DESIGN AND CONSTRUCTION FOR TRADITIONAL HOUSE BUILDING

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Summary

This study is concerned with quality and productivity aspects of traditional house building. The research focuses on these issues by concentrating on the services and finishings stages of the building process. These are work stages which have not been fully investigated in previous productivity related studies.

The primary objective of the research is to promote an integrated design and construction led approach to traditional house building based on an original concept of 'development cycles'. This process involves the following: site monitoring; the analysis of work operations; implementing design and construction changes founded on unique information collected during site monitoring; and subsequent re-monitoring to measure and assess the effect of change.

A volume house building firm has been involved in this applied research and has allowed access to its sites for production monitoring purposes. The firm also assisted in design detailing for a small group of 'experimental' production houses where various design and construction changes were implemented.

Results from the collaborative research have shown certain quality and productivity improvements to be possible using this approach, albeit on a limited scale at this early experimental stage. The improvements have been possible because an improved activity sampling technique, developed for, and employed by the study, has been able to describe why many quality and productivity related problems occur during site building work.

Experience derived from the research has shown the following attributes to be important: positive attitudes towards innovation; effective communication; careful planning and organisation; and good coordination and control at site level. These are all essential aspects of quality led management and determine to a large extent the overall success of this approach.

Future work recommendations must include a more widespread use of innovative practices so that further design and construction modifications can be made. By doing this, productivity can be improved, cost savings made and better quality afforded.

KEY WORDS: Design & Construction, Quality, Productivity, House Building, Innovation

To Maria and our daughters, Catherine and Helene

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CHAPTER 1

1.0 INTRODUCTION

1.1 Preface

The British Cement Association (BCA) has a long-standing technical involvement with the construction industry. This has led, in recent years, to an extensive programme of research and development by the organisation. Included in this programme have been aspects of design and construction concerned with traditional house building. Their commitment to efficiency improvement in this field has led to their joint funding of this study together with the Science and Engineering Research Council (SERC).

The initial intentions of the study were to focus specifically on productivity improvements at all stages of the house building process. This emphasis was redirected during initial discussions as it became clear that quality and its cost were complementary issues very much related to improved site productivity. Because of this, it was considered important to limit the scope of the study and to concentrate research efforts on two specific work stages.

The study is concerned primarily with improving quality and productivity levels in the field of traditional house building by analysing site operations. To do this, the research has concentrated attention on the services and finishings stages. These are stages, which reliable data from various earlier research studies, have shown to be in need of improvement. Thus, further research into those factors affecting quality and productivity within these work stages is of prime importance if traditional house building practices are to be improved.

The study describes an applied research project which has involved the collaboration of Lovell Homes Midland Limited (formerly Charter Homes Limited). They are a Tamworth based private house building company employing traditional masonry construction techniques. A database has been developed as a result of fieldwork monitoring on their developments and this has been used as evidence to support changes to design and construction practices employed by the company. These changes were introduced with the aim of improving quality and productivity aspects of normal production working.

The process of collecting data, and analysing, refining, and implementing new ideas for improved quality and productivity has been termed a 'development cycle'. This is a new research concept which forms the original contribution made by the study. In order for this concept to be more widely practised it should first be understood that improved quality standards and improved productivity are not mutually exclusive. They can be developed successfully together in an environment led by research, development and innovation.

The potential quality gains discussed in the study can be paid for by genuine increases in productivity. This can be made possible by implementing construction process rationalisation in which design plays an important and integrated role. In this study, construction process rationalisation implies the simplification of on-site construction processes. This can be achieved by employing similar building sequences and by encouraging larger, and more independent, trade operation working. The research programme on which this study is founded is a contribution to such an approach.

1.2 The general layout and structure of the study

Chapter 1 of this study describes the research subject area and argues a requirement for basic changes in approach and practice by traditional house building firms in Britain. This is so that quality can be improved, better use can be made of skilled labour resources and cost savings can be made. These improvements can be achieved simultaneously with better productivity brought about by fieldwork monitoring.

A selected literature review relating to the main objectives of the study is presented in Chapter 2. The literature review cites important papers, articles and other works which have been published in the main topic areas appertaining to productivity and quality issues. The studies incorporated in the literature review span from the early post war period to the present day, the period where much of the research effort has been focused.

In Chapter 3 the research technique of activity sampling is described. Here, emphasis is placed upon an enhanced form of activity sampling. This new research method incorporates qualitative data and has been developed to provide support to quantitative data. The latter data type is normally generated by conventional activity sampling techniques.

Chapters 4, 5 and 6 of the study discuss three separate periods of site monitoring fieldwork on two different house building sites and describes the experiences and outcome of each. The information derived from the fieldwork forms a unique data set which is used in the subsequent quantitative/qualitative data analysis described in Chapter 7.

A number of important factors relating to attitudes to innovation are also discussed in Chapter 5. These topics are discussed because the practical application of new ideas can be difficult to accomplish. Unfavourable attitudes to change and inflexibility by individuals can jeopardise attempts to implement design and construction changes of the type advocated by the study.

Finally, Chapters 8 and 9 set out the main conclusions and various recommendations resulting from the work. Future work recommendations include refining the research technique already utilised in order for further improvements to be made. For this to be possible, house building firms must be more willing to invest in research and development based work, and to implement the findings of the research.

1.3 Background to the study

1.3.1 The meaning of productivity

Productivity is described as a ratio between input and output in many work study sources. It is a subject concerned with the effective use of available resources. This includes the allocation and deployment of skilled labour resources which are in short supply. The term 'input' in this productivity definition is equated to 'manhours'. Similarly, the term 'output' is equated to operations completed, and of course, quality. An overall increase in output for the same input is not a true productivity improvement if quality is seen to suffer. In fact, it can be argued that by analysing site operations for improved productivity, better quality should follow. As an example, data might identify excessive on-site handling and preparation time of materials which could be reduced with the introduction of good quality factory-finished components. In this example, consideration would need to be given to the additional cost of off-site assembly, finishing work and transportation.

The standard industrial measure of productivity used in this study is the number of manhours (inputs) required for a given work operation (output). By definition, the smaller the number of manhours expended on an operation, the more productive or effective an operation has been. Improved productivity can lead to numerous benefits, even when recessive economic conditions prevail. Some of the many potential benefits associated with improved productivity include:-

1. Building more houses for the same monetary investment through reducing the cost per unit;

2. Employing the same monetary investment to pay for better quality building materials thereby reducing subsequent maintenance costs;

3. Increasing profits for the construction firm and shareholders.

4. Increasing operatives pay or decreasing the working hours for the same pay, whilst holding building costs constant;

5. Providing cash discounts for purchasers;

1.3.2 The meaning of quality

Related to productivity in house building are the dual factors of quality and cost. This is an area of considerable importance and of increasing concern to the general public due to the high cost of quality homes. The term 'quality' can be misinterpreted. It encompasses a number of issues including quality control (QC), quality assurance (QA) and quality management (QM). All are referred in their respective contexts throughout this thesis. QM, however, (often called TQM, Total Quality Management) is the most important level in a quality hierarchy. QM is concerned with 'getting things right first time'. If a job has been done properly first time, that is, in a 'quality' manner, then it has been done efficiently. Also, if a job has been done efficiently, then it has been done cost effectively. As a converse argument, it could be argued that if poor productivity is observed, then work has not been conducted in a 'quality' manner and will cost more. By viewing total 'quality' in this way it is possible to consider that quality and productivity issues can be developed together.

1.3.3 The need for change

When homes are built and sold, the purchase price comprises four main components. These are land costs, over which house building firms have little control because these are determined by market conditions; overhead costs which include all administrative, design, technical and site set-up works; a profit margin, without which firms would be unable to invest, develop and generally grow; and building costs, which are the costs relating to the materials, plant and labour utilised on site. This last component represents an area where good organisation, control and planning, linked within a 'quality' framework, can lead to potential cost savings.

It is of importance to the study that house building practice can influence the price of new homes. This is because the price paid for a new home by a purchaser is a factor which is directly related to productivity levels on site. Ultimately, the price paid for a new home must be an average cost. The average cost is generally a sum figure based on the monies spent on homes which are built efficiently and under favourable conditions and those homes which are not. It is unsatisfactory that the end user should be expected to pay for the inefficient work practices which lead to high costs. Firms who realise this and take action to prevent high costs, which reduce their chances of achieving sales, are more likely to improve their profitability and gain a more substantial portion of a very competitive house building market.

The construction industry in the United Kingdom (UK) is responsible for almost 10%[1] of the nation's Gross Domestic Product (GDP) and actively employs tens of thousands of people either directly (on construction sites) or indirectly (in materials supply, consultancy and so forth). Of the many thousands who are employed in the industry as site operatives, too few command the craft skills which are needed. These skills are important to bring about better standards which are demanded by designers and users alike.

A long period of inadequate training opportunity has led to the gradual demise of the skilled construction worker in the industry. In times of recession, there is little financial incentive to train operatives. Thus, in periods of expansion, there has been a shortage of skilled labour. High interest rates can also have a dramatically decelerating effect on the housing market, squeezing investment and spending. Regardless of these problems, it is important that future research aims to make the best possible use of skilled labour through improved performance.

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[1] Statistical Source: Central Statistical Office, Annual Abstract of Statistics, No. 126, 1990 Edition, London, HMSO.

During the period of this study, 1985-1988, an average of 200,000 new homes were built each year in this country (private and public sector), although high interest rates sharply reduced demand during the period 1989-1990. In value of output terms this figure represents nearly £8.5b (excluding land costs), accounting for over 36% of all new-build construction work. Around 90% of all orders for new house building work, representing some £7.5b, were based in the private sector. Improved productivity clearly has an important role if these high levels of expenditure are to be reduced.

The last major house building development period in the United Kingdom took place between the early 1960's and the late 1970's. During this growth period the majority of research attention was concentrated on improving public sector construction. Since 1979, however, expenditure within this sector has been steadily declining. Current building indicators[2] suggest that this trend is likely to continue, whilst private sector house building completions are predicted to increase (subject to periodic slumps instigated by economic factors). Because of this, all new initiatives to improve quality and productivity should be financially supported, implemented and refined by private sector funding.

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[2]market indicators: Building Market Report, Building (Publishers) Ltd., period 1988-1990

1.4 Historical background

During the last major development period, the now defunct National Building Agency (NBA) and the Building Research Establishment (BRE) were amongst the organisations which sought to improve labour productivity in order to make cost savings. The work of these organisations was characterised by design rationalisation as opposed to monetary incentive schemes. The difference between these two methods are that incentive schemes generally serve to improve productivity by making people work harder whereas design rationalisation is concerned with making the actual work process easier.

Design rationalisation in house building focuses on a number of factors such as: dimensional coordination - improving the fit of components and minimising cutting to reduce waste; standardisation - using readily available materials and components; and simplification of construction - improving buildability by considering detailing and construction methods which avoid unnecessary complications to aid the on-site construction process.

Design rationalisation in its purest form has principally served to improve productivity by enabling a house to be built more quickly through the specification of simplified designs incorporating standard components. The design-led emphasis employed by this approach has often meant that certain aesthetic quality aspects, especially relating to the superstructure of the house, have suffered. This has been due to a bias towards a singular aim of productivity improvements.

The work which has been carried out by the BRE and NBA and based on this approach, has predominantly focused on the substructure and superstructure stages of production. Their work has aimed to simplify assembly during construction. In practice, the superstructure stage represents a relatively straightforward option for productivity researchers to study. First, it involves operations such as bricklaying, roof carpentry and roof tiling, which are amongst the largest and most independent of trade operations on site; and secondly, because of this independence of operation, the number of interruptions to the general flow and pattern of work are low. As a consequence, productivity levels are generally good. This fact is borne out in productivity figures collated by the BRE for bricklaying operations[3].

From a labour cost stance, the superstructure stage generally only represents approximately a quarter of the total labour costs required to construct a house (excluding external works). Although this figure is

[3]The output of bricklayers, W.S. Forbes and J.F. Mayer, Building Research Station Current Paper 32/68, March 1968.

significant, limited productivity savings have been made against it. In view of this, it is debatable whether or not the sacrifices made to quality of design were justifiable at the time. It can be argued that this is a price which is paid for adopting a purely design rationalisation led approach to improvements.

Some of the later studies carried out by the BRE have indicated that there are other areas which offer even greater potential for cost savings. These concern the services and finishings operations. Despite many research studies, relatively little attention has been given to these stages. Moreover, these stages may typically represent almost half of the total labour inputs required to build a house. The stages mentioned involve operations such as plumbing, electrical and joinery work. All of which are known to produce relatively more variations, work interruptions and non-productive work hours than the superstructure stage.

Since the current directive in the house building industry is to work for improved product quality - this is quality which can be afforded by savings from reducing costs by improving productivity - then it is clear that previous efforts may have been misdirected. Much more attention needs to be paid in future development work to improving productivity within the services and finishings stages for it is here where the greatest potential labour cost savings lie. These are also areas where the effects of rationalisation on product aesthetic quality are least likely to be questioned.

An important outcome from the last house building initiative was a tendency by some designers to over-rationalise designs. This left many other designers and end users concerned with design quality ambivalent about the benefits which were actually achieved. Due to this imbalance, little has been done by either central government, or private firms, to follow up the aims and objectives which were originally introduced at the time. The study sets out to change this situation by promoting an approach in which research and development encourages a context for greater interest and investment.

1.5 The objectives of the study

The cost-led, single-factor productivity improvement approach to house building which has been described is now outdated and needs to be replaced before any future house building initiatives take place. A main objective of this study has been to develop an original construction process led approach to house building based on 'development cycles'.

This approach is concerned with providing good quality site feedback for design and construction improvements to take place. It is an approach which requires extensive site monitoring to determine the factors which underlie quality and productivity issues on site. The development cycle philosophy concerns the following: collecting data using method study techniques; analysing the data to determine the cause and effect of problems relating to quality and productivity; refining design and construction practices by introducing changes which have been supported by the data; and then re-monitoring to assess the effect of changed practices.

The type of approach outlined is more likely to lead to overall gains than an approach led solely by design rationalisation. To test out this hypothesis, the study avoids further research appertaining to the superstructure. Instead, it places emphasis on the services and finishings stages which offer good scope for cost savings, but where prejudice to aesthetic quality is unlikely to be a problem.

The construction rationalisation led approach to quality and productivity improvement is concerned with simplifying the individual building processes undertaken on site. This must be done whilst preserving product quality at all times. This can only be done effectively if the creation of simpler site processes is also made an important function of design. By doing this, design and construction integration can be achieved. This is important because the lack of integration which exists between the design and construction functions is probably the single weakest link in the construction industry today.

The design function has an influential role to play in the research. First, it must be responsible for specifying product quality. It is of little importance if productivity gains are made and at the same time quality is seen to suffer. Secondly, the design function must be responsible for developing ways which allow work on site to be executed as a series of trade operations that are as large in scale, and as independent as is practically possible. This is necessary in order to reduce the number of individual work divisions and to simplify the problem of site organisation which tends to lower productivity. Furthermore, the building sequence in which work is carried out must be rationalised. This means that the work sequence detailed for any given house type can be the same. The BCA have advocated the use of larger work operations and rationalised building sequences such as this in their publication[4] concerned with efficient masonry house building.

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[4]Efficient Masonry Housebuilding: Design approach
W.E. Anderson, J.J. Roberts and P. Watt
Cement and Concrete Association, 1985.

This applied research study is principally concerned with good quality in design. An important aim throughout the study has been to preserve quality in design, yet not to concede to the principle of construction rationalisation if quality is likely to be compromised. For example, construction rationalisation which allows the plumbing and heating work to be carried out in one continuous operation requires considerable design input to establish suitable distribution routes. At the same time, this construction process change does little to compromise quality in design through unacceptable standardisation.

1.6 Limitations of the study

The construction industry and its allied professions historically have been reluctant and often slow to accept new and innovative ideas and work practices. This inertia has meant that some of the more controversial proposals presented for trial by the study have been difficult to implement fully. Included in this category have been process changes based on the services and finishings operations.

A second limiting factor encountered in the research concerns build programme delays. Delays which occur due to factors outside the control of the study, mean that the time needed for comprehensive fieldwork monitoring can exceed that which is planned. Because of this, it has only been possible to implement a single development cycle during the course of this research where more may have been possible. Subsequent monitoring cycles must now must be taken up in further research where the data collection critique can be refined still further.

The external factors which have been described should in no way distract from the important steps which can be made by this applied research work. The study should be assessed primarily on its ability to demonstrate some of the ways in which goals can be achieved rather than to ensure that goals are realised within the constraints of a short research programme.

Finally, this study should be regarded as a first step in collaboration with an industry which is in need of significantly improved spending on research and development work. Factors such as industry fragmentation, high costs, low profit margins, long lead times and easy copying of new ideas should no longer be given as the causes of low spending on this type of work.

CHAPTER 2

2.0 A SELECTED LITERATURE REVIEW

2.1 An outline of the literature review

The references cited in this chapter have been selected from the best available construction and management material. They cover a period spanning from the early post war years to the present day. These key references have been chosen because they relate to the main objectives of the study and because they provide valuable insight, evidence and support for undertaking research in this subject field.

The literature review begins with various studies concerned with construction productivity. In particular, attention is focused on those studies which involve productivity improvements based upon design rationalisation in house building.

The second section is concerned with quality issues in construction. In this section, 'quality' is discussed in terms of quality control, quality assurance and quality management. In the final section, innovation is discussed. Innovation is concerned with the application of new ideas and is needed in order for quality and productivity improvement to be viewed in a new way.

2.2 Productivity

The following section incorporates a wide collection of material which is related to the subject of productivity. Although noteworthy productivity studies have been carried out in many countries worldwide, the weighting of emphasis in this section is predominantly British based. This is due to the importance of the BRE and NBA in many of the productivity research studies concerned specifically with house building.

In 1949, a British productivity development team studied methods for improving productivity in the American building industry. During their visit to the United States, the 17 strong team attempted to identify those factors which had produced the high levels of productivity observed on various American construction sites. Typically, productivity levels were estimated to be 50% better than in the UK.

Of particular interest to this study, the following factors were reported to be of importance for improving productivity:-

1. The proper coordination of subcontractors' work and the effective collaboration between them and the general contractor;

2. The complete pre-planning of the work by the building team;

3. The recognition of the importance of continuous research into building materials and techniques.

Following this visit the team made their recommendations. They recommended that all of the factors noted could be implemented in the UK by effort from within the industry. Thus, designers were pressed to pre-plan effectively, to obtain a firm brief from the client and to have all working drawings completed by the tender stage.

From a construction perspective, contractors were advised to start work on site only when full information was made available to them. Contractors were also advised to develop effective planning procedures and to enforce them on their subcontractors, to improve the technical training of site supervisors and to make better use of mechanisation. Many of the materials and practices which were considered unusual by the team at the time have since been absorbed in the UK industry.

In a later study by Rosner (1955), which was concerned with the massive re-building programme which was then taking place in West Germany, a number of interesting points were established. Two of the main findings of this work reported the following as being important factors which could improve general building, including productivity in house building:-

1. The rationalisation of site operations;

2. The analysis of site operations.

The rationalisation of site operations, as described by Rosner, concerns the simplification of certain on-site construction processes. To be able to do this, it is first necessary to determine where to focus attention so that site operations can be studied and analysed. In so doing, work operations that cause problems can be identified and solutions sought and applied.

In order to obtain data which can be used to analyse site operations it is necessary to have a system for providing feedback. Throughout this study considerable emphasis has been placed upon the importance of site monitoring to obtain production feedback. This type of data forms the basis for design and construction changes in the research where aspects of normal production working are monitored.

An American study by Kaplan (1957) identified two significant factors which had contributed to the growth of improved productivity in the USA since the end of World War 2. These were:-

1. The increased scale of operations;

2. Better organisation of the production process.

Kaplan concluded this work by emphasising the need for further productivity improvements through the simplification of individual operations, by minimising handling and greater improvements in site organisation in an effort to reduce indirect time.

Kaplan's argument for simplifying work operations by increasing the scale of operations was similar to one expressed by Rosner two years earlier concerning the rationalisation of site operations. Both require good organisation and some degree of operational research to determine which site operations are in need of improvement or attention.

The claims for a need to reduce indirect time in construction work are substantiated by evidence produced by the BRE. Reports which are concerned with the allocation of work time have suggested that as little as one third of the manhours recorded on site are actually spent fixing components. The balance of manhours comprises non-productive and indirect time spent handling materials, in preparation and in other non-direct activities.

In 1965, The United Nations produced a report on the effect of repetition on building site operations with respect to productivity. The report has particular relevance to house building where repetition of house type designs is common. The conclusions arising from this all member country report cited the following as being some of the important factors affecting productivity:-

1. Adequate day-to-day management and supervision of site works;

2. The need for proper planning and organisation of site works;

3. The importance of the continuity of work on site.

Good planning and site organisation were now common conclusions in productivity research work. However, the United Nations finding concerning the importance of work continuity to productivity was an important conclusion.

Good site management, supervision and planning can lead to high morale amongst individual subcontractors. This can have a beneficial effect on continuity of work and therefore productivity. Subcontractors are generally more willing to work and remain loyal to competent house building firms than those which lack the ability to organise and control their work effectively.

Bishop (1966) discussed three significant aspects in a paper concerning the role of architects and productivity:-

1. Variations in manhours for repeated operations;

2. Interruptions to work;

3. Site organisation.

Variations in manhours and interruptions are particularly important factors which can be derived from the analysis of site operations.

Since the 1950's, research work at the BRE has given exposure to some of the problems discussed by Bishop, but results have met with varying degrees of success. For the most part, research work carried out by the BRE has had little impact on the construction industry. The main reason for this is because the industry has been allowed to continue building houses, often in a very costly and unproductive manner. Public opinion and attitudes are now changing. This will mean that inefficient practices, which lead to high costs, will cease to be tolerated.

These important factors, which were discussed by Bishop, were drawn from, amongst others, a 1965 study by Clapp.

This report concerned the detailed use of activity sampling data. The author argued that there was a scarcity of good quality data available concerning productivity. Notwithstanding the few activity sampling studies which have been undertaken since this survey, the lack of factual information discussed by Clapp remains largely the same today. This situation needs to be rectified if solutions are to be found to the many problems which still affect productivity in the construction industry. In order to assist in this process, research methods must incorporate data collection techniques which are able to provide better explanation of the problems underlying poor productivity.

A series of surveys undertaken by the Building Research Establishment in the early 1960's produced information relating to the manhour requirements and progress achieved on house building sites of two-storey dwellings. In a subsequent report by Forbes (1969), which was based on these findings, it was found that the variation in manhours expended for repeated site operations was often in the range 1:3 from the best to worst work context.

These findings substantiated similar results which were apparent in an earlier post war investigation by Reiners and Broughton (1958) which was concerned with trends in house building productivity. It is of interest that these later results showed a marked reduction in average manhour requirements for house building, 1110 manhours compared with 2665 in 1949. Despite this, a 1:3 variation field was still evident for many operations. This order of variation continues today for certain trade operations and thus indicates still further scope for improved productivity in the field of house building.

The Sidwell report in 1970 was also concerned with variability. The purpose of the report was to make a comparison of the cost of private house building in Scotland and England. By comparing data for 3-bedroomed, semi-detached homes with garage (this being the most popular form of construction in both countries at the time) it was found that on average the Scottish homes could be built 14% cheaper than those in England. Of this cost difference, which is a partial measure of relative productivity, it was only possible to explain away 65% in differences of location and regulatory requirements, traditional trade and construction practices, space standards and so forth. It was not possible to find an explanation for the residual 35% of difference. This example, yet again, points at a need for good qualitative data, generated from site monitoring, to help explain away variations.

In 1972, the results of the Finchampstead Project were published by Forbes and Stjernstedt. The scheme comprised 172 public sector dwellings and was the first major construction project in the United Kingdom to employ activity sampling techniques to analyse site operations. The study was limited to design rationalisation involving the substructure and superstructure stages.

A basic aim of the project was to use design rationalisation in order to reduce the number of separate visits by trade operatives to any one house. Another aim was to concentrate the work on site to a few houses at a time. These aims were largely successful up to, and including, the stage of jointing the plasterboard. However, for the remaining stages of work, which comprised the services and finishings stages, the problems of variations in manhours, interruptions and non-productive manhours, which were encountered in previous studies, were still evident. The pattern of the work in these latter stages was shown to be confused and the manhour requirements high.

In conclusion, the authors stated that further systematic rationalisation of the building design should concentrate on the services and finishings stages. This was suggested in order to reduce the complexity of the work, to simplify the efforts of site organisation and to reduce manhour requirements. All of which are objectives of this current research.

The Finchampstead Project was followed by a number of other BRE productivity studies over the next decade, including schemes at Crawley New Town, Hillingdon and Peterborough, amongst others. In each of these subsequent schemes, further data concerning productivity was collected using a BRE data analysis package. This package was developed for collecting coded activity sampling data which is later read by an optical reader. During these studies, opinion continued to harden that design decision making could have an important impact upon buildability and so upon productivity.

Forbes reviewed these results again in 1977 when he expressed the opinion that in order to achieve real progress in house building productivity, organisational problems would have to be resolved and design detailing would have to aim at the minimum number of continuous operations. Single operation electrical installations in house building were cited as an example for such an approach. For this to be possible, it was further stated that design rationalisation would first have to make considerable provision for allowing this to be done. The ideals expressed by Forbes in this work were good, although the emphasis was perhaps somewhat misdirected. The main emphasis leading this single operation approach was one of improving productivity by a purely design led approach. Design changes which do not also draw on the contributions which can be made from construction process rationalisation must be regarded as narrow in outlook.

A number of other important projects were also undertaken during the 1970's. These were mainly conducted by the BRE and the Scottish Development Department (SDD). The projects included housing at Arbroath and Greenfields Estate, Glasgow. A major design rationalisation project was also undertaken at a housing development in Blantyre, Lanarkshire.

On each of these projects, the contractors methods were studied and measurements were taken of the manhours expended on site. During these exercises, BRE opinion continued to promote the virtues of design rationalisation as an important link for improved productivity.

These studies culminated in a major exercise involving the NBA and incorporating the very best design rationalisation proposals to date. The project in Glenrothes New Town, known as the 'Pitcoudie' project, demonstrated that design rationalisation could yield significant cost savings in the order of 30%. This figure had been derived from a comparison of the average manhours expended on 27 other sites which had been covered in less detail by Fraser and Evans (1980) in a paper concerned with Scottish house building performance.

The Pitcoudie exercise was concerned only with the single aim of productivity improvements in house building. The ultimate objective being to provide more houses for the same monetary investment, or the same number of houses for less investment. With this type of philosophy, other factors, such as product quality, stood little chance of being improved. Paradoxically, quality aspects related to the Pitcoudie development have been reported as being good. This is not a common finding on developments led by a purely design rationalisation led approach to house building.

In work by McLeish (1981), concerned with manhours and interruptions in traditional house building, BRE activity sampling data was analysed for the two Scottish sites at Blantyre and Greenfields Estate. One of the aims of this work was to examine the value of activity sampling data for detailed analysis of the relationship between design and site organisation and productivity.

The author concluded by stating that the activity sampling data derived from the BRE studies could not explain the causes of the main findings. These were the large variation in manhours for identical operations, and the frequent number of visits necessary to complete work operations. It was suggested that future work in this area should focus on the services and finishings operations and, most importantly, that future work should concentrate on developing a more detailed analysis than the BRE activity sampling method could provide. Such detailed analysis is necessary in order to explain the causes underlying the need for further visits to complete operations, which lead to an increase in labour requirements as well as other problems.

In 1983 McLeish describes a more detailed data collection technique based on the BRE activity sampling method. The BRE activity sampling method is a particularly effective technique used for providing 'quantitative' data; this is the type of data which was used by McLeish and which led to his findings. It does not, however, explain why variations and interruptions exist for repeated operations. The author goes on to describe a form of 'qualitative' data. This is a diary type of data entry which can be collected on site by trained observers during normal quantitative data observations. This type of data aims to explain the cause of variations and interruptions found for apparently identical work contexts - evidence which can then be used to bring about changes to design and construction practices employed by firms for improved productivity.

More recently, Anderson, Roberts and Watt (1985) have revived interest in the design approach to efficient building with the publication of a manual aimed at improving productivity in masonry house building construction. With particular interest to this study, the authors promote the case for fewer and larger trade operations and the use of same building sequence approaches to improve productivity.

Also of considerable interest, the work provides details of an integrated pricing/costing document which can be used when estimating the material, plant and labour requirements for housing developments. The labour estimates can prove difficult to establish in practice and these are often derived from calculations. However, when these are derived from site feedback, such as that obtained from this study, the estimator is able to gain knowledge of production standards which reflect real work contexts. This is because the site feedback does not simply consider tasks in isolation. It takes into account the effects of the interdependence of operations and the effect the pattern of work on site has upon productivity.

2.3 Quality

In recent years quality has become a key issue in the construction industry. The term 'quality' is often misunderstood and confused. It can be used in its technical and scientific sense to imply integrity and the suitability of a product for its intended purpose. Alternatively, quality can be defined in terms of a ranking on a good-bad scale. In a house building context, the houses which are built must be functionally sound and subjectively acceptable for them to be marketable products. Functional quality includes being free from structural movement and damp, not being subject to chemical faults in materials or engineering faults in service equipment. The acceptance of a house as a marketable product is concerned mainly with the visual quality of finishes, the standard of decoration, fittings, the feel of surfaces and other such tangible elements.

At a broader level there is quality control. The term QC is now widely used in the construction industry and is considered by many to be the subject encompassing the issues of quality. This is not so. It is a subject primarily concerned with activities such as inspection, sampling and testing which relate solely to the specification of a product or service. QC is actually one of three areas which comprise the subject of quality assurance. The other two areas concern quality administration, which is concerned with the company organisation; and quality engineering, which deals with the design concept, quality of the design drawings and technical specifications as a means of communicating the correct design and quality levels to the contractor.

QA is a relatively new and a less widely accepted concept than QC. QA is concerned with the attainment of quality during every stage including design, procurement and installation. QA exists because of the degree of dissatisfaction experienced by the industries clients over a long period, combined with a growing impatience by some to achieve value for money.

QA can provide real benefits for the firms which have adopted the system. However, major improvements and increased profits for firms materialise when QA is applied in the context of quality management. At the centre of QM is the principle that 'prevention is better than cure' or, put another way, 'it always costs less in the long term if things are done right first time'. This is also a fundamental precept of QA. QM, however, takes this to the practical limit by allaying it to the maxim 'money is the most important material firms deal with'.

The importance of planning and other factors in relation to quality was discussed by Powell (1976). In a paper concerned with quality control in speculative house building the following statements were made:-

1. Good planning is more likely to lead to good quality work;

2. Materials should arrive when required, neither excessively early nor inconveniently late;

3. Panic and confusion mean poor quality;

4. Steady, controlled progress makes for better quality work;

5. Trade operations need to be carried out in the correct order and the situation should not arise where a month's work has to be done in a week at the end of the job because of inadequate coordination between sales and production staff.

Data collected during the course of this research confirms and substantiates each of these quality control issues as being factors which affect quality and productivity in traditional house building.

In 1980, Freeman and Bentley wrote of an increasing concern over the standards being achieved in building construction. Their study, which was based on 27 non-housing construction sites, involved the observation of building site staff to reveal those quality control factors which had contributed to a lack of quality. The main conclusions which relate to the study area stated that:-

1. Tradesmen's lack of care caused more faults than their lack of skill;

2. Unclear or missing design and project information could have a detrimental effect on quality;

3. Improved quality standards result from creating an environment where good work can take place;

4. Sites with better quality standards tend to be characterised by a consultative approach to problem solving where anyone on site can raise questions and where many individuals contribute towards solutions;

5. For a large number of problems, identification of the problem on site did not result in effective remedial action being taken.

The method of observation utilised by this study was to accompany site management continuously throughout the day, noting anything which caused the site agent, architect or tradesman on site to pause in their work and consider the quality of the building. Each entry was called a Quality Related Event (QRE). Analysis revealed that workmanship related QREs accounted for 36% and design/project information related QREs for 57% of the total number of observations recorded.

The authors considered the roles of the participants in quality control across the 27 sites covered by the study. Some of the sites were found to maintain high quality standards whilst others were disaster sites where many problems were evident. It was found that the quality achieved was far more the result of the total system of individuals and tasks than it was of formal checking. Formal checking and acceptance or rejection of completed work seldom took place. On the better sites, management tended to put emphasis into creating an environment where good work could take place. This took the form of making sure project information was complete and rational, and that the most suitable tradesmen were used in any given situation.

Of particular interest to the research, the study also states that the cause and effect of many quality problems are not easy to detect. This need not be the case. The type of qualitative data technique employed by this research is able to explain, in many cases, the cause or 'why' in relation to quality problems. Data in this form can then be analysed in order to determine effective solutions to common quality problems.

Another project headed by Bonshor and Harrison (1982) for the BRE (NBA assisted) concerned the types of faults arising during the construction of mainly 2-storey built housing. The research team observed 15 sites under construction and identified where various regulations, codes, standards or authoritative advice was not being followed. These were termed as 'faults'. The faults were analysed as a basis for actions to improve quality. The analysis revealed that of the total 72000 faults recorded, 50% were attributable to design and 41% to site. These distributions were very similar to those derived by Bentley and Freeman two years earlier on a wide ranging group of construction projects.

Some of the important conclusions arising from this work include:-

1. On site, lack of care appeared to be a more important cause of faults than lack of skill and knowledge;

2. Just over a quarter of all fault types were judged to be partly or wholly due to inadequate information provided by designers to site;

3. The majority of the fault types related to traditional well established practice; it is not possible to lay the blame for poor quality on innovation;

4. The average cost of putting a fault right after construction was assessed as at least five times the cost of getting it right first time;

5. The number of faults can be markedly reduced as a result of methodical checking during or at the end of design and at appropriate phases of site construction.

Also in 1982, a Dutch team reported on the concern for quality in the house building industry. The team described the period between 1960-1975 to be a period aimed at solving the 'quantitative' housing shortage. It was suggested that the period 1975-1990 should place importance on the solution of a 'qualitative' housing shortage where the control of costs should come from standardisation and in associated prefabrication, construction precision, less labour on site and from better planning and coordination. This tendency leads to a scale increase for the supply industry and specialisation and decentralisation in construction with more subcontracting.

On many house building sites there is evidence of this sort of change, including a much more significant use of pre-fabricated and pre-finished components. This means that much of the preparation work, which traditionally has been undertaken on site, can be eliminated. By using more pre-finished and pre-fabricated components, site operatives can operate more productively. This is because a greater proportion of their time can be spent fixing components (direct work), whilst indirect preparation and handling time is minimised. At the same time product quality can be improved because the installed components are assembled and finished under factory controlled conditions before arriving on site.

Quality issues in general, are now a key concern for the general public. The speculative house building sector must realise this because the quality levels set within the industry are still largely determined by the individual firms. Because house builders are arbiters of their own quality, and because they are not obliged to take note of the views and opinions of customers, many still see no incentive to change their method of operation.

This aspect of the role of the customer in quality control was discussed by Price (1984) when he wrote:-

"...it seems to be the norm with many companies who believe it is cheaper to let their customers carry out the quality control which they should be doing on their own product. There is very low mileage in this approach, but short distances tend to suit much of our thinking."

Clearly, this attitude is outdated and needs to be replaced. For this to be possible, there is a need for a much wider acceptance by firms of the principals concerning quality management.

In the same work the author describes the quality function as an information gathering agency which selects, abstracts, and amasses data about the process and the product. It can be argued, therefore, that the quality function described by Price has characteristics which are common with the development cycle approach advocated by this research. Also of interest, the author argues that improved quality and improved productivity are best developed together and the better the product quality, the less it should cost.

These beliefs fit in well with the philosophy underlying this research, that is, quality and productivity are not mutually exclusive; and, the more rigorous the application of design and construction rationalisation which results in improved productivity, the greater the cost savings which can be made and the better the quality which can then be afforded. It must be this sort of belief which forms the basis for future research and development work.

The real cost of quality was discussed by Pateman in 1986 who wrote:-

" The cost of quality is the sum of the costs associated with trying to get it right first time and all those costs incurred when you don't, and you have to do it again (and again). Unfortunately most companies have no real idea of how much time is wasted by managers resolving problems that should never have occurred, or by designers having to re-calculate, re-design or re-detail because the correct information (which must exist) was not passed on to them."

By viewing quality in this way, it is clear that quality has a lot more to do with people than formal checking procedures. In order for firms to participate fully in the quality management approach they will have to challenge some of their concepts on quality and management style. They will then have to set aside the traditional idea that quality refers only to the product integrity, and replace it with a broader concept that relates to the entire scope of a business.

2.4 Innovation

Innovation is an important aspect of research and development work and is needed in order for significant productivity and quality gains to occur. It is concerned with the successful application of something new, or the re-use of older and more established ideas. The industry has been slow to realise its importance and because of this a wider acceptance of innovation seems more remote than ever at the present time. This must not be allowed to continue.

Locke (1973) discussed the problems associated with innovation with respect to the construction industry. Three main types of problem were identified for most sorts of innovation, including a situation such as house building where market forces are not normally a significant factor in influencing innovation within the industry. These were:-

1. Slippage in time generally - applicable to all projects including innovation;

2. Lack of business urge, correlation and management generally;

3. Insufficient rate of resource flow.

Each of these factors may turn eventual technical success into commercial failure. Slippage of time is particularly insidious since nothing can be done to retrieve lost time.

Wissema, Benes and Diepeveen (1982) discussed a series of factors which were believed to either foster of impede innovation in the industry. One of these concerned the important role of the customer in influencing innovation in the private sector:-

> " Market-orientated building, that is speculative building, generally fosters innovation and public building retards it."

Firms which undertake market research and listen to their customers opinions of their product and service are likely to be firms which prosper from innovation. Peters and Waterman (1982) also write of the importance of listening to customers. They describe excellent companies not only as companies which provide first class service, quality and reliability, but companies which listen to their customers. This is because many of the users want the latest in quality, comfort, popularity, and most importantly price, in terms of value for money. Few multi-national firms outside construction would disagree that most of their real innovations come from the market. The same must be true for construction.

In an important work by Holt (1983) concerned with innovation management the author stated that:

" Successful innovation depends on a positive attitude towards change."

The term 'positive attitude towards change' is important. Too many individuals within the industry at the present time are unwilling to accept innovation and the changes this brings. Instead, they remain complacent and hold on to tried and tested practices. Those who reject new ideas or practices without trial are the people who retard innovation within the industry. There is no room for such complacency. It is fact that customers are now demanding improved products and service and this will only be possible with more innovation.

CHAPTER 3

3.0 METHOD

3.1 The need for good quality data

Chapter 1 of this study has discussed a requirement for change within the British house building industry. A basic change in approach to house building practice is needed, amongst other reasons, to enable more effective competition to be possible in a unified European market. Changes are likely to affect many areas, including the refinement of design and construction practices. One of the main purposes of change must be to improve product quality and reduce costs by improving productivity.

In order for changes to be introduced successfully, it is first necessary to produce evidence which supports a call for change. Without conclusive evidence, it is unlikely that any significant progress will be made in achieving change. Companies will be reluctant to alter long established practices, beliefs and attitudes unless they are irrefutably convinced that it is right to do so. A substantial amount of good quality evidence can be derived to substantiate change with an increase in site production monitoring based on the research method of activity sampling. This fact, coupled with a Total Quality Management led approach to business can provide firms with the necessary formula for success.

The data generated as a result of fieldwork monitoring must be able to identify those areas offering the best scope for improvement. For example, activity sampling studies conducted by the BRE have shown the services and finishings operations in traditional house building to be in need of attention. Most importantly, this data must be of a form and quality which is able to explain the cause and effect of the many and varied reasons underlying multiple trade visits, interruptions to work and high manhour requirements. Activity sampling studies conducted by the BRE have demonstrated that these problems are commonplace in the field of house building. However, the BRE data has been unable to provide specific explanation to the cause of the problems which have been identified.

An important function of this research has been the collection of data during the construction of new homes. This has then been used to compile a comprehensive data base of 'informed' feedback. The information contained in the data base can be used in design in order to facilitate better construction, whilst retaining overall control of product quality. Also, this feedback can be used to improve the on-site construction process by indicating which trade operations are in need of attention to overcome some of the problems described previously.

The aim of collecting good quality data from developments is to improve quality and productivity on a cyclical, or development cycle basis. The term 'development cycle' concerns both the design and construction functions and describes a period from design to construction, including site monitoring, to feedback and back to design again. This approach is the unique contribution made in the area of construction research by this study.

3.2 The activity sampling method

Activity sampling is a well established research method which can be used to determine the proportion of the working day during which operatives and/or machines are working or subjected to specified delays. In its elementary form, it can provide a reliable indication of problem areas. With further refinement, it can give accurate data on trade working, including standard times and current performance levels.

The method has been applied successfully to measure performance levels in factories and can be used to obtain information on the usage of different machinery; the labour requirements of the operations performed to produce finished components; and the amount of handling required to transport the component pieces around the factory. In more recent years it has been applied to provide a measure of productivity in the construction industry.

The method was adapted and developed by the BRE over twenty five years ago in order for it to be used in the detailed study of building projects. In house building, for instance, activity sampling data can be used to assess the manhours required to complete certain building operations. One of the main developments introduced by the BRE has been the use of special recording forms which can be read as input by an optical reading device. Checking and analysis of data, which has historically been extremely time consuming, can now be carried out automatically by a digital computer using this method. Details of this approach are fully documented in the BRE Current Paper CP 16/69.

A significant advantage of activity sampling methods over other method study techniques are that the operations as a whole can be observed and evaluated. This is particularly useful where large work gangs or dispersed work is involved. Also, the information can be obtained quickly, to predetermined levels of accuracy and interruptions may occur without invalidating the results of the study. A further consideration is that the method does not require highly skilled work study engineers to undertake the work. Also, the observation time on site is less than conventional work study methods. This can reduce monitoring costs significantly.

3.3 The statistical basis of activity sampling

In summary, the method involves making direct observations on site of each operative covered by a sampling survey. Trained observers are generally used for this purpose. The approach is based on probability theory and assumes that a sample taken at random from a large group tends to have the same pattern of distribution as the large group. Thus, the activity which operatives can be observed doing at randomly chosen times will reflect how, on average, their working day is spent.

In practice, a quantitative record is maintained of what each operative covered by the survey is observed to be doing at particular, randomly selected, moments in time. These observations are called 'snaps' and the period in which they are collected are called 'rounds'. This method assumes the greater the number of observations that are made, the greater is the accuracy of the approximation. The distribution of observations between the chosen parameters, such as, fixing, standing idle, or receiving instructions, is an approximation to the distribution of the operatives' time between these parameters.

3.4 The accuracy of the method

Before observations are made on site it is common practice to establish that the frequency of the observations will obtain a sufficient number of snaps to ensure that the desired degree of accuracy is achieved.

The accuracy of the estimate for any part of the activity sampling survey can be calculated from the following formula which gives the relationship between the degree of accuracy (A) and the number of observations (N):

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

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

(The values of A and P must be expressed in decimal form)

By rearranging this formula it is possible to determine the number of observations required to attain a predetermined accuracy level.

$$N = \frac{4(1-P)}{A^2P}$$

Table 1 is a partial table which shows the relationship between the required number of observations for a given degree of accuracy against the percentage of the total time occupied by a work operation or activity. For calculation purposes, the value of P has been taken as

50% and the generally recognised limit of error for activity sampling for construction operations is taken as + or - 5%. Therefore, it can be seen from Table 1 that 1600 observations are needed to satisfy these limits. Alternatively, a pilot study can be undertaken to estimate the percentage of time spent on a particular operation or activity. If the results of such a pilot study were to show P = 35%, for example, with a total of 4500 observations, then the degree of accuracy (A) obtained will be approximately + or - 4%.

P values (%)	(A) Degree of accuracy (+ or - %)				
	1	3	5	7	9
1	3960000	440000	158400	80800	40900
2	1960000	217800	78400	40000	24200
3	1293300	143700	51700	26400	16000
4	960000	106700	38400	19600	11900
5	760000	84400	30400	15500	9390
7	531400	59000	21300	10800	6660
10	360000	40000	14400	7340	4450
15	226700	26200	9070	4620	2800
20	160000	17800	6400	3260	1980
25	120000	13300	4000	2450	1480
30	93000	10400	3730	1900	1150
35	74300	8250	2790	1620	915
40	60000	6670	2400	1220	740
45	48900	5430	1960	1000	605
50	40000	4440	1600	815	495

Table 1: Observations required for given P and A values

In the majority of BRE studies, observations have been made at hourly intervals. This means that each observation represents one manhour in the assessment made by the sampling method. For surveys such as this one, which are narrower in scope, and which cover only the services and finishings operations, it is necessary to make more frequent observations in order to achieve a satisfactory level of accuracy. This is because some work operations are small in scale and are completed in a short time period. Some other operations, such as bricklaying, are large in scale and continue for many weeks on site. For these larger type of operations, observations can be made at less frequent intervals, yet a sufficient number of observations can be made to satisfy accuracy levels.

The ability to make more frequent observations, and thus obtain more accurate results, depends, however, on the number of observers on site and on the number of operatives being covered by each observer. In view of this fact it is commonplace for observers to monitor activities at time intervals which are easily manageable and in which all operatives can be comfortably recorded. This approach has been observed here. It results in a number of observations, either more, or frequently less than those required to satisfy the + or - 5% accuracy level normally produced for construction work. By doing this, the resultant number of observations derived from the study of the building operations can be used to calculate the actual accuracy level.

In the case of this study, it was considered more important to determine the cause and effect of manhour variations, interruptions and multiple visits rather that to provide statistics with high degrees of accuracy. It was not necessary to prove that these were the areas which should be investigated in greater detail. This was known from earlier BRE studies.

The accuracy level derived from the actual number of observations recorded can be used to determine a full range of manhour values either side of a mean value. Three example calculations showing full range manhours are illustrated in Table 2 below.

Observations (N)	Accuracy (%)	Full range of manhours
15	+ or - 52	7-23
150	+ or - 16	126-174
300	+ or - 11	267-333

Table 2: Example of full range manhour figures

3.5 The activity sampling data collection procedure

The observer begins the activity sampling rounds, in which observations are made, at regular intervals. To ensure that observations are kept as random as possible, the exact round times are commenced at slightly altered time intervals each day. This is usually done by adding ten minutes from day to day, including further adjustments to allow for regular breaks. As a further assurance of randomness, the observer starts each round from a different position on the site and also takes different routes around the site.

The observer uses a coded framework which describes the specific works included in the survey when making observations. An alpha-numeric coding system is normally employed for this purpose. This is because observers find this type of coding easier to remember, and less likely to produce errors than a wholly numeric system. The number of individual attributes, or pieces of information, which are defined within the coded framework and recorded at each observation, should be kept to a minimum. This is because each attribute adds to the codes to be remembered by the observer and to the time taken for an observer to complete a round of observations.

Each observation which is made by the observer can potentially contain the following main attributes (these are the attributes used in BRE surveys):-

1. the week number of the construction period.
2. the site observers own coded number (if there is more than one observer recording on site).
3. the date incorporating the day and the month.
4. the round time in which the observation was made.
5. the operatives code number which denotes his trade.
6. the operatives status within his trade.
7. the house block number to provide location.
8. the individual house number within the block to provide sub-location.
9. the stage of work in progress.
10. the operation within the stage of work in progress.
11. the activity within the operation.

To illustrate these latter three attributes: point 9 might represent, for example, the plumbing stage; point 10, the plumbing carcase operation within this stage; and point 11, the activity of preparing pipework bends within the operation.

3.6 Quantitative data

The activity sampling method which has been described is a particularly useful work study technique which can provide reliable data relating to the following areas:-

1. the movement of operatives around site;

2. the labour expenditure for each operative for each house (or block);

3. the way in which time is expended per operation and by whom;

4. the amount of productive or non-productive time, and where and when it was expended.

Activity sampling can also provide direct comparisons on the labour expenditure between different house types, between blocks and between different construction techniques. The activity sampling technique can, if carefully applied, be used to determine production output data and method related constants for use in estimating and planning the duration of construction operations.

Activity sampling has been used by the BRE to indicate typical variation fields of 3 to 1 or more (sometimes as much as 10 to 1) for many of the repeated work operations found in house building. In addition, numerous interruptions during work have been shown to exist for the same repeated operations. Furthermore, statistical analysis of BRE activity sampling data has indicated a common correlation between the number of interruptions and variations in manhours within many building operations. However, these points are derived from alpha-numeric coded data which is purely quantitative in nature. This type of data is unable to explain why these large variations exist. An important aim of this study has been to collect data which attempts to provide some of the answers to these problems.

3.7 Qualitative data

To explain the variations in manhours found, or the number of interruptions encountered in repeated operations, additional data is required. This type of data needs to be qualitative and, therefore, informative in nature. Qualitative data is needed to explain why certain conditions produce low manhour requirements for an operation in one house, or conversely, why conditions in an identical, or similar, house produce high manhour requirements.

One possible solution to this problem is to extend the activity sampling research method to include a series of 'qualitative observations'. Qualitative data can take the form of a rationalised site diary which can aim to explain those factors either impeding or promoting better quality and/or improved productivity in the building process.

An important question is how such records should be developed. One main problem stems from the fact that the range of productivity figures, indicated in manhours by the activity sampling method, cannot be prejudged. Any relevant information which can be relied upon to explain productivity and quality variations may occur at random. In view of this fact, a research method employing qualitative text must provide a comprehensive record of all relevant production data and other associated information if it is to be effective.

3.8 An enhanced activity sampling technique

An essential problem which concerns the approach described rests on the large number of factors which can potentially affect or influence design and construction on the building site. Of the many potential influences, it is likely that only a few will be very significant. The task of the extended research method, which has been termed an 'enhanced activity sampling technique', was to isolate those significant factors for each work context. As an example, this might include isolating all records relating to the various electrical operations within a particular house in order to determine the nature or cause of problems.

From this data it is possible to calculate average manhour figures and to determine where interruptions have occurred. Associated qualitative observations which have been linked to quantitative data entries can then be used to build-up an historical picture of events which have occurred during the work stage within a house or block. This informed feedback can then be used by design and construction with the aim of improving quality and productivity during the second phase of a development cycle.

3.9 Factors influencing good qualitative data

The data collected during normal activity sampling studies can be pre-coded based on specific details of certain trade stages, operations, activities and on a number of operatives. These codes need to be pre-defined prior to commencing the activity sampling survey.

This was not possible with the qualitative observations made during the study. There are three main reasons why it was not prudent to pre-code qualitative data. These are:-

1. The observer does not know the full range of data codes which need to be operated from the outset of the study;

2. If the number of qualitative data codes are restricted to a manageable number then the codes are in danger of becoming too general for good quality data to be derived from each individual work context;

3. In an attempt to collect qualitative data by a pre-coded approach it is possible that data may be mis-classified. Also, similar data may be classified in

different code categories by different observers.

An open approach to qualitative data collection has been adopted by the enhanced activity sampling approach used in this research. This has meant that informative comments relating to observations have simply been recorded in summary form as and when they have occurred. Two important aspects appeared to be important with this data collection process:-

1. that the data must be refined during the process of development to take into consideration any unknown variables encountered during monitoring;

2. the data collection must be responsive to each specific work context in order that the factors affecting quality and productivity can be clearly identified.

With this approach, it may prove that a large proportion of the qualitative text describes very general factors surrounding the work context and offers limited evidence for improvements to follow. However, a smaller proportion of accompanying text may be very significant. It is this text which can be used to identify those areas where important changes can be implemented.

3.10 Preparation work prior to data collection

A hand written activity sampling format was devised (Figure 1) for data collection on site. The survey sheet was designed to contain certain information based on a preliminary investigation of the services and finishings operations and the trade and house types to be included in the survey. The following information was collected on the fieldwork sheets:-

1. sheet number
2. date
3. round time
4. trade code reference number
5. house type
6. house number
7. work stage
8. operation
9. activity
10. qualitative observations

Details of numeric trade codes (point 4) are shown in Table 3. Alpha-numeric codes were also devised for the various stages and work operations covered by the sampling survey work and these are described in Table 4. A further set of activity codes (Table 5) describe states of productive and non-productive activity which could be made during snap observations.

SITE:			DATE:				SHEET No:
Rnd Time	Trade Ref	Type	Plot No	Stage	Operation	Activity	Qualitative Observations

Fig 1: Enhanced activity sampling format

To illustrate the usage of these codes, a wall tiler, say reference code 702 (indicating the second wall tiler observed during monitoring work), might on the 11th March 1988 at 11.30 am., be fixing wall tiles in the kitchen of a Lichfield house type, plot number 17. The quantitative record for this observation would be as follows:-

Date	Time	Ref	Type	No.	Stage	Operation	Activity
11MAR88	11.30	702	L	17	13	C	F

The stage and operation codes which are shown, relate to a coding system used by Lovell Homes to determine the state of weekly progress on their sites. In view of this fact, it was considered appropriate to utilise this meaningful reference framework for codes.

TRADE	TRADE REFERENCE CODE
1st/2nd fix carpenter	100
Plumber	200
Electrician	300
Plasterer/dry-liner trades	400
Floor screeder	500
Bricklayer	600
Glazed Wall Tiler	700
Painter/Artexer	800
Floor Tiler	900

Table 3: Trade operative activity sampling codes

STAGE	OPERATION	WORK DONE
8	A	floorboards & staircase
8	B	partitions & linings
8	C	plumbing carcase
8	D	heating carcase
8	E	electrical carcase
9	B	plastering/dry-lining
10	A	screed sub-floor
11	A	sanitary ware
11	B	build fireplace
11	C	electrical finishings
12	A	skirtings & architraves
12	B	joinery fittings
13	A	plaster patching
13	C	wall tile kitchen
13	D	wall tile bathroom
14	A	test plumbing/heating
14	B	Artex ceilings
15	A	painting
16	A	plumbing finishings
16	B	pre-occupation work
16	C	floor finishes

Table 4: Stage and operation activity sampling codes

Productive	Code	Non-productive	Code
constructive task	F	absent	A
preparation	P	walking	W
handling	H	not working	I
setting-out	SO	not at work place	N
supervision	SU	personal/meal break	BK
testing	T	rained off	RO
unloading	U	repeat work	RW
cleaning tools	CL		

Table 5: Activity codes

3.11 Data collection, transposition and handling

The monitoring of the construction industry is characterised by the high volumes of data which are generally produced. In this study, the same is true because data has been collected in a very intensive manner at what is best described as a 'micro level'. An important development for this work has been the application of an IBM AT personal computer and a Danish project management system called PROXIMA. These tools have been used to handle the data generated from fieldwork monitoring far more efficiently than would have been possible through manual methods. The full potential of the PROXIMA system was not used for the study, but the package was used because of its excellent data handling facilities.

In general, there are two important stages in the data collection and subsequent handling procedure:-

1. The physical collection of data on site using either hand written sheets or a hand-held data terminal;

2. The transposition of data from site records to a computer system for manipulation and interrogation;

There are two ways in which this latter stage can normally be achieved. First, by physically inputting data from hand written record sheets into a computer for

analysis (as in this study); or secondly, by down-loading data from data logger RAM-packs into a computer.
Prior to commencing fieldwork monitoring on site, plans were made to utilise a prototype hand-print recognition system called 'Micropad'. This was to be used for collecting the activity sampling codes and qualitative text on site in order to facilitate fast and efficient data transposition from a data logger RAM-pack to computer. This was not to be possible due to a number of technical operating problems within the system.

The absence of suitable hand-print recognition equipment meant delays during the data transposition stage. Instead of being able to down-load data at the end of each monitoring period it was necessary to input each data item manually. This method proved to be very time consuming and at times cumbersome. Great care was taken to minimise the number of errors which could potentially be introduced when double handling data. This was achieved by double checking all data output for type mismatches.

The data was transposed from weekly field sheets into PROXIMA data files, each with a different week file name. Successive week data files were then merged to form a single complete data base for each period of site monitoring. There were three of these data bases in total. Data manipulation from the individual data bases was extremely simple. The PROXIMA application software was used to sort the following information from the raw data bases:-

1. Information relating to each individual plot (house);

2. Information concerning the various trade operations undertaken in each plot included in the survey;

3. Information relating to the operatives.

The results and detailed analysis of the fieldwork data for each of the main periods of site monitoring is discussed in detail in Chapter 7.

CHAPTER 4

4.0 SITE MONITORING: PERIOD 1

4.1 The selection of a house builder for collaboration

The British Cement Association established contact with a select number of national volume house building firms during the initial months of this applied research. The specific aim of this contact was to secure the cooperation of a suitably large speculative house building company and to obtain access to some of their developments for fieldwork monitoring purposes. Of those companies contacted by the BCA, Lovell Homes were identified as being particularly suitable candidates for collaboration. There were three main reasons for this decision. First, Lovell Homes were sixth ranked amongst British volume house builders, building approximately 3000 homes per annum; secondly, the BCA had already established a working relationship with the Y.J. Lovell Group of companies who were recognised as an organisation with a strong interest in quality; and thirdly, the Lovell Homes division had a regional operation centred on Tamworth in Staffordshire, known as Lovell Homes Midland Limited (LHM). This fact would have a bearing on travel times from a study base at Aston University in Birmingham.

4.2 An initial meeting with Lovell Homes Midland Ltd.

As a direct result of the preliminary BCA enquiry, a meeting was arranged in December 1985, at the Lovell Homes Midlands regional office in Tamworth. Those in attendance at this first meeting comprised the Managing and Production Directors of the company together with representatives from the BCA and Aston University. The main purpose of this meeting was to discuss the aims and objectives of a project proposal from a research perspective and also to establish a profile of LHM in terms of their house building philosophy and work practices.

In summary, it was learned that the Midland region was one of six regional head offices which comprised the Lovell Homes Division of the Y.J. Lovell Group. The Midland office had established a reputation within the Homes Division for building high quality homes targeted mainly at second and third time buyers. Typically, these were three and four bedroomed detached homes of traditional brick and block cavity wall construction with tiled pitched roofs and garage. Although some semi-detached and small starter homes were being built by the company, these were less common. The size of the homes varied between house types; they ranged between 800 ft^2 (approximately 75 m^2) for the smaller units, through to 1600 ft^2 (approximately 150 m^2) for the larger units. On average, the internal floor areas were in the region of 1200 ft^2 (approximately 112 m^2).

The geographical area covered by the Midlands regional operation spanned from North Staffordshire, across East to Northamptonshire and South as far as Gloucester. It was here where borders met with the Lovell Homes Western region. The Midlands head office were also responsible for running the business of two smaller local area offices situated in Northampton and Gloucester.

From a production stance, all site work was undertaken by subcontractors. Brickwork and carpentry were subcontracted on a labour only basis, where the company provided all necessary plant and materials. The remaining works were all on a supply and fix subcontract basis where the subcontractor supplied both the necessary labour and materials to complete various site works. The site manager, a storeman and a few labourers were the only directly employed staff to be found on LHM developments.

One important outcome from this preliminary meeting concerned the time taken by LHM to build houses in a normal production context. This was important if measures were to be made of productivity levels on site. The total building period for a typical home was estimated to be around 26 weeks by the Production Director. This covered a period from the site strip operation, where the vegetable top soil was removed, through to the final completion where the house was ready to be occupied by a purchaser. By eliminating the substructure stage, that is the works below ground level, a building period of 20 weeks was generally thought to be necessary to complete the works above ground level. This build period was judged to be excessive by the Lovell Homes Management Team and they welcomed research and development collaboration which could help to reduce this site working time.

The Managing Director was particularly interested in developing research ideas which could be used to reduce the construction period for a typical house from a 26 week total build programme to around 18 weeks, without any compromise to the quality of the finished homes. This period of 18 weeks was an average building period taken to complete houses by the largest of the national volume house building companies. If this were to be possible, then the company would have greater flexibility to meet customer demand when the house building market was in a boom period.

4.3 Conclusions drawn from the first meeting

Three main conclusions were drawn from the initial meeting with LHM. These were:-

1. LHM wanted to improve the quality of their homes and their service to their customers. This factor was of prime importance to the company and was to take precedence over all other considerations;

2. Improved quality should be paid for through cash savings made by improving productivity. By improving productivity it would also be possible to reduce the length of the building period on site. It was recognised that this could have a beneficial effect on cash flow because monies were tied up in the houses until they were actually sold;

3. In the long term, the company wished to improve their profitability through research and development collaboration. Despite this, it was understood that uncertainty is associated with the trial of new ideas and this might actually result in additional expenditure at first.

At this point, no specific proposals were forwarded for design and construction improvements on the sites as these would be derived from actual site monitored data. However, the general concept of construction rationalisation, including the argument for increasing the scale and independence of trade operations, were presented to the Management Team for consideration. The philosophy of large scale trade operations was considered to be vital if productivity was to be improved. This was because the interruptions which result from small scale operation working have been shown by BRE studies to have a detrimental effect on productivity which increases manhour requirements for a given task.

Although the collaboration did not require LHM to make any financial contributions to the study at this point, it did necessitate a commitment to undertake certain design and construction changes, based on site feedback, and to allow these to be monitored over a period of time. This commitment was given and an appropriate site was sought for an initial period of fieldwork monitoring.

4.4 The selection of an appropriate site

After some deliberation, a large, medium density development known as 'Manor Park', was selected by LHM. The site was situated at Reddicap Hill, Sutton Coldfield (Figure 2), which is approximately 10 miles North of Birmingham. A plan was established to commence fieldwork in the Spring of 1986 when it was judged that a full range of site operations could be observed. Although this was the initial plan, a subsequent decision was made to monitor only those operations which fell into the services and finishings stages category. The main reasons for this decision were:-

1. Previous work, especially by the BRE, had shown these work operations to be amongst those operations most effected by interruptions which lead to high manhour requirements;

2. Due to the nature of the funding of the project, it would not be possible to employ more than one observer on site. This would necessarily reduce the number of trade operatives which could sensibly be included in the survey;

3. The proposed form of activity sampling, which was to include a form of qualitative data, meant that only a select few operations could be practically covered in a given round time. This was due to the detailed nature of the enhanced activity sampling method.

Following this initial meeting and planning stage, it was agreed that the Lovell Homes site management at Manor Park should be notified of the pending fieldwork by their head office. It was further agreed that a follow-up meeting should take place as soon as specific proposals aimed at improving quality and productivity had been established from fieldwork data.

4.5 A pilot activity sampling exercise

Prior to commencing the fieldwork proper it was deemed necessary to undertake a pilot activity sampling exercise at the Reddicap Hill development. The main purpose of this exercise was to familiarise the observer with the site layout, to meet site management and operatives, to gain practical knowledge of activity sampling, but most importantly, to obtain experience in qualitative data collection. Unlike quantitative data which records factual events such as the workplace and activity of a particular operative, the qualitative data, due to its subjective nature, was open to interpretation by the observer. Careful judgement was needed to ensure that a balanced explanation was provided to those problems considered to be influencing productivity, and or, product quality.

A set of alpha-numeric activity sampling codes were devised in preparation for the dry-run exercise. These included codes for the various tradesmen (Table 3), work stages and operations to be covered by the survey (Table 4) and a further set of codes to describe the various states of productive and non-productive activity observed during each snap reading (Table 5). The coding system used for the various stages and work operations in Table 4 were based on site progress report/payment codes used by Lovell Homes and were, therefore, meaningful to the company.

The pilot exercise commenced in January 1986 and continued for a period of four weeks. During this four-week period a substantial amount of quantitative data was recorded, but very little qualitative data. The latter data type took time to develop and only became less difficult to collect when the production methods and trade relationships employed on site were more fully understood.

4.6 Site monitoring

Following the pilot exercise tentative plans were made to commence site monitoring proper during March 1986. However, during the first quarter of that year, a combined problem of long periods of inclement weather and a general shortage of bricklayers meant that production at the superstructure stage had ground to a virtual halt. As a result, it took several weeks before production had recovered sufficiently to start monitoring services and finishings operations.

Production work was back to normal during April 1986 and so it was decided to commence monitoring at the end of that month for a period of 10-12 weeks. This monitoring period actually lasted for a total of 11 weeks. During this time information relating to the services and finishings operations was gathered for 15 of the 127 dwellings which would eventually comprise the development. Of the 15 units, all services and finishings operations were monitored on 8 of the houses. These 8 included 4 different house types namely, the New Wessex, Arden, Hartford and Bronte.

The data derived from this work study was then used to form a PROXIMA database detailing the production methods and problems encountered during the construction of normal or 'control' houses. This data would later be used as informed feedback to locate and identify problem areas so that design and construction changes might be made. Figure 3 shows a typical page of data from the resultant database.

4.7 The collection of qualitative data

It was necessary for the observer to adopt an unbiased approach to the qualitative data collection and this was a time consuming process. This was because the tradesmen might provide responses to questions or volunteer information which was not founded on fact and was therefore biased. To illustrate this point it is necessary to understand the manner in which data was collected. Due to the sampling technique, which required all operatives covered by the survey to be included in each half hour round time, it was not possible to monitor any single operation continuously. This meant that there were two categories of data which could be potentially recorded by the survey:-

1. First, on those occasions when the observer was in a particular house, a problem, or its cause, might be witnessed first hand. This information was factual;

2. The second type of event occurred on occasions when the observer was elsewhere on site when a problem or interruption to normal working was encountered by an operative. When this happened, it was often necessary to ask operatives discrete questions during the next round in order to ascertain the reasons for a particular problem. Efforts were always made to view this type of second-hand information more carefully in order that a balanced explanation should be established.

The data collection method was generally found to be very demanding and required a considerable amount of effort to implement properly. The main justification for this method was the necessity to obtain detail at a micro level which could explain the nature of the many problems and complex trade inter-relationships which were clearly evident on site. Future monitoring work might choose to concentrate on less intensive monitoring methods, perhaps undertaken on a daily or weekly basis. In the first place, however, this more general, or macro level data, is not sufficiently detailed to provide a clear and concise framework in which to understand the problems faced in the house building industry.

Date	Round	Ref	T	No	StOpn	Act	Qualitative Observations
15MAY86	08.05	203	W	23	16 A	P	The plumber is attempting to pipe up to a radiator through a small removable floor trap in the first floor. This task is aggravated by the fact that the trap has been mis-positioned and is 5 boards away from the actual radiator position.
15MAY86	08.35	203	W	23	16 A	W	
15MAY86	08.35	302	W	23	11 C	P	The electrician attempts to centralise a ceiling rose in the lounge. He pulls through the circuit cabling which has been inaccurately located by the plasterboarder and in the process of doing so damages the Artexed ceiling.
15MAY86	08.35	401	A	26	9 B	I	
15MAY86	08.35	402	A	26	9 B	I	401 & 402 are unable to start work because their company have not yet delivered the necessary materials for use in plot 26.
15MAY86	08.35	101	W	23	12 B	F	101 recommences 2nd fix work in plot 23. This plot is now worked in by 3 trades (plumber, electrician and joiner).
15MAY86	09.05	101	W	23	12 B	H	
15MAY86	09.05	203	W	23	16 A	F	203 explains that many of the smaller items such as tap heads, washing machine taps, w.c. seats, shower control valves and so forth are fitted during the final stages of work in order to reduce the occurrence of damage and theft.
15MAY86	09.05	302	W	23	11 C	W	
15MAY86	09.05	402	A	26	9 B	U	Materials arrive on site in order for the plasterers to start their work.
15MAY86	09.05	401	A	26	9 B	H	
15MAY86	09.05	801	W	22	15 A	P	The painter recommences work on plot 22 having been recalled to another plot to make good after an electrician.
15MAY86	09.35	801	W	22		BK	801 takes a tea break in plot 22. The floors in this plot are strewn with paper litter and cans. This untidy work environment reflects in the quality of some of the workmanship.
15MAY86	09.35	302	W	23	11 C	W	
15MAY86	09.35	203	W	23	16 A	P	
15MAY86	09.35	101	W	23	12 B	H	
15MAY86	09.35	401	A	26	9 B	SU	401 has been instructed by the site manager not to board over studwork without first checking that the pipework has been installed. His failing to do this on previous plots has caused a good deal of extra work for the plumber and plaster patcher.
15MAY86	09.35	402	A	26	9 B	P	402 lays Browning plaster to the blockwork walls. He completely covers one of the recessed socket boxes and does not bother to remove the surplus material. This will cause problems for the electrician during 2nd fix work.
15MAY86	10.05	101	W	23		BK	
15MAY86	10.05	801	W	22	15 A	F	801 cuts-in around pre-fixed light switches and socket outlets. It is very difficult to do this work without marking the fittings in some way.
15MAY86	10.05	302	W	23	11 C	P	
15MAY86	10.05	203	W	23	16 A	H	A number of radiators are located below ground floor windows to help reduce cold bridging at these points. In order to facilitate this, the joiner is called upon to form a removable skirting duct.
15MAY86	10.05	402	A	26	9 B	F	
15MAY86	10.05	401	A	26	9 B	H	

Fig 3: Sample of fieldwork data

4.8 Factors influencing the collection of data

In order to obtain the quality of data which was demanded by this approach it was necessary to develop a good rapport with the tradesmen on site. Only in this way could those problems which were effecting quality and productivity be properly identified and effectively dealt with. Initially there were a few inherent difficulties relating to this approach. For example, the observer required sufficient time to become accepted by the tradesmen on site as part of the day-to-day site team. Another difficulty concerned collecting accurate records yet at the same time remaining discrete. This latter problem proved less difficult as the observer became more familiar with the sequencing of the site operations and the individual component work of each operation.

On a conventional activity sampling survey, such difficulties would not exist because the purely quantitative data collection approach does not require an explanation of site problems to be documented. This means that the observer is able to record data from a remote location without the need to make contact with the operatives on site.

At first, many of the tradesmen were suspicious of the intentions of the activity sampling work and some automatically assumed it to be a time and motion study. It was therefore crucial to establish a good rapport with the men to allay any prejudices. In view of this fact, the rounds were conducted at half hour time intervals and not at more frequent intervals. By doing this, it would not be possible to record as many quantitative observations as might have been desired for a 95% confidence limit (the normal level of accuracy taken for construction related activity sampling surveys). However, as previous BRE studies had already identified the services and finishings stages to be the most problem fraught areas, it was not judged to be important to achieve high levels of statistical significance. It was considered more important to place emphasis on the development of the qualitative information which was being drawn from observations as this could be used to bring about significant change.

A final factor which was found to have an effect on the quality of the data concerned the rate of production. If production was to slow right down on a house or group of houses, the causes of certain problems would become more difficult to identify. It also transpired that more frequent and better qualitative records followed a good production run on site. This finding demonstrated that it was more difficult to extract qualitative data from a poor work environment than a good one.

4.9 The attitude of the operatives to the study

Initially, the operatives were generally very reluctant to part with information and it was only after a period of several weeks that the observer became fully accepted by the operatives. This was partly due to continuous daily presence around the site. At this point tradesmen were asked which factors they thought most affected their ability to be more productive and which factors affected quality in their work. Their responses were varied.

For the majority of tradesmen money was a key issue. Wages were generally earned on price work. With this payment system, each individual either worked for a subcontractor or for themselves on a self-employed basis and received payment for carrying out certain priced work tasks. It was, therefore, in the interest of the individual tradesman, as well as LHM, to be able to achieve higher levels of productivity. Most operatives considered factors such as site management, inadequate job prices and materials shortages to be the main causes of low productivity. The complex inter-trade working practices, and often far from satisfactory work conditions, were not automatically viewed as serious problems which could affect productivity or quality. Although the study was unable to concern itself with the fairness of prices for work tasks, because these were set by LHM and tended to reflect the current rates in the industry, it was possible to consider other aspects which were said to be affecting performance.

As the objectives of the research work were informally described and discussed over a number of weeks, the operatives tended to be become more helpful and began to volunteer information which they thought might assist in the data collection process. At first, a certain amount of prompting was necessary because many of the problems which were experienced on a daily basis by most of the tradesmen were accepted as being traits of their job. It was found that tradesmen would often put up with problems rather than offend or upset their working relationship with another trade. As a consequence, the site operations were sometimes hindered by problems which could cause interruptions to work. This in turn had an effect on influencing the resultant quality and productivity achieved on site. To illustrate this point, out of sequence working by one trade might lead another trade to be interrupted. This might then prompt the need for a return visit to that house. By doing this, work completed by the previous trade was sometimes damaged or disturbed. In this example, both productivity and quality are effected by out of sequence working.

At the end of the first period of fieldwork monitoring some operatives still found it difficult to equate work study with anything other than improving profits for the house building company. Others were beginning to understand that, in principle, improved productivity could lead to mutually beneficial effects. Certain operatives expressed a willingness to see changes made to their own trades whilst other saw their own particular trade to be satisfactory and only other trades needing reform. There were a small group who believed that the house building industry needed no change at all.

In some respect, the presence of an observer on site was regarded as a novelty. Although most operatives were generally suspicious at first, it was possible to collect a considerable quantity of data (the completed database totalling 2 Mbytes in volume). The success of this first period of fieldwork monitoring stemmed from the fact that at no point were established practices, views or attitudes threatened. As long as this was seen to be the case it was not difficult to obtain a level of cooperation from site management and operatives. It remained to be seen whether or not the introduction of design and construction changes would alter this attitude.

CHAPTER 5

5.0 SITE MONITORING: PERIOD 2

5.1 The background to site monitoring : period 1

The first period of site fieldwork monitoring resulted in the formation of a comprehensive database which exceeded 2 Mbytes in volume. This was the first attempt, following a pilot exercise on site, to apply the enhanced activity sampling technique described in detail in Chapter 3. In summary, the database comprised information relating to the production methods observed and recorded on a speculative house building site developed by Lovell Homes Midland at Reddicap Hill in Sutton Coldfield. The data was collected over a period of 11 weeks between April and July 1986 and included data relating to the services and finishings operations carried out on 15 of the houses which were built on that site.

The data transposition stage had taken almost 16 weeks to complete following data collection. This time lag was mainly due to a period of familiarisation with the PROXIMA project management package and to the large quantities of data which had to be input and checked for errors. Following the data transposition stage the feedback data was analysed to extract manhour figures for each of the services and finishings operations undertaken in each of the houses covered by the survey (these figures are analysed in Chapter 7). At the same time a preliminary analysis was made of the text data in order to extract a number of key qualitative points. These were points which were shown to have been some of the main problems encountered by individual trades on site.

5.2 Qualitative information derived from the survey

The following points are examples of the type of qualitative observations made during monitoring work. It was these types of problems which were shown to lead to high manhour requirements and poor quality when carrying out certain operations. Observations are listed in trade by trade order according to the pre-defined coding system established at the start of monitoring.

5.2.1 1st fix and 2nd fix carpenter (code 100)

Excessive time was spent organising, sorting and collecting materials at the site storage compound. This included kitchen fittings, doors, frames, loose joinery items and ironmongery.

Problems were often experienced by the 1st fix carpenter when fitting staircases into stairwells which had not been built squarely by the bricklayer.

In order to fit wardrobe fronts it was necessary to cut down laminate sheets to form infill pieces either side of the main wardrobe frame. This job would not have been necessary if proper opening sizes were achieved on site by the 1st fix carpenter.

Difficulty was often experienced when attempting to fix loose joinery items, for example, when fixing skirting boards and architraves to backgrounds. Nails did not hold securely in lightweight blockwork and surplus plaster prevented architraves from being fixed tightly against door linings.

Full width architraves were frequently reduced in order to achieve a fit and excessive use was made of quadrant beadings to close internal junctions between door linings and adjacent walls.

Fit problems associated with kitchen units, wall cupboards and work tops were commonplace due to inaccurate walls and floors.

Difficulty was often experienced when fitting kitchen units and worktops because of the intrusion of service supply pipework and cables.

Excessive time was spent assembling loose joinery items such as balustrading and hand rails on site. Greater use could have been made of pre-assembled components.

Some finished joinery items, for example, kitchen units, were adapted on site in order to achieve a good fit.

Too much time was spent on the preparation of surfaces prior to the fixing of skirting boards and architraves, for example, hacking off lumps of dried surplus screed from around the edges of floors and scraping dried plaster off door linings.

Site fixed doors took a long time to fit and often needed to be reduced or the door linings altered. During the 1st fix carpentry operation it was necessary to level and pack internal door linings and staircases to allow for the thickness of the screeded floor finish.

On some house types the shop fixed window furniture was removed and replaced with brass fittings or similar. The specified ironmongery could have been fitted and shrink wrapped for protection at the factory to save on site fixing time.

5.2.2 Plumber (code 200)

Return visits to complete outstanding work items were commonplace during these work operations. This problem was mainly due to a shortage of plumbers with which to meet production demand.

The preparation work, for example, notching joists, was awkward for the plumber at the carcase stage. This was because they had to balance on the chamber joists. This type of preparation work would have been better carried out by the carpenter who could work off floorboards.

The gas carcase pipework was often fixed too late in the build process, that is, after the plasterer. This meant that finished surfaces were damaged when the pipework was let into walls.

A substantial quantity of the plumbing work was concentrated in the roof space. This included tanks, feed and expansion pipework and insulation. This work was invariably carried out in near darkness.

The pipework was set in either the plastered walls, in boxings or within the floor space and as such was completely inaccessible for subsequent maintenance work.

The plumbing installations below the hot water cylinder plinth, including the pump, 3-port valve, supply and return pipework, were particularly awkward to fit due to confined working conditions.

There was difficulty piping up to radiators because of poor access to tail end pipework. Better pipework distribution routes were needed.

Problems were often experienced when installing and connecting up sanitary fittings, for example, letting baths and shower trays into plastered walls and breaking open pipework boxings to connect up to water supply pipes. Similar difficulties were evident during the installation of the kitchen sink top and wastes.

It was sometimes not possible to heat or water test a house (or both) because the necessary connections had not been made by the statutory authorities when requested to do so.

The carcase pipework was sometimes nailed through by the 1st fix carpenter when floorboarding. Pipework was also damaged by the electrician when drilling cable routes through sole plates and joists.

5.2.3 Electrician (code 300)

Multiple visits to complete electrical wiring were commonplace, especially over the garage roof void where it was not possible to route cables to the consumer unit until the garage roof trusses had been fixed. It was not possible to fix garage roof trusses at the same time as the main building was constructed due to the close proximity of plots on high and medium density developments.

Extensive preparation work was required at the carcase stage. This included notching, drilling holes through joists, chasing walls and forming vertical wiring routes.

When distributing cables through Paramount partition walls it was necessary to form a wiring route through the cellular core of the partition material with a flexible plastic pipe. This method was awkward and sometimes resulted in damage to the plasterboard surface.

At the 2nd fix stage, the electrician spent a considerable amount of time removing dried plaster from inside recessed switch and socket boxes. This tended to create plaster patching work later on.

Access was generally severely restricted at the carcase stage due to the broken bricks, blocks, timber and Paramount off-cuts which littered the floors of the houses when the bricklayer and carpenter had finished their work.

Fittings were sometimes incorrectly located and had to be moved because they fouled with waste pipes or other fittings. Poor planning and coordination of trades was the main cause of this problem.

A 3rd fix electrical stage was necessary to fit valuable items including, boiler controls, thermostats, immersion heaters, safety sockets and shaver points. This work was nearly always carried out during the painting operation and thus affected the performance of the painter.

It was difficult to achieve good background fixings for switch and socket boxes in the Paramount partitions and block walls. Boxes were sometimes knocked out of level at the plastering stage.

5.2.4 Plasterer and dry-liner trades (code 400)

Excessive time was spent preparing walls prior to actual plastering, for example, removing dried mortar droppings from blockwork.

It was often necessary to dub-out poor quality blockwork before the normal two-coat plasterwork could begin due to inaccuracies in the walls. This meant that extra material had to be used.

The plasterers frequently plastered over recessed electrical and heating boxes without cleaning out the surplus plaster afterwards.

The house was rarely weathertight when the plastering work commenced and as a consequence finished walls were damaged. The glazing work could have been completed before the plasterer started work on a house but this was rarely done.

It was a common practice to plasterboard over pipework boxings without first checking that plumbing supply pipework had been extended by the plumber.

It was not possible to achieve a good plastered finish to some areas. In particular, those situations where carcase pipework or incoming supply ducts were set too close to the wall.

The plasterer periodically broke off from work in one house in order to board out the first floor ceiling in another. This was to allow the 1st fix carpenter to proceed with first floor Paramount partitioning. This work operation could have been undertaken by the 1st fix carpenter.

Window reveals were rarely closed effectively by the bricklayers. The plasterers simply filled the open cavities with Browning plaster in order to carry on with their work. A similar situation occurred around the ground floor door linings where a gap between the structural opening and the frame was also filled with plaster.

The plaster patching work was sometimes excessive and much of this work was caused by lack of care by individual tradesmen.

5.2.5 Floor screeder (code 500)

The screeders were sometimes delayed from starting their work because gas carcass pipework had not been fixed or raised thresholds had not been reduced in height.

The ends of the polythene damp proof membrane were often damaged and rarely tucked in below the damp proof course. At external threshold details the cavity was filled with a screed mix with no attention being paid to the possibility of subsequent damp penetration.

The screeders did not work to timber ground datums but instead levelled the screed between the bottom of the staircase and internal door linings. This was not a very satisfactory method of working because the finished floors were not always level and problems existed with uneven surfaces (especially in the kitchen).

5.2.6 Bricklayer (code 600)

The fireplaces were often constructed to suit the bricklayer (often when it was raining). This meant that on many occasions the fireplaces were built too late in the build sequence and other trades performances were affected.

Finishes were sometimes damaged by the careless handling of materials when the bricklayer did not carry out work in the proper sequence.

5.2.7 Glazed wall tiler (code 700)

The wall tiler often needed to either reduce or increase the height of a window cill (when there were two adjacent windows) in order to achieve proper coursing of tiles.

Excessive tile cutting was necessary. It would have been far easier and would have made good sense for the tiler to tile down from an established datum to a level just below the proposed bath or work top height. Fittings could then have been installed as furniture items.

Return visits were commonplace for the wall tiler. This was to grout, fix pattern tiles and to apply silicone sealants.

5.2.8 Painter and Artexer (code 800)

The painters tended to work one man to a house. This practice had the effect of drawing out production. Two men appeared to be an optimum gang size for most house types.

Sockets and switches were nearly always marked with paint when cutting-in thereby causing extra cleaning work.

Excessive time was spent preparing surfaces prior to painting, for example, removing dried plaster and Artex splashes from joinery and radiators.

The small panel Georgian windows were particularly time consuming to paint. Pre-finished windows would have provided a better alternative.

The Artexer generally commenced work after the joiner. This meant that Artex splashed over radiators, 2nd fix joinery items and units. The Artexing work ought to have been undertaken immediately after the plastering stage.

5.2.9 Floor tiler (code 900)

Internal doors had to be removed by the floor layer in order to lay vinyl to the kitchen floors.

The sheet flooring in the kitchen had to be cut to the profile of the kitchen base units and this resulted in a considerable quantity of wasted material.

The screeded floor surfaces were frequently pitted and had to be levelled using a levelling compound. This resulted in return visits by the floor layer to complete works.

Having studied the common faults derived from the site monitoring, a set of sequence diagrams showing the typical sequence of work for the services and finishings stages were prepared. These are described in Figure 4 which shows 19 individual trade operations when various work items were carried out. The purpose of the research was to reduce this number of individual trade visits by increasing the scale of certain key operations so that overall productivity could be improved.

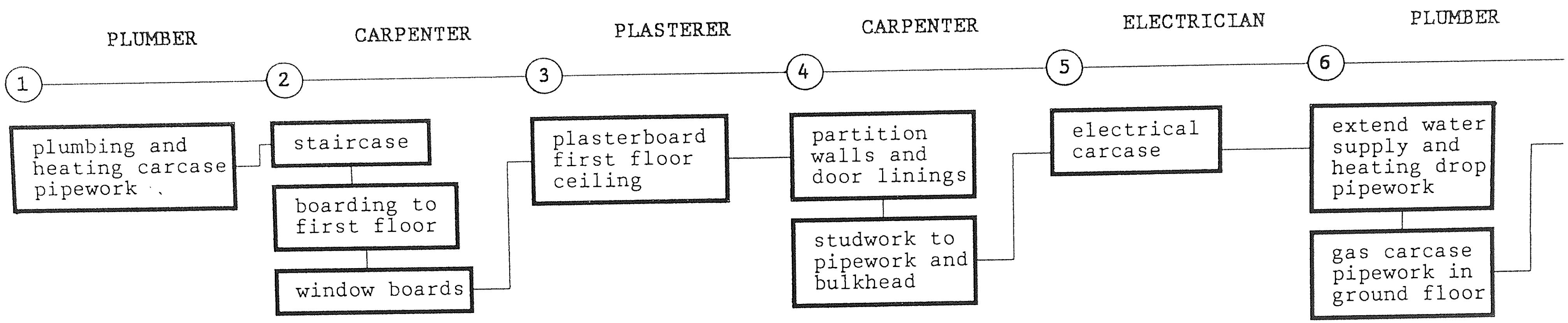

Fig 4: Typical sequence diagram for services and finishings operations (part 1 of 3)

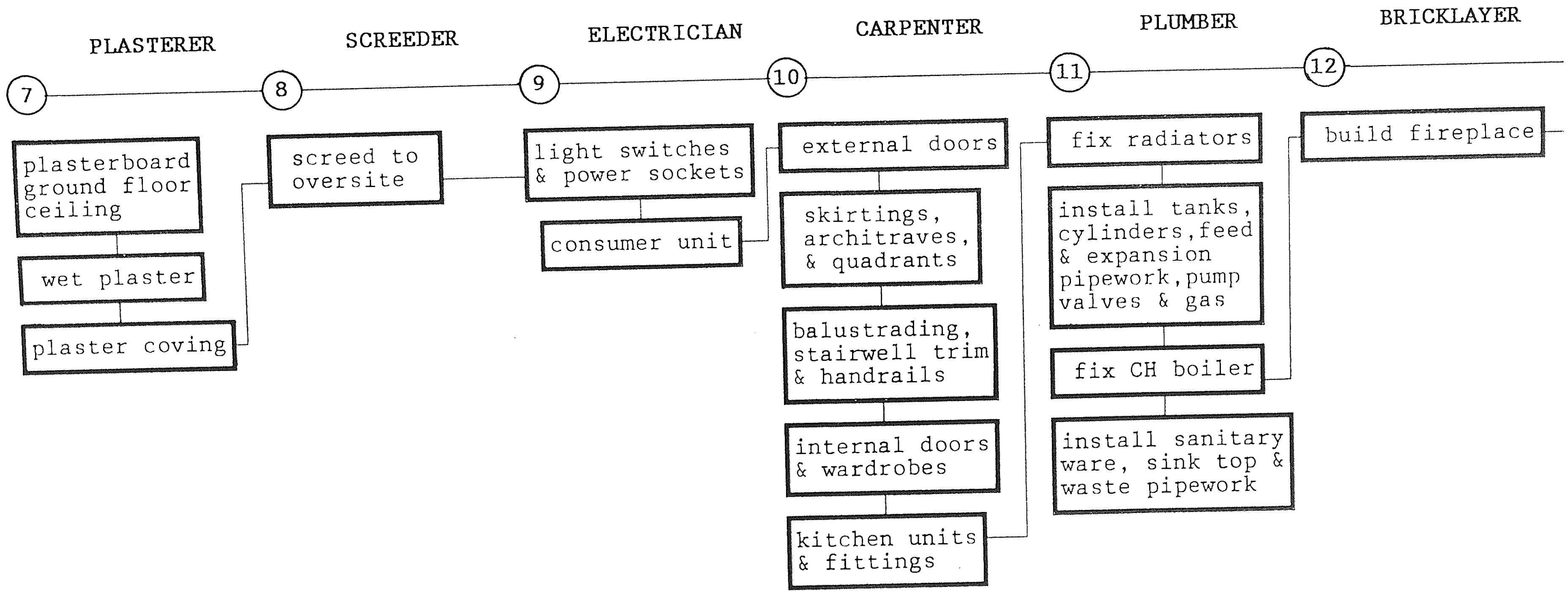

Fig 4: Typical sequence diagram for services and finishings operations (part 2 of 3)

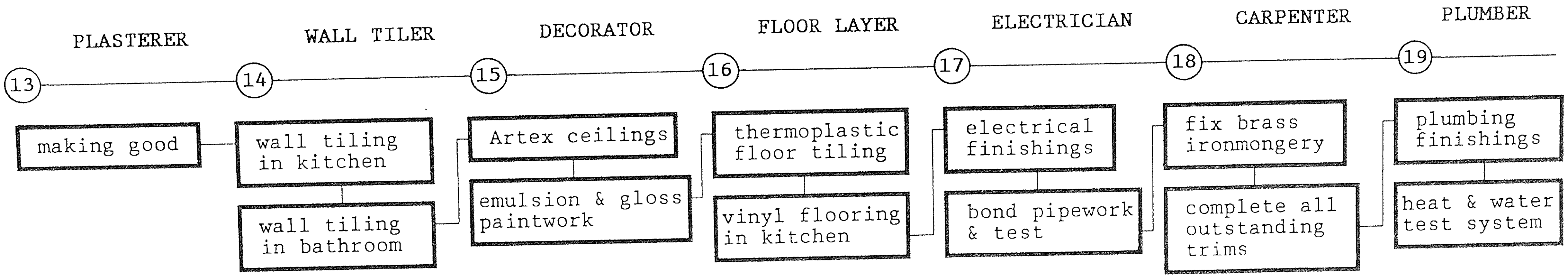

Fig 4: Typical sequence diagram for services and finishings operations (part 3 of 3)

5.3 Preparation meetings for subsequent fieldwork

A series of tentative design and construction proposals were prepared from the qualitative data observations made during the first period of site monitoring. It was proposed that these might be adopted for trial in a group of houses at some future date on one or more of Lovell Homes sites. These points were briefly discussed with Lovell Homes management in November 1986.

At this meeting, particular interest was expressed in the activity sampling data. This data was meaningful to the Management Team because it was able to describe the typical problems encountered during the normal production of houses on their sites in both quantitative and qualitative terms.

A group of typical manhour figures had been extracted from the data and these clearly showed considerable variations in manhour requirements for undertaking identical work operations in similar houses. For some trades, variations of 3:1 were evident. These initial results, although restricted to a small range of house types, were consistent with the findings of earlier works carried out by the BRE and supported the need to carry out further work in this area.

In December 1986, a follow-up meeting was held. This meeting, comprising design, construction and costing disciplines from LHM, considered the main objectives of the research and discussed the design and construction proposals presented at the very first meeting.

Analysis of the qualitative data from the first period of site monitoring had shown that the cause of many of the manhour variations was discontinuous working caused by interruptions. In view of this fact, the proposals put forward for consideration at the meeting attempted to include the introduction of work operations which were designed to be as large in scale and as independent as practicably possible. Single operation plumbing, heating and electrical work were emphasised for specific attention due to the frequent visits made to houses by these trades during normal production working. In addition, a greater use of pre-finished components was recommended together with the introduction of early finishing work.

It was suggested that in order to test this hypothesis, a number of control and experimental houses should be monitored. The control houses would be built exactly as normal and the experimental houses, which would incorporate a number of design and construction changes, would be built to measure anticipated improvements in productivity and quality levels. A commitment was given to implement these changes in the Spring of 1987 at a development in Tamworth. Between that time, LHM agreed to carry out the necessary design detailing and to coordinate the various changes in order that the work could be monitored.

5.4 Site monitoring

The second period of site monitoring began in April 1987 and continued for a period of 13 weeks. During this period sporadic monitoring work was carried out on 5 control houses on a 66 house site (details of this site will be discussed in more detail in Chapter 6). No experimental houses were constructed during this period. Despite the preparation work which had taken place beforehand, this period of fieldwork was fraught with problems. The underlying reasons for the problems experienced during this second stage of monitoring are detailed below:

Prior to the fieldwork monitoring commencing, the site manager had been briefed that a number of design and construction changes were to be made on designated experimental houses on the development. The site manager had been given very sparse design information concerning the extent of the proposals and was concerned that he had not been consulted about the full extent of the work by his management team. This point showed a lack of communication between LHM head office and site manager. Initially, the site manager expressed considerable concern about the proposed changes being made to normal production houses and argued that the methods currently adopted on site were tried and tested and were therefore the best. This attitude typified the thoughts of a number of 'traditionalist' individuals and operatives who were now to face real changes to their conventional working practices. It was precisely these sort of attitudes which promoted opposition to the innovative practices sought by the study.

A number of other important factors arose during the second stage of fieldwork which were to adversely affect the outcome of this phase of the work. In particular, these factors related to personnel changes at the head office where the Production Director left the employ of LHM to be replaced by the Technical Services Director. This caused problems because the Technical Services Director had not been involved in all of the research discussions and was unaware of the emphasis being put on the project by the Managing director. As a consequence, inadequate design details were passed onto site.

Production problems were also being experienced on site where a third phase of the development was started before the second phase was completed. This meant that the site manager had to carefully balance labour resources to ensure the correct rate of production on both phases. Unfortunately, the experimental work fell into phase III production and because the site manager found that he had insufficient resource to begin the third phase with a full labour allocation, the production work on this phase suffered. Because of this, labour was only allocated to phase III production as and when it became available.

Collectively, these factors led to the creation of an environment which was not conducive to monitoring work. Subsequently, it became quite clear, after a short period of time, that insufficient work had, or was being done in respect to the research proposals by LHM. It was also clear that the research and development project was moving too fast and too soon for some employees within the organisation. As a direct result of these factors, the site monitoring fieldwork was temporarily suspended and the applied research programme was re-assessed to ensure that on subsequent fieldwork trials similar problems would not be confronted.

CHAPTER 6

6.0 SITE MONITORING: PERIOD 3

6.1 Background to site monitoring: period 3

The LHM management team placed substantially more emphasis on the applied research during a third and final period of site work. It was clear that design and construction proposals which were put forward for implementation on site would not work out as anticipated without much closer involvement from the head office. To aid this process, a number of subcontractor meetings were arranged to include representatives from the key carpentry, plumbing/heating and electrical trades. The buying, production and design departments were also represented. The main reason for involving subcontractors was to provide a better understanding of the research objectives and to obtain feedback on proposals which might be considered impractical.

The management team selected a number of control and experimental houses for monitoring work for this third fieldwork study, in addition to those previously monitored. The control houses were to be built exactly as normal and the experimental houses, which would incorporate a number of design and construction changes, would be built to evaluate any improvements to productivity and quality. Houses on a development known as Wentworth Park in Stonydelph, Tamworth (Figure 5), were chosen for this purpose.

Production had recently re-started on this development of 66 homes, comprising 7 different detached house types, thus offering an ideal opportunity for fieldwork in the near future. Work had previously been suspended on Wentworth Park (known as phase III) due to labour shortages on site. It was proposed that a total of 11 houses should be monitored; these would comprise 3 different house types namely the Wessex, Lichfield and the Shakespeare. Of these 11, 7 houses (3 Lichfield, plots 17,30,31 and 4 Shakespeare, plots 18,20,42,43) were to be monitored as experimental houses. The Wessex house types were identical to the Shakespeare houses internally and 2 of these (plots 15 and 16) were to form part of the control contingent (together with some partial data collected during the second period of site work on plots 26,27,28). 2 Lichfield 'controls' were to form the balance (plots 37 and 38), again with partial data on Lichfield house types collected during the second period of site work (plots 25 and 29).

A set of options were prepared for possible design and construction changes based on some earlier proposals planned for the abortive second period of site monitoring

work. These included a number of ideas on how the plumbing, heating and electrical services could be distributed within the Lichfield and Shakespeare house types. The various managers within LHM were now aware of the aims and objectives of the research and it was possible to make firm decisions on which proposals should be selected for inclusion in fieldwork trials.

6.2 Design and construction proposals

The design and construction considerations raised at the meetings covered three main areas. These were as follows:

6.2.1 General preparation work

First, it was suggested that the preparation work currently undertaken by the 1st fix carpenter could be increased in scale in order to reduce the preparation time taken by other closely dependent trades. This was a finding derived from the 1st and 2nd periods of pre-fieldwork. Preparation work was seen as an important pre-requisite for any major changes to be implemented.

During normal production, the plumber would have to fix plumbing and heating carcase pipework across floor joists prior to the carpenter fixing the floor covering, staircase, door linings and erecting partitions. The electrician could not start work until the partitions were erected because light switches and socket outlets needed to be installed in some partition walls. In each of these instances, the trades would be responsible for their own preparation.

The work relationship of the carpenter to the electrician and plumber in the building programme suggested that a more responsible role could be played by the carpenter in overall preparation work. This preparation work could include the formation of floor ducts, access traps and access panels for distribution by the plumbing and electrical trades at a later stage. By doing this, it was considered appropriate that the carpenter could also be requested to carry out work which would not normally be undertaken by his trade. For instance, it might be deemed necessary for the carpenter to fix electrical socket boxes or to set gas and heating carcase pipes into the walls if this were to reduce the need for a return visit to a house by the electrical or plumbing trades.

The main implication of increasing the preparation work undertaken by the carpenter would mean a larger work package which would clearly impose a cost implication. In addition, the 1st fix carpentry operations would take longer to complete due to the increased volume of work. However, if these additional cost and time factors could be offset against quality gains and shorter and potentially less expensive operation times by the electrical, plumbing and heating trades, then the method of work could be justified.

6.2.2 The services and finishings operations

The finishings operations, which included wall, ceiling and floor finishes, as well as joinery items, were known to account for a large proportion of the total manhour requirements to complete a house, again from data derived during fieldwork. Under the current construction sequence, the services in the form of cables and pipework, had traditionally been sandwiched between the blockwork of the superstructure and the plaster of the finishings. The aim of the proposals would be to separate the services from the superstructure/finishings interface and for them to be installed independently at a later date.

In selecting this approach it would be possible to bring a house to a stage of partial completion ready for 'kitting-out' with the more expensive electrical, plumbing, heating and joinery items nearer to the time of completion. At the same time other trades would benefit from an improved work context. For example, the painter would be able to paint the kitchen and bathroom areas without the need to carefully cut-in around fixed items such as kitchen units, switch and socket outlets and sanitary ware. The plasterer would be able to carry out work without having to plaster around awkward pipework details. The glazed wall tiler would be able to fix tiles to open expanses of wall without have to cut and fit tiles around ready-fixed sanitary ware.

This 'late installation' approach would mean that the major capital expenditure on plumbing, heating, electrical and joinery works, which is normally paid for throughout production by interim stage payments, could be shifted to the latter weeks of the production programme on a house. An added advantage with this approach, besides the obvious quality gains, resulting from less damage and trade interruptions, would be that the firm could maintain better cash flow control. If the approach were fully developed, it would be possible to reduce borrowing requirements to pay for completed work because the work could be afforded with the monies resulting from the sale of properties.

6.3 Proposed changes to build sequence

In order to illustrate these proposals more clearly, a sequence diagram was prepared to show a proposed sequence of operations which could be followed on the 7 experimental houses (Figure 6). The sequence diagram shows a total of 12 separate work operation stages, 7 less than the 19 stages observed during normal production working.

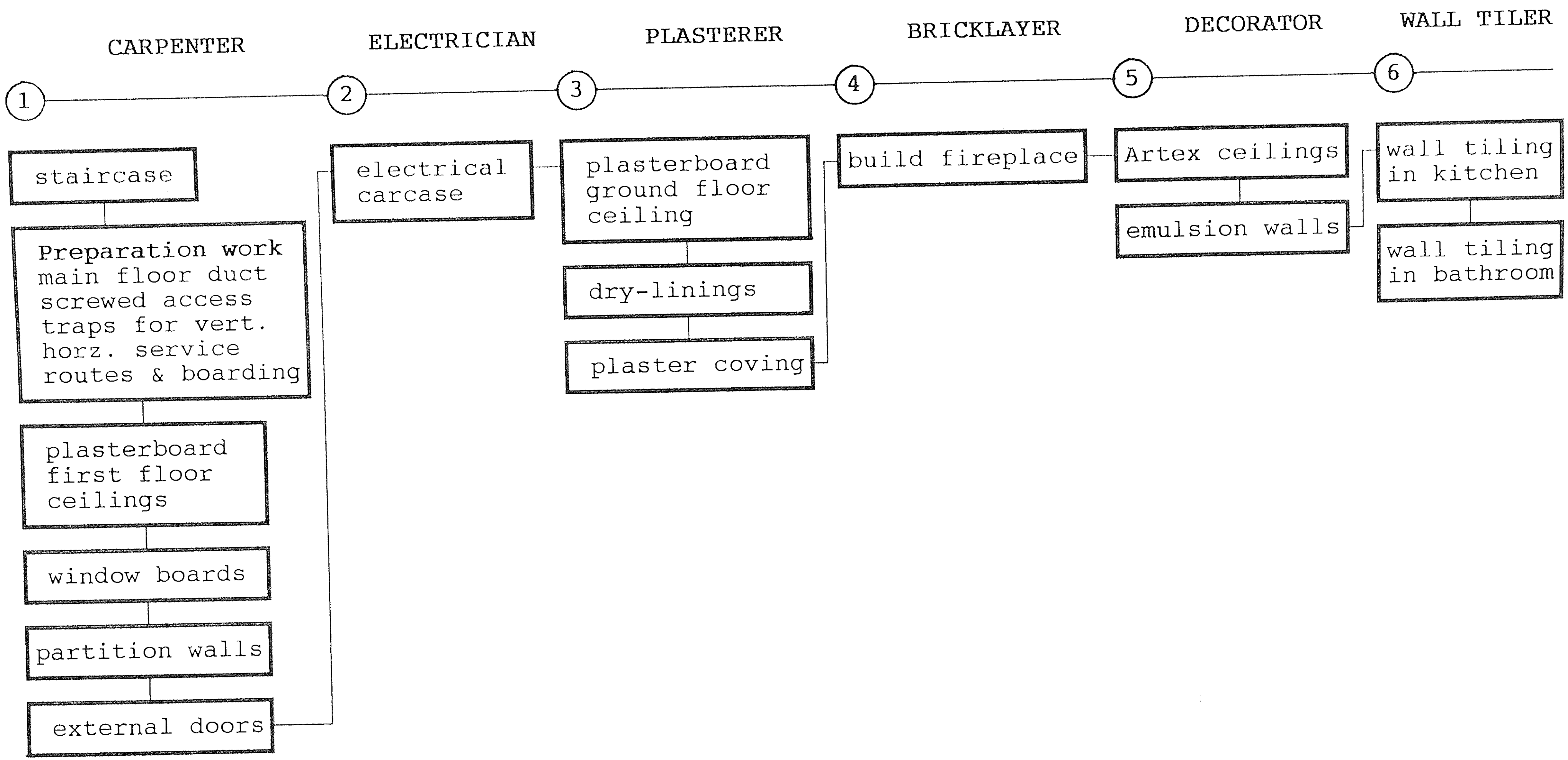

Fig 6 : Proposed sequence diagram for services and finishings operations (part 1 of 2)

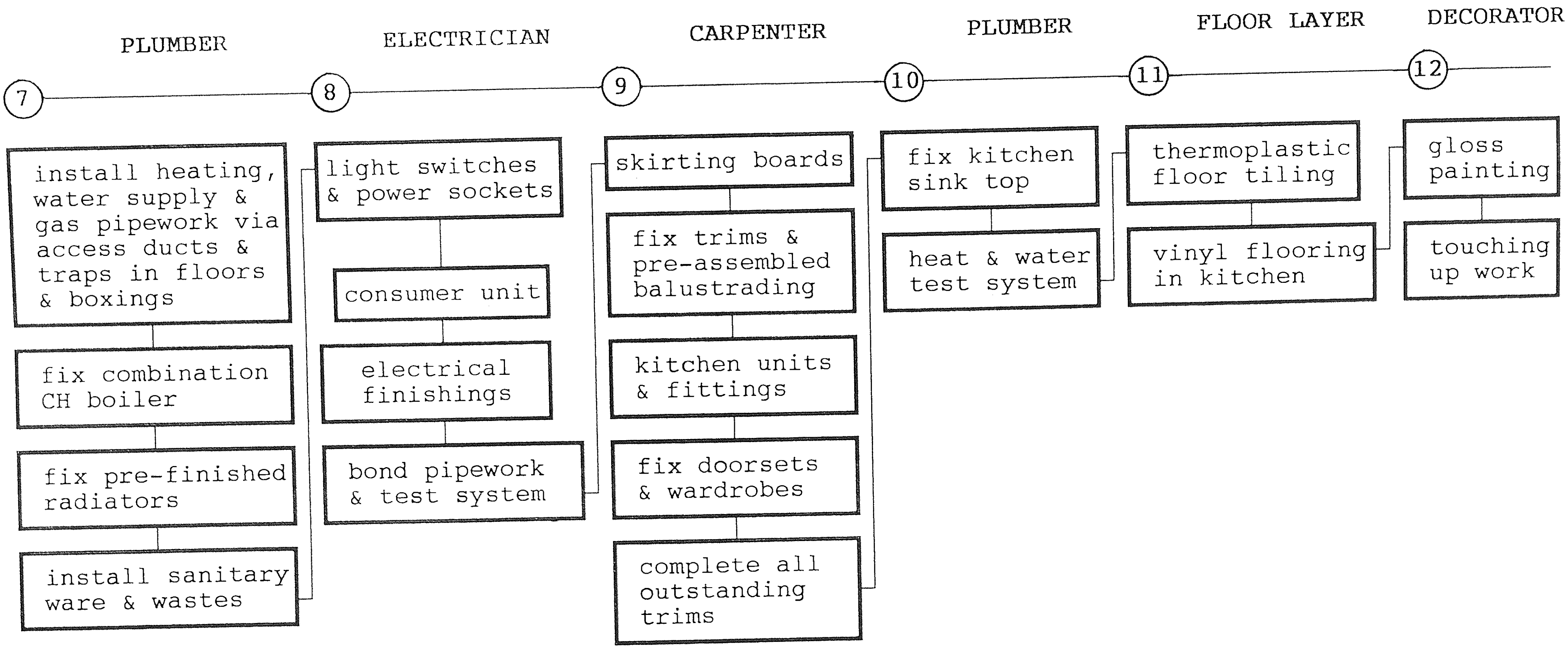

Fig 6 : Proposed sequence diagram for services and finishings operations (part 2 of 2)

The main operational changes resulting from the new working method are discussed next for each trade affected by the changes:

6.3.1 1st fix carpenter

Originally, it was proposed that the carpenter should not only be responsible for floor ducts and access panels, but also for fitting switch, socket boxes and conduits to walls to facilitate one large electrical operation later on in the build sequence. However, this proposal was rejected by both LHM and the electrical subcontractor, because the additional cost and uncertainty associated with drawing cables through concealed conduits was considered too great a risk. In view of this fact it was agreed that a separate electrical carcase operation, identical to that carried out on normal production houses, should take place. Essentially, the 1st fix carpenter was now to undertake three new items of work:

- increased preparation in the form of vertical and horizontal access routes;

- to fit the external doors in order to secure the house at an early stage.

- plasterboarding the ceiling at first floor level prior to erecting partition walls (referred to as 'tacking').

This latter work had formerly been undertaken by the plastering subcontractors who were required to break off from their work in other houses to complete the tacking before partitions could be erected.

One other important change was also to be implemented to reduce preparation work by the carpenter. This was to be achieved by providing a power floated type finish to the oversite concrete prior to curing. This work was to be undertaken by the groundworker gang as part of their normal operation. By doing this there would not be a need for a screeding operation and the carpenter would benefit from having a finished surface on which to set out the staircase and ground floor door linings.

6.3.2 Electrician

The electrician was required during this first visit to distribute wiring and to recess socket and switch boxes as he would do during normal operation working.

6.3.3 Plasterer

It was proposed that the tacking work at first floor level should now be undertaken by the carpenter in order to save on a visit by the plasterer trade. The ground floor ceilings were to continue to be boarded by the plasterer trade because electrical wiring needed to be distributed before the ceiling boards could be fixed.

The main process change to take place for the plasterer trades was to be the introduction of a dry-lining operation (dry wall boards with a thin plaster skim coat). Although this work practice was commonplace amongst several other volume house builders, it was a marked change from the wet plastering technique generally employed on LHM developments.

On completion of the dry-lining work the plaster coving work was to be undertaken. Although this was familiar practice on some developments, including the Manor Park development where the sequence diagram for typical services and finishings operations was derived, it was subsequently discovered to be non-standard practice on other sites. In order to address this issue, the plaster coving work operation is shown occupying a very definite position in the proposed sequence diagram. No plaster patching operation is shown on the proposed sequence diagram because by doing this undue carelessness by tradesman could result in damage to plaster skim finishes. Emphasis is placed on providing an environment where subsequent damage is substantially reduced.

6.3.4 Bricklayer

On other LHM developments the bricklaying trade were known to complete fireplace construction work to suit themselves. On some occasions this was legitimate because if it was raining this work provided obvious continuity in a dry environment. More frequently, the construction of the fireplace was regarded as a poorly paid task and as a result the work was only undertaken when the bricklayers were looking for small jobs to complete at the end of the working day. From a quality viewpoint, this is not a good practice because by doing this work late in the programme finishes can become damaged and spoilt (fireplaces were actually constructed during the painting operation on some of the houses at Manor Park).

In the proposed sequence diagram the fireplace construction is shown following on from the plaster coving work. This is so that 'wet' operations can be completed as soon as practically possible.

6.3.5 Decorator

The decoration work, comprising Artex plastic ceiling finish and internal painting work, had always been completed late in the building sequence, normally just prior to the floor tiling work. This often resulted in joinery items, sanitary ware and electrical fittings being marked with Artex material or paint. It was also very awkward for the decorator trades to work in houses where these items had been fixed because great care was needed to work around fixtures. By bringing some of this work forward in the build sequence it was envisaged that productivity could be improved in addition to subsequent quality brought about by cleaner fixtures. Instead of having to Artex around ceiling fittings, the Artexer was now expected to simply complete his work in rooms void of fixtures. The painter was to follow-on by emulsion painting the walls. By doing this, it was anticipated that overall painter performance could be improved and a much lighter working environment could be provided for follow-on trades - even though this would mean an additional work visit for the painter.

6.3.6 Wall tiler

On standard production houses glazed wall tiling was undertaken prior to decoration work. In the proposed sequence diagram this work was brought forward in the programme. It was envisaged that by doing this, the performance of the wall tiler could be improved because walls were to be tiled prior to kitchen units and sanitary ware being fixed. This would result in less tile cutting and less awkward details for the wall tiler trade to contend with.

6.3.7 Plumber

The changes to the plumber's work were significant. Under the proposed method of working the plumber was to carry out all work which had formerly been done as a separate carcase operation through specially designed and prepared access points. After this work had been completed the plumber was to fix and pipe-up pre-finished radiators to the pre-painted walls, thus ensuring that the radiators did not have to be subsequently removed for painting by the painter trade.

Another important change concerned the heating/hot water installation to be employed on the experimental houses. Instead of installing a conventional wall-hung balanced flue boiler, complete with cylinder, tanks and controls, the plumber was now to install an un-vented combination boiler system to provide mains pressure sourced hot water. By doing this, plumbing work could be rationalised to eliminate the need for pipework and tanks in the roofspace. At the same time, a full height airing cupboard, incorporating a heat source, could be provided to yield a quality gain now that the cylinder was to be omitted.

The sanitary ware was to be fitted to pre-tiled bathroom and en-suite walls. To aid this process, site management were to be responsible for checking and maintaining accurate opening sizes. The method of working would require extra vigilance on the part of the plumbing trade who generally created a considerable amount of plaster patching work when opening up pipework boxings and setting-in fittings. This work had always been done in the knowledge that a plaster patcher and wall tiler would be following-on afterwards to make good any damage. Access for pipework connections was now to be made through removable ducts in the bathroom floor where pipework could be brought up from specially formed and trimmed services voids between the joists.

6.3.8 Electrician (2nd and 3rd fix work)

It has previously been explained that LHM and the electrical subcontractor were unprepared to allow the electrical carcase operation to be conducted as part of a larger, independent operation at a later stage in the build programme. This left two other distinctive trade operations of second and final fixing (3rd fix). Instead of allowing the electrician to fix switches, power sockets, light pendants and the consumer unit immediately after the plaster trade, it was proposed that this work should be carried out after the plumber. By doing this, final fix items such as frost thermostats, shaver and shower lights, boiler controls and pipework bonding and testing could be carried out at the same time in an extended work operation. Under normal production conditions this latter work operation would have been completed after the floor layer had finished his work.

6.3.9 2nd fix carpenter

A number of changes were introduced in an attempt to simplify the work operation of the 2nd fix carpenter (joiner). After fixing skirting boards in the normal manner, the carpenter was to install pre-assembled balustrading, thereby reducing on-site preparation time. He was also to fit kitchen units and wall cupboards to pre-tiled walls in the kitchen and cupboards in the bathroom/en-suite areas where applicable. Wardrobes were to be fitted as normal and pre-hung doorsets, complete with ironmongery, were to be utilised, again to reduce on-site preparation work. Instead of creating a 3rd fix visit to the house, the carpenter was to complete outstanding finishings items during this larger work operation. Because the doorsets were being delivered to site complete with ironmongery, this meant that the 3rd fix work element of fitting latches and lever furniture would be substantially reduced.

6.3.10 Plumber

The plumber was to make a final visit to the house when the 2nd fix carpenter had completed work in order to fit a kitchen sink into the work top. In addition, it would now be possible to heat and water test the water/heating system. It would not be possible to do this work beforehand because an electricity supply was needed and this could only be connected by the local electricity board on satisfactory testing of the house electrics.

6.3.11 Floor layer

The floor layer was to fix thermoplastic floor tiles to ground floor areas and vinyl in the kitchen as late as practically possible in the proposed building sequence. Earlier thoughts were to lay floor coverings prior to the kitchen units being fitted in order to reduce awkward cutting and wastage, but this proposal was dismissed as it was thought that too much damage would occur to the floor finish by follow-on trades.

6.3.12 Decorator

The final proposed visit to the house was to be undertaken by the painter. This would be to carry out gloss painting work internally and to undertake any touching-up work which may have resulted from carelessness by earlier trades. This might include possible damage to Artexed ceiling finishes.

6.3.13 Other changes

There were two other changes, not shown on the sequence diagram, because they were taken to fall outside the services and finishings categories. These related to the power-floated type ground floor which was to be prepared, and early glazing. The ready finished floor finish previously described, served to simplify work operations for the carpenter; the early glazing was to be introduced in an attempt to make the houses weathertight prior to services and finishings work commencing.

Having expanded on the logic behind the changes, the next step was to prepare for, and to monitor the work on site, liaising with LHM head office to ensure that the research proposals now formalised were properly followed through by site management and subcontractors.

6.4 Layout drawings

The design department within LHM were responsible for preparing the necessary working drawings which would enable the 1st fix carpenter to carry out his preparation work. A set of six layout drawings were drawn for this purpose (see Figures 7-12). These A3 sized drawings show the main service distribution routes to be used by the plumber.

Special attention had to be given to the provision of a strengthened bulkhead staging in the Lichfield house type because a floor mounted 'Hi-Flow' combination boiler was to be sited on this. This unit was somewhat heavier than the conventional wall mounted gas-fired boiler normally installed in this position. An additional exploded detail on Fig.8 shows the manner in which the joists were notched in order to facilitate pipework runs parallel to the main joist layout. Vertical distribution routes are indicated behind dry-linings for gas and heating drop pipework and also inside full height accessible boxings. Other points for distribution include a trimmed duct in the bathroom area of the Shakespeare house type (see Fig.11); clay liners between the main building and adjacent garage; and strategically positioned lighting battens to ensure the accurate location of pendant light fittings.

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6.5 Site monitoring

Site monitoring work re-commenced in mid January 1988. This lasted for a period of 29 weeks, although the intensity of the monitoring reduced during later weeks as work on the majority of the houses covered by the study was completed. The plots covered in the fieldwork were monitored in the following order:-

1. plot 15 (Wessex control);
2. plot 16 (Wessex control);
3. plot 18 (Shakespeare experimental);
4. plot 17 (Lichfield experimental);
5. plot 20 (Shakespeare experimental);
6. plot 30 (Lichfield experimental);
7. plot 31 (Lichfield experimental);
8. plot 37 (Lichfield control);
9. plot 38 (Lichfield control);
10. plot 42 (Shakespeare experimental);
11. plot 43 (Shakespeare experimental)

6.5.1 Pre-requisite work

Prior to commencing fieldwork on site, certain important works relating to the designated experimental plots, had already taken place. The groundworker subcontractor had completed the ground floor slabs on plots 17,18,20,30 and 31; and the bricklayers had been instructed to form openings through which to pass pipework, and to build-in clay duct liners between the main building and attached garages.

Despite clear instructions being passed onto site with respect to the quality of finished floor, the resultant concrete finish was shown to be totally unacceptable. The floors were both uneven and pitted. The groundworker gang who had carried out this work had no previous experience with power floated floor finishes. In addition, the bricklayer's had allowed mortar droppings to build-up around the perimeter walls during construction work. Dried mortar had bonded to the uneven floor surface and could be removed only with considerable effort by site labourers. This problem could have been avoided with some form of edge protection.

A second groundworker gang were later employed for work on plots 42 and 43. The gang were properly experienced and supervised during their work and the final floor finishes were excellent. The bricklaying gang which followed took care to use edge protection and did not spoil the concrete floor finish.

6.5.2 Communication

Poor and inadequate communication between head office and site was shown to be a problem in the period between finalising proposals and actually starting fieldwork. This was due, in part, to LHM starting a number of new developments in that period which required priority design attention.

It materialised that the majority of tradesmen working on site knew nothing, or very little, of the changes to work sequences and practice which were to be implemented in the 'experimental' houses. A few trades, including the carpenter and plumber, appeared to be better informed. Site management had been sent copies of the layout drawings previously described, together with copies of the proposed sequence diagram so that these could be followed on site. The site manager had been told of a pending activity sampling exercise and of the experimental work by his contracts manager, but had not attended any of the earlier briefing meetings in person. In a similar way, the actual plumber and carpenter operatives had been told about the changes by their employers, but were not in attendance during meetings to raise questions.

The LHM head office were contacted about these problems and some effort was made to ensure better control over the implementation of proposals. This took the form of site visits by the Technical Services Director and members of his design team to explain the detailed sequence of build to the site manager and various subcontractors. It was noted that some of the access arrangements designed for the plumber, which comprised the bulk of the design input, were impractical. Suggestions were offered by the carpenters and plumbers on ways in which these problems could be resolved and drawings were amended accordingly. A comment was made by one of the trade operatives affected by the changes implying that proposals would have probably worked first time had the design department consulted in detail with the site team during initial discussions.

6.5.3 Production delays

The site work progressed satisfactorily following the design office support meetings, with a few noticeable exceptions. These were mainly caused by labour shortages where site management were unable to match the rate of production completions to sales demand. During this boom production period there was an acute shortage of carpenters on site. At the same time, the carpentry and plumbing trades were undergoing learning curve experience on the experimental houses and were now less productive than they would have been under normal circumstances. This meant that the general production programme began to fall behind schedule.

Opinions were raised by site management to head office in response to this problem. It was suggested that the experimental houses should be taken out of the building programme or be built when sales demand was less intensive. This request was over-ruled by the head office who were aware that by doing this, an unrepresentative comparison would be made between control and experimental houses, both of which needed to be monitored under identical conditions. Despite this, site management were observed to remove operatives from work on the experimental houses when they considered production to be falling behind schedule on other plots. This had the effect of increasing the number of separate visits originally proposed in the sequence diagram for certain trades.

6.5.4 Out of sequence working

The plumbing subcontractor expressed concern about an inability to match labour resources to production requirements. This was because plumbing and heating work was now to be condensed into larger operations. This resulted in the plumbing subcontractor starting work generally sooner than requested when operatives had no other work to do. When this happened, the follow-on trades also commenced their work in a sequence which followed the plumber.

In general terms, the proposed sequence diagram was followed through to the early painting and Artexing work, but then work patterns became more confused as trades resumed ad-hoc working sequences. Sometimes the sequence diagram would be followed and other times it would not. The observer could have no influence on the outcome of the site trials, despite the fact that working methods were not being followed as planned. Work was monitored exactly as it occurred. Site management administered ultimate control over the method of working because it was they who were accountable for meeting production targets. Problems resulting from out of sequence working were accepted as their sole responsibility.

6.5.5 Plot 18: a case of poor communication

Plot 18 provided a number of difficulties for site management and operatives. The main reason for this was poor communication between the design and sales departments. The design department had failed to notify the sales department that plot 18 was to be an experimental house. A purchaser later reserved the plot but then noticed that sheet flooring was being utilised instead of the normal floor boards and complained about this fact to the sales department. In order to secure the reservation, the sales department agreed that floorboards would be fitted, believing the problem to be a site management misunderstanding.

After some days, site management were notified of this agreement and were forced to organise the demolition and subsequent re-installation of flooring and partition walls. This had the outcome of demoralising the 1st fix carpenters who had completed so much of the work already. A dispute arose because of this incident and carpenters were consequently paid an hourly 'daywork' rate for undertaking preparation work in the experimental plots. The carpenters did not envisage that this particular element of their new work package would be cost effective and would no longer accept the normal price work system of remuneration.

Poor communication had resulted in this abortive work, which, in turn, had affected some operative's attitudes to the experimental method of working. This was an unfortunate outcome as plot 18 was only the first of the experimental houses. Many tradesmen who had since been briefed on the design and construction proposals began to question the outcome of the trials and suggested that changes would not work without still closer involvement from LHM head office.

For the remainder of the study, plot 18 was described as an 'abortive' plot, but continued to be monitored in order to demonstrate the effect that poor communication and decision making can have on productivity.

6.6 Attitudes to the changes

The attitudes and views of the trade operatives affected by the changes were mixed. These are now discussed in summary for each trade. A more detailed description of findings for certain individual plots is given in Chapter 7.

6.6.1 1st fix carpenter

The carpenters were one of the trades most significantly affected by the changes. Had they been provided with the correct information, based upon good consultation between design and site, the carpenter's agreed that the method of working could yield benefits for follow-on trades.

Some carpenters were concerned that their work was taking longer than normal and expressed the opinion that this working method would probably not continue in future as a result of this. However, this view did not take into account the learning curve experience they were undergoing, or the fact that their increased work load needed to be viewed in the context of all services and finishings work.

Another of their concerns related to the plasterboard tacking work at first floor level. Although this work operation was an operation which could have been undertaken in a proficient manner by a carpenter, it was seen to represent a conflict of interests. The carpenters believed that the plasterer trade would be able to carry out this work more productively by virtue of the fact that they were more experienced. In addition, LHM (design) had failed to communicate this process change to the buying department so plasterboard sheets had not been ordered for labour-only fixing. At the same time, the plastering subcontractor had not been told that this work item was to be omitted from his normal work package and had already pre-ordered materials for the job. In response to this problem, LHM site management agreed that this work operation should be undertaken in the normal way by the plastering subcontractor.

6.6.2 Electrician

The electrician found his carcase operation to be much simplified. During this operation it was possible to drill cable routing holes through sole plates and floors with the assurance that there were no concealed pipework runs which might be damaged. The light fitting positions could be accurately located through lighting battens and because walls were to be dry-lined, it was not necessary to recess switch and socket back-boxes into walls to the same extent as normal. This was because the dry-lining boards were set off the block walls on plaster dabs.

The electricians were generally in favour of installing switches, sockets, light fittings and finishings items in a larger second operation, but were prevented from doing so by site management who had expressed concern that some finishings items might become damaged or be stolen. This meant that the electrician often continued to carry out his work during three separate visits.

6.6.3 Plasterer trades

The plasterer gangs undertaking the dry-lining work offered strong support for the dry-lining method of working. Although the actual boarding and plaster skimming took approximately the same time to complete as wet plastering work, it offered a number of advantages. These included the fact that smaller quantities of bagged plaster material needed to be mixed up on site; that rooms dried out more quickly for decoration work; and that it was not necessary to cut out around heating distribution boxes (pipework distribution points were now to be cut out of the dry-linings by the plumbing trade). LHM responded very favourably to this positive feedback and immediately advised their plastering subcontractors to utilise dry-linings on all developments.

The ceiling coving work followed on after the dry-lining operation. This process change was welcomed by the coving gangs who continued to complete this messy work operation, in the same sequence, on all plots (whether experimental or control).

The plaster patchers were the least satisfied of the plasterer trades. This was clearly due to the frequent visits they had to make to some experimental houses when making good. Most of this work could have been avoided, or even eliminated, had greater care been taken by the plumbers and 2nd fix carpenters during their installation work.

6.6.4 Bricklayer

The fireplaces on the Wentworth Park development comprised pre-finished 'Adam' style fire surrounds and a marble hearth. When the actual fireback had been positioned, the fire surround and hearth were simply bedded into position. By imposing a sequence discipline on the bricklayer it was possible to complete this work, in all cases, without subsequent damage to fixtures and fittings. The bricklayers were fully in favour of the work sequence they were requested to follow.

6.6.5 Decorator

The painting tradesmen were opposed to early emulsion painting work initially but were seen to be in favour of the approach when it became apparent that a house, void of fixtures and fittings, could be rolled-out with emulsion paint in a matter of a few hours. In practice, the experimental houses were only given a single coat of emulsion during the first visit. This was done because the painting subcontractor would not risk applying two coats if there was a possibility that damage might occur. The work content was found to be very straightforward during the second visit when a second emulsion coat of emulsion was applied and gloss paintwork was completed.

The Artexing gang were very much in favour of an early finishes approach. By Artexing at an earlier stage, it was not necessary to protect fixtures and fittings from splashes. The Artexing work operation was considerably improved because of the approach and the only concern was that follow-on trades did not damage the ceiling finishes with careless handling of materials.

6.6.6 Wall tiler

The wall tiler approved of early wall tiling in the bathroom areas, but held reservations about pre-tiling in the kitchen area. The main reason for this was that very accurate levels needed to established and that wall cupboards would have to be packed off the walls by the thickness of a wall tile. It was agreed that the wall tiler should, therefore, make two visits to a house. Once before the plumber started work and a second time after the carpenter had fixed units in the kitchen area. It was considered more important in this instance to improve quality than to concede to productivity gains by imposing a single work operation on the wall tiler.

6.6.7 Plumber

The plumbing trade was least in favour of the experimental working method. This was not due to the retro-fit access approach, which they actually found to work quite well, but to a lack of guidance and pre-planning.

The combination boilers saved a considerable amount of work in the roofspace, but their unfamiliarity with this new system, outweighed, in their opinion, any advantages which were accrued. To compound this situation, their employer was paying them a lower price for carrying out this work stating that it would be easier to distribute pipework in these houses than it would be in normal production houses. This action was, perhaps, unfair considering the learning curve experience and lack of well planned access which the plumbers had to contend with.

6.6.8 2nd fix carpenter

The 2nd fix carpenters thought the pre-assembled balustrading and pre-hung doorsets to be a marked improvement because these resulted in time savings. Unfortunately, on some of the later houses, the doorsets did not arrive on site when needed. LHM decided to employ pre-assembled balustrading on all of their developments as a direct result of this experience. Doorsets were seen to offer real advantages, providing that a reliable supplier could be sourced.

The combined 2nd and 3rd fix operation was favoured by the 2nd fix carpenters who were able to fix ironmongery, trims and other finishings items during a larger work operation. Window furniture had previously been taken off windows and substituted for fittings with a higher specification. This work task was eliminated when windows were delivered to site complete with shrink-wrapped brass furniture.

6.6.9 Floor layer

The floor layer had layed floor finishes to power-floated type floors on other contracts and was confident that this process change was a good one. A major concern on the first five experimental houses, however, was the poor quality of floor finish. In each of these houses it was necessary to make a visit prior to floor laying in order to apply a levelling compound to uneven areas. On the last two experimental plots, 42 and 43, this visit was not needed due to the good quality surface achieved by an experienced and properly supervised groundworker gang.

6.7 An overview of site monitoring: period 3

The third period of fieldwork provided an abundance of good factual information. This information would be of significance when assessing the trials and identifying which design and construction proposals would require further refinement prior to future fieldwork by LHM.

The main outcome of this particular period of fieldwork was that traditional work practices and attitudes were being challenged. This applied to LHM staff and site management, as well as to tradesmen on site. It was clear that many of the changes offered potential improvements, both in terms of quality and productivity, but these would only materialise with yet further effort and refinement of ideas. The fieldwork data identified where problem areas lay, it was LHM senior management who had to implement directives to ensure that future trials were more successful.

CHAPTER 7

7.0 ANALYSIS AND DISCUSSION OF RESULTS

7.1 Data analysis for site monitoring period: 1

The data gathered during fieldwork monitoring at the Manor Park development was examined prior to design and construction changes being introduced on another LHM development at Wentworth Park in Tamworth. The Manor Park data was used to determine some of the main areas where problems existed, so that practical design and constructions could be sought. Some of the main qualitative findings have already been described in outline in Chapter 5.

The data for this period of fieldwork will be analysed more broadly than that pertaining to the second and third periods, where comparisons are made between some control and experimental houses. The reasons for this are as follows:-

1. During the first period of fieldwork, no records of 1st fix carpentry work were made. This omission was addressed during subsequent work to account for the important role performed by this trade in preparation work. The manhours figures are therefore incomplete for this fieldwork.

2. All houses monitored during this period were control houses. The majority of these were smaller units, of similar size, and could not be used for direct comparison purposes with the larger units which were to be built at Wentworth Park.

7.1.1 Summary of data collected (Manor Park)

Over 8,000 separate quantitative 'snap' observations were made during the first period of site work, with 7,256 of these relating directly to work operations which were monitored in full (3,628 total manhours). The balance comprised observations relating to part-finished work operations. Table 6 shows the overall breakdown of manhours by trade operations for each of the plots covered by the survey. On the right-hand column, total manhour figures are presented. These should be viewed with caution, as only plots 23-30 represent full data for the services and finishings operations. The other figures are the sums of partial work operations completed.

In addition to the above, over 1,600 qualitative observations were recorded during the same snap observations. Thus, qualitative records are shown to have been collected for 1 in every 5 snap observations made. Approximately 40% of these were significant in being able identify the main factors influencing quality and productivity on site. The remainder, were useful observations and suggestions, often made by site

Table 6: Manhours per trade per plot (Manor Park development)

Plot	Type	Class	100 1st fix	100 2nd fix	200 plumb	300 elec	400 plast	500 screed	600 b'layer	700 tiler	800 Artex	800 paint	900 floor	Plot total
20	H	C	-										13.0	13.0
21	A	C	-							11.5	13.5	73.5	6.0	104.5
22	NW	C	-	66.0						16.0	12.0	70.5	7.0	171.5
23	NW	C	-	80.0	62.5	22.0	116.5	11.5	7.0	13.5	17.0	80.5	18.0	428.5
24	NW	C	-	80.0	57.5	23.5	112.0	6.5	3.5	13.5	12.0	79.0	13.0	400.5
25	H	C	-	57.5	60.5	25.0	116.0	13.5	12.0	9.5	14.5	58.5	5.5	372.5
26	A	C	-	59.0	58.5	20.0	80.0	10.5	13.5	20.0	9.0	38.0	7.0	315.5
27	A	C	-	45.0	47.0	22.0	79.5	7.0	10.0	19.0	10.0	58.0	6.5	304.0
28	B	C	-	71.0	45.5	16.0	86.0	7.0	13.5	5.0	8.5	51.5	6.0	310.0
29	B	C	-	43.0	38.0	20.0	65.0	8.0	7.5	5.0	9.0	50.5	7.0	253.0
30	H	C	-	62.0	44.0	21.5	79.0	5.0	6.5	6.0	18.0	52.0	5.5	299.5
31	U	C	-	43.5	44.5	19.0	75.0	4.0	10.0	11.5	13.0	40.5		261.0
32	U	C	-	54.0	46.0	18.0	69.0	7.0	8.5					202.5
33	H	C	-				87.0	12.0						99.0
36	A	C	-				67.5	16.5	9.0					93.0
Trade total				661.0	504.0	207.0	1032.5	108.5	101.0	130.5	136.5	652.5	94.5	3628.0

KEY

C = control plot
A = Arden house type
B = Bronte house type

H = Hartford house type
U = Upton house type
NW = New Wessex house type

management and subcontractors. These could be used as informed feedback at some later stage in the development cycle process to influence better design and construction practice.

7.2 Quantitative data analysis (Manor Park)

The quantitative data was used to assess the following:-

1. Variations in average manhours for repeated work operations between houses;

2. The linear relationship (if any) between the number of manhours taken to complete a work operation and the number of separate visits caused by interruptions to work;

3. The percentage of work time spent productively and non-productively for each work operation (according to the pre-defined activity categories established and described in Chapter 3).

For the purpose of the analysis, the number of separate visits has been derived on the definition that a visit is a continuous period of work, when an operative, or operatives, are observed working on a house. When operatives are taken off work operations to carry out work elsewhere, they are recorded as starting a further visit on their return. The continuation of work operations from one day to the next has not been taken to constitute a separate visit.

7.2.1 Analysis of variations in manhours

For calculation purposes, the average manhour figures are rounded either up or down to the nearest half hour.

2nd fix carpentry work (code 100)

range 43-80 manhours

average 60 manhours (across 11 plots)

variation < 2:1

Plumber (code 200)

range 38-62.5 manhours

average 50.5 manhours (across 10 plots)

variation > 1.5:1

Electrician (code 300)

range 16-25 manhours

average 20.5 manhours (across 10 plots)

variation > 1.5:1

Plasterer trades (code 400)

range 65-116.5 manhours

average 86 manhours (across 12 plots)

variation < 2:1

Screeder (code 500)

range 4-16.5 manhours

average 9 manhours (across 12 plots)

variation > 4:1

Bricklayer (code 600)

range 3.5-13.5 manhours

average 9 manhours (across 11 plots)

variation < 4:1

Wall tiler (code 700)

range 5-20 manhours

average 12 manhours (across 11 plots)

variation 4:1

Artexer (code 800)

range 8.5-18 manhours

average 12.5 manhours (across 11 plots)

variation > 2:1

Painter (code 800)

range 38-80.5 manhours

average 59.5 manhours (across 11 plots)

variation > 2:1

Floor layer (code 900)

range 5.5-18 manhours

average 8.5 manhours (across 11 plots)

variation < 3.5:1

The variation fields for the diverse trade operations are shown to range from approximately 1.5:1 to 4:1. This clearly indicates that there is considerable scope for improved productivity. The cumulative affect of the variations, for each trade, in each completed plot, results in a total manhour figure for the services and finishings operations in that plot. This figure can be seen to range from an average of 253 manhours in plot 29, to 428.5 manhours in plot 23. A variation of 1.7:1. In real terms, the cost of this variation is spread across the labour costs for each plot on this development. This would result, in this example, to a labour cost reflecting the average 335.5 manhours taken to complete these work stages for each plot.

All plots with completed operations

range 253-428.5 manhours

average 335.5 manhours (across 8 plots)

variation > 1.5:1

7.2.2 Analysis of manhours and number of visits

The Pearson Product Moment Correlation test is used in order to assess if a linear relationship exists between manhours and the number of separate visits required to complete work operations. This test is used to produce a correlation coefficient (r) for paired sets of data in order to reflect the nature and strength of a linear relationship between the two variables.

Two other statistics, both functions of 'r', are also determined to provide more useful representations of the strength of 'r'. These statistics are the coefficient of determination, r^2, and the coefficient of non-determination, k^2, which is equal to $1 - r^2$. The coefficient of determination will indicate, for example, the proportion of variance in the number of visits, which can be explained by the linear relationship between this variable and the corresponding manhour figures. The coefficient of non-determination will indicate the proportion of this variance not explained by the manhour figure variance.

<u>2nd fix carpenter (code 100)</u>

$r = + 0.661$

$r^2 = 0.437$

$k^2 = 0.563$

This value represents a moderate positive correlation

Plumber (code 200)

$r = + 0.087$

$r^2 = 0.007$

$k^2 = 0.993$

This value represents a low positive correlation

Electrician (code 300)

$r = - 0.325$

$r^2 = 0.106$

$k^2 = 0.894$

This value represents a low negative correlation

Plasterer trades (code 400)

$r = + 0.873$

$r^2 = 0.762$

$k^2 = 0.238$

This value represents a high positive correlation

Screeder (code 500)

$r = + 0.627$

$r^2 = 0.393$

$k^2 = 0.607$

This value represents a moderate positive correlation

Bricklayer (code 600)

$r = + 0.696$

$r^2 = 0.484$

$k^2 = 0.516$

This value represents a moderate positive correlation

Wall tiler (code 700)

$r = + 0.721$

$r^2 = 0.520$

$k^2 = 0.480$

This value represents a high positive correlation

Artexer (code 800)

$r = + 0.752$

$r^2 = 0.565$

$k^2 = 0.435$

This value represents a high positive correlation

Painter (code 800)

$r = + 0.765$

$r^2 = 0.585$

$k^2 = 0.415$

This value represents a high positive correlation

Floor layer (code 900)

$r = + 0.965$

$r^2 = 0.931$

$k^2 = 0.069$

This value represents a very high positive correlation

It can be seen from these results that the floor laying work represents the only trade operation where a high percentage of the average manhour figures can be explained directly by the number of separate visits made to each plot.

The majority of operations show a moderate to high linear correlation coefficient, which suggests that there is only some degree of relationship between average manhours and the number of separate visits made. Conversely, the plumbing and electrical work shows very little linear correlation between the same two variables.

That variation which is not explained by this relationship test can, in many instances, be more fully explained by the qualitative data. This can, for example, indicate why additional work visits have been necessary to complete operations, or why work in one particular house has taken less time to complete than that in another.

7.2.3 Productive and non-productive time

Table 7 shows the average productive and non-productive percentage time expended by each of the services and finishings trades rounded to the nearest half hour.

Trade	Productive (%)	Non-productive (%)
2nd fix carpenter	**72**	**28**
(range)	67-80	20-33
Plumber	**69**	**31**
(range)	63-77	23-37
Electrician	**75**	**25**
(range)	64-82	18-36
Plasterer trades	**80**	**20**
(range)	69-86	14-31
Screeder	**68**	**32**
(range)	40-87	13-60
Bricklayer	**62**	**38**
(range)	50-71	29-50
Wall tiler	**79**	**21**
(range)	56-100	0-44
Artexer	**77**	**23**
(range)	65-88	12-35
Painter	**78.5**	**21.5**
(range)	68-88	12-32
Floor layer	**72.5**	**27.5**
(range)	53-91	9-47

Table 7: Average productive and non-productive times

The results for average productive and non-productive time shows there to be a generally high percentage of productive time for most trades. These have not, however, been separated into direct (fixing) and indirect (preparation, handling and so forth) productive time.

The average productive time for the floor laying work can be seen to range between 53-91%. When examining the qualitative records for this operation, it is possible to understand why a figure as low as 53% was recorded in plot 23. Of the balance (non-productive time), 38% was spent undertaking 'rework' because the original work operation had not been carried out to a satisfactory standard.

7.3 Qualitative data (Manor Park)

The following records relate to the sequence of events which took place in those plots selected for more detailed analysis. It has already been explained that the quantitative data analysis is important for providing hard facts concerning the deployment and usage of site labcur over time. To support this data, qualitative records are included to explain factors influencing interruptions, delays, manhour variations and quality. A wide and varied range of comments and observations were made against quantitative records.

It is of interest that the conventional form of activity sampling, used most noticeably by the BRE, would only be able to confirm the statistics which have been derived so far in the analysis. It would not be possible to use this basic form of method study to explain the variance shown by them. This is why qualitative data has such an important contribution to make to research in this field of study.

Qualitative records have been analysed in an attempt to explain why some of the variations of this magnitude exist. To do this, records relating to the best and worst cases (shown by the lowest and highest manhour figures respectively) are compared. Qualitative information relating to the mid-range average manhour values also explain the same type of issues.

7.3.1 2nd fix carpenter (comparison of plots 23 and 29)

The tradesman 101 undertook the 2nd fix carpentry work in both plot 23 and 29. Although plot 23 was slightly larger in floor area than plot 29, this did not account for all of the variation in manhours to complete the work operations.

Plot 23 was shown to be fraught with problems. During the initial setting-up operation it was found that there were insufficient materials to complete the work. When materials were delivered to the plot some were damaged and had to be re-ordered. There was a considerable amount of preparation work to be done in this plot including the re-levelling of door linings which had been inaccurately fitted by the 1st fix carpenter. Until this work had been done, it was not possible to hang the internal doors. A similar problem, concerning inaccurate studwork walls, meant that the fitted wardrobe units could not be offered into position with ease. In the kitchen area it was found that concealed gas and electrical supplies fouled with the position of wall cupboards. These all had to be relocated before work in this area could be completed.

In plot 29, the 2nd fix carpenter again experienced problems in the kitchen area. The main problem concerned the fitted kitchen units which could not be located as shown on the kitchen layout drawing. In addition to this problem, the door linings also needed to be re-levelled before doors could be hung.

The numerous problems experienced on plot 29 suggested that with better organisation, control and planning, the figure of 43 manhours could be reduced considerably. It was clearly evident that the same argument applied to plot 23.

7.3.2 Plumber (comparison of plots 23 and 29)

Three different plumbers (202, 204,205) worked on plot 29 at various times, during seven separate work visits. The high number of visits were necessary because site management were continually requesting that the plumber's finished off outstanding work elsewhere on site. The plumbing trade were observed as being the most discontinuous workers on site and this was due to the fact that they were not properly supervised.

Despite the high number of visits to this plot, the average manhour figure to complete the work was low. This was mainly due to the fact that the plumbing layout was rationalised, with the bathroom sited directly above the kitchen area. The heating distribution routes were also rationalised with some of the radiators sited away from window walls (this meant that the pipework runs were generally shorter).

Plot 23 plumbing work was shown to have had many problems including inaccurate 1st fix carpentry work, which meant that the bath and shower tray could not be fitted easily; concealed pipework was nailed through by the carpenter when fixing floor boarding; the plumbing and heating distribution routes were complicated and did not follow a rationalised layout; access traps for connections to radiator pipework were inaccurately located; the bricklayer gang had not formed an opening for the balanced flue boiler; there were delays with materials not arriving on site in time; and multiple trades were observed working in the plot at the same time. On one occasion 2 plaster covers, a 2nd fix carpenter and an electrician were restricting the free access and movement of the plumber.

In addition to the above, a new plumber started work on this plot (203). This tradesmen was a very methodical worker who produced workmanship of a very high standard, but he was also extremely slow. This had a negative affect on the time taken to actually complete work.

The main findings from the plumbing work suggested that simplified distribution routes were needed, together with better quality layout drawings. The 1st fix carpenter was seen to be responsible for a considerable amount of the delays experienced by the plumber and this could be addressed by involving the carpenter more closely in preparation work for the plumber trade.

7.3.3 Electrician (comparison of plots 25 and 28)

The electrical work in plot 28 proceeded without too much difficulty, although five separate work visits were made to the house. The high number of return visits was caused by an incomplete kit-of-parts to finish the 2nd fix installation work. This kit was also shown to be incomplete on a subsequent visit. An incorrectly positioned pull switch in the cloakroom also meant a further visit to complete work.

The electrical installation work undertaken in plot 25, although carried out by the same electrician (302), was fraught with problems. The following significant observations were made:- insufficient cable had been delivered to site to complete the carcase work; that the electrician was unfamiliar with the electrical layout in the Hartford house type; that the electrician had started work too early, because the 1st fix carpenter had not completed the partition wall work through which lighting cabling was to be fed; a trench had not been dug in time to lay an armoured cable from the house to a detached garage; that the consumer unit was located at high level above a kitchen wall cupboard and cable ends could not be wired up without considerable difficulty; and an electrical fault emerged because a carpenter had nailed through a concealed cable.

These findings suggested that proper trade sequencing was needed, together with reliable materials supply and good service layout drawings to indicate the exact position of wiring routes.

7.3.4 Plaster trades (comparison of plots 23 and 29)

The main cause of the high plaster trade manhour figures in plot 23 was directly attributable to the size of the gang carrying out the wet plastering work. Four plasterers were observed carrying out this work (including two apprentice plasterers). The output of the apprentices was shown to be low and the total non-productive time in this house was 31%. An additional problem was experienced on plot 23 and this was caused by delays waiting for the delivery of materials to start work. Almost half a day of lost production resulted because of this.

The majority of work in plot 29 was carried out by two experienced plasterers, who were able to complete work without any difficulty. One of the main problems for follow-on trades concerned the poor work practice of plastering over recessed socket, switch and heating distribution boxes. These were rarely cleaned out by the plasterer's and this caused considerable frustration to the electrician and plumber trades who had to break out dried plaster at a later date before being able to connect fittings.

7.3.5 Screeder (comparison of plots 31 and 36)

The same basic screeding gang (502 and 503) undertook work in both plots 31 and 36, with the work in plot 31 proceeding without problems. A third screeder (501) joined the gang for work on plot 36. Certain significant observations were made during this work operation to account for the high variation in manhours (> 4:1).

On their first visit to plot 36, the screeding gang were concerned that an insufficient quantity of sand had been delivered. It transpired that a quantity of material had been delivered some days before, some of which had been used by the local electricity board for back-filling a service trench. More sand was ordered, but a return visit was necessary to complete this operation the following day.

An inspection of the finished work showed a number of quality defects. In some areas the surplus screed had been left around the perimeter walls in rooms. This would have to be removed by the 2nd fix carpenter before skirting boards could be fixed. The screed thickness also varied between rooms. The specified thickness of 50mm tapered off to a few millimetres in the cloakroom and utility areas. There was also an obvious lack of established datums from which to work. This meant that the finished floor levels were uneven across the ground floor area.

A ready finished floor was seen as being the best solution, a view also expressed by the site manager at Manor Park. This could be achieved by addressing the preparation and finishing of the concrete floor slab by the groundworker gangs.

7.3.6 Bricklayer (comparison of plots 24 and 26)

The bricklayer's commenced the construction of the full height feature fireplace in plot 26 on a rainy day, when they were unable to proceed any further on superstructure work. By doing this, they affected the progress of a 2nd fix carpenter who was also working in the living room area. The three man gang were too large for this work operation and this meant that one bricklayer was continually standing idle.

The fireplace construction in plot 24, which comprised a pre-formed hearth and fire surround, was carried out without problems. This was largely due to the fact that the preparation and handling work was significantly reduced.

In general terms, fireplaces were being constructed too late in the building sequence, often just prior to decoration works taking place. Some internal doors were also being damaged as a result of carelessness when handling materials. This work operation needed to be carried out soon after the plastering work had been completed in order to reduce damage and also to finish 'wet' trade working at an earlier stage of build.

7.3.7 Wall tiler (comparison of plots 26 and 28)

The wall tiling in plot 28 was undertaken by the wall tiler 703. Although this work was carried out quickly, the standard of workmanship was poor. The converse was true in plot 26 where the wall tiling operation took four times as long.

Qualitative records showed that an experienced wall tiler (701) and an apprentice (704) were working in plot 26. The work was carried out to a high standard, but three separate work visits were made when only one was actually necessary. The tiler's were unable to complete work on their first visit because the bath, around which they had to tile, was a different colour to that specified by the purchaser. The bath was supposed to have been changed by the plumber, but this had not been done. A third visit was required because the patterned tiles in the kitchen area were different to those specified.

In both examples, the wall tiler's work was impeded by excessive tile cutting. This was necessary around fixed sanitary ware, between the window cill and kitchen work top, and above the rim of the bath. The problem experienced by the wall tiler trade could have been eliminated had the walls been pre-tiled ready for fixtures to be offered into position.

7.3.8 Artexer (comparison of plots 28 and 30)

The Artex ceiling finish work in plot 30 was carried out by three tradesmen (810, 811 and 812), over two separate work visits. This work could have been completed more efficiently by a two-man gang. The work was started late during the afternoon of the first visit and was completed during the afternoon on the following day. The same work in plot 28, was carried out in a single visit by 814, in less than half the time taken on plot 30.

In both plots, it was observed that the Artexing work was being undertaken very late on in the building sequence, just prior to the painter starting work. Some protection was offered to fixtures and fittings when carrying out this work, but in many cases items were splashed with wet Artex material. This invariably added to the preparation work undertaken by the painter and cleaner who would follow-on.

Early Artexing was identified as a method of simplifying this work operation. The Artexer's consulted about possible proposals favoured carrying out their work on completion of the plaster coving. This would prevent the need for protection and offer the tradesmen a clearer working environment.

7.3.9 Painter (comparison of plots 23 and 26)

Painting work in plot 26 proceeded without any problems. The painter 803 was shown to be a very neat and methodical worker, who insisted that the house was clean and tidy before he commenced his work. During the course of his work, there were no interruptions from other trades and this resulted in the very low average manhour figure of 38 hours.

In plot 23, however, the work pattern of the painter (801) was shown to be confused. The house was untidy when he started work and was untidy when he finished. Some of the variation in manhours between these two plots can be explained by the excessive preparation work required in plot 23. The internal doors were of hardwood and had to be carefully rubbed-down between coats. Another influencing factor concerned the Artexer's who had not cleaned up after their work. Splashes of Artex material were evident on many fixtures and fittings. In addition, the painters progress was hindered by a wall tiler who commenced the wall tiling work very late on in the building programme.

In summary, the main findings suggested that the wet plastered walls were taking a considerable time to dry out ready for painting. Dry-linings were seen as a way forward in which to overcome this problem. Early painting was also seen as a possible way to overcome the large amounts of cutting-in work, which was necessary in all houses. This process change would enable the painter to complete a substantial proportion of his work at an earlier stage.

7.3.10 Floor layer (comparison of plots 23 and 30)

Floor laying work was carried out by the tradesman 904 on plot 30. This work was undertaken without any problems, on a floor which was clean and level. Plot 23, however, suffered a number of serious set-backs, which resulted in four separate work visits, and an average manhour figure of over three times that of plot 30.

The qualitative data showed that too many tradesmen were working in plot 23 (three compared to the one in plot 30). In addition, the screeded floor finish was observed as being uneven and out of level. A second visit was necessary to lay a levelling compound to the uneven floor areas; a third to re-lay vinyl which had been rejected by LHM due to a poor colour match; and a fourth to replace the kitchen vinyl yet again, this time because the vinyl had been cut short and had been laid out of square (the pattern did not follow the wall).

7.4 Data analysis for site monitoring periods: 2-3

The fieldwork data from two periods of site work was used to provide measures for the control and experimental plots at Wentworth Park. Before site-work commenced, it was envisaged that certain quality and productivity gains could be accrued by implementing a number of design and construction proposals, previously outlined, and drawn from data collected during fieldwork on the Manor Park development.

7.4.1 Summary of data collected (Wentworth Park)

During the last two periods of fieldwork nearly 12,000 quantitative snap observations were made with 11,064 of these relating to site operations which were monitored in full (5,532 total manhours). The balance comprised observations relating to part-finished work operations. Table 8 provides an overall breakdown of manhours by trade operation for each of the plots covered by the surveys. The overall manhour figures per plot, on the right-hand column, represent full data sets for plots 17, 18, 20, 25, 30-1, 37-8 and 42-3 only. The remaining values in this column are for partially completed work operations.

During these snap observations, a further 4800 qualitative records were made. This means that qualitative records were made for 2 in every 5 snap observations (double the percentage made for the first

Table 8: Manhours per trade per plot (Wentworth Park development)

TRADE CODE

	Plot	Type	Class	100 1st fix	100 2nd fix	200 plumb	300 elec	400 plast	500 screed	600 b'layer	700 tiler	800 Artex	800 paint	900 floor	Plot total
	15	W	C		98.5						16.0	12.0	80.5	9.0	216.0
	16	W	C								13.0	12.0	80.5	8.0	113.5
	17	L	E	64.5	75.5	71.0	23.0	102.5	-	4.5	9.5	9.0	46.0	7.0	412.5
	18	S	A	138.0	145.0	64.5	19.5	104.0	-	6.0	11.5	10.0	76.0	12.5	587.0
	20	S	E	99.0	143.0	59.0	19.5	99.5	-	4.0	12.5	9.5	45.0	14.5	505.5
*	25	L	C	46.5	168.0	62.0	24.0	100.5	7.0	4.5	26.0	18.0	89.0	10.0	555.5
*	26	S	C	37.0	166.0	50.5	26.5	100.0	8.0	5.0					393.0
*	27	S	C	60.0				148.5							208.5
*	28	S	C	51.0											51.0
*	29	L	C	46.5				100.0	9.0						155.5
	30	L	E	93.5	66.5	55.0	25.0	117.0	-	3.0	9.5	9.0	39.5	8.5	426.5
	31	L	E	52.5	68.5	52.5	20.0	80.0	-	3.5	11.0	10.0	72.5	11.0	381.5
	37	L	C	44.0	53.0	32.5	20.5	106.5	8.0	5.0	12.0	11.0	53.0	10.0	355.5
	38	L	C	36.0	57.0	34.5	23.0	99.5	7.0	3.0	11.0	11.0	52.0	8.5	342.5
	42	S	E	73.0	68.0	47.0	23.0	101.0	-	3.5	13.0	12.0	69.5	10.0	420.0
	43	S	E	62.5	74.0	39.5	21.0	96.0	-	3.5	17.0	10.5	73.0	11.0	408.0
	Trade total			904.0	1183.0	568.0	245.0	1355.0	39.0	45.5	162.0	134.0	776.5	120.0	5532.0

KEY

* = monitored during 2nd period of fieldwork
C = control plot
E = experimental plot
A = abortive plot (former experimental plot)

W = Wessex house type
L = Lichfield house type
S = Shakespeare house type

period of site monitoring). This higher figure can be taken to imply that more problems were encountered, that more work was taking place on site, or that the observer was now more experienced and sensitised at collecting this form of data. All were true.

7.5 Quantitative data analysis (Wentworth Park)

The quantitative data was used to assess the following:-

1. Variations in average manhours for repeated work operations between houses;

2. The linear relationship (if any) between the number of manhours taken to complete a work operation and the number of separate visits caused by interruptions to work;

3. A detailed analysis of the percentage of work time spent productively and non-productively for each work operation;

4. Graphical representations of the progress of work on site for those plots where services and finishings operations were monitored in full.

7.5.1 Analysis of variations in manhours

For calculation purposes, the average manhour figures are rounded either up or down to the nearest half hour.

1st fix carpentry work (code 100)

overall range 36-138 manhours

average 64.5 manhours (across 14 plots)

overall variation < 4:1

experimental plots only

(taking plot 18 1st fix carpentry as an experimental work operation)

range 52.5-138 manhours

average 83 manhours (across 7 plots)

variation > 2.5:1

control plots only

range 36-60 manhours

average 46 manhours (across 7 plots)

variation > 1.5:1

2nd fix carpentry work (code 100)

range 53-168 manhours

average 98.5 manhours (across 12 plots)

variation > 3:1

Plumber (code 200)

overall range 32.5-71 manhours

average 51.5 manhours (across 11 plots)

overall variation > 2:1

experimental plots only

range 39.5-71 manhours

average 54 manhours (across 6 plots)

variation < 2:1

control plots only

(taking plot 18 plumbing work as a control work operation)

range 32.5-64.5

average 49 manhours (across 5 plots)

variation 2:1

Electrician (code 300)

range 19.5-26.5 manhours

average 22 manhours (across 11 plots)

variation < 1.5:1

Plasterer trades (code 400)

range 80-148.5 manhours

average 104 manhours (across 13 plots)

variation < 1.5:1

Screeder (code 500) (control plots only)

range 7-9 manhours

average 8 manhours (across 5 plots)

variation < 1.5:1

Bricklayer (code 600)

range 3-6 manhours

average 4 manhours (across 11 plots)

variation 2:1

Wall tiler (code 700)

range 9.5-26 manhours

average 13.5 manhours (across 12 plots)

variation > 2.5:1

Artexer (code 800)

range 9-18 manhours

average 11 manhours (across 12 plots)

variation 2:1

Painter (code 800)

range 39.5-89 manhours

average 64.5 manhours (across 12 plots)

variation > 2:1

Floor layer (code 900)

range 7-14.5 manhours

average 10 manhours (across 12 plots)

variation 2:1

All plots with completed operations

range 342.5-587 manhours

average 439.5 manhours (across 10 plots)

variation > 1.5:1 (actual 1.7:1)

control plots only

(taking the abortive work on plot 18 as control work)

range 342.5-587 manhours

average 460 manhours (across 4 plots)

variation > 1.5:1 (actual 1.7:1)

experimental plots only

range 381.5-505.5 manhours

average 425.5 manhours (across 6 plots)

variation < 1.5:1 (actual 1.3:1)

Even when discounting the abnormally large manhour total for plot 18, due to high 1st and 2nd fix carpentry manhour values, the control plots variation field is still greater than 1.5:1. This means that the average control manhour figure drops from 460 to 418 manhours (only 7.5 manhours less than the 'all experimental' plots). This would suggest that, on average, both the experimental and control plots were carried out in more or less the same time. An allowance should be made for the fact that learning curve experience was in operation on the experimental plots.

Only 1st fix carpentry and plumbing manhours have been compared in terms of experimental and control plots. For the remaining trade operations, despite certain process changes, the manhour values do not vary greatly. These have been compared to illustrate the extreme average manhour values only.

7.5.2 Analysis of manhours and number of visits

1st fix carpenter (code 100) (control plots only)

$r = + 0.660$

$r^2 = 0.436$

$k^2 = 0.564$

This value represents a moderate positive correlation

1st fix carpenter (code 100) (experimental plots only)

$r = + 0.450$

$r^2 = 0.202$

$k^2 = 0.798$

This value represents a low positive correlation

2nd fix carpenter (code 100)

$r = + 0.754$

$r^2 = 0.568$

$k^2 = 0.432$

This value represents a high positive correlation

Plumber (code 200) (control plots only)

$r = + 0.692$

$r^2 = 0.479$

$k^2 = 0.521$

This value represents a moderate positive correlation

Plumber (code 200) (experimental plots only)

$r = + 0.827$

$r^2 = 0.684$

$k^2 = 0.316$

This value represents a high positive correlation

Electrician (code 300)

$r = + 0.487$

$r^2 = 0.237$

$k^2 = 0.763$

This value represents a low positive correlation

Plasterer trades (code 400)

$r = + 0.047$

$r^2 = 0.002$

$k^2 = 0.998$

This value represents a low positive correlation

Screeder (code 500)

$r = + 0.802$

$r^2 = 0.643$

$k^2 = 0.357$

This value represents a high positive correlation

Bricklayer (code 600)

$r = + 0.301$

$r^2 = 0.091$

$k^2 = 0.909$

This value represents a low positive correlation

Wall tiler (code 700)

$r = - 0.402$

$r^2 = 0.162$

$k^2 = 0.838$

This value represents a low negative correlation

Artexer (code 800)

$r = + 0.333$

$r^2 = 0.111$

$k^2 = 0.889$

This value represents a low positive correlation

Painter (code 800)

$r = + 0.039$

$r^2 = 0.002$

$k^2 = 0.998$

This value represents a low positive correlation

Floor layer (code 900)

$r = + 0.795$

$r^2 = 0.632$

$k^2 = 0.368$

This value represents a high positive correlation

For the vast majority of these operations, no definite linear relationship exists between manhours and the number of visits made. The largest proportion show a low to moderate correlation. The two exceptions concern the floor laying operation and the plumbing work in the experimental plots, where a high linear correlation is shown to exist between average manhours and visits. Again, the qualitative data set is able to explain far more of the variation than that which is determined by this statistical relationship.

7.5.3 Productive and non-productive time

The quantitative data has first been broken down into broad categories of productive and non-productive activity. Table 9 shows the average percentage of productive and non-productive time expended by each of the services and finishings trades across all plots. Tables 10 and 11 show the same information, but for 'all experimental', and 'all control', plots respectively.

Trade	Productive (%)	Non-productive (%)
1st fix carpenter	**73**	**27**
(range)	64-79	21-36
2nd fix carpenter	**69**	**31**
(range)	62-75.5	24.5-38
Plumber	**65**	**35**
(range)	39.5-75	25-60.5
Electrician	**75**	**25**
(range)	65-79.5	20.5-35
Plasterer trades	**76**	**24**
(range)	70.5-85	15-29.5
Screeder	**72.5**	**27.5**
(range)	66-81	19-34
Bricklayer	**85**	**15**
(range)	71.5-100	0-28.5
Wall tiler	**79.5**	**20.5**
(range)	64-91	9-36
Artexer	**77.5**	**22.5**
(range)	68.5-94.5	5.5-31.5
Painter	**75.5**	**24.5**
(range)	69-82	18-31
Floor layer	**81**	**19**
(range)	62-94.5	5.5-38

Table 9: Average productive and non-productive times (all plots)

Trade	Productive (%)	Non-productive (%)
1st fix carpenter	**69**	**31**
(range)	64-77.5	22.5-36
2nd fix carpenter	**70.5**	**29.5**
(range)	65.5-74.5	25.5-34.5
Plumber	**60**	**40**
(range)	39.5-72.5	27.5-60.5
Electrician	**77**	**23**
(range)	68.5-79.5	20.5-31.5
Plasterer trades	**75.5**	**24.5**
(range)	70.5-79.5	20.5-29.5
Bricklayer	**85.5**	**14.5**
(range)	71.5-100	0-28.5
Wall tiler	**85**	**15**
(range)	77-91	9-23
Artexer	**81**	**19**
(range)	70-94.5	5.5-30.5
Painter	**74.5**	**25.5**
(range)	69-82	18-31
Floor layer	**80**	**20**
(range)	62-93	7-38

Table 10: Average productive and non-productive times (experimental plots)

Trade	Productive (%)	Non-productive (%)
1st fix carpenter	**76**	**24**
(range)	72-79	21-28
2nd fix carpenter	**67.5**	**32.5**
(range)	62-75.5	24.5-38
Plumber	**71**	**29**
(range)	64-75	25-36
Electrician	**73.5**	**26.5**
(range)	65-79	21-35
Plasterer trades	**76.5**	**23.5**
(range)	70.5-85	15-29.5
Screeder	**72.5**	**27.5**
(range)	66-81	19-34
Bricklayer	**84**	**16**
(range)	80-88.5	11.5-20
Wall tiler	**74**	**26**
(range)	64-84.5	15.5-36
Artexer	**74.5**	**25.5**
(range)	68.5-89	11-31.5
Painter	**76.5**	**23.5**
(range)	71.5-81	19-28.5
Floor layer	**81**	**19**
(range)	70-94.5	5.5-30

Table 11: Average productive and non-productive times (control plots)

Appendix 1 provides a detailed analysis of productive and non-productive time for those plots monitored during the second and third periods of fieldwork. It also shows other details relating to the duration of operations, trade operatives and visits.

It can be seen from Tables 10 and 11 that the percentages of productive time, generally reflect the high values determined at Manor Park. The detailed analysis in Appendix 1 provides a fuller explanation of events. The actual time spent fixing, or physically making the building grow, can be seen to vary between 11.5-59%. Those trade areas showing low fixing times are areas which might be addressed with more pre-finished or pre-assembled components. This could help to reduce the high handling and preparation times which are associated with normal site working.

7.6 Qualitative data (Wentworth Park)

The time allocated for monitoring did not allow for inordinately long periods on site, so it was not possible to collect a full control plot contingent. By the end of the third period of site work, full control plot data had been collected for plots 25, 37 and 38 only (Lichfield house types). Full data sets were not made for any of the control Shakespeare house types and the next group of this type were not to be built until several months after the fieldwork was due to conclude.

The following text should be read in conjunction with Figures 13-22. These graphs show representations of the progress of work over time for the plots where all services and finishings operations were completed. Sloping lines represent work in progress and horizontal lines represent delays, or time spent waiting for another operation to commence. A sloping line following on from a horizontal line shows the recommencement of work (a new visit). Of additional interest, the graphs show when more than one trade was observed to be working in a house at any given time. This is indicated by the intersection of two or more sloping lines on an imaginary vertical axis.

Although the qualitative records indicate the cause of each delay shown, it would prove repetitive and futile to explain the cause and effect of each observation. The graphs show the actual sequence of operations which took place. They show confused work patterns for all but two of the experimental plots (31 and 43). For the most part this was caused by poor organisation, control and coordination at site level.

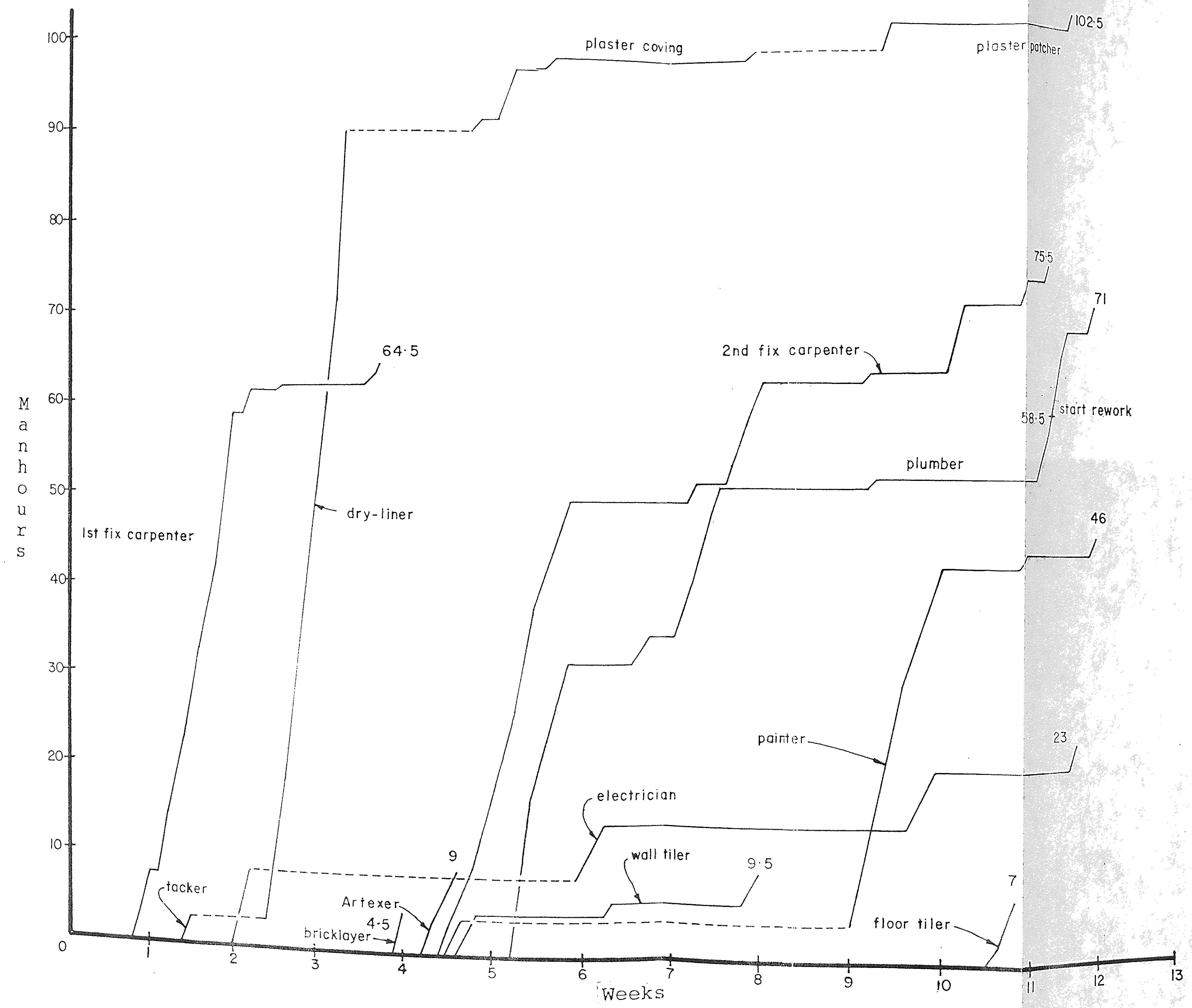

Fig.13: Graph of progress (Plot 17)

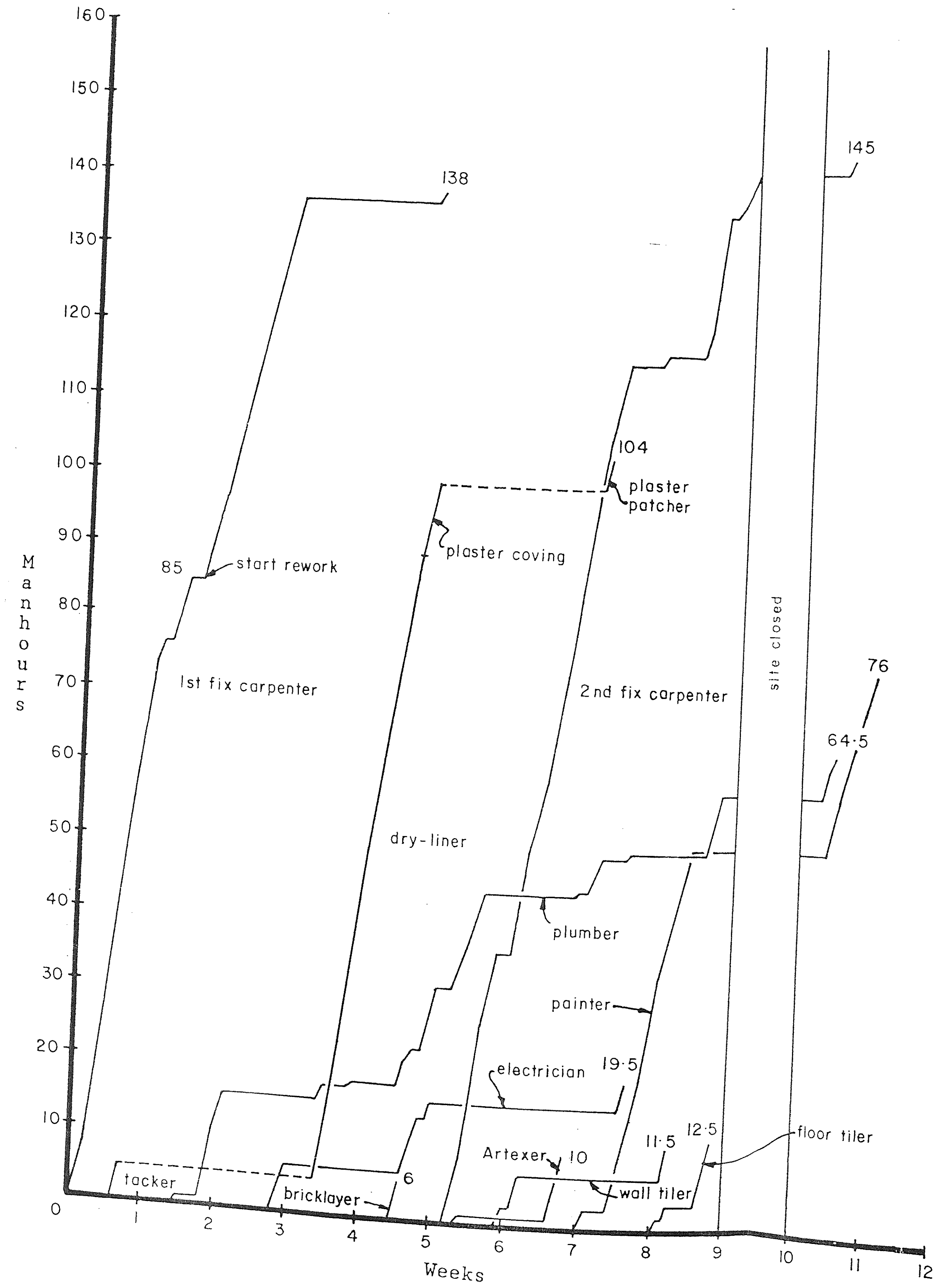

Fig.14: Graph of progress

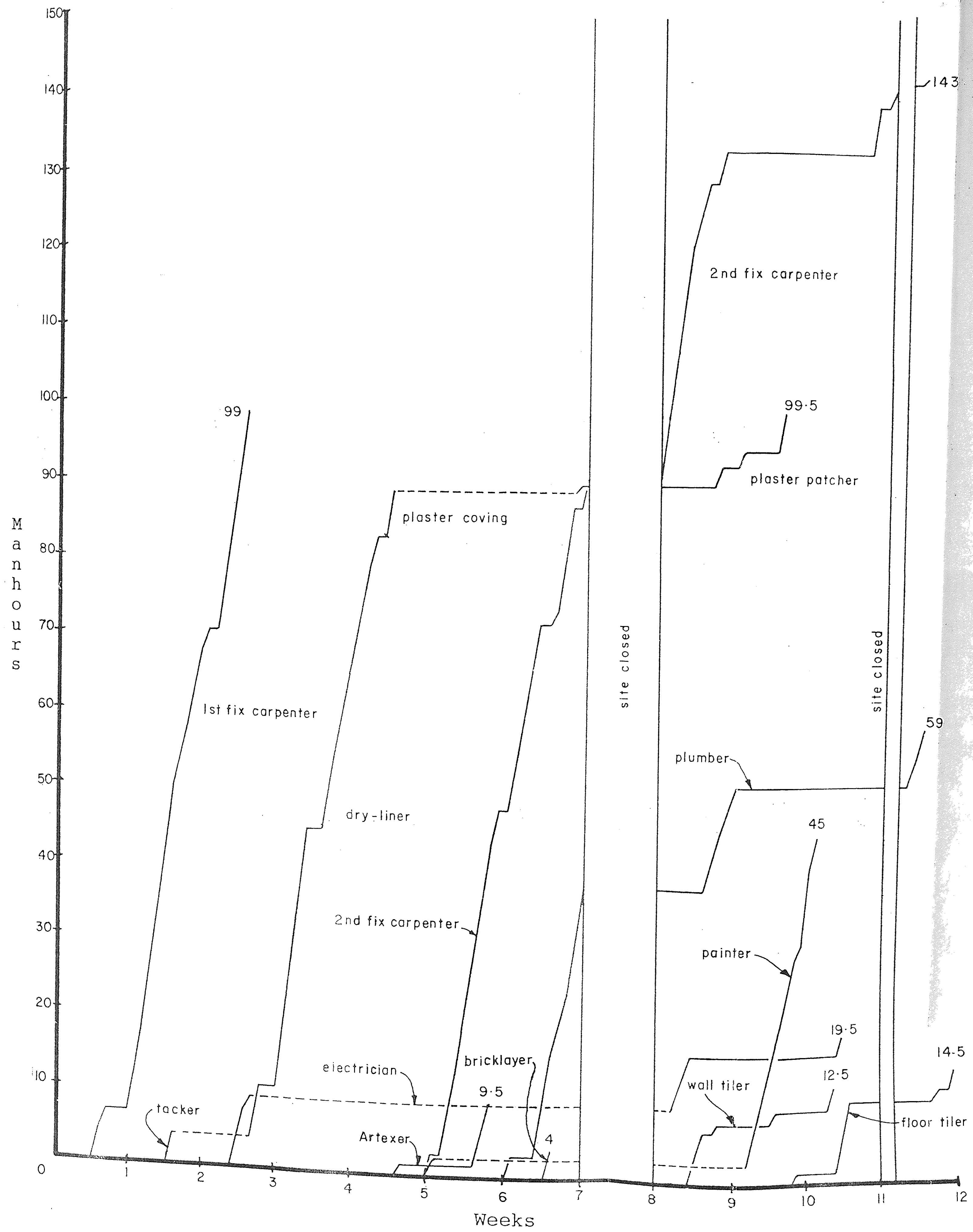
Manhours
Weeks
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
1
2
3
4
5
6
7
8
9
10
11
12
1st fix carpenter
99
dry-liner
plaster coving
2nd fix carpenter
electrician
tacker
bricklayer
9·5
Artexer
4
site closed
2nd fix carpenter
99·5
plaster patcher
plumber
45
painter
19·5
wall tiler
12·5
site closed
143
59
14·5
floor tiler

Fig 15:

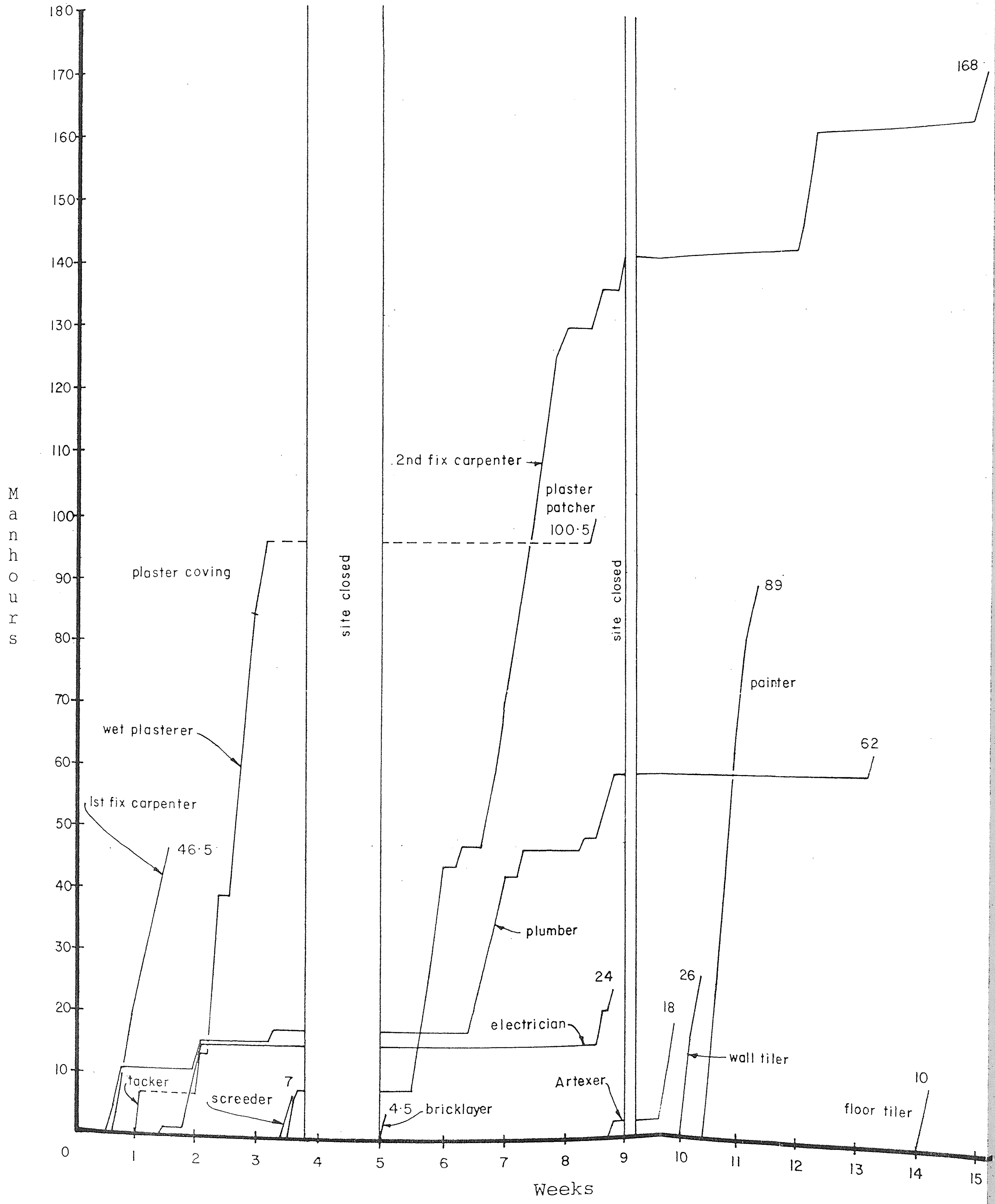

Fig. 16: Graph of progress (Plot 25)

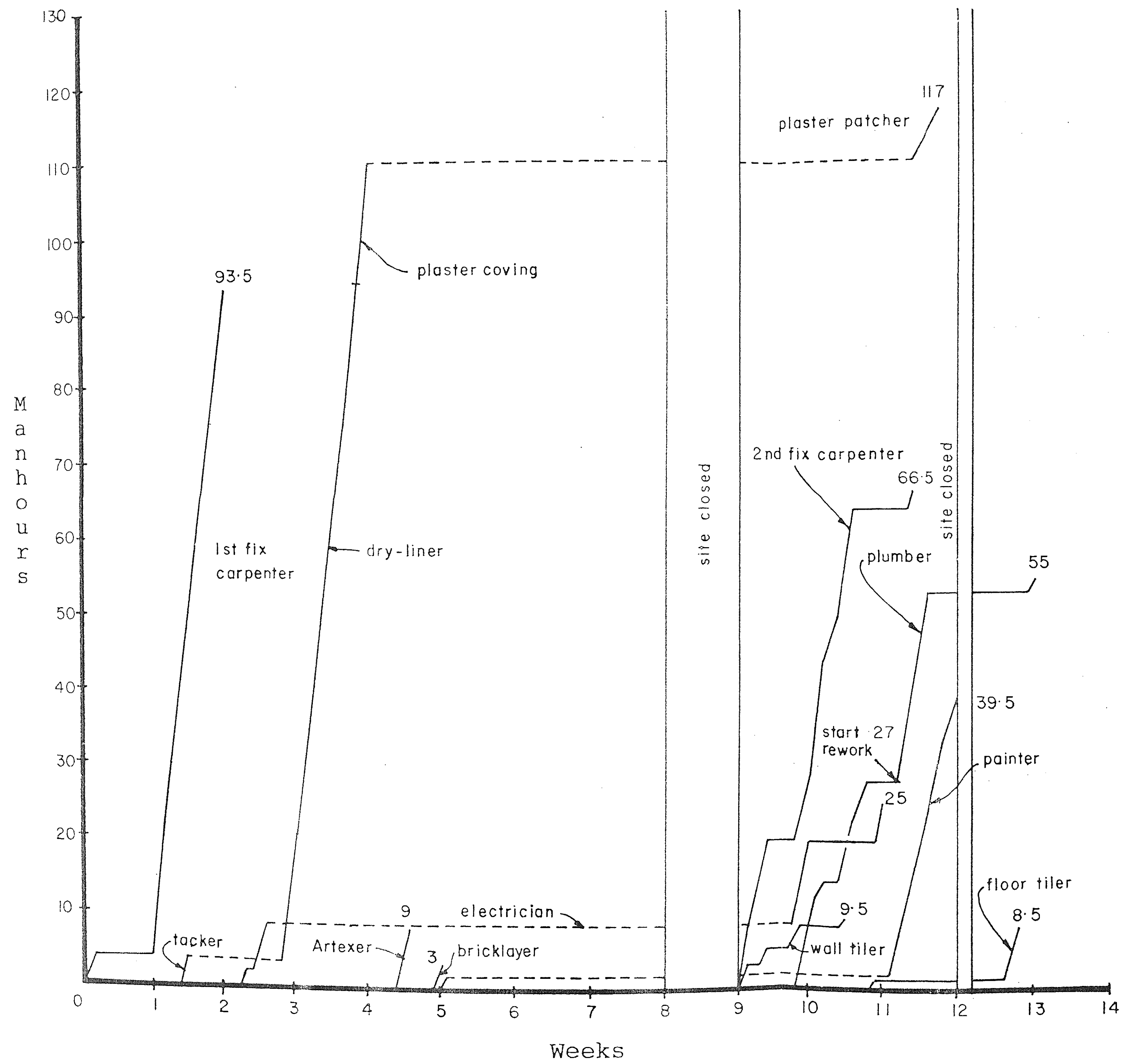

Fig. 17: Graph of progress (Plot 30)

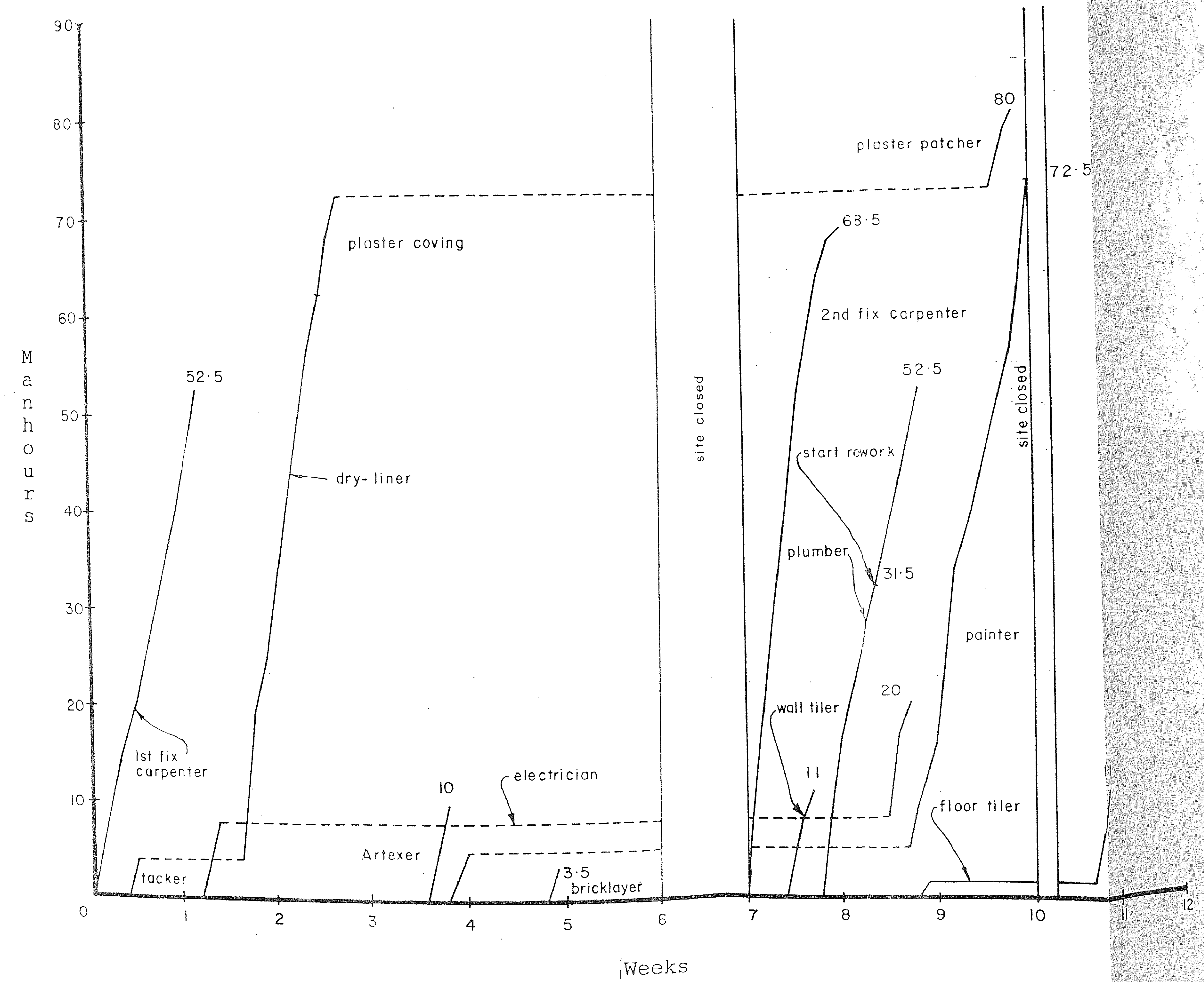

Fig. 18: Graph of progress (Plot 31)

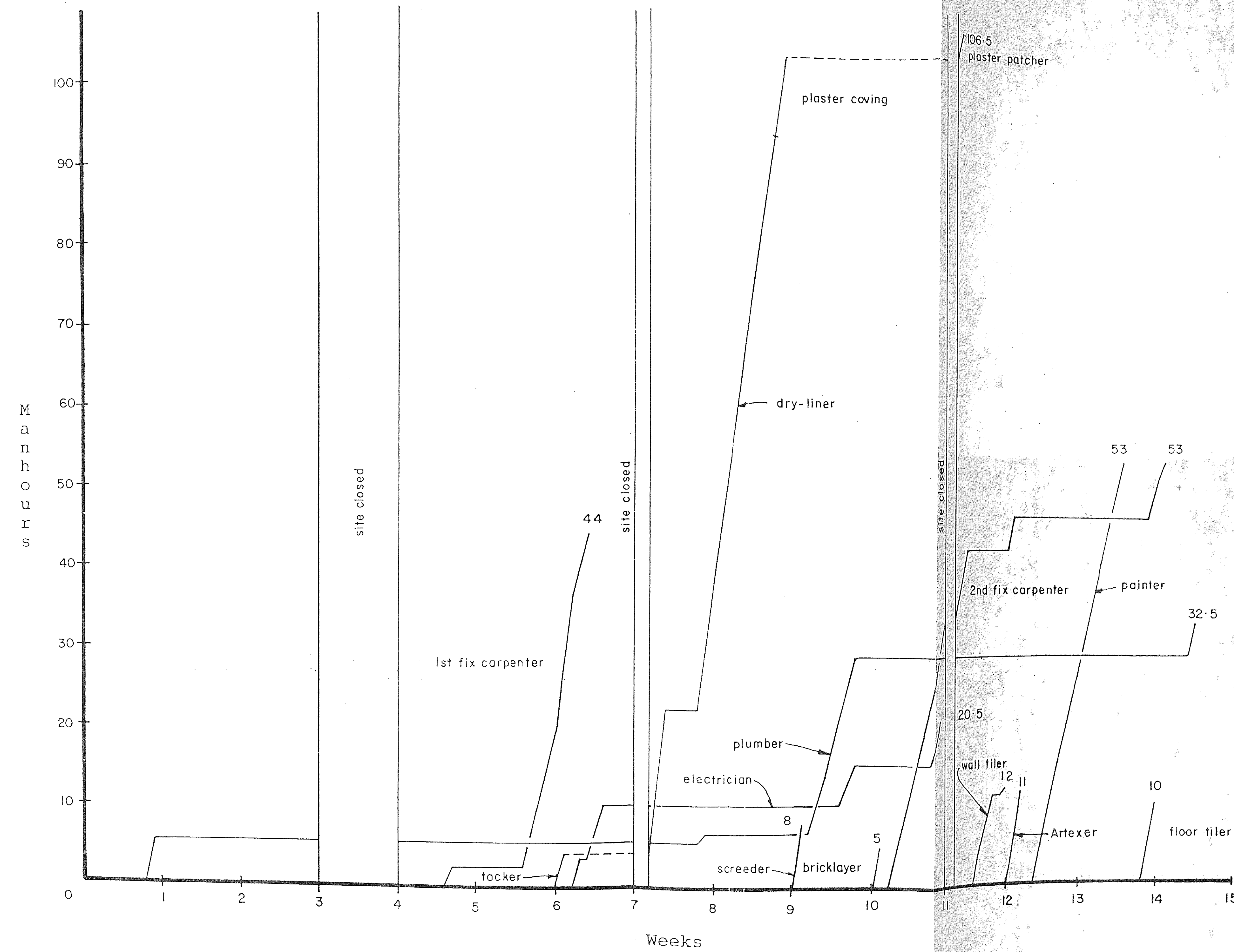

Fig.19: Graph of progress (Plot 37)

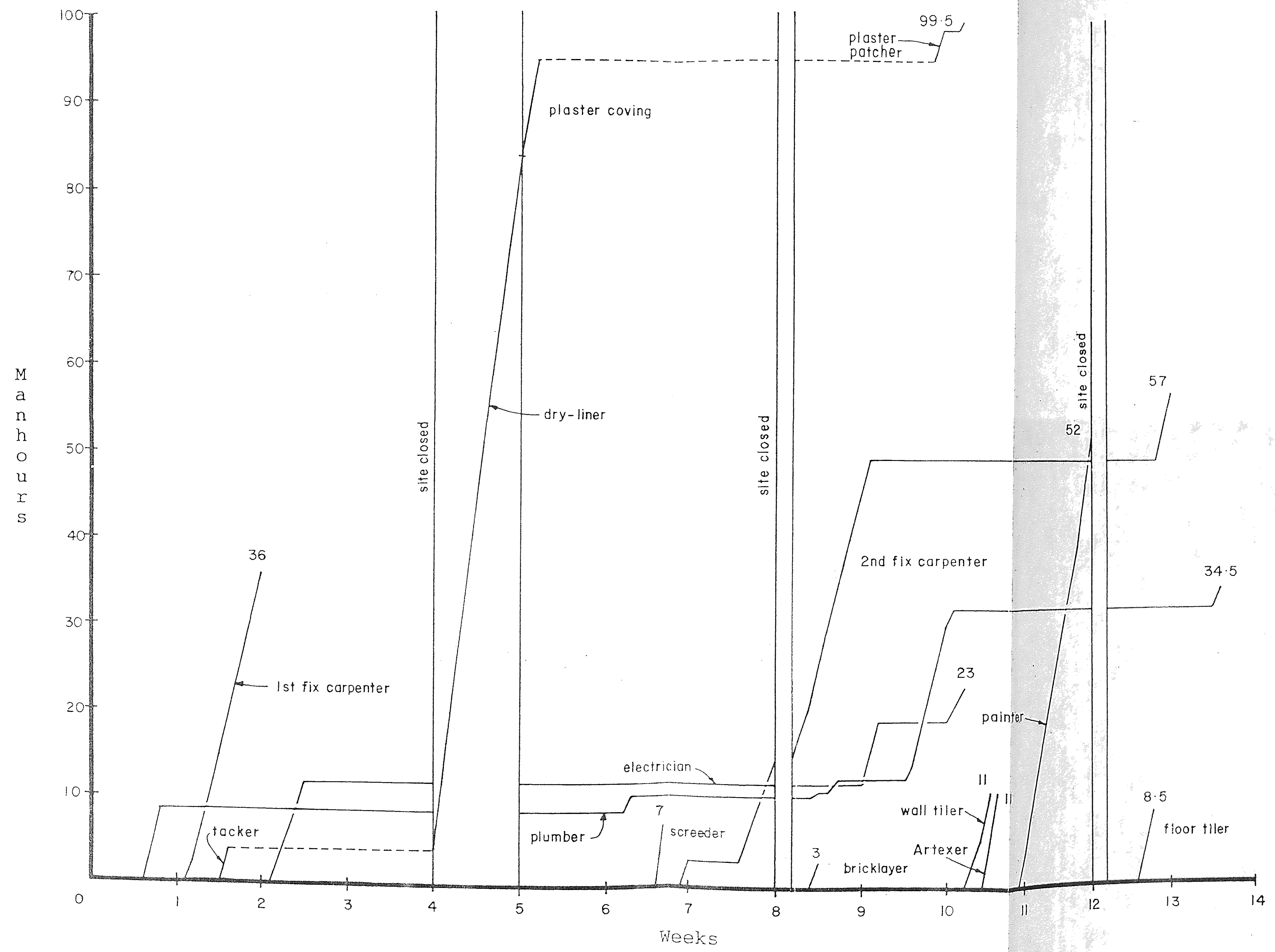

Fig 20 : Graph of progress (Plot 38)

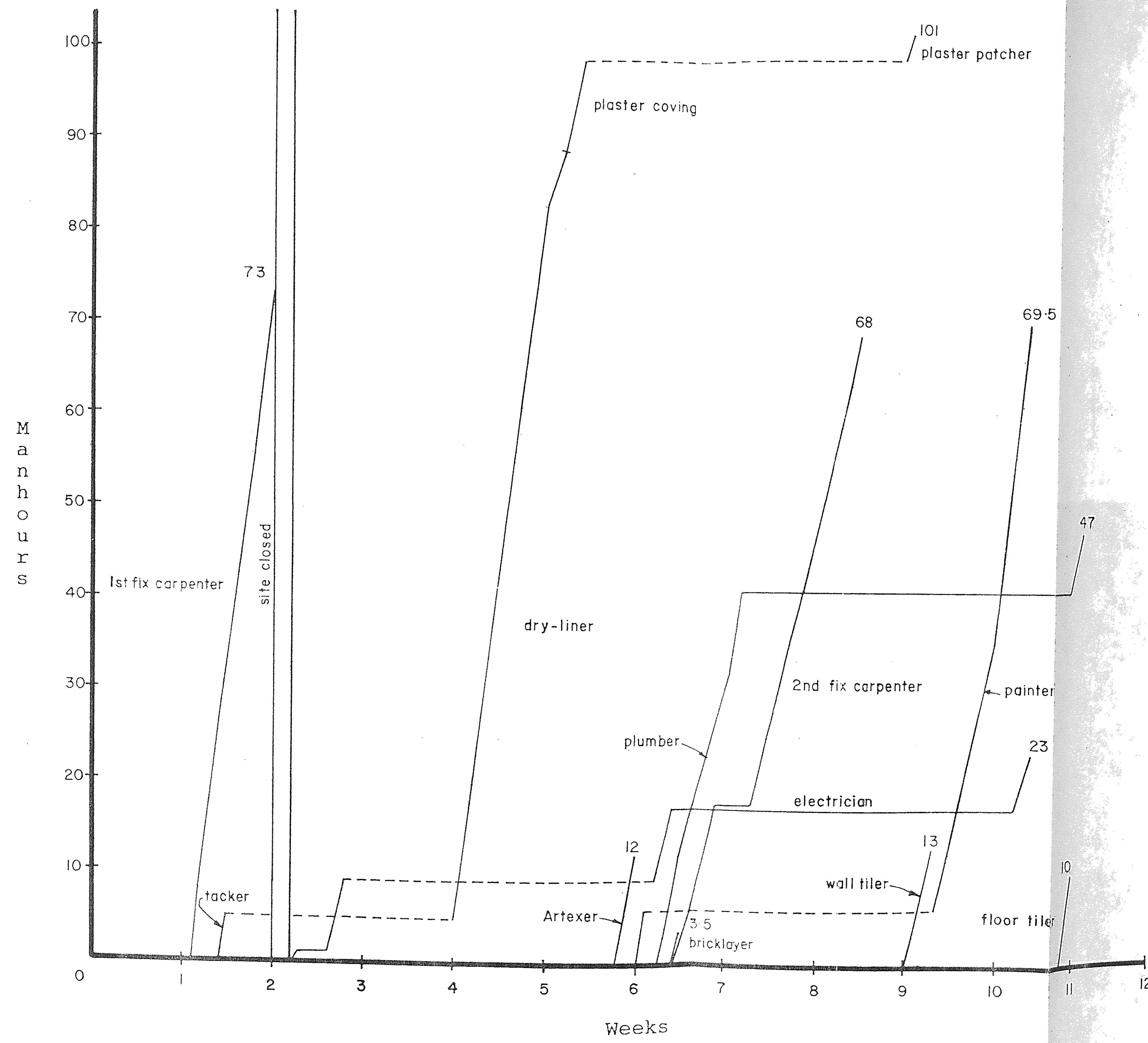

Fig 21: Graph of progress (Plot 42)

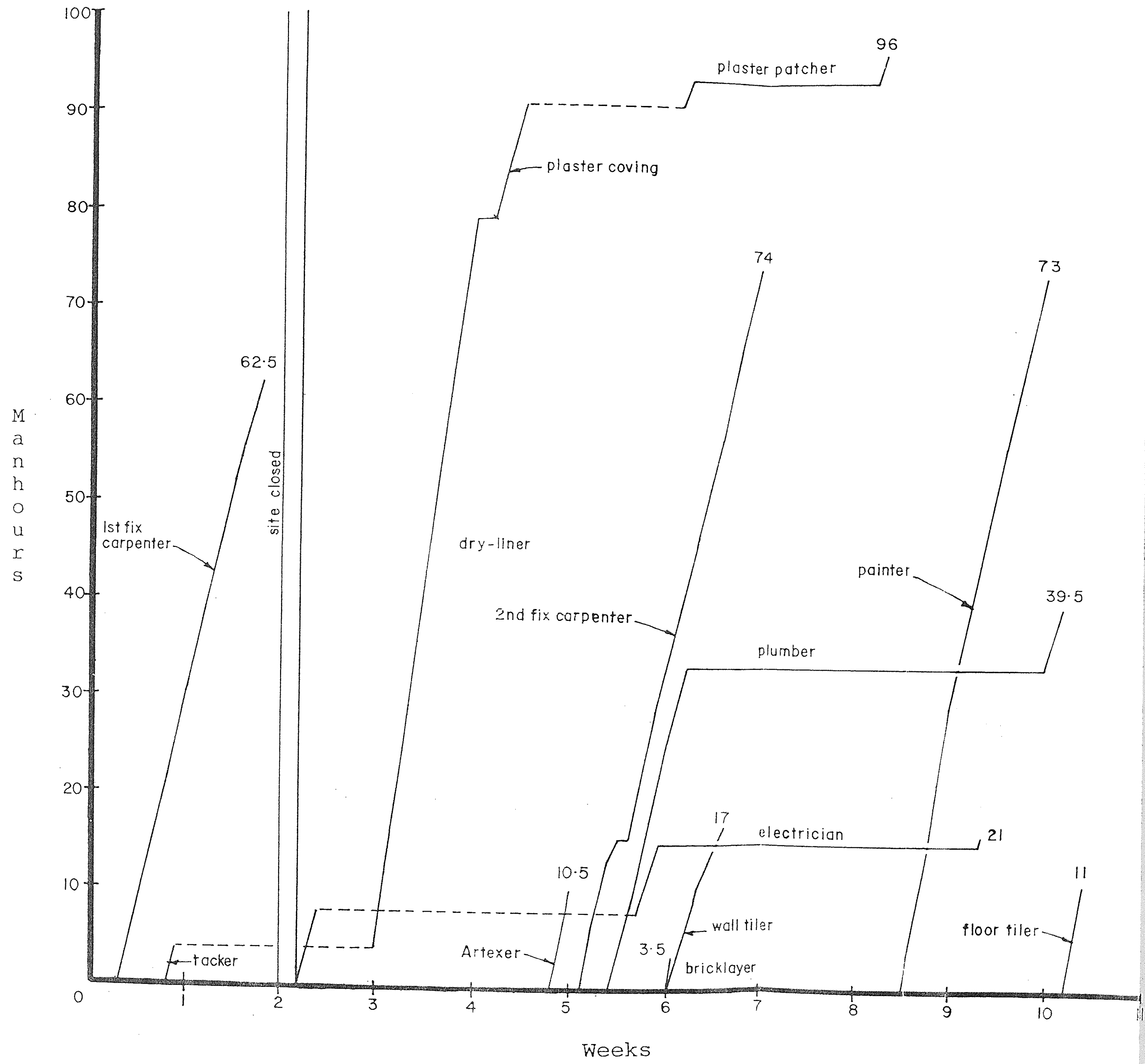

Fig.22: Graph of progress (Plot 43)

The 1st fix carpentry, 2nd fix carpentry, plumbing and painting work have been examined in some detail because it was these areas where the greatest differences in manhours were shown to be evident. Differences in average manhour requirements were evident for the other trade operations, but these were not as distinct. For the purpose of this analysis, the qualitative data has been examined for the best control plot, determined by the lowest total manhour requirements. This is then compared to the first and last experimental plots for both of the house types, where the findings/results for these later plots should show improvements due to learning curve experience.

7.6.1 1st fix carpenter (Shakespeare)

Plot 18 was shown to account for the highest average manhours for the Shakespeare house types (138), with plot 43 representing the lowest (62.5). The high manhour requirements to complete this work, compared to the manhour figures available for plots 26, 27 and 28, can partially be explained by the increased work content for the carpenter in the experimental plots and also by learning curve experience. The qualitative records show other important factors to have been significant in influencing this large variation between experimental and control plots. These include problems with communication, attitudes, poor quality working information and site organisation and control.

When the 1st fix carpenter commenced work on plot 18, the first of the experimental group (abortive experimental), it was noted that the carpenters had not been briefed on the objectives of the study. One of their first tasks was to form a trimmed floor duct in the joists, which was to serve as a service distribution area. This had not been created earlier by the carcasing carpenters because drawings detailing the extent of the work had not been sent to site in time. When working details were eventually sent to site, these were shown to be lacking in information.

Materials delays were shown to be another significant problem on this plot. This was because an inadequate quantity of sheet flooring material and timber had been ordered. The reason for this was the fact that this method of flooring was new to LHM and no allowance had been made for cutting and wastage. Better site organisation and communication could have identified this problem at an earlier stage.

Another significant problem concerned inaccurate superstructure work. The staircase installation work was made difficult because the blockwork forming the stairwell walls had not been constructed as shown on the main layout drawing. Dimensional errors of + or - 50mm were commonplace.

The drawings showing the position of duct positions were shown to be impractical for some situations. For example, access ducts were shown in positions where they could not be lifted without obstruction from skirting boards. These problems caused certain tradesmen to become disenchanted with the working method. As a result, complaints were made to the head office about the extent of the carpenters work, and it was suggested that this element of the experimental working should be abandoned.

These problems were compounded when inadequate communication between the Design and Sales departments concerning the extent of the experimental work meant that the sheet flooring laid in plot 18 had to be removed on request of the purchaser. The collective effect of these problems, which could have been overcome with proper planning and communication, was that the majority of carpenters involved in this work developed the attitude that the proposals were totally impractical and would therefore fail. This situation was exacerbated still further as site management frequently removed labour from this plot to carry out work elsewhere on site. Because of the problems experienced with the prospective purchaser over the choice of flooring material, it was deemed necessary that plot 18 should revert back to a normal production house.

When work commenced on plot 20, the second of the designated experimental Shakespeare houses, many of the problems experienced on plot 18, were replicated. The most noticeable of these concerned the access as extra time was spent refining the access routes which had already been established by the Design department. During the refining process, plywood duct covers were prepared to be laid over the main pipework ducts and tongue and grooved flooring was substituted for the sheet flooring which was shown to be a problem in plot 18.

Work on plot 43, the fourth of the designated Shakespeare experimental houses, proceeded with few interruptions. The refinements introduced in plot 20 were subsequently repeated in plots 42 and 43 and were shown to work well. The average manhour requirements for this work fell from 99 on plot 20, to 73 on plot 42, then still further to 62.5, on plot 43. This suggested that the carpenters were undergoing a learning curve experience and that this improving process would follow on future plots employing the same approach.

7.6.2 1st fix carpenter (Lichfield)

The 1st fix carpentry work undertaken on plot 38 was a familiar work operation to the tradesman 105, who was responsible for much of this work on the Wentworth Park development. The work proceeded without problems and was completed during a single visit over a period of 4.5

days. The speed with which the work was carried out can be explained by a familiar work context and by the fact that the carpenter was being paid a lump sum price for the work. It was in his interest to complete quickly and efficiently.

The same tradesman was jointly involved on the experimental work in plot 17, together with 108. Since undertaking work on plot 18, both of these tradesmen had voiced opposition to the experimental method of working. Because of this, they were being paid 'daywork' (an hourly rate of pay) for this particular element of their work. This invariably affected the time taken to complete the work. There was little incentive to sort out problems quickly because they were being paid regardless of whether they were actually producing or not.

The time taken to complete the 1st fix carpentry in plot 17 was 64.5 manhours. This high figure can be explained in the terms previously described and by the access problems, materials shortages and dimensional inaccuracies, which were found to create set-backs in all of the first few experimental plots. The average manhour figure can still be seen to be less than that for the first experimental Shakespeare house type and this can generally be explained by the rationalised nature of the plumbing and heating access arrangements.

The carpentry work on plots 30 and 31 was undertaken by a new gang of 1st fix carpenters who were uninfluenced by the attitudes and views expressed by the existing carpentry gangs on site. This gang were keen to obtain further work with LHM and as a result viewed the proposals without bias.

The work on these plots was carried out considerably faster than that in plot 17 and was of good quality. This was because many of the impractical access arrangements, initially shown on the layout drawings, had since been revised. The relative success of the work at this stage suggested that had the correct information been available from the outset, then the extent of the resultant problems would not have been so distinct on the first few experimental plots.

The manhours required to complete the work on plot 31, the best of the experimental plots, was ten and a half hours longer than the average time taken to complete the conventional 1st fix carpentry operations on the control houses (based on the average manhour requirements for plots 25, 37 and 38). This extra time does not appear excessive when considering the additional work which had to be undertaken by the carpenters.

7.6.3 2nd fix carpenter (Shakespeare)

The time taken to complete the 2nd fix carpentry work on plot 18 was 145 manhours. The extraordinary high manhour figures observed for this plot and plots 20, 25 (control Lichfield) and 26 can partly be accounted for by the performance of tradesmen 106 and 107. These particular operatives were observed to be extremely slow workers, who consistently took longer to complete operations than other tradesmen doing the same work.

The 2nd fix work in plot 20 took place over a period of 26 days, during ten separate work visits. This work operation had commenced too early, and progress was undoubtedly affected by a number of other trades who were found to be working in the house at the same time as the 2nd fix carpenters.

The main problem experienced on plot 20 concerned the installation of pre-hung doorsets. The doorsets were intended to be offered into structural or partition wall openings during second-fix carpentry work but this was not possible due to inaccuracies in the blockwork and partition openings. A considerable amount of adaption work was required before the doorsets could finally be offered into position. The need for improved accuracy during superstructure construction was identified as being a crucial consideration if the doorsets were to be installed without problems.

This problem was not repeated on plots 42 and 43 because the bricklaying and 1st fix carpenters had been informed about the problems and were instructed to take greater care when setting-out. As a result, the door openings were prepared to the correct tolerances and doorsets were installed with relative ease. The manhours requirements for this work dropped from 143, in plot 20, to 74, over two work visits, in plot 43. This is important because it demonstrates the fact that the proposal of utilising doorsets was valid. However, the poor workmanship which initially prevented their successful application was not anticipated.

One of the noticeable quality gains concerned the use of pre-assembled balustrading, which, due to its success, was subsequently used on both the control and experimental plots. The pre-hung doorsets, despite fitting difficulties, were of good quality and were acknowledged by the tradesmen as offering a sensible alternative to site-hung doors. Several problems were still evident with the installation of kitchen units, including incomplete component parts and dimensional inaccuracies which prevented straightforward fitting.

7.6.4 2nd fix carpenter (Lichfield)

The 2nd fix carpentry work in plots 37 and 38 was familiar to the 2nd fix carpenters and took 53 manhours to complete in plot 37 and 57 manhours in plot 38. However, an initial delay was experienced in plot 38 and later in plot 37, due to material shortages.

The high manhour figure of 75.5 observed in plot 17 was partly due to problems when fitting the doorsets, but was mainly accounted for by materials shortages. Both the kitchen and wardrobes fittings for this plot had not been ordered and this resulted in a total of 7 separate work visits to the house over a period of 34.5 days to complete small amounts of outstanding work. The carpenter was also observed to start work too early in this house.

The same work was completed in 66.5 manhours in plot 30, and 68.5 manhours in plot 31. Unfortunately, the problems experienced with the doorsets was also repeated on these plots. Again, it can be assumed that these figures could have been significantly reduced had the door openings been formed to the correct sizes. Further delays concerning the delivery of kitchen units also caused interruptions for the carpenter in plot 30.

7.6.5 Plumber (Shakespeare)

The plumbing work in plot 18 was shown to be chaotic. The work operations took place over a period of 40 days, during 12 separate visits. This plot had reverted from an experimental to a control plot after the 1st fix carpentry work, and as a result, a conventional carcase operation was undertaken. The plumbers found this work operation to be easy because they were able to lay pipework runs, from an existing floor, into pre-formed pipework routes.

The causes of the various delays were wide and varied, but mainly concerned intermittent working, where a small amount of work was done before leaving the house to continue working elsewhere on site. The total manhour requirements of 64.5 manhours for this work could have been substantially reduced had better site supervision been evident.

Work on plot 20, was shown to be fraught with problems. These were caused by difficulty experienced when making pipework connections through some of the access ducts; by inaccurate 1st fix carpentry work, which meant that the bath and shower tray could not be fitted first time; and by the general attitude of the plumbers who were reluctant to accept the new method of work. This latter point is probably the most significant, because the plumbers believed that by decrying the approach they could prevent the continuation of this working method on the remaining experimental plots. The basis of the approach was not too different to the installation of plumbing and central heating in existing dwellings. But, it was undoubtedly more exacting than installation by more conventional means.

The same work was undertaken far more successfully in plots 42 and 43. This is shown by the comparatively low manhours requirements of 47 and 39.5 hours for these two plots. The reduction in manhours taken to complete this work can be accounted for by improved learning experience, but most importantly by the fact that the plumber's were now more in favour of the working method. This change in attitude was attributable to LHM, who refused to compromise and abandon the retro-fit access approach on the experimental plots. The experiences derived from work on plot 20 were of benefit to the plumber's in their subsequent work because they were able to overcome many of the access problems more quickly.

The adoption of floor mounted combination boilers proved to be the main success in this particular house type. By siting the boiler in a cupboard off a small bedroom it was possible to reduce the length of pipework runs which had formerly been made. Pre-finished radiators were found to offer an obvious quality gain and were used very successfully on these and all other plots on the site.

7.6.6 Plumber (Lichfield)

The work undertaken on plots 37 and 38 was completed in what would appear to be very acceptable times of 32.5 and 34.5 manhours respectively. When this is seen in the context of other factors, a different conclusion might be drawn. In plot 37 the work operations took place over a period of 61.5 days, during 4 separate visits. In plot 38, the same work took 58 days over 6 visits.

The time taken to complete the work in plot 17 was very high at 71 manhours, but must be seen in the terms of refining access problems, previously described for plot 20. The events relating to this plot have been separated from the data set and are included in Appendix 2. This shows, in case history form, the observations made for the plumber trade in this particular plot. It can be seen from this data extract that problems with water pressure and communication meant that the combination boilers proposed for this house type had to be abandoned. If the time spent reworking the plumbing and heating systems is taken into consideration, an actual manhour figure of 58.5 can be derived for the time which could have been expected to complete this work.

A similar conclusion can be drawn from the results derived for plots 30 and 31. When the rework element is deducted, again due to replacement of the combination boilers, the total manhours requirements can be shown to be 27 and 31.5 manhours respectively. This shows a marked improvement over the time taken to complete this work in the control plots 37 and 38. Furthermore, the work was shown to be completed in a much shorter duration (15 and 5 days), and in the case of plot 31, during a single visit.

7.6.7 Painter (Shakespeare)

The painting work in plot 18 was carried out in 76 manhours in 3 separate work visits by the painter 808. This figure can be seen to compare closely to the values determined for the same work in plots 15 and 16 (both at 80.5 manhours). These typical values provide a sharp contrast to that concluded for plot 20, where the same painter took only 45 manhours to complete the work.

This reduced manhour value was mainly attributable to the early painting approach, whereby the painter emulsioned all walls in the house after the Artexer had completed work. This entire part-operation was completed within a few hours. By doing this, follow-on trades, such as the plumber and electrician, were able to fix their fittings directly to pre-painted walls. This resulted in noticeable quality gains because these fittings were clean and unmarked by paint.

The same order of improvement was expected in plots 42 and 43 but this did not materialise. In plot 42, the work was undertaken by a new gang of painters, and the high manhour figure of 69.5 hours was directly attributable to the over-sized painting gang assigned to do the work. In plot 43, the early part-operation approach was not followed because the painter was not instructed to start the work on time by site management. This resulted in the manhour requirements soaring to the high figure of 73 manhours. These high values were determined despite the fact that no major problems were experienced on either of these plots. This fact would suggest that there were in fact benefits in adopting an early painting approach.

7.6.8 Painter (Lichfield)

The painting work in plot 38, the best of the Lichfield controls, took 52 manhours to complete, and 53 manhours in plot 37. Both of these plots were completed during the normal single work visit.

The benefits of the early painting approach reduced these requirements to 46 manhours in plot 17, despite the fact that the work was carried out in 4 separate visits, and not the 2 originally intended. The last 2 work visits can readily be accounted for because these were necessary to make good after the plumbers had complete their rework in this plot.

In plot 30, the values dropped still further to 39.5 manhours, but rose sharply to 72.5 in plot 31. This large increase in manhour requirements was due to the size of the painting gang. Three men were working on this plot when only one was actually necessary. These findings suggested that given a correct gang structure and an early painting approach, the average manhour requirements for painting work could consistently be maintained at around 40 hours for this particular house type.

CHAPTER 8

8.0 Conclusions

8.1 The importance of site monitoring to LHM

The fieldwork data gathered during the course of this study provides an extremely valuable, and unique set of measurements, which have been used to determine levels of productivity for site based work on LHM developments. The data also provides information, in qualitative form, which attempts to explain why variations in manhours can occur for undertaking what appear to be similar work operations. This form of data can also be used to identify problems which have resulted in unacceptable levels of quality, or conversely, highlight areas where design and construction changes have resulted in improved quality and productivity levels. The conclusions have been grouped together under three headings; those which are a result of the quantitative analysis of the database; those which are related to interpreting the qualitative data recorded; and those which are purely anecdotal in nature.

The data set generated from the fieldwork was considered very important by the LHM Management Team. It was seen as irrefutable evidence of what actually happened on their sites on a day-to-day basis. Some of the wide range of individual qualitative points sited in the data set were known to exist, but had at no point been collated into 'case history' form to demonstrate the collective effect that various problems can have on productivity and quality.

Although the 1st fix carpentry and plumbing process changes did not yield anticipated improvements, this must be seen in the context of applied research, where factors outside the control of the research may affect results. The type of factors concerned include inadequate communication of intentions, individual's attitudes to innovation, ineffective site organisation and control, and lack of planning.

LHM have not allowed these significant problems to distract from the importance of site monitoring and development cycles. They readily conceded that an abundance of factual information had been gathered concerning productivity and quality issues on their developments and this could form the basis of subsequent work. The firm have now actually expanded on this commitment, which continues within a Research and Development function at their Tamworth office.

8.2 General conclusions resulting from the site work

A total of ten general conclusions were drawn during the collaborative work with LHM. These were later discussed with LHM and are seen as conclusions which could equally apply to any major volume house builder where similar problems are known to exist. Included in these, are some fundamental issues concerning 'quality' systems. These are areas which need to be addressed prior to the radical proposals advocated by the study being further applied.

The conclusions are as follows:-

<u>Quantitative conclusions</u>

1. The principal of development cycle philosophy was shown to work well with general improvements in productivity over time evident for the bricklaying, wall tiling, Artexing, painting and floor tiling trades. The plumbing work operations were also shown to be fairly productive on the latter experimental plots after rework hours had been discounted;

<u>Qualitative conclusions</u>

2. A 'quality management' philosophy should be adopted if LHM are to resolve many of the communication, attitude, organisation and control issues, which clearly influenced the outcome of trials on their sites. This philosophy needs to extent from Managing Director level through to individual subcontractor operatives on site, where the 'right first time' philosophy needs to been seen to work for everyone;

3. A greater degree of integration is required for research and development proposals to succeed, not only between the design and construction functions, but also between them and their subcontractors and suppliers;

4. When faced with strict sales completions dates, site management tended to compress the majority of the services and finishings work into a short time period in an effort to complete on time. This results in poor quality. Future trials need to be conducted without time constraints to ensure that changes are properly implemented. This takes pressure off site management and is likely to result in better quality and more efficient working. Only when design and construction changes have been refined and are shown to work, should they be introduced as new production work practices;

5. Productivity improvements may be used to offset the cost of incorporating higher quality components within a building;

6. Improvements in productivity, and particularly quality, can be achieved by bringing finishing work earlier into the building programme;

Anecdotal conclusions

7. Research and development work must be adequately funded for it to be of value. There is no benefit in conducting site trials if site management and subcontractors view the trials as 'one-off' experiments. This can only be achieved if firms actually invest in this type of work and stress its importance with respect to the future growth and development of the company;

8. Improvements in quality and productivity can be made by house building firms by directly applying the design and construction philosophy to an existing product range and by implementing specific proposals in a controlled manner;

9. An improvement in terms of cash flow can be achieved by moving expensive, capital cost work items such as plumbing, heating and joinery work to the latter part of the building process where work can be paid for with the monies resulting from the sale of houses;

10. Site operatives may respond positively to a rationalised work context, particularly where their level of income is directly related to their level of output.

8.3 Design and construction rationalisation

The problems faced during site work can largely be overcome by proper management control at the early stages of design. This is the stage at which firm policies need to be established relating to the quality of specification and the degree of design and construction process rationalisation which can practically take place on site.

Most sites, including LHM sites, appear on the surface to be disorganised with men and materials spread around. This leaves very little scope for trade operatives to work coherently. Construction process rationalisation, which will facilitate coherent work, can only occur effectively if designers have a greater input. To do this, designers must be fully aware of the problems faced by the site team. In addition, designers must achieve the following to enable their production team on site to work steady and continuously:-

- Rationalisation of the building work into large work operations in order to increase the work time spent on site from a few hours to a minimum of one day's continuous work for each operative (whenever possible);

- Remove unnecessary tasks by re-design. Manufacturers in other areas are now involved in this process in order to improve productivity;

- Remove the need for depending on other subcontractors work/components to provide a fixing base. This then removes the need for breaking off from work and subsequent visits;

- To specify the assembly of more complex components off-site and include more pre-finishing. As productivity and quality levels off-site tend to be better than levels on-site, progressively more work should be removed from site. However, the movement of more work off sites is likely to result in higher transport costs so this proposition should be studied in more detail in relation to the work actually carried out on site. As an alternative solution, the conditions on site must more closely resemble those in a factory, which could result in better quality and productivity;

- Design and construction integration should ensure that on each single visit work can be finished in its entirety as far as is practically possible.

By consistently applying these principles, the motivation of operatives will increase because they will see that their work operations have been carefully considered by management care and who are interested in benefits not only for themselves, but also for their employees.

8.4 Site organisation and control

If a workforce is to retain high morale it is imperative to improve working conditions. Masonry housebuilding has intrinsic problems because site work can be wet and dirty and physically demanding. There are two aspects to this problem, namely site organisation and control.

Site work can readily be broken down into a number of operations, with each operation being carried out by identifiable trades. Because of the dispersed nature of building work, each operation is normally carried out at a number, and sometimes a large number, of workplaces. For example, in house building, work comprises a number of individual workplaces. Therefore, a trade tackling an operation will move from workplace to workplace to be followed by trades tackling subsequent operations. In such circumstances, a queuing situation arises in which the available workplaces may be considered as customers awaiting service by the next gang in the sequence of construction.

If one trade is held up, the effect is passed down the line. Subsequent trades can either be delayed by the same time period or speed up their operation by deploying additional labour (if this is possible). Alternatively, the follow-on trade may also be delayed for some reason. This combined effect is then passed onto the next trade and so on. Site Management are then faced with the difficult task of controlling and co-ordinating this process to minimise problems.

Frequently site management adopt the solution described in point 4 of the general conclusions, and 'flood' houses with labour in an attempt to make up lost time. All too often this only serves to exacerbate the situation because trades get in one another's way. The problem which exists is one of how long should be left between successive trade operations to ensure that the affect of delay is not passed on. The situation is further complicated in practice by the employment of specialist subcontractors, some of whom might tackle comparatively limited operations yet expect to have a substantial proportion of their work available each time they come onto a site.

If there is no particular necessity to build quickly, the difficult organisational problems implicit in this situation can be resolved by creating a large number of work places for every trade, so that each trade is able to continue an operation somewhere on the site on completion of a task. In reality, this is not always possible because a slow build rate is often indicative of a difficult sales market. If market conditions are difficult, firms will invariably reduce their work in progress to minimise production costs.

The extreme solution is for each gang to complete one operation throughout the whole site before the next gang commences work, which leads to an inordinately long building time. In view of this, a balance has to be struck between building speed and the time interval between successive trade operations. Building slowly makes few demands on management and nearly always leads to lower non-productive time but increases the overheads and funding costs; building quickly probably increases non-productive time (unless adequate control is given to resources, labour, materials, plant and so forth) but reduces overhead costs.

The circumstances described are ideal. In reality, a dire shortage of skilled labour, a rapid turnover of available labour, technical problems, delayed delivery of materials, lack of instructions and so forth all combine to make a mockery of planning, and the day-to-day control and co-ordination of work on site. This factors result in a chaotic work pattern, a situation which is clearly shown on some of the graphs indicating the progress of works during fieldwork at Wentworth Park. (Figs. 13-22 in Chapter 7).

8.5 The benefits of improved productivity and quality

The ultimate goal of improved productivity and quality must be to provide tangible benefits for all involved in the production and purchase of new homes. House building firms applying the development cycle philosophy may benefit simply by running ever more efficient businesses.

For subcontractors, past performance will invariably influence future tenders for work because the subcontractors employed will always equate their level of output to the general level of organisation and morale on site. Construction process rationalisation will allow the subcontractors to build more houses more quickly and for less effort, thereby saving costs and improving personal remuneration. At the same time, it could make labour resourcing an easier task when work operations are larger and fewer in number.

Most importantly, the purchaser, that is the end-user, must be provided with a quality home, which benefits from a high standard of design and construction. Homes should be priced to reflect the efficient work practices of the house building firm which has built it. This might mean that a significant cost differential could exist between two developers, building identical or very similar houses on a joint development. The firm employing tried and tested design and construction changes is likely to be able to build not only a less expensive home than it's competitor, but also a home with better quality. For instance, a fairly priced home benefiting from fully finished, maintenance free windows, or better standards of insulation.

CHAPTER 9

9.0 RECOMMENDATIONS AND FEEDBACK FROM LHM

9.1 Refinement of the data collection technique

The data collection technique employed by this study has proven to be very time consuming to administrate. It has been necessary to spend long periods of time on site in order to monitor 'real time' production, where unexpected problems can result in substantial delays to the time which may have been originally planned for site work. The problem of data handling has also been complicated because of the manual data input and checking procedures which were necessary.

The data collection critique needs to be refined in order to obtain further benefit from the qualitative text element. This data has already provided extremely comprehensive information, which can be used to assist LHM in decision making processes. Ideally, the technique could be usefully employed over a shorter period of time, employing the benefit of a reliable data logger system. This would allow data to be quickly and effectively transferred to a computer system for interrogation and analysis. It is extremely important that this detailed data is analysed quickly and efficiently, otherwise there is a risk that the important information derived from it can decline into insignificance.

For this to be possible, it would be necessary to produce a coded framework to identify any frequently occurring qualitative points, where a code would not necessarily distract from the importance of the statement being made. In situations where problems or points arise which cannot be easily categorised, it is important that the diary-type entry system is utilised in order for the message of the data not to be lost or mis-classified.

Having collected and analysed data at this detailed 'micro' level, it should be possible to bring about rapid change. Once changes have been introduced, there may be a difficulty in maintaining them. Site management and subcontractors must learn to develop a positive attitude towards change. If a proposal is seen to be ineffective because a solution to a problem has not been resolved in detail, then it is site based staff and operatives who need to identify this fact and respond accordingly. The design and costing functions need to respond quickly to problems which have been identified on site in order to reduce delay and to avoid rejection of proposals or negative attitudes from developing.

When changes have been established there must be no room for complacency. There may be many changes which require attention and management must ensure that the momentum already established continues to flourish. There is considerable difficulty in preserving change. When changes to work practice are perfected, then subsequent changes are likely to be met with less resistance. As soon as changes are viewed as improvements, because all are benefiting from an improved work context, then little resistance is likely to be offered. Properly managed change and innovation will be seen as on-going improvement and not obstacles to be contended with in the short term.

9.2 Recommendations for further work

In addition to a refinement of the technique already described, an end-of-day type assessment could be employed to deal with the collection of site-sourced data. This might involve shorter periods of site monitoring during a period of production, to first identify problems. During a subsequent site audit the observer might only need to go onto site once, say at the end of each day, to speak to site management and operatives and to determine their progress and work places during the course of the day. Some form of qualitative record is vital if the causes underlying problems are to be identified. Site management and operatives may need to be given training in order for them to become sensitive to what is required for this.

If certain operations are shown to produce more problems than others, then they could be followed more closely. It is clear that there is a prominent need to provide factual data in both quantitative, but most importantly, qualitative form, to show senior management what is actually happening on their sites.

Operational delay surveys, often termed 'foreman delay surveys' could provide another alternative sampling method. These could be implemented when site management have been trained, are aware of what to look for and know how to record facts in a uniform manner. These surveys would invariably have to rely on manual data input methods until computers become commonplace on building sites.

9.3 Operational delay surveys

The operational delay survey (ODS) is a technique involving site managers and is used to identify the many causes of delay encountered on a daily basis on their sites. However small each of these delays may be, their cumulative effect can seriously retard progress on site, leading to overruns on programme and budget. The site manager is the person best placed to identify the causes of delay since he is most directly affected by them and will be primarily responsible for implementing remedial measures.

An operational delay survey requires that each site manager keeps a daily record of all delays and interruptions that affect men under his supervision. He must note the plot, trade, number of men affected, the length of each disruption (any delay of 15 minutes or more), total manhours delayed and the cause of each delay. As an additional measure, the cause of the delay can also be categorised (for instance: weather, subcontractors, suppliers or rework). After the survey period has expired, the sheets are analysed by a survey co-ordinator in order to isolate and address the main problem areas which lead to delay. The format could also be expanded to allow comments to be made on issues which are shown to be affecting quality.

9.4 Work undertaken by LHM since the study

Since completing the site monitoring work and disseminating findings to LHM, many of the work practices identified as causing problems have been addressed. Early Artexing, fireplace construction, plaster coving and dry-linings, are now carried out as normal work practices.

The self finished floor option is no longer considered as a viable proposition by LHM due to the quality of floor finish achieved by some of the groundworker gangs. But, this example can be used to illustrate subsequent change derived from the site feedback. Floor screeding continues to be used, but the work operation has been brought forward in the building programme and now takes place, when the roof is completed, at a point before the carpenter starts work. This means that the 1st fix carpenter is able to fix doors linings and the staircase directly to an established floor level (the carpenters no longer have to carry out packing preparation work). In order for the screeding work to take place, the house under construction has to be thoroughly cleaned out. This means that the carpenter also benefits from a clean working environment - a factor which can have a positive influence on resultant quality.

The retro-fit ductwork arrangements are now used on some house types where the plumbing and heating layouts are rationalised. This normally implies that a bathroom is either sited directly above, or to the side of a kitchen (in the case of apartments). In many instances, this applies to the smaller homes, where combination boilers are also installed. This provides a quality advantage where the space formerly occupied by the hot water cylinder is utilised as a full-height linen cupboard.

In larger homes, thermal storage technology is applied. With this system, all pipework, tanks and insulation associated with the plumbing and heating installation is removed from the roof space. The conventional indirect hot water cylinder is replaced with a thermal storage vessel which supplies mains pressure domestic hot water to all outlets. Added advantages with this system include lower running costs for the consumer, a more efficient heating system and reduced boiler cycling (which can reduce subsequent maintenance costs).

Some of the many difficulties raised during the 2nd fix carpentry work have also since been dealt with. The kitchen and wardrobe installation work, which was formerly undertaken by the 2nd fix carpenter and shown to be a problem when components were delivered to site either incomplete or damaged, is now undertaken by specialist fitters who are employed by the companies who supply the fixtures. This means that available opening sizes and tolerances are considered at a much early stage by the suppliers. This process change has resulted in much improved productivity and better quality.

The principle of pre-assembled and pre-finished components continues to be advanced by LHM. Not only are internal doorsets and pre-assembled balustrading being utilised, but also fully finished, pre-glazed and maintenance-free windows and external door systems.
The added cost, but better quality, of pre-assembling and finishing has shown to be comparable to that of conventional site practices when the cost of the individual items are analysed on an installed cost basis.

Operational delay surveys have also been implemented by LHM. These have proven to be a cost effective way of identifying problem areas. At the same time, the Lovell Homes division have introduced a total quality management system of operation. This extends not only to directly employed Lovell Homes staff, but also to their suppliers and subcontractors. Everyone working for LHM are now far more aware of the cost of not doing work 'right first time'.

Finally, the research and development function created by LHM following the study has been recognised as an invaluable asset. Information and findings resulting from site studies is not only disseminated locally, but is used by all regions within the Homes division. The environment which now exists within LHM was ideally needed during the period of the research work for more wide reaching changes to have been made. Now that an environment conducive to research work has been established, it is far more likely that subsequent fieldwork trials will produce even more successes.

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Appendix 1

Summary of percentage productive and non-productive time (periods 2 and 3)

Summary of data (plot 15)

Trade codes	Duration (days)	No. of visits	F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
			Productive								Non-productive								
108,109,105 (2nd fix)	29	8	18.0	15.0	26.5	1.5	.5			.5	19.0		10.0	2.0		7.0	62.0	38.0	98.5
810,816	1	1	36.5	9.0	4.5		14.0	4.5			18.0		9.0	4.5			68.5	31.5	12.0
808	15	4	43.0	11.0	13.0		14.0				8.5		9.0	1.5			81.0	19.0	80.5
702	7	3	19.0	3.0	31.0		9.5	3.0			12.5		12.5			9.5	65.5	34.5	16.0
907,908	1	1	44.5	22.0	17.0		5.5	5.5			5.5						94.5	5.5	9.0

Summary of data (plot 16)

Trade codes	Duration (days)	No. of visits	F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
			Productive								Non-productive								
703,705,702	4	2	30.5	19.0	27.0		4.0	4.0			11.5		4.0				84.5	15.5	13.0
810,816	1	1	43.0	18.0	14.0		11.0	3.0			11.0						89.0	11.0	12.0
808,809	11	3	43.0	12.5	11.0	.5	11.0				12.5		9.0	.5			78.0	22.0	80.5
907,908	1	1	41.0	11.5	23.5		11.0			6.5	6.5						93.5	6.5	8.0

Summary of data (plot 17)

Trade codes	Duration (days)	No. of visits	F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
			Productive								Non-productive								
108,109,105	14.5	5	19.0	25.0	18.0	4.5				1.5	13.5		11.0	7.5			68.0	32.0	64.5
406,407,430,431,420,423, 424,413	51	8	31.0	22.0	18.5		8.0				7.5		8.0			5.0	79.5	20.5	102.5
302	48.5	4	25.5	17.0	21.0	2.5		2.5			15.0		6.0	4.5		6.0	68.5	31.5	23.0
605,606	0.5	1	22.0	44.5	33.5												100.0	.0	4.5
810,816	2	1	56.0	5.5	16.5		16.5				5.5						94.5	5.5	9.0
110,108,101,107	34.5	7	27.0	16.0	26.0	.5					17.5		11.5	1.5			69.5	30.5	75.5
808	38	4	52.0	5.5	15.0		7.5				11.0		9.0				80.0	20.0	46.0
702	17	3	47.5	9.5	24.0			5.0			9.0		5.0				86.0	14.0	9.5
201,202	33.5	6	12.5	18.5	22.5	1.5			1.0		15.5		11.0			17.5	56.0	44.0	71.0
909	1.5	1	50.0	21.5	21.5						7.0						93.0	7.0	7.0
																			412.5

Summary of data (plot 18)

Trade codes	Duration (days)	No. of visits	F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
			Productive								Non-productive								
105,108,111	23	4	19.0	19.0	22.0	1.0				3.0	11.0		11.0	1.0		13.0	64.0	36.0	138.0
406,407,420,423,424,413	32	3	31.0	17.0	17.0	.5	7.0				15.5		11.0	1.0			72.5	27.5	104.0
201,202	40	12	15.5	24.0	22.5	1.0			1.0		21.5		11.5	3.0			64.0	36.0	64.5
302	24	4	23.0	15.5	28.5			2.5	5.0		18.0		7.5				74.5	25.5	19.5
605,606	0.5	1	16.5	25.0	42.0						16.5						83.5	16.5	6.0
810,815,816,817	7.5	2	25.0	10.0	10.0		20.0	5.0			25.0	5.0					70.0	30.0	10.0
106,107	21.5	6	16.5	20.0	27.0		2.0				19.0		14.0	1.5			65.5	34.5	145.0
702	11.5	3	30.5	13.0	22.0		4.0	8.5			13.0		9.0				78.0	22.0	11.5
808	15	3	44.5	5.5	18.5		6.5				16.0		9.0				75.0	25.0	76.0
907,909	4	3	36.0	16.0	12.0			8.0			20.0		8.0				72.0	28.0	12.5
																			587.0

Summary of data (plot 20)

Trade codes	Duration (days)	No. of visits	Productive F%	H%	P%	SU%	CL%	U%	T%	Non-productive SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
108,109,105	10.5	3	22.0	20.5	24.0	1.0				2.5	16.0		9.5	2.5		2.0	70.0	30.0	99.0
406,407,434,435,436,437, 420,423,412,413,414	35.5	9	26.5	18.0	16.5	.5	8.0	1.0			16.0	1.5	9.5	1.0		1.5	70.5	29.5	99.5
302	35.5	3	27.5	19.5	27.5	1.5		3.0			13.0		8.0				79.0	21.0	19.5
810,815	6	2	47.5	10.5	16.0		10.5	5.0			10.5						89.5	10.5	9.5
808	20.5	2	45.5	5.5	21.0		10.0				8.0		10.0				82.0	18.0	45.0
106,107	26	10	16.0	20.0	28.0		1.5				18.0		10.5	5.5		.5	65.5	34.5	143.0
201,202	22.5	4	20.0	15.5	23.5	6.5			4.5		19.0		8.0	3.0			70.0	30.0	59.0
604,606	0.5	1	37.5	12.5	37.5						12.5						87.5	12.5	4.0
702	10	4	27.5	13.5	27.5		18.0	4.5					9.0				91.0	9.0	12.5
907,908,909,910	9.5	4	31.0	7.0	20.5			3.5			10.5					27.5	62.0	38.0	14.5
																			505.5

Summary of data (plot 25)

Trade codes	Duration (days)	No. of visits	Productive: F%	H%	P%	SU%	CL%	U%	T%	Non-productive: SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
202,206,201	57.5	8	17.5	22.0	32.0			2.5		1.0	20.0		4.0	1.0			75.0	25.0	62.0
105	5	1	31.0	23.5	24.5						7.5		10.0	3.5			79.0	21.0	46.5
406,407,403,404,405, 420,422,413	31.5	5	29.5	15.0	20.0	.5	11.0	1.0			13.0		9.0	1.0			77.0	23.0	100.5
302,309	30	4	14.0	16.0	25.5			7.0	2.5		25.5		2.5	7.0			65.0	35.0	24.0
502,504	1	1	28.5	7.0	22.0		7.0	7.0			28.5						71.5	28.5	7.0
106,107	52	8	12.5	20.0	24.0		4.5	1.0		1.0	19.5	1.0	14.0	2.5			63.0	37.0	168.0
604,605	0.5	1	11.5	33.0	44.0						11.5						88.5	11.5	4.5
810,815,816	5	2	34.0	14.0	20.0		3.0	3.0			26.0						74.0	26.0	18.0
702,704	2	1	17.0	13.0	24.5		7.5	2.0			17.0	4.0	9.5	5.5			64.0	36.0	26.0
805,806	5	1	37.5	9.5	16.0		8.5				16.0	1.5	6.5	4.5			71.5	28.5	89.0
905,906	1	1	15.0	10.0	35.0		5.0	5.0			25.0	5.0					70.0	30.0	10.0
																			555.5

Summary of data (Plot 26)

Trade codes	Duration (days)	No. of visits	F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
			Productive									Non-productive							
201,202	54	3	18.0	19.0	27.0			1.0	2.0	1.5	15.0		12.5	4.0			68.5	31.5	50.5
105	5	1	31.0	22.0	22.0		1.0	2.0		1.0	13.0		8.0				79.0	21.0	37.0
302,301,311	28	4	17.0	21.0	32.0	1.0			1.0		15.0		11.0	2.0			72.0	28.0	26.5
406,407,420,421,413	36	4	35.0	29.0	14.0		5.0	2.0			9.0		6.0				85.0	15.0	100.0
502,503	1	1	21.0	35.5	14.0		1.0				15.5		13.0				71.5	28.5	8.0
106,107	25	7	17.0	20.0	27.0			2.0		1.0	15.0		16.0	2.0			67.0	33.0	166.0
604,603	1.5	2	16.5	34.0	35.0						14.5						85.5	14.5	5.0

Summary of data (plot 27)

Trade codes	Duration (days)	No. of visits	F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
			Productive								Non-productive								
105	7	2	23.0	19.0	25.5			2.5		2.0	13.0		13.0			2.0	72.0	28.0	60.0
406,407,420,422,423,414,	37	5	28.0	20.0	24.0		3.0	2.0			12.0		11.0				77.0	23.0	148.5

Summary of data (plot 28)

Trade codes	Duration (days)	No. of visits	F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
			Productive								Non-productive								
105	6	2	23.0	18.0	31.0	1.0		1.5		2.0	11.5		12.0				76.5	23.5	51.0

Summary of data (plot 29)

Trade codes	Duration (days)	No. of visits	F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
			Productive								Non-productive								
105	5	1	27.5	15.5	28.0		1.0	2.0		1.0	15.0		9.5	.5			75.0	25.0	46.5
406,407,420,423,413	36	4	34.0	23.0	12.0		3.0	1.0			12.0		13.0	2.0			73.0	27.0	100.0
500,502,503	1.5	2	23.0	19.0	24.0						20.0		14.0				66.0	34.0	9.0

Summary of data (plot 30)

Trade codes	Duration (days)	No. of visits	F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
			Productive							Non-productive									
105,112,113,114	10	2	24.0	22.0	28.0	1.5	.5			1.5	11.0		9.5	.5		1.5	77.5	22.5	93.5
406,407,432,433,420,423 413,410	46.5	3	33.0	18.5	16.5	.5	9.0	.5			11.5		6.5	1.0		3.0	78.0	22.0	117.0
302	38.5	4	23.0	27.5	26.0	1.5			1.5		11.5		7.5			1.5	79.5	20.5	25.0
810,816	1	1	28.0	11.0	22.0		11.0				17.0		11.0				72.0	28.0	9.0
604,606	0.5	1	16.5	50.5	16.5								16.5				83.5	16.5	3.0
820,808	30	2	35.5	9.0	20.0		6.5				15.0		10.0	4.0			71.0	29.0	39.5
108,110,105	22	3	21.0	19.5	32.0						12.0		10.0	5.5			72.5	27.5	66.5
702	7.5	4	31.5	16.0	31.5		11.0				5.0		5.0				90.0	10.0	9.5
202,201,207,209	15	4	16.0	13.0	20.0						10.0		8.0		33.0		49.0	51.0	55.0
909,907,908	9	2	59.0	11.5	17.5						6.0		6.0				88.0	12.0	8.5
																			426.5

Summary of data (plot 31)

Trade codes	Duration (days)	No. of visits	F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
			Productive							Non-productive									
113,114,108	6	1	19.0	18.0	25.0	1.0	1.5			1.5	14.0	1.0	10.0			9.0	66.0	34.0	52.5
430,431,406,407,420,423 412,413,414	42	3	27.0	18.0	20.5		5.5	1.0			14.5		10.5	1.5		1.5	72.0	28.0	80.0
302	32.5	2	23.0	23.0	25.0	2.0		2.0			16.5		6.5			2.0	75.0	25.0	20.0
810,815,817	1	1	35.0		10.0		20.0	5.0			15.0		15.0				70.0	30.0	10.0
805,806,821	26	2	37.0	8.5	20.5		7.5				12.5		12.0	2.0			73.5	26.5	72.5
604,606	0.5	1	14.0	29.0	43.0		14.0										100.0	.0	3.5
108,105	5.5	1	21.0	22.0	30.5	1.0					12.5		10.0	3.0			74.5	25.5	68.5
702	1.5	1	36.5	4.5	27.5		13.5			4.5	4.5		9.0				86.5	13.5	11.0
201,202,207,208	5	1	12.0	11.0	14.0				2.5		8.5		10.0	2.0		40.0	39.5	60.5	52.5
909,907	9	2	59.0	9.0	18.0						9.0		5.0				86.0	14.0	11.0
																			381.5

Summary of data (plot 37)

Trade codes	Duration (days)	No. of visits	F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
			Productive								Non-productive								
201	61.5	4	22.0	19.0	26.5	1.5		1.5	3.0		15.5		11.0				73.5	26.5	32.5
105,108	9	2	29.0	14.0	32.0					1.0	10.0		11.5	2.5			76.0	24.0	44.0
404,405,440,441,442,406 407,420,422,413	24.5	4	40.0	18.0	17.0		5.5				10.0		9.0	.5			80.5	19.5	106.5
302	22.5	4	23.5	20.0	30.0			3.5			16.5		6.5				77.0	23.0	20.5
503,502	1	1	25.0	25.0	31.0						12.5		6.5				81.0	19.0	8.0
604,605,606	0.5	1	20.0	20.0	40.0						10.0			10.0			80.0	20.0	5.0
101,110	18	3	28.0	13.0	34.5						14.0		10.5				75.5	24.5	53.0
702	2.5	2	37.5	8.5	17.0		8.0	4.0			12.5		12.5				75.0	25.0	12.0
816,810	1	1	41.0	9.0	4.5		18.0				23.0	4.5					72.5	27.5	11.0
805	6.5	1	51.0	4.0	9.5		9.5				14.0		10.0	2.0			74.0	26.0	53.0
907,908	1	1	40.0	10.0	15.0		5.0	5.0			15.0		10.0				75.0	25.0	10.0
																			355.5

Summary of data (plot 38)

Trade codes	Duration (days)	No. of visits	Productive F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	Non-productive I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
201,202	58	6	20.0	23.0	24.5			1.5	3.0	1.5	14.5		9.0	3.0			73.5	26.5	34.5
105	4.5	1	28.0	18.0	28.0					2.5	12.5		11.0				76.5	23.5	36.0
406,407,438,439,420,423 425,413	37.5	4	26.5	18.5	19.5		6.0				15.0	1.5	11.0	2.0			70.5	29.5	99.5
302	34.5	3	29.0	13.0	31.5			5.5			10.5		8.0	2.5			79.0	21.0	23.0
502,503	1	1	21.5	21.5	21.5		7.0				21.5	7.0					71.5	28.5	7.0
108,110	28.5	3	24.5	21.0	25.5						15.0	1.0	11.0	2.0			71.0	29.0	57.0
608	0.5	1	33.5	33.5	16.5						16.5						83.5	16.5	3.0
702	2	1	32.0	4.5	23.0		9.0	9.0			13.5		9.0				77.5	22.5	11.0
810,816	1	1	41.0	4.5	9.0		13.5	4.5			18.5		9.0				72.5	27.5	11.0
808	5.5	1	57.0	4.0	8.5		10.5				13.5		6.5				80.0	20.0	52.0
909	1	1	41.0	12.0	12.0		5.5	12.0			12.0		5.5				82.5	17.5	8.5
																			342.5

Summary of data (plot 42)

Trade codes	Duration (days)	No. of visits	F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
			Productive								Non-productive								
106,107	4.5	1	20.5	15.0	27.0		1.5	1.0			18.0	1.5	14.0	1.5			65.0	35.0	73.0
406,407,420,422,413	37.5	3	42.5	18.0	10.0		4.5	.5			15.5		8.0	1.0			75.5	24.5	101.0
302	40.5	4	36.0	13.0	21.0			4.5	4.5		12.5		8.5				79.0	21.0	23.0
810,816	1	1	40.0	4.0	20.0		16.0				12.0		8.0				80.0	20.0	12.0
823,824	22	2	42.0	4.5	15.0	.5	7.0				19.0		11.5	.5			69.0	31.0	69.5
201,202	24.5	2	23.5	16.0	26.0			2.0	3.0	1.0	15.0		10.5	3.0			71.5	28.5	47.0
609	0.5	1	28.5	28.5	14.5						14.5		14.0				71.5	28.5	3.5
110	10.5	2	27.5	15.5	24.0	.5	.5				18.5		12.0	1.5			68.0	32.0	68.0
702	1.5	1	34.5	8.0	23.0		11.5				15.0		8.0				77.0	23.0	13.0
907,908	1	1	40.0	10.0	30.0						15.0		5.0				80.0	20.0	10.0
																			420.0

Summary of data (plot 43)

Trade codes	Duration (days)	No. of visits	F%	H%	P%	SU%	CL%	U%	T%	SO%	W%	I%	BK%	N%	A%	RW%	% prod	% non prod	Manhours
			Productive								Non-productive								
111,105	7.5	1	29.5	20.0	22.5	1.0				1.0	15.0		11.0				74.0	26.0	62.5
406,407,420,422,413	36.5	5	39.0	15.0	17.0		5.0	1.0			15.0		7.5	.5			77.0	23.0	96.0
302	36	3	33.5	5.0	33.5			2.0	5.0		14.0		7.0				79.0	21.0	21.0
816,810	1	1	42.0	4.0	12.5		17.0	4.0			12.5		8.0				79.5	20.5	10.5
101	9.5	2	28.5	21.0	22.5		1.0				14.0		11.0	2.0			73.0	27.0	74.0
210,202	25.5	2	21.5	18.0	28.0				2.5	2.5	15.0		10.0	2.5			72.5	27.5	39.5
609	0.5	1	14.5	28.5	28.5						14.0		14.5				71.5	28.5	3.5
702	3	1	35.0	2.5	30.0		11.0	2.5			11.0		8.0				81.0	19.0	17.0
808,822	8.5	1	50.0	4.0	11.5		7.0				16.5		9.5	1.5			72.5	27.5	73.0
908,907	1	1	45.5	9.0	9.0		4.5	4.5			23.0		4.5				72.5	27.5	11.0
																			408.0

Appendix 2

Fieldwork data for PLUMB-17

Hrs Date	Rnd Time	Ref	T	No	St	Opn	Act	Qualitative Data
15MAR88	08.35	201	L	17	16	A	H	The plumbers 201 & 202 start the plumbing and heating installation work on L17. This work is being started far too early, but site management seem intent on completing the house to the build programme date at all costs. In this case at the cost of the experimental sequence previously agreed. 110 has not yet finished his work in the house.
15MAR88	09.05	201	L	17	16	A	H	
15MAR88	09.35	201	L	17	16	A	P	201 and 202 are not at all happy about the experimental work. They complain that they were told the fixing rates for the experimental houses this morning and they are going to be worse off financially as a consequence. Their employer, Peter Stratton has been paid more money overall for the experimental work because of the increased boiler cost (pump, valves, cylinder and additional pipework were deducted). However, he did not give a deduction on the fixing element of the costs. In spite of this fact he has reduced his payment to his employees saying that certain elements of the work will be easier. It now transpires that the plumbers, who were always going to voice some objection to a change of practice, are now very much against this new method of working due to their negative attitude caused by a reduced income.
15MAR88	10.05	201	L	17			BK	201 and 202 have been told to carry out some snagging work after their break on a house which is to be handed over. This practice of taking off tradesmen from their place of work must be avoided.
15MAR88	11.35	201	L	17	16	A	W	
15MAR88	12.05	201	L	17	16	A	H	201 lays and bends pipework to and from the space below the boiler staging. A large access trap was supposed to have been formed by 108 during the 1st fix access preparation work but the drawing was not followed. Instead, 108 has formed a hole which is too small for 201 to comfortably work through.
15MAR88	12.35	201	L	17	16	A	P	This house is now extremely conjested with two plumbers (201 & 202), and two joiners (108 & 110) working in it. The practice of flooding the house with labour to complete work is very common during the S & F operations. It is quite chaotic at first floor level at the present time.
15MAR88	13.05	201	L	17			BK	
15MAR88	13.35	201	L	17	16	A	H	201 complains that the access ducts are in his way when he works and suggests that the normal method of carcassing a house is preferable. At least with this method it should be possible to carry out the main work in one continuous operation without the danger and discomfort of balancing on the chamber joists to carcase. 201 ought to lift the access traps and store them safely in one of the rooms until he has finished work.
15MAR88	14.05	201	L	17	16	A	W	201 points out that a bi-pass valve which he has fitted needed to be 2m from the boiler. He suggests that another floor trap is needed in order to gain access to the valve because it is difficult to turn in the place where he has fitted it.
15MAR88	14.35	201	L	17	16	A	F	
15MAR88	15.05	201	L	17	16	A	P	201 has consulted with the 1st fix carpenter during his preparation work but is still unhappy with some of the access arrangements. In particular, he criticises the access method to the gas supply in the kitchen (from the garage roof void), the height of the clay liner pots (these are too low) and makes a general point that some of the ducts are too small. These problems should all have been resolved before work even started on site.
15MAR88	15.35	201	L	17	16	A	F	
15MAR88	16.05	201	L	17	16	A	F	201 comments on the door to bedroom 2. He says that the door swings into the radiator position and that the radiator must be moved otherwise the door could warp from the heat. He also points out that the electrician has fixed a socket outlet in the same space as the radiator so this will have to be moved. The layout drawing shows the new radiator layout, but does not show the relative position of electrical fittings. It would appear that the electrical subcontractors were not informed of the changes

Hrs Date	Rnd Time	Ref	T	No	St	Opn	Act	Qualitative Data
								or, conversely, did not bother checking to see if there were any differences. Instead of fixing the radiators as planned, 201 leaves this one loose so that the electrician is able to gain access to relocate the socket.
15MAR88	16.35	201	L	17	16	A	H	201 lifts a floorboard access trap in the bathroom in order to gain access to the dining room radiator below. A plywood trap was to have been formed by 108 but this was not done. 201 is suprised at how easily the heating drop pipework feeds down the battened access points in the dry-lined walls. The DPC membrane makes this work easy.
15MAR88	17.05	201	L	17	16	A	F	201 says that this work is more exacting than normal and that it is quite difficult working through the access traps and ducts, especially when hooking through bends to radiator positions at the same level. He quite likes the vertical drop access points behind the dry-lined walls. For all of his complaints regarding the time taken to do the work (it normally takes one man around 3/4 day to complete a carcass), he forgets that they are learning how to work a different way (and this takes time) and with this method they are also extending the vertical pipework and fixing the radiators to ready painted walls. With some refinement, this method could offer real advantages.
15MAR88	17.35	201	L	17	16	A	W	
15MAR88	08.35	202	L	17	16	A	H	The plumbers 201 & 202 start the plumbing and heating installation work on L17. This work is being started far too early, but site management seem intent on completing the house to the build programme date at all costs. In this case at the cost of the experimental sequence previously agreed. 110 has not yet finished his work in the house.
15MAR88	09.05	202	L	17	16	A	P	
15MAR88	09.35	202	L	17	16	A	P	201 and 202 are not at all happy about the experimental work. They complain that they were told the fixing rates for the experimental houses this morning and they are going to be worse off financially as a consequence. Their employer, Peter Stratton has been paid more money overall for the experimental work because of the increased boiler cost (pump, valves, cylinder and additional pipework were deducted). However, he did not give a deduction on the fixing element of the costs. In spite of this fact he has reduced his payment to his employees saying that certain elements of the work will be easier. It now transpires that the plumbers, who were always going to voice some objection to a change of practice, are now very much against this new method of working due to their negative attitude caused by a reduced income.
15MAR88	10.05	202	L	17			BK	201 and 202 have been told to carry out some snagging work after their break on a house which is to be handed over. This practice of taking off tradesmen from their place of work must be avoided.
15MAR88	11.35	202	L	17	16	A	H	
15MAR88	12.05	202	L	17	16	A	P	
15MAR88	12.35	202	L	17	16	A	W	This house is now extremely conjested with two plumbers (201 & 202), and two joiners (108 & 110) working in it. The practice of flooding the house with labour to complete work is very common during the S & F operations. It is quite chaotic at first floor level.
15MAR88	13.05	202	L	17			BK	
15MAR88	13.35	202	L	17	16	A	P	202 is a little more convinced about the merits of this system than 201. He comments that the vertical access points appear to work well and that in principle it is a good idea to be able to complete the work in one continuous operation. He is quite concerned that the work is taking longer to do than the normal control houses because this will affect his take home pay. He sees the plumbers as the 'guinea pigs' on the experimental work- the trade with the most to loose.
15MAR88	14.05	202	L	17	16	A	F	
15MAR88	14.35	202	L	17	16	A	P	202 uses battery powered tools in his work. Early power supplies need to be brought to site to improve quality and productivity.

Hrs	Date	Rnd Time	Ref	T	No	St	Opn	Act	Qualitative Data
	15MAR88	15.05	202	L	17	16	A	F	
	15MAR88	15.35	202	L	17	16	A	P	
	15MAR88	16.05	202	L	17	16	A	H	202 says that the radiators are more difficult to hang in this house. He argues that because the radiators have been relocated from the window walls to a more central position on partition walls, it has been necessary to use toggle fixings instead of plugs and screws. At g.f. level, where there are no partition walls, he says that the dry-lined walls do not have enough plaster dabs behind and the plasterboard deforms as the screws are tightened up. Longer plugs and screws are also need.
	15MAR88	16.35	202	L	17	16	A	W	
	15MAR88	17.05	202	L	17	16	A	P	
	15MAR88	17.35	202	L	17	16	A	W	
	16MAR88	08.40	201	L	17	16	A	P	The plumber now says that he would not feel so bad about this work if he was getting the same money as he was before. He is really annoyed with Peter Stratton for cutting his prices on the experimental houses.
	16MAR88	09.10	201	L	17	16	A	H	
	16MAR88	09.40	201	L	17	16	A	P	The combination boiler system does not utilise storage or header tanks. This means that 201 does not have to carry out work in the dark and cramped conditions within the roof void. This must be a big advantage.
	16MAR88	10.10	201	L	17			BK	
	16MAR88	10.40	201	L	17	16	A	P	201 says that the bricklayers have made up between the joists, but have taken their brickwork as high as normal. They ought to have left a course off so that the plumber is able to feed radiator pipework through the main ducts and then parallel to the joist runs. To overcome this problem 201 has to use a lump hammer and chisel to break out this top course of bricks. This greatly hinders his progress.
	16MAR88	11.10	201	L	17	16	A	F	
	16MAR88	11.40	201	L	17	16	A	P	201 connects up the radiator in bedroom 2. He comments that one of the main problems with feeding long lengths of pipework parallel to the joist span is the presence of herring bone struts which prevent easy routing.
	16MAR88	12.10	201	L	17	16	A	F	
	16MAR88	12.40	201	L	17	16	A	H	The radiator in bedroom 3 has been moved from the far side of the room to a more rationalised position adjacent to the door.
	16MAR88	13.10	201	L	17			BK	210 complains because a plaster patcher boarding and skimming an area of wall above the bath head is in his way.
	16MAR88	13.40	201	L	17	16	A	P	A major critisism with the ducts is that they have been cut too tight and will not lift easily. Those traps against external walls were set too close to the blockwork and are extremely difficult to lift without damaging. This is due to the dry-lining which runs over the top of the traps. Traps need to be set in away from the edges.
	16MAR88	14.10	201	L	17	16	A	H	201 has damaged the dry-lined wall in the cloakroom. Instead of using a pad saw to cut out an aperture and then feed down radiator drops from above, he has used a hammer to knock open a hole. This lack of care will result in the need for plaster patching.
	16MAR88	14.40	201	L	17	16	A	W	201 is unable to lift a duct in the corner of the bathroom in order to drop down hot and cold water supplies to the kitchen sink (via the accessible svp boxing). It is not possible to do this because 108 has nailed the sole plate of the svp boxing (in the bathroom) to the plywood access panel. 108 was never committed to this work and has interpreted details. It should have been clear than vertical access was required at this point. 201 damages some of the bottom course tiles when attempting to lift the corner access trap. This is precisely what 702 was concerned about. The only way in which it will be possible to drop supplies now will be down the side

Hrs	Date	Rnd Time	Ref	T	No	St	Opn	Act	Qualitative Data
									of the kitchen wall (within a new boxing) because access through the vertical duct is impossible.
	16MAR88	15.10	201	L	17	16	A	P	S. Poole, a Stratton foreman comes to site to see 201. The plumber has been working without full information up until now and is unsure whether a separate indirect cold water supply should be taken from a storage tank to the shower control when combination boilers are used. S. Poole has recently been on an installation course at Worcester Engineering (the boiler manufacturers) and says not. 201 asks his foreman several questions regarding take off points from the boiler. Strattons should have sorted out these type of queries some time ago.
	16MAR88	15.40	201	L	17	16	A	W	
	16MAR88	16.10	201	L	17	16	A	F	201 still ponders the possibility of vertical access via the svp boxing to the kitchen below. It is clear that access will be impossible for even if the hot and cold supplies could be dropped vertically at this point, it would then be impossible to route the pipework horizontally through to the sink position. This is because the svp stack is set tight against the wall and is in the way. 201 suggests that on other houses it would be a good idea if he were to make up a series of bends ('L' shaped) which he would then leave in the site storage compound. When the joiner came to fit the kitchen sink base units he could then take one of these bends, form holes in the units and thread the pipework into place, positioning the top of the pipework just through the ceiling finish. This would mean that the interdependence commonly seen at the kitchen sink installation stage would be avoided. The plumber could simply come along after the joiner and wall tiler have finished and make all of his connections at first floor level through the access traps. In fact, this same principle could follow for all vertical plumbing runs. They could be fixed by either the carpenter or dry-liner, whichever is concealing areas where pipes must be routed. This way, the problem of vandalism and theft of copper pipework could be avoided.
	17MAR88	08.45	201	L	17	16	A	H	
	17MAR88	09.15	201	L	17	16	A	P	201 completes plumbing work within the floorspace, the heating circuits and water supply pipework is now in place. He then replaces the floor ducts. It now appears these might be screwed down and fixed by the joiner although there is no reason why this could not be done by the plumber on completion.
	17MAR88	09.45	201	L	17	16	A	P	The plumber is concerned that he will be held up on plot 30 (his next mové) because there are not enough joiners on site. P. Clift does not have enough men to generally meet production needs and has to switch his resources between sites.
	17MAR88	10.15	201	L	17			BK	
	17MAR88	10.45	201	L	17	16	A	F	
	17MAR88	11.15	201	L	17	11	A	H	201 starts work on the sanitary installation. This should be much easier because with this new bathroom layout there are no longer any pipework boxings to work through. The tail-end pipework has simply been brought up through the floor by 201 in the necessary position. However, 201 has complained that in order to do this, he must be very precise.
	17MAR88	11.45	201	L	17	11	A	P	201 offers the assembled bath into position to find that it fits perfectly. This has only happened because checks were made at each stage to ensure that a required dimension was being achieved. Instead of chopping the bath into the wall, an edge sealing strip will be used to make the joint between the bath and wall tiles. 201's only concern is that the bath is secure (normally a metal strap is used to secure the bath to the wall before tiling).
	17MAR88	12.15	201	L	17	11	A	W	
	17MAR88	12.45	201	L	17	11	A	F	110 fits window furniture at first floor level. He is in the way of 201 who now works in the bathroom area.
	17MAR88	13.15	201	L	17			BK	
	17MAR88	13.45	201	L	17	11	A	F	201 uses a power drill and special cutting bit to cut out a hole for the cistern

Hrs	Date	Rnd Time	Ref	T	No	St	Opn	Act	Qualitative Data
									overflow pipe in the tiled wall. 201 had previously said he would knock a hole through.
	17MAR88	14.15	201	L	17	11	A	H	201 has now completed the sanitary installation in the bathroom and it looks very neat. This is a clear quality gain. It is a pity that the wall tiler will have to return to the bathroom to tile a newly extended section of stud wall and to replace some damaged tiles adjacent to the floor trap.
	17MAR88	14.45	201	L	17	16	A	W	
	17MAR88	15.15	201	L	17	16	A	SU	201 has studied the floor mounted boiler unit which has arrived on site and says that it is simply too large and heavy and will be extremely difficult to install. He then goes on to form a hole through the wall (this should have been formed by the brick-layers as the work proceeded) only to find that the flue position fouls with the line of the garage roof flashings. Clearly, this is a major blunder. This problem should have been seen from the start. Lovell's design office were aware that this was a critical position because they detailed the boiler cupboard staging to be higher than normal, presumably to clear the line of the roof. 201 seeks advise. The sub-agent takes great delight in this error commenting 'what has gone right with these houses?' This sort of divorced attitude to R&D work is not good. It appears likely that these boilers will have to be substituted for Heatslave 9.24 boiler units which only have half of the domestic hot water output of the Hi-Flow unit (Hi-Flow is rated at 4 gallons/minute). A meeting will be arranged to discuss the next step. 201 is unable to do any more work on L17 because the kitchen units have not yet been delivered, neither has the sanitary ware for the cloakroom.
	23MAR88	15.35	201	L	17	11	A	H	201 returns to L17 in order to fit sanitary ware in the cloakroom. This work could have been finished off during the main 2nd fix work but 201 is a very discontinuous worker. D. Smith called onto site yesterday to look at the problem with the heating system (not fitting). It was eventually agreed that a Worcester Heatslave 9.24 should be fitted even though D. Manton wanted to revert back to the conventional indirect method. D. Smith said that some good things were coming out of this work no matter what was said by some of the less willing participants to the work. P. Stratton was concerned about the ability of the Heatslave 9.24 to cope with the domestic hot water requirements in the Lichfield but was willing to try out this boiler unit. It was generally agreed that one of the main problems has been trying to adopt new ideas to suit an existing range of house types.
	23MAR88	16.05	201	L	17	11	A	P	201 complains that the wc pan cannot be secured to the power floated concrete floor because his battery operated power drill does not have a hammer action. 201 says that he prefers screeded floors for this reason (minor point considering advantages).
	23MAR88	16.35	201	L	17	11	A	P	The plumber forms an over-sized hole in the external wall for the w.h.b. waste pipework. In order to reduce the amount of making-good necessary, it should be possible for the bricklayer to sleeve the wall during construction.
	24MAR88	09.10	201	L	17	16	A	W	201 comments on the gas carcase access in the kitchen. He says that the restricted headroom in the garage roofspace prevents him from feeding down gas supply pipework in a single length (about 3No short sections would be needed). He says that he will have to let the copper pipe into the plasterboarded wall, but in the process of locating the battened pipe route he has already damaged the plasterboard. All he had to do was to read the measurement to the battened route which is indicated on the working drawing. This pipework could be set in by the dry-liner during his work. He does not fix the pipework but seeks confirmation that it is ok to set the pipe into the wall.
	24MAR88	09.40	201	L	17	16	A	P	
	24MAR88	10.10	201	L	17	16	A	W	201 has formed an oversized hole in the cloakroom boxing in order to connect up to the incoming water supply. He has brought the supply pipework right around the back of the wc pan and up to the w.h.b. position. This looks unsightly and a better route needs to be established. The site agent comes into the house and tells 201 that A32

Hrs	Date	Rnd Time	Ref	T	No	St	Opn	Act	Qualitative Data
									needs to be 2nd fixed urgently and that he should leave work on L17 now. These frequent interruptions do nothing for improved productivity. The site agent complains that Strattons are useless plumbing subcontractors and deploy only two men on site regardless of how many are needed. This set-up suits 201 who is able to pick and choose the well paid work items.
	28MAR88	11.20	201	L	17	16	A	H	The Stratton foreman (S. Poole) delivers a Worcester Heatslave 9.24 boiler unit to site for installation on L17. D. Smith has agreed to try out this unit on site, but has said that if the D.H.W. flow rate is unacceptable it will be necessary to revert back to an indirect system with cylinder and tanks. It is worth trying the boiler unit on this one house as a rationalised heating system is an important aspect of the work. There should not be a problem on the Shakespeare house types because they can easily be fitted with a Hi-Flow boiler units.
	28MAR88	11.50	201	L	17	16	A	W	
	28MAR88	12.20	201	L	17	16	A	H	
	28MAR88	12.50	201	L	17	16	A	P	201 uses a template to set out for the boiler flue position. He comments that the working space in the boiler cupboard is still a little tight. This cupboard was made too narrow by 108 during 1st fix carpentry work.
	28MAR88	13.20	201	L	17			BK	
	28MAR88	13.50	201	L	17	16	A	P	There is no need to form a strengthened boiler stand in the Lichfield house types in future if wall hung boiler units are to be used.
	28MAR88	14.20	201	L	17	16	A	W	
	28MAR88	14.50	201	L	17	16	A	H	201 complains that these boilers are not straightforward like the Potterton units. The 9.24 must be partially stripped down in order to make connections, but this extra time must be offset against the time taken to fit a pump and 3-port valve on an indirect system. A learning process follows any new practice, but 201 does not make allowance for this.
	28MAR88	15.20	201	L	17	16	A	F	201 cannot get a good fixing for the boiler against the back wall because the hole previously made for the Hi-Flow flue fouls with one of the fixing points.
	28MAR88	15.50	201	L	17	16	A	H	
	28MAR88	16.20	201	L	17	16	A	W	201 continues to work on the boiler saying that with a 'normal' boiler this job would have been done long ago. The restricted workspace does not help matters.
	29MAR88	08.55	201	L	17	16	A	H	201 continues with the boiler installation in L17. He completes and then finds a labourer to brick up around the 100mm dia. fanned flue on the external wall.
	29MAR88	09.25	201	L	17	16	A	P	
	29MAR88	09.55	201	L	17			BK	
	29MAR88	10.25	201	L	17	16	A	RW	201 has to remove the 22mm D.H.W. pipework he has already fitted into the floor ducts and replaces it with 15mm. This is necessary because the 9.24 unit has a slower hot water flow rate than the Hi-flow unit.
	29MAR88	10.55	201	L	17	16	A	RW	201 again complains that these boilers are too complicated to fit. The Stratton plumbers ought to have been sent on an installation course with Worcester Engineering because they have never fitted a combination type boiler before.
	29MAR88	11.25	201	L	17	16	A	RW	
	29MAR88	11.55	201	L	17	16	A	RW	
	29MAR88	12.25	201	L	17	16	A	RW	One of the access traps in the floor of bedroom 3 is missing (possibly thrown out by one of the labourers) so 201 is unable to replace it on completion of work.
	29MAR88	12.55	201	L	17	16	A	H	
	29MAR88	13.25	201	L	17			BK	
	29MAR88	13.55	201	L	17	16	A	W	201 makes the various heating drop and gas pipework connections within the garage roof void. This work could easily have been completed as part of the main 2nd fix. It

Hrs Date	Rnd Time	Ref	T	No	St	Opn	Act	Qualitative Data
								is very difficult to carry out the work within the dark roof void.
29MAR88	14.25	201	L	17	16	A	F	
29MAR88	14.55	201	L	17	16	A	F	201 cuts a large vertical chase into the kitchen wall and sets in the gas carcase pipework. This drop could have been made from above, but 201 was not prepared to feed down and joint three separate sections of pipe.
29MAR88	15.25	201	L	17	11	A	W	
29MAR88	15.55	201	L	17	11	A	H	201 cannot complete the installation work in the cloakroom because the w.h.b. has not yet been delivered to site.
30MAR88	09.00	201	L	17	16	A	P	201 suggests that in future, the supply pipework should be dropped down from f.f.l. in a boxing adjacent to the door/w.h.b. The pipework now has to run from the w.h.b. and behind the wc pan to the boxing position.
30MAR88	09.30	201	L	17	16	A	H	201 is unable to carry out any more work in L17. He cannot fix the sink unit until the kitchen fittings are fitted and he cannot heat and water test the heating system until the electrician has finished off the final fix work.
30MAR88	10.00	201	L	17			BK	
30MAR88	09.00	202	L	17	16	A	P	
30MAR88	09.30	202	L	17	16	A	P	202 extends and secures the gas supply (dropped down from f.f.l.) adjacent to the fireplace. Site management have suggested that the access traps are no longer needed after the plumber has completed his work and therefore they can be boarded over after by the plaster patcher.
30MAR88	10.00	202	L	17			BK	
11APR88	12.00	202	L	17	11	A	H	808 contacts a plumber and requests that the waste pipework is finished off in the cloakroom. There is absolutely no reason why the plumber could not have finished this waste pipework weeks ago. 201 is not fond of finishing off the smaller (and less well paid) jobs and tends to leave these for 202 to finish off.
11APR88	12.30	202	L	17	11	A	P	202 works on site by himself today and says that he is under a lot of pressure. His workmate, 201, is attending a two day course on the installation of unvented hot water systems. It appears that Strattons are aware that new practices and products are inevitable and they must train men to keep abreast of new developments.
25APR88	11.15	201	L	17	14	A	W	The gas supply to L17 has now been connected (this should have been done weeks ago) and so 201 sets about testing the combination boiler heating system.
25APR88	11.45	201	L	17	14	A	H	Before 201 is able to test he has to fit a copper overflow pipe to the pressure vessel sited on top of the main boiler (used instead of a header tank). This job is very awkward to do because it has to be carried out in a confined space. 201 rightly points out that the combination boiler units are best sited in a kitchen location.
25APR88	12.15	201	L	17	14	A	P	It is not necessary for 201 to fit insulation in the experimental houses because they do not have any pipework located in the roof space.
25APR88	12.45	201	L	17	14	A	F	
25APR88	13.15	201	L	17	14	A	W	201 has been unable to turn the water supply on to test the heating system and water supplies. It appears very likely that the stop tap outside has been buried (this is a common problem because protection is not afforded). A labourer is asked to dig out the stop tap whilst 201 continues work elsewhere on site.
25APR88	14.15	201	L	17	14	A	P	The plumber returns to L17 to find that the water supply has been located. A piece of hardcore had dropped down the duct and prevented the wheel head from turning.
25APR88	14.45	201	L	17	14	A	T	201 fires up the boiler and then runs the taps. He deals with the odd loose fitting but then realises something is wrong upstairs. It turns out that the water which was running into the bath then ran out onto the floor and through the ceiling below

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because the 'U' trap had been removed (this should have been spotted before the joiner fixed the bath panel last week). The water runs out and soaks the kitchen ceiling causing damage. He quickly obtains another trap and then continues the test.

25APR88 15.15 201 L 17 14 A W The heating side of the system has turned out well and the radiators heat up very quickly. However, 201 now points out that the DHW supply rate is too low. If supplies are all turned on at first floor level, then the supplies to the kitchen and cloaks are starved altogether. 201 is quite amused about this and goes off to tell the site agent.

25APR88 15.45

25APR88 16.15 201 L 17 14 A W 201 is unable to continue work on this house and so arranges the necessary men and materials required for a conventional heating and hot water system. This problem is blamed directly on the experimental proposals by site management and the plumbers. It is really no good these people complaining after the event when throughout the monitoring work and Lovell design meetings it was stressed that the boiler suppliers and Strattons should get together to design a working system. Strattons have not really put much effort into this work and are only really wise after the event. Likewise, too little communication has taken place between the design office and site about the proposals. The office have simply left site with a set of drawings and expected them to get on with it. The people on site have generally not been briefed about the experimental work and have regarded the whole exercise as a one off and the sort of outcome which has been seen with the combination boilers will only strengthen this belief. D&C must be more integrated and goals clearly laid down if real improvements are to be made. Combination boilers are now commonplace and the problems which have led to their rejection on this group of houses must be overcome.

26APR88 08.20 201 L 17 16 A RW The plumbers (201, 207, 208 and 209) commence work in the Lichfield house types. They have been instructed to remove the combination boilers and the majority of the DHW supply pipework (because this is in 15mm) and refit the house with a conventional boiler, tanks and hot water cylinder. Additional expansion and separate cold supply pipework for a shower will also have to be installed. Nothing else can be said about this situation except that this is the cost of insufficient pre-planning, communication and poor attitude to innovation within the firm.

26APR88 08.50 201 L 17 16 A RW

26APR88 09.20 201 L 17 16 A RW A carpenter has returned to L17 in order to install a tank stand in the roof void. This job is awkward because it now has to be carried out in virtual darkness. Also, the carpenter is in the way of the plumber.

26APR88 09.50 201 L 17 BK

26APR88 10.20 201 L 17 16 A RW

26APR88 10.50 201 L 17 16 A RW

26APR88 11.20 201 L 17 16 A RW The large airing cupboard which was in this house has now been filled up with a hot water cylinder. This was one of the quality gains prior to finding out that the boiler would not be suitable.

26APR88 11.50 201 L 17 16 A RW

Hrs	Date	Rnd Time	Ref	T	No	St	Opn	Act	Qualitative Data
	26APR88	12.20	201	L	17	16	A	RW	
	26APR88	12.50	201	L	17			BK	
	26APR88	13.20	201	L	17	16	A	RW	It emerges that Worcester Engineering have been told about the problems with the 9.24 Heatslave boilers. They request that a water pressure test is carried out on site. This reveals the fact that the water supply to the Stonydelph development is in fact a pumped supply, only giving around 1 Bar (15 p.s.i.). Worcester Engineering state that if Strattons had followed the boiler installation instructions they would have seen that the boilers can only be used with an operating pressure of 2 Bar. The failure of Strattons to carry out a water test is in fact the underlying reason of the boiler's failure to perform. A clear lesson in poor communication if any is still needed.
	26APR88	13.50	201	L	17	16	A	RW	
	26APR88	14.20	201	L	17	16	A	RW	
	26APR88	14.50	201	L	17	16	A	RW	
	26APR88	15.20	201	L	17	16	A	RW	
	26APR88	15.50	201	L	17	16	A	RW	
	26APR88	16.20	201	L	17	16	A	RW	
	27APR88	08.25	201	L	17	16	A	RW	201 continues work in L17. A patcher will need to be brought back to make good where the pipework rises between the cylinder cupboard and roof space. The holes formed at this point are too large. Patching could have been avoided altogether is a brace and bit were used to form the holes.
	27APR88	08.55	201	L	17	16	A	RW	
	27APR88	09.25	201	L	17	16	A	RW	
	27APR88	09.55	201	L	17	16	A	RW	
	27APR88	10.25	201	L	17	16	A	RW	201 has not yet completed work in L17, but due to a shortage of plumbers (202 has taken time off) has had to break off work in order to carcase a house before the carpenters progress too far and are held up. A return visit will be necessary to complete the outstanding work. The pressure has now been taken off these houses and the build programme set back a few weeks.
	29APR88	08.30	201	L	17	16	A	H	201 returns to L17 in order to complete the tank installation in the roof-space. He was previously called off L17 in order to carry out a 1st fix carcase operation.
	29APR88	09.00	201	L	17	16	A	P	
	29APR88	09.30	201	L	17	16	A	F	201 is the only plumber on site at the moment because 202 has taken this week off. He has been under considerable pressure to complete work and has only now got around to finishing off here. Site management's main complaint is with Strattons for never deploying enough plumbers and never providing proper work supervisors.
	29APR88	10.00	201	L	17			BK	
	29APR88	10.30	201	L	17	16	A	F	
	29APR88	11.00	201	L	17	16	A	W	