailed data on operations, if a clearer understanding is to be gradually formed between design and productivity. The creation of simpler site organisation must become part of the design process i.e. design and production must achieve closer links. In the future, education for the professions in the building industry must endeavour to create more understanding of the necessary links between design and production, as this could make a major contribution to finding

ways of improving productivity, while at the same time striving to develop higher design standards.

3

CRITIQUE OF THE BRE ACTIVITY SAMPLING METHOD

The Blantyre and Greenfield activity sampling surveys analysed in this study generated large quantities of data that required the use of a computer. However, in the BRE method the computer application was relatively simple, producing tables of data that still had to be hand worked for analysis (very little data could be used directly from the computer produced tables). The hand sorting of the data for detailed analysis, involving the numerous weekly computer tables on each site, was extremely cumbersome. Early discovery in the study of the problem of handling the data led to the extension of the BRE method (made in this study) for use in the Blantyre data. The extension to the BRE method was successful and vastly improved the rate and possible access to the Blantyre activity sampling data for detailed analysis.

Future activity sampling surveys should employ the same method development i.e. the more sophisticated use of computers in handling the data precisely for analysis purposes, so as to reduce to a minimum the amount of necessary hand work. The new method would eliminate the large amount of computer work involved in producing dozens of sets of weekly tables, as was done by the BRE for Blantyre and Greenfield.

On completion of the weekly tables for Blantyre and Greenfield, the BRE activity sampling method again used a computer with all the data for each site, to produce two sets of summary tables. These

summary tables required additional hand sorting work to suit the overall data analysis (which again could be avoided by the use of more sophisticated computer programmes). Nonetheless, once the additional hand sorting on the summary tables was done, this study found the BRE activity sampling method excellent for the overall assessment of labour requirements for operations in the Blantyre and Greenfield construction.

Some comparison was possible between the Blantyre and Greenfield overall results and the results in similar form of surveys made by the BRE at the Finchampstead and Crawley house building sites in England. So far, the majority of findings from activity sampling surveys have been in this overall summary form.

However, as mentioned already, this study represents an extension of the use of the BRE methods into rather more detailed analysis and provides detailed data results about labour requirements in house building, particularly traditional house building in Scotland. To this end, the ability of the activity sampling data to provide reliable results on the variation in manhours for operations of reasonable size between blocks was employed.

The continuous problem encountered in interpreting the results obtained was that there was insufficient data to explain, adequately, the variation in manhours. Further methods that collect more data on each operation need to be explored if this is to be achieved. However, more detailed methods that collect ever more data would eventually lead to a large increase in the volume of data for a whole site such as Blantyre. The more detailed the method, the more expensive the survey would be, and even using a computer for

sophisticated handling, the data would become progressively too large in volume for likely analysis use.

FUTURE WORK

One solution would be to select a few operations worthy of investigation (based on previous survey analysis conclusions) by more intensive data collection. This solution seems attractive, but the data would then describe a few operations in great detail, that would be out of the context of the whole site construction. A good working solution would seem to be a simplification of the present overall BRE activity sampling method as an overall data background. In addition, within the background provided by this simpler activity sampling survey, more detailed data collection methods could be applied to certain operations which earlier surveys (or the current survey, if the overall data can be handled by computer concurrently) had found in need of further explanation e.g. the variation in manhours between blocks for the installation of the electrics in a single operation.

APPENDIX 1

BLANTYRE HOUSE CONSTRUCTION ACTIVITY SAMPLING CODE LIST

CODE	STAGE OF WORK	CODE	OPERATION
	SUBSTRUCTURE		
3	Excavate foundation trenches	A	Excavate house foundation trenches
		B	Level and compact trenches
		C	Disposal of surplus soil
		D	Protection of foundation trenches
		E	Consolidating bad ground
4	Concrete foundations	A	Formwork in foundation concrete
		B	Placing concrete in foundations
		C	Reinforcement in foundations
5	Brickwork up to damp proof course	A	Cavity brickwork in party walls
		B	Inner leaf of front and rear walls
		C	Outer leaf of front and rear walls
		D	Inner leaf of gable walls
		E	Outer leaf of gable walls
		F	Honeycombe dwarf walls
		G	Damp proof course
		H	Concrete threshold
		J	Key pointing
6	Underfloor filling	A	Blaes filling
		B	Ash blinding
		C	Pitch damp proof course

CODE	STAGE OF WORK	CODE	OPERATION
7	Suspended gound floor	A	Wall plates
		B	Floor joists
		C	Pre-cast concrete heater base
		D	Floor boarding
	SUPERSTRUCTURE		
14	Roughcasting	A	1st coat
		B	2nd coat
		C	Dash
15	Scaffolding	A	Erect scaffold
		B	Strike scaffold
16	Brickwork ground floor to first floor or to eaves for single storey	A	Cavity brickwork in party walls
		B	Inner leaf of front and rear walls
		C	Outer leaf of front and rear walls
		D	Inner leaf of gable walls
		E	Outer leaf of gable walls
17	Sundries up to first floor or to eaves for single storey	A	Pre-cast concrete sills
		B	Pre-cast concrete lintels
		C	Door and window units
		D	Seal cavities
		E	Mastic pointing around frames
		F	External off-peak electric control cupboard
18	Brickwork first floor to eaves	A	Cavity brickwork in party walls
		B	Inner leaf of front and rear walls
		C	Outer leaf of front and rear walls

CODE	STAGE OF WORK	CODE	OPERATION
		D	Inner leaf of gable walls
		E	Outer leaf of gable walls
19	Sundries up to eaves level	A	Pre-cast concrete sills
		B	Pre-cast concrete lintels
		C	Window units
		D	Seal cavities
		E	Mastic pointing around frames
20	Brickwork, eaves to apex	A	Brickwork in party walls
		D	Inner leaf of gable walls
		E	Outer leaf of gable walls
		F	Rough rendering to party walls
		G	Beam filling
21	Roof construction	A	Roof wall plates
		B	Roof trusses
		C	Ceiling dwangs
		D	Eaves, fascias, bargeboards tilting fillets
		E	Tank bearers
		F	Ceiling hatch
22	Roof covering	A	Plasterboard sarking
		B	Verge felt
		C	Tiling battens
		D	Fix roof tiles
23	Glazing	A	Temporary glazing
		B	Double glazing
		C	Glazing internal doors and frames

CODE	STAGE OF WORK	CODE	OPERATION
		D	Single glazing
24	Stud partitions and first floor joists	A	Timber ground floor stud partitions
		B	Honeycomb plasterboard partitions
		C	First floor boards
		D	First floor joists
25	Staircases	A	Stair flights
		B	Balustrade
		C	Cover beads
		D	Framing for plasterboard
	SERVICES AND FINISHES		
27	Dry linings to walls and ceilings	A	Party walls
		B	External walls
		C	Flank end walls
		D	Partitions
		E	Encase beams
		G	Encase heating appliances and ducting
28	Plumber work	B	Lead flashings
		C	PVC rainwater goods
		D	Cast iron soil and vent stack
		E	Carcassing for hot and cold services
		F	Fittings and appliances
		G	Builder work
29	Electrical work	A	Fixing wiring and outlet boxes
		B	Fix electrical fittings and appliances

CODE	STAGE OF WORK	CODE	OPERATION
		C	Install television and radio point
		D	Builder work
30	Heating Engineer work	A	Carcassing for service
		B	Install warm air heating units ducts and flues
		C	Install water heating units
		D	Cut and fix timber cradling, framing etc, enclosing warm air ducting and heating unit
		E	Builder work
		F	Install electric meter
31	Joinery second fix	A	Pre-hung door units
		B	Architraves
		C	Ironmongery
		D	Storage and work fitments
		E	Sealing strip etc to windows
		F	Cut and fix skirtings
		G	Cut and fix bath panels and pipe casings
		H	Cut and fix shelving
		J	Cut and fix coatrails and fix coat hooks
32	Final joinery items	A	Fix toilet roll holder and grab rails
		B	Fix pvc extrusions to bath and wall
		C	Fix aluminium grills to doors and windows
		D	Fix aluminium edge protecting strip between tiles and concrete floor
		E	Fix door stops
		F	Snagging

CODE	STAGE OF WORK	CODE	OPERATION
33	Jointing dry linings to walls and ceilings	A	Complete jointing external walls
		B	Complete jointing party walls
		C	Complete jointing partitions
		D	Complete jointing ceilings
		E	Apply Artex to ceilings
34	Decoration	A	Two coat emulsion paint walls and ceilings
		B	Internal painting
		C	External painting and decorating
35	Ground floor finishes	C	Ceramic wall tiles
		D	Cleaning up after all other operations are complete
36	Hand over, maintenance	A	Snagging in occupied dwellings

APPENDIX 2

GREENFIELD HOUSE CONSTRUCTION ACTIVITY SAMPLING CODE LIST

CODE	STAGE OF WORK	CODE	OPERATION
	SUBSTRUCTURE		
1	Foundations	A	Excavate foundation raft
		B	Concrete in foundations
2	Brickwork substructure	A	All brickwork up to damp proof course
		B	Steps
3	Underfloor fill	A	Blaes filling, ash blinding and pitch damp proof membrane
	SUPERSTRUCTURE		
4	Timber shell	A	Wall plates and ground floor joists
		B	Ground floor boarding
		C	Erect ground floor wall panels and load bearing partitions
		D	First floor joists
		E	First floor boarding
		F	Erect first floor wall panels
		G	Roof trusses including bracing
5	Roof covering	A	Roof tiles including sarking and battens
6	Brickwork	A	External walls including sundries
		C	Flank end walls
		E	Party walls
7	Dry dash	A	All work
8	Scaffolding	A	All work

CODE	STAGE OF WORK	CODE	OPERATION
9	Glazing	A	All work
	SERVICES AND FINISHES		
10	Plumbing	A	Gutters and downpipes
		B	Soil and vent pipe
		C	Carcassing for hot and cold services
		D	Fittings and appliances
11	Electrics	A	Wiring and outlet boxes
		B	Fittings and appliances
12	Gas	A	Carcassing for service
13	Heating	A	Gas fired warm air heating unit
14	Dry linings	A	Honeycomb plasterboard partitions
		B	Plasterboard to ceilings
		C	Plasterboard to walls
		D	Jointing in drylining
15	Staircase	A	All work
16	Joinery	A	Doors including linings and ironmongery
		B	Kitchen units
		C	Skirtings, shelves, coatrails
17	Decoration	A	Artex ceiling finish
		B	Emulsion paint to internal walls
		C	Gloss paint internally
		D	Gloss paint externally

CODE	STAGE OF WORK	CODE	OPERATION
18	Wall and floor finishes	A	Floor tiling
		B	Wall tiling
19	Handover, maintenance	A	Snagging in occupied dwellings

APPENDIX 3.1

SCHEDULE OF ACTIVITIES IN THE BLANTYRE ACTIVITY SAMPLING SURVEY

ACTIVITY	CODE	DETAIL OF ACTIVITY
UNLOADING	U1	Unloading materials into compounds or stores, to be subsequently handled to other locations i.e. a block, house or site area
	U2	Unloading materials direct to other locations
HANDLING	H1	Handling materials from the compound or stores to other locations;
	H2	Handling materials during the operation for immediate use e.g. the pre-loading of bricks on to scaffolding prior to use, and similar pre-loading
	H3	Handling materials from one location to other locations, or within the same location i.e. double handling or repeat work (R)
SETTING OUT	T1	Setting out, erecting profiles, site rails
PLUMBING, LEVELLING AND ALIGNING	T2	Check for and obtain accuracy
TESTING SERVICE INSTALLATION AND APPLIANCES	T3	Testing out completed and semi-completed service cables and pipework, including the appliances during (and after) installation of the services and fittings
WORKING	F	operatives carrying out an operation, unless as otherwise described in this schedule of activities
PREPARATORY WORK	P	Preparation of material for subsequent fixing or application e.g. 1 fabrication of bulk materials into pre-fabricated building components, e.g. 2 heating bitumen and e.g. 3 in-situ preparation of materials components prior to or during the operation
CONNECTING AND JOINTING	J	Breaking into service cables and pipework for jointing branch and/or other connections, including fixing the junction box, troughs, saddles, sleeves, turncocks and/or similar jointing fittings

ACTIVITY	CODE	DETAIL OF ACTIVITY
CLEAN-UP	CL	Cleaning and clearing up after or during an operation
SUPERVISION	SU	'Non working' supervisory staff, e.g. visiting, general and trade formen and charge hands not engaged on actual building operations
NOT WORKING	N	Operatives not working while at the work place
REPEAT WORK	R	The extra work undertaken to complete operations, prefabricated and fully finished components, in correcting and making good defective workmanship, material and/or design and organisation

NON PRODUCTIVE ACTIVITY	CODE	DETAIL OF ACTIVITY
WALKING	I	Operatives not working and not at the workplace
RAINED OFF	RO	Operatives not working because of inclement weather
STANDING	S	Operatives not working because of late arrival or early departure at or from the work place, breaks only
ABSENT	A	Operative not observed during the recording period

SPECIAL ACTIVITIES FOR BRICKLAYING

WORKING

F1 Lay bricks or blocks to rule

F2 Lay bricks or blocks to line

F3 Spread mortar

PREPARATORY WORK

P1 Cutting bricks

P2 Prepare mortar

P3 Set-up line

APPENDIX 3.2

SCHEDULE OF ACTIVITIES IN THE GREENFIELD ACTIVITY SAMPLING SURVEY

ACTIVITY	CODE	DETAIL OF ACTIVITY
UNLOADING	U1	Unloading materials
HANDLING	H1	Handling materials from the compound or stores to other locations i.e. a block, house, or site area
	H2	Handling materials during the operation for immediates use e.g. the pre-loading of bricks on to scaffolding prior to use and similar pre-loading
SETTING OUT PLUMBING, LEVELLING AND ALIGNING	T1	Setting out, erecting profiles, sight rails, checking for and obtaining accuracy
WORKING	F	Operatives carrying out an operation, unless as otherwise described in this schedule of activities
PREPARATORY WORK	P	Preparation of material for subsequent fixing or application e.g. 1 fabrication of bulk materials into pre-fabricated building components, e.g. 2 heating bitumen and e.g. 3 in-situ preparation of materials or components prior to (or during) the operation
CLEAN UP	CL	Cleaning and clearing-up after (or during) an operation
SUPERVISION	SU	'Non working' supervisory staff e.g. visiting, general and trade foremen and charge hands not engaged on actual building operations
NOT WORKING	N	Operatives not working while at the work place
REPEAT WORK	R	The extra work undertaken to complete operations, prefabricated and fully finished components, in correcting and making good defective workmanship, material and/or design and organisation

NON PRODUCTIVE ACTIVITY	CODE	DETAIL OF ACTIVITY
WALKING	I	Operatives not working and not at the workplace
RAINED OFF	RO	Operatives not working because of inclement weather
STANDING	S	Operatives not working because of late arrival or early departure at or from the work place, breaks only
ABSENT	A	Operative not observed during the recording period

SPECIAL ACTIVITIES FOR BRICKLAYING

WORKING

F1 Lay bricks or blocks to rule

F2 Lay bricks or blocks to line

F3 Spread mortar

PREPARATORY WORK

P1 Cutting bricks

P2 Prepare mortar

P3 Set-up line

APPENDIX 4

BLANTYRE ACTIVITY SAMPLING DATA

SET OF WEEKLY TABLES: EXAMPLE PAGES

4.1 Table 1 checks each site observer data sheet in order by observation round each day for coding errors in collecting the data.

4.2 Table 2 lists each operative by number and trade, for each observation round in each day (reading from top left to right) the block number, house number, stage number, operation letter and activity letter in each observation.

4.3 Table 3 shows the number of operative working days by trade each day and the total for the week.

4.4 Table 4[A] lists for each block and house, the number of observations in each stage and operation, by activity and trade.

4.5 Table 5 provides a summary of the number of observations for each block and house, by stage and operation.
Key to observations in summary:
. 5 observations
+ 5-8 observations
* 9-18 observations
X 19 or more observations

4.6 Table 6 lists the number of non-productive observations in each trade, for each non-productive activity.

4.7 Table 7 totals the number of observations for each stage and each operation.

4.8 Table 8 totals the number of observations for each block and the non-productive observations, in each trade.

4.9 Table 9 records the number of observations collected by each of the three site observers, for each activity.

A Table 4 was not completed by BRE for all the weeks at Blantyre (only as far as Week 58) because the tables were large and duplicated the data held in Table 2, which could be used for detailed data analysis instead.

DAY	MONTH	SHEET NO	OBSERVATION TIME
14	10	45	1435
14	10	46	1435
14	10	47	1435
14	10	48	1435
14	10	49	1435
14	10	50	1435
14	10	51	1435
14	10	52	1435
14	10	53	1435
14	10	54	1535
14	10	55	1535
14	10	56	1535
14	10	57	1535
14	10	58	1535
14	10	59	1535
14	10	60	1535
14	10	61	1535

OBS	TRADE	NUMBER	BLOCK	HOUSE	STAGE	OPERN	ACTY	
2	G-LAB	891	*	4	27	*	CL	NO BLOCK NO OPERN

DAY	MONTH	SHEET NO	OBSERVATION TIME
14	10	62	1535
14	10	63	1645
14	10	64	1645
14	10	65	1645
14	10	66	1645
14	10	67	1645
14	10	68	1645
14	10	69	1745
14	10	70	1745
14	10	71	1745
14	10	72	1745
14	10	72	1745
14	10	73	1745
15	10	1	805
15	10	2	805
15	10	3	805

OBSERVATION 4 ON OPERATIVE 456 CHANGED TO OPERATIVE 500 AS THIS OPERATIVE ALREADY OBSERVED DURING ROUND

15	10	4	805
15	10	5	805
15	10	6	805
15	10	7	805
15	10	8	805
15	10	9	905
15	10	10	905
15	10	11	905
15	10	12	905
15	10	13	905
15	10	14	905
15	10	15	905
15	10	16	905
15	10	17	905
15	10	18	905
15	10	39	1015
15	10	20	1015
15	10	21	1015

TRADE	NUMBER	ROUND 1 855	ROUND 2 1005	ROUND 3 1105	ROUND 4 1205	ROUND 5 1335	ROUND 6 1435	ROUND 7 1535	ROUND 8 1645	ROUND 9 1745
BRICK-FOR	101	20 7 5 H H2	13 3 5 H F	13 2 5 H H2	13 3 5 H F	13 5 5 H F3	13 5 5 H F	13 5 5 H H2	13 7 5 H F	17 2 28 G F
BRICK-LAB	111	20 7 5 H H2	13 3 5 H H2	13 2 5 H H2	EXT 5 H P1	19 5 H P1	13 5 5 H F	13 5 H P1	13 7 5 H F	13 5 H CL
CARP	153	13 5 24 B F	NOT WK	13 3 24 A F	13 2 24 B F	13 2 24 B F	IDLE	13 8 24 B F	NOT WK	13 1 25 A F
	154	13 5 24 B F	NOT WK	13 3 24 A F	13 2 24 B F	13 2 24 B F	IDLE	13 8 24 B F	NOT WK	13 1 25 A F
	155	9 3 25 B F	10 1 25 A F	9 3 25 H F	10 2 31 A F	9 3 25 B F	10 2 31 B F	10 3 25 B F	9 2 25 A P	IDLE
	156	IDLE	IDLE	10 6 31 A F	10 6 31 A F	10 6 31 A F	10 6 31 A F	10 6 31 F F		
	158	13 2 27 E F	13 3 27 E F	13 3 27 E F	NOT WK	13 8 27 E F	13 8 27 D F	13 8 27 D F		
	161	1 3 31 C F	IDLE	2 4 32 F RT	2 6 31 A F	4 2 31 C F	IDLE	IDLE	NOT WK	IDLE
	172	9 3 31 F F	IDLE	9 3 31 G F	10 7 31 A F	10 8 31 A F	10 7 31 A F	10 7 31 A F		
	173	10 5 31 F F	NOT WK	10 5 31 B F	10 5 31 A F	10 5 31 H F	10 5 31 A F	10 5 31 F F	10 5 31 A F	IDLE
	174	12 3 31 D F	12 3 31 D F	11 3 31 G F	EXT 31 G P	12 2 31 D F	12 2 31 D F	12 2 31 D F	NOT WK	IDLE
	175	12 3 31 D F	11 3 31 D F	12 3 31 D F	EXT 31 G P	12 2 31 D F	12 2 31 D F	EXT 2 31 D F	NOT WK	IDLE
	180	10 4 31 B	10 2 31 A	10 4 31 H	IDLE	10 4 31 H	10 4 31 F	14 31 B		ABSENT

NUMBER OF MAN-DAYS WORKED PER TRADE

WEEK NUMBER 42

OCTOBER 1971

DATE	11	12	13	14	15	16	17	TOTAL
ASPH		4	2					6
BRICK-LAB	1	1	1	1	1	1		6
BRICK-FOR	1	1	1	1	1	1		6
CARP	12	14	14	13	14	10		77
CARP-APP	1	1	1	1	1			5
ELECT	2	2	2	2	3	2		13
ELECT PWKS	2	4			4			10
ELECT-APP	2	1	2	2	2	1		10
GLAZR	1	1	1					3
PAINT	5	5	5	5	5	5		30
PAINT-FOR	1	1	1	1	1	1		6
PLUMB-FOR	1	1	1	1	1			5
PLUMB-APP	2	2	2	2	1			9
PLAST	7	9	8	8	8	1		41
PLAST-LAB	2	2	2	2	2			10
PLAST-FOR	1	1	1	1	1			5
PLAST-APP	1	1	1	1	1			5
DRIVR	2	2	2	1	1	1		9
OFFIC	1	1	1		1	1		5
GANGR				1				1
G-LAB	20	20	19	18	20	16		113
LIGHT PWKS	3							3
TOTAL	68	74	67	61	68	40	0	378

TIME = 104.913 SECS

BLOCK NUMBER 4

STAGE	OPERN	ACTY	TRADE		DWELLING NUMBER 0	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
21	D	F	GLAZR				1											1
							1											1

STAGE	OPERN	ACTY	TRADE		DWELLING NUMBER 0	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
29	B	F	ELECT					2										2
		F	ELECT	PWKS		1	1											2
						1	1	2										4

STAGE	OPERN	ACTY	TRADE		DWELLING NUMBER 0	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
30	A	F	ELECT				1		2									3
		F	ELECT	PWKS			1	2	1									4
							2	2	3									7

STAGE	OPERN	ACTY	TRADE		DWELLING NUMBER 0	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
31	B	F	CARP						1									1
									1									1

STAGE	OPERN	ACTY	TRADE		DWELLING NUMBER 0	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
31	C	F	CARP			1	1	3										5

BLOCK	HOUSE		STAGE	1	2	3	5	7	10	12	14	15	16	21	23	24	25	27	28	29	30	31	32	33	34	35	38	39	43	44
			OPERATION	A	H	B	D	E	H	C	D	C	A	B	C	K	A	B	O	C	D	O	B	A	B	O	A	B	H	C	A
				B	D	E	K	O	C	D	E	F	G	O	A	B	D	F	K	O	A		O	A	B	C	D	E	F	G	H
8	1																													
8	2																													
8	3																													
8	4																													
8	5																													
8	6																													
8	7																													
8	8																													
9	1																													
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12		4																												
12		5																												
12		6																												
12		7																												
12		8																												
12		9																												

NON PRODUCTIVE OBSERVATIONS

TRADE	STANDING	IDLE	RAINED OFF	ABSENT	HANDLE	UNLOAD	SUPER VISION	CLEAN UP	NOT WORKING	SET OUT	TOTAL
ASPH	3	5		4							12
BRICK-LAB	1	10	1						2		14
BRICK-FOR	1	12	1						2		16
CARP	6	154		3	4		1		28		196
CARP-APP		10							2		12
ELECT		18							4		22
ELECT PWKS		9									9
ELECT-APP	1	20		1					2		24
GLAZR		6							1		7
PAINT		35							7		42
PAINT-FOR		19					1		3		23
PLUMB-FOR		16		2					2		20
PLUMB-APP		18		2					3		23
PLAST		79		1					17		97
PLAST-LAB		14							6		20
PLAST-FOR		4							3		7
PLAST-APP		13							3		16
DRIVR	3	8		1					1		13
OFFIC		1									1
GANGR		3					2				5
G-LAB	19	215	14	4	1		6	22	9		290
	34	669	16	18	5		10	22	95		869

TIME = 115.263 SECS

STAGE - OPERATION BREAKDOWN

STAGE	OPERATION	OBSERVATIONS	TOTAL
1	A	3	
	H	1	4
2	B	2	
	D	47	49
3	E	6	6
5	H	48	48
7	C	8	
	D	4	12
12	C	1	1
14	A	38	
	B	8	
	C	24	
	K	1	71
15	A	15	
	B	1	16
16	C	1	1
21	C	1	
	D	1	2
23	B	8	8
24	A	24	
	B	48	72
25	A	9	
	B	24	
	H	1	34
27	A	32	
	B	43	
	D	16	
	E	38	
	K	10	139
28	C	2	
	D	9	
	E	13	
	F	26	
	G	1	51
29	A	39	
	B	66	
	D	8	

TRADE BREAKDOWN

TRADE	BLOCK	OBSERVATIONS	TOTAL
ASPH	1	6	
	2	1	
	5	3	
	6	2	
	7	2	
	EXT	18	
	NONPROD	12	44
BRICK-LAB	1	1	
	9	2	
	10	6	
	12	1	
	13	6	
	16	2	
	19	2	
	20	2	
	EXT	8	
	NONPROD	14	44
BRICK-FOR	1	2	
	9	3	
	10	8	
	12	1	
	13	7	
	16	3	
	17	1	
	19	1	
	20	2	
	EXT	3	
	NONPROD	16	47
CARP	1	34	
	2	17	
	4	8	
	5	4	
	6	4	
	7	2	
	8	7	
	9	38	
	10	100	
	11	2	
	12	55	
	13	81	
	14	1	
	17	1	
	20	1	
	22	16	
	EXT	39	
	NONPROD	196	606
CARP-APP	13	17	
	22	6	
	EXT	2	

ACTIVITY	OBSERVER 1	2	3
F	434	370	669
F1			1
F2	5		
F3			5
U1		2	6
U2	9		
H1			4
H2	42	40	34
H3	11	7	3
T1		8	4
T3	35	16	41
P	11	45	
P1	6	2	11
J		10	
SU	5	1	4
CL	6	1	18
N	50	5	
RT	3	9	11
S	23		11
I	255	119	296
RO	16		
A	1		17
H		5	
SU		10	
CL	5	17	
N	9	86	
	926	753	1135

TIME = 115.782 SECS

APPENDIX 5

BLANTYRE ACTIVITY SAMPLING DATA

SET OF TOTAL DATA SUMMARY TABLES: EXAMPLE PAGES

5.1 Table 1 lists for each trade, the number of observations[A] in each activity and the total.

5.2 Table 2 lists for each trade, the number of observations in each non-productive activity and the total.

5.3 Table 3 lists the number of operatives in each trade employed on the site each week.

5.4 Table 4 lists for each stage and operation, the number of observations by block in each activity.

5.5 Table 5 lists for each stage and operation, the number of observations by block in each house.

5.6 Table 6 lists for the operations and trades in each stage, the number of observations in each activity.

5.7 Table 7 lists for each stage and operation, the average number of observations per house type and the average for all house types.

5.8 Table 8 records the total number of observations collected by each of the three site observers, for each activity.

A The figures for observations in the total data summary tables for Blantyre can also represent manhours, as the observation interval in the activity sampling survey was hourly.

TRADE		F	F1	F2	F3	U1	U2	H1	H2	AUTHORITY H3	T1	T2	T3	P	P2	P2	P3	J	SU	CL	N	R1	TOTAL
ASPH		996					3		142	2				104					1	42	227	17	1524
ASPH	PWKS	3																					3
ASPH-FOR		13					1															1	15
BRICK		1525	560	4365	2541	7	9	1	782	120	14	1		30	23	107	68			32	570	59	10814
BRICK-LAB		338	2	5	5	17	13	18	6689	431	1		1	31	1855		5			89	297	37	9834
BRICK-FOR		754	387	1637	646	8	5	1	291	52	14	1		25	11	56	25		4	51	171	49	4188
CARP		13800			2	326	259	48	984	252	1			933	1				3	23	768	266	17864
CARP	PWKS	3																		1			4
CARP-LAB		19							1	2			1	5					1	1	1		31
CARP-FOR		508				6	7		4	9									31			1	566
CARP-APP		1462				34	35	1	64	25				23	1				2	7	72	41	1767
CARP-APP	PWKS	1							1														2
ELECT		2127				10	1	24	72	57	2		14	37						6	139	61	2550
ELECT	PWKS	501							15				7	46				121	2	5	22	51	770
ELECT-LAB		2													1								3
ELECT-LAB	PWKS	476	2	1			2		6	2				1					2		27	5	524
ELECT-FOR	PWKS	39					1							1					28		4		73
ELECT-APP		918				5	1	3	47	35	1		4	9						1	66	36	1124
ELECT-APP	PWKS	1																1					2
FLOOR		2																			2		4
HEATG		12											2										14
HEATG	PWKS	1																					1
HEATG-FOR		198				19	34		20		1		15	1					1		3		276
HEATG-FOR	PWKS	1											1										2
GLAZR		302				4	5	2	24	2				7						1	3	45	395
GLAZR	PWKS	1																					1
PAINT		6886				6		8	77	31			1	154					1	40	249	36	7487
PAINT	PWKS	1																					1
PAINT-FOR		1016				7	4	1	7	6				4					208	3	20	1	1277
PAINT-APP		29												3						1	6		39
PLUMB		571				10	4		38	17			9	121				1	1		26	4	803
PLUMB-LAB									1														1
PLUMB-FOR		493				23	10	12	57	20	2		36	138	1				14	3	15	11	835
PLUMB-FOR	PWKS	1																					1
PLUMB-APP		980				33	7	11	135	32	3		17	160				1		3	63	19	1454
PLAST		4716	1			51	45	7	113	19			1	146	7					48	79	27	5260
PLAST	PWKS	2																					2
PLAST-LAB		159			1	29	24	4	687	8				83	218		1			62	48	1	1325
PLAST-LAB	PWKS	1																					1
PLAST-FOR		725				8	5	1	20	3				21	4					9	16		812
PLAST-APP		246				8	12	1	34	1				8	6					20	12		348
TILER		315				6	7		14					10	1						10		363
TILER-LAB		361			1	12	16		360	4				34	1						24	4	817
TILER-APP		188				7	7		82	1				25	4						12	2	328
SCAFF		2												1									3

NON. PRODUCTIVE OBSERVATIONS

TRADE		STANDING	IDLE	RAINED OFF	ABSENT	HANDLE	UNLOAD	SUPER VISION	CLEAN UP	NOT WORKING	SET OUT	TOTAL
ASPH			31	8	4					6		49
ASPH		97	173	40	43				1	51		405
ASPH-FOR					2							2
BRICK		40	1471	421	62		18		2	59		2073
BRICK-LAB		42	1540	376	82	3	79		17	56		2195
BRICK-LAB	PWKS		2									2
BRICK-FOR		11	657	161	27	1	6	1	1	30		695
BRICK-FOR	PWKS		1									1
CARP		197	4257	17	176	19	4	7	3	904		5584
CARP	PWKS		5					1				5
CARP-LAB			7					43	1	9		8
CARP-FOR			566	1	29	2				82		651
CARP-APP		27	490		15	3	1					608
CARP-APP	PWKS		1									1
ELECT		33	851	1	43					128		1056
ELECT	PWKS	3	257	6	32					32		330
ELECT-LAB			4									4
ELECT-LAB	PWKS		199	8						15		222
ELECT-FOR	PWKS		76							2		78
ELECT-APP		11	404	1	13					63		492
FLOOR			3									3
HEATG					2							2
HEATG	PWKS			1								1
HEATG-FOR		3	57		17					20		97
GLAZR		7	102	1	19	1			1	23		154
PAINT		104	1166	5	60				8	252		1595
PAINT	PWKS		1									1
PAINT-FOR		3	534	1	2			18		38		596
PAINT-APP			5		2							7
PLUMB		16	337	8	23	3		1	1	35		418
PLUMB-LAB					1							1
PLUMB-FOR		16	616	3	40	2		1		105		788
PLUMB-FOR	PWKS		1									1
PLUMB-APP		34	718	9	46	4	1			116		928

5.3

BLANTYRE SITE CONTINUED

WEEK NUMBER

TRADE		36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
ASPH		2	2	1	2	4	4	4		4								9	9
ASPH-FOR																			
BRICK		4	1	5	2	4												1	1
BRICK-LAB		3	1	3	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1
BRICK-FOR		1	1	1	1	1	1	1	2	2	2	2	2	2	2	1	1	1	1
CARP		18	21	16	20	18	16	14	14	13	11	12	11	11	14	11	10	9	11
CARP-LAB					1										1				
CARP-FOR		1	1	1											1	1	1	1	1
CARP-APP		2	2	1	1	1	2	1	3	2	2	1	1	1	1			1	1
ELECT		2	4	5	2	2	2	3	2	3	3	3	3	1	2	2	2	2	2
ELECT	PWKS	4	4	4	2	2	2	4	4		1	2	6	2	2	2	4	5	3
ELECT-LAB	PWKS		1	1		5	6							1			6		
ELECT-FOR	PWKS					1	1										1		
ELECT-APP		1	1	1	1	2	2	2	3	2	2	2	2	2	2	2	2	2	2
FLOOR																			
HEATG																			
HEATG	PWKS																		
HEATG-FOR				4		3	1		1	1	1	4	3	2	2		2	3	3
GLAZR		1	1	1	1		1	1	1	1	1	1	1		2		2	2	
PAINT		3	3	5	6	6	6	5	5	5	7	7	6	7	7	7	8	8	7
PAINT-FOR		1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
PAINT-APP																			
PLUMB		1	1	2	1	1													
PLUMB-LAB		2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1
PLUMB-FOR		3	2	2	3	1	3	2	2	1	2	2	1	2	2	3	2	1	1
PLUMB-APP																			
PLAST		8	9	9	9	9	8	9	8	10	10	7	7	7	6	7	5	5	5
PLAST-LAB		2	3	4	4	3	2	2	2	2	2	1	1	1	1				
PLAST-FOR		1	2	3	3	3	1	1	1	1	1								
PLAST-APP				1	2	1	1	1	1	1	1	1	1	1					
TILER																			
TILER-LAB																			
TILER-APP																			
SCAFF																			
SCAFF-APP																			

TRADE		54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
ASPH			4	4	4						4	4	4	7	7		3	6
ASPH-FOR																		
BRICK			2		2	2				2								
BRICK-LAB				1	2	2	1	1		2								
BRICK-FOR					1	1	1	1		1								
CARP			11	10	12	11	11	7	7	6	7	8	6	6	6	4	5	2
CARP-LAB			3	1					1	1		1						
CARP-FOR																		
CARP-APP				1	1	1	1	1		1	1	1	1	1	2	1	2	1
ELECT			2	2	2	2	2	2	2	2	2	2	2		2			2
ELECT	PWKS		2	2	2	1	2	1	2	3	6	3	1					
ELECT-LAB	PWKS													3				
ELECT-FOR	PWKS																	
ELECT-APP			1	1	1	1	1	1										1
FLOOR			2															
HEATG																		
HEATG	PWKS		1															
HEATG-FOR			2	2	2	4	2	4	3		1			1				
GLAZR			1	1	1	2	2	1	1	2	2	1					1	
PAINT			7	7	7	7	7	7	7	7	7	7	8	7	7	5	4	4
PAINT-FOR			1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1
PAINT-APP			1															
PLUMB			2								1	1	1	1				
PLUMB-LAB			1	1	1	1	1	1	1	1								
PLUMB-FOR			1	1	1	1	1	1	1	1	1	1	1	1		1	1	
PLUMB-APP																		
PLAST			7	5	3	2	4	2	2	2	1	3	2	1	2	2	1	2
PLAST-LAB			1															
PLAST-FOR			1					1		1	1							
PLAST-APP						1	1											
TILER													1	2				
TILER-LAB									1				1					
TILER-APP																		
SCAFF			1															
SCAFF-APP			1															

										8	1					3						3				15

ACTIVITIES

STAGE	OPERN	BLOCK	F	F1	F2	F3	U1	U2	H1	H2	H3	T1	T2	T3	P	P1	P2	P3	J	SU	CL	N	RT	TOTAL
20	A	1	3		17	12				3							3	1						39
		2	4		5	8				2								2				1		22
		3		4	13	2				2														21
		4	1		6	2				2												4		11
		5	2		14	10				3														33
		6		3	15	14				7						1								40
		7	1		12	1				2												2		16
		8	5	2	9	15				7		4				1								45
		9				4				1						1								6
		10	7	4	4	7				3						1								26
		11	3		6	6				5						1								21
		12	2		11	4				3														20
		13	3		3	5				3	1					1								16
		14			3	4																		7
		15			1																			1
		16			2	5																		7
		17			5	8																		13
		18		2	8	13																		23
		19			8	4																		12
		20			14	8				5						1						2		28
		21			4					4	1													11
		22			5																			5
		EXT			2	1				4						3								10
			31	15	167	133				56	2	4				10	3	3				9		433

ACTIVITIES

STAGE	OPERN	BLOCK	F	F1	F2	F3	U1	U2	H1	H2	H3	T1	T2	T3	P	P1	P2	P3	J	SU	CL	N	RT	TOTAL
20	B	2								1														1
		4			2													1				1		4
		14				1																		1
		20				3																		3
					2	4				1								1				1		9

ACTIVITIES

STAGE	OPERN	BLOCK	F	F1	F2	F3	U1	U2	H1	H2	H3	T1	T2	T3	P	P1	P2	P3	J	SU	CL	N	RT	TOTAL
20	D	1			3													1				2		4
		2	1		3																			6
		3		2	1	1				1														5
		4			4	1																1		5
		5			2																			3
		6				3																		3

STAGE	OPERN	BLOCK	DWELLINGS 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL
18	C	1	1	7	10	8	10	8	12	9	15	10	5					95
		2	6	11	13	10	15	11	8	5								79
		3		12	9	13	12	14	15									75
		4							1									1
		5	1	10	11	12	14	15	15									78
		6	4	19	13	12	19	15										82
		8	2	12	13	13	17	8	9	8	7							89
		9	10	6	8	11												35
		10	14	8	8	5	4	3	9	10	8	9						78
		11			1													1
		12		15	16	14	9	13	6	8	9	6						93
		13	9	4	6	10	2	8	7	16	13							75
		14		1	3	7	8											19
		16	2	16	11	10	9	6										54
		17	3	5	4	8	13	14	14									61
		18		9	8	5	6	10	14	5	6							63
		19		8	5	8	11	9	12									53
		20	2	8	7	5	14	13	3	11								65
		21		8	6	9	4	5										32
		22	2	2	4	5	6	7										26
		EXT	5	3	2	2	3	5	1									21
			61	164	153	164	176	164	126	72	58	25	5					1173

STAGE	OPERN	BLOCK	DWELLINGS 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL
18	D	1	3										4					7
		2		5						6								11
		3		4					6									10
		5		6					8									14
		6	5	4							2							9
		8		5														7
		9				3												3
		10		8								2						8
		12		3														5
		13		4														4
		14		3		1	3											7
		16						4										4
		17		3					5									8
		18		3							2							5
		19		6														6
		21		3														3
		22		6				2										8
		EXT		1														1
			8	64		4	3	6	19	6	4	2	4					120

STAGE 34

OPERN	TRADE	F	F1	F2	F3	U1	U2	H1	H2	H3	T1	T2	T3	P	P1	P2	P3	J	SU	CL	N	RT	TOTAL
																							2
A	ELECT	2						1	12	1				36					1	3	29	13	1330
	PAINT	1234							2					1					1		1		53
	PAINT-FOR	48												9									31
	PLAST	22																					
																							1
B	BRICK-FOR	1																					8
	CARP	8																					2
	ELECT	2																					1
	HEATG-FOR	1																		11	171	22	4415
	PAINT	4085						4	28	19				75					19		7	1	171
	PAINT-FOR	140					1			2				1									3
	PAINT-APP	3																					11
	PLUMB	11																					5
	PLAST	5																					3
	G-LAB	3																					
																							5
C	CARP	5							5	2				5						1	13		1203
	PAINT	1178																	2		4		178
	PAINT-FOR	172												1									7
	PAINT-APP	6																					1
	PLUMB	1																					1
	PLUMB-FOR	1																					1
	PLAST	1																					1
	SCAFF	1																					18
	G-LAB	18																					
																							1
D	PAINT-FOR	1																					
																							1
F	CARP	1																					
																					1		1
H	CARP																						
																							2
K	CARP	2												1									1
	HEATG-FOR													29						20	25		137
	PAINT	20					6		3	25	9								80	1	1		89
	PAINT-FOR						1		1	3	2									95			95
	G-LAB																						
	TOTAL	6978					7	1	9	75	35			158					103	131	252	36	7778

STAGE	OPERN	HOUSE TYPE 2 PERSON	4PER C	4PER D	5PER C	5PER D	AVERAGE ALL TYPES
1	A	4	4	4	4	4	4
	B	0	0	0	0	0	0
	C	0	0	0	0	0	0
	D	0	0	0	0	0	0
	H	0	0	0	0	0	0
2	A	0	0	0	0	0	0
	B	1	1	1	1	0	1
	C	0	0	0	0	0	0
	D	16	17	15	16	16	17
	K	0	0	0	0	0	0
3	A	6	8	9	10	7	8
	B	5	2	6	2	3	3
	C	1	1	1	2	1	1
	D	0	0	0	0	0	0
	E	1	2	1	2	1	2
	F	0	0	0	0	0	0
	K	0	0	0	0	0	0
4	A	0	2	1	2	0	1
	B	4	8	6	10	6	6
	C	1	3	1	2	1	2
	E	0	0	0	0	0	0
	K	0	0	0	0	0	0
5	A	4	3	5	4	5	4
	B	4	7	3	9	6	6
	C	6	6	5	10	6	6
	D	2	1	1	1	1	1
	E	1	1	2	2	2	2
	F	3	7	7	11	8	7
	G	0	0	0	0	0	0
	H	12	16	12	17	12	14
	J	1	1	2	1	2	1
	K	14	19	16	21	18	18
6	A	10	9	5	8	9	8
	B	9	9	7	11	8	9
	C	0	1	1	0	0	1
	D	0	0	0	0	0	0
	K	0	0	0	0	0	0
7	A	1	1	1	2	1	1
	B	2	1	2	2	2	2
	C	2	1	1	1	2	1
	D	7	6	5	10	6	6

ACTIVITY	OBSERVER 1	2	3
F	20925	21941	20785
F1	77	207	650
F2	2921	2743	198
F3	668	723	1723
U1	76	759	222
U2	520	77	125
H1	16	8	203
H2	4656	4416	3036
H3	740	1080	28
T1	112	169	14
T2		6	1
T3	389	193	333
P	845	1402	275
P1	579	858	772
P2	80	77	3
P3	76	25	
J	1	121	2
SU	220	420	245
CL	1084	851	747
N	3328	655	129
RT	593	417	339
S	356	51	514
I	10866	6052	8819
RO	769	561	168
A	495	405	480
H	80	130	73
U	55	67	27
SU	9	305	15
CL	72	177	19
N	66	2744	396
TR	38	8	
	50712	47648	40341

TIME = 71.206 SECS

APPENDIX 6

GREENFIELD ACTIVITY SAMPLING DATA

SET OF WEEKLY TABLES: EXAMPLE PAGES

6.1 Table 1 checks each site observer data sheet in order by observation round each day for coding error in collecting the data.

6.2 Table 2 lists each operative by number and trade, for each observation round in each day (reading from top left to right) the block number, house number, stage number, operation letter and activity letter in each observation.

6.3 Table 3 shows the number of operative working days by trade each day and the total for the week.

6.4 Table 4 lists for each block and house, the number of observations in each stage and operation, by activity and trade.

6.5 Table 5 provides a summary of the number of observations for each block and house, by stage and operation.
Key to observations in summary:
. 5 observations
+ 5-8 observations
* 9-18 observations
X 19 or more observations

6.6 Table 6 lists the number of non-productive observations in each trade, for each non-productive activity.

6.7 Table 7 totals the number of observations for each stage and each operation.

6.8 Table 8 totals the number of observations for each block and the non-productive observations, in each trade.

6.9 Table 9 records the number of observations collected by each of the three site observers, for each activity.

3	BRICK	1128	16		6	E	P2
4	BRICK-LAB	88	14		6	A	H2
5	BRICK	89	14		6	A	F2
6	BRICK	90	14		6	A	F2
7	BRICK						

OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED

DAY MONTH SHEET NO OBSERVATION TIME

19 3 14 830

OBS	TRADE	NUMBER	BLOCK	HOUSE	STAGE	OPERN	ACTY
1	BRICK-LAB	130	14		6	A	P2
2	BRICK-LAB	1106	15		6	E	H2
3	BRICK-LAB	1115	15		6	E	H2
4	BRICK	1039	28	4	26	A	F
5	BRICK	1062	28	4	26	A	F
6	BRICK-APP	142					IDLE
7	BRICK-LAB	1130	28		26	A	H2

OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED

DAY MONTH SHEET NO OBSERVATION TIME

19 3 15 830

OBS	TRADE	NUMBER	BLOCK	HOUSE	STAGE	OPERN	ACTY
1	BRICK	1040	12		6	E	P
2	BRICK	1058					IDLE
3	BRICK-LAB	1129					IDLE
4	BRICK	1059	EXT		43	B	F
5	BRICK-LAB	1133	EXT		43	B	P2
6	PLAST	571	7		7	A	F
7	PLAST	572	7		7	A	F

OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED

DAY MONTH SHEET NO OBSERVATION TIME

19 3 16 830

OBS	TRADE	NUMBER	BLOCK	HOUSE	STAGE	OPERN	ACTY
1	PLAST	573	27		27	A	N
2	PLAST-APP	646	27		27	A	N
3	PLAST-LAB	623	27		27	A	P2
4	PLAST	577	6		7	A	F
5	PLAST	589	6		7	A	F
6	PLAST-LAB	622	6		7	A	H2
7	CARP	1201					STANDING

OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED

DAY MONTH SHEET NO OBSERVATION TIME

19 3 17 830

OBS	TRADE		NUMBER	BLOCK	HOUSE	STAGE	OPERN	ACTY
1	CARP		1202					STANDING
2	CARP		1203					STANDING
3	GAS-LAB	PWKS	1331	EXT		47	A	F
4	GAS-LAB	PWKS	1332	EXT		47	A	F
5	GAS-LAB	PWKS	1333	EXT		47	A	F
6	ELECT-FOR	PWKS	1276	EXT		46	A	F
7	ELECT-LAB	PWKS	1261	EXT		46	A	F

OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED
OBSERVATION ACCEPTED

TABLE 2 SCOTTISH DEVELOPMENT DEPARTMENT GREENFIELDS SITE WEEK NUMBER 42 DATE 23 MARCH

TRADE	NUMBER	ROUND 1 825	ROUND 2 955	ROUND 3 1135	ROUND 4 1335	ROUND 5 1505
CARP	13	19 3 36 A F	19 7 36 C F	19 3 36 A F	19 3 36 C F	19 3 16 A F
	14	19 4 36 A F	19 7 16 C F	19 4 36 A F	19 4 36 C F	19 4 16 A F
	15	5 8 16 A N	5 9 16 C F	5 4 16 A F	IDLE	5 4 16 A F
	16	5 7 16 A F	5 10 16 C F	5 3 16 A F	5 10 16 C F	5 3 16 A F
	17	5 7 16 A F	5 10 16 C F	5 3 16 A F	5 10 16 C F	5 3 16 A F
	21	3 11 4 B F	EXT 16 A H2	3 8 4 B F	3 2 16 C F	1 4 B F
	22	19 11 36 B P		19 11 36 A F	19 12 36 C F	19 11 36 A F
	24	29 3 34 B F		29 3 34 B F	28 7 34 B F	29 3 34 B F
	29		19 11 36 C F		19 2 36 C F	
	30		29 7 24 B F	29 7 24 B F	29 7 34 C F	29 7 24 B F
BRICK	88	IDLE		14 6 A F2	15 6 A F2	15 6 E F2
	89	IDLE		14 6 A F2	15 6 A F2	15 6 E F2
	90			14	15	15

220

WEEK NUMBER 42

DATE	MARCH 19	20	21	22	23	24	25	TOTAL
BRICK	10	15	14	17	17		2	75
BRICK-LAB	8	10	5	10	12		1	46
BRICK-FOR		1						1
BRICK-APP	1	2		2	2			7
CARP	25	28	11	31	32		8	135
CARP-LAB	5	6	7	6	6		2	32
CARP-FOR	3	3	3	2	3		3	17
CARP-APP	1	1	1	1				4
ELECT	6	6		6	6			24
ELECT PWKS	3	1		4	6			14
ELECT-LAB	1	1		1	1			4
ELECT-LAB PWKS	4	4	4	3	5			20
ELECT-FOR PWKS	1	1	1	1	1			5
ELECT-APP	5	5		5	5			20
GAS-LAB PWKS	3	4	4	4	4			19
GLAZR		5	5	5				15
PAINT	5	4		4	5			18
PAINT-FOR	1	1		1	1			4
PAINT-APP	1	1		1	2			5
PLUMB	19	16	6	14	14		10	79
PLUMB-FOR	1	1		1	1		1	5
PLUMB-APP		2		2	2		2	8
PLAST	21	22	6	21	20		3	93
PLAST-LAB	4	4	3	4	4		2	21
PLAST-APP	1	1		1	1			4
TILER		2		2				4
TILER-APP		1		1				2
SCAFF	7	9	1	8	9		3	37
DRIVR	3	4	1	8	8		1	25
GANGR	2	2	1	2	2		1	10
G-LAB	8	13	8	11	13		4	57
WATER-LAB PWKS	3							3
HEATG	1	3		2	2			8
HEATG-APP	1	1						2
TOTAL	154	180	81	181	184	0	43	823

				2	2	1		2											7

BLOCK NUMBER 5

STAGE	OPERN	ACTY	TRADE	DWELLING NUMBER 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL
9	A	F	GLAZR		1														1
					1														1

STAGE	OPERN	ACTY	TRADE	DWELLING NUMBER 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL
10	A	H2	ELECT			1		1											2
						1		1											2

STAGE	OPERN	ACTY	TRADE	DWELLING NUMBER 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL
10	C	F	PLUMB	2		1		1		1	1			1					7
		H2	PLUMB	4	1		1	1		1									8
		H2	PLUMB-APP		1			1											2
		P	CARP	1															1
		P	PLUMB			5	1	2		1	1								10
		P	PLUMB-APP					1											1
				7	2	6	2	6		3	2			1					29

STAGE	OPERN	ACTY	TRADE	DWELLING NUMBER 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL
10	D	F	BRICK-FOR				1					2							1
		F	PLUMB			1	2		1	2	2	1	1	1					10
		P	PLUMB									2							3
						1	3		1	2	2	3	1	1					14

TABLE 5

SUMMARY OF MAN-HOURS

CONTINUED

BLOCK	HOUSE	STAGE	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	23	24	25	26	27	28	29	30	31	32	33
		OPERATION	ABH	BHI	A	AC	EH	IAH	IA	IA	ABCD	IAB	DIA	IABE	IABCDH	IA	IABCH	IABCDH	ID	IABK	HIA	IAE	HIA	DIA	IA	IA	IABCD	IABCDH	IA	IBC
5										+																				
5	1																													
5	2																													
5	3																													
5	4																													
5	5																													
5	6																													
5	7																													
5	8																													
5	9																													
5	10																													
6																														
6	2																													
6	4																													
6	5																													
7																														
7	4																													
7	5																													
7	6																													
7	7																													
7	8																													
7	9																													
7	10																													
8																														
9																														
10																														
11																														
11	7																													
11	8																													
11	9																													
11	10																													
12																														

TABLE 6

NON PRODUCTIVE OBSERVATIONS

TRADE	STANDING	IDLE	RAINED OFF	ABSENT	HANDLE	UNLOAD	SUPER VISION	CLEAN UP	NOT WORKING	SET OUT	TOTAL
ASPH		1	2								3
BRICK	46	14		2							62
BRICK-LAB	28	16		3							47
BRICK-APP	7	8		1							16
CARP	93	49		4							146
CARP-LAB	20	16									36
CARP-FOR	8	24									32
CARP-FOR PWKS	1										1
CARP-APP	4	5									9
ELECT	36	25									61
ELECT PWKS	13	1		4							18
ELECT-LAB		3									3
ELECT-LAB PWKS	23			3							26
ELECT-FOR PWKS	6			1							7
ELECT-APP	28	20									48
FLOOR		1									1
GAS-LAB PWKS	8	5									13
GLAZR	13	1		2							16
PAINT	16	3		1							20
PAINT-FOR	4	3									7
PAINT-APP	5	4									9
PLUMB	59	46		4							109
PLUMB-FOR	3	9									12
PLUMB-APP	5	7									12
PLAST	78	44		13							135
PLAST-LAB	13	2						1			16
PLAST-APP	1	1									2
TILER	4	9									13
TILER-APP	2	5									7
SCAFF	34	20	1								55
DRIVR	11	2		1							14
ENG	1										1
GANGR	5	10									15
G-LAB	16	20									36

TABLE 7

STAGE - OPERATION BREAKDOWN

STAGE	OPERATION	OBSERVATIONS	TOTAL
2	A	5	
	B	52	
	H	1	58
4	B	4	
	H	2	6
5	A	14	14
6	A	197	
	C	36	
	E	118	
	H	2	353
7	A	138	
	H	1	139
8	A	90	90
9	A	12	12
10	A	9	
	B	6	
	C	125	
	D	41	181
11	A	45	
	B	25	
	D	1	71
12	A	3	3
13	A	48	
	B	1	
	E	1	50
14	A	3	
	B	2	
	C	2	
	D	32	
	H	8	47
15	A	2	2
16	A	93	
	B	7	
	C	51	
	H	11	162
17	A	45	

TABLE 8

TRADE BREAKDOWN

TRADE	BLOCK	OBSERVATIONS	TOTAL
BRICK	1	12	
	2	3	
	3	2	
	4	2	
	6	1	
	12	42	
	13	4	
	14	45	
	15	18	
	16	53	
	17	26	
	18	36	
	19	1	
	28	6	
	29	2	
	31	2	
	32	4	
	36	1	
	37	1	
	EXT	11	272
BRICK-LAB	1	4	
	2	1	
	3	1	
	4	1	
	7	3	
	12	24	
	13	2	
	14	22	
	15	13	
	16	18	
	17	12	
	18	11	
	28	4	
	29	4	
	31	2	
	36	2	
	EXT	38	162
BRICK-FOR	3	1	
	5	1	2
BRICK-APP	1	4	
	4	1	
	7	4	
	27	1	
	28	3	
	29	4	
	31	2	
	32	4	23
CARP	1	2	

TABLE 9

ACTIVITIES RECORDED

ACTIVITY	OBSERVER 1	2	3
F	707	476	161
F1			19
F2	79	85	18
F3	7		26
U1	16	30	17
U2			4
H1	2		27
H2	173	160	216
P	89	52	302
P1	1		
P2	12	18	10
SU	23	17	17
CL	52	32	31
N	17		
RT			2
S	136	12	455
I	122	82	182
RO		2	1
A	19	4	20
U		1	
SU	1		
CL			1
	1456	971	1509

APPENDIX 7

GREENFIELD ACTIVITY SAMPLING DATA

SET OF TOTAL DATA SUMMARY TABLES: EXAMPLE PAGES

7.1 Table 1 lists for each trade, the number of observations[A] in each activity and the total.

7.2 Table 2 lists for each trade, the number of observations in each non-productive activity and the total.

7.3[B]

7.4 Table 4 lists for each stage and operation, the number of observations by block in each activity.

7.5 Table 5 lists for each stage and operation, the number of observations by block in each house.

7.6 Table 6 lists for the operations and trades in each stage, the number of observations in each activity.

7.7[C]

7.8 Table 8 records the total number of observations collected by each of the three site observers, for each activity.

7.9 Table 9[D] lists for each block by stage and operation, the number of observations by activity and trade in each house.

A The figures for observations in the total data summary tables for Greenfield were multiplied by 3 in the BRE computer programme to represent ½ manhours from the 1½ hour observation intervals in the activity sampling survey; so that the tables need not contain a decimal point for odd numbers of observations.

B The Table 3 form of data tabulation in the Blantyre total data summary set was not provided by the BRE for Greenfield.

C The Table 7 form of data tabulation in the Blantyre total data summary set was not provided by the BRE for Greenfield.

D Table 9 was a new form of data tabulation provided by the BRE for Greenfield, that was not provided earlier for Blantyre.

TRADE	ACTIVITIES F	F1	F2	F3	U1	U2	H1	H2	H3	T1	T2	T3	P	P1	P2	P3	J	SU	CL	N	RT	TOTAL	W
ASPH	3130		3		24			264					332						33	369	8	4163	1
BRIC	6187	4181	24666	7650	12	3	27	1747		16			1884	147	170	179	3	7	284	548	726	46427	11
BRIC-LAB	975	11	77	27	49		72	19636	15				892	151	6411	3			835	208	374	29723	7
BRIC-FOR	6							2					6		3							17	0
BRIC-APP	1004	29	456	164	11			253					121	6	23				14	45	172	2259	1
CARP	47293	306	14	4	195	12	191	3316	3				13420	112	23		3	270	51	813	1364	67390	15
CARP-LAB	324		2		286		929	7351	3				191		3			12	1293	61	18	10463	2
CARP-FOR	2709	3			24		18	279		3			596					1625	63	18	8	5346	1
CARP-APP	704						48	195					264						45	13	219	1408	0
ELEC	8511				180		609	1332					3210					651	3	129	237	14862	3
ELEC-LAB	256				21		12	96					824						6	20	3	1238	0
ELEC-FOR	6												3					21			3	33	0
ELEC-APP	4758				144		936	1395					2145					3		81	147	9609	2
FLOR	6	5	25																			36	0
FLOR-LAB	15		9					6													3	33	0
FLOR-APP			3																			3	0
GAS	252		9				12	21					88						3	9		394	0
GAS-LAB	39							3					30									72	0
GLAZ	1560				114		66	228					228		3					27	300	2526	1
GLAZ-LAB	6							6					6									18	0
GLAZ-FOR	6							3													3	12	0
GLAZ-APP	6						3						3									12	0
PAIN	13851				60		357	711					1410					270	15	63	558	17295	4
PAIN-LAB	3																					3	0
PAIN-FOR	840				15		39	54					156					42	9		81	1236	0
PAIN-APP	1560				21		219	222					216						15	24	138	2415	1
PLUM	12070		3		721	6	794	3749		21		3	6322					699	9	299	253	25949	6
PLUM-LAB							6	6					12						3			27	0
PLUM-FOR	638				58		57	134		2			692					319	6	15	22	1993	0
PLUM-APP	1216				162		388	1190		6			1210					3	18	24	145	4362	1
PLAS	22326			3	315		327	1497					5085		102			249	267	297	345	30313	7
PLAS-LAB	690			9	141		12	4221					1407		1491			9	396	78	78	8532	2
PLAS-FOR	3							3														6	0
PLAS-APP	384							159					81		6				33	36		699	0
TILE	3111			6	228		3	1086					480		6			3	3	30	228	5184	1
TILE-LAB	282				15			165					60							9		531	0
TILE-FOR	6							3					3								3	15	0
TILE-APP	291				36		3	303					75		3					9		720	0
SCAF	6215				527		24	2866					525		3				33	114	153	10460	2
SCAF-LAB	3																		3			6	0
DRIV	8868		3		428		222	7807	3				410					9	1419	518	120	19807	4
ENG	22		6				3	3					8					3		3	2	50	0
OFFI	7				2			4					3					2			3	21	0

GREENFIELDS SITE - FINAL ANALYSIS, FOR WEEK 2 TO WEEK 95

NON PRODUCTIVE OBSERVATIONS

TRADE		STANDING	IDLE	RAINED OFF	ABSENT	HANDLE	UNLOAD	SUPER VISION	CLEAN UP	NOT WORKING	SET OUT	TOTAL
ASPH		1014	384	357	162				3	105		2025
BRIC		7154	2921	1940	615	2			6	126		12764
BRIC	PWKS		6									6
BRIC-LAB		4041	1998	1120	363		23		15	67		7627
BRIC-LAB	PWKS	6										6
BRIC-FOR					6							6
BRIC-APP		436	619	124	47			3		29		1258
CARP		9097	7887	278	2106				3	504		19875
CARP	PWKS	45	15	3								63
CARP-LAB		1291	1913	34	63	6	3		81	38		3429
CARP-LAB	PWKS	9								3		12
CARP-FOR		1239	2730	24	43			6	3	24	2	4071
CARP-FOR	PWKS	21	36	3								60
CARP-APP		275	594		9					3		881
CARP-APP	PWKS	3										3
ELEC		3288	2976	21	99		3	3		57		6447
ELEC	PWKS	690	312	12	282					9		1305
ELEC-LAB		200	194		24					8		426
ELEC-LAB	PWKS	1779	264	429	123		3					2598
ELEC-FOR		6	6									12
ELEC-FOR	PWKS	348	60	75	21					3		507
ELEC-APP		2490	2409	3	27		3			36		4968
ELEC-APP	PWKS		2	3								5
FLOR		2	3									5
FLOR-LAB			3									3
GAS		69	27	2	51							149
GAS	PWKS	198	29	59	32					14		332
GAS-LAB		3										3
GAS-LAB	PWKS	348	138	75	42					6		609
GLAZ		549	399	72	255							1275
GLAZ-LAB			6									6
GLAZ-APP			3									3
PAIN		3510	1902	12	375			3		30		5832
PAIN	PWKS			3								3
PAIN-FOR		219	324	3	93							639
PAIN-APP		600	483	6	48					3		1140
PLUM		6538	4178	44	389	3	3		3	91		11249
PLUM	PWKS	6	3									9

STAGE	OPERN	BLOCK	F	F1	F2	F3	U1	U2	H1	H2	H3	T1	T2	T3	P	P1	P2	P3	J	SU	CL	N	RT	TOTAL
			ACTIVITIES																					
11	A	1	291							21					78					3		6		399
		2	123							6					33					3				165
		3	129							21					87									237
		4	153							18					66					9			6	252
		5	171							6					63					3			3	246
		6	93							9					12					3				117
		7	99							12					69					3				183
		8	72				3			3					27								3	106
		9	114							15					54					6		6		195
		10	51												21									72
		11	231							24					96					6				357
		12	48							12					63					3				126
		13	33												33									66
		14	99							3					72									174
		15	30							3					21									54
		16	231							18					180					6		9		444
		17	75												27									102
		18	123												15					6				144
		19													3									3
		20													30									30
		22													3									3
		26	3																					3
		27													3									3
		41													6									6
		42	3						9	6					6									24
		EXT	21				48		399	351					219					9				1047
			2193				51		408	528					1287					60		21	12	4560

STAGE	OPERN	BLOCK	F	F1	F2	F3	U1	U2	H1	H2	H3	T1	T2	T3	P	P1	P2	P3	J	SU	CL	N	RT	TOTAL
			ACTIVITIES																					
11	B	1	138							6					33					15				192
		2	96							6					18					3				123
		3	54												18								6	78
		4	54							3					3									60
		5	147							27					39					6		3		222
		6	54												21					6				81
		7	102							21					72					6				201
		8	30												9								6	45
		9	114							12					12									136
		10	54							6					3									63
		11	138						3	12					18					18		3	3	195
		12	54																	3				57
		13	60																	6				66
		14	45							9					21					9				84
		15	99												18					3				120
		16	177							3					48					12		15		255
		17	111							3					21						3	3		141
		18	84							6					24					3				117
		24	6																					6
		40	3																					3
		42	6																					6
		44																		3				3
															162					21				738

GREENFIELDS SITE - FINAL ANALYSIS, FOR WEEK 2 TO WEEK 95

STAGE	OPERN	BLOCK	DWELLINGS 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL
1	A	1	30															30
		2	4															4
		4	4															4
		5	4															4
		6	94															94
		7	335															335
		8	106															106
		9	250															250
		10	182															182
		11	130															130
		12	112															112
		13	34															34
		14	124															124
		15	94															94
		16	185															185
		17	80															80
		18	144															144
		27	6															6
		38	2															2
		39	12															12
		42	26															26
		EXT	270															270
			2228															2228

STAGE	OPERN	BLOCK	DWELLINGS 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL
1	B	1	184															184
		4	2															2
		6	124															124
		7	250															250
		8	118															118
		9	110															110
		10	92															92
		12	82															82
		13	78															78
		14	112															112
		15	94															94
		16	267															267
		17	18		3													21
		18	80															80
		23	2															2
		24	6															6
		27	12															12
		38	12															12
		39	4															4
		42	10						2									12
		EXT	62															62

GREENFIELDS SITE - FINAL ANALYSIS, FOR WEEK 2 TO WEEK 95

STAGE 5 ROOF COVER

OPN	TRADE	F	F1	F2	F3	U1	U2	H1	H2	H3	T1	T2	T3	P	P1	P2	P3	J	SU	CL	N	RT	TOTAL
A	CARP	834							108					126						3		6	1077
	CARP-LAB	6				15			72													3	96
	CARP-FOR					3			3										3				9
	CARP-APP								3					3								3	9
	ELEC								3														3
	ELEC-FOR																		3				3
	ELEC-APP	3																					3
	PLAS	6																					6
	PLAS-LAB	6							6														12
	PLAS-APP	3																					3
	TILE	1755			3	117		3	567					249		3				3		39	2739
	TILE-LAB	171				9			102					21									303
	TILE-FOR	6																					6
	TILE-APP	150				12		3	174					30		3							372
	DRIV								27														27
	GANG																		2				2
	GLAB	2				6			3														11
	WATR-LAB PWKS	3																					3
K	TILE	3																				3	6
	TILE-LAB	3																					3
	TILE-APP													3									3
	TOTL	2951			3	162		6	1068					432		6			8	6		54	4696
	%AGE	63				3			23					9								1	99

ACTIVITY	OBSERVER 1	2	3
F	96070	85143	41411
F1	264	455	3880
F2	10664	11650	3102
F3	1884	102	6023
U1	1895	1800	2255
U2	5		15
H1	229		5379
H2	20253	25597	24277
H3	12	17	
T1	6	70	12
T3		3	
P	11540	14126	36034
P1	316	14	104
P2	2412	2229	3994
P3	116	35	31
J		3	3
SU	2714	3293	3376
CL	5077	4953	4599
N	4192	199	275
RT	15	41	57
S	27094	17100	30318
I	12194	22343	17692
RO	3243	2520	3324
A	3059	1674	4802
U		17	5
H		44	45
SU	9	30	12
CL		198	13
N	5	1944	256
T1			5
	203268	195600	191299

STAGE	OPERN	ACTY	TRADE	DWELLING NUMBER 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL
16	A	F	CARP	15	30	66	51	72	66	60	54	36	9	54	18	9			540
		F	CARP-FOR	3													6		9
		H2	CARP	3															3
		H2	CARP-LAB	12															12
		H2	CARP-APP	3															3
		P	CARP		6	3	9	6	18	6	6	18		6	9	6	6		99
		P	CARP-FOR												3				3
		SU	CARP-FOR	18	3						3								24
		N	CARP		3			6											9
		N	CARP-APP			3													3
				54	42	72	60	84	84	66	63	54	9	60	30	15	12		705

STAGE	OPERN	ACTY	TRADE	DWELLING NUMBER 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL
16	B	F	CARP		3		6	6				6		6	3				30
		F	CARP-FOR										3				3		6
		H2	CARP								3								3
		P	CARP	3	3		3	9		3	3	3	6	6		3	3		45
		SU	CARP-FOR				3												3
				3	6		12	15		3	6	9	9	12	3	3	6		87

STAGE	OPERN	ACTY	TRADE	DWELLING NUMBER 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL
16	C	F	CARP	9	18	33	51	48	48	42	48	45	9	45	18	36	3		453
		F	CARP-LAB		3			3											6
		F	CARP-FOR	3				3					3		15		12		36
		F	CARP-APP				3										3		6
		F	GAS-LAB		3														3
		H2	CARP							3									3
		H2	CARP-LAB			3													3
		H2	CARP-APP				3	3											6
		P	CARP		12	9	3	3	3	12	6	18	9	27	3	3	6		114
		P	CARP-APP			3							3						6
		SU	CARP-FOR	6															6
		CL	CARP-LAB	6										3					9
		CL	GLAB					3											3
				24	36	48	60	63	51	57	54	63	24	75	36	39	24		654

STAGE	OPERN	ACTY	TRADE	DWELLING NUMBER 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL

APPENDIX 8

BLANTYRE ACTIVITY SAMPLING DATA

THREE FORMS OF DATA TABULATION PRODUCED DURING THIS STUDY, AS AN EXTENSION TO THE BRE DESIGNED DATA TABLES, TO FACILITATE THE DETAILED DATA ANALYSIS ON BLANTYRE: EXAMPLE PAGES

8.1 Table 1 lists by block the number of observations[A] by week in each operation of the house construction at Blantyre - the table was divided across two pages to show all the site construction weeks from 3 to 76, excluding holiday weeks 30, 31 and 54.

8.2 Table 2 lists by operation, the number of observations contributed by each operative to each block.

8.3 Table 3 lists by block and stage, for each week number, date and operative by number and trade (reading from left to right) the operation letter, house number and activity letter of each observation - the table includes non-productive observations on each recorded operative day, that appear as single non-productive activity letters in the table eg I.

A The figures for observations in the tables can represent manhours, as the observation interval in the Blantyre activity sampling survey was hourly.

SDD ARCHITECTS - RESEARCH AND INFORMATION GROUP
HOUSE BUILDING SITE LABOUR PRODUCTIVITY STUDY
BLANTYRE SITE - 132 SINGLE AND TWO STOREY HOUSES

BLOCK0010
OPERATIONS 27A - 30F

PRODUCTIVE MANHOURS ONLY BLOCK X OPERATION X WEEK

WEEKS 3 - 41 (EXCLUDING HOLIDAY WEEKS 30 AND 31)

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	32	33	34	35	36	37	38	39	40	41
27A																							1		1	4	18			15	27	2			2		
27B																										2	21			14	31	13			1		
27C																														1							
27D																											2		12	14	10	18					
27E																									20		16	6		25	2	2					
27K																														6	10						
28C																				10	6	2	3														
28D							1																														
28E																						11															3
28F																																			3		3
28G									3	3				2				4			1																
28K																																					2
29A																							4	1		8	6	5	10	35	33	8					2
29D																														3	9	1					
30A																										6			2								
30B																													8								

SDD ARCHITECTS RESEARCH AND INFORMATION GROUP
HOUSE BUILDING SITE LABOUR PRODUCTIVITY STUDY
GLANTYRE SITE 132 SINGLE AND TWO STOREY HOUSES

BLOCK0010
OPERATIONS 27A - 30F

PRODUCTIVE MANHOURS ONLY BLOCK X OPERATION X WEEK

WEEKS 42 - 76 (EXCLUDING HOLIDAY WEEK 54)

	42	43	44	45	46	47	48	49	50	51	52	53	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	TOTALS
27A																																			70
27B							1																												83
27C																																			1
27D								1																											57
27E											2				1																				74
27F				1																															1
27K															1																				17
28B									3																										3
28C										1																									22
28D																																			1
28E			2								2																								16
28F	8			2	6										1																				43
28G																																			13
28K																																			2
29A							2	24	17	3																									156
29B				1	3	5	2	15	18	5	1	2			1																				53
29C								1																											1
29D																																			13
29K									4	1																									5
30A						2		5	2			1																							18
30B			4			5	2	1		2	2																								24
30C							4				1																								5
30D					1						1																								2
30E					1	3				1	1																								6
30F									5	2																									7

SDD ARCHITECTS RESEARCH AND INFORMATION GROUP
HOUSE BUILDING SITE LABOUR PRODUCTIVITY STUDY
BLANTYRE SITE 132 SINGLE AND TWO STOREY HOUSES

OPERATION 16C

PRODUCTIVE MANHOURS ONLY OPERATION X TRADESMEN X BLOCKS

TRADESMAN CODE NUMBERS / BLOCK NUMBERS

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	EXT	TOTALS
11	BRICK			1																					1
51	BRICK		11	7		1	1	6				10	1												37
52	BRICK		12	8				9				5	1		2		5		16		2				60
53	BRICK			7																					7
54	BRICK		13	9				8				5			2		8		13					1	59
55	BRICK	20								5	14											9			48
56	BRICK	13								5	13											9			40
57	BRICK	16								3	14											8			41
58	BRICK				7	10	9						22											1	49
59	BRICK				7	10	9				1		21											2	50
60	BRICK								11												17			2	30
61	BRICK								20												16			1	37
63	BRICK				9	8																			17
64	BRICK					2	14						17					9						1	43
65	BRICK					1			18												15			1	35
66	BRICK													16						3					19
68	BRICK													18		4				8			8		38
69	BRICK													17		3				9			10		39
70	BRICK				2	1	2												1						6
71	BRICK													1	2		8		14		2				27
72	BRICK															3				4			9		16
73	BRICK												2					8							10
74	BRICK												2					8							10
75	BRICK										1														1
76	BRICK -FOR																				3				3
101	BRICK -FOR		15	14				11				5	1	1	6	1	9	1	16	1					81
102	BRICK -FOR	19								5	14											8			46
103	BRICK -FOR				8	9	12						21					7						3	60
104	BRICK -FOR								13												17			1	31
105	BRICK -LAB													14		4				10			8		36
111	BRICK -LAB		1	1				1				1	1					1	1						7
112	BRICK -LAB												1						1						2
114	BRICK -LAB										3														3
115	BRICK -LAB										3														3
116	BRICK -LAB										1														1
117	BRICK -LAB												2											1	3
118	BRICK -LAB												5											1	6
121	BRICK -LAB																				4			1	5
123	BRICK -LAB												5											1	6
124	BRICK -LAB																				4			1	5
128	BRICK -LAB													4						5					9
129	BRICK -LAB			1										5						3					9
130	BRICK -LAB			1										4						2					7
131	BRICK -LAB																		1		1				2
132	BRICK -LAB																				4			1	5
133	G-LAB				1								1											1	3
878	G-LAB																		2						2

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8-2

SDD ARCHITECTS RESEARCH AND INFORMATION GROUP
HOUSE BUILDING SITE LABOUR PRODUCTIVITY STUDY
BLANTYRE SITE 132 SINGLE AND TWO STOREY HOUSES

BLOCK 1
STAGE 24

PRODUCTIVE AND NON-PRODUCTIVE OBSERVATIONS

BLOCK X STAGE X WEEK X DATE X TRADESMAN X ROUND

WEEK DATE	TRADESMAN NUMBER AND STATUS	ROUND 1	ROUND 2	ROUND 3	ROUND 4	ROUND 5	ROUND 6	ROUND 7	ROUND 8	ROUND 9	ROUND 10	ROUND 11
14 29 3	153CARP			A 9F	D10F	D 7H2	D 8F	D 7F	D 6F	D 8F		
14 29 3	154CARP			A 9F	D10F	D 8H2	D 8F	D 7F	D 6F	D 7F		
14 29 3	155CARP				I			D10F		D 7F		
14 2 4	153CARP	D H2	I	D 1F	D 4H2	D 4F			D 3F			
14 2 4	154CARP	D H2	I	D 1F	D 5H2	D 4F			D 3F			
14 2 4	155CARP		I	D 1F	D 5F	D 4F			D 4F			
15 7 4	154CARP					D 1RT						
20 11 5	156CARP	C 9F		C 9F	C10F	C 8N	I	C 8F		I		
20 11 5	157CARP	C 9F		C10F	C 9F	C 7N	I	C 7F		I		
21 7 5	165CARP	B 3F										
21 17 5	156CARP					I		C 5H2				
21 17 5	157CARP							C 5H2				
21 18 5	156CARP	C 4H2	C 6F	C 6F	C 4F	C 4F	C 4F	C 2F	C 2F			
21 18 5	157CARP	C 4H2	C 5F	C 6F	C 3F		C 1F		C 1F			
21 19 5	156CARP	C 1N	I			I						
21 19 5	157CARP	C 1F	I			I						
22 26 5	167CARP					N	I		I		B 7F	
22 26 5	168CARP					N	I		I		B 7F	
22 27 5	165CARP		N		B10F		B 3F		B10F			
22 27 5	166CARP		N		B10F		B 3F		B10F			
22 28 5	159CARP		N	B 7N	N			B 7H2				
22 28 5	160CARP	B 7F	N	B 7N	N			B 6H2				
22 28 5	165CARP		N	I	N		B 8F	B 8F	B 8F			
22 28 5	166CARP		N	I	N		B 8F	B 8F	B 8F			
22 29 5	165CARP	B 8F	B 8F	B 8F								
22 29 5	166CARP	B 8F	B 8F	B 8F								
23 31 5	156CARP	I		N	A 6F	I						
23 31 5	157CARP	I		N	A 6F	I						
23 31 5	159CARP			N			B 6F	B 6F	B 6F	B 6N	N	
23 31 5	160CARP			N			B 6F	B 6F	B 6F	B 6N	N	
23 31 5	165CARP		B 8F		B 8F		B 4F	I				
23 31 5	166CARP		B 8F		B 8F		B 4F	I				
23 31 5	169CARP		B 5F	B 5F	B 5F		B 3F					
23 31 5	170CARP		B 5F	B 5F	B 5F		B 3F					
23 31 5	891GLAB							B 9CL				
23 1 6	891GLAB		B 8CL									
23 2 6	169CARP		I				B 3H2	B 3F	B 3F		I	
23 2 6	170CARP		I				B 3H2	B 3F	B 3F		I	
23 2 6	891GLAB				B 5CL		B 3CL		K 1CL			
23 3 6	169CARP	B 3F	B 2F	B 2F	B 2F	B 2N	B 1F	B 1F	B 1F	B 1F	I	
23 3 6	170CARP	B 3F	B 2F	B 2F	B 2F	B 2N	B 1F	B 1F	B 1F	B 1F	I	
23 3 6	891GLAB	C 1CL						B 2CL		B 2CL		
23 4 6	169CARP		B 1F	B 1F	B 6F		I	A				
23 4 6	170CARP			B 1F			I	A				
23 4 6	891GLA8		K 4CL									

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8.3

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