Managing maintenance of multiple domestic accommodation

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MANAGING MAINTENANCE OF MULTIPLE DOMESTIC ACCOMMODATION

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ABSTRACT

Buildings rarely fail within a short time of commissioning; most become unsatisfactory gradually, over a period of many years, as the design becomes obsolete and/or inadequate maintenance and improvements fail to keep pace with demand. Maintenance work is thus necessary to keep a building in an acceptable minimum condition. The industrialised building methods much used in the 1960s were frequently innovative and, at that time, unproven methods of construction. When these are added to the list of 'traditional build' failure contributors, the need for additional and regular maintenance is increased.

Various factors contribute to domestic accommodation buildings ceasing to be satisfactory – to fail in their purpose of providing a safe, warm and dry environment for the occupants. To the layperson, bad workmanship by the builders, poor quality materials, poor design and inadequate maintenance are common causes for complaint.

This research investigated the cost of maintenance for buildings of multiple domestic accommodation, methods used to organise maintenance planning and budgeting, and considered whether the use of industrialised building methods had affected that cost. The current and anticipated future use of Planned Preventative Maintenance, together with other management methods, as tools for minimising maintenance cost is also examined. A method for introducing a system of planned preventative maintenance that is specifically tailored to individual buildings from a common pattern was developed as an output of this research.

'Designing out' the need for maintenance requires an understanding of maintenance activity cost centres (i.e. where does the money go and what elements of maintenance account for the greatest expenditure?). The way that building professionals perceive potential maintenance cost requirements is therefore investigated and comparison made with actual costs for the same elements of maintenance.

Key Words: *Building maintenance, planned preventative maintenance, maintenance cost categories, multiple domestic accommodation, Delphi technique, industrialised building methods.*

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Chapter 1 - Introduction

In the 1960s, many forms of industrialised building methods were used, with Government encouragement, as part of the national housing policy. Built with a design life of sixty years, many are now some forty years old. Discussions between the author and the managing agents of such buildings at sites in London (Packington Street) and Brighton (The Whithawk Estate) revealed that the maintenance cost of these buildings is beginning to rise to levels that are unacceptable to the owners. The initial build cost of these 'system built' homes, mainly flats in medium or high rise blocks, was proposed to be less than it would have been for more traditional construction. Much of the work did not rely on traditional building skills. Whether the long-term maintenance requirement and costs were given the special consideration they may have warranted, because of the new and unproven techniques being used, is unclear (Finnimore, 1998. Bates, A. CIB 3rd 1996).

In addition to the above, many buildings of traditional construction are much older than their 'design life'. Some, such as 'buildings of historic or architectural merit' cannot be demolished and replaced, even if it would be economic to do so. The maintenance costs of these buildings must therefore be met now and in the future. If it is important that repair and maintenance work should provide 'value for money' and that all necessary works are carried out properly and at minimum cost, priorities will exist where there are limited financial resources. Therefore Architects, surveyors and like professionals need to ensure that their perceived priorities match reality.

Magazines and publications, such as 'Facilities Manager' and the like, promote advertisements for companies offering 'planned preventative maintenance' (ppm) services. Whilst there may be evidence that ppm is used in office building maintenance, no published information was found that specifically quantified the incidence of the use of ppm in the maintenance of domestic dwelling units.

The above raises many questions, including:

- How much does domestic dwelling maintenance cost in the U.K.?
- Is the maintenance of dwellings created by industrialised building methods different to that of traditional construction?
- What are the principal maintenance cost categories?
- Are these categories and their influence on maintenance costs understood by domestic dwelling designers?
- Is the industry 'designing out' maintenance in these and other categories?
- How frequent is the use of pro-active planned preventative maintenance?
- How can planned preventative maintenance be implemented by housing managers without external consultants?

The above list is not exhaustive, but illustrates the core questions behind this research. These ideas, and others relative to the theme, have been framed together into the following objectives:

1 To investigate maintenance costs of traditional and 'industrialised system built' multiple domestic accommodation buildings, and compare their maintenance costs.

2 To identify the principal maintenance cost categories perceived by various construction industry professions and test the hypothesis that 'actual highest cost maintenance categories for domestic dwellings are not the same as those perceived as the highest cost categories by domestic dwelling design professionals'.

3 To measure and compare the use of planned preventative maintenance programmes against other maintenance and repair policies.

Chapter 2 - Methodology

2.1 Introduction

The design of the methodology used for this research commenced with a review of literature identifying and recommending procedures for research projects.

'A body of methods, procedures, working concepts, rules and postulates' is the definition of methodology provided by Webster's International Unabridged Dictionary. The Shorter Oxford dictionary gives a more brief meaning as 'the science of method', where method is defined as 'procedure; way of doing anything, especially according to a regular plan; systematic or orderly arrangement; orderliness and regularity'.

2.2 Sequence of works

Specific reference has been made to Fellows and Liu (1997), who stress the need for rigour in applying the research method appropriate for the subject under investigation. Time planning and allocation to topics is taken from Cryer (1996), strategy selection and check list application from Denscome (1998), and further general reference on methodology from Kumar (1999), who describes methodology as the 'how' of scientific research. A suggested construction management research process flow chart (from Fellows and Liu, source: SERC 1982) is reproduced as figure 2.0 and another, similar flow chart, taken from Kumar (1996), is shown as figure 2.1. Procedures used in this research are shown as figure 2.2, with the sequential activities arising from the methodology illustrated in figure 2.3.

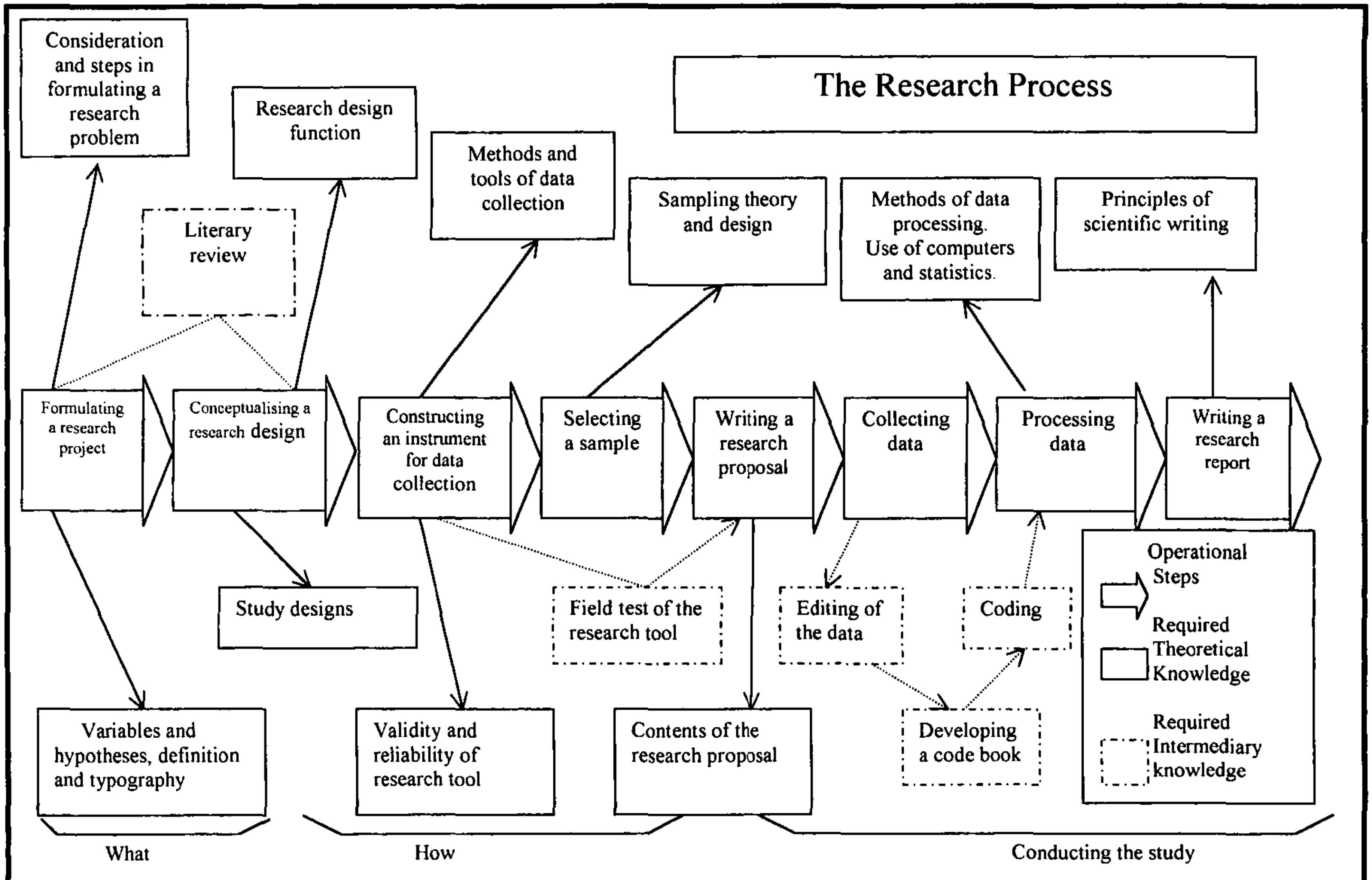


Figure 2.0 – The Research Process from Fellows and Liu, SERC 1982.

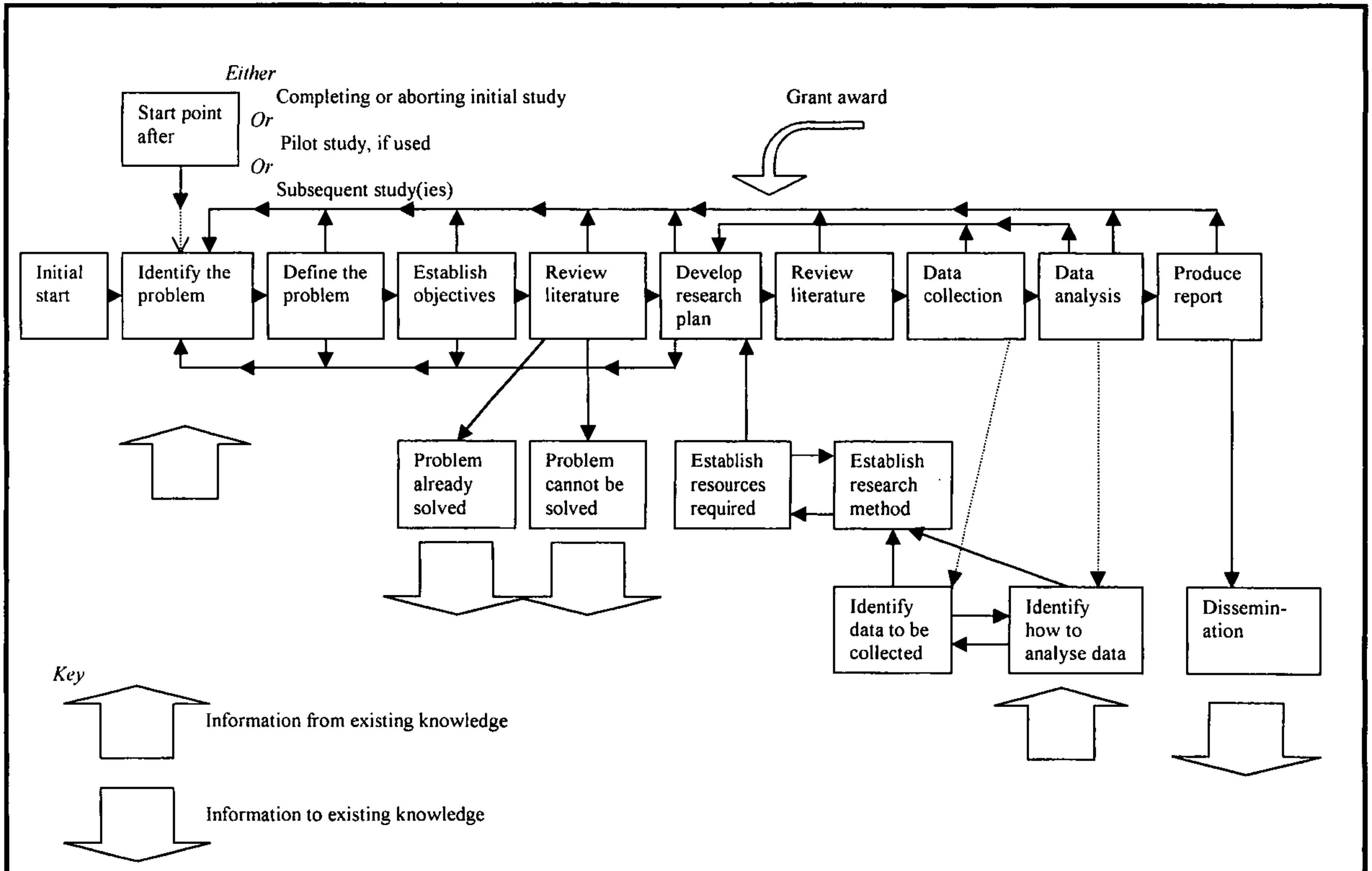


Figure 2.1 – Simplified Flow Chart of the Research Process.
Kumar (1999), not specific to the construction industry.

FLOW CHART OF METHODOLOGY.

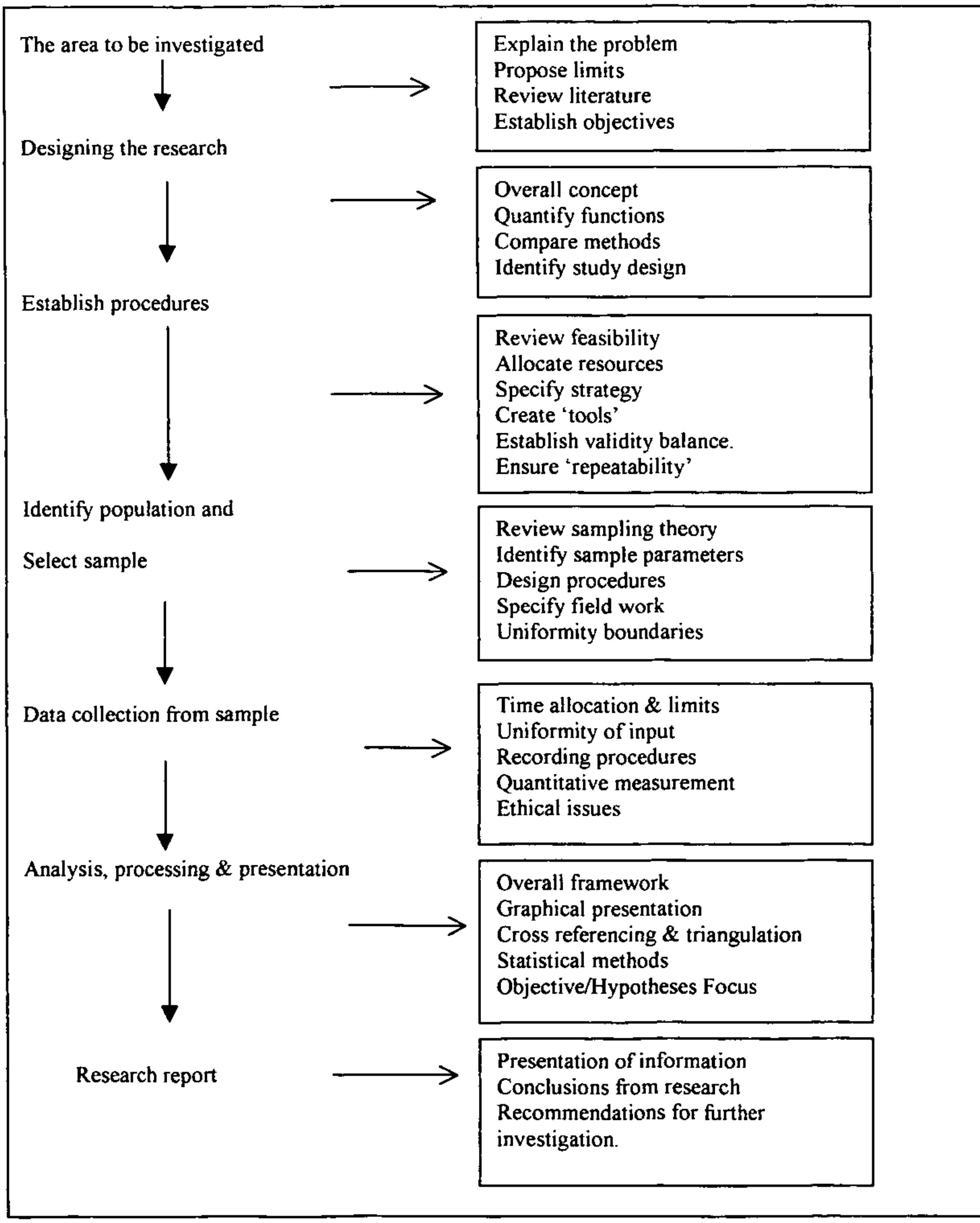


Figure 2.2 – Flow Chart of Methodology Used in this Research

Literature review	Critical comparison of publications relating to maintenance management, building types, historical background and the development of industrialised building methods.
Delphi 1 (Objective 2)	Collection of two sets of data indicating rated overall cost importance of 15 maintenance categories and the selection and ranking of 5 categories in importance in using planned preventative maintenance to reduce costs.
Delphi 2 (Objective 2)	A re-examination of categories remaining after Delphi 1, providing data on perceived cost influence by category and importance relative to planned preventative maintenance.
The Questionnaire (Objectives 1,3&4)	Collection of data on actual cost of building maintenance for the period 1995-1999, together with a comparison of current use of planned preventative maintenance with other methods. Data on possible future use planning was obtained from the same survey.
Analysis	Systematic examination of survey input tabulated and plotted graphically to identify specific information.
Validation	Comparison of information from the analysis, with discussion of anomalies shown by the results.
Conclusions	Presentation of results and development arising from the research.

Figure 2.3 – Sequential List of Research Activity

The research process shown in figure 2.1, and described by Kumar (1999) as 'the research process at a quick glance', identifies the major steps and their progression relationship. However, as Kumar (1999) and Cryer (1996) point out, there is no 'hard and fast' rule in defining relevance. Fellows and Liu (1997) stress the importance of examining all potential indications, although they may lead nowhere, before deciding on their relevance to the research in hand. Unless material is considered relevant to the research, or is considered necessary for providing a more comprehensive background, these items are not included.

Within the overall concept of gathering reliable data, the design of the collection method must enable separation and extraction of individual information items. Each of the three objectives sought dictates common and specific input requirements. Questionnaire and interview question 'script' must thus function to provide overall document data and individual question data.

2.3 Research process selection

Data collection methods available include data from primary sources: by observation, interviewing and questionnaires, or combinations thereof. Data from secondary sources (i.e. from preceding research by others) may also be available. Government type publications, covering topics such as economic forecasts, may be considered reasonably impartial, whilst individual research may be formatted in a way that makes the information unreliable, or even contain personal bias (Kumar 1999). Bias can be unwittingly written into a questionnaire or 'pushed' during an interview (Denscombe 1998).

A pilot investigation to check the validity of the stated objectives and availability of information needed to complete the research was considered necessary. This pilot study took the form of a telephone survey with the help and co-operation of two Local Authorities and two commercial operators of buildings in the categories of 'traditional building' (e.g. bricks and slates) and 'engineering construction' (concrete frame or 'system built') multiple domestic accommodation.

The pilot revealed considerable interest in (1) the research objectives by the organisations involved and (2) that such data was available.

2.4 Data collection method.

The proposed design of the data collection methods and tools was changed as a result of the pilot survey to include qualitative data. Guidance on analysis of subjective views was researched from Fieldman (1995), Bateson (1984), Edwards (1957), and, principally, Yin (1989). This qualitative data was obtained via a Delphi survey of domestic building design professionals (specifically relevant to objective two only).

Following Yin (1989) and Fellows and Liu (1997), the data requirement, sample size, and collection methods were identified from working back from the objectives. 'To determine the inputs of an information system, the outputs must be decided first' (Fellows and Liu, 1997).

The inputs, as defined by the outputs sought, vary between the four objectives. Where possible, common boundaries and measures of (a) time period, (b) location, (c) size and (d) type of building, (e) existing age, and (f) anticipated future life span should be maintained, for consistency in any comparison made (Fellows and Lui 1997). Additional information, rather than alternative information, should be sought for the specialised areas under investigation in each objective.

The pilot study revealed that although Local Authorities may have records of maintenance expenditure going back many years, only the records for those years which had been stored on computer were likely to be accessible. As virtually all organisations keep financial records for six years (as normal operational management and to satisfy legal and tax requirements), the time span for the survey was fixed at five years.

2.5 Sample selection

The age of the buildings under consideration for objective 1 was limited to between around thirty and forty years, following the Government's encouragement of Local Authorities to use industrialised construction methods during the 1960s. The operation of these buildings may be considered to be continuing beyond their 'economic life', but the very specialised nature of their construction and emerging maintenance problems is considered to be sufficiently complex to warrant a separate study. Buildings studied as 'operating beyond their economic life' are taken mainly from those classified as 'Large Houses' (Brunskill, 1978), originally occupied by people of local, rather than national, importance. Many such buildings are now converted into flats, but some remain virtually intact, operating as lodging houses, hotels and youth hostels.

Locations identified during the pilot study included the London Boroughs of Enfield and Islington north of the river Thames, and Southwark and Croydon to the south. Birmingham and Brighton also had extensive developments based on various forms of engineering construction during the 1960s. 'Large Houses' that have survived tend to be in semi-rural locations, possibly because the building and generally extensive grounds were not taken for redevelopment before their Heritage value was recognised. Buildings at Salisbury, Stratford-upon-Avon and York are identified as suitable for study, based on the check-list shown in figure 2.4.

The unit size of buildings has been taken as an individual unit of accommodation. Most developments within the category of 'multiple domestic accommodation' consist of several separate buildings, each of which may form up to 100 separate units of accommodation. Mixtures of 'bedsit' and 'multi-bedroomed' accommodation are common, resulting from attempts at designing a mixed community. Considerations of whether these attempts were successful are outside the scope of this work.

Checklist for Evaluating a Building for Objective 1 Study.

1	Is the building between 100 and 200 years old?	☐
2	Is it operated as one building under one management?	☐
3	Is the building still in the 'as built' (with some	☐
4	modernisation not extensive alteration) form?	☐
5	Are maintenance records existing and accessible?	☐
6	Will full co-operation be provided by the operator?	☐
7	Can areas of confidentiality be identified and respected?	☐
8	Is this building a suitable comparison with other buildings also under investigation in this research?	☐
9	Is this building one that must be maintained because of 'Listed' status?	☐
10	Are there any plans to radically change or demolish the building or its environment within the next five years, that might jeopardise follow up research?	☐

Figure 2.4 – Checklist for Evaluating a Building for Objective 1 Study.

Traditional buildings under consideration are large family houses, perhaps containing as many as twenty-five bedrooms, with usual domestic offices. Although these were originally built to be heated by open coal fires, none have been found that do not now have central heating installed.

Precast concrete structures predominate as the building type satisfying the other restraints imposed by the methodology. These are essentially Local Authority-provided dwellings, where the maintenance is supplied and controlled by a division of the local council. Some traditional methods are incorporated within most of these forms of construction, perhaps with original feature panels of brickwork. Subsequent design changes after the completion of the main building could not have been done in concrete, as completed work above would impede access by crane. Hence, the addition of ground floor playrooms and other, mainly communal, facilities now stand as traditional construction amongst, inside, and under the original engineering forms of construction.

From the literature review, it became apparent that some 'system' buildings were many years in design before building started, and that 'prototype' units were often provided during the early stages of the actual building process (Finnimore, 1998. Vale B, 1995). With concrete structural frames and light-weight internal partitioning, considerable flexibility could be achieved. It is not part of this work to investigate any intention to use this flexibility facility at a future date, should living condition requirements make a different layout desirable. Changes in layout would only be possible during a major refit, as electrical installation, plumbing, and heating would all require adapting. Following the industrialised building boom of the 1960s, many of these buildings are now between 30 and 40 years old, and this dictated the age of buildings under consideration.

For traditional buildings, the age has been taken at between 100 and 200 years. Many 'Large Houses' were built with wealth from the industrial revolution or gained during the Napoleonic War, (1799-1815), when agricultural profits were considerable.

Government backed financial support for housing development stipulated that the life span of 'system-built' accommodation was for not less than 60 years. Whether this was simply the term of the financial package, offered by the Government to Local Authorities, or the planned life to the building is not clear (Seeley, 1983).

For those buildings that must be preserved and maintained, perhaps because of their historic or cultural conservation requirement, the situation is very different. There is effectively no end to the period for which maintenance must be planned.

Strategies selected for data collection are partially dictated by what is to be collected and the nature of the sample it is to be collected from (Fellows and Liu, 1997, Kumar 1996, and Denscombe 1998).

Denscombe (1998) points out the possibilities and danger of 'face interviews' allowing any personal bias held, even sub-consciously, by the interviewer to distort the responses by 'leading' the questioning. A set parameter of questions was therefore prepared for the Delphi survey (objective 2), to which additional, but not alternative, notes or comments were added.

This consideration extends to building type, size, and location. Use is confined to 'buildings of multiple domestic accommodation'. Local Authority-controlled 'blocks of flats', private landlord managed buildings, and the like that have common maintenance problems were included.

Prior to preparation of the survey interview questionnaire, a checklist was prepared to assist in ensuring that the possible pitfalls indicated by Denscombe (1998) and Fellows and Liu (1997) were avoided. This checklist is shown in Appendix 4b.

Following Denscombe (1998), a checklist system was created, indicating the essential and desirable input required from that section of the information gathering process to which the checklist relates. The resulting hierarchy of lists breaks down the checks to ensure, as far as possible, that essential information is gained, together with some additional and desirable – but not essential – input, and avoiding unnecessary or irrelevant data.

Using the checklists as a guide, and as a planning tool, the actual interview questionnaires were prepared. These questionnaires are shown in Appendices 2 and 3.

The methods of measuring and assessing the data were treated separately for sections of the gathered information, with priority given to ensuring that the accuracy of individual items of data obtained was not compromised.

For the outputs of the research to be valid, it is essential that the information gathered and the selected processes used to analyse and interpret the data into outputs are rigorously applied.

A high degree of external validity is required and the sample must therefore be an accurate representation of the population. The nature of the different construction methods and the resultant dependant maintenance needs were spread over a considerable range. As it was not possible to achieve both high internal and high external validity (Jung, 1991), rigorous objectivity was necessary in obtaining data, so that cross referencing and comparisons could based on established facts only.

Recording systems used by the sample providing data were required to be such that information obtained during this research could be obtained again and should, thus, be exactly the same for an identical survey. However, it is accepted that, in the time lapse between an original and a repeat survey, there may be unforeseen changes in record-keeping methods. Historical data may be transferred from written documents onto computerised database records, and some detail is likely to be lost during that transfer.

Kumar (1999) suggests that there are three basic principles that affect sampling.

Principle 1:

> 'In a majority of cases where sampling is done, there will be a difference between the sample statistics and the true population mean, which is attributable to the selection of the units in the sample'.

Principle 2:

> 'The greater the sample size, the more accurate will be the estimate of the true population mean'.

Principle 3:

> 'The greater the difference in the variable under study in a population, for a given size, greater will be the difference between the sample statistics and the true population mean'.

Fellows and Liu (1997) stress the importance of sample size and obtaining 'representativeness', as well as discussing the possible need for 'constrained sampling' (as used in this work) and the essential boundary framework that is

required for this approach. The boundary framework is provided by a checklist so constructed that each site investigated complies with the identified boundaries. Thus the sample used in this work was not a random selection from a general population, but a non-random judgmental selection, taken from a carefully identified strata of the population.

Oliver (1997) proposes that the key question to be asked by a researcher when choosing methodology is: 'What is the appropriate method or methods to resolve this question?' More than one method may be used, and they may be linked and compared, such that outcomes from different approaches may be focused to a common agreement.

A simplified representation of the results of the three different methods of collecting (ideally) the same data is shown in figure 2.5. Areas 1, 2, and 3 represent the plotted data (which overlap, indicating the area of agreement between them all). The central core of this common focus provides a more reliable source of information than any single area alone.

Kumar (1999) suggests that greater accuracy can be obtained by disproportionate stratified sampling, but that considerable rigour is necessary in identifying both the strata and the sample selected from it. Fellows and Liu (1997) suggest that this method of sampling is appropriate where the population occurs in distinct groups, or strata, and suggest methods of establishing appropriate sample size. However, whilst size is of relative importance, the crucial factor is to ensure that the samples themselves are truly representative of the population, in order to achieve a high level of validity.

Following Fellows and Liu (1997), Oliver (1997), and Kumar (1999), it is clear that each individual making up the total sample must be representative of the

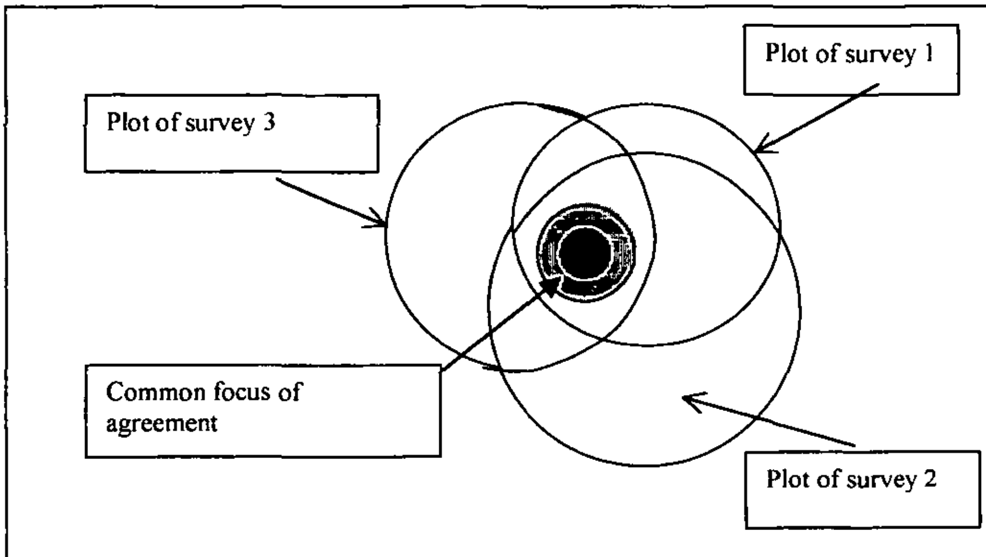


Figure 2.5 – Common Focus of Agreement by Multiple Methods.

whole population, or as representative as is possible within the restraints of time and cost. In compliance with this, input from responders was first examined to ascertain suitability for inclusion, and those whose building did not match the criteria of the checklist were discounted.

Following this scenario, it is clearly not possible to use any form of 'Random Probability' sampling technique and a mixture of 'Non-random' and 'Mixed (systematic) sampling' was selected. The sampling method relationship is shown in figure 2.6.

Geographical distribution presents a problem of both time and cost, unless it is possible to collect more than one set of data at a location. The several industrialised building methods trials at Brighton, on the South Coast, during the late 1960s, and the local authorities response at the Pilot Study indicated that localised group data gathering might be a possible method of obtaining the quantity of information sought within the time/cost constraint.

The size and complexity of the population does provide the opportunity to collect from a large sample, but consideration has been given to the amount of specific information required and the potential for diluting the data by over collection. Of the total population, a relatively small proportion was revealed by the pilot study to be available for detailed study, and 'judgemental' choice

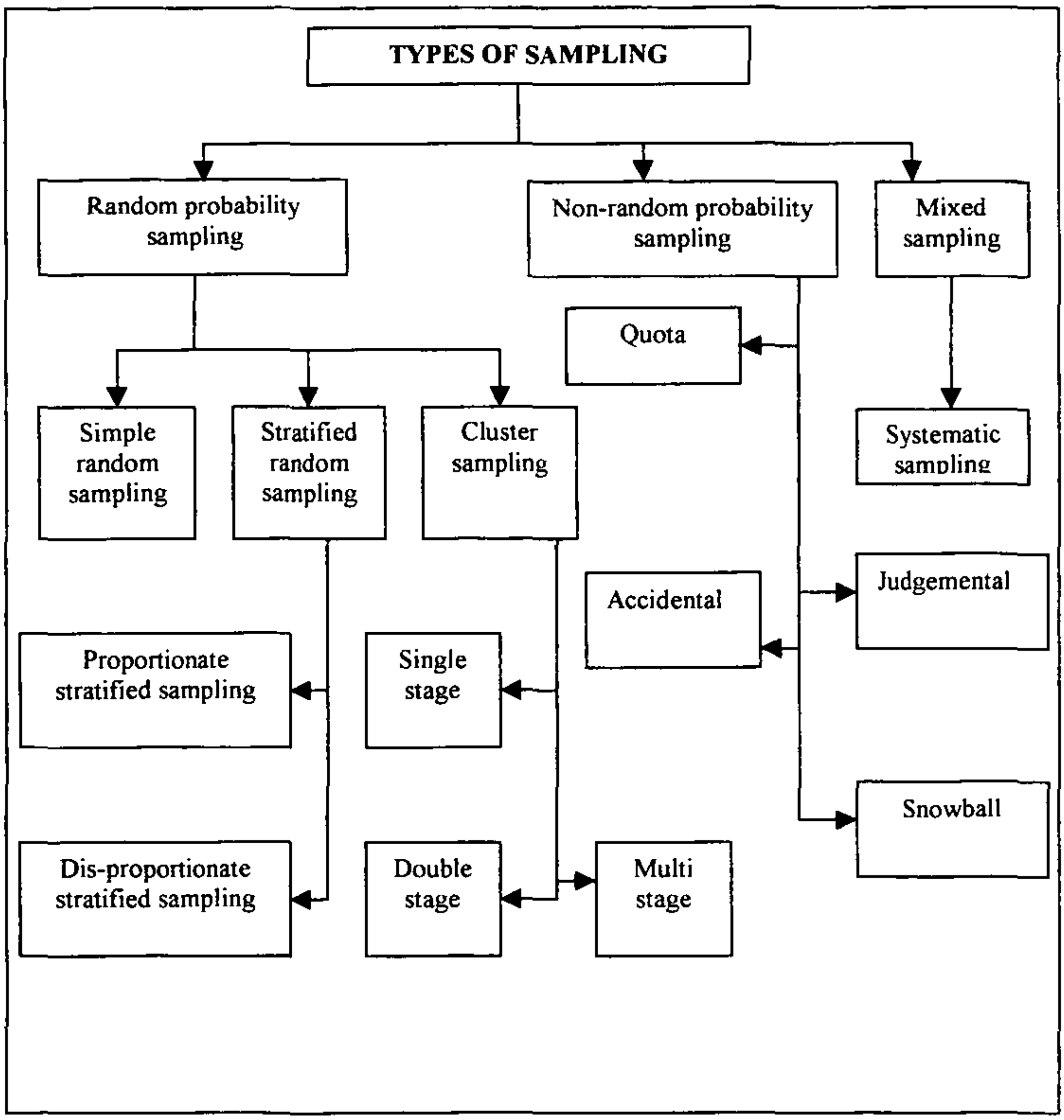


Figure 2.6 – Types of Sampling Used for this Work: Relationship Diagram (adapted from Kumar, 1999)

was identified as the main route to sample selection, taken to ensure that any bias – even sub-consciously held – by the researcher did not influence the selection of further data input. This was achieved by adherence to the limiting parameters set out in the checklist.

Within the limits of the buildings selected under figure 2.4, the research was restricted to those elements of maintenance that were indicated to be (1) of greatest cost significance and (2) as most important in preventing breakdowns by regular planned maintenance.

The five elements considered most important were identified using the Delphi technique, via a panel of independent and non-communicating experts, anonymous to each other. Delphi is 'a structured approach to gaining the judgement of a number of experts (i.e. in developing a consensus) on a specific issue relating to the future' (Bartol 1999) and 'to prevent the lobbiest from pushing their views onto others by force of personality' (Massie 1979).

Fleet (1991), Schwatz (1980), and Dessler (1985) all confirm the descriptions given above, whilst Koontz and Weihrich (1998) stress the value of the technique as a means of obtaining several independent opinions, without any being influenced by any other.

Procedures for each of the objectives varied to suit the individual requirements.

2.6 Procedure for objective 1: 'to investigate the maintenance costs of traditional and system built multiple domestic accommodation buildings and compare their maintenance costs'.

Lists of addresses of housing providers were obtained from web sites and reference library sources. In each case, an initial telephone call was made to establish:

a) That the organisation being called had buildings matching the checklists.
b) That records were available and that the organisation was willing to participate in the survey.
c) The name of the person to whom the enquiry should be sent and, where possible, their direct telephone number.

Items (a) and (b) were generally given freely, but there was noticeable reluctance to provide (c).

2.7 Procedure for objective 2: 'to identify the principal maintenance cost categories perceived by various construction industry professions and test the hypotheses that 'actual highest cost maintenance categories for domestic dwellings are not the same as those perceived as the highest cost categories by domestic dwelling design professionals''.

A two-stage investigation, using a 'Delphi' survey technique, was carried out with 10 individual professionals operating in practices where future maintenance management practice would form a major part of their recommendations. These professionals include Architects (both in public and private practice), Surveyors, and Quantity Surveyors. The survey was conducted by establishing telephone contact, followed by an interview of approximately one hour. Each participant was invited to complete a simple questionnaire, without any prior notice of the questions, so that their 'initial response' would be recorded. On completion of the questionnaire, a semi-structured discussion on building maintenance issues followed. This discussion period was started by using the same 'prompting question' of "what are your thoughts on building maintenance issues?". This was followed by "how do you see maintenance costs being reduced in the future?" These questions were selected (1) to start the discussion that could then follow the interviewees' particular interest, and (2) to allow the points raised to be noted without introducing any bias from the interviewer.

The results of this first round of interviews were tabulated to identify those categories marked as having the highest influence on building maintenance cost and, separately, the top five categories where regular planned maintenance was believed to be most important to prevent breakdowns requiring unplanned maintenance. These results were returned to the original panel for further consideration of the reduced range of categories, and those 'second round' results tabulated as round one, indicating the primary category believed to have the greatest influence on maintenance costs. Similar calculations indicated the category considered most important for preventative maintenance (if breakdowns and unplanned maintenance and repairs are to be avoided), and other categories (ranked in importance).

2.8 Procedure for objective 3: 'to measure and compare the use of planned

preventative maintenance programmes against other maintenance and repair policies'.

Data for objective 3 was obtained as question 10 of the questionnaire for objective 1 (shown in chapter four). Contributors were asked to indicate those methods of maintenance used – where more than one might apply – and to indicate the predominate method in a second column. Question 10 is shown as figure 2.7.

Restraints of time and cost required that fieldwork was kept to a minimum. Visits and interviews were carried out for objectives 1 and 3, where specifically requested by the potential interviewee during the initial telephone contact. The form of interview granted was generally the only opportunity to extract the required data from a mass of record sheets. All participants in the Delphi survey for objective 2 were interviewed, with a set time limit of one hour. Geographically, the interviewees ranged from Southwest and Southeast England, through London and the Midlands to Manchester.

(Q10)

Maintenance work is done:		(✓those that apply,↓)	(the predominate method is ✓ ↓)
1	Only done when considered necessary.	☐	☐
2	Only done when something breaks down.	☐	☐
3	Done as soon as necessary.	☐	☐
4	As a planned maintenance routine.	☐	☐
5	A mixture of more than one, (✓ them).	☐	☐
6	Left until funds available.	☐	☐
7	Other	☐	☐

Figure 2.7 – Question 10 Extracted from Questionnaire.

Following Denscombe (1998) and the need for uniformity in selecting a sample – combined with the pilot study's indication that being overcautious and restrictive in specification of the sample could result in limited data being obtained – a checklist (Appendix 4a) was used to check that the buildings forming the sample all fell into the same category (i.e. whilst they are not all identical, as a model of the Ford Mondeo car, they are all of the same type – i.e. salon – and in size and price range). Thus, the boundary for the sample was limited to buildings of the same type and occupational use, with the different build methods being identified from the questionnaire survey.

Some survey replies were in very precise form, with percentages calculated to 2 decimal points, but generally, the replies were rounded to the nearest whole percentage point (or £1000). The survey did not ask for precise calculation, as it was anticipated that responders would begrudge the time required. Necessary calculations to convert from pounds to percentages, etc., were generally done by the researcher.

The Delphi survey to establish the 'instinctive reaction' of industry professionals was initially programmed to be carried out within a three-month period and was completed during November 2001. Input from this survey is used in preparing the questionnaire for the main survey, which commenced in January 2002 and was completed by March 2002.

Returned questionnaires were reviewed against the checklist to ensure that the information referred to the appropriate building type (i.e. multiple domestic accommodation). Those questionnaires not applicable to the research were discarded.

A master list of each enquiry sent out was generated at the same time as address labels were printed. This list was not definitive as the introductory cover slip asked the recipient to pass the enquiry on if they were not the correct person or department to be able to provide the information. The responders were also listed and compared to the initial enquiry list.

Output from the numerical data obtained is analysed in chapter 4, and, following discussion in chapter 4, the conclusions shown in chapter 6. This data was obtained from the main questionnaire survey and is presented in various forms. As it was not possible to view and vet every individual building for which a survey return was made, the vetting was by comparison of the returned questionnaire against the checklist, discarding all those that did not fit within the limits of the defined category. An initial target of 500 enquiries was increased to 784, following improved leads to likely sources of information. A response rate of 11.7% gross was obtained, resulting in a net input of 4.9% (when adjusted within the limits of the checklist to achieve uniformity).

All information supplied as part of this research has been treated as confidential. Members of the Delphi survey panel were given the choice of their identity remaining confidential, or being included in a list of panel members on completion of the research. Every Delphi survey questionnaire invitation contained the option for the organisation to remain anonymous and for the individual completing the questionnaire to remain anonymous. The main survey offered no choice and assured anonymity. This was deliberately worded to encourage response, following indications – given verbally during the pilot survey – that some responsibility for the way that maintenance issues were managed might be attributable to individuals if the outcome showed their management as less efficient than another method.

Chapter 3 - Literature Review.

3.1 Introduction

This Literature Review was developed after the initial research outline design. Following Denscombe (1998), it considers existing work on the subject, identifies key issues, and indicates 'where the research is coming from'. Theories and principles influencing previous works by others are discussed and compared as a starting point. Following Fellows, Liu (1997), and Oliver (1997), these are reviewed under topics common to various writers, rather than as inputs from the writers themselves.

Not all writers have defined the meanings of terms used in their texts and whilst File (1991) defines maintenance as 'the act of keeping in repair' (citing the Oxford Dictionary as his source), a better definition may be found in Clifton (1974). Clifton identifies the discrepancies in meanings attributed to 'planned maintenance' and uses British Standard 3811:1964, titled 'Glossary of General Terms Used in Maintenance Organisations'. This describes planned maintenance as 'the maintenance organised and carried out with forethought, control, and the use of records to a predetermined plan'. An extract of this standard is reproduced in Appendix 1.

During the initial reading for this review, it became apparent that there are many publications dealing with facilities management and the organisation and planning of maintenance procedures for plant and equipment, and relatively few concerned with the building fabric itself. Of those publications dealing with plant maintenance, many were concerned with production plant in a factory environment. However, some of the procedures advocated, and the graphical analyses presented, that are discussed here as the underlying principles of preventing deterioration through systematic maintenance may be considered the same when applied to buildings (Howlett 1991, Chudley 1981, File 1991).

Relevant charts and diagrams have been reproduced which contain references to machines or plant, and maintenance being carried out whilst being in action or not operating. Rather than abridge the original work, the original text has been reproduced with added subtitles: 'buildings' for 'machines' and 'plant'; 'occupied' to represent 'running'; and 'unoccupied' to represent 'stopped'.

3.2 Types of Maintenance

The consensus between many writers, including Howlett (1991), White (1973), Husband (1976), and File (1991), is that all maintenance falls into one of the following four principal categories:

1) Replacement instead of maintenance,
2) Planned replacement,
3) Breakdown maintenance, and
4) Preventative maintenance.

1) Replacement instead of maintenance: an item may be more efficiently replaced than repaired. Even if maintained to its original standard, an item may not be considered adequate by today's standards. Double glazed and draught proofed 'replacement windows' may be included in this category.

2) Planned replacement: allows for deliberate minimal maintenance from the outset. Good quality equipment is installed with the intention of replacing it after a predetermined span of time. Heating boilers still operating reliably are replaced with current technology and fuel conversion efficiency. The introduction of condensing boilers could be included under this category.

3) Breakdown maintenance (or run-to-failure maintenance): involves only minor servicing or lubrication, if any. The item is operated until it fails and is then maintained. The item must be something that can allow the building to operate without it working, and this can involve a duplication of

the item to allow for the eventual breakdown. Ventilation fans and the like could be included under this category.

4) Preventive maintenance: requires systematic and regular planned checking and maintenance to prevent breakdown. This is generally used to prevent business-critical failures, where the cost of breakdown is likely to be far greater than the cost of the repair. Sealed buildings cannot be used without their air-conditioning and heating systems, and high-rise buildings lose efficiency without lifts operating. Preventive maintenance is required by legislation for certain operations (for example, lift maintenance).

The separation and identification of planned and unplanned maintenance policies is discussed by various writers, with, perhaps, the clearest diagrammatic example being Howlett (1991), reproduced below as figure 3.1.

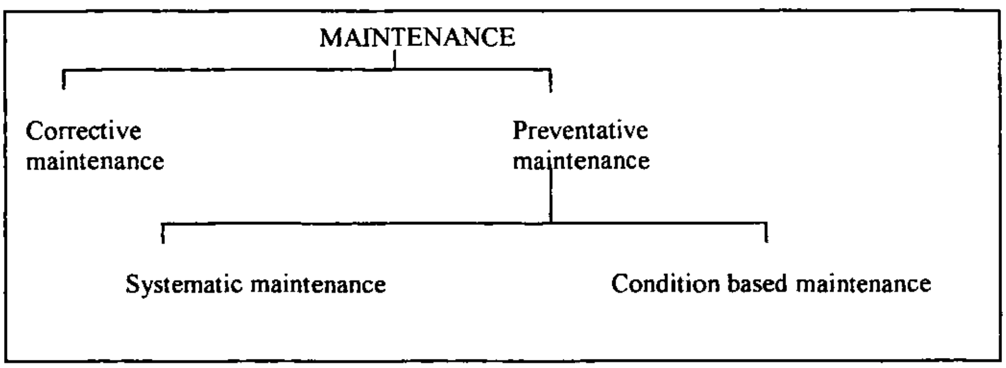


Figure 3.1 – Maintenance Policies (Howlett 1991)

This basic separation analysis is taken further by White (1973), although the terminology is different. Where Howlett's initial separation of all maintenance is into corrective and preventive, White inserts an additional tier of planned and unplanned maintenance at the top of the tree (shown as figure 3.2) and makes further separations of method lower down. These must be considered as events, if unplanned, rather than planned activities. White and Howlett also consider various other policies, and the interrelationship of prevention to cure. White, who uses further sub-categories to identify whether the machine/building can be running/open during the maintenance operation, considers the effect of maintenance work on the usability of the building (figure 3.2).

Further subdivisions are indicated by Husband (1976), who shows the position of the 'unplanned' maintenance item in a 'planned maintenance' environment. A 'decision tree' indicating the various forms of maintenance and their interrelationship is shown in figure 3.3. Husband expands the relationship between the various forms of maintenance to a much fuller extent than either White or Howlett, and to the extent that Howlett's initial analysis appears over-simplistic.

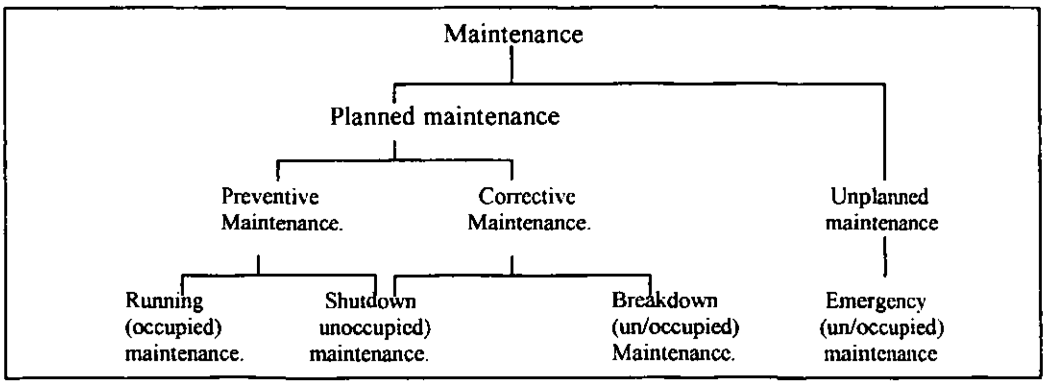


Figure 3.2 – Maintenance Policies (White 1973)

The incidence of (or allowing provision for unprogrammed maintenance as part of) a preventive maintenance policy is explored by Husband (1976), who provides an argument for what he describes as 'running to breakdown'. Both Husband and Clifton suggest that such a deliberate procedure is only possible where back up equipment is available. This must cover the period during which corrective maintenance will be done as a result of the breakdown. Thus, a ventilation system with two fans can be run until the operating fan breaks down. The other one will then operate whilst the first one is repaired. Mobley

(1990) claims that repair costs for 'run to failure' breakdowns are approximately three times higher than for the same repair made within a scheduled or preventive mode. Both Husband and Mobley make the point that, in order to operate a reactive breakdown maintenance policy; the facilities must exist and be quickly available, so that the reactive repair can be carried out immediately. Chudley (1981) argues for planned maintenance, claiming that 'a planned maintenance program will make the most efficient use of resources such as men and equipment'. He goes on to state that 'emergency maintenance is something to be avoided whenever possible'.

RICS Practice Note 4 (1980) echoes the above point, but accepts the inevitability of emergencies, stating that 'the prudent manager will therefore plan against such emergencies'. It also states that: 'before any effective or economic maintenance programme can be prepared, a policy must be agreed between the client and the maintenance manager within which the manager can operate'.

This degree of importance given to establishing a 'policy' is confirmed by an advice note to Local Authorities from the Department of the Environment in the same year, which states: 'for many years, repairs and maintenance in Local Government have been dominated by the idea of doing the best possible with as much money as could be obtained; this has been the overall measure of performance. But conditions have changed; tenants want a reliable service – may even be prepared to pay more for it – and authorities themselves want a more objective measure of 'best possible' (Department of the Environment, Maintenance Review Paper, 1980).

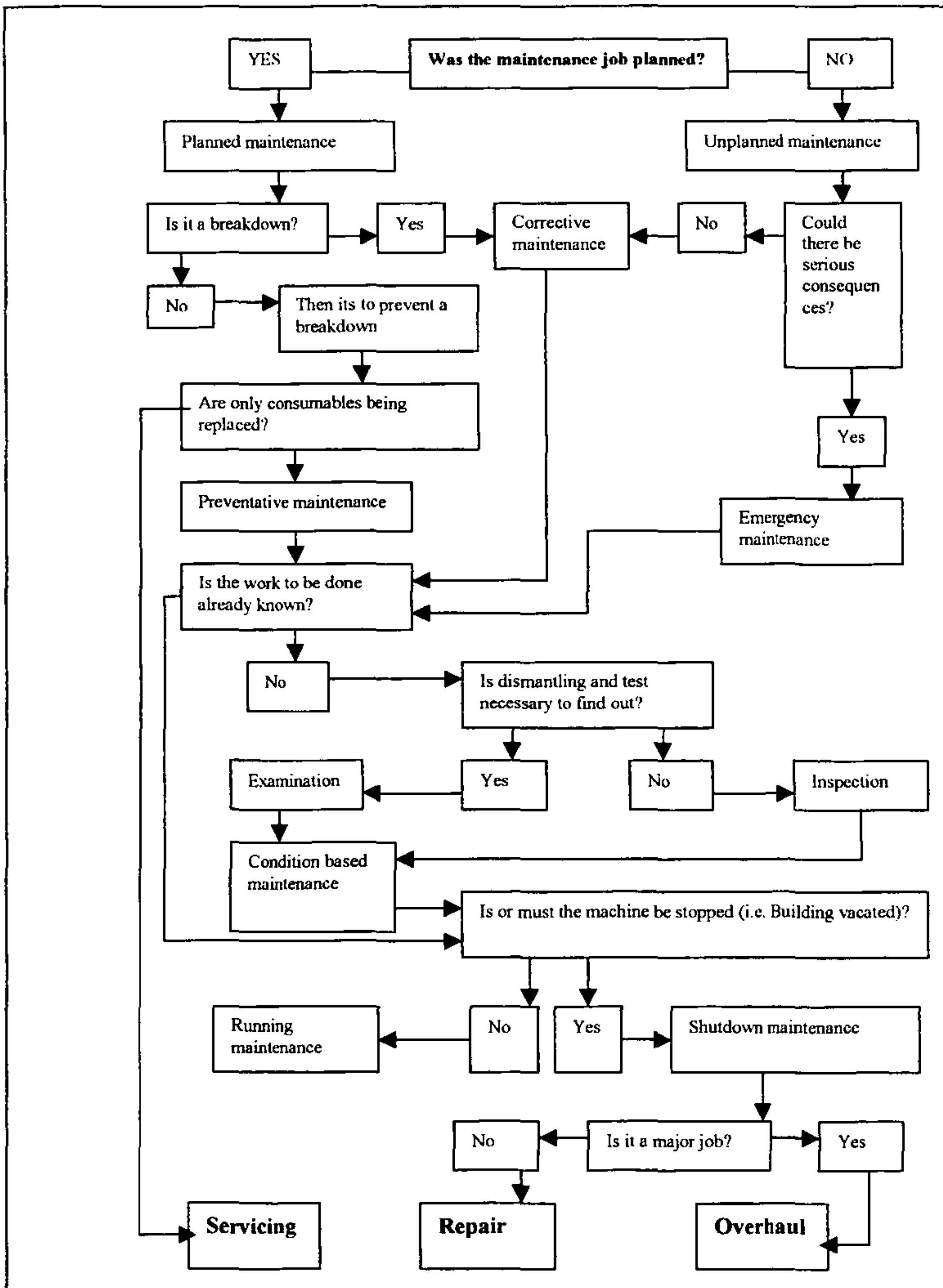


Figure 3.3 Decision tree illustrating the relationship between various forms of maintenance. Source: Department of Industry.1980.

approach. The report is concerned mainly with the maintenance work necessary before any re-let of vacant houses and how to avoid the periods of non-occupancy between tenants. It suggests that part of the non-occupancy problem is caused by new tenants refusing to move in until repairs are completed. It also concedes that lack of proper maintenance may have caused the original tenants to move out!

3.3 Costs of Maintenance

The actual costs of maintenance, if the amounts spent are accepted as the actual costs forming the basis of the published figures, vary considerably within individual categories. The accounting methods are not necessarily the same and comparisons may not be valid. Information from published guides by the Chartered Institute of Building, The Royal Institute of Chartered Surveyors, and the Royal Institute of British Architects are thus not suitable for comparison, as there is no common standard or 'control sample' against which to make critical comparison. A need for specific empirical research was thus found to be necessary and is shown later, in Chapter Four.

File (1991) suggests that, for maintenance to be effective in keeping the equipment in proper operating order – and to be economically operated – the maintenance aspect of the plant/building must be considered at the initial purchase stage. This may, and preferably will, involve much consideration at the design stage, for it is then that the choice of equipment and fittings is made. Low cost fittings may require greater and more expensive maintenance than a higher quality, but higher cost, equivalent.

In discussing maintenance budgets, Mann (1982) states that 'most budgets are categorised according to labour, material, and equipment'. He suggests an alternative, where the same amount of money is allocated to what it will be actually spent on. By this method, management can alter the emphasis on maintenance, perhaps to enhance the visible image of the property. By spending a greater proportion on external painting and less on internal decorations, the building (and hence the organisation?) will appear smarter and more prosperous to the outsider. Wireman (1990) comments that 'one of the prime attitudes here is the sacrificing of long term planning for short term gains'.

3.4 Costs of Not Maintaining

The direct cost of maintenance or remedial work necessary because of failure will, at best, be the same as it would be for the work being done before failure, as part of preventive maintenance. The indications are that the cost will be greater, and may be up to three times as high (Mobley 1990). Indirect costs can vary from nil, where there is no financial penalty attributable to the breakdown, up to the total measurable loss caused by closing a building whilst the maintenance is carried out.

The possible losses and costs consequent upon an ingress of water, because of lack of roof maintenance on a hotel building, could include:

a) Cost of re-accommodating guests.
b) Compensation for damage to guest's luggage/property.
c) Loss of future trade from those guests affected.
d) Loss of current profit from those guests who have to leave.
e) Repairs to plaster work and decorations.
f) Replacement or cleaning of carpets and furniture.
g) Loss of additional income until the rooms affected are reopened (The Caterer, 1998).

3.5 Penalties of Not Maintaining

Statutory requirements exist for certain classes of equipment: gas boilers, lift equipment (passenger and goods), and fire detection systems being examples. Failure to adhere to the requirements laid down by these regulations is an offence prosecutable by the Health and Safety Executive (whilst outside the scope of this work, it should be noted that there are also penalties, under the Construction (Design and Management) regulations for failure to notify the HSE of maintenance work falling within prescribed limits of type and manpower involvement, etc.).

Failure to maintain the built environment may constitute a breach of statute, leading to prosecution resulting in a fine or closure of the premises. Inadequate maintenance may lead to the deterioration of working conditions. This, in turn, may result in non-productivity from staff: sickness, malingering, strikes and resignations (Facilities Management UK, Nov 98). Potential loss centres as a result of failure to maintain are shown as figure 3.4.

3.6 Cost Control and Recording Procedures

'A cost control system must provide accurate costings for work and materials for all maintenance activities' (White 1973). This quotation sums up the underlying theme of Lewis (1960), written when industry was 'beginning to turn' to automation and capital intensive equipment. Although much of this 'capital intensive' equipment was new and of unknown reliability, Lewis's forcast has been proven correct by subsequent events. Building's manangement systems are now widely available and most buildings of any size are now being operated and monitored by automatic systems and controls. Seeley (1993) illustrates manual record keeping and also advocates the use of a computerized system to track activity and provide cost feedback.

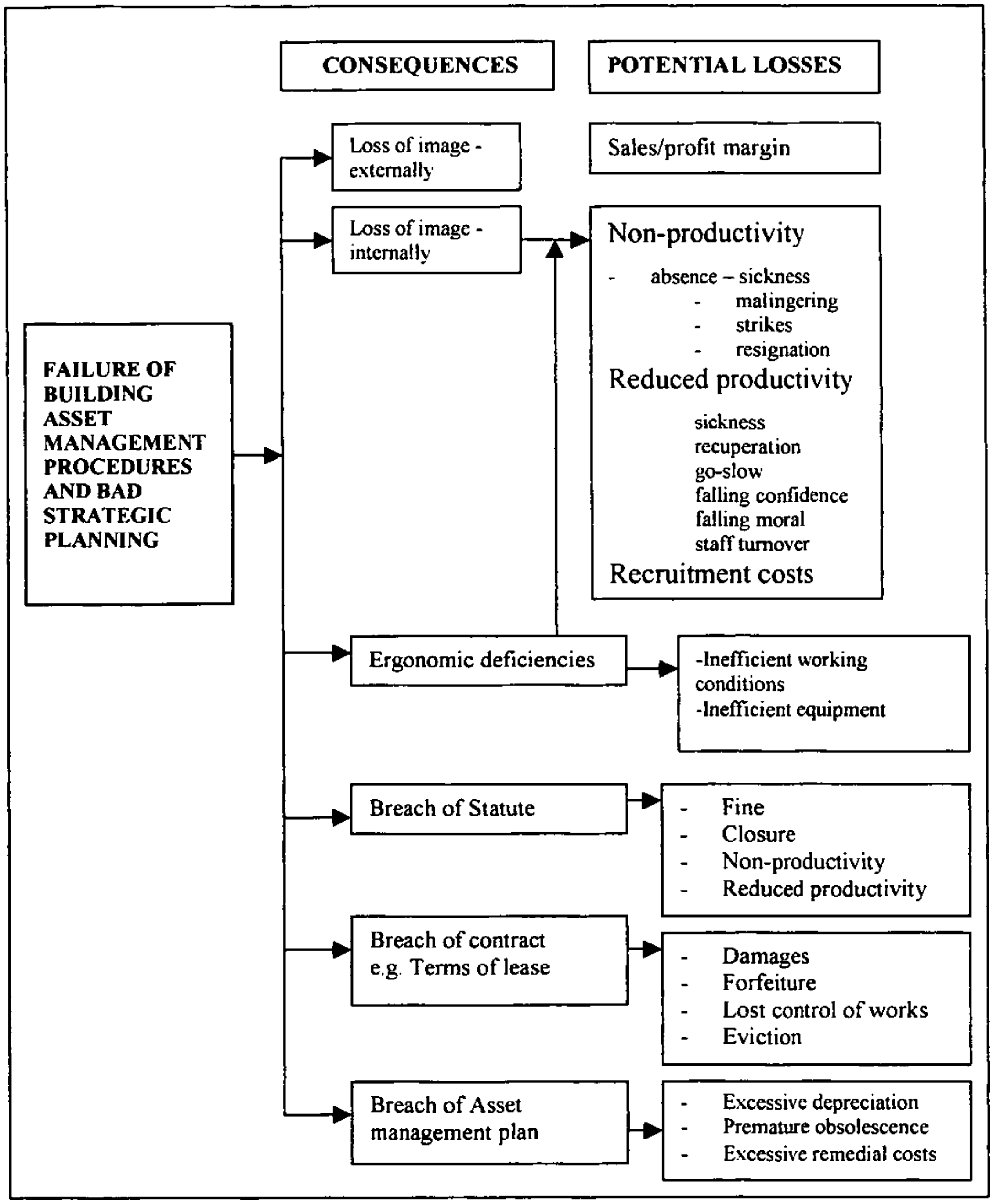


Figure 3.4 – Potential Consequences and Losses of Failure of Building Asset Management Plan (Facilities Management (UK), November 1998).

Ten cost (or budget) headings are identified by White, as:

1) External decoration.
2) Internal decoration.
3) Main structure (including windows and gutters).
4) Internal construction (including partitions and doors).
5) Fittings (shelves, closets, etc).
6) Plumbing and sanitary services.
7) Mechanical, gas, and air conditioning services.
8) Electrical services (including kitchens).
9) External and civil engineering works.
10) Routine cleaning.

Although White identified cost headings, actual costs for a specific period of time were not included. Cost data collected by the main survey has followed these cost headings to establish a pattern for future surveys to enable a 'change over time' comparison to be made at a future date.

The basic concept of a cost-centered approach is supported by Mann (1982), and Husband (1976), who also suggest and support the use of computerized systems for record keeping. Later publications – File (1991) and Howlett (1991) – refer to the use of computers as an everyday tool of maintenance, indicating the rate of development during the intervening period.

3.7 Budget Forecasting and Provision

Yeates (1994) suggests the operation of a sinking fund arrangement to provide a cost buffer for major repairs. An example is given of a spread sheet calculation showing the build-up and depletion of this fund over a period of 35 years. This enables a proportion of annual maintenance costs to be held in a specifically identified budget, until the fund is large enough and the job needs doing. Thus, a roof that will need overhaul in 20 years' time requires

$1/20^{th}$ of that cost allocated for each year until then (interest earned, inflation, etc., must also be accounted for). For his example, based on Housing Association stock, he uses an annual contribution to the sinking fund of 0.85% of capital value per property. Different types of building, and differing use buildings may require a different percentage contribution, or a contribution on a different basis, but the underlying principle of making provision for future expenditure remains valid.

3.8 Life Cycle Costing and Terotechnology

Terotechnology has been defined as 'a combination of engineering, management, financial, and other practices applied to physical assets in pursuit of economic life cycle costs' (Terotechnology for Better Resource Management Conference, 1975).

Life cycle costs are the cumulative costs associated with acquisition, using, and keeping in desired condition (until final disposal) (File 1991). These can be summarised as the cost of operation, plus the cost of ownership, over a period of time calculated to give the best return for investment. 'Proper maintenance management, therefore, should embrace not only managing the building in use, but also play an important part in its procurement (Chanter et al, 1996). This calculated approach to the economic life of a building is not appropriate where buildings are maintained in use because of their historic or architectural merit.

Husband states that terotechnology is another name for life cycle management, but stresses the need for 'design for reliability'. The underlying philosophy is that the life and operation of a building, including its initial design, planned use, running costs, maintenance requirements, and initial capital investment must all be balanced, such that the total overall cost is minimised. 'At the design stage of the process, the designer is disciplined to design out maintenance and design in reliability'. This cannot be done without the co-operation of the team of managers responsible for the various departments that will eventually operate the finished building. The process is geared to a long term pay off, and the inevitable higher initial costs will require positive justification to achieve the support of stake holders who will have to wait longer for an overall return on their investment, even if it is a greater return. Parslow (1992) advocates the application of individual life cost assessments – to all separate items of plant at the design/installation stage – as crucial for the overall philosophy to be effective. A published article by Stuart Bell on life cycle costing is reproduced in Appendix 8 (Construction Computing 5, October 1999).

3.9 Maintenance Policy Decisions

Yeates (1994) suggests that maintenance policy decisions are controlled by available finance and that it is inevitable that maintenance need will exceed available resource. He suggests that any planned preventative maintenance system must be part of an overall maintenance policy – a component part of medium term strategic planning, affecting the whole organisation. Lund (1998) states 'probably the most difficult part of maintenance work is to make the parties involved aware of its benefits, and the drawbacks of no maintenance'.

'Rational decisions on policy and procedure require the identification of operational and cost objectives for the maintenance department, starting with the identification of maintenance tasks, the standards to be achieved, and the limits of cost' (Lee 1987).

Six 'types of decisions' are identified:

1. Preventive versus failure maintenance.
2. Internal or external service personnel.
3. Repair versus replace.

4. Contract versus single incident negotiation for external services.
5. Replacement parts inventory.
6. Maintenance job assignment control.

Lee's graphical presentation of the interaction of these decisions is shown in figure 3.5.

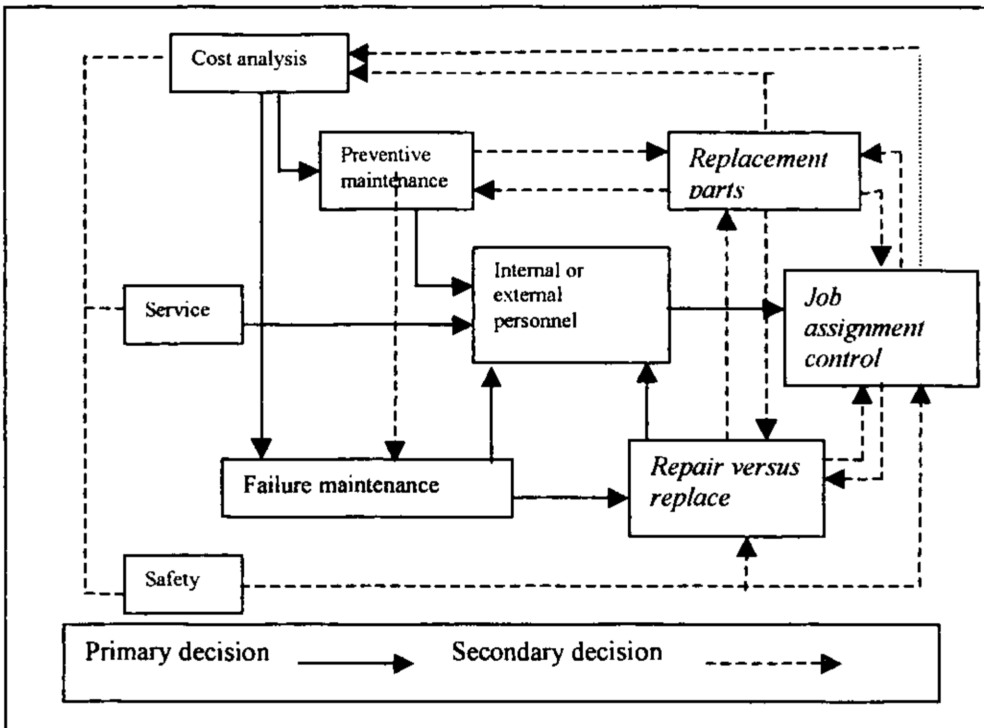


Figure 3.5 – Maintenance Decision Network (Reed 1967)

Lee's analysis supports Yeates's contention that available budget controls the primary maintenance policy decision: the selection of some form of either preventative or failure maintenance. He suggests that, frequently, the decision is not made deliberately, and states: 'in most cases, maintenance decisions are based on expediency and, over a period of time, represent a series of *ad hoc* and unrelated compromises between the immediate physical needs of the building and the availability of finance'.

Yeates (1994) argues that planned preventative maintenance is the key element in operating at minimal maintenance cost. However, the fact remains that, if there is a shortfall in expected available finance – perhaps caused by factors outside the immediate control of the management – then reducing or delaying maintenance work will reduce expenditure immediately. These 'outside factors' may be poor sales or high interest rates, producing results that are not as anticipated. This basic economic force may be the cause of the *ad hoc* compromises identified by Lee (1996).

3.10 Condition Surveys, Standards, and Monitoring Systems

The starting point in any maintenance programme is to determine the current condition of the property to be maintained. Different standards may be expected by various occupiers, but all writers agree that conducting a condition survey is the first step – and the actual condition can then be compared with the desired condition. Clifton (1974) suggests a preliminary 'general appraisal of the whole situation'. This appraisal is to obtain an overall view of the situation, general state of the property, skills available to make a full survey, and budget parameters for the whole project. Holmes et al (1996) support this view. If consultants are brought in, it is difficult to imagine how they may get to know the extent of the problem without this step. An existing employee may already have much of the knowledge that an outsider will gain in this way. Clifton's first-step 'general appraisal' advice is supported by Holmes et al (1996), who state that too much detail at an early stage can result in abortive work. The information may have a relatively short shelf life and, thus, be out of date before it can be acted upon. Yeates (1994) advocates the use of a pro-forma survey form during the initial condition survey and indicates factors that need to be considered in the design of a satisfactory survey form. His diagram, illustrating factors influencing the design of such a form, is reproduced in fig 3.6 by permission of The Chartered Institute of Building.

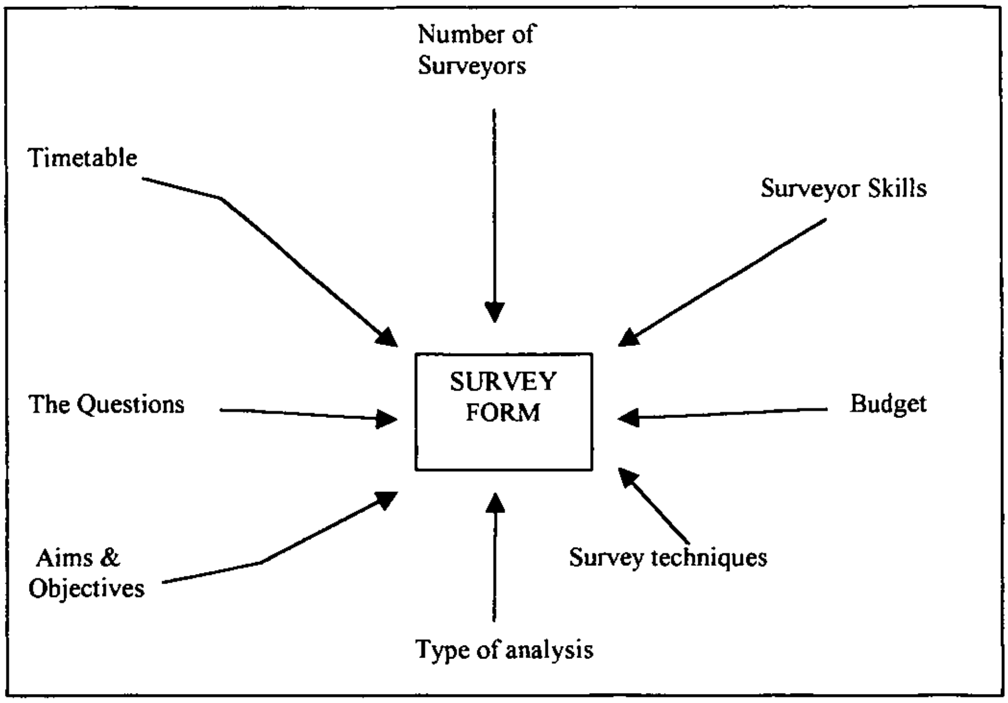


Figure 3.6 – Factors Influencing the Design of the Survey Form (CIOB Construction Papers, 1996)

Special surveying skills may be required, and it is important that the surveyor identifies the condition of the building and its components, and does not produce a list of defects only (CML 1994). The condition of the 'good' parts of the building must also be identified, and the use of the pro-forma approach suggested by Yeates may be important in ensuring that all aspects are covered.

Where more than one surveyor is engaged in similar work (i.e. multiple buildings), it is important that uniformity of interpretation of the pro-forma is achieved, so that comparison of results is made on an equal basis. Subjective views of individual surveyors, whilst they may be important, should not affect the marking system, and comments are better expressed as additional notes (Lee 1987).

Information gained from surveys is vital for the future maintenance process, but too much information can be overwhelming (CML 1994). Even with the use of computer data base storage, excess data is time consuming to the user and a hierarchy of general categories, down to detailed information, should be established, so that retrieval can be at the level required (CML 1994, Buckland 1993, Holmes et al 1996). The information needed from a survey will vary with the particular requirements of the organisation, but the following six general objectives are suggested by Holmes et al (1996):

a) establish maintenance priorities;
b) assess the maintenance backlog;
c) prepare maintenance strategies;
d) calculate maintenance budgets;
e) upgrade property files;
f) provide data for stock valuations.

In testing the survey 'on site', Holmes found that surveyors had difficulty in assessing the need for an element more than five years in advance. However, as the survey procedure is a dynamic programme, repeated every fourth or fifth year, it is possible to confirm or defer proposed action within the critical period. Data collected is wasted if the information cannot be acted on within the same year.

Whilst current standards or conditions may be shown to be good as a result of a survey, they may not be the desired condition or standard. Careful analysis of user requirements is clearly essential if the survey is to have a worthwhile benefit to the commissioners. Even if maintained at an 'as new' condition, unless the original designer had accurately anticipated the future requirements of the building, that standard could now be inadequate. The relationship between user requirements, future expectation, maintenance, and modernisation is shown in figure.3.7 (Lee 1987).

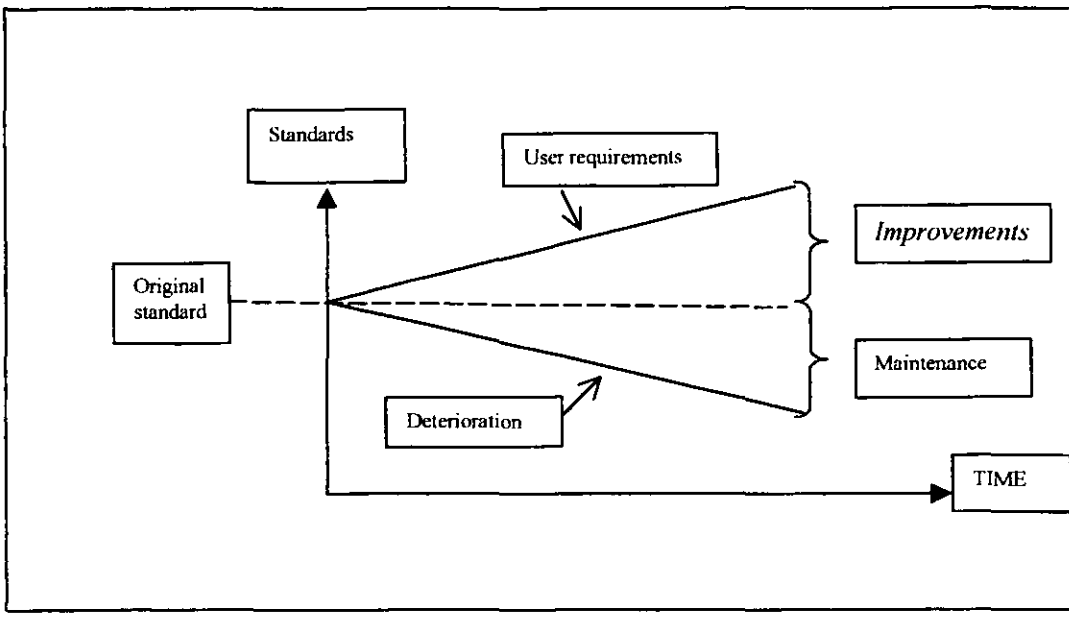


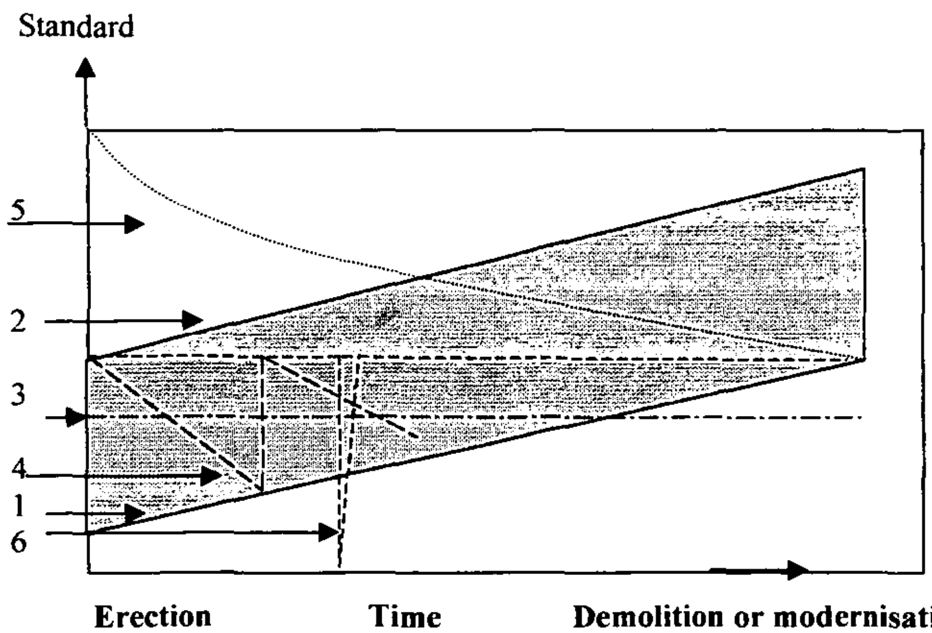
Fig 3.7 – Relationship Between Maintenance and Improvements (Lee 1987)

'The gap between the deteriorating original condition and the increasing expectation of the building user increases with the passage of time and, even if the building is maintained at original condition, more may be required by the occupiers than can be achieved without improvement or modernisation in later years' (Lee 1987).

For the condition of buildings to be monitored so that a measure of the rate of deterioration can be assessed, records must be clear about the condition on previous inspections. Clifton (1974) and Holmes et al (1996) have suggested that survey results need to be updated yearly, giving one year as maximum shelf life. This may not be possible in all cases, and may need to be more frequent in others. Where maintenance has been deferred, it may become critical before the next monitoring visit. A window that is scheduled for replacement next year, because it is beyond economic repair, may fall apart in use and have to be replaced immediately. If we consider the scenario where the window does not fail, and funds are very limited, replacement may be deferred again.

This last deferment would be a subjective decision taken by the surveyor, based on his assessment of the rate of deterioration. If the surveyor is not the same one that made previous inspections, there will only be the records, kept as part of the monitoring system, on which to base a decision. "Condition monitoring can only be effective if a failure can be predicted by some form of deteriorating performance over a sufficient period of time" (File 1991).

Figure 3.8 illustrates the relationship between acceptable standard and maintenance requirement during the life of a building. Within the limits of optimal and minimum acceptable standards, shown by the shaded area, routine repairs can operate on a pre-planned basis. Unexpected failures (6) require immediate emergency action to return the standard of the building to within the acceptable limits.



Key

1- Lowest acceptable standard in time of use. The upward slope of the line symbolizes change in the level of requirements.

2- Optimal standard during time of use; the area between lines 1 and 2 is the accepted standard area.

3- Element with immutable quality (i.e. horizontal line).

4- Rapid wear, leading to maintenance during time of use (e.g. wallpaper).

5- Slow, undramatic change during time of use; can be compensated by providing higher standard from the beginning.

6- Dramatic failure, calling for immediate action (e.g. leakage in water or sanitary installations).

Figure 3.8 – Maintenance Requirements Related to Standards Over a Period of Time (Lee 1987). Source: ECE; Proceedings of Seminar on Management Maintenance and Modernisation of Housing (Warsaw, United Nations, 1969).

3.11 Time scale of Maintenance Programs

Timing of many maintenance operations will depend on the nature of the work to be done. Patching of small areas or parts can be an on-going activity with little inconvenience to occupiers, whilst replacement of major components or protective coverings may require careful scheduling to minimise disruption to the use of the building. The frequency of repair/replacement depends on the reaction between the exposure and use conditions, and the resisting properties of the building element. Lee (1987) suggests the following six categories:

1. Those which should last the lifetime of the building (e.g. foundations).
2. Those whose life can be extended by regular maintenance (e.g. roof tiles).
3. Those which wear out in normal use (e.g. floor coverings).
4. Those which achieve obsolescence because of changing fashion or technology.
5. Those which are exposed to weather (e.g. external; cladding and roof coverings).
6. Protective coverings which require renewal to prolong the life of the protected element.

The typical cycle of renewal suggested by Lee and shown in figure 3.9 is probably more suited as a financial planning tool than as a work programming aid, when consideration is given to the identified difficulty for a surveyor to recommend work more than four or five years ahead. Lee uses the chart (figure 3.9) to estimate cash flow (at current prices) for a sixty year anticipated life of the building.

Years

Item ↓ Years →	0	5	10	15	20	25	30	35	40	45	50	55	60
Foundations													
Frame													
Upper floors													
Roof:													
Construction													
Coverings					♦				♦				
Stairs													
External walls													
Pointing							♦						
Windows													
Doors													
External							♥						
Internal													
Partitions													
Ironmongery					♥				♥				
Wall finishes							♠						
Floor finishes			♠		♠		♠		♠		♠		
Ceiling finish							♠						
Decoration		♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	
External		♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	
Internal													
Sanitary fittings					♥				♥				
Water or sanitation									♦				
Heating													
Boiler					♦				♦				
Pipes and radiators									♦				
Electrical													
Wiring							♦						
Fittings				♦			♦			♦			
Drainage													
External works						♣				♣			

♦= 100% ♥=50% ♠=10% ♣=25%

Figure 3.9 – Renewal Cycle Planning Chart.
Adapted from Lee (1987).

3.12 Mathematics for Maintenance

This condensed extract and reference is included to indicate the extent and complexity of predicting maintenance failure. Whilst largely outside the main scope of this research, this example is included to show that record keeping is essential, as it is only with the application of data from past performance that any prediction of failure is to be calculated.

For a preventative maintenance programme to be effective, it is essential to predict the frequency and probability of breakdown. Thus, if it can be shown that a lift will malfunction after 5000 activities, it is necessary to arrange a service interval that will be less than 5000 uses. This will help to prevent breakdowns, but may not be frequent enough to minimise overall costs. It is also possible that overall costs might be less if the lift was run to breakdown before servicing. It is thus necessary to have a method of calculating the most economic servicing schedule to prevent unnecessary wear and reduce the probability of breakdowns. There will be an end to the time scale of this schedule, when, despite regular maintenance, the lift will require capital funding for refurbishment and replacement of major components. The following example is taken from the University of Bath Construction Study Unit, Faculty of Architecture and Civil Engineering (Robinson A, 1991, Management Science Module).

A calculated probability that an event will occur is given by enumerating all the possibilities:

$$P(E) = \frac{\text{Number of cases favourable to } E}{\text{Total number of possible cases}}$$

This simple calculation gives the 'true' probability, but can only be achieved by overcoming the difficulty of how to enumerate the possible cases. An alternative is to physically count by observation. This is the 'frequency' definition of probability, and the greater number of observations, the closer the frequency approaches the 'true' probability. Thus $P(E) = 0$ means that *(E)* will not occur, and $P(E)=1$ means that *(E)* is certain to occur.

The probability of joint failures occurring is generally considered as one failure if they are attributable to the same cause, and as separate events if attributable to different causes. The probability of two events, *(A)* and *(B)*, occurring, which are not dependant on each other, is $P(A) \times P(B)$. Thus, if the probability that event A will occur is 0.25, and the probability that B will occur is 0.33, then the probability that these two independent events will occur at the same time is:

$$P(A) \times P(B) = 0.25 \times 0.33 = 0.0825$$

Thus, the probability of several *(N)* independent events occurring at the same time is thus: $P(A_1) \times P(A_2) \times P(A_3) \times \ldots P(A_n)$

Where events are dependant on each other, the probability that (A) occurs, given that (B) occurs, leads to the probability of the joint occurrence as P(A) x P(B/A). Using the above example, this gives a probability of:

$$P(A) \times P(B/A) = 0.25 \times (0.33/0.25) = 0.33$$

The above concepts can be applied to the calculation of maintenance schedules, especially where mechanical or electrical equipment is involved. The following example illustrates the application:

Consider a piece of equipment that has operated without failure from time 0 when it started, to time *T*; what can we say about the probability that it will run without failure to time $T + t$?

Let A be the event 'equipment runs from 0 to T', and

B be the event 'equipment runs from T to $T + t$.

The probability that the equipment runs from 0 to T, and from T to $T + t$ is :

$P(B/A) \times P(A)$

Thus, if $R(t)$ is what we shall call the reliability of the equipment (that is, the probability that it runs fault-free from 0 to t).

Probability [equipment runs fault free from T to T + t, knowing that it has run fault free from 0 to T] = $R(T + t)/R(t)$

If the records show that, for some times T and t, $R(T)$=0.7, and $R(T + t)$ = 0.6, and inspection at T shows that the equipment is running, we can say that the probability that it will continue to T + t is 0.6/0.7 = 0.8571

It must be remembered that this form of calculation can show, as in the example above, that the equipment is more likely to continue working than fail; there is no account taken of wear and deterioration that may result from further, prolonged use. Eventually, capital (rather than maintenance funded) refurbishment will be required. However, none of the writers cited so far appear to have considered a process for optimising the working economic life of equipment where historical records are not available. The timing of capital replacement works can be calculated using probability theory as above, but, again, it is necessary to obtain reliability estimates from observation of similar equipment in similar use situations.

3.13 Industrialised Building: Origins and Methods.

Non-traditional forms of construction can use innovative methods, including (usually) some off-site prefabrication. Used extensively during the 1960s, some forms of construction – that are now subject to the true test of time – may require an innovative approach to maintenance.

'After years of trying to plug holes in two of Oldham's best-known landmarks … the Landlord that manages Oldham's ex-council called a halt to repairs and took an entirely different approach'. Faced with water penetration and insulation at less than current standards, this manager decided to clad the entire 15 storey buildings with a waterproof insulated cladding. Additional to stopping the water penetration, this treatment is predicted to generate savings in fuel and $C0_2$ emissions up to 20% (CIOB Construction Manager, February 2003).

Built of pre-cast concrete and using techniques at the forefront of the then-current technology, the waterproofing between the large concrete cladding panels proved inadequate over time. Other types of 'industrialised building' have also exhibited weakness, either in the form of water penetration or through structural failure. Explanation of some of the more common forms is, therefore, appropriate.

Industrialised building methods, partly using trades and industries other than solely the traditional construction industry, require a common unit of measurement: a 'module'. A building sized at multiples of the module can utilize degrees of pre-assembly.

'Modular construction' is, thus, a global term, descriptive of building components and parts ranging from small standard components (e.g. door and window frames, etc.) right through to substantial 'delivered ready to use' buildings (e.g. washrooms and canteens). These 'ready to use' solutions may be delivered, requiring just connection to the main services – drainage, water, and electricity – to be ready for use. A Modular Building may thus be described as a complete building, assembled from modular units that comprise both the envelope and the structure (Gibb, 1999). The essential component is a core unit of measurement – a 'module' – used as a standard grid throughout the structure (MacLean et al, 1993). The standardization of component sizes and off-site manufacture are compatible to the extent that they may be considered synonymous (White, 1965, Gibb, 1999).

Using Gibb's (1999) definition of a modular building, component parts, manufactured off-site as degrees of pre-assembly, fall into two categories;

1 Volumetric: a unit that encloses a virtually finished usable space, requiring little work on site – connection of services, perhaps. Washrooms and kitchens fall in to this category, as do bedrooms complete with en-suite bathrooms used by roadside Hotel chains.

2 Non-volumetric: units and parts that do not form a usable space, but may comprise plumbing stacks or wiring looms. The door and frame fitted to a Hotel bedroom before delivery to site becomes part of the volumetric unit, whilst the door and frame delivered to site with the door fitted and hung in its frame as a corridor fire break is non-volumetric. All the pre-cast concrete sections or timber framed wall panels, etc., used in forms of industrialised building systems are, thus, non-volumetric.

Quoting various sources, Gibb (1998) identifies the differences between prefabrication and pre-assembly as:
'Prefabrication is a manufacturing process, generally taking place at a specialised facility, in which various materials are joined to form a component part of the final installation'.

'Pre-assembly is a process by which various materials, prefabricated components, and/or equipment are joined together at a remote location for subsequent installation as a sub-unit. It is generally focused on a system'.

A 'system' can be considered as a method of building differently to the traditional bricks and mortar approach. Generally, separate contractors had their own separate system of industrial building usually, but not always, utilising prefabrication as a main difference to traditional methods (Maclean et al, 1993).

3.14 Origins of and Incentives for Prefabrication: A Brief History.

'I have been looking eagerly, ever since I took office, for some system of prefabrication which would enable us to build houses in the same way as cars and airplanes. So far, my search has been in vain, but I do not despair' (Aneurin Bevan, Minister of State for Health, 1945).

What Aneurin Bevan was looking for in 1945 did not really exist then in Britain. There were various designs and systems beginning to emerge, particularly in America where the Modern Movement of Architecture provided encouragement. The possible benefits of using modern manufacturing methods to create buildings was an incentive to the manufacturers, and the stark angularity made fashionable by the Modern Movement made sectional construction easier.

At the end of the Second World War, the newly elected Labour Government was faced with, and had foreseen, the problem of a severe housing shortage. Many houses had been destroyed or badly damaged, and many of the skilled workers needed to construct new homes had been killed in the war. Craftsmen were too few to train the numbers of apprentices needed to fill the vacancies.

In any case, the time taken to train these men in traditional methods would have been too long to cope with the immediate demand. There was also a shortage of young men to train in traditional skills, and those that may have taken apprenticeships on leaving school had soon become involved in the war. At the end of the war, those that had survived were too old to be apprentices.

'It cannot be too often stressed that the entrepreneur invests only his money in industry and may withdraw and transfer to more lucrative fields if he so desires. The craftsman, however, is bound by years of training to invest his life in the industry and can rarely escape the consequences of being irrevocably committed at an early age' (Weaver, 2nd CIB, 1992).

In the same way that there was a shortage of building tradesmen, there was now a surplus of men and manufacturing capacity in the armaments, aircraft, and shipbuilding industries (Finnimore, 1998; Vale, B., 1995). New materials were available, such as polyester and epoxy resins. The development of jointless waterproof membranes enabled alternative methods of waterproofing to be used. These new materials needed new skills, and these skills were imparted to adults instead of being part of an apprentice training program, as it would have been before the war (Bates, A., 3rd CIB, 1996).

In May 1944, nearly a year before the end of the war, a prototype bungalow was exhibited at the Tate Gallery. Referred to as the Portal Bungalow (Lord Portal was Minister of Works, and largely responsible for the bungalows development), this design was never mass-produced. Its purpose was to invite comment and encourage manufacturers to produce their own designs based on the ideals illustrated by the prototype.

It is interesting that there was similar concern at the end of the First World War, and half a million dwellings were promised under the Addison Housing

Programme as 'an insurance against revolution'. Following economic depression, this target was reduced to 176,000 in 1921. Despite this setback, a total of 579,000 state built homes were constructed during the inter-war years 1924-1935 (Merett 1979). The 1917 Tudor Walters report (discussed earlier, in Chapter 1) examined the implication of a State funded housing programme and suggested that house building should be the product of "up to date methods of business organisation, scientific costing, and standardisation".

3.15 Economic Factors

Seeley (1983) argues that industrialised building methods invariably require higher capital investment and, if the industrialised method is to be successful, this must be compensated by lower labour costs, by achieving greater productivity. Seeley suggests that, to achieve this higher productivity and contain costs, the various systems and methods available sort themselves into categories:

(1) Load-bearing wall construction is best suited to building types with small spans, such as dwellings.

(2) Systems for buildings up to five stories high are more economically designed as column and beam structures.

(3) Structures over five stories high, with increases in vertical loading, are well suited to panel construction.

(4) Savings in cost stem from a reduction in the number of different materials used for walls, floors, and facades.

Stone (1976) stresses the need for accurate planning and cost forecasting.

3.16 Construction Methods and Systems

3.16.1 The 'Prefab'

Four main types of prefabricated bungalow, now commonly referred to as 'Prefabs', were produced as a result of concerted efforts to combine the shortage of skilled building workers, surplus factory production capability and a severe housing shortage (Vale 1995). Labour for the production was, thus, generally unskilled (or skilled in other industries). Materials were not easily available, and the designs allowed for the most economical use. Ceiling/roof joists on the Uni-Seco bungalow, for example, were machine-jointed from smaller section timbers to achieve the depth required for the span of 10 feet - 3 inches. There were several other designs and manufacturers, but none produced numbers that can be considered as more than trial production runs of prototypes (Vale 1995). The four main types produced were:

3.16.2 The 'Arcon' Bungalow.

Taylor Woodrow Construction Ltd. was the construction arm of Arcon, and an order for 86,000 bungalows was placed with them in September 1944 (Vale 1995). In the end, 38,859 were produced. Despite major redesigning of components (found necessary to aid mass production and achieve improvements), the first family took occupation in July, 1945. Experience gained during the War was used to enable the transition from prototype to inhabited dwelling in less than a year.

It is important to note that the Arcon bungalow was not seen as temporary housing only, but specifically as temporary housing on a specific site; the bungalow was to be dismantled, moved and re-erected when permanent building could be done. Many were moved and re-erected, often in a different configuration. The ability to interchange wall panels within the size grid formation allowed alternative positions of doors and windows.

3.16.3 The Uni-Seco.

This was less of a complete unit, but a kit of section and panels that allowed variations of design by interchanging units within a grid. A moulded timber post with rounded grooves on all four faces accepted the rounded tongue on the edges of wall panels. The bottom edge of the panel had a groove that sat on a tongue formed on the perimeter edge timber, and a head rail was similarly located. Panels were then screwed to the posts and rails, with a mastic bead sandwiched between. Wall construction was of asbestos cement sheets with a wood fiber and cement filling and timber edges. This produced a stressed skin type panel with thermal insulation almost as good as a 280mm cavity wall of brick. Internal layout was very similar on all four bungalows, following the Portal example (many of these were dismantled, sold, and re-erected on alternative sites, providing low-cost agricultural seasonal workers accommodation).

3.16.4 The Tarran Bungalow

Unlike the other three, this was not so much the production of a committee of various experts, but the result of one man's drive and obsession with prefabricated housing. Originally a carpenter, Robert Tarran developed a firm that produced timber huts for wartime use. Shortage of timber may have led him to consider alternative materials, and the resultant design consists of concrete panel walls with a shallow-pitched Asbestos sheet roof. This was the only design that could be produced in a terrace form.

3.16.5 The Aluminium Temporary Bungalow

Some 54,500 were built, and this was the most successful – but also the most expensive – of the four principal types. There was an important difference in the construction method, in that it was built and entirely assembled in a factory, and then dismantled into four sections and transported to site partly-assembled. On site, the sections were re-connected and the bungalow was virtually complete. Because of limits that existed on the width of items that could be transported by road, the maximum width of each section was 7 feet – 6 inches. A crane was needed to lift each section into place on site. All fittings and finishes were installed and applied at the factory, and the section containing the services, water, drainage, electricity, and gas required connecting to the mains services, and the building was then ready for occupation.

'Whilst the construction of 'prefabs' was clearly a means to an end – the easing of the housing shortage – their importance in the development of industrialised building methods cannot be ignored. Prefabs clearly demonstrate the first major attempt to produce multiple dwellings using off site fabrication techniques' (Vale 1995).

3.16.6 Steel Framed Buildings and Timber Framed buildings

The British Steel Corporation developed a Steel Framed House that enjoyed little commercial success, although many were built. In an effort to improve the balance of payments, the Government introduced an imports quota, or licensing system, on timber. This restriction was removed in 1953 and, although steel framed houses continued to be built, timber framed houses began to take over. Prior to 1957, a steel and concrete framed building was sponsored by Unity, but this was then abandoned in favour of a timber framed two-story house system, with brick cross walls (timber party walls were not allowed under the Building Regulations until 1964).

The 'cross wall and infill panel' approach used in the Unity method allowed for a combination of traditional bricks and mortar and also off-site fabrication of the infill panels and (sometimes) floor platforms. Prefabricated roof trusses appeared as part of the process, which became known as the Rationalised Building Method, or 'Platform Frame'. The essential difference of the platform frame method was that there was no skeletal frame erected by skilled tradesmen. The walls were assembled by unskilled labour, on large benches in a factory, and delivered to site ready to erect. The traditional jointing techniques were abandoned in favour of simple butt joints, held together by steel plates. In many factories, the frames were merely tacked together before passing through giant rollers, which pressed home jointing plates and trued the frames flat of any twisting. Similar methods are still used today (Finnimore 1989).

3.16.7 Pre-cast concrete

One of the first pre-cast concrete dwellings was erected by Cubitts for the Cheap Cottages Exhibition in 1905. This consisted of story-height slabs arranged in a polygonal shape. Further systems developed, and smaller concrete panels became popular in systems such as the 'Cornish Unit' and the 'Airey' House. These were post and panel type constructions, not unlike the American 'Clapper board' houses, but of concrete instead of timber. In 1946, using experience gained in wartime, Wates introduced the first British system to use room-sized panels.

By 1950, the use of large pre-cast panels had developed, and stimulation for further development was provided by the Government. This took the form of a subsidy to local authorities, which varied with the number of stories of the building. This favored high-rise development to restrict land use, and approvals for buildings over 5 stories increased from 8,044 in 1955, to over 44,000 in 1956. The development of the tower crane made erection possible, and improved jointing techniques made the use of large panels more practical. Two of the principal producers of high-rise pre-cast concrete flats were Concrete Ltd. (Bison Wallframe) and Wates (London) Ltd. The systems were very similar in construction and the principal difference may be considered that Concrete Limited established a series of five production plants, spread over the country, whilst Wates established a temporary on-site factory for each development (Finimore 1998).

3.16.8 'No fines' Concrete houses.

This system consisted of a reusable set of shuttering that allowed for the in-situ casting of an entire house in one pour. There were other firms that used a similar technique, but to anyone involved in rationalised building systems, it is difficult to speak of the 'no-fines' method without saying 'Wimpey no-fines'. Although used by several firms, including Laing and Cubitt, it was George Wimpey that persevered with the system and, eventually, made it their own. By 1968, Wimpey claimed that over three-quarters of a million people were living in 'no-fines' houses. The success of the method may be due to its simplicity. The concrete mix contained no fine sand and produced a lighter honeycombed concrete with better thermal insulation. Shutters were lighter and could be moved by hand, reducing craneage costs. The variations in design available was an added attraction to many local authorities, as it allowed a less regimented final product – eleven different designs being used on one estate in Coventry in 1953 (Finnimore 1998).

Although only four types of industrialised methods are considered here, the considerable differences in the forms of construction and materials indicate the diversity of problems that can be encountered during maintenance of these buildings. Many other types and variations exist, and new methods and materials are being developed; timber framed buildings now extend up to 5 stories, and pre-cast concrete floor beams are replacing the traditional timber joist (Building Engineer, February 2000). Within the range of available materials and skills available following the reduction in armaments production after the War, many different methods – and variations of methods – were Employed, with varying degrees of success. Consideration of these additional methods and materials is considered outside the scope of this work.

3.17 Maintenance Provision and Problems Specific to Industrialised Building.

Few writers include maintenance 'problems' in literature about industrialised building. In Wates high-rise system buildings at Whitehawk estate, Brighton, a tried and proven method of waterproofing the joints between the large concrete panels failed, because of the coastal location. In tests conducted by the author in 1968, the actual failure proved to be impossible to replicate. The local Fire service exercised a pump engine with various jets and sprays directed at the joints, and a moisture meter was used inside the building to detect any rise in the moisture content of the wall panels. The jointing method, also used by Bison, consists of a loose Neoprene tongue hanging in a groove formed in the edges of adjacent panels. This tongue deflected rain, hail and snow, and even fire hose concentrated water. It failed, because heavy sea mist rose around the tongue and settled on the concrete behind. Instead of running down the tongue and out over the lower concrete panel, this moisture soaked into the concrete. This problem was overcome by expanding mastic caulking to all joints. The Wates system is shown in Appendix 7.

The technology of mastic pointing – and the solution – is described in detail by Lee How Son et al (1993), together with a list of 'mastic failure' causes. Had the problem not been detected during the construction stage, it is probable that it would not have been identified as a 'general problem', but as an 'isolated failure' some time later on, and it would then have been more difficult to correct. Both Wates and Bison systems were constructed without external scaffolding, and mastic pointing was carried out from cradles suspended from the concrete roof slab.

Equipment, generally in the form of scaffolding poles and counter weights, was lifted to the roof using the construction tower crane, and was lowered by hand on ropes at completion. This allowed a lower cost remedy – applied to the potential long term problem specific to that exposed coastal site – to be achieved than would have been possible using scaffolding as access to the external elevations.

'The performance of any building can be affected by decisions taken and actions performed at any stage of a building project, from its initial conception to its final demolition. This reflects the importance of maintenance throughout the life of a building' (Lee How Son et al, 1993). More usual maintenance, such as cleaning or repair of broken windows, or decoration to the timber frames of windows and balcony doors, is carried out from within the building; it could be considered that the building's design therefore restricts the maintenance requirement to the absolute minimum. Where required, safe access was provided within the design – in this respect, predating the CDM regulations by some 30 years!

Myrvin Haley of Leeds City Council Department of works produced a system for remedial works to the Council's stock of Airey concrete houses (Appendix 6). This system of repair virtually removed the industrialised building component of the houses and replaced it with traditional bricks and mortar. The documentation, shown in full in Appendix 6, indicates the exacting detail necessary to enable the work to be carried out with the buildings occupied, to maintain structural integrity, and to allow for even more 'traditionalisation' of the building at a future date, should it be necessary.

Some buildings erected using industrialised methods failed, because of a combination of factors: changing social condition as well as ventilation and condensation problems merged to make both the buildings unsuitable for the tenants, and the tenants unsuitable for the building. The resulting slum conditions, which the buildings were designed to replace, became as bad as before. Glasgow City Council identified point blocks as acceptable only to tenants without children, but the deck access style of development that followed was not acceptable to any. Some developments were demolished, and others, like the Springburn C development, built in 1971, were transferred out of the system, totally refurbished, and sold (Horsley 1990).

3.18 Government Encouragement of System Building

During the early 60s, there was considerable 'encouragement' from various State Ministers, including Sir Keith Joseph, Geoffrey Rippon, and, after a change to the Labour Government, Mr. Crossman. The National Building Agency (NBA) was formed in 1963. Its services were intended to adapt local authority building policies to the use of system building. These included:

- helping individual authorities to group their requirements and create enlarged programmes for system building,
- advice on administrative procedures related to system building,
- a full system building design and planning service,
- advice on the suitability of individual sponsors,
- assistance in forming "sound working relationships" with sponsors, and
- advice to sponsors on the development and modification of their products to suit local authority requirements (Finnimore 1989).

Although the NBA charged a fee for its services, it was far from self-funding, and relied on a government subsidy for over half of its operating cost.

Selective Employment Tax was introduced in 1966. This tax was levied on 'service industries' with the intention of encouraging the transfer of labour from service to manufacturing industries. This was intended to increase the production of goods for export by utilising scarce manpower, and on site building work was included as service industry. Any labour used off site, in a factory production of system building components, for example, was exempt. The National Builder publication claimed this tax increased the cost of a traditional house by around £70.

3.19 Sponsors and Surplus Production Diversification

In much the same way that manufacturers of prefabs had sponsors, each system had a sponsor. It was possible for one organisation to sponsor more than one system, and for a system to have more than one sponsor. According to Finnimore (1998), there were three types of sponsor: building firms, non-building firms, and clients. Non-building firms subcontracted building firms to erect their systems on site, and building firms tended to be large national contractors. Client sponsors were either government departments or consortia of local authorities.

At the end of the Second World War, various firms attempted to use their surplus production capacity to produce buildings. Apart from some instances in the early production of 'prefabs', this experiment was short lived. The construction industry adapted itself to the revised demands of local authorities, and to the use of new technology. Established building firms thus became sponsors for various systems, some buying a license to use an established – and often foreign – system, whilst others developed their own. Virtually all the large national construction companies became involved: Laing, for example, using 'Easiform' and a derivative for high-rise, which they later replaced by buying the Jespersen system. Whilst Easiform and Storiform were in-situ cast systems, the Jespersen system was entirely pre-cast. R.M. Douglas used a Lift Slab system, bought under license from America, and formed a subsidiary company to market the system in the UK. Wates (London) and Bison both used their own, if similar, system and

Wimpey continued to advance the no-fines system to produce medium-rise blocks of flats.

3.20 Summary of Literature Review

A search for category-specific costs required for two of the three objectives did not reveal any suitable and verifiable data. Cost categories identified by White have thus been used for data collection in the main survey.

The literature reviewed has shown maintenance works separated into categories of work, policies applicable for getting that work done, and the importance of cost monitoring throughout. The relationship between work required to enable the building to deliver the increasing expectation of the user, and the planning and maintenance policy choices available are shown to range from 'run to failure' to total 'planned preventive maintenance'.

There is considerable agreement between many writers, with differences being generated by the approach taken to investigate specific detail. There is little work relating to the maintenance of buildings constructed by industrialised methods, and those publications which do exist indicate that traditional building trades and methods are used when repairs or improvements are necessary (as shown with Leeds City Council and Oldham examples).

Chapter 4 Empirical Data

4.1 Introduction

This chapter examines the data collected from the proceedings of two surveys, described in Chapter 2. The objectives of the thesis are repeated below for ease of reference:

1 To investigate maintenance costs of traditional and 'industrialised system built' multiple domestic accommodation buildings, and compare their maintenance costs.

2 To identify the principal maintenance cost categories perceived by various construction industry professions and test the hypothesis that 'actual highest cost maintenance categories for domestic dwellings are not the same as those perceived as the highest cost categories by domestic dwelling design professionals'.

3 To measure and compare the use of planned preventative maintenance programmes against other maintenance and repair policies.

The smaller of the surveys, using the Delphi technique, is shown first, and provides information relative to objective 2. The larger survey, providing information relative to objectives 1 and 3, is then shown as a collection of sequential analyses, following the pattern of the data collection questionnaire.

4.2 The Delphi Survey

A 2-stage Delphi survey of 10 building industry professionals, including Architects, Building Surveyors, and Quantity Surveyors from both the public and private sectors (as described in Chapter 2) was carried out in the sequence as shown in Figure 4.0.

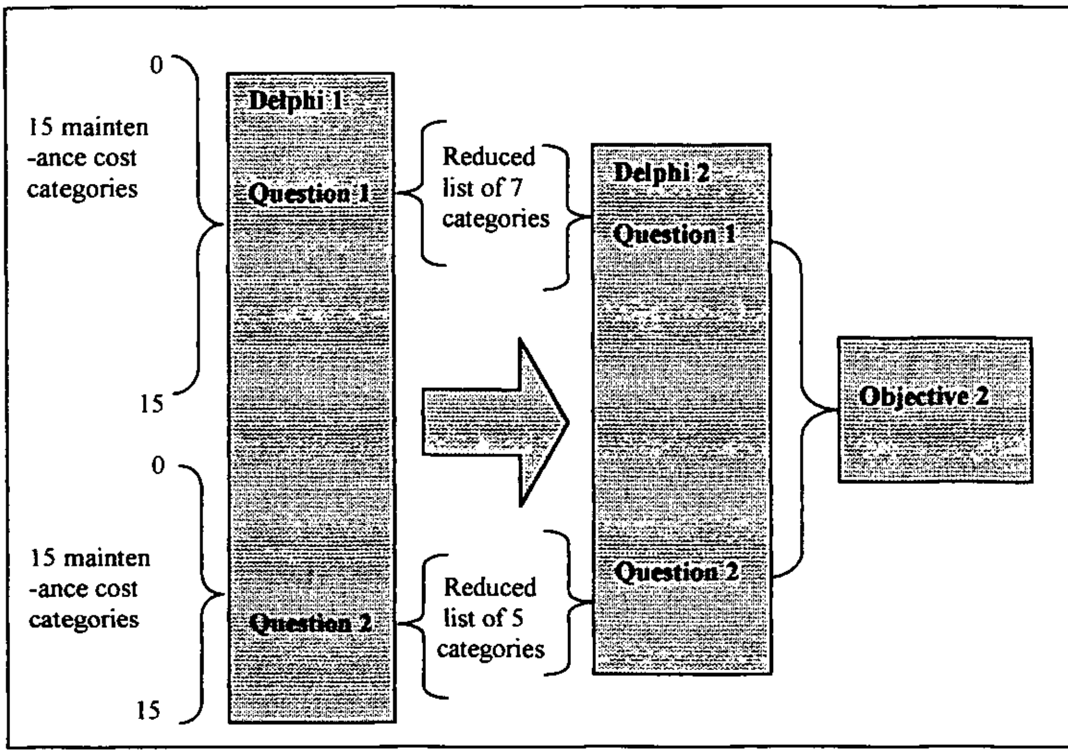


Figure 4.0 – Diagrammatic Representation of Delphi Survey Sequence.

4.3.1 The Delphi Survey: Round One
Maintenance Cost Influence Rating Analysis

Table 4.1 shows the data recorded from the first round of the Delphi survey.

In round one, contributors were asked to rate 15 maintenance cost categories to show those that they believed had the greatest influence on maintenance costs. Rating Figures shown in column 2 are derived from the 5 possible grades of importance, with A = very important having a value of 5, through 4,3,2, until E = least important having a value of 1. These aggregated scores from the total contributors provide the 'Total Value of Round 1' rating (column 2). Second highest scores, items 1 and 9, both scoring 33, were thus considered to be just less important than item 8, with 36 points.

Row number from questionnaire	Total value of round one rating	Category description
1	33	External decoration
2	21	Internal decoration
3	27	Main external structural envelope
4	28	Windows and external doors
5	31	Roofs and gutters
6	22	Floor coverings
7	21	Internal construction, partitions, doors.
8	36	Plumbing, Heating, Hot water systems.
9	33	Kitchens and Bathrooms.
10	25	Electrical excluding fire alarm systems.
11	22	Fire detection and alarm systems.
12	27	Lifts and common stair cases.
13	15	Woodworm and beetle infestation, rot.
14	15	Security and door entry systems.
15	2	External works and landscaping.

Table 4.1 – Aggregated Rated Values from First Round.

The data shown in Table 4.1 is depicted graphically in Figure 4.2, with the vertical broken line separating the upper third of score values forming the basis of the second round of data collection.

In order to enable the contributors to focus, in the second round, on a reduced list (containing only half of the original first-round list of options), only the highest-ranking 7 of the original 15 options were selected and carried forward to comprise the second-round list of options.

The second question of the first round asked contributors to select five categories of the original fifteen categories that were provided for round one. These five were to be ranked in order of importance of planned preventative maintenance for preventing breakdowns and unplanned maintenance of multiple domestic accommodation. Table 4.3 shows the total scoring aggregated from all contributors.

Categories scoring 23.9 or less eliminated and excluded from the second round of Delphi survey.	Categories scoring 24 or more to be ranked in second round of survey.

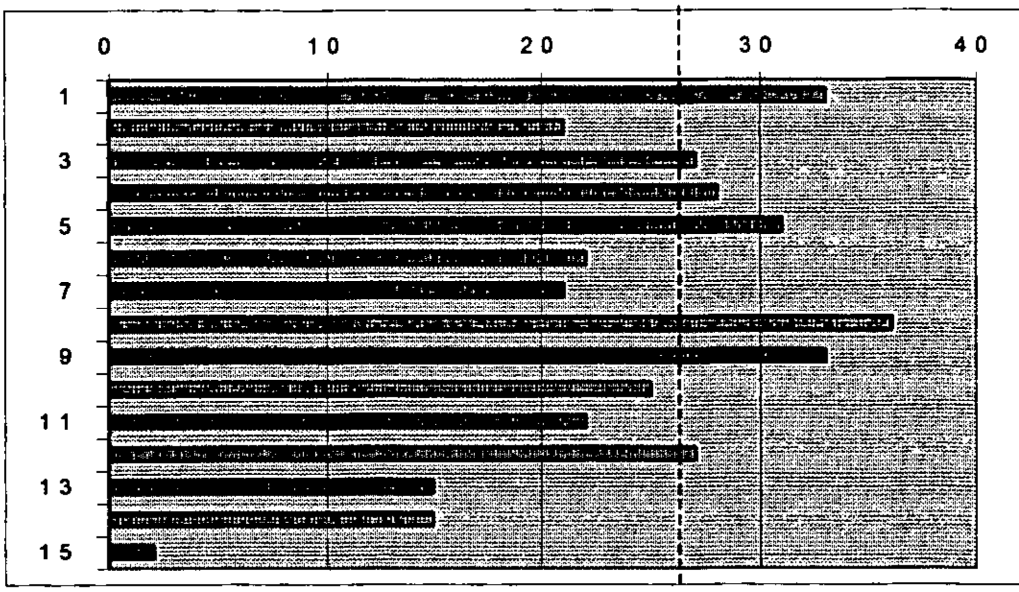


Figure 4.2 – Graphical Presentation of Table 4.1a

A	21	Roofs, gutters and drainage
B	3	External decoration
C	10	Main structural envelope
D	6	Windows and external doors
E	0	Security and door entry systems
F	4	Floor coverings
G	0	Internal construction, partitions and doors
H	27	Plumbing, heating , hot water systems.
I	12	Kitchens and bathrooms
J	10	Electrical installation (not fire alarms)
K	0	Fire detection and alarm systems
L	5	Lifts an common stair cases
M	5	Wood worm, beetle and rot.
N	2	Internal decoration
O	0	Other

Table 4.3 – Aggregated Ranking Scores from First Round of Survey.

The data shown in Table 4.3 is depicted graphically as Figure 4.4. The vertical line drawn at 9 points (1/3 of the highest score) indicates the separation point between those categories that ranked highest – and that were, therefore, to be reconsidered in the second round – and the lower remainder, which were deleted from the list of available options to be carried forward to round 2.

Categories A (roofs and gutters) and H (plumbing, heating, and hot water systems) were ranked as clear leaders, with C (main structural envelope), I (kitchens and bathrooms), and J (electrical installation) as a group of secondary importance. All five categories were included in the second round, to ensure that enough options were given to obtain a representative evaluation (which might not have been possible had only the leaders gone forward).

Categories scoring 8.9 or less excluded from second round.	Categories scoring 9 or more to be reconsidered in second round of survey.

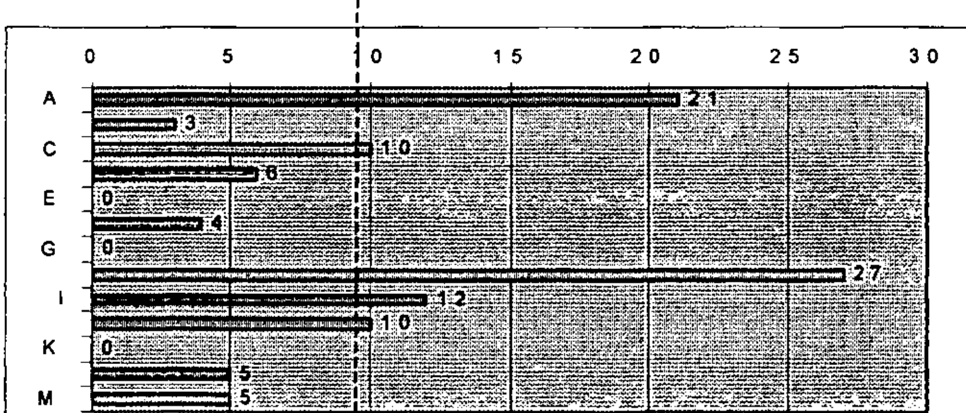


Figure 4.4 – Category Importance Ranking for Breakdown

4.4 The Delphi survey : Round Two

The first question of the second round, built upon information obtained from the first question of the first round, asked the contributors to look again at the reduced categories resulting from the first round and, again, to rank them. The eight remaining categories were to be ranked in the order of importance according to the contributors with respect to their influence on the overall maintenance costs of buildings. Table 4.5 shows the aggregated scores for the separate categories; showing 'roofs and gutters' as the identified category having the highest cost influence on overall maintenance.

'Roofs and gutters' was shown to be the highest scoring category, and the information in Table 4.5 is shown graphically in Figure 4.6, illustrating the variation in overall rating. Category numbers are provided on the vertical axis and rating scores on the horizontal axis.

The second question of the second round asked contributors to reconsider the reduced list of categories that were identified in the first round. Contributors were asked to rate this reduced list again, and, thus, to rank the order of importance in which they believed these categories to be placed in planned preventative maintenance to prevent breakdowns, as well as unplanned repairs and maintenance. The data is presented in Table 4.7, with the highest rated category – 'plumbing and hot water systems' – shown shaded.

Analysis of the data from the Delphi survey indicates that domestic accommodation building design professionals believe that 'roofs and gutters' is the category that has the greatest influence on overall building maintenance costs.

ANALYSIS OF HIGHEST COST INFLUENCE FROM DELPHI 2ND ROUND DATA					
Category description	Item No	Total value of round 2 rating -10%	Data	+10%	Grouping by ± 10%
Roofs and gutters	4	55	61	66	Highest influence
Kitchens and bathrooms	6	42	47	63	2nd highest influence
Plumbing & hot water systems	5	35	39	43	
External envelope	1	30	33	36	3rd highest influence
Windows and external doors	3	26	29	32	
Main structural envelope	2	24	27	30	
Lifts and common staircases	8	22	24	26	4th highest influence
Electrical excl. fire alarms.	7	17	19	21	

Table 4.5 – Category Cost Influence on Overall Maintenance Cost.

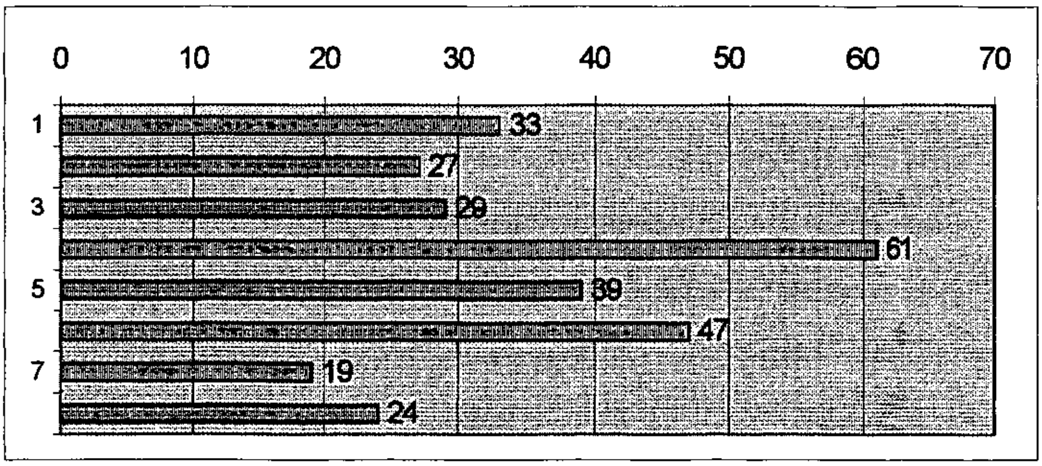


Figure 4.6 – Category Cost Influence on Overall Category Cost.

ANALYSIS OF IMPORTANCE OF PREVENTATIVE MAINTENANCE FROM DELPHI SECOND ROUND DATA		
Category description	Item	Total value of
	number	round 2 rating
Roofs, gutters and drainage	1	27
Main structural envelope	2	10
Plumbing & hot water systems	3	31
Kitchens and bathrooms	4	20
Electrical installation excl. fire alarms	5	18

Table 4.7 – Category Importance Rating for Breakdown Prevention

According to this data, plumbing and hot water systems is the category most requiring planned preventative maintenance to prevent unplanned maintenance and breakdowns.

4.5 The Main Survey

The main survey was a postal survey of 784 'maintenance managing agents', ranging from private landlords through to professionals managing many buildings, and consisted of a 4 page questionnaire, presented in booklet format for ease of completion. The following 12 questions, presented in multiple choice format where possible, and asking for detailed financial information, or other written reply, are briefly summarised as follows:

Q1 Name and address of respondent.

Q2 Address of building information relates to.

Q3 Age of building.

Q4 How built (i.e. traditional or other)?

Q5 How is the building's maintenance management controlled?

Q6 Expenditure on categories during 1995 to 1999.

Q7 Is budget satisfactory?

Q8 What is the building's use (i.e. private/local authority flats, etc.)?

Q9 How is the maintenance budget allocation decided?

Q10 When is maintenance work done?

Q11 What is the future maintenance policy?

Q12 How can maintenance costs be reduced?

The survey questionnaire is included in full in the following pages for clarity, and each question's data is then presented in numerical order.

4.5.1 Annual cost comparison

The following data were extracted from the master sheet, containing a section of the input data from the survey questionnaire. Costs in Table 4.9 are total maintenance costs. This total cost is examined further, separated into exclusive cost or budget headings as defined by White (1973), in subsequent analysis. These budget headings are:

1) External decoration.
2) Internal decoration.
3) Main structure, including windows and doors.
4) Internal constructions, including partitions.
5) Plumbing and sanitary services.
6) Mechanical systems, gas, and heating.
7) Electrical work, including kitchens.
8) External and civil engineering works.
9) Routine cleaning.
10) Other works

White included another heading of 'Fittings' (shelves, closets, etc.), which is not examined here, although some may be included in the category of 'other works' – included here as a 'catch all' for costs recorded without attachment to a specific category. The cost relationship between these 10 categories, separated for years 1995-1999, is shown in Figure 4.8.

YOUR HELP IS IMPORTANT, THANK YOU FOR YOUR CO-OPERATION.

This questionnaire will provide valuable information for research by the author at the Faculty of Civil and Building Engineering at Loughborough University, into expenditure on maintaining large buildings used for multiple domestic accommodation.

These buildings will be typically purpose built flats, buildings converted into flats or for multiple occupation, Halls of Residence, Hostels and the like.

Information on accommodation constructed by Industrialized Buildings Systems, pre-cast concrete 'System Build', and other rationalized building methods will be of especial value as a comparison with traditionally built structures.

ALL INFORMATION PROVIDED IS CONFIDENTIAL AND INDIVIDUALS AND ORGANISATIONS WILL NOT BE IDENTIFIED.

This survey forms part of research investigating maintenance costs and procedures for both traditional and modular 'system built' domestic accommodation buildings. Where specific costs are not available, please insert approximate figures (marked App.£)

(Q1)Information provided by (name) (Job title)

(address)

(Post code) (Tel)

(Q2)The address of the building this questionnaire is examining is

Post code

(Q3)How many years old is the building, please tick box below Built in?

10	20	30	40	50	60	70	80	90	100	

(Q4) Is the building of (tick box)

	YES	NO		YES	NO
Traditional bricks and mortar			With traditional pitched roof?		
Reinforced Concrete			With Flat roof?		
No-fines Concrete			Of pre-cast panel walls?		
Other			5 or more stories high?		

(Q5)WHO MANAGES THE BUILDINGS' MAINTENANCE?

	✓
Specific maintenance manager	
Part of General Manager's duties	
By outside consultants — As required	
By outside consultants — All the time	
Others	

(Q6)ANALYSIS OF MAINTENANCE COSTS

Please complete the totals cost on the top line, and % separations where known below

TOTAL ANNUAL COST	YEAR 1 1999	YEAR 2 1998	YEAR 3 1997	YEAR 4 1996	YEAR 5 1995
TOTAL AMOUNT SPENT ON MAINTENANCE PER YEAR	£,000				
External decoration % of total					
Internal decoration %					
Main structure including windows and gutters %					
Internal construction including partitions and doors %					
Plumbing and sanitary ware %					
Mechanical including gas, heating and air conditioning %					
Electrical work including kitchens %					
External civil engineering works %					
Routine cleaning %					
Other %					
(Any Short fall in total will be distributed pro rata)					

(Q7) Do you believe the budget as allocated is sufficient for full and adequate maintenance of the building?

YES ☐ NO ☐

If no, what increase in funding do you believe is necessary. (✓ appropriate box)

0-10 %	11-20%	21-30%	31-40%	41-50%	51-60%	61-70%	71-80%	81-90%	91-100%

More than 100% ☐

(Q8)What is the building used for.

How many? Sq Mt	Flats	Bedrooms	Occupants	
Private Landlord Flats				
Local Authority Flats				
Hotel / Hostel				
Other ________				

(Q9)How is the maintenance budget allocation decided ? √

1 Based on last years costs ☐

2 Percentage of Capital value. ☐

3 Percentage of overall maintenance budget. ☐

4 Planned works + emergency works cost. ☐

5 No formal itemised budget in place. ☐

6 Other ________ ☐

(Q10)

Maintenance work is done (√those that apply,↓) (the predominate method is ✓↓)

1 Only done when considered necessary. ☐ ☐

2 Only done when something breaks down. ☐ ☐

3 Done as soon as necessary. ☐ ☐

4 As a planned maintenance routine. ☐ ☐

5 A mixture of more than one. (✓ them) ☐ ☐

6 Left until funds available. ☐ ☐

7 Other. ________ ☐ ☐

(Q11)What is the Policy for future maintenance?
Please tick in the grid under the appropriate years and opposite the proposed policy.

	YEARS 2 - 3	3 -5	5 - 10	10
Planned Maintenance Policy				
Corrective works only				
Mend it when it breaks only				
Other				

(Q12)
Do you believe that overall maintenance costs can be reduced by.

1 Planned regular maintenance.

2 Better original specification.

3 Additional contribution from occupier to specific items.

4 Other views ______________________

Thank you for your help in completing this Questionnaire, a stamped and addressed envelope is provided for its return. If you would like to discuss any part of this research, or to receive a copy of the findings, conclusions and recommendations, please include your requirements when returning this survey.

Thank you for your co-operation with this project. If you would like to discuss any aspect of this research, or have a query, please contact me.

H.Keith Farmer. Pleamore Cross farm, Pleamore Cross, Wellington, Somerset, TA21 9QE.

Tel. 01823 666223 Mobile 07831316839, Email: [illegible]

Figure 4.9 shows the individual expenditure of the ten categories adapted from White (1973) for the years 1999 (on the left of the scale) to 1995 (on the right-hand side). Each category is shown individually, with the actual cost figures in Appendix 5. This work does not claim to explain fully the somewhat erratic variation in annual expenditure, although suggestions are offered for each category where appropriate.

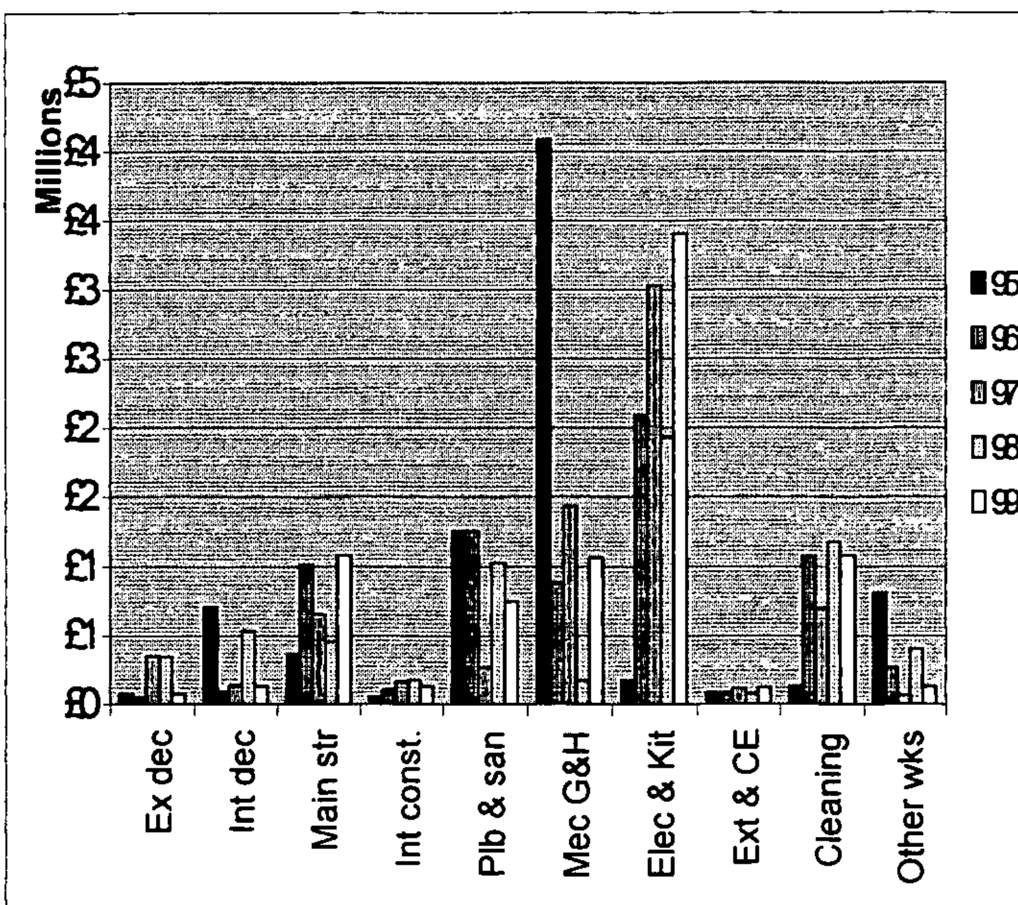


Figure 4.8 – Annual Cost Variation Comparison Between Maintenance Categories

4.5.2 Annual Cost Variation

The survey shows that average maintenance costs have risen by 39% between 1995 and 1999. The rate of increase is not regular and some possible reasons for this irregularity are suggested below.

Year	1995	1996	1997	1998	1999
£ per unit	£, 740	£,890	£,880	£,910	£1,030
% variation	-	20%	-1%	3%	9%

Table 4.9 – Maintenance Expenditure per Unit of Accommodation, 1995-1999

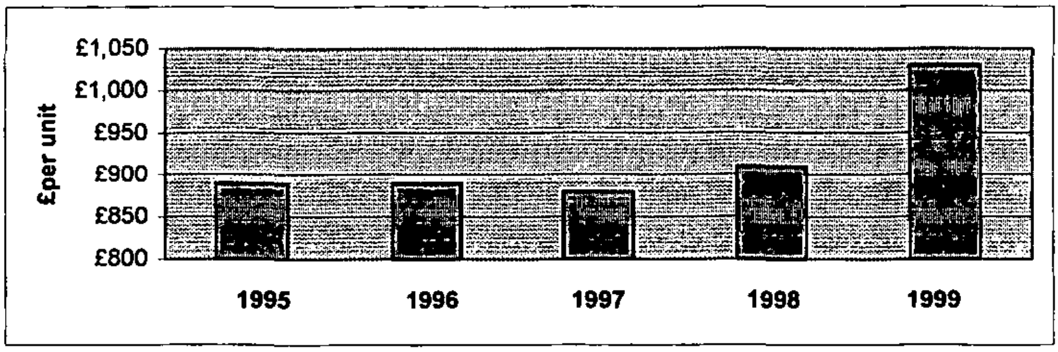


Figure 4.10 –Variation in Maintenance Expenditure, 1995 – 1999.

Costs prior to 1995 are not available, but, following Newcombe et al (1992), these figures may indicate that the 20% increase year on year, from 1995 to 1996, includes:

a) the cost of 'catching up' on postponed maintenance held over during the financial recession and activated because the economy was improving,
b) items that could not be further postponed, and
c) private landlords, who may be more likely than local authorities to hold back expenditure during a recession, as private landlords may be able to 'carry forward' unspent budget more easily than local authorities.

Political uncertainty and a change of government in 1997, together with the catch up work in the previous year, may then have caused the reduction in maintenance expenditure shown at –1% growth for that year, and account for the gradual increases in the following two years, as confidence returned.

4.5.3 External Decoration

Expenditure on external decoration rose sharply in 1997, and continued through 1998, before dropping sharply back to virtually 1995 levels in 1999. Following Lee (1997), if buildings are decorated externally at 5 yearly intervals, some irregularity can be anticipated. In this survey of 7611 units of accommodation, 6600 were decorated during the years 1997 and 1998, and row 6 of Table 4.11, below, shows alternative figures, excluding the extraordinary 6600 units decorated and their associated costs.

Fellows (1993) postulates that maintenance work/cost is easily deferred during times of financial restraint and that recovery from economic recession had already started in 1996. Therefore, the possibility that external decoration programmes, principally operated by local authorities, were not much affected by the recession, must be considered.

7611 units	1995	1996	1997	1998	1999
Total cost	£71,150	£47,210	£348,030	£340,000	£72.780
Variation		- 2 %	+537%	-2%	-79%
1 unit cost	£9.35	£6.20	£45.75	£44.67	£9.56
Cost over 5 year period per unit			115.51		
1011 units	£71,150	£47,210	£166,210	£70,900	£72,780
	£70.38	£46.70	164.49	£70.13	£71.99
Average annual cost per unit			£84.74.		

Table 4.11 – External Decoration Costs, 1995 – 1999.

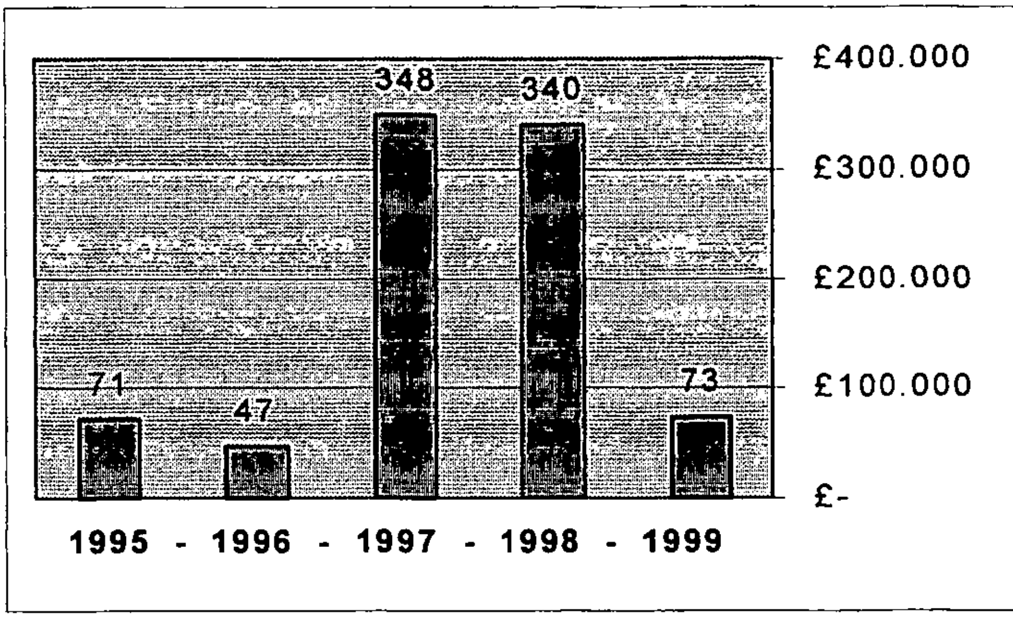


Figure 4.12 – Annual Variation of External Decoration Costs

If we accept that external decoration includes a measure of preservation and is the visual representation of maintenance to the layperson, that representation may have further consequences. If woodwork is not painted, then it will eventually decay, leading to lack of support to fascia-supported gutters, dampness in wall from leaking gutters and down pipes, and decay of window frames and doors. Painted walls, sound, but requiring redecoration for cosmetic reasons, do not suffer the same degree of deterioration in the short term, but present an image of a less desirable residence and, thus, attract less desirable tenants. At this point, maintenance becomes a greater priority, as the lack of maintenance can be recognised as a loss maker. From Table 4.11, the average cost of external decoration, which should not include any items except decorating, is shown as approximately £115 every five years.

4.5.4 Internal Decorating

During introductory and follow-up telephone calls, it became clear that very few landlords carry out internal decorating to dwellings, unless it is between tenants. Common areas are decorated and cleaned, unless serving a small number of units (when a tenant apparently assumes the responsibility for cleaning, generally unpaid).

The pattern of expenditure is irregular, and some landlords suggested that internal decoration of common areas is a source of frequent complaints from tenants who are less concerned about the exterior of the building. No reasons for this have been found in the literature, but some managers feel that tenants believe that the 'close-up' visual image is what tenants believe visitors judge the standard of the tenants accommodation by, and, by implication, the standard of the tenants themselves.

Year	1995	1996	1997	1998	1999
£ Per unit	£92.55	£11.69	£17.48	£69.39	£16.89
7611 units	£704,360	£88,940	£133,050	£528,130	£128,580
Average annual cost per unit £41.60					

Table 4.13 – Internal Decoration Costs.

Table 4.13 shows the average annual expenditure on internal decorating as £41.60, which can be compared with £115.51 for a 5-year period for external decorating, thus showing that internal decoration costs are roughly half those of external decorating. On the basis that internal decorating is essentially for public areas, and between tenants, it must be considered as mainly cosmetic finishes, rather than protection of the building from natural elements.

The buildings examined by this survey were built in the 1960s, and many buildings of that era were designed to have minimal external maintenance requirements. Windows that can be decorated from inside the building, without the need for scaffolding, are an example, and the minimization of external woodwork has reduced the decorating requirement, and, hence, the cost still further.

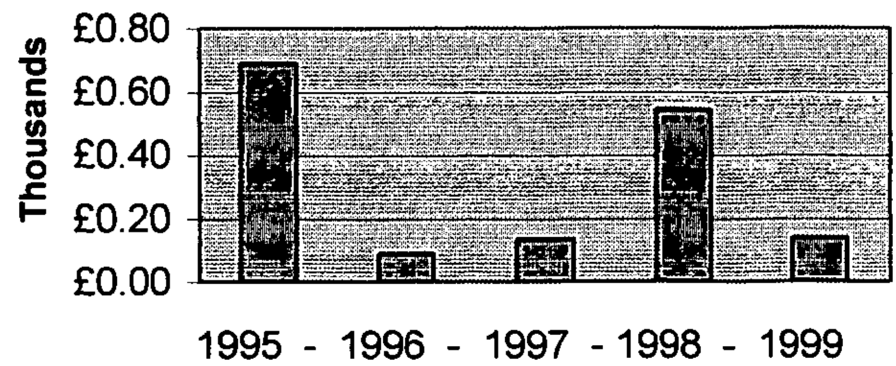


Figure 4.14 – Annual Variation of Internal Maintenance Costs

Figure 4.14 illustrates the variation in annual expenditure on internal decoration. Little was spent in 1996 and 1997, which may simply be the result of bunching of four yearly programmes. It is notable that internal decoration was largest in 1995, when overall expenditure was lowest, suggesting that money was spent on decoration, rather than on more significant maintenance.

4.5.5 Main Structure, Including Windows and Doors

When asked to indicate some principal costs in this category, 'replacement windows' was the most frequently stated example, and it appears to form a significant percentage of expenditure under this heading. Clearly, when all necessary windows are replaced, this expenditure will cease until those replacement windows have become too expensive to repair. Additionally, as more and more are completed, the need for external decorating of windows will also reduce. In some instances, the move to maintenance-free windows has been accompanied by replacement of items such as timber fascia boards, etc., with plastic, although in one instance, these were simply fixed over the top of the existing defective wood. The author was assured that this was normal practice, because the plastic fascia was 9mm thick, and needed the full-length support behind it.

Year	1995	1996	1997	1998	1999
7611 units	£362,050	£1,002,290	£649,120	£449,650	£1,074,080
Per unit	£47.57	£131.69	£82.29	£58.08	£141.12
Average annual cost £92.15					

Table 4.15 – Main Structure, Including Windows and Doors

Average cost over the years 1995 - 1999 is shown in table 4.14 at £92.15. This has been exceeded by approximately 50% on two of the five years, alternating with correspondingly lower figures. Sales literature indicates that the average installed cost of £92.15 represents approximately one replacement window, and that the average unit of accommodation has five windows and a door; this could indicate that approximately one sixth of the housing stock are having replacement windows fitted each year. If the average cost of a replacement window is £500 (Europlas Window Systems Guide cost, 2001), and allowing for 'rounding up' to allow for cost increases over the five year period (i.e. £92.15 x 5 ≦ £500), the indication is of $1/6^{th}$ x $1/5^{th}$ = $1/30^{th}$ of the housing stock being fitted with replacement windows annually. Some replacement windows are known to have failed after 7 years (failure of hinges and sash-fasteners being the main cause). As these would normally be maintained at around a 5-year interval, during decoration of wooden frames, UPVC replacement units may not be such a low maintenance item as claimed by sales literature. Figure 4.16 shows the annual variation of maintenance expenditure on main structure, including doors and windows.

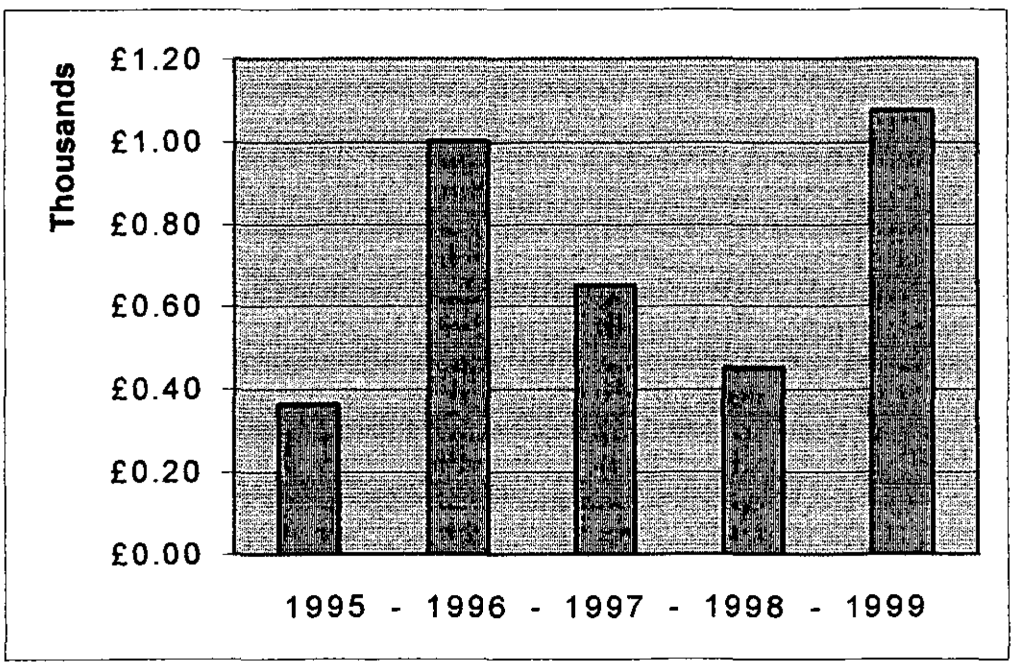


Chart 4.16 – Annual Variation of Main Structure Maintenance Costs

4.5.6 Internal Construction, Including Partitions

This category includes various minor internal repairs to areas such as storage for dustbins and some other communal facilities, as well as replacing internal doors. Deliberate damage was cited as a contributory cause to internal repairs cost, with doors 'kicked in' or stolen suggested as common reasons.

Year → / Units ↓	1995	1996	1997	1998	1999
7,611	£57,140	£102,450	£164,680	£177,680	129,820
Per unit	£7.51	£13.46	£21.64	£23.34	£!7.06
Average per unit per year		£16.60			

Table 4.17 – Internal Construction, Including Partitions and Doors Maintenance Cost.

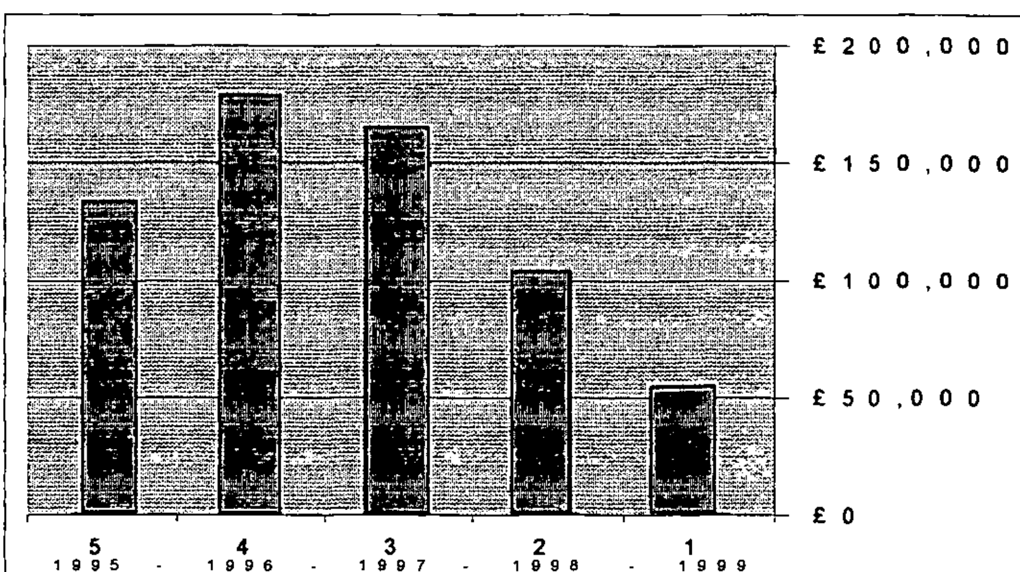


Figure 4.18 – Internal Construction, Including Partitions and Doors Maintenance Cost Annual Variation.

Costs in this category are shown to be rising steadily over the four years 1995 – 1998, with a reduction to just below average for 1999. The average amount per unit is small, and this reflects the fact that some landlords carried out no maintenance in this category. Others may have maintained only a proportion of their units.

211 units are recorded as having no internal maintenance carried out during the five years examined. There is some acceptance that this category of maintenance is not capable of being planned. When damage occurs, it might not be possible to leave it unrepaired and still collect the rent, whilst graffiti on walls is expected to attract additional contributions if not removed immediately.
'Fair wear and tear' must occur, but with internal decoration almost exclusively the responsibility of the tenant, it may be that many minor repairs are carried out unrecorded by the tenants themselves. For example, in one case, a tenant is known to have replaced all the internal doors as part of his interior design scheme, and without his landlord's consent.

4.5.7 Plumbing and Sanitary Installations

This category produced higher cost records than most, but incidental damage arising – redecoration after a leak, for example – is not included. Replacement of sanitary ware was mentioned as a 'routine job' and this may be an indication of planned preventative maintenance, but equally possible is a form of improvement in line with customer expectations, as identified by Lee (1987). Costs generally show a steady decline, with the exception of 1997, when expenditure dropped to £266,510 (approximately 25% of the average, over the other four years, of £1,068,203).

Year	1995	1996	1997	1998	1999
	£1,255,420	£1,255,440	£266,510	1,022,280	£739,670
Per unit	£164.95	£164.95	£35.02	£134.35	£97.18
Average per unit per annum			£119.29		

Table 4.19 – Plumbing and Sanitary Ware Maintenance Costs

Relatively low expenditure in 1997, following two high expenditure years, with nearly five times the 1997 figure spent each year, may indicate the completion of major phases of plumbing and sanitary installation refurbishment (with the building approximately 50 years old). A possible explanation is that of a planned and phased replacement plant, in the form of boilers, storage cylinders, and distribution pumps, etc., followed later by replacement of distribution pipe work and sanitary fittings.

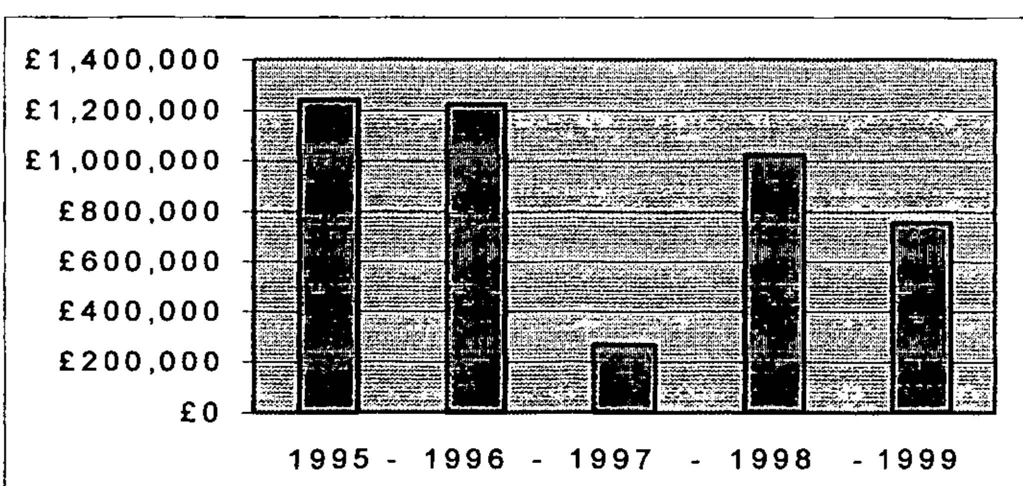


Figure 4.20 – Plumbing and Sanitary Ware Maintenance Costs, Annual Variation

As with a number of other categories, the uneven pattern of expenditure may be an indication of particular areas of maintenance that were tackled in a specific year.

This would indicate that funds are allocated to a specific project within the overall maintenance budget, in order to achieve specific aims (i.e. to improve bathrooms, as suggested by Yeates (1994) and supported by Lee (1987)).

4.5.8 Mechanical Services, Gas, and Heating

Major expenditure in 1995, shown in Table 4.21, was followed by a more even pattern, and the dip in 1998 may be a result of changes in regulations governing ventilation and exhaust gas dilution (BSS 5410, Part 1, 1997). In some cases, compliance with these requirements necessitated renewal of the boiler installation, in order to provide space for dilution equipment installation, and the opportunity to install a modern, smaller, and more efficient boiler.

Year	1995	1996	1997	1998	1999
7611 units	£4,084,280	£873,420	£1,426,560	£165,520	£1,060,770
Per unit	£536.63	£114.76	£187.43	£21.75	£139.37
Average per unit per year			£199.99		

Table 4.21 – Mechanical, Gas, and Heating Maintenance Costs

Routine planned maintenance of boilers, ventilation fans, distribution pumps, and the like is considered necessary and sensible by all managers with whom a discussion was possible, although not all were aware of legal requirements relating to ventilation of gas appliances.

If only routine preventative maintenance (servicing) is carried out, the maximum annual cost will be as year 1998 (assuming that no other work was done in that year). If this is true (actual expenditure on 'servicing' could be lower), then the balance must represent breakdowns, improvements, and general improvements.

The survey did not reveal what proportion of properties had central heating before or after 1995, and the addition of heating systems where none existed before is a possible explanation. The expenditure shown in Table 4.21 is shown graphically in Figure 4.22.

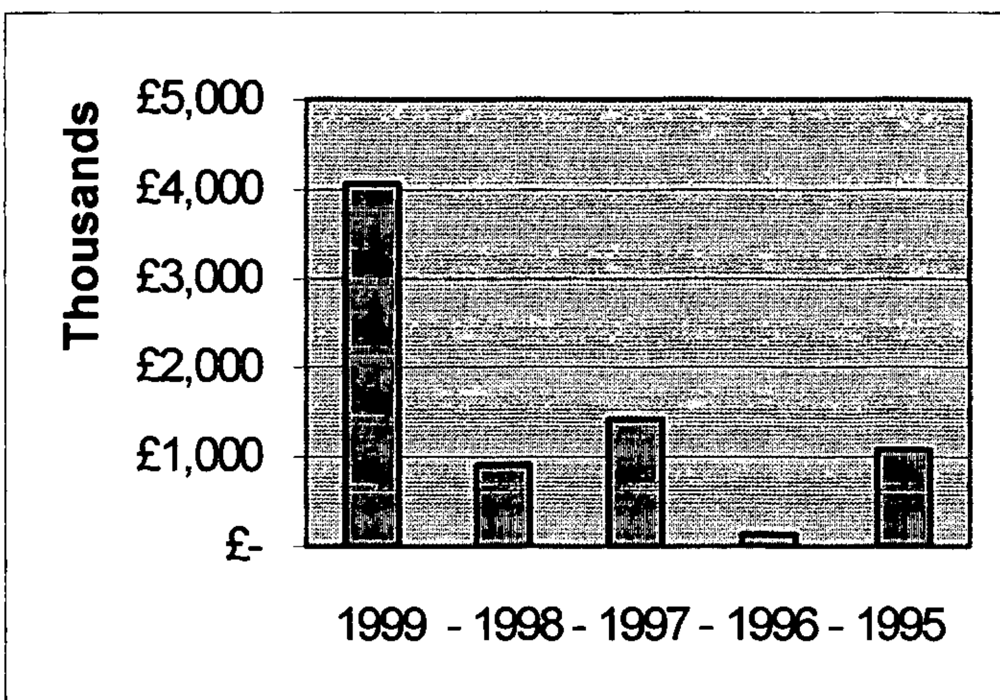


Figure 4.22 – Mechanical, Gas, and Heating Maintenance Annual Variation

4.5.9 Electrical Maintenance, Including Kitchens

White (1973) does not explain the reasoning behind combining electrical and kitchen maintenance costs into the same category, but it is possible that some additional outlets and better safety protection may be required for today's use, than was anticipated during the initial installation.

Table 4.23 shows expenditure rising from under £200,000 in 1995 to nearly £3,500,000 by 1999.

Year	1995	1996	1997	1998	1999
7611 units	£167,940	£2,093,30	£3,036,620	£1,985,77	£3,406,140
Per unit	£22.07	£275.04	£398.98	£260.91	£447.53
Average per unit per annum			£278.28		

Table 4.23 – Electrical, Including Kitchens, Maintenance Costs

Further investigation is required to separate electrical maintenance work from that of kitchen maintenance. Kitchen maintenance, in the form of new fitted kitchen units, indicated by many in this survey as included in the category 'internal construction, including partitions', may include complete refitting of kitchens, and repairs to floor coverings in hard-wear areas, where tenants' own flooring is not installed. Cookers and other major appliances (white goods) are the tenant's responsibility, and ventilation is covered elsewhere, under mechanical services; there is little else to repair, except the kitchen cupboards themselves. As electrical outlets serving kettles and smaller cooking appliances are likely to have the heaviest electrical load and high frequency use, it is possible that electrical works carried out specifically to kitchens represent a major proportion of the combined costs.

Replacement kitchen installation, assuming that the existing is still usable, even if out of date and unhygienic, may be a suitable category for postponement when funding is restricted. Fellows (1993) suggests that for maintenance costs to be postponed during periods of restraint, the item must be easily postponed, and not a health and safety risk.

4.5.10 External and Civil Engineering Works

254 of the 7611 units forming this survey showed nil expenditure in this category. The average cost is calculated using the total in the survey of 7611 units. Tables 4.21 and 4.22 show that the average expenditure is approximately £4.50 per unit of accommodation annually.

Year	1995	1996	1997	1998	1999
7611 units	£85,540	£85,400	£114,310	£76,080	£1,211,830
Per unit	£11.00	£11.22	£15.02	£10.00	£159.22
Average per unit per annum			£41.41		

Table 4.24 – External and Civil Engineering Works Maintenance Costs

A secondary analysis, using only the number of units where actual works were recorded as carried out, is shown in Table 4.25, below. There is minimal difference between the five-year average, as the percentage of units, where no work was carried out, is small.

Year	1995	1996	1997	1998	1999
7357 units	£85,540	£85,400	£114,310	£76,080	£1,211,830
Per unit	£11.62	£11.61	£15.34	£10.34	£164.72
Average per unit per annum		£42.73			

Table 4.25 – External and Civil Engineering Works Maintenance Costs on Units Where Actual Work Was Carried Out

Annual budget forecasting is not predictable, following the above analysis, and the annual variation is shown in figure 4.26.

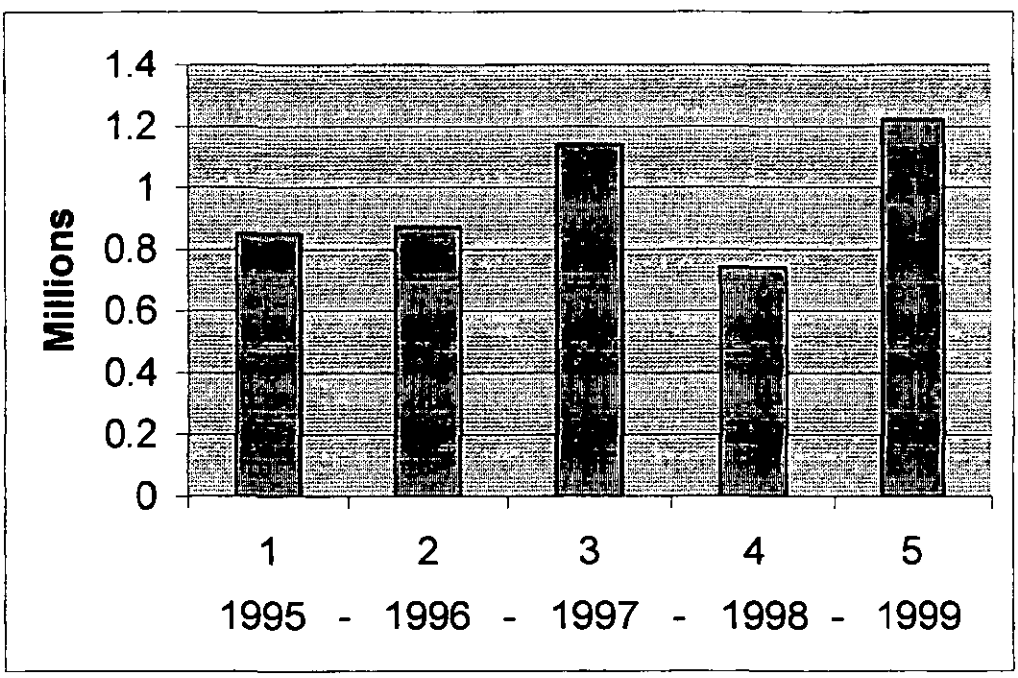


Figure 4.26 – External and Civil Engineering Works Annual Cost

4.5.11 Routine Cleaning

As a maintenance category, routine cleaning involves works not in the general run of household activities. Rather, it includes items such as the cleaning of communal stairs and hallways to multi-unit apartment buildings, and the removal of accumulated debris from fire escape routes that are normally unused by the occupants. That this description belies the amount spent is purely subjective, and just over half of contributors, private landlords with smaller numbers of units, did not record any cost in this category. Table 4.27 shows the average cost at £139.08 per unit annually.

Year	1995	1996	1997	1998	1999
7611 units	£1,282,670	£1,070,290	£695,840	£1,174,950	£1,078,160
Per unit	£168.29	£140.62	£91.43	£153.38	£141.66
Average cost per unit per annum		£139.08			

Table 4.27 – Routine Cleaning Costs

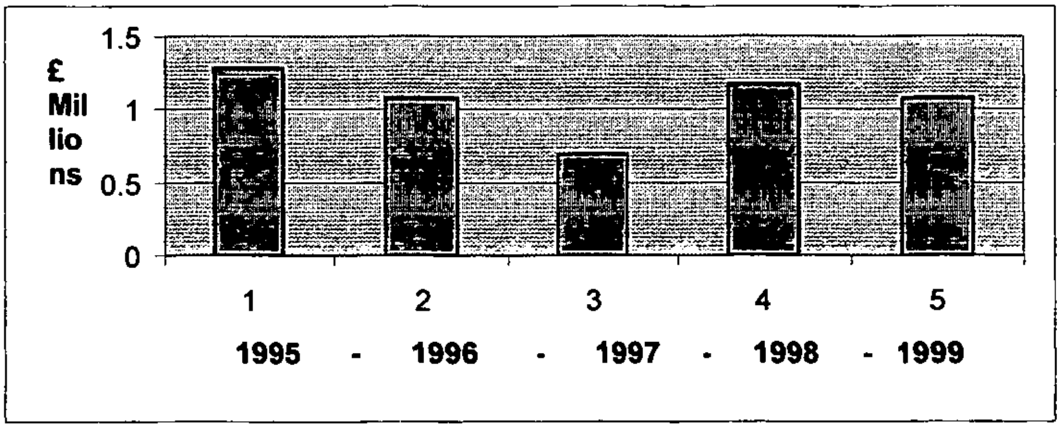


Figure 4.28 – Annual Variation in Routine Cleaning Costs

This level of consistency, not shown in many of the other categories, may be an illustration that routine cleaning is not a category that is easily deferred to moderate expenditure. Failure to carry out routine cleaning would lead to a rapid deterioration in the appearance of buildings, and would be noticeable by all, irrespective of their knowledge of building maintenance.

4.5.12 Other Works

This category was introduced to provide a 'catch all' for all and any items of maintenance expenditure that do not fit into the previous specific categories. Changing light bulbs in common areas, for example, is a job that is often carried out during routine cleaning, although it is not specifically cleaning; whilst it may be argued that it could be included in the 'electrical and kitchens' category, that sort of 'general maintenance activity' has instead been included here, so that it may be recorded as an item of expenditure.

Approximately half of the respondents entered nil in this, the last category in the matrix forming the main input of the questionnaire. Expenditure is shown in Table 4.29, with the annual variation graph thereof shown as Figure 4.30.

Year	1995	1996	1997	1998	1999
7611 units	£806,470	£265,500	£68,450	£402,920	£124,800
Per unit	£105.96	£34.88	£8.99	£52.94	£16.40
Average cost per unit per annum			£43.83		

Table 4.29 – Maintenance Costs of 'Other Works' Not Recorded Under Previous Categories.

Expenditure in this category includes such items as surveyors' travel expenses, items of consultation and survey work, etc., where the survey may have covered a broad band of categories, as well as incidental expenses recorded as 'sundry expenses'. Annual variation shown in figure 4.30 indicates no regular pattern to this expenditure.

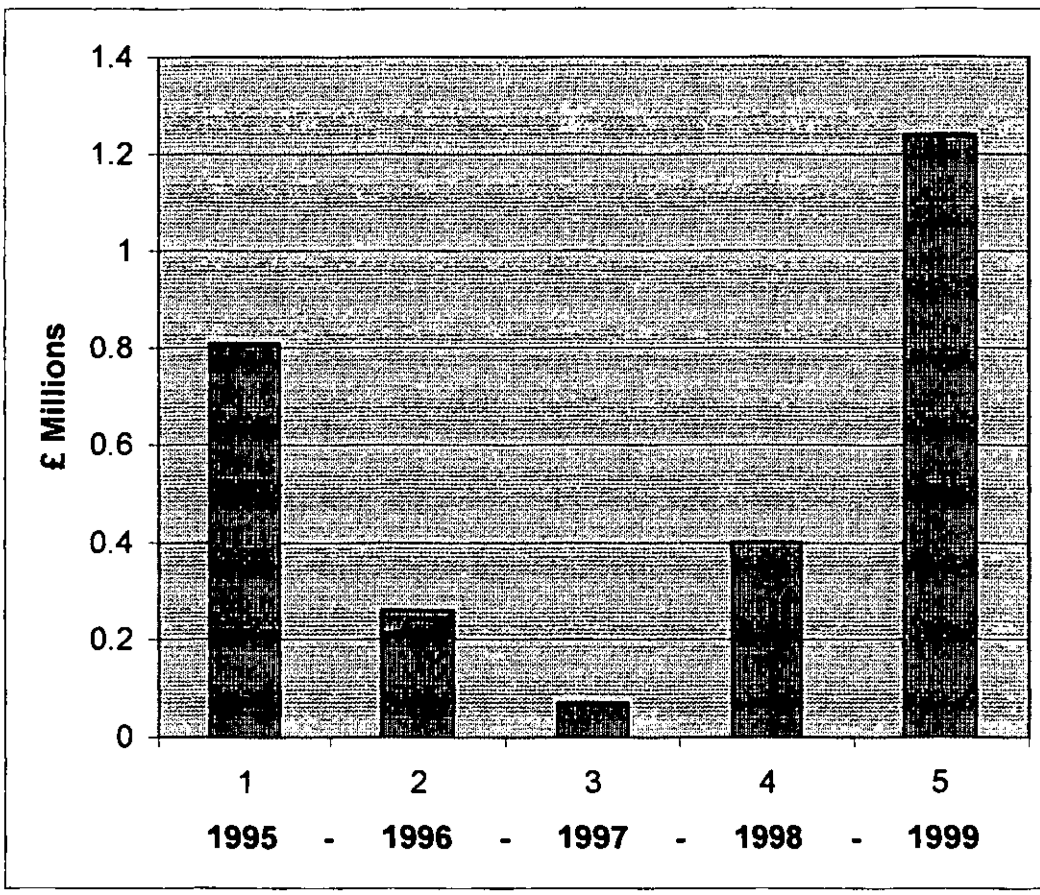


Figure 4.30 – Annual Variation of Non-Specific Maintenance Costs

4.5.13 Who Manages Maintenance?

Of the 7674 units investigated by this survey, 728 are 'maintenance managed' by a dedicated, specific Maintenance Manager, whilst the remainder are managed by a 'General Manager' (as part of his/her overall duties), or by external consultants (i.e. a letting agent), or by other, unspecified means.

Approaching the question of 'who manages maintenance?' from the direction of numbers of managers, it is observed that 12 out of 32 landlords use a dedicated maintenance manager system, and manage 311 units. 15 landlords put maintenance management as part of the general manager's duties, thus managing 616 units. Four landlords use 'other means', and one uses a part-time consultant (a letting agency). Whether these different manager categories affect the cost of maintenance has not been investigated as part of this study. Figure 4.31 shows the relevant data.

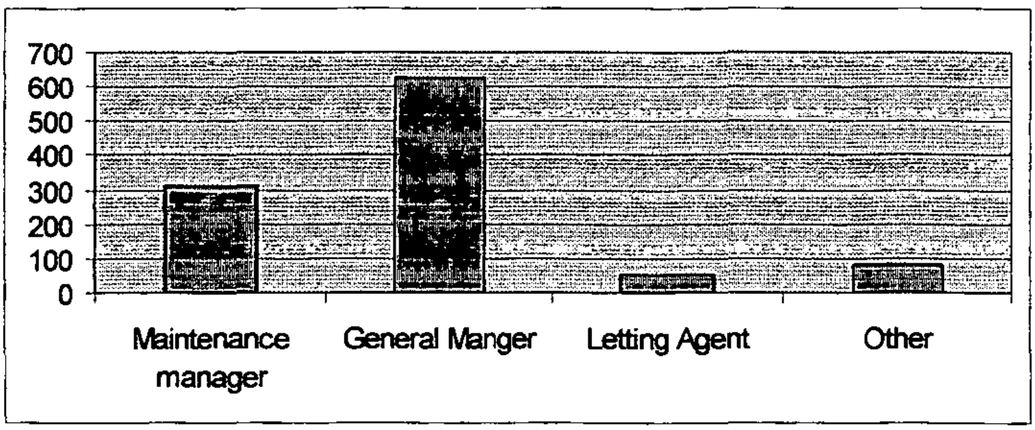


Figure 4.31 – Maintenance Manager Type Distribution

It should be noted that the numbers shown in Figure 4.31 (above) include the discounting of one large contributor, with 6600 units and a numerically unspecified hierarchy of maintenance managers, loosely described as 'well over a hundred'.

This survey shows that the level of allocated maintenance budget, which may be different than the actual expenditure, is decided by four principal methods:

1) based on the previous year's costs (13),
2) as a percentage of the overall budget for the Landlord (4),
3) planned maintenance cost, plus emergencies (8), and
4) no actual budget set (i.e. the budget will be post-rationalised to be whatever the final cost is) (8).

Figure 4.32 compares the budget-setting criterion used by those responsible for deciding budget levels, plotted against the 'number of domestic units managed'. Graphic comparison between Figure 4.32 and Figure 4.33 indicates some consistency in the ratio of units to budget-setting method. The least efficient is indicated as the 'no set budget' method; however, the cost of managers' salaries, secretarial services, and the like are not included in the net costs of maintenance collected in the survey.

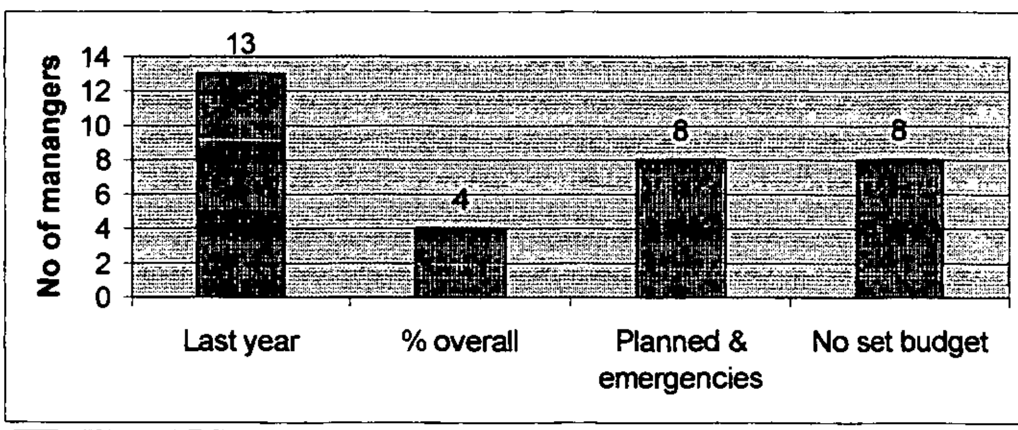


Figure 4.32 – Maintenance Budget-Setting Methods

For maintenance works not forming part of a pre-planned scheme, there must be some trigger that sets the work in motion. From a total of five categories of 'trigger' mechanism, two specific categories of 'planned preventative maintenance' and 'a mixture of methods' include those working to a planned

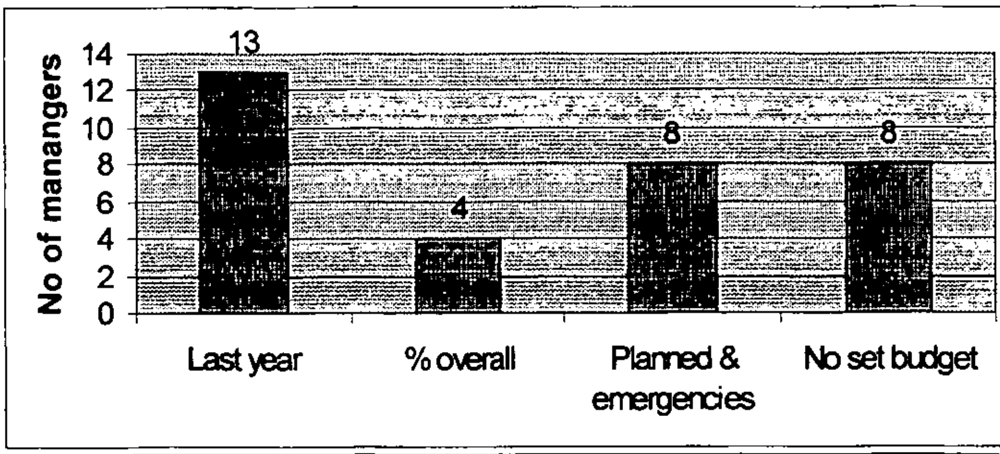


Figure 4.33 – Distribution of Maintenance Managers to Budget-Setting Criterion

maintenance routine and accepting that some unplanned, unexpected, and emergency works will be necessary.

Three other actuation mechanisms remain:

1) Work done when considered necessary.
2) Work done when something breaks down.
3) Work done as soon as necessary .

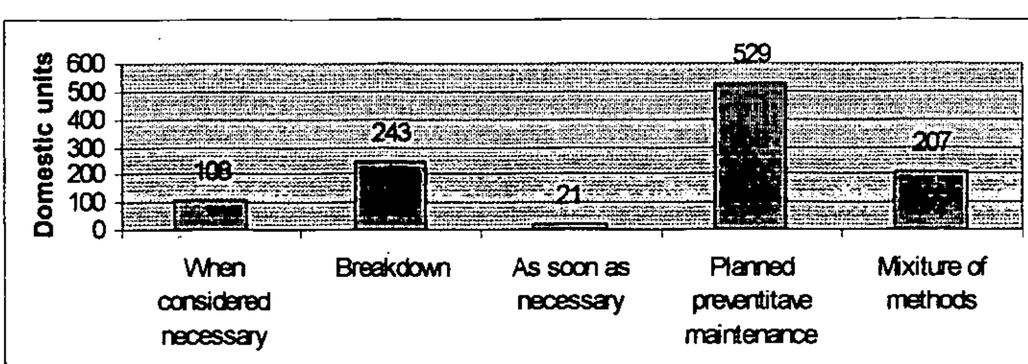


Figure 4.34 – Maintenance Work Actuation Trigger Mechanisms

4.5.14 Anticipation of Future Maintenance Policies

22 out of 33 managers stated that the use of planned preventative maintenance was their preferred future policy, with implementation times ranging from 1 to 5 years. 67% of respondents opted for this method, with corrective work only representing 24%. As corrective works includes general maintenance of both a proactive and a reactive nature, but is simply not pre-planned, the remaining 7% consists of 'mend only when it breaks' – and 'other' must be considered as planning to operate a 'run to failure' policy. How this policy will cope with items such as external or internal decorating has not been determined, but it is difficult to foresee how this can lead to anything other than a deterioration of the building.

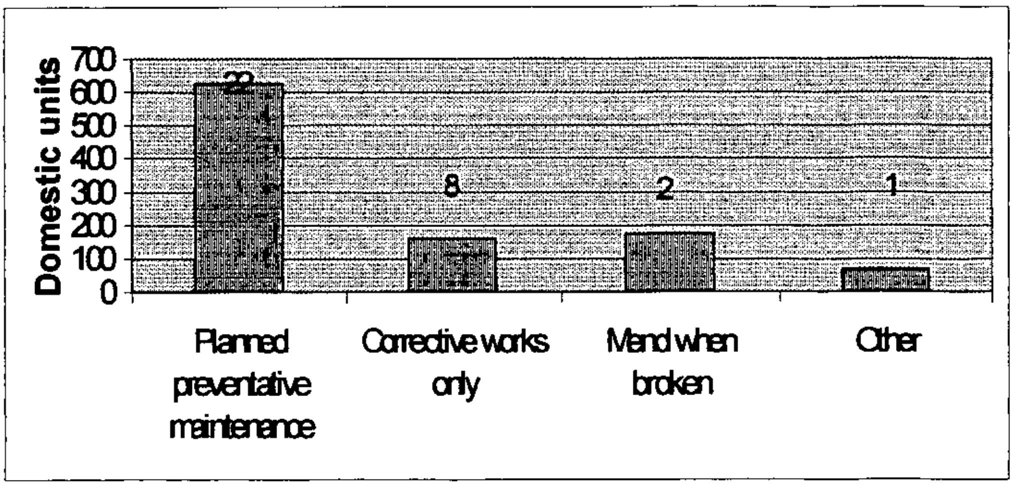


Figure 4.35 – Anticipated Future Maintenance Policies; numbers above columns represent numbers of respondents.

4.5.15 Maintenance Cost Reduction

For buildings to be maintained adequately, sufficient funds must be available. Following the 'do-it-yourself' movement, many tenants are not only prepared to do their own internal decoration, but actually enjoy the activity and, as such, landlords now expect tenants to be responsible for their own internal decoration. Landlords may, however, redecorate internally between tenants, and be responsible for internal public areas of buildings and, generally, the exterior. In seeking to identify how to minimise maintenance costs further, three possibilities were offered, together with the opportunity to provide their own suggestion. The three options offered were:

1) Use of planned preventative maintenance.

2) Better original specification.

3) Additional contribution from occupier to specific items.

The survey form did not specify that only one option should be chosen, and some respondents selected more than one. The selected ratio is shown in figure 4.36.

From figure 4.36 it can be seen that there were no additional/other methods of cost reduction suggested by respondents. Of the three possibilities offered, the least popular was 'additional contribution from tenants'. The most popular was 'planned preventative maintenance', at more than four times the level of the least acceptable, which was 'better original specification', at a mid-point between the two.

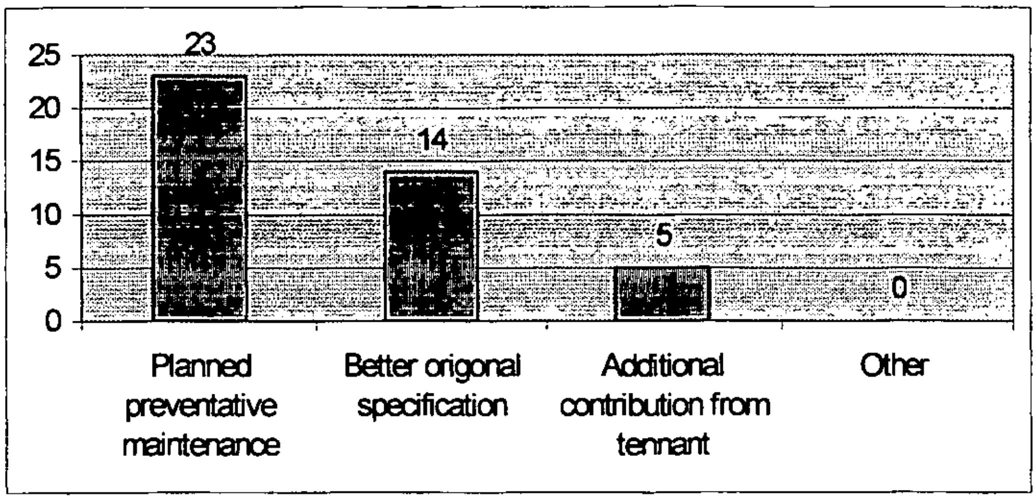


Figure 4.36 – Popularity Ratio of Cost Reduction Suggestions

4.6 Summary of Empirical Data

Despite the range of complexity apparent over a number of different buildings, it is clear that all buildings need maintenance, and that around half of that maintenance is carried out on an *ad hoc* basis. Managers change frequently and maintenance may not be high on a new manager's agenda. The data from the Delphi survey showed that building professionals believed plumbing and hot water systems to be the category that has the strongest requirement for planned preventative maintenance. Roof and gutters was shown to be the category they believed to have the greatest influence on overall maintenance cost.

The actual costs of maintenance of the listed categories was examined from data collected from a postal survey and analysed on a year–by-year basis. Criteria for setting and managing maintenance budgets and anticipated future trends in maintenance management were also examined.

Chapter Five – Discussion of Empirical Data

5.1 Introduction

This chapter reviews the implications arising from the empirical work and considers how the information obtained can contribute to maintenance management and practice. A new approach to planned maintenance is suggested, together with a proposed 'maintenance log-book' approach to identifying maintenance need and operation.

5.2 Maintenance cost difference between traditional and industrialised construction.

Identification of the construction methods of buildings has shown that there is no appreciable difference in maintenance costs that is attributable to their category as either an 'industrialised building' or a building of 'traditional construction'. Verbal criticism of industrialised buildings frequently quoted height as a maintenance cost factor, with the requirement for extensive scaffolding or cradles adding considerably to the cost of working on isolated items that are at a high level. Whilst many industrialised buildings are medium or high-rise, a traditionally constructed building of the same height has exactly the same problems if a window needs to be replaced on the 6th floor, and, therefore, this access cost must be attributed to height and not to construction method.

With few exceptions as outlined below, maintenance work to buildings is carried out by traditional methods, regardless of the original method of construction. Failing concrete within pre-cast panels, unless structurally significant, is generally replaced by render repair materials. The opportunity to exchange a complete damaged panel section for a new one does not now exist. There are no 'spares' available, and lifting equipment positions used in the original construction are no longer viable. Costs of storage of 'spares' over the intervening years, together with the cost of crane hire and erection for isolated units, would be prohibitive, and no initial provision was made for the 'replacement unit' eventuality.

Individual components, such as timber single glazed windows, installed in the 1960s, are now frequently replaced with a 'modern equivalent', incorporating features such as better thermal and acoustic insulation, trickle ventilation, and security locking.

5.3 Over-cladding as preventative maintenance

Poor (by current standards – not by the standards of 1965) thermal and acoustic insulation are also matters of concern. Water penetration and evidence of ongoing damp/condensation, combined with a requirement for better thermal insulation, can now be addressed by over-cladding the entire building as shown at Oldham (Construction Manager, February 2002). This system, used in the US for some 40 years, is relatively new to the UK, but is rapidly becoming popular. Specifically detailed to provide a lasting cure to problems of moisture penetration and thermal insulation to high-rise buildings of industrialised methods of construction, this external cladding is also suitable for low-rise buildings.

The new 3-story head office, adapted from disused offices and works buildings of concrete frame and panel construction, for the Youth Hostel Association at Matlock in Derbyshire was clad externally during this research. Whether this is the use of a new 'modular building component', specifically designed for remedial work on buildings constructed by industrial methods, or simply a traditional cladding system adapted to suit the new use, is unclear. It does indicate, however, that – even if maintenance of industrialised buildings has been carried out by traditional methods until recently – new methods (in the UK) are appearing and being used, and these methods are closer to industrialised building than traditional building methods.

It must be stressed that the 'over-cladding' treatment is primarily designed to provide a weatherproof jacket, and to support and protect insulation sandwiched between the existing structure and the new outer skin. The building must be structurally sound and suitable to support any new covering. This is an important consideration in the decision to use a cladding system, and can be balanced with other factors: such as improved/changed visual appearance, reduced future external maintenance requirement, tenant satisfaction, and reduced fuel costs.

5.4 Consideration of budget variation cause factors.

Whilst the overall average cost of maintenance is shown to have risen gradually between 1995 and 1999, the gradual rise has not applied equally to the individual categories of work. Considerable differences are shown for expenditure on the same category from year to year, with a category consuming a large proportion of the total expenditure during one year, and a minor expenditure in other years. An explanation may lie in the use of 'directive budgeting', where a decision had been made to allocate specific funds to correct a targeted category. In this case, the indication is that some pre-planning has occurred, as budgets have been created to deal with specific areas of maintenance. This 'pre-planning' may be of a short-term nature, as full planned preventative maintenance could have prevented the requirement 'to do something about the heating next year'. This is also possible evidence of a longer-term strategy involving the grouping of similar works into batches in order to enable more competitive contract procedures to be used. If this is the case, research is necessary into tenants' views on almost annual disruption *as a sequence of repairs is made*, instead of a less frequent – but more comprehensive – overhaul of the whole of the landlord's maintainable items that form the accommodation.

The possibility of 'directive budgeting' being combined with 'batch buying for competitive contract procedures' was not foreseen prior to the outset of this research, and the effect of this link on budget planning is worthy of further research.

The highest cost category was shown to be 'electrical maintenance, including kitchens'. Around 1995, some insurance companies began insisting on a more rigorous inspection and testing programme as a condition of continuing insurance cover. Organizations managing the letting of domestic buildings (and possibly other use buildings) were faced with remedial works to electrical systems shown to fall short of the required standard. This is clearly an isolated cost that will not recur until the next inspection, when some further modernization may be required.

Additionally, when one considers that insurance companies have now had computerised records for a sufficient period of time to allow for analyses of claims-causes, thus leading to the requirement for electrical testing (perhaps following electrically-caused fires), it leads one to recognise the possibility that further 'tests' might be required (i.e. as a process of eliminating the most commonly identified expenditure). These could take the form of testing against failing plumbing or heating systems, causing claims for water damage and the like. This scenario could, thus, cause a higher than expected expenditure on wet systems in a future period, similar to that identified for electrical systems in this research.

5.5 Comparison of main survey and delphi survey.

Whilst the main survey shows 'electrical, including kitchens', the Delphi survey showed that professionals thought that 'roof and gutters' was the category that most affected overall maintenance cost. Following this indication and as a validation process, a detailed breakdown of maintenance expenditure was carried out on 6 further buildings fitting the criteria specified for the main survey, but not previously included. These buildings are currently run and occupied as Youth Hostels. Detailed examination of maintenance cost records revealed the average cost of electrical maintenance without kitchens to be 17% of the total maintenance expenditure for the years 1995-1999, whilst the expenditure on roofs and gutters amounted to under 3%. This analysis was carried out only on hostels where a regular programme of electrical maintenance had been in place for the years under examination. This analysis of past expenditure could not be repeated 'across the board' with the other buildings in the same ownership, as historical records are not yet available in suitable detail. The six buildings investigated have records covering the period, as a result of being operated under a planned preventative maintenance system over that period. This programme required that the electrical systems were brought up to current standards to enable minimum maintenance thereafter.

As a result of these findings, and in the absence of specific historical information, a study of current electrical maintenance costs is now being carried out on the entire stock of some 230 buildings, incorporating the electrical testing and remedial works requirement specified by the insurers. Those results will not be known until the programme is completed in 2006, although 'early indications' are that many of the buildings surveyed already require, and are undergoing, extensive electrical maintenance. These 'early indications' cannot be considered as useful data. The buildings themselves are subject to analysis for compliance with the set criteria, and the work carried out analysed to ensure separation of maintenance from alteration or improvement.

Whilst the two surveys in this work establish that the principal maintenance cost categories are not the same as those perceived by domestic dwelling design professionals, the surveys did not attempt to explain why any such difference should occur. Informal discussion with Delphi contributors subsequent to the survey has indicated that some designers are heavily influenced by the advice of their electrical, mechanical, heating, and ventilation consultants. This can result in a specification that has remained adequate and undiluted by budget adjustments prior to the construction phase. It was also apparent that designers, architects, and surveyors felt that they could understand and even see what was wrong with a roof or gutter, and how the problem could be fixed. Mechanical systems remain more of a mystery, and a specialist is required and called in to advise. This is an aspect of control fear for the designer, as he is now in the hands of another. The designer must analyse the information provided by the specialist and relay it, in his report, to the client. The client may be under pressure from tenants, who are without heating or hot water, and may pass that pressure on to the architect/surveyor, who is thus aware of the need to prevent a repeat of the failure. Thus, a subconscious tendency to 'design out' costly future maintenance on those categories might exist, and the designers are actually successfully reducing maintenance cost on those categories, thus raising 'roofs and gutters' in the designers' conscious priorities. This unproven theory helps to partially explain the differences between (1) the results obtained from the main survey, and (2) the order of cost category influence that is perceived by the building professionals contributing to the Delphi survey.

5.6 Preventing the need for reactive maintenance.

The main survey showed that at least half of all maintenance work is carried out only when necessary (i.e. is reactive to a fault occurring). Under this system, a building manager has to be pro-active in getting the maintenance work carried out. A new system is needed, whereby the maintenance work will happen automatically, without prompting, and will only *not* occur when a manager is pro-active in preventing it. This is virtually a reversal of most current maintenance work ordering policies.

A system that allows the creation of a comprehensive maintenance work schedule, with provision to correct accrued dilapidations to maintainable standards, is needed, such that a 'maintenance log' – similar to that used for most car servicing – can be created for a building. However, whilst there are many (perhaps thousands) of identical cars of each make, most buildings are different. Some estates may contain perhaps over a hundred 'identical' houses, but even these are likely to have differences. An example is heating boilers, where a faulty boiler has been replaced with a newer model in one unit, but not in the other 'identical' units. Thus, a system must allow for the creation of a 'maintenance logbook' that is specific to each individual building/dwelling, and also have the provision for whole – or partial – duplication, where multiple similar /identical units exist.

The 'ownership of the problem' by managers of buildings proved to be a stumbling block to the introduction of maintenance schedules prepared by others. A two-stage training programme, with practical examples and practice papers was introduced at a two-day seminar. This 'first attempt' was on trial for a year at 7 separate buildings, and it covered the preparation of an actual working maintenance schedule, by the manager, for the specific building. This was followed by a 'trial and test' period of a year, and followed up at the end of that year, when revisions and amendments were made. The revised scheme was then put into full operation at 24 youth hostel buildings for a further year. It is currently being rolled out to an additional 200. The resulting program, in the form of a 'maintenance logbook', is shown in Appendix 9 in its working form, as prepared for the International Cities Division of the Youth Hostels Association as a potential solution. The document consists of introductory and explanatory notes, survey and listing sheets, a servicing frequency guide, and general preparation and recording documents that are necessary to produce a full working planned maintenance programme. This programme, when compiled, may need only part of the materials contained in the complete blank 'Logbook Kit', as variations between buildings make parts unnecessary for some and require duplication for others. The format is arranged so that even small items, such as cleaning dust from a domestic sized ventilation fan, can be included. This 'logbook' format is constantly being modified and tweaked to suit individual buildings, which range from those having complex mechanical and electrical services, to some isolated and very basic structures without mains services.

The introductory pages describe why the maintenance logbook is necessary and how it will assist the manager in the maintenance of the building. To get the system started, the manager is asked to fill in sheets with every possible and necessary item of maintenance work, and it's required frequency. As the list of works leads on to the identification of an annual budget for the maintenance of the building, it is suggested that items that occur at intervals greater than one year are allocated on a fractional basis.

Thus, if external decorating is done every 5 years, 1/5 of the cost is allocated for each year. In practice, it is often possible to decorate one elevation each year, whilst also doing minor 'touch-up' works to the remainder. This has the advantage of keeping the whole of the building in overall good condition and appearance.

Whilst it is anticipated that many buildings managers will need advice on service frequency for mechanical plant and help with specification for decoration works and the like, recommended service intervals for most common items are shown as a reference sheet. A summary or 'quick contact' list is also included for easy reference to emergency glaziers, etc.

The introduction of the logbook leads to several conclusions, summarised as:

a) Buildings managers must accept that they 'own the problem' of maintaining the building.

b) Buildings managers need to be actively involved with the preparation of the maintenance schedule if they are to benefit from it working for them.

c) With the schedule in operation, and maintenance contracts placed or forming part of normal routine operation, a manager has to be pro-active to prevent a planned maintenance operation. Thus, with service agreements in place, service engineers will arrive to carry out planned maintenance work *unless actively stopped by the building manager*. An example is external repair brought forward, or delayed, because of a booking for an important function at the building.

d) Managers do prefer to let the maintenance system operate for them, rather than to *react* to the individual maintenance needs of different equipment.

e) Managers installing or taking over an established maintenance program need to accept that the program is rarely complete and that they are also taking on responsibility for future updating.

f) Managers perceive 'tweaking' the installed and operating system as relatively easy (once they have surpassed the initial fear of installation).

5.7 Conclusions from a maintenance system introduction.

Both the main survey and the logbook introductory seminar revealed a willingness to identify maintenance issues and the costs associated with them, and a reluctance to accept ownership of the problems associated with organising *ad hoc* maintenance work. The use of planned preventative maintenance to reduce breakdowns and minimise costs is generally accepted by managers of buildings as the most suitable tool for creating the optimum balance between achieving (1) the best building condition for use, and (2) management convenience at a minimum and, perhaps most importantly, a known cost.

Chapter Six – Conclusions, Recommendations, and Developments

6.1 Introduction

The previous chapters contain the origins and the objectives of this research, as well as the reasoning and the methodology used to obtain and analyse the data. This chapter deals with the lessons learnt, the conclusions reached, the practical development in creating a method of introducing planned preventative maintenance, and recommendations arising from the knowledge gained.

Some 'resulting information', not sought specifically as part of the original research objectives, has appeared by default. The reluctance of managers to accept responsibility for, or 'ownership of', the maintenance of buildings – for which they have, otherwise, full responsibility – was very clear during the follow-up chasing of questionnaires and, also, during the introduction of the planned preventative maintenance programme that was developed from this research (as shown in Chapter 5).

It was clearly evident that, whilst building managers wanted full and complete control of 'their building', they were reluctant to take responsibility for issues relating to that building's maintenance. When the maintenance responsibility rested elsewhere, managers were content, and preferred to consider falling building condition standards to be a situation beyond their control. The process of introducing the developed Planned Maintenance Programme, shown in Chapter 5, indicates how this reluctance has been overcome by giving the managers the responsibility of including the items of maintenance they consider necessary for their building. Other anomalies were evident and, where these justify further research, they are shown later.

6.2 Conclusions Specific to Individual Objectives

Objective 1: 'To investigate maintenance costs of traditional and 'industrialised (modular) system built' multiple domestic accommodation buildings, and compare their maintenance costs'.

The survey did not reveal any measurable difference in the maintenance cost of traditional and system built domestic accommodation. For reasons discussed earlier, all current maintenance on system built dwellings is carried out by traditional means, and the maintenance cost per unit is not now affected by the method of construction. Whether there were significant savings, or increased costs earlier in the life of the buildings, was not investigated by this study. The system of external cladding described, used on both the Oldham high-rise blocks and the new Youth Hostel Association head office is applied equally to buildings of traditional and 'system' built construction, whatever their use.

Conclusion for Objective 1:

a) There is no significant difference in the maintenance costs of system built and traditional buildings.

b) Maintenance of industrialised, or system built, and traditional buildings is carried out by traditional methods not related to the industrialised building method.

Objective 2: 'To identify the principal maintenance cost categories perceived by various construction industry professions and test the hypothesis that 'actual highest cost maintenance categories for domestic dwellings are not the same as those perceived as the highest cost categories by domestic dwelling design professionals'.

The highest cost category influencing overall maintenance cost was perceived by the Delphi survey of domestic building professionals as 'roofs and gutters', followed by 'kitchens and bathrooms', with 'plumbing and hot water systems' coming third. Electrical maintenance, shown by the main survey to have been the highest actual cost influence for the years 1995-1999, came last in the Delphi final round.

The Delphi survey showed that the panel professionals thought the most important category for 'planned preventative maintenance in preventing breakdowns and unplanned maintenance' to be 'plumbing and hot water systems'. The main survey revealed that the actual highest cost category for the years 1995-1999 was 'electrical maintenance, including kitchens', with unit costs averaging £278 for the five year period, and reaching as high as £447 for 1999.

	SURVEY RANKING ORDER		
	DELPHI		MAIN
Category	Cost Influence	Preventative importance	Actual cost
Roofs and gutters	1	2	2
Kitchens and bathrooms	2	3	
Plumbing and hot water systems	3	1	3
External envelope	4	5	
Electrical and kitchens	8	4	1

Conclusion for Objective 2:

a) The hypothesis that 'actual highest cost maintenance categories for domestic dwellings are not the same as those perceived as the highest cost categories by domestic dwelling design professionals' is supported.

b) Despite disagreement over the leading category, there is general agreement between the second- and third-ranked actual cost and the professionals' intuitive assessment.

Objective 3: 'To measure and compare the use of planned preventative maintenance programmes against other maintenance and repair polices'.

Of 1108 units in this survey, 48% use planned preventative maintenance as the trigger mechanism for maintenance work to commence. 33% use other methods, split 2-1 between 'when considered necessary' and 'when it breaks down'. A further 19% operate a 'mixture of methods', including some planned preventative maintenance within that mixture. 67% of managers indicated that the use of planned preventative maintenance was their preferred future policy.

After (1) making an allowance that planned preventative maintenance in the unspecified 19% 'mixture of methods' proportion might be as low as 10% of that 19% (i.e. that 10% of the 19% might actually be utilising planned preventative maintenance – thus representing 2% of the total), and (2) taking that together with the 48% that was specifically identified, then one may equate to 50% of the buildings in the survey using planned preventative maintenance as the operating method.

Conclusion for Objective 3:

a) Even if that allowance, detailed above, should be higher than 10%, it is clear that planned preventative maintenance is used on approximately half of the properties in the survey.

b) The use of planned preventative maintenance is increasing and will rise to about 66% over the next 5 years.

Both the Delphi survey and the main survey revealed a willingness to identify maintenance issues and the costs associated with them, and a reluctance to accept ownership of the problems associated with organising *ad hoc* maintenance work. The use of planned preventative maintenance to reduce breakdowns and minimise costs is generally accepted as the most suitable tool for creating the optimum balance between achieving (1) the best building condition for use, and (2) management convenience at a minimal, and perhaps most importantly, a known cost.

6.3 Limitations

This research was strictly restricted to buildings of a specific age and use. Different data might be obtained for buildings of an alternative use, and, although many maintenance issues may be common to all buildings, the major categories of expenditure or 'cost headings' are possibly different.

6.4 Recommendations for Further Research

- Investigate the maintenance policies for commercial buildings other than dwellings. Buildings used for offices, factories, and utilities may be managed with a different commercial attitude to preventative maintenance.
- Investigate what happens to existing, non-planned preventative maintenance plans when managers change; do new managers generally 'start again'?
- Investigate changes in maintenance policies and costs in the years following the introduction of planned preventative maintenance.
- Investigate how much, if any, bias is given to cosmetic improvements as a result of new managers seeking to show a rapid visual improvement.
- Investigate the incidence of 'change for efficiency'; an example of this is the upgrading of equipment, such as boilers, that still functions perfectly, but is inefficient by current standards.
- Investigate what encouragement now exists to private and public landlords, by the central government, to commission minimal maintenance buildings?
- Investigate how much influence tenants associations have in maintaining planning.

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Maintenance terms	From BSS 3811, 1964.
Active corrective maintenance time.	That part of the active maintenance time during which actions of corrective maintenance are performed on an item.
Active preventative maintenance time.	That part of the active maintenance time during which actions of preventative maintenance are performed on an item.
Automatic maintenance	Maintenance accomplished without human intervention.
Conditional appraisal	A formal and systematic appraisal of the condition of an item in respect of its ability to perform its required function.
Condition-based maintenance	The Maintenance carried out according to the need indicated by condition monitoring.
Consumable stock	Expendable material (for example oils, lubricants, nails, packing) that are held available for maintenance purposes.
Controlled maintenance	A method to sustain a desired quality of service by the systematic application of analysis techniques using centralised supervisory facilities and/or sampling to minimise preventive maintenance and to reduce corrective maintenance.
Corrective maintenance	The maintenance carried out after fault recognition and intended to

	put an item into a state in which it can perform a required function.
Corrective maintenance time	That part of the maintenance time during which corrective maintenance is performed on an item including technical delays and logistic delays inherent in corrective maintenance.
Daywork	Charging for work for which control standards have been determined, for example quality, but that cannot readily be measured in accordance with general principles. Note: The normal practice is to record labour, materials and plant used as the work proceeds and to change at standard rates plus agreed overheads.
Deferred maintenance	Corrective maintenance which is not immediately initiated after a fault recognition but is delayed in accordance with given maintenance rules.
Elementary maintenance activity	A unit of work into which a maintenance activity may be broken down at a given indenture level.
Emergency maintenance	The maintenance that it is necessary to put in had immediately to avoid serious consequences.
Fault correction	Actions taken after fault localisation to restore the ability of the faulty item to perform a required function.

Fault correction time — That part of active corrective maintenance time during which a fault correction is performed.

Fault diagnosis — Actions taken for fault recognition, fault localisation and cause identification.

Fault diagnosis time — The time during which fault diagnosis is performed.

Fault localization — Actions taken to identify the faulty sub-item at the appropriate indenture level.

Fault localization time — That part of active corrective maintenance during which fault localisation is performed.

Fault recognition — The event of a fault being recognised.

Forced outage duration — Within a specified period of time, the period of time during which an item is incapable of performing its function because of a fault.
Note: This term is used in the electricity supply industry.

Function-affecting maintenance — A maintenance action during which one or more required functions of the item under maintenance are interrupted or degraded.

Function check-out — Actions taken after fault correction to verify that the item has recovered its ability to perform the required function.

Function-degrading maintenance — Function-affecting maintenance that degrades one or more of the required functions of a maintained item, but not to such an extent as

	to cause complete loss of all the functions.
Function-permitting maintenance	Maintenance action during which one of the required functions of the under maintenance is interrupted or degraded.
Function-preventing maintenance	Function-affecting maintenance that prevents a maintained item from performing a required function by causing complete loss of all the functions.
Indenture level	For maintenance. A level of subdivision of an item from the point of view of a maintenance action. Note 1: Examples of indenture levels could be a subsystem, a circuit board, a component. Note 2: The indenture level depends on the complexity if the items construction, the accessibility to sub-items, skills level of maintenance personnel, test equipment facilities, safety considerations, etc.
Level of maintenance	The set of maintenance actions to be carried out at a specified indenture level. Note: Examples of a maintenance action are replacing a component, printed circuit board, a subsystem.
Maintenance action; Maintenance task	A sequence of elementary maintenance activities carried out for a given purpose. Note: Examples are fault diagnosis, fault localisation, function checkout or combinations thereof.
Maintenance echelon; line of maintenance	A position in an organisation where specified levels of maintenance are to be carried out on an item.

Note 1: Examples of maintenance echelons are: field, repair shop, manufacturer.
Note 2: The maintenance echelon is characterised by the skill of the personnel, the facilities available, the location etc.

Maintenance entity
Any sub-item of a given item which can have a fault and which, by alarm, or any other means, can be unambiguously identified for replacement or repair.

Maintenance history
A record of past maintenance tasks that is used for the purpose of maintenance planning.

Maintenance management
The organisation of maintenance within an agreed policy.

Maintenance man-hours (MMH)
The accumulated durations of the individual maintenance times, expressed in hours, used by all maintenance personnel for a given type of maintenance action or over a given time interval.

Maintenance philosophy
A system of principles for the organisation and execution of the maintenance.

Maintenance planning
Deciding in advance the jobs, methods, materials, tools, machines, labour, time required and timing of maintenance actions.

Maintenance policy
A description of the interrelationship between the maintenance echelons, the indenture levels and the levels of maintenance to be applied for the maintenance of an item.

Maintenance programme	A time-based plan allocating specific maintenance tasks to specific periods.
Maintenance requirements	A statement of the nature of the maintenance method, in particular the skill of the personnel involved, their facilities and the duration and frequency of maintenance action. Note 1: The information forms part of the technical manual.
Maintenance support	The provision on demand of the resources required to maintain an item under a given maintenance policy.
Maintenance support performance	The ability of a maintenance organisation, under given conditions, to provide upon demand, the resources required to maintain an item, under a given maintenance policy. Note: The given conditions are related to the item itself and to the conditions under which the item is used and maintained.
Mean operating time between failures (MTBF)	The expectation of the operating time between failures.
Mean time between failures	The expectation of the time between failures. Note: The term is normally used in connection with non-repairable items.
Mean time to first failure (MTTFF)	The expectation of the time to first failure.
Mean time to restoration; mean time To recovery (MTTR)	The expectation of the time to restoration.

Modification	of an item. The combination of all technical and administrative actions intended to change an item.
Nugatory time	That portion of time for which payment is made but for which no services is rendered.
Off-site maintenance	Maintenance performed at a location different from that where the item is used. Note: An example of off-site maintenance is the repair of a sub-item at a maintenance centre.
On-site maintenance; in-situ maintenance: Field maintenance	Maintenance performed at the location where the item is used.
Opportunistic maintenance	Maintenance of an item that is deferred or advanced in time when an unplanned opportunity becomes available.
Other operational delay time	The period of time during which the item is unable to perform due to a failure that has not been scheduled for action.
Parts List	A definitive list of all items that form the asset. Note: This document forms part of the technical manual.
Planned maintenance	The maintenance organised and carried out with forethought, control and the use of records to a predetermined plan. Note: Preventative maintenance; corrective maintenance may or may not be.
Preventative maintenance	The maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the

	probability of failure or the degradation of the functioning of an item.
Preventative maintenance time	That part of the maintenance time during which preventative maintenance is performed on an item, including technical delays and logistic delays inherent in preventative maintenance.
Reaction time	The time that elapses between the recognition of a need for repair and its execution.
Remote maintenance	Maintenance of an item performed without physical access of the personnel to the item.
Running maintenance	Maintenance that can be carried out whilst the item is in service.
Running maintenance time	The period of time during which maintenance is carried out whilst the item is in service.
Scheduled maintenance	The preventative maintenance carried out in accordance with an established time schedule. Note: In certain instances, for time read operating hours, distance traveled, etc as appropriate.
Shutdown maintenance	Maintenance that can be carried out only when the item is out of service.
Spares policy	A declared basis by which the holding of a stock of spares is determined.
Spares stock	Items that are held available for maintenance purposes or for the replacement of defective parts.

	Note: If spares stock is associated with a saleable product, it is regarded as direct stock, whereas if associated with the fixed assets (e.g., plant, vehicles) it is regarded as indirect stock.
Stock	All the tangible material assets of a company other than the fixed assets; comprising all the finished or saleable products, all the items to be incorporated into the finished products and all the items to be consumed in the process of manufacturing the product or in the carrying out of the business. Note 1: Inventory, when used as a generic term, is synonymous with stock. This use is common in the USA and extensive in the UK. Note 2: An inventory, when used specifically, is defined as a list of tangible material assets. For production control purposes this can be limited to being a list of stock.
Storage life	The specified length of time prior to use for which items that are inherently subject to deterioration are deemed to remain fit for use under prescribed conditions.
Strategic spares	Spares held against circumstances that are not expected to arise routinely or frequently during the life of the asset but which would have serious consequences is they did occur.
Undetected fault time	The time interval between failure and recognition of the resulting fault.
Unplanned maintenance	The maintenance carried our to no predetermined plan.

Unscheduled maintenance	The maintenance carried out to no predetermined plan.
Unscheduled maintenance	The maintenance carried out not in accordance with an established time schedule, but after reception of an indication regarding the state of an item.

Maintainability Terms

Accessibility	A qualitative of quantitative measure of the ease of gaining access to a component for the purposes of maintenance.
Maintainability	The probability that a given active maintenance action for an item under given conditions of use can be carried our within a stated time interval, when the maintenance is performed under stated conditions and using stated procedures and resources. Note: The term maintainability is also used to denote the maintainability performance quantified by this probability.

Interview by H.Keith Farmer.	Date	Location	
NAME & QUALIFACATION (RIBA, RICS, etc.)	ORGANISATION SECTOR (PRIVATE) (PUBLIC)	ADDRESS POST CODE	'PHONE FAX Email

Data protection Act. Information collected during this survey may be stored and retrieved electronically only by the survey taker and his agents. Specific acknowledgement may be given to individual contributors in final publication of findings. If you do not want to be identified as a contributor, or for your organization to remain anonymous, please indicate and sign below.

I want to remain anonymous. [ ] I want my organization to remain anonymous [ ]

Signed [ ]

Notes.

	Please rate <u>all</u> the following classifications of areas of maintenance showing those that you believe have the highest maintenance cost influence on the overall maintenance cost of a building, using the scale: **A= very important through to E= least important.** (highest cost) (lowest cost)	A	B	C	D	E
1	External decoration					
2	Internal decoration					
3	Main external structural envelope					
4	Windows and external doors					
5	Roofs and gutters					
6	Floor coverings					
7	Internal construction including partitions and doors					
8	Plumbing and heating systems including water heating.					
9	Kitchens and bathrooms					
10	Electrical installation (excluding fire alarm systems)					
11	Fire detection and alarm systems					
12	Lifts and common staircases					
13	Wood worm and beetle infestation					
14	Security and door entry systems.					
15	Other, please specify.					
16	Other, please specify.					

	Please rank 5 only of the following maintenance classification to show the top five areas that you believe must be regularly maintained to prevent breakdowns and unplanned maintenance buildings of multiple domestic accommodation. **(e.g. Hostels, Hotels, apartment blocks)** **1 = most important through to 5 = least important**	1	2	3	4	5
A	Roofs and gutters and drainage					
B	External decoration					
C	Main external structural envelope					
D	Windows and external doors					
E	Security and door entry systems.					
F	Floor coverings					
G	Internal construction including partitions and doors					
H	Plumbing and heating systems including water heating.					
I	Kitchens and bathrooms					
J	Electrical installation (excluding fire alarm systems)					
K	Fire detection and alarm systems					
L	Lifts and common staircases					
M	Wood worm and beetle infestation					
N	Internal decoration					
O	Other, please specify.					
P	Other, please specify.					

Pleamore Cross Farm House
Sampford Arundel
Wellington
Somerset
TA21 9QE

Date

Dear

Thank you for participating in the first round of this survey into maintenance costs. A **very brief second round questionnaire** is attached on the next page, and I will be grateful if you will complete this as before. The survey is in the 'tick in appropriate box' format, and should take a few minutes only to complete. When you have finished, simply click the return button and I will print it out at this end. (If I have problems with Email I will send it by post with SAE)

Pages 3&4 show the aggregated data obtained during the first round of this survey, and is provided for your information and to indicate the rational behind this final round of questions.

The final analysis and results will be issued to you as soon as all the contributors have returned this form and this survey analysis is complete. On conclusion of the full survey, the conclusions will be made available. It is planned that this will provide an indication of true maintenance costs for the categories of buildings examined, and a basis for systematic reduction of building maintenance costs via planned preventative maintenance.

Thank you very much for your co-operation on this project.

H Keith Farmer.

This survey forms the **second part** of a section of research by the author at the Faculty of Civil and Building Engineering at Loughborough University, into the cost of maintaining large buildings used for multiple domestic accommodation.

Thank you for your participation and co-operation during the first round of the survey. A copy of your individual input is attached for your reference, together with a graphical analysis of the first round data aggregated from all contributors.

Based on the output of the first round data, a second round questionnaire is shown below. This is in a similar format to the first round, and seeks to clarify and consolidate the data from the inputs obtained from the previous questionnaire, and which are provided for you information in pages 3 & 4.

Please **rank all** the following classifications of areas of maintenance in the order that you believe that they have the highest maintenance cost influence on the overall maintenance cost of a building. Please ensure one category to each of the 8 rankings 1st = Highest cost 8th = lowest cost	Order of importance 1st	2nd	3rd	4th	5th	6th	7th	8th
External envelope								
Main structural envelope								
Windows and external doors								
Roofs and gutters								
Plumbing, heating , hot water systems								
Kitchens and bathrooms								
Electrical excluding fire alarms								
Lifts and common staircases								

Please **rank** the following 5 categories in the order of importance that you believe they must have regular planned maintenance to prevent breakdowns and unplanned repairs. 1st = most important 5th = least important	Order of importance 1st	2nd	3rd	4th	5th
Roofs, gutters and drainage					
Main structural envelope					
Plumbing, heating and hot water systems					
Kitchens and bathrooms					
Electrical installation, not including fire alarm systems					

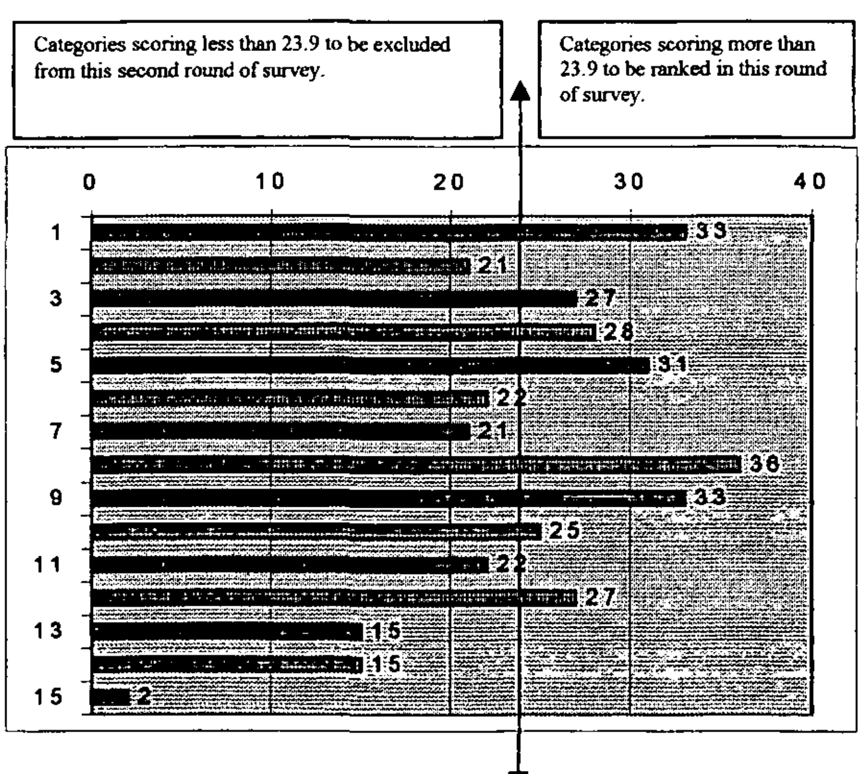
MAINTENANCE COST INFLUENCE RATING ANALYSIS FROM 1ST ROUND DATA.

Table D1a showing aggregated rated values from first round.

Total value of round 1 rating (* = reappraise in next round)	**Category description**
33 *	External decoration
21	Internal decoration
27 *	Main external structural envelope
28 *	Windows and external doors
31 *	Roofs and gutters
22	Floor coverings
21	Internal construction, partitions, doors.
36 *	Plumbing, Heating, Hot water systems.
33 *	Kitchens and Bathrooms.
25 *	Electrical excluding fire alarm systems.
22	Fire detection and alarm systems.
27 *	Lifts and common stair cases.
15	Woodworm and beetle infestation, rot.
15	Security and door entry systems.
2	External works and landscaping.

The data shown above is depicted graphically below, with the vertical line separating the higher scoring elements which form the basis of this second round of data collection.

GRAPHICAL REPRESENTATION OF TABLE D1a ABOVE

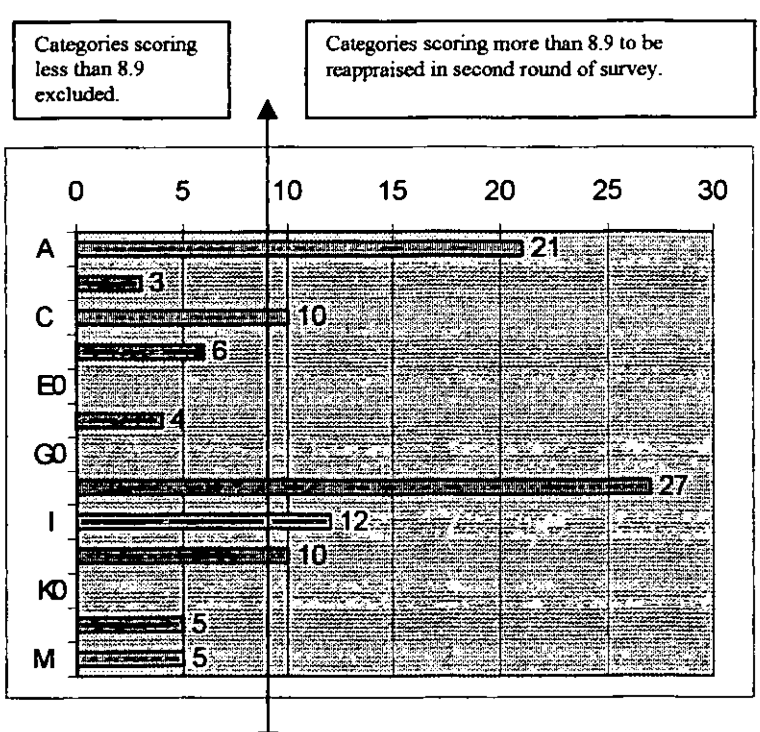


PLANNED MAINTENANCE IMPORTANCE RANKING ANALYSIS FROM 1ST ROUND

Table D1b Showing aggregated ranking scores from first round of survey

Total value of round 1 rating	Category description
21	Roofs, gutters and drainage
3	External decoration
10	Main structural envelope
6	Windows and external doors
0	Security and door entry systems
4	floor coverings
0	Internal construction, partitions and doors
27	Plumbing, heating , hot water systems.
12	Kitchens and bathrooms
10	Electrical installation (not fire alarms)
0	Fire detection and alarm systems
5	Lifts an common stair cases
5	Wood worm, beetle and rot.
2	Internal decoration

The date shown in table D1b is depicted graphically below. The vertical line drawn at 8.9 points, indicates those categories that ranked higher and which are to be reconsidered in this second round.



Check list for evaluating a building for Objective 1 study.

1	Is the building between 30 and 50 years old?	☐
2	Is the building of 'traditional' construction?	☐
3	Is the building of Modular Construction (Ind. Bld. Method)	☐
4	Is it operated as one building under one management?	☐
5	Is the building still in the 'as built' (with some modernisation not extensive alteration) form?	☐
6	Are maintenance records existing and accessible?	☐
7	Will full co-operation be provided by the operator?	☐
8	Can areas of confidentiality be identified and respected?	☐
9	Is this building a suitable comparison with other buildings also under investigation in this research?	☐
10	Are there any plans to radically change or demolish the building or its environment within the next five years, that might jeopardise follow up research?	☐

Check list for evaluating a building for Objective 2 study.

11	Is the building between 100 and 200 years old?	☐
12	Is it operated as one building under one management?	☐
13	Is the building still in the 'as built' (with some modernisation not extensive alteration) form?	☐
14	Are maintenance records existing and accessible?	☐
15	Will full co-operation be provided by the operator?	☐
16	Can areas of confidentiality be identified and respected?	☐
17	Is this building a suitable comparison with other buildings also under investigation in this research?	☐
18	Is this building one that must be maintained because of 'Listed' status?	☐
19	Are there any plans to radically change or demolish the building or its environment within the next five years, that might jeopardise follow up research?	☐

CHECK LIST FOR PREPARATION OF INTERVIEW QUESTIONNAIRE.

Does the questionnaire ask for the following information?

1. Source of information,
2. Name of interviewee providing information.
3. Identity of building, address etc. Post code.
4. When built, age.
5. How built, traditional or modular.
6. Building operator, managing agent.
7. Building use. Private dwellings, L.A. flats, Hotel/Hostel.
8. How many units of accommodation/persons/floor area.
9. How maintained, direct labour, contracted out.
10. Maintenance planning, planned maintenance, unplanned, corrective, run to failure.
11. Maintenance costs for last five years separated into categories (as White 1973).
    a) External decoration.
    b) Internal decoration
    c) Main structure, including windows and gutters.
    d) Internal construction, partitions and doors.
    e) Plumbing and sanitary ware.
    f) Mechanical, gas and air conditioning.
    g) Electrical including kitchens.
    h) External civil engineering works.
    i) Routine cleaning.

Ref	Units	Total annual cost 1999	1998	1997	1996	£K 1995
1	16	9.00	5.00	5.00	5.00	9.00
2	48	24.20	22.90	19.70	21.30	18.72
3	69	50.00	50.00	50.00	50.00	50.00
4	41	23.63	18.60	17.86	10.38	7.60
5	6600	6000.00	5700.00	5414.00	5144.00	4887.00
6	14	8.40	6.50	7.70	4.40	6.10
7	6	2.40	2.28	2.17	2.06	2.00
8	12	6.00	20.00	100.00	5.00	15.00
9	89	419.00	44.00	28.00	641.00	35.00
10	28	34.00	34.00	32.00	30.00	29.00
11	81	4.00	2.00	2.00	2.00	5.00
12	28	26.02	24.78	23.60	22.42	21.30
13	11	100.00	10.00	6.00	7.50	7.50
14	72	84.00	79.00	72.00	54.00	21.38
15	4	0.00	0.00	0.00	0.00	0.00
16	1	75.00	70.00	70.00	60.00	50.00
17	126	504.00	500.00	500.00	270.00	230.00
18	55	90.00	20.00	10.00	10.00	5.00
19	6	7.50	0.00	0.00	0.00	10.00
20	56	42.00	57.00	49.00	27.00	35.00
21	41	114.80	98.00	110.70	68.00	50.00
22	42	41.21	37.25	33.29	29.33	25.37
23	48	55.30	48.00	61.00	213.63	17.00
24	12	11.00	10.50	10.00	9.50	9.00
25	16	17.50	17.00	16.50	16.00	15.00
26	15	12.00	11.00	12.00	9.00	8.00
27	21	20.00	20.00	20.00	20.00	20.00
28	14	9.70	15.00	9.00	7.00	7.00
29	10	14.00	17.00	11.00	10.00	7.00
30	9	6.00	6.00	5.00	5.00	2.00
31	8	6.32	6.00	5.60	5.10	4.90
32	6	4.31	7.40	2.67	2.00	2.00
33	6	3.00	3.00	2.00	2.00	1.00
Totals=>	7611	7824.28	6962.21	6707.78	6762.61	5612.87
Average per unit £k =>		1.03	0.91	0.88	0.89	0.74

Ref	Units	External decoration 1999	1998	1997	£K 1996	1995
1	16	3.00	0.00	0.00	0.00	3.00
2	48	2.17	2.06	1.80	1.92	1.69
3	69	10.00	10.00	10.00	10.00	10.00
4	41	0.00	0.00	0.00	0.00	0.00
5	6600	0.00	269.10	181.82	0.00	0.00
6	14	0.00	0.00	0.00	0.00	0.00
7	6	2.40	2.28	2.16	2.06	0.20
8	12	0.00	8.00	0.00	0.00	0.00
9	89	0.00	0.00	0.00	0.00	0.00
10	28	2.04	2.04	1.90	1.80	1.74
11	81	4.00	0.00	0.00	0.00	7.50
12	28	1.65	1.58	1.50	1.43	1.35
13	11	6.00	0.00	0.00	0.00	0.00
14	72	0.00	0.00	0.00	0.00	11.25
15	4	0.00	0.00	0.00	0.00	0.00
16	1	3.05	3.50	2.50	3.00	2.50
17	126	0.00	0.00	100.00	0.00	0.00
18	55	0.00	0.00	0.00	3.00	0.00
19	6	0.00	0.00	0.00	0.00	10.00
20	56	0.00	0.00	11.00	0.00	0.00
21	41	22.96	19.60	22.14	13.60	10.00
22	42	8.24	7.45	6.66	5.87	5.07
23	48	2.77	2.40	3.05	2.04	0.85
24	12	0.00	0.00	0.00	0.00	0.00
25	16	1.50	1.50	1.50	1.50	1.50
26	15	0.00	0.00	0.00	0.00	0.00
27	21	1.00	1.00	1.00	1.00	1.00
28	14	0.00	0.00	0.00	0.00	1.00
29	10	0.00	5.00	0.50	0.00	1.00
30	9	2.00	0.00	0.00	0.00	1.50
31	8	0.00	0.50	0.50	0.00	0.00
32	6	0.00	4.00	0.00	0.00	0.00
33	6	0.00	0.00	0.00	0.00	0.00
Totals=>	7611	72.78	340.00	348.03	47.21	71.15
Average		0.93				
per unit £k		0.01	0.04	0.05	0.01	0.01

Ref	Units	Internal decoration 1999	1998	1997	1996	1995
1	16	1.00	0.00	0.00	0.00	1.00
2	48	3.63	3.44	3.00	3.20	2.81
3	69	15.00	15.00	15.00	15.00	15.00
4	41	0.00	0.00	0.00	0.00	0.00
5	6600	0.00	420.00	0.00	0.00	120.70
6	14	1.60	0.78	1.46	1.41	1.40
7	6	0.60	0.57	0.54	0.42	0.50
8	12	0.00	4.00	30.00	1.00	0.00
9	89	0.80	1.09	1.10	7.24	1.49
10	28	1.36	1.36	1.20	1.20	1.16
11	81	6.00	0.00	0.00	0.00	2.50
12	28	1.32	1.26	1.20	1.14	1.08
13	11	4.00	3.00	1.80	2.25	2.25
14	72	2.17	0.00	4.15	2.00	10.14
15	4	0.00	0.00	0.00	0.00	0.00
16	1	18.75	17.50	17.50	15.00	12.50
17	126	25.20	25.00	25.00	13.50	11.50
18	55	0.00	0.00	0.00	0.00	0.00
19	6	7.50	0.00	0.00	0.00	0.00
20	56	3.00	0.00	9.00	0.00	4.00
21	41	11.5	11.07	0.68	5.00	5000.00
22	42	2.06	1.86	1.66	1.47	1.27
23	48	8.30	7.20	9.25	6.12	2.55
24	12	2.50	2.50	2.00	2.00	2.00
25	16	2.00	3.00	2.50	2.00	2.50
26	15	3.00	3.00	2.50	2.50	2.50
27	21	2.00	2.00	2.00	2.00	2.00
28	14	0.00	3.00	0.00	0.00	2.00
29	10	1.00	1.00	1.00	1.00	1.00
30	9	0.00	0.00	0.00	2.00	0.00
31	8	1.00	0.50	0.50	0.50	0.50
32	6	3.31	0.00	0.00	1.00	0.00
33	6	0.00	0.00	0.00	0.00	0.00
Totals=>	7611	128.58	528.13	133.05	88.94	5204.36
Average per unit £k =>		0.02	0.07	0.02	0.01	0.68

Ref	Units	Main structure incl windows/doors 1999	1998	1997	1996	1995
1	16	1.00	1.00	1.00	1.00	1.00
2	48	3.63	3.44	3.00	3.20	2.81
3	69	5.00	5.00	5.00	5.00	5.00
4	41	1.62	0.12	0.67	0.42	0.16
5	6600	410.40	312.20	509.70	719.92	216.00
6	14	0.00	0.00	0.00	0.00	0.00
7	6	0.00	0.00	0.00	0.00	0.00
8	12	0.60	0.00	0.00	0.00	0.00
9	89	367.79	5.76	2.44	3.20	0.11
10	28	6.12	4.76	5.44	4.50	4.60
11	81	6.00	2.00	3.00	2.00	7.50
12	28	7.99	7.61	7.25	6.89	6.54
13	11	83.00	0.00	0.00	0.00	0.75
14	72	22.35	11.00	25.46	30.50	0.00
15	4	0.00	0.00	0.00	0.00	0.00
16	1	0.00	0.00	0.00	0.00	0.00
17	126	50.40	50.00	50.00	27.00	23.00
18	55	70.00	6.00	5.00	0.00	1.00
19	6	0.00	0.00	0.00	0.00	0.00
20	56	1.00	3.00	0.00	0.00	5.00
21	41	17.22	14.70	16.61	10.20	75.00
22	42	8.24	0.45	6.66	5.27	5.07
23	48	0.00	0.00	0.00	172.80	0.00
24	12	1.00	1.00	1.00	1.00	1.00
25	16	1.00	2.00	1.00	2.00	1.00
26	15	1.00	1.00	1.00	1.00	1.00
27	21	3.00	3.00	3.00	3.00	3.00
28	14	3.12	3.00	0.00	0.00	0.00
29	10	0.00	5.00	0.50	2.00	0.00
30	9	1.00	4.00	0.00	0.00	0.00
31	8	1.00	1.00	1.00	0.50	0.50
32	6	0.00	2.00	0.00	0.50	0.00
33	6	0.60	0.60	0.40	0.40	2.00
Totals=>	7611	1074.08	449.65	649.12	1002.29	362.05
Average		13.73				
per unit £k =>		0.14	0.06	0.09	0.13	0.05

Ref	Units	Internal construction, partitions 1999	1998	1997	1996	1995
1	16	0.00	0.00	0.00	0.00	0.00
2	48	1.21	1.15	1.00	1.67	0.97
3	69	2.50	2.50	2.50	2.50	2.50
4	41	0.00	0.00	0.00	0.00	0.00
5	6600	0.00	74.60	21.00	0.00	0.00
6	14	5.29	3.51	1.62	0.53	0.67
7	6	0.00	0.00	0.00	0.00	0.00
8	12	1.80	0.00	20.00	1.25	0.00
9	89	13.41	4.93	6.00	28.82	6.38
10	28	2.72	2.38	2.24	2.10	2.61
11	81	6.00	3.00	1.00	1.00	5.00
12	28	1.76	1.68	1.60	1.52	1.44
13	11	2.00	3.00	6.00	0.00	0.00
14	72	11.01	2.75	14.59	6.00	0.00
15	4	0.00	0.00	0.00	0.00	0.00
16	1	3.75	3.50	3.50	3.00	2.50
17	126	50.40	50.00	50.00	27.00	23.00
18	55	0.00	0.00	0.00	0.00	0.00
19	6	0.00	0.00	0.00	0.00	0.00
20	56	17.00	12.00	19.00	16.00	5.00
21	41	0.00	0.00	0.00	0.00	0.00
22	42	2.06	1.86	1.66	1.47	1.27
23	48	0.00	0.00	0.00	0.00	0.00
24	12	0.80	0.80	0.80	0.80	0.80
25	16	2.00	1.00	2.00	1.00	1.00
26	15	0.70	0.00	0.00	1.00	0.00
27	21	2.00	2.00	2.00	2.00	2.00
28	14	0.40	4.00	0.00	1.80	1.00
29	10	0.50	1.00	4.00	1.00	0.00
30	9	1.00	1.00	1.00	1.00	0.00
31	8	0.50	1.00	0.50	1.00	1.00
32	6	1.00	0.00	2.67	0.00	0.00
33	6	0.00	0.00	0.00	0.00	0.00
Totals=>	7611	129.82	177.66	164.68	102.45	57.14
Average		1.66				
per unit £k =>		0.02	0.02	0.02	0.01	0.01

		Plumbing and sanitary ware				
Ref	Units	1999	1998	1997	1996	1995
1	16	1.00	1.00	1.00	1.00	1.00
2	48	3.63	3.44	3.00	3.20	2.81
3	69	2.50	2.50	2.50	2.50	2.50
4	41	1.81	0.83	2.14	1.01	1.08
5	6600	460.20	781.30	10.27	489.11	521.18
6	14	0.59	0.78	0.15	0.44	0.85
7	6	0.36	0.34	0.33	0.31	0.30
8	12	1.80	0.00	15.00	0.00	0.00
9	89	5.95	5.93	4.88	5.99	8.95
10	28	4.08	5.10	4.80	3.60	4.06
11	81	2.00	1.00	1.00	2.00	2.50
12	28	6.62	0.63	0.60	0.57	5.42
13	11	0.00	0.00	3.00	0.75	1.50
14	72	21.80	16.59	22.16	11.00	0.00
15	4	0.00	0.00	0.00	0.00	0.00
16	1	11.25	10.50	10.50	9.00	7.50
17	126	126.00	125.00	125.00	675.00	575.00
18	55	15.00	3.00	1.50	3.00	2.00
19	6	0.00	0.00	0.00	0.00	0.00
20	56	12.00	12.00	7.00	4.00	5.00
21	41	11.48	9.80	11.07	6.80	50.00
22	42	8.24	7.45	6.66	5.87	5.07
23	48	13.83	12.60	15.25	10.21	42.50
24	12	4.30	4.20	4.00	3.50	3.00
25	16	5.00	5.00	4.50	4.00	3.00
26	15	4.50	4.50	3.50	3.50	3.00
27	21	3.00	2.00	2.00	2.00	2.00
28	14	2.44	2.50	2.30	2.20	1.00
29	10	7.50	2.00	1.00	2.00	3.00
30	9	1.00	0.00	0.00	1.00	0.00
31	8	1.20	1.00	1.00	1.00	1.00
32	6	0.00	0.70	0.00	0.50	0.00
33	6	0.60	0.60	0.40	0.40	0.20
Totals=>	7611	739.67	1022.28	266.51	1255.44	1255.42
Average		9.45				
per unit £k =>		0.10	0.13	0.04	0.16	0.16

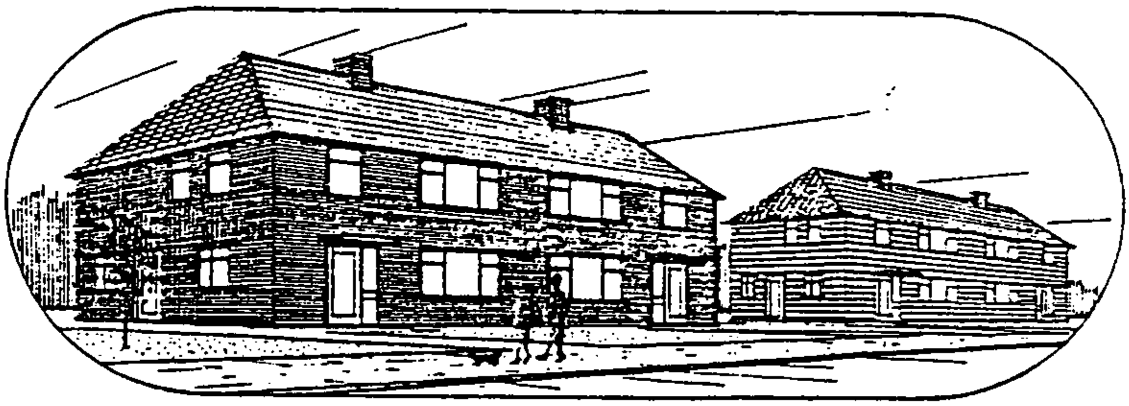
Ref	Units	Mechanical,gas, heating 1999	1998	1997	1996
1	16	1.00	1.00	1.00	1.00
2	48	4.84	4.58	4.00	4.26
3	69	5.00	5.00	5.00	5.00
4	41	3.56	4.88	2.20	2.87
5	6600	904.80	27.00	1311.22	793.76
6	14	0.00	0.00	0.00	0.00
7	6	0.60	0.57	0.54	0.42
8	12	1.20	0.00	10.00	0.00
9	89	0.31	2.98	2.90	2.82
10	28	5.78	5.10	4.48	4.50
11	81	38.00	4.00	4.00	4.00
12	28	2.87	2.73	2.60	2.47
13	11	2.00	1.00	0.60	2.25
14	72	17.93	25.04	9.41	0.00
15	4	0.00	0.00	0.00	0.00
16	1	11.25	10.50	10.50	9.00
17	126	25.20	25.00	25.00	13.50
18	55	0.00	6.00	1.50	2.00
19	6	0.00	0.00	0.00	0.00
20	56	9.00	17.00	3.00	3.00
21	41	4.59	3.92	4.43	2.72
22	42	4.12	3.72	3.33	2.93
23	48	8.30	7.20	9.15	6.12
24	12	0.00	1.00	1.00	1.00
25	16	2.00	2.50	1.50	2.00
26	15	0.00	1.00	1.00	0.00
27	21	3.00	3.00	3.00	3.00
28	14	1.62	1.50	0.00	1.50
29	10	2.50	1.00	1.00	2.00
30	9	0.00	0.00	3.00	0.00
31	8	1.00	1.00	1.00	1.10
32	6	0.00	0.00	0.00	0.00
33	6	0.30	0.30	0.20	0.20
Totals=>	7611	1060.77	168.52	1426.56	873.42
Average		13.56			
per unit £k =>		0.14	0.02	0.19	0.11

Ref	Units	Electrical including kitchens 1999	1998	1997	1996	1995
1	16	0.00	0.00	0.00	0.00	0.00
2	48	1.47	1.37	1.20	1.28	1.12
3	69	5.00	5.00	5.00	5.00	5.00
4	41	12.42	9.03	6.52	2.27	1.26
5	6600	3162.08	1741.37	2777.61	1936.10	44.43
6	14	8.40	0.59	1.23	1.23	1.53
7	6	0.00	0.00	0.00	0.00	0.00
8	12	0.00	0.00	15.00	0.00	0.00
9	89	11.82	18.77	33.66	20.88	6.53
10	28	3.40	3.40	3.20	3.00	2.90
11	81	8.00	2.00	2.00	1.00	2.50
12	28	3.67	3.49	3.33	3.16	3.00
13	11	3.00	3.00	0.00	2.25	1.50
14	72	5.69	21.71	11.07	4.00	0.00
15	4	0.04	0.04	0.04	0.04	0.04
16	1	11.25	10.50	10.50	9.00	7.50
17	126	100.80	100.00	100.00	54.00	46.00
18	55	5.00	5.00	2.00	2.00	2.00
19	6	0.00	0.00	0.00	0.00	0.00
20	56	0.00	10.00	0.00	0.00	5.00
21	41	22.96	19.60	22.14	13.60	10.00
22	42	4.12	3.72	3.33	2.93	2.54
23	48	11.06	9.60	12.20	8.17	3.40
24	12	14.00	0.00	12.00	12.00	12.00
25	16	2.50	2.00	1.50	1.50	2.50
26	15	1.80	0.00	2.00	1.00	1.00
27	21	3.00	3.00	3.00	3.00	3.00
28	14	1.08	1.00	4.20	1.50	1.00
29	10	1.00	2.00	2.00	2.00	1.00
30	9	1.00	1.00	1.00	1.00	0.50
31	8	1.00	1.00	0.50	1.00	0.50
32	6	0.00	7.00	0.00	0.00	0.00
33	6	0.60	0.60	0.40	0.40	0.20
Totals=>	7611	3406.14	1985.77	3036.62	2093.30	167.94
Average		43.53				
per unit £k =>		0.45	0.26	0.40	0.28	0.02

Ref	Units	External & civil engineering works 1999	1998	1997	1996	1995
1	16	0.00	0.00	0.00	0.00	0.00
2	48	2.42	2.29	2.00	2.13	12.87
3	69	1.25	1.25	1.25	1.25	1.25
4	41	0.22	0.02	0.02	0.00	0.16
5	6600	60.00	18.00	54.06	11.00	41.19
6	14	0.00	0.00	0.00	0.00	0.00
7	6	0.00	0.00	0.00	0.00	0.00
8	12	0.00	0.00	0.00	0.00	0.00
9	89	0.00	0.00	0.00	0.00	0.00
10	28	1.02	1.02	0.06	0.90	0.87
11	81	0.80	2.00	2.00	3.00	5.00
12	28	0.00	0.00	0.00	0.00	0.00
13	11	0.00	0.00	0.00	0.00	0.00
14	72	2.50	0.90	4.15	0.00	0.00
15	4	0.00	0.00	0.00	0.00	0.00
16	1	3.75	7.00	3.50	3.00	2.50
17	126	25.20	25.00	25.00	13.50	11.50
18	55	0.00	0.00	0.00	0.00	0.00
19	6	0.00	0.00	0.00	0.00	0.00
20	56	0.00	0.00	0.00	0.00	0.00
21	41	11.48	9.80	11.07	6.80	5.00
22	42	0.00	0.00	0.00	0.00	0.00
23	48	5.53	4.80	6.10	40.82	1.70
24	12	1.00	1.00	0.00	0.00	0.00
25	16	2.50	1.00	2.00	2.00	2.00
26	15	1.00	1.00	0.00	0.00	0.00
27	21	1.00	1.00	1.00	1.00	1.00
28	14	1.05	0.00	0.50	0.00	0.00
29	10	0.50	0.00	1.00	0.00	0.00
30	9	0.00	0.00	0.00	0.00	0.00
31	8	0.62	0.00	0.60	0.00	0.50
32	6	0.00	0.00	0.00	0.00	0.00
33	6	0.00	0.00	0.00	0.00	0.00
Totals=>	7611	121.83	76.08	114.31	85.40	85.54
Average		1.56				
per unit £k =>		0.02	0.01	0.02	0.01	0.01

Ref	Units	Routine cleaning 1999	1998	1997	1996	1995
1	16	1.00	1.00	1.00	1.00	1.00
2	48	1.21	1.15	1.00	1.06	0.97
3	69	1.25	1.25	1.25	1.25	1.25
4	41	3.62	3.44	3.27	3.10	2.95
5	6600	918.00	1031.00	549.30	973.60	1193.20
6	14	0.00	0.00	0.00	0.00	0.00
7	6	0.24	0.23	0.22	0.11	0.20
8	12	0.00	0.00	0.00	0.00	0.00
9	89	15.59	9.73	9.51	8.72	8.34
10	28	5.10	5.10	4.80	4.50	4.35
11	81	6.00	3.00	3.00	2.00	5.00
12	28	1.10	1.05	1.00	0.95	0.90
13	11	0.00	0.00	0.00	0.00	0.00
14	72	10.00	10.00	10.00	10.00	10.00
15	4	0.00	0.00	0.00	0.00	0.00
16	1	11.25	7.00	10.50	9.00	7.50
17	126	100.80	100.00	100.00	54.00	46.00
18	55	0.00	0.00	0.00	0.00	0.00
19	6	0.00	0.00	0.00	0.00	0.00
20	56	2.00	0.00	0.00	0.00	0.00
21	41	0.00	0.00	0.00	0.00	0.00
22	42	0.00	0.00	0.00	0.00	0.00
23	48	0.00	0.00	0.00	0.00	0.00
24	12	0.00	0.00	0.00	0.00	0.00
25	16	0.00	0.00	0.00	0.00	0.00
26	15	0.00	0.00	0.00	0.00	0.00
27	21	1.00	1.00	1.00	1.00	1.00
28	14	0.00	0.00	0.00	0.00	0.00
29	10	0.00	0.00	0.00	0.00	0.00
30	9	0.00	0.00	0.00	0.00	0.00
31	8	0.00	0.00	0.00	0.00	0.00
32	6	0.00	0.00	0.00	0.00	0.00
33	6					
Totals=>	7611	1078.16	1174.95	695.84	1070.29	1282.67
Average		14.17				
per unit £k =>		0.14	0.15	0.09	0.14	0.17

Ref	Units	Other works 1999	1998	1997	1996	1995
1	16	1.00	1.00	1.00	1.00	1.00
2	48	2.50				
3	69	1.25	1.25	1.25	1.25	1.25
4	41	0.39	0.34	3.05	0.70	0.40
5	6600	84.52	354.00	0.00	220.51	766.09
6	14	0.84	0.84	3.23	1.39	1.65
7	6	0.36	0.34	0.32	0.31	0.30
8	12	0.60	0.40	10.00	2.75	5.00
9	89	0.00	0.00	0.00	0.00	0.00
10	28	2.38	3.78	2.88	3.90	4.60
11	81	0.40	3.00	4.00	5.00	7.50
12	28	1.10	1.05	1.00	0.95	0.90
13	11	0.00	0.00	0.00	0.00	0.00
14	72	0.00	0.00	0.00	0.00	0.00
15	4	0.00	0.00	0.00	0.00	0.00
16	1	0.00	0.00	0.00	0.00	0.00
17	126	0.00	0.00	0.00	0.00	0.00
18	55	0.00	0.00	0.00	0.00	0.00
19	6	0.00	0.00	0.00	0.00	0.00
20	56	0.00	0.00	0.00	0.00	0.00
21	41	22.96	19.60	22.14	13.60	10.00
22	42	4.12	3.72	3.33	2.93	2.54
23	48	1.38	12.60	15.25	10.21	4.25
24	12	0.00	0.00	0.00	0.00	0.00
25	16	0.00	0.00	0.00	0.00	0.00
26	15	0.00	0.00	0.00	0.00	0.00
27	21	1.00	1.00	1.00	1.00	1.00
28	14	0.00	0.00	0.00	0.00	0.00
29	10	0.00	0.00	0.00	0.00	0.00
30	9	0.00	0.00	0.00	0.00	0.00
31	8	0.00	0.00	0.00	0.00	0.00
32	6	0.00	0.00	0.00	0.00	0.00
33	6					
Totals=>	7611	124.80	402.92	68.45	265.50	806.47
Average		1.59				
per unit £k =>		0.02	0.05	0.01	0.03	0.11



to

Traditional dwellings

by

LEEDS

LEEDS CITY COUNCIL,
DEPARTMENT OF PUBLIC WORKS

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BRIEF DESCRIPTION OF THE AIREY SYSTEM

The prefabricated dwellings were built on traditional concrete strip foundations or in cases where deep foundations were deemed necessary, on concrete 'trench fill' foundations. Both methods supported 9" (230 mm) brickwork.

Following the casting of the ground floor insitu concrete floor slab, a precast concrete box structure was erected using 4" x 2¼" (104 x 57mm) storey height columns fixed at 18" (455 mm) centres. First floor and roof beams transmit vertical loadings to the columns.

The external weather-proof envelope was formed with concrete cladding panels 3'0" x 10" (915 mm long x 250 mm) tied to the columns with copper wire.

An internal spine wall incorporated 3" x 2¼" (75 x 57 mm) columns or brickwork. The Leeds Airey houses were built with traditional breeze block or brick party walls.

The internal plasterboard finish was fixed onto timber fillets. The fillets were attached to the columns in the concrete moulding process.

THE PROBLEM

The load bearing concrete columns were reinforced longitudinally with a thin walled hollow steel tube. In many instances the steel tube had corroded causing cracking and spalling of the concrete.

The cause of this deterioration has been identified as:-

1) Insufficient concrete cover to the steel tubes.

2) Carbonation of the concrete - reduction of the protective alkalinity of the concrete caused by the action of acidic gases present in the atmosphere.

3) Chlorides in the concrete - probably added originally to aid rapid manufacture by speeding up the rate of setting and hardening of the concrete to allow early removal from the mould.

The above factors contribute to the gradual and continuous disintegration of the load-bearing structure.

THE LEEDS CITY COUNCIL SOLUTION

After extensive investigations the following brick solution was developed by the City Council's Technical Officers with structural advice from the County Council's Engineering Department.

From an initial brief requiring minimum tenant disturbance, a method of working from the exterior of each dwelling was devised.

The system involves cavity wall construction with a concrete block inner leaf, 50 mm cavity and outer leaf of facing brick-work. The light-weight blocks are cast incorporating a recess to accommodate the existing columns and allow the direct relief of their load-bearing function. Timber or lattice beam floor joists are extended with steel angle cleats.

Where the existing columns formed window mullions in the dwellings, these are trimmed to form clear structural openings.

The design details are set down in the form of pictorial sections explained by brief schedules of work.

ADVANTAGES OF THE 'LEEDS' SYSTEM

A) An overall enhancement of the dwelling which dispels the 'Prefab' stigma using traditional construction methods of repair.

The prototype houses have been well received by both tenants and former tenants who have now purchased their homes. It is the intention of the local members of the Airey Owners Association to use the Leeds system to restore their properties.

B) By careful selection of facing brick texture and colour, the restored property can significantly improve the local built environment.

C) The current topical problems of condensation, standards of thermal insulation, sound insulation and ventilation of roof spaces have all been considered within the scheme, and all modern standards are met.

D) An adjustable temporary panel support system obviates the need to strip large areas of concrete cladding during the execution of remedial works, thus maximising the protection from the elements and intruders.

E) Construction techniques allow all the structural work to be completed from the outside of the dwelling. Only release, relocation of existing doors and windows and replacement of window boards and linings need to be carried out from the inside when all other works have been completed. A team of four men can carry out these operations with a minimum of inconvenience in less than 3 working days per dwelling.

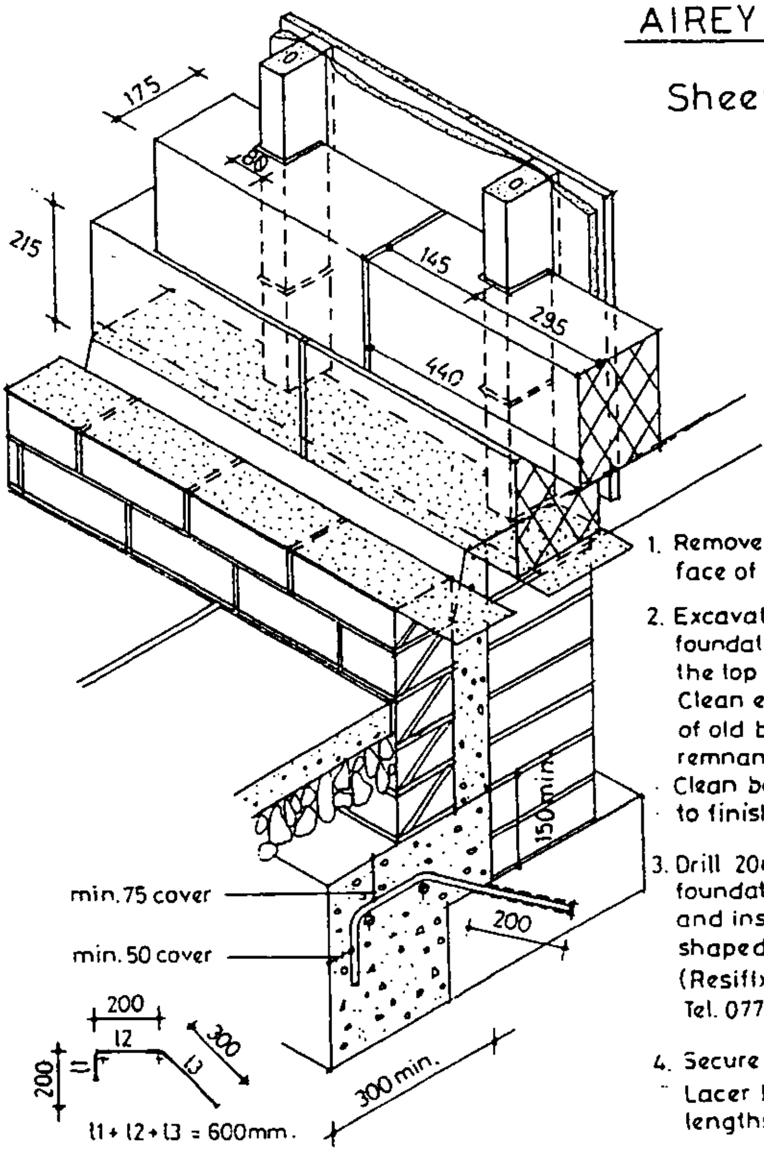
F) The retention of the existing plasterboard system prevents the pattern staining problems associated with modern insulating blockwork and their mortar joints.

G) This system eliminates the risk element associated with non-traditional remedial methods which have no proven reliability.

DETAILS

AIREY HOUSES

Sheet No. 1

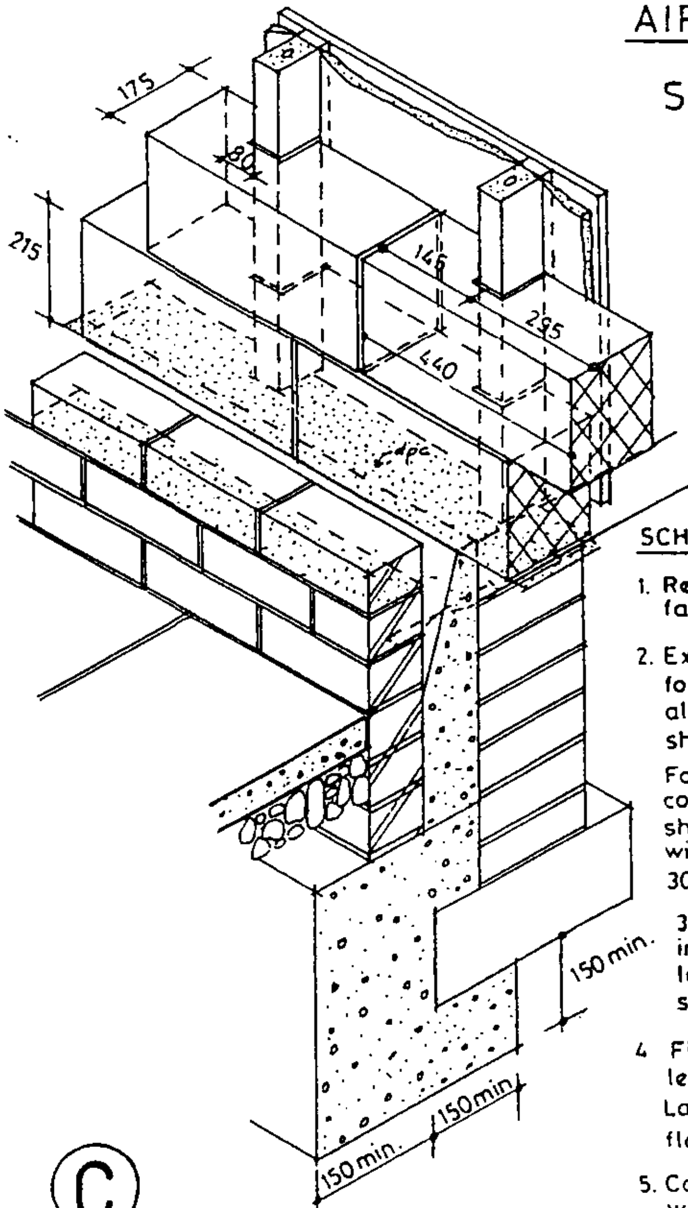


1. Remove concrete panels on face of structural posts.
2. Excavate for extended foundations and expose fully the top and edge of old base. Clean existing brick and conc. of old base to remove soil remnants and mortar droppings. Clean bottoms of excavation to finish level with existing
3. Drill 20mm. dia. holes in exist. foundation at 1000mm centres and insert 16mm. dia. specially shaped dowels in fixing grout (Resiflx 3S by Celtite Selflx Ltd.) Tel. 0773 604131-5
4. Secure 12mm. dia. straight Lacer bars (2no.) in random lengths min. lap 500mm.
5. Wet existing brickwork and concrete to receive new founds. of C 20 N/mm. conc. mix, 20mm max. aggregate and min. cement content of 290 kg./m3
6. Build up external skin in bk.work to f.f. level.
7. Fill cavity from floor level to slope to ground level with lean concrete. Lay d.p.c. to both walls at floor level.
8. Construct wall above floor with special blocks and facing bricks in CII mortar incl. wall ties. Blocks are handed each alternate course and dimensioned as shown.

Detail for shallow foundation and wall construction.

AIREY HOUSES

Sheet No. 1.a



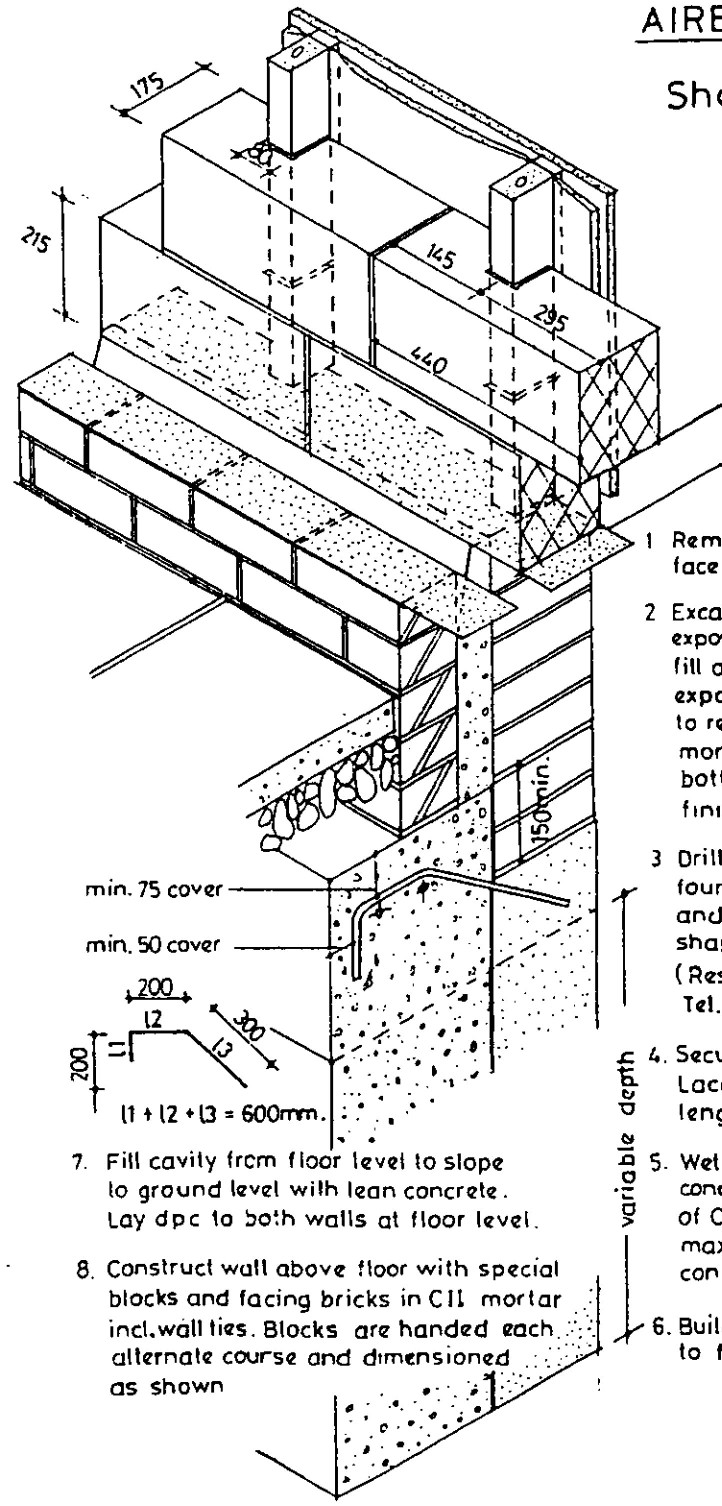
SCHEDULE OF WORK

1. Remove concrete panels on face of structural posts.
2. Excavate for extended foundations in 1·5m. stages allowing for workspace and shuttering if necessary.
   Form foundations in 1:3:6 concrete to dimensions as shown. Stages connected with 3no. 20 mm. bars 300 long.
3. Build up external skin in brickwork to footpath level. Include 4 no. galv. strip ties per metre
4. Fill cavity below ground level with lean concrete. Lay d.p.c. to both walls at floor level.
5. Construct wall above floor with special blocks and facing bricks in 1:1:6 mortar incl. wall ties Blocks are handed each alternate course and dimensioned as shown.

Detail for shallow foundation and wall construction.

AIREY HOUSES

Sheet No. 2



1 Remove concrete panels on face of structural posts

2 Excavate for extended foundations exposing bk.work and conc. trench fill of existing base. Clean exposed bk.work and conc. to remove soil remnants and mortar droppings. Clean bottoms of excavation to finish level with existing

3 Drill 20mm dia. holes in exist. foundation at 1000mm. centres and insert 16mm dia. specially shaped dowels in fixing grout (Resifix 3S by Celtite Selfix Ltd.) Tel.0773 604131-5

4. Secure 12mm dia. straight Lacer bars (2no.) in random lengths min. lap 500mm.

5. Wet existing brickwork and concrete to receive new founds. of C 20 N/mm. conc. mix, 20mm. max. aggregate and min. cement content of 290 kg/m3

6. Build up external skin in bk.work to f.f.level.

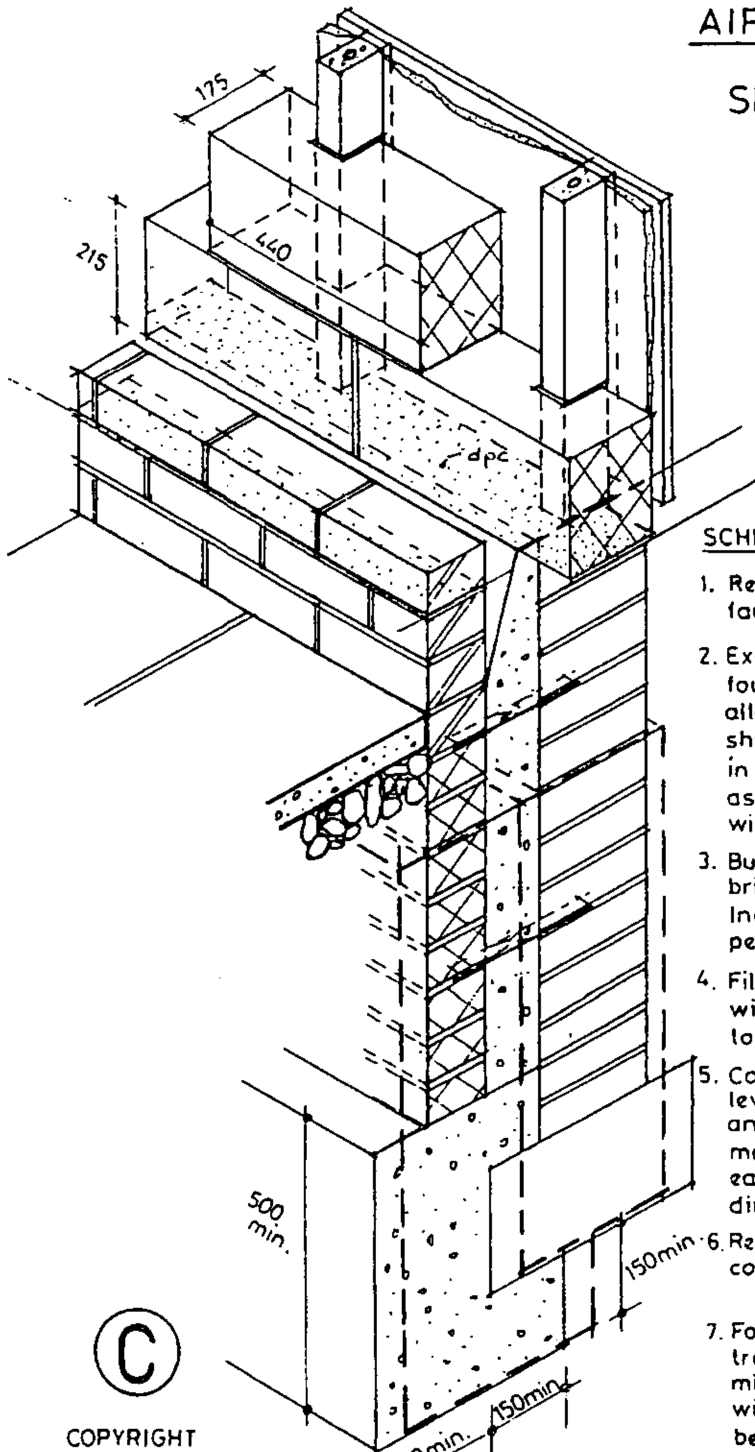
7. Fill cavity from floor level to slope to ground level with lean concrete. Lay dpc to both walls at floor level.

8. Construct wall above floor with special blocks and facing bricks in CII mortar incl. wall ties. Blocks are handed each alternate course and dimensioned as shown

Detail for narrow strip and deep trench fill foundation.

AIREY HOUSES

Sheet No. 2a



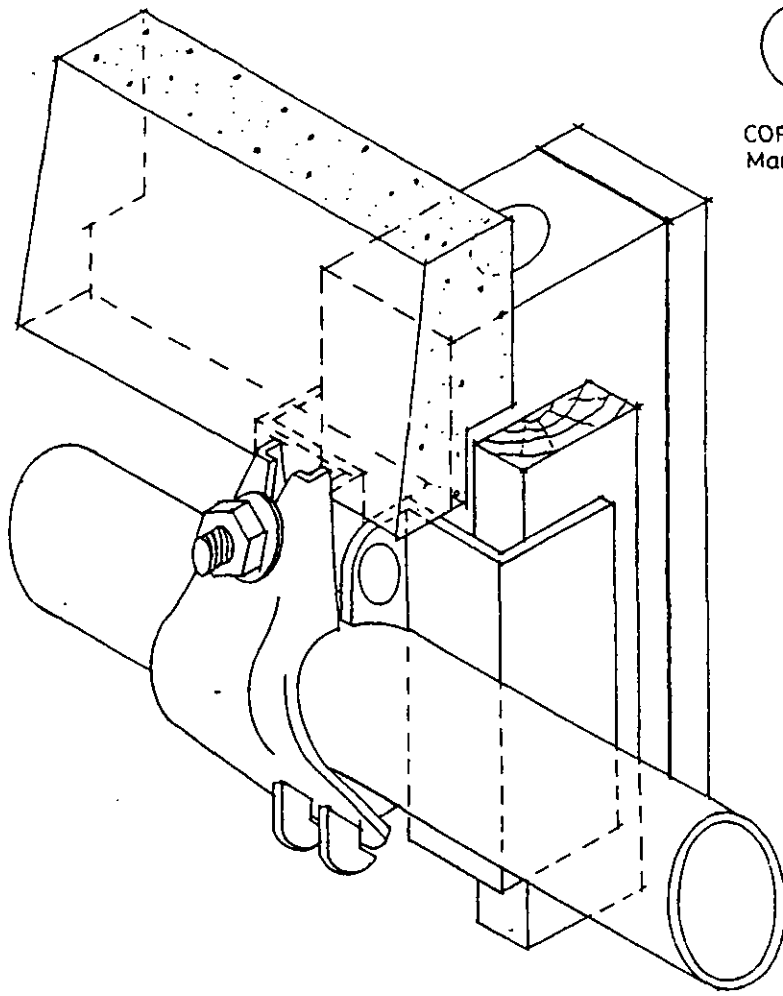
Detail for deep foundations.

SCHEDULE OF WORK.

1. Remove concrete panels on face of structural r.c.posts.
2. Excavate for extended foundations in 1·5m. stages allowing for workspace and shuttering. Form foundations in 1·3·6 concrete to dimensions as shown. Stages connected with 3no. 20mm.bars 300 long
3. Build up external skin in conc. brickwork to footpath level Include 4no. galv. strip ties per metre.
4. Fill cavity below ground level with lean concrete. Lay d.p.c. to both walls at floor level.
5. Construct wall above floor level with special blocks and facing bricks in 1·1·6 mortar. Blocks are handed each alternate course and dimensioned as shown.
6. Re-lay conc. paving slabs on consolidated hardcore
7. For existing and new deep trench filled foundations minimum thickness and width of dimensions must be maintained. (shown dotted.)

AIREY HOUSES

Sheet No. 3

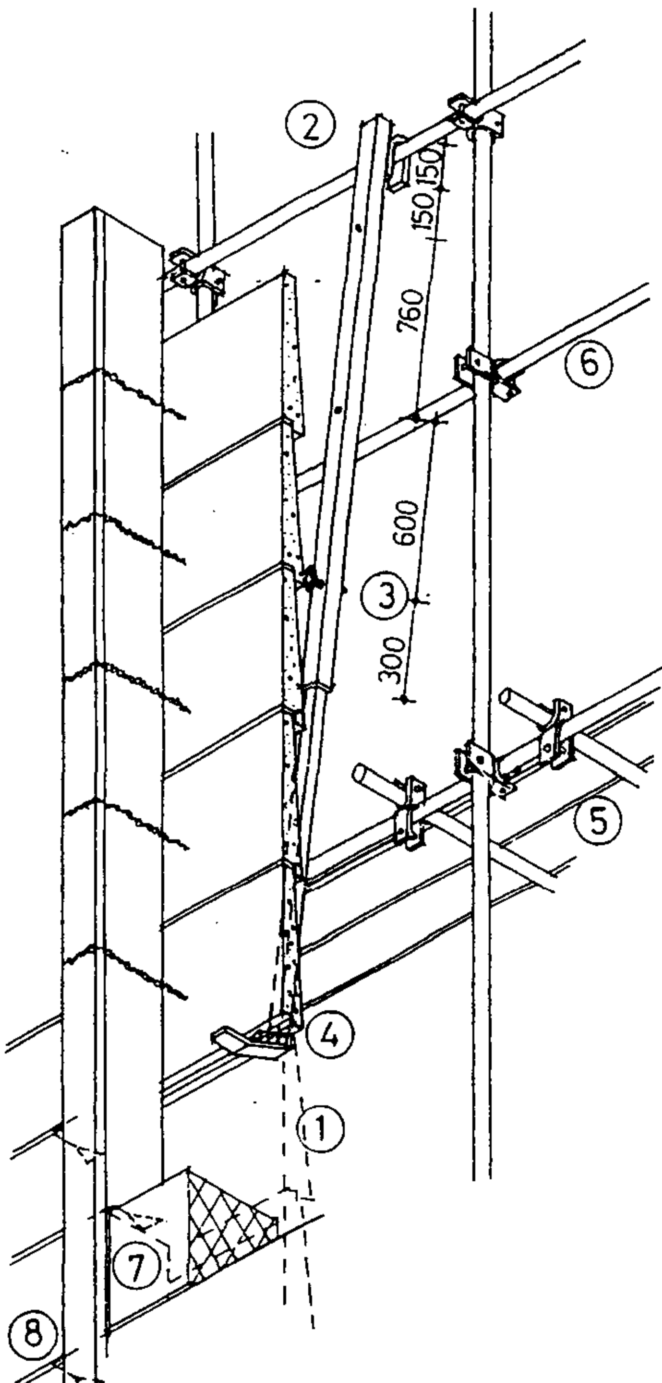


Remove existing conc. panels as required to proceed with brick and block wall construction Panels are removed by cutting copper tie wires from below.
Remaining panels above must be retained by using 'Boulton' joist coupler. Pack conc. post to receive clamp teeth and secure coupling with ears supporting panel. Insert scaffold tube to enable coupling nut to be tightened and jaws to clasp timber packing to conc. post.

Method of suspending concrete panels.

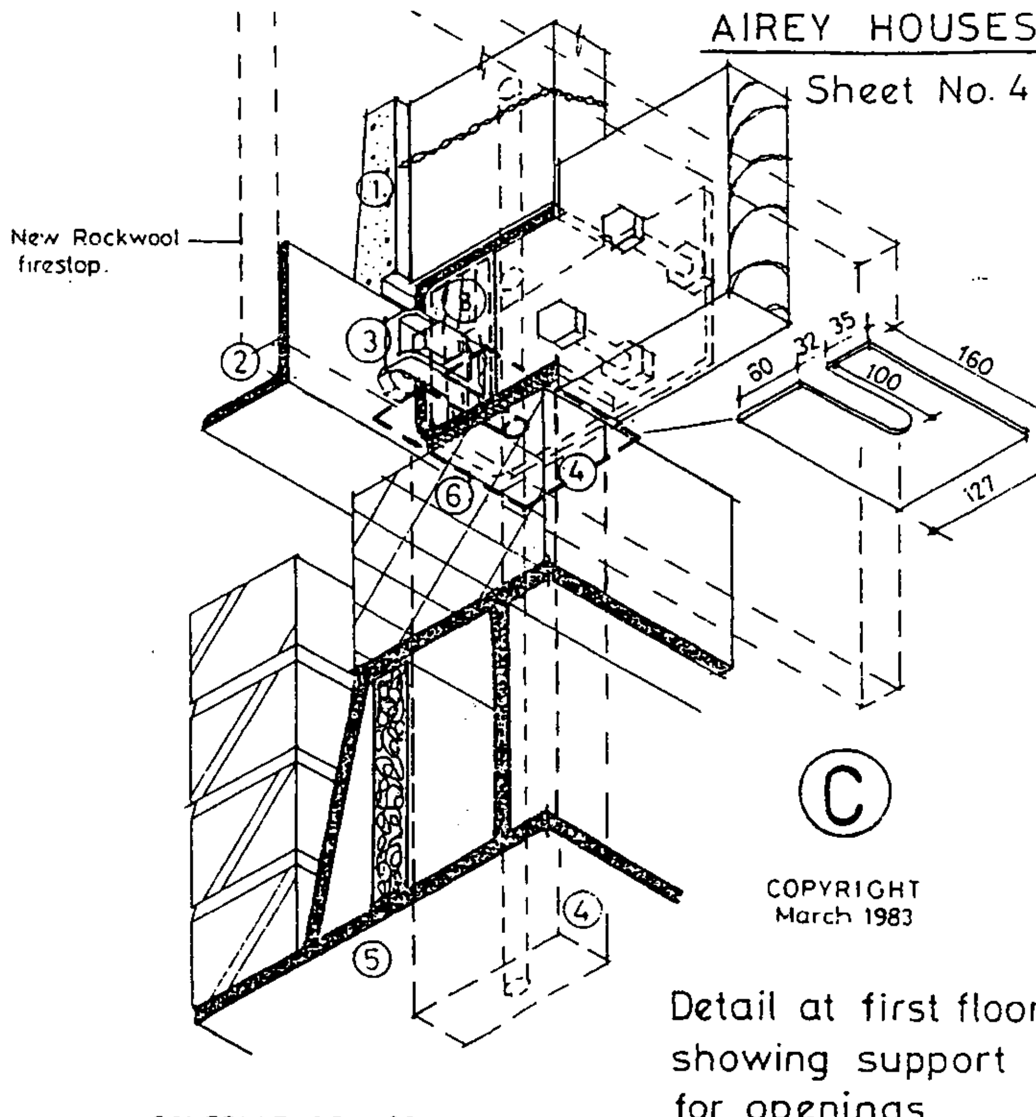
AIREY HOUSES

Sheet No. 3.a.



1. Remove concrete panels as necessary to excavate for foundations and building of block wall.
2. Hangers suspended from scaffold transome between windows and doors. Transome can be moved up or down to suit length of hanger.
3. Holes for pin in three suitable positions to make hanger telescopic Top section 50mm. square,
4. Two wedges pinned under conc. slab to stop movement in hanger.
5. Scaffold platform level
6. Guard rail.
7. New wall in special blocks.
8. Plasterboard laths to be retained by special spiked galv. tie built into blockwork.

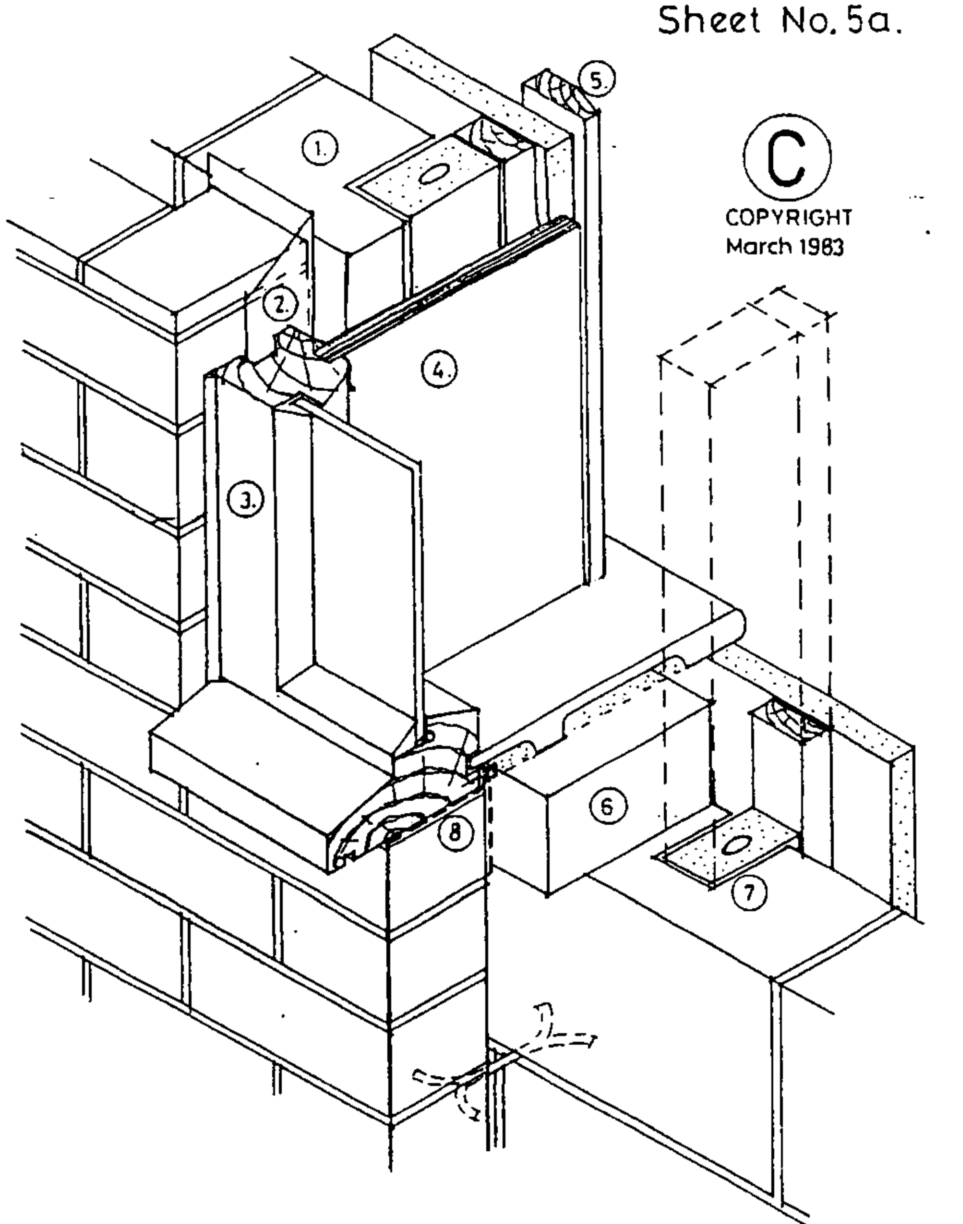
Method of suspending concrete panels.
(alternative method where column in poor condition.



SCHEDULE OF WORK

1. Remove concrete panels on face of structural r.c. posts.
2. Build up block wall 300mm. wide of each window reveal for support to 100 x 75 mm. mild steel angle behind joist shoe.
3. Drill m.s. angle to secure 'Lindapter' bolt to joist shoe.
4. Cut existing conc. posts (mullions) below joist shoe.
5. Build up window reveals in brick and block to position 'Catnic' lintol
6. Cut and lay concrete blocks on 'Catnic' and under joist shoe.
7. Cut and remove asbestos fire stop between conc. posts. Wedge in special bearing plate under joist shoe forcing out remainder of asbestos sheet and enabling 'Catnic' to take the floor load.
8. Remove 'Lindapter' bolts and m.s. angle and continue walling special blocks and facing bricks after inserting h/wood filler piece 50 x 25 x approx. 112 mm. grain lengways on

AIREY HOUSES
Sheet No. 5a.

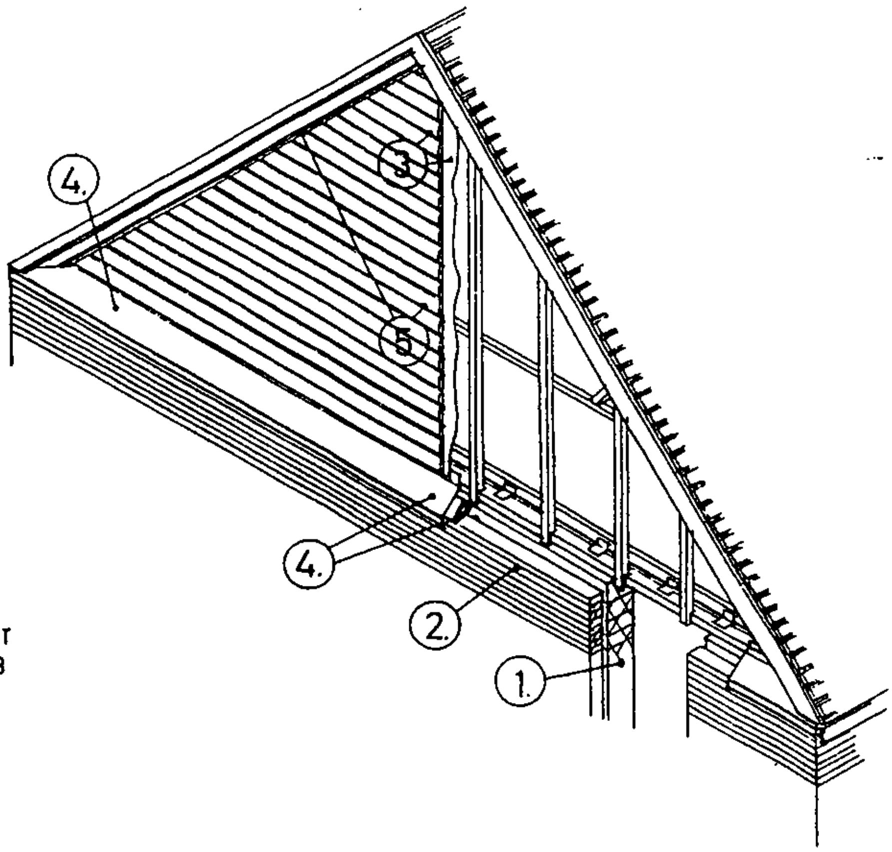


Window detail – timber cill

1. Special block for finishing reveal detail round conc post.
2. D.p.c. at window reveal and returned between brick and block
3. Standard window with timber cill.
4. 6·5mm. plywood lining ploughed into window frame.
5. 75 x 19 s/w splayed architrave. 6. 75 block on face to seal cavity (cut as reqd.)
7. Cut conc. posts approx. 100mm. below cill.
8. D.p.c. under cill and between brick and block tacked to timber cill.

AIREY HOUSES

Sheet No. 6.



SCHEDULE OF WORK

1. Build up internal skin of cavity wall with 175 mm. thick special blocks up to and packed under wall plate.

2. Build up external skin of brickwork in 1:1:6 mortar and include 4 no. wall ties per metre.

3. Remove existing weatherboarding and felt. Treat frame with preservative Fix 'Sisalcraft 40' breather paper.

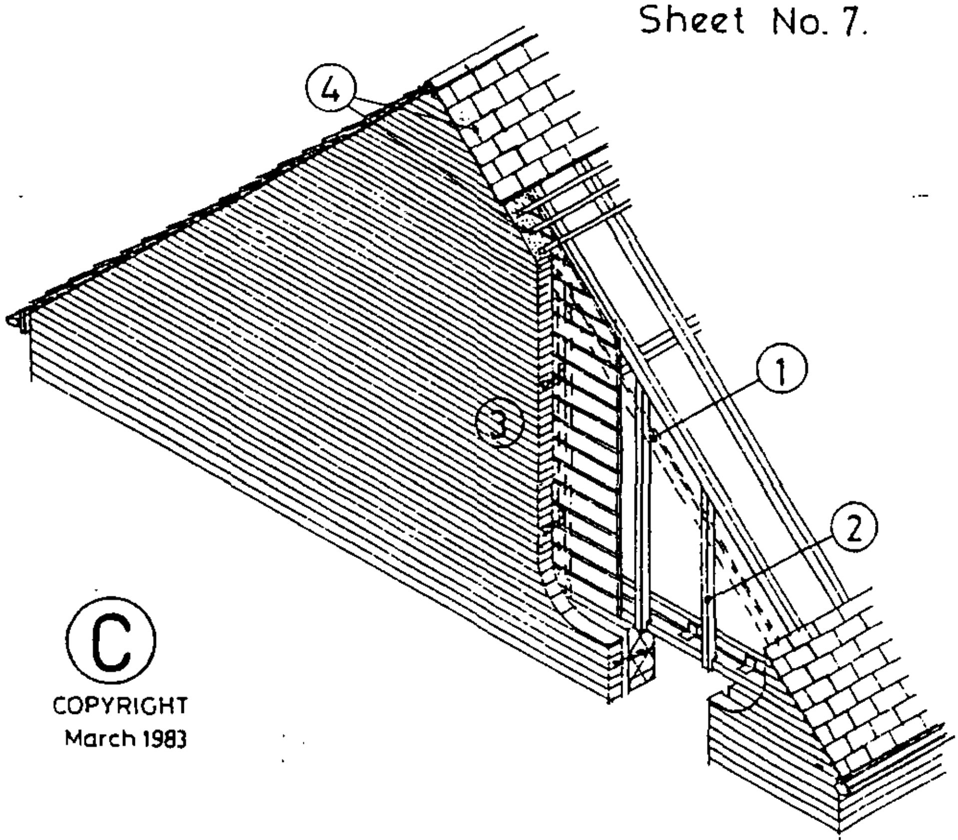
4. Aluminium cill flashing spiked to frame and laid on slate and mortar bed

5. 'Celuform' deep shiplap boarding and universal channel edging fixed to manufacturer's instructions.

Alternative to brick gable.

AIREY HOUSES

Sheet No. 7.



SCHEDULE OF WORK

1. Remove bargeboard, asbestos soffit and soffit bearers.
   Remove verge tiles.

2. Inspect timber frame and weatherboarding and treat with preservative.

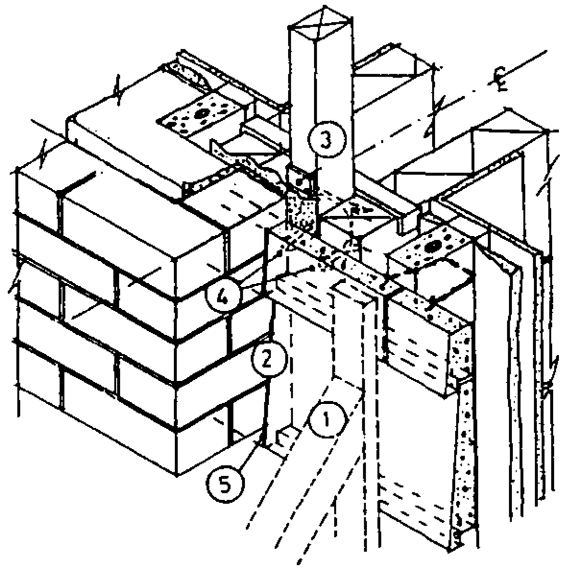
3. Build up external brick skin and cut bricks level with underside of tile laths.
   Include for wall ties screwed to timber frame.

4. Set laths and new tiles on bed of sand and cement mortar. Point up verge tiles along overhang with brickwork. Tile or slate width increases approx. 75mm
   On exposed gables verge tiles or slates should be clipped by non ferrous clips built into brick joints.
   All slates or tiles must match existing.

Brick gable.

AIREY HOUSES

Sheet No. 8

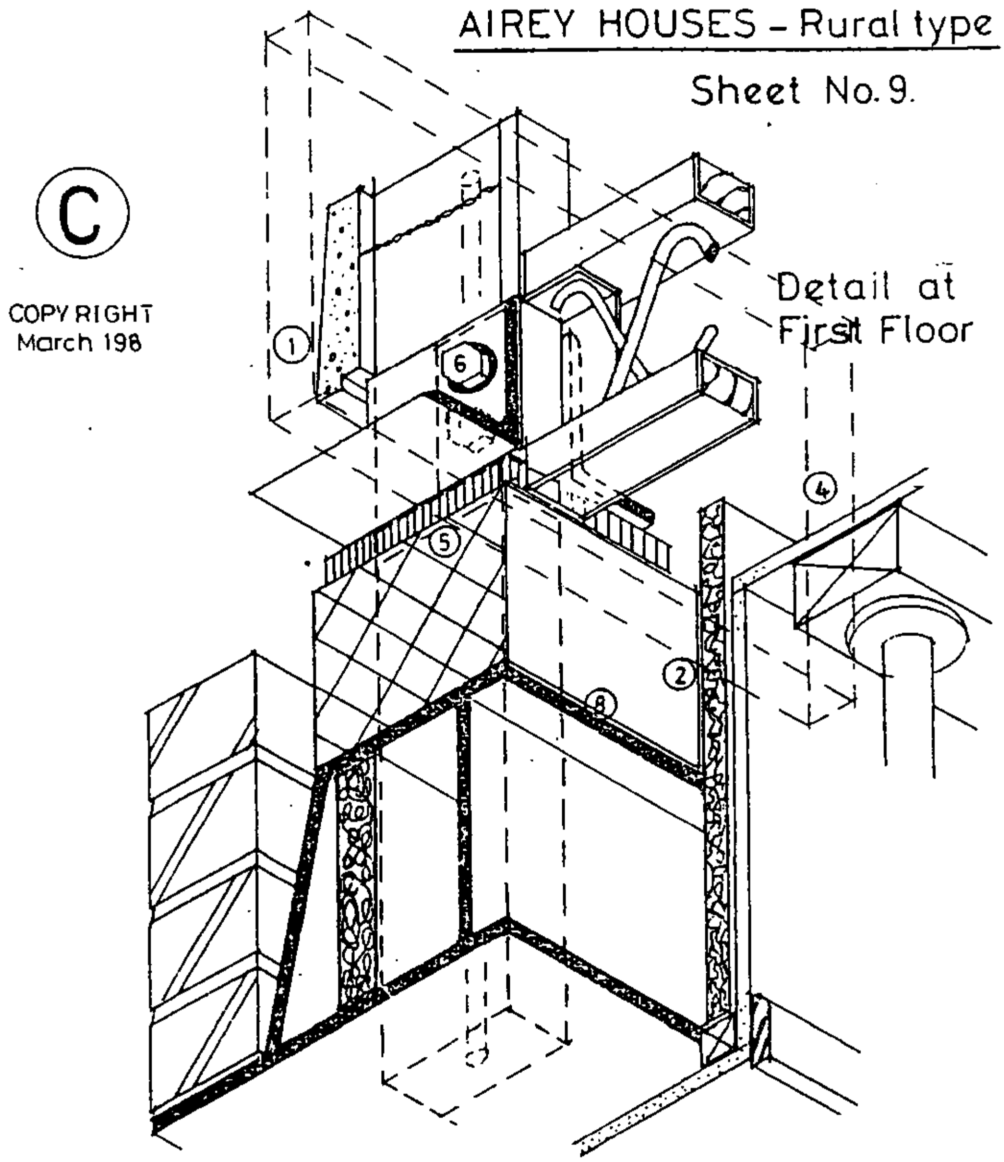


The following work can be carried out only with the permission of the adjacent owners.

1. Support concrete panels on adjacent property by temp.s/wood shores or steel props to retain existing position while cutting.
2. Cut concrete panels down centre line of party wall
3. Insert 75x50 timber bearer behind concrete panels and plug to 75 breeze wall at 750 centres. Bearer to be in one length from ground floor to wall plate Alternatively bearer can be secured to party wall brackets by ties or clips. Include vert. d.p.c.
4. Drill and countersink concrete panel and scew to bearer or plug to breeze wall. Cover recessed screw heads with conc. filler.
5. Fill and point in rubber mastic the joint between conc. panels and bk.w

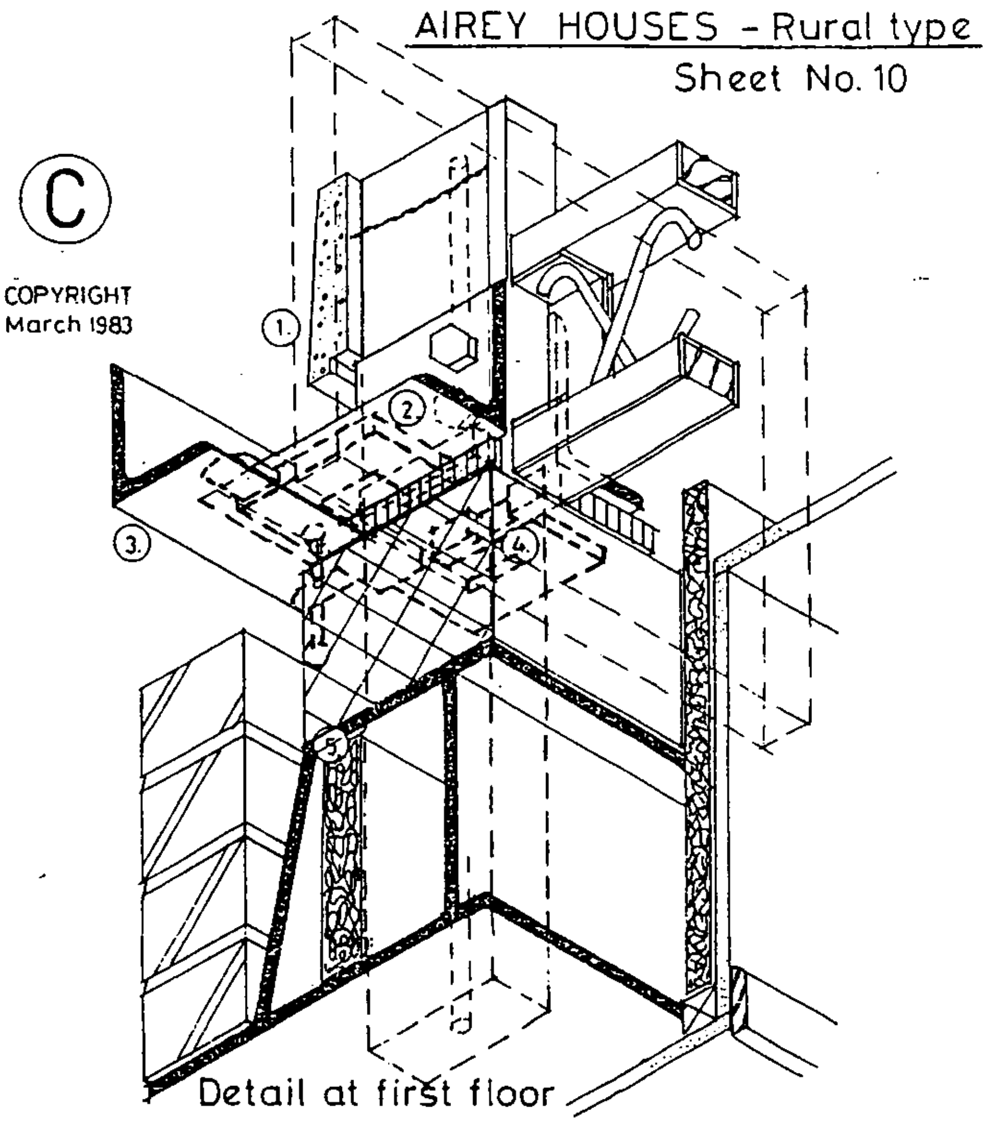
Temp. junction at party wall where new work is omitted to adjacent dwelling.

This detail has not yet been constructed by Leeds City Council
Some minor amendments may be necessary.



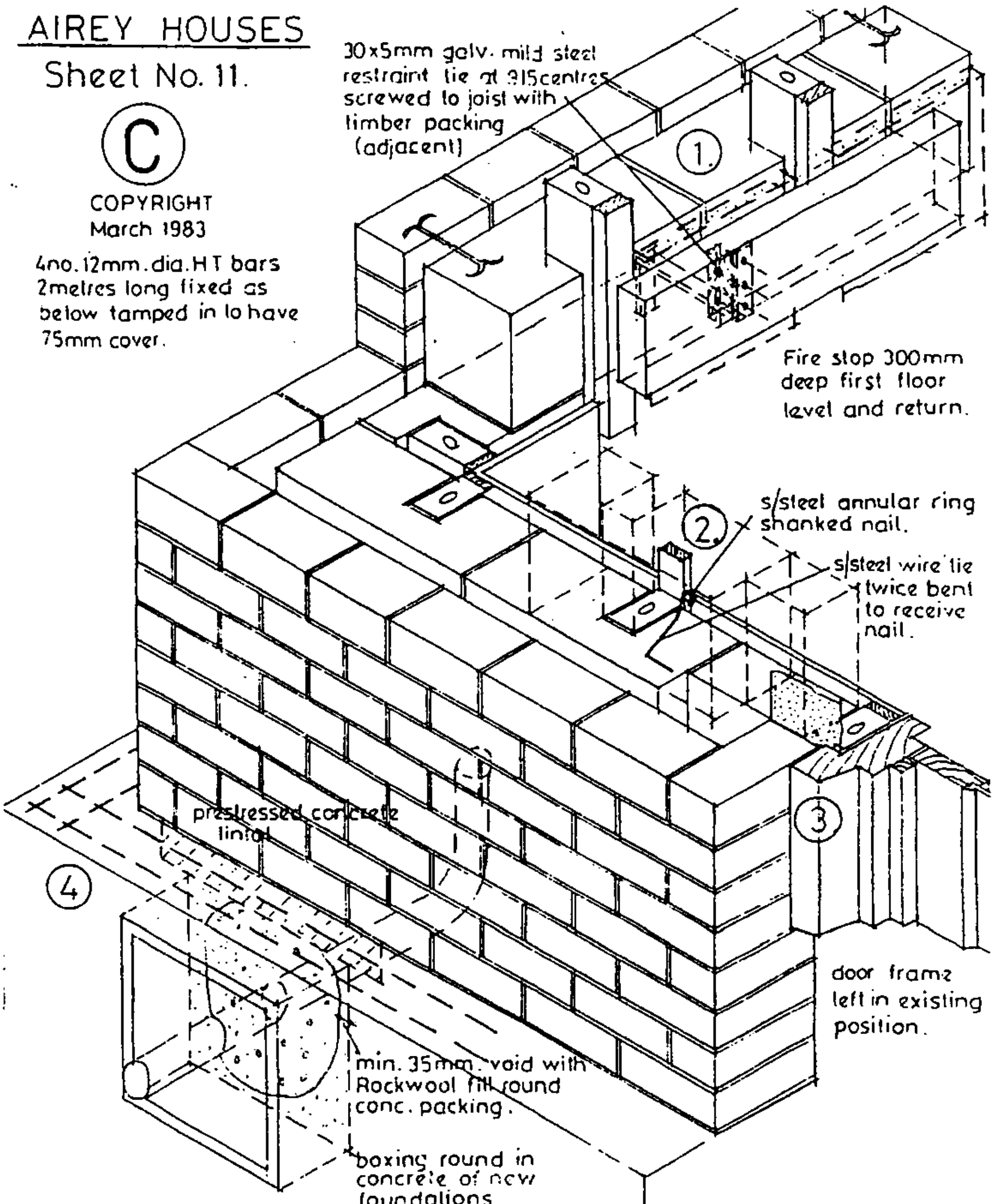
SCHEDULE OF WORK - INTERNAL SUPPORT TO FLOOR

1. Remove existing concrete panels on face of structural r.c.posts
2. Lay 40 mm. Rockwool insulation in cavity between new blocks and ex. plst/bd.
3. Build up brick and block walls at reveals of openings ready to receive 'Catnic'.
4. Prop up tubular steel lattice joists with timber bearers and 'Acrow' props. across window openings.
5. Cut conc. posts(incl. those at reveals of openings) below existing joist shoe.
6. Remove existing nuts and bolts. Fix new angled brackets to each side of post and shoe with 9·5mm.dia. bolts, nuts and washers - all to be galvanised.
7. If conc. posts break up when bolts are tightened, fill with h/w packing pieces in shoe. Bracket size is 125 x 75 x 8 x 165 long m/steel
8. Set 'Catnic' in position, build up conc. blocks and insert non ferrous packing under brackets only (not under conc. posts.) Insert 60 mm. 'Rockwool'.



SCHEDULE OF WORK – EXTERNAL SUPPORT TO FLOOR

1. Remove ex. conc. panels on face of structural r.c. posts.
2. Fix 'Carver' cramp to r.c. posts immediately under joist shoe for support. Remove nuts and bolts of joist shoe and fix new angled bracket size 125 x 75 x 8 mms x 165 long at each side of shoe with new 9·5 dia. bolts, nuts and washers - all to be galvanised. Remove cramp. If conc. posts break up when bolts are tightened, fix hardwood packing piece in shoe.
3. Build up brick and block walls at reveals of openings for support of temporary angle which will hold new brackets and floor structure in position. Insulate wall between new blockwork and ex. plst./bd with 40 mm Rockwool.
4. Cut conc. posts (incl. those at reveals of openings) below ex. joist shoe.
5. Set 'Catnic' in position with 60 mm 'Rockwool' strip. Build up conc. blocks and insert non-ferrous packing behind temp. angle under brackets (not under conc. posts.) Take out temp. angle and pack under remainder of bracket.

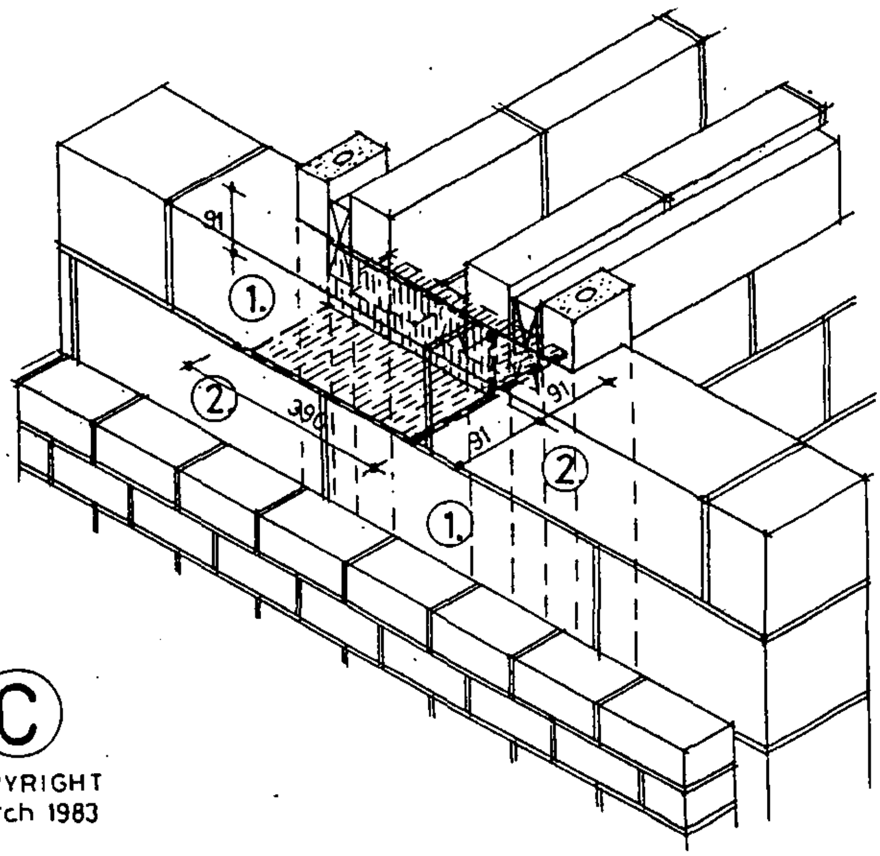


Details showing –

1. Lateral restraint to first floor level & eave
2. Restraint of timber fillet in case of furthe column deterioration.
3. Door reveal.
4. Service pipe entry on corner.

AIREY HOUSES

Sheet No. 12.



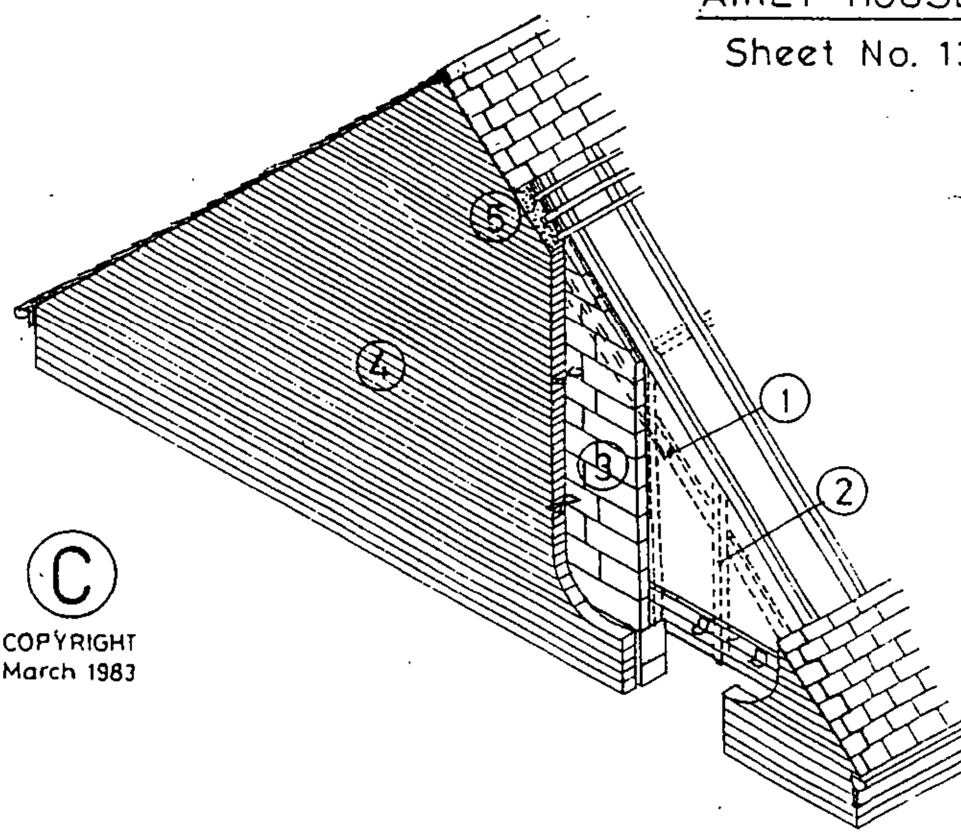
Build up conc. block internal skin to finish level with bottom of floor beams including special blocks to face of party wall.
1. 90mm reveal block 2. Special lightweight block 440mm. long with nib removed.

Cut into conc. blocks of party wall and insert Catnic T section into blocks and under floor beams. Continue wall in blockwork with special blocks at party wall junction. Ensure horizontal flanges are fully bedded in mortar in both new and existing party wall blockwork.

Detail of party wall junction at first floor level.

AIREY HOUSES

Sheet No. 13

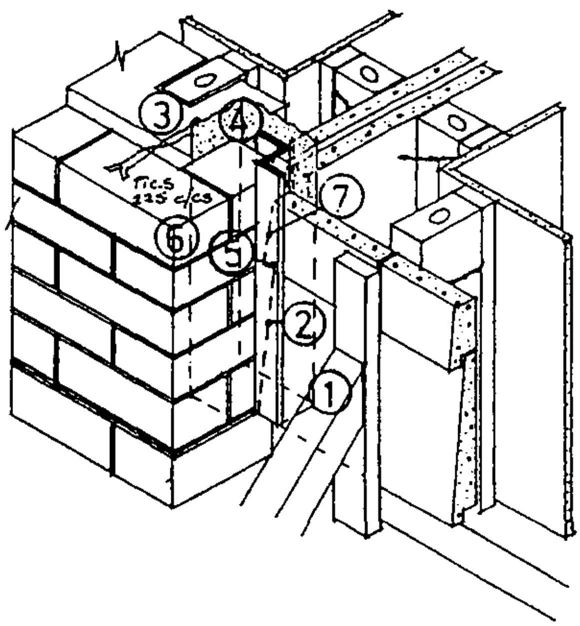


SCHEDULE OF WORK

1. Remove bargeboard, asbestos soffit and soffit bearers. Remove verge tiles.
2. Prop up roof from wall plate. Retain wall plate and ceiling joist, but remove boarding and framework to gable.
3. Build up 100 mm. thick conc. block wall in gable to continue vertically from outside face of 175 block wall at ceiling level. Cut blocks at existing roof joist level to receive mortar . Build in ends of purlins and include st. steel straps to purlins and wall plate.
4. Continue 100 thick brick wall to gable and cut bricks at verge to receive bed of mortar for tiles and laths. Include standard wall ties to cavity wall.
5. Set laths and new slates or tiles on bed of sand and cement mortar. Point up verge along overhang with brickwork. Tile or slate width on roof increases by approx. 75 mm. On exposed gables, verge tiles or slates should be clipped by non-ferrous clips built into brick joints. All slates or tiles to match existing.

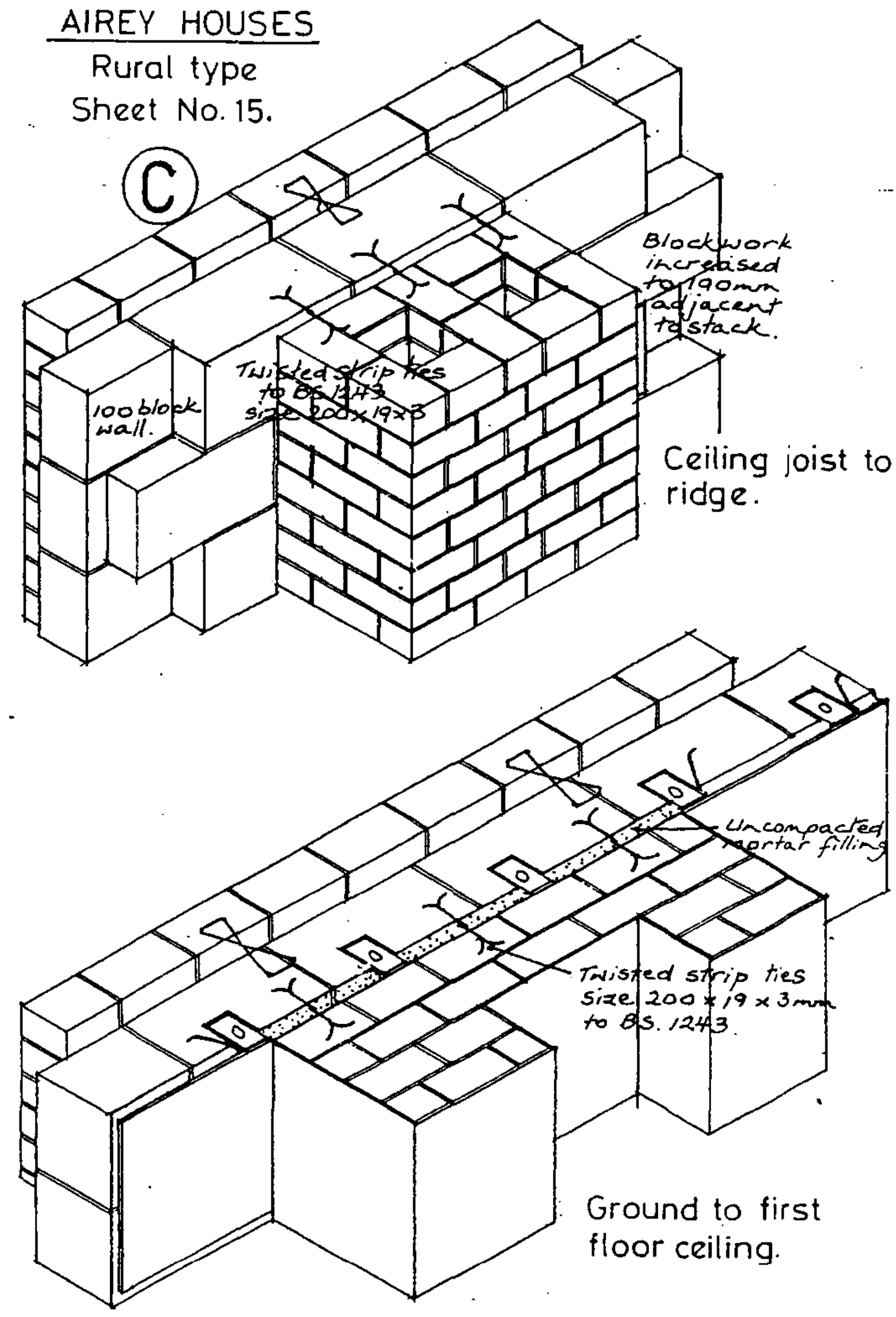
Brick and block gable.

AIREY HOUSES
Rural type
Sheet No. 14



1. Support conc. panels on adjacent property by temp. s/w shores or steel props. to retain existing position while cutting.
2. Cut concrete panels down centre line of party wall.
3. Build up internal skin with special blocks and cut end blocks to form vertical joint
4. Insert pvc. damp proof course across end of internal conc. panels and turn out at base
5. Place in position aluminium 'Z' section against conc. panel
6. Build up external skin of brickwork with return end and wedge in dpc and alum. 'Z' section.
7. Fill joint in rubber mastic between 'Z' sect. and cut conc. panels.

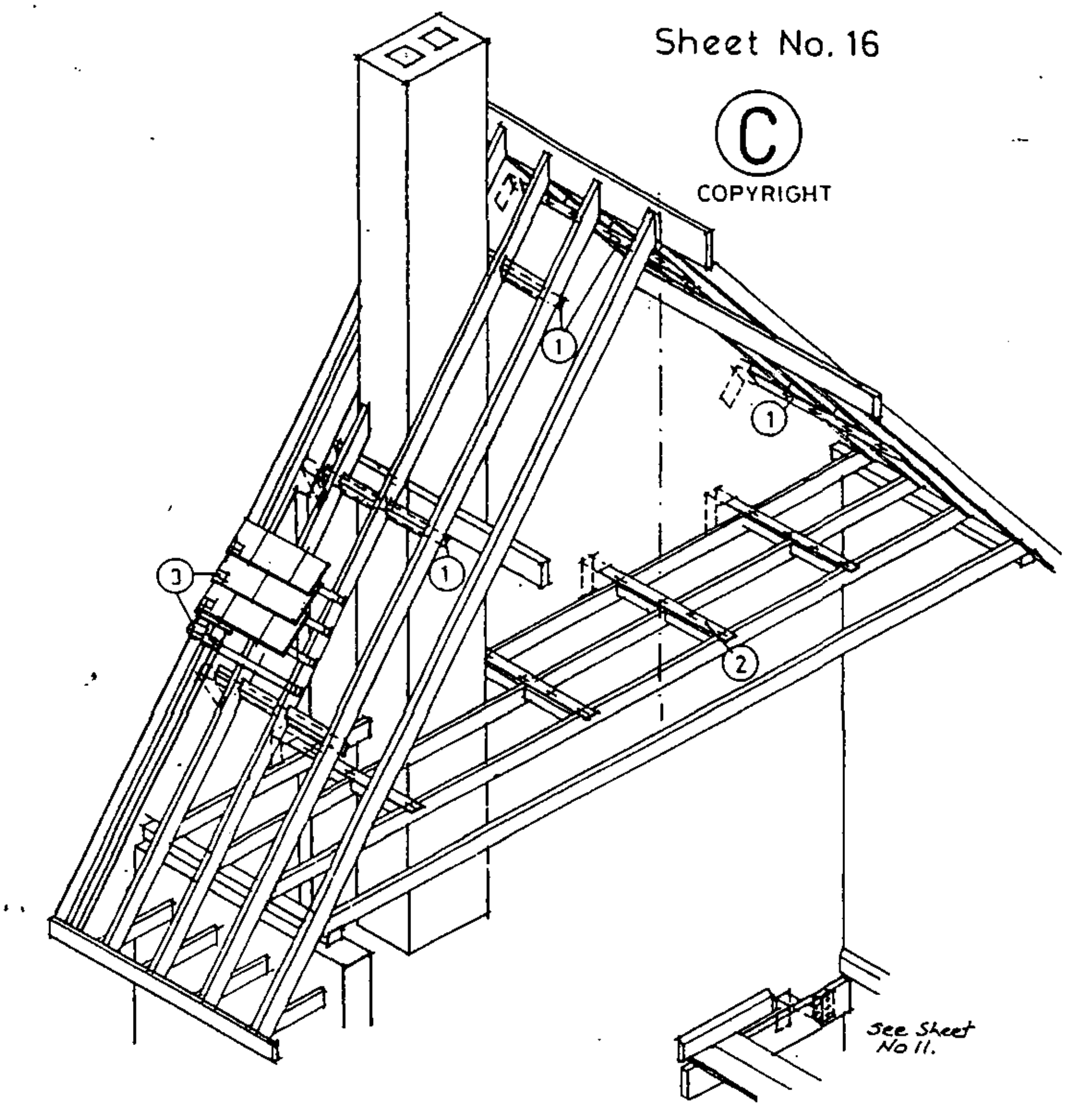
Permanent junction at party wall where new work is omitted to adjacent dwelling



Tie in brick chimney stack to brick and block gable .

AIREY HOUSES

Sheet No. 16



Galvanised mild steel restraint straps.

(1.) 6 no. to underside of rafters.

(2.) 4.no. over ceiling joists

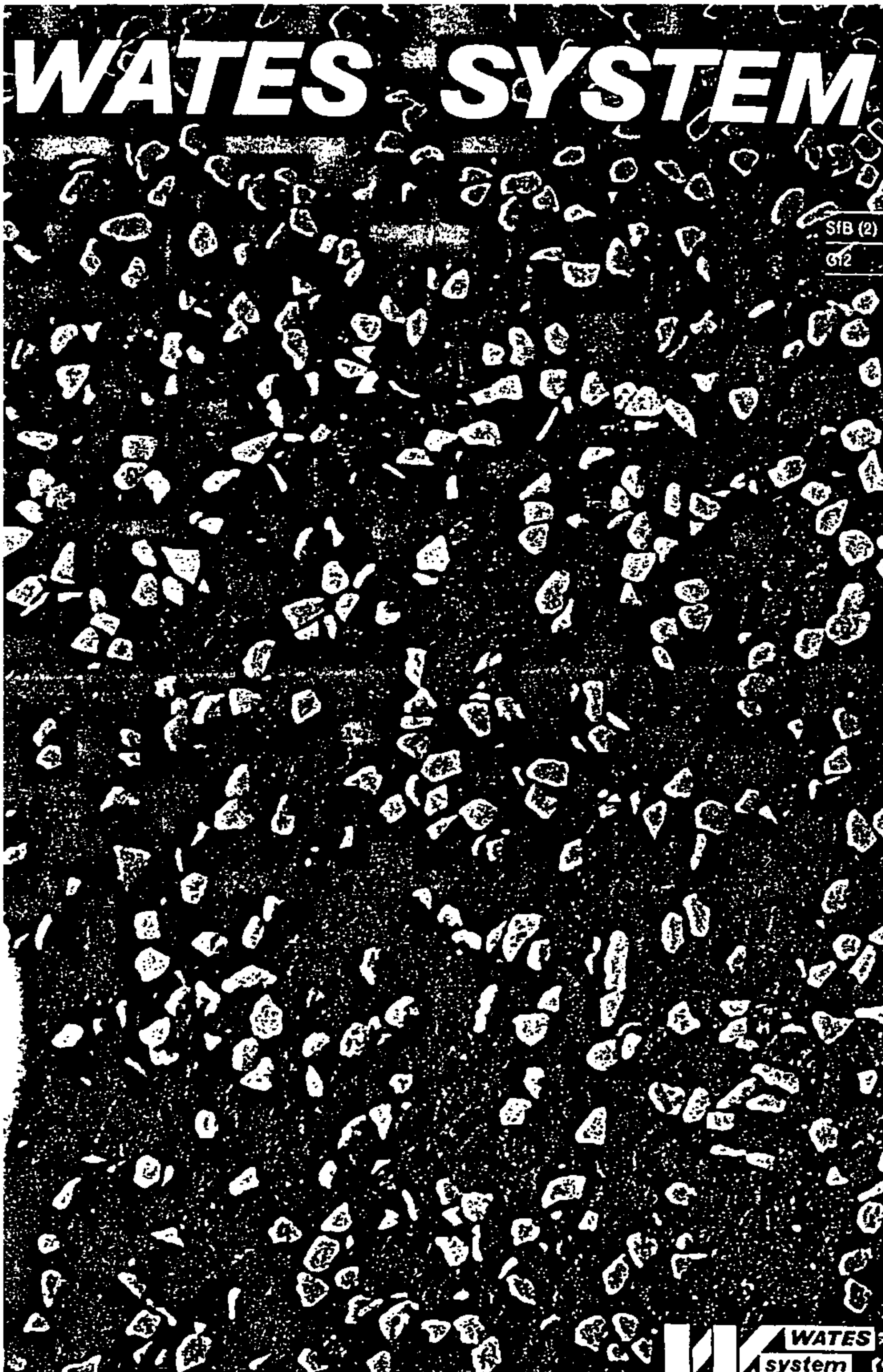
(3.) S/steel verge clips fixed to battens.

(4) 30 x 5mm galv. ms. restraint strap at 1m.centres screwed to packing and joist with 3 no. 40mm x 12 gauge bright zinc plated r.heads.

Each strap to have 50 x 50 treated noggins and both to be fixed with 5 no. galv. screws. 12 x 50mm zinc plated round head.

850 or 1300 exposed
150
30x5mm thick

Gable stability


WATES SYSTEM
SfB (2)
Gf2
WATES
system

Introduction

During the war years our company built hundreds of vessels for the Admiralty in reinforced concrete. These ranged from barges to a 1,000-ton floating dock and all the floating sections of the famous Mulberry Harbour. This was the beginning of the Wates System.

After the war the experience gained in this specialised concrete technique was applied to housing and some 40,000 two- and three-storey houses were built in this country and abroad.

In those days the precast units were produced in factories and transported to the site. With the appearance of the tower crane, the use of which we pioneered in this country, we began the rationalising of multi-storey buildings. At first our factories produced precast cladding units and certain other high quality units. But while we applied our precasting experience more widely to the construction of tall buildings, we were also becoming more and more impressed by the costs and hazards of transporting finished units from factory to site.

We began research into the possibilities of introducing factory techniques and quality control to the sites themselves. We thought that if we could achieve the smoothness and efficiency, the consistent quality of finish and the production rate of our existing factories, we should gain valuable advantages. We could eliminate the non-productive costs of transport and multiple handling; we could minimise the possibility of damage to units; we could more easily balance unit supply with the progress of erection.

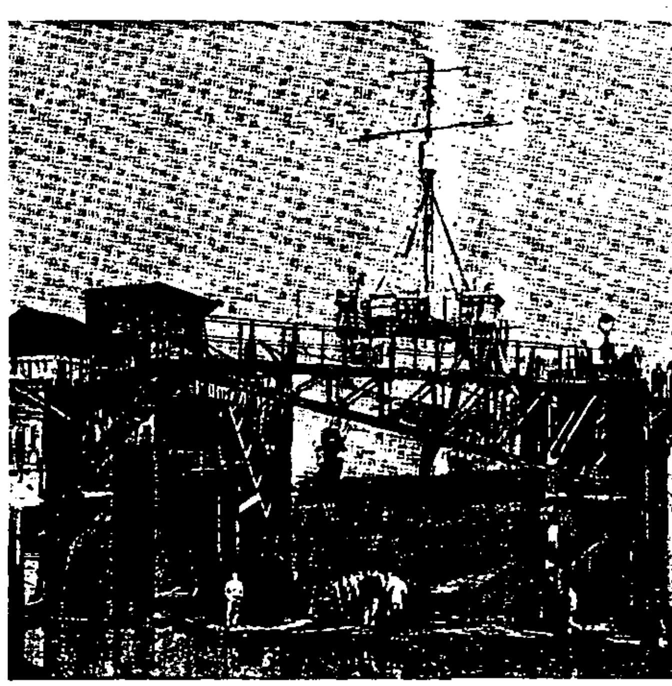
When we succeeded, we found another advantage. The men who produce the units are there with the men who erect them and the site manager is in complete control. It is remarkable how often this helps to iron out problems with a minimum of delay.

When we were sure of our success we closed the centralised factories and went over completely to on-site precasting in fully equipped, well protected factories scaled to the production rate required for the project, at a cost roughly equivalent to that of transporting units from a factory elsewhere.

During this time the Wates System was developed, expanded and refined. It did not appear overnight. It was a steady growth from our war-time and post-war experience. It *exists*—in literally concrete form and many examples can be seen and studied.

It is a large precast panel technique of interlocking wall and floor elements, covered by British and foreign patents. It is designed for maximum flexibility; it offers a great variety of finishes. It has disciplines, of course. But they give an architect room to breathe, as several eminent firms of architects already designing in our system would acknowledge.

Although it was originally designed for the production of high and low rise blocks of flats, it is capable of application over a much wider field and embraces hospitals, offices and factories.



The 1,000 ton precast concrete floating dock during lifting trials in May, 1944

1

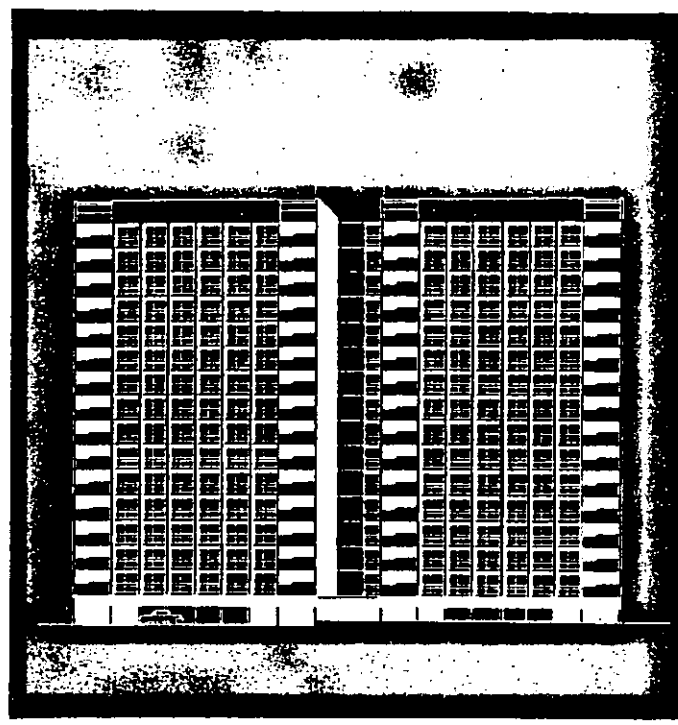
Design

The Wates System offers the designer a rationalised and economic approach to construction and assembly; it uses the very latest plant, methods, planning and techniques, backed by an organisation enthusiastic and experienced in all facets of industrialised building. It is economically viable at 250 units for high rise and 300 units for low-rise developments.

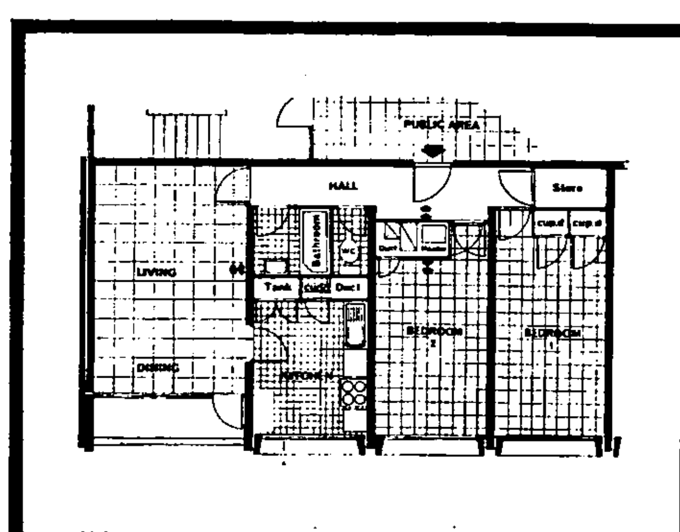
The system is suited for the construction of both multi-storey slab and point blocks, and low-rise blocks utilising the same components. We have standard plans covering a wide range of accommodation. However, we prefer to develop plans jointly with the architect to suit his particular requirements, working within the simple disciplines of the system.

Consulting engineers to the Wates System are Ove Arup and Partners. The Wates System is being used for both low rise and high-rise blocks of flats of 21 storeys and even higher.

Elevation of a 16-storey block of flats in High Street, Brighton



Floor plan of one of the two-bedroom flats in the Brighton block

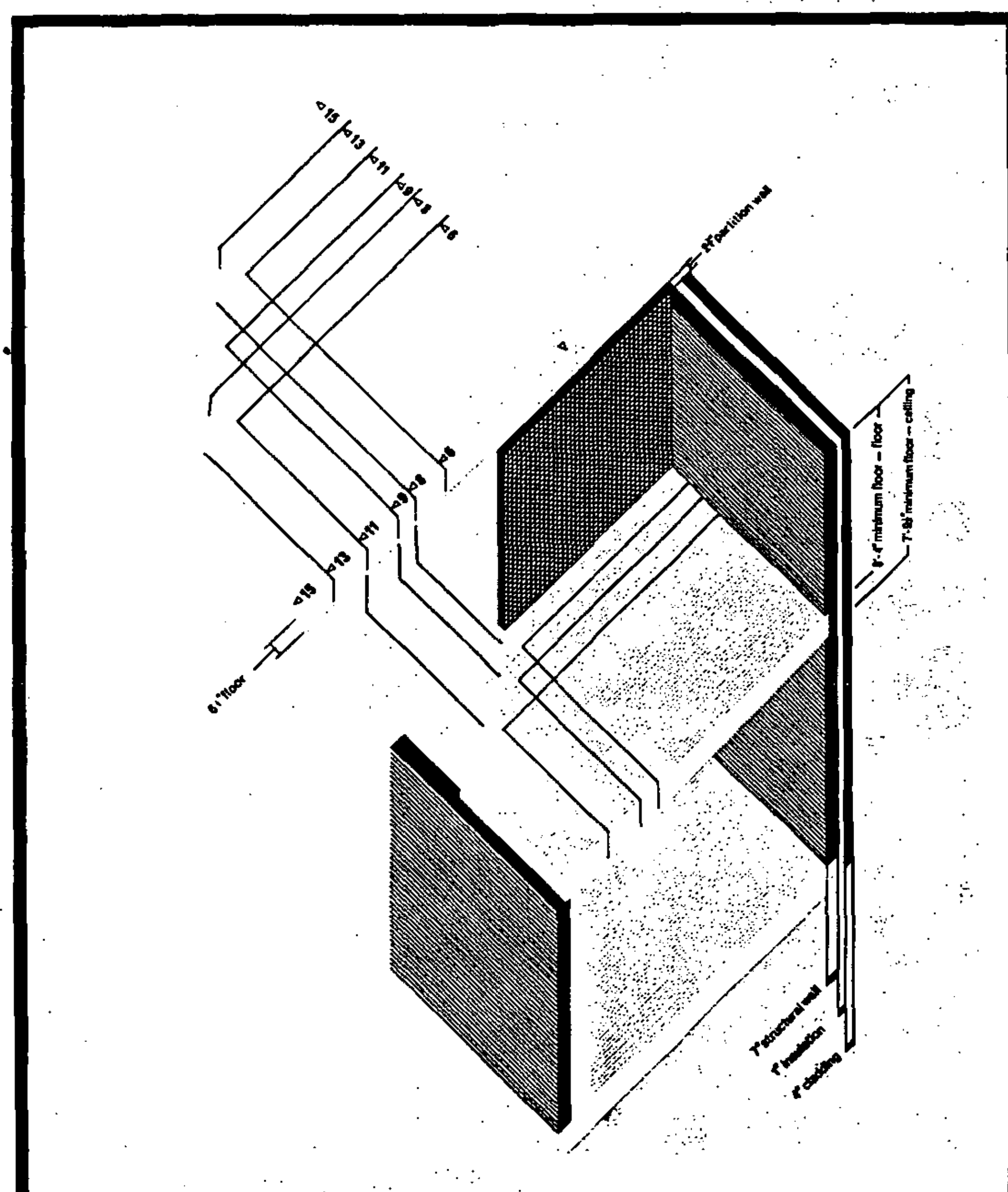


The disciplines are primarily dimensional. Our precast elements—floors, walls, staircases, refuse chutes—are cast in standard steel moulds based on the 12in. grid recommended by the Ministry of Housing Design Bulletin No. 8. Skill in design is reflected in the reduction of component types and in designing the building so as to utilise to the full the optimum capacity of the lifting equipment.

We welcome enquiries from forward thinking architects who accept the challenge of system building and who believe that therein lies the solution to the problem of bringing building up to the standards set by modern industry.

We like to start with the architect's basic conception of planning, inside and outside—a sketch scheme in fact. This is the stage at which industrialisation should begin. We can then rationalise spans and explore every aspect of construction and its consequences upon the specification, finishings and cost.

Primary vertical and horizontal dimensions of the Wates System



8

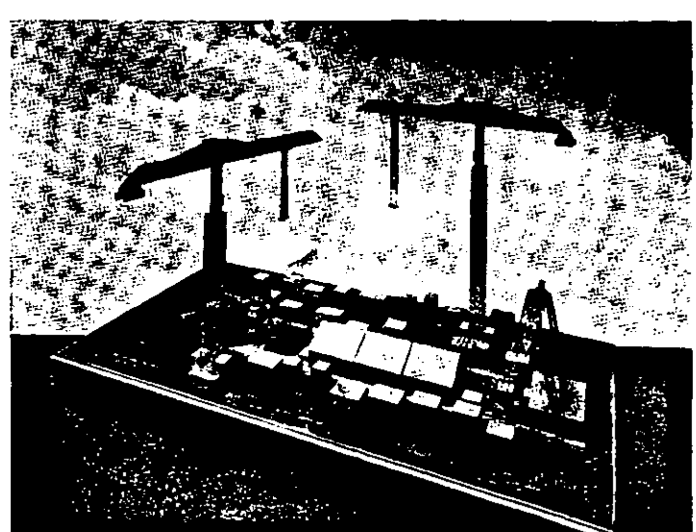
Construction

1 Foundations and substructure
These obviously vary from site to site. *In situ* construction is almost always used although we have sometimes included precast components in the substructure. During this phase of the operation, we set up our precast factory and plan the coordination of production with the erection programme of the superstructure.

2 Site factory
The location and layout of the site factory is one of the earliest decisions to be made in the pre-contract stages. The area in which we manufacture our precast components is the nucleus of the job. The factory we set up is controlled and operated by a factory manager and staffed by a mobile team of skilled operatives. Its location will vary according to the site, but we always choose a position which reduces handling to a minimum, if possible ensuring direct stacking at erection points. An actual layout illustrating this is shown (p.5).

Vertical battery casting is used for wall units

A model of a typical on-site factory showing the preferred relationship between factory cranes and erection cranes



The standard production lines are 30 ft. wide and are covered with mobile shelters running on rails. Electricity, water and steam supplies are built in, with appropriate outlets alongside the moulds. Vertical battery casting is used for the walls and in some cases for the floor units.

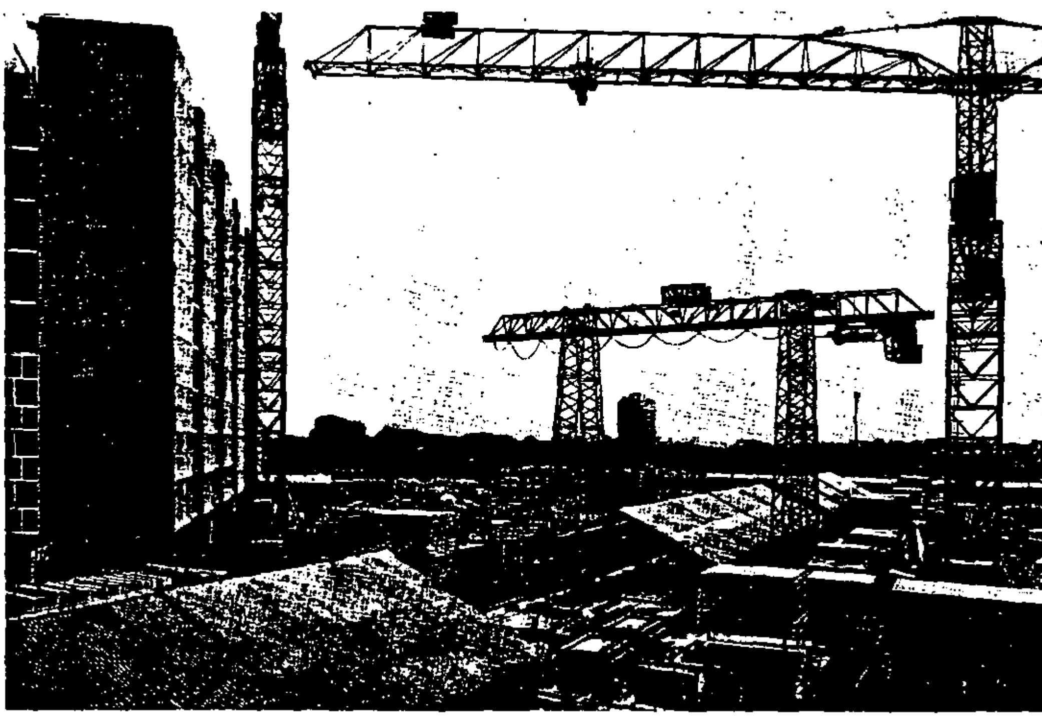
Standard steel moulds are used, designed for assembling and dismantling with the minimum of labour; the sides are adjustable in 12in. increments to give the variations in dimension that the Wates System offers.

All electrical conduits, fixings and inserts are cast in and a high level of precision and finish is maintained.

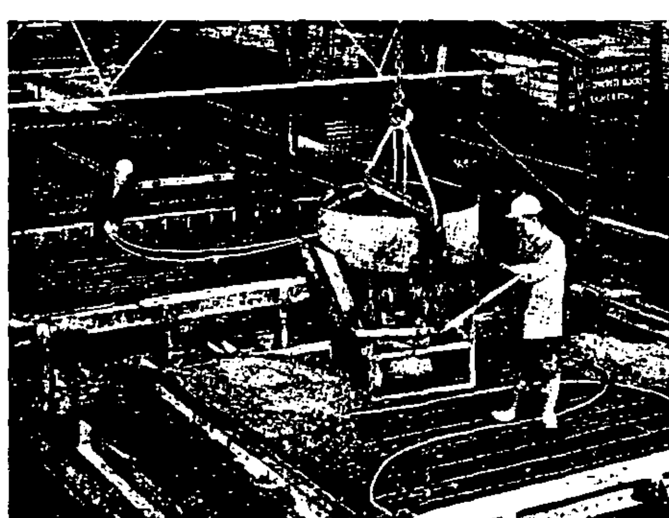
Accelerated curing is used to ensure a 24-hour turn round of the moulds and the units are comparable in every way, especially in quality, to those of any centralised factory.

3 Handling equipment

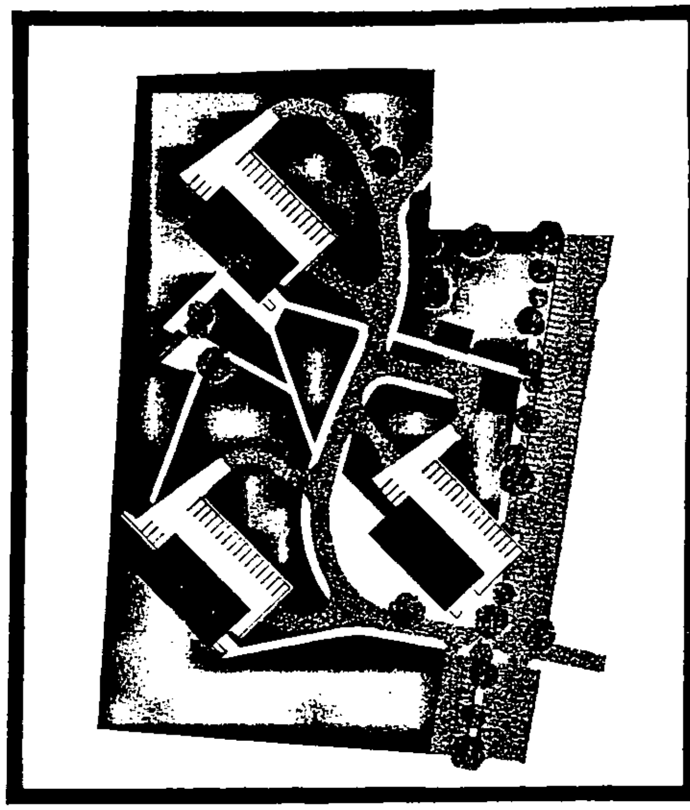
Handling and lifting requirements for the size and weight of the units to be



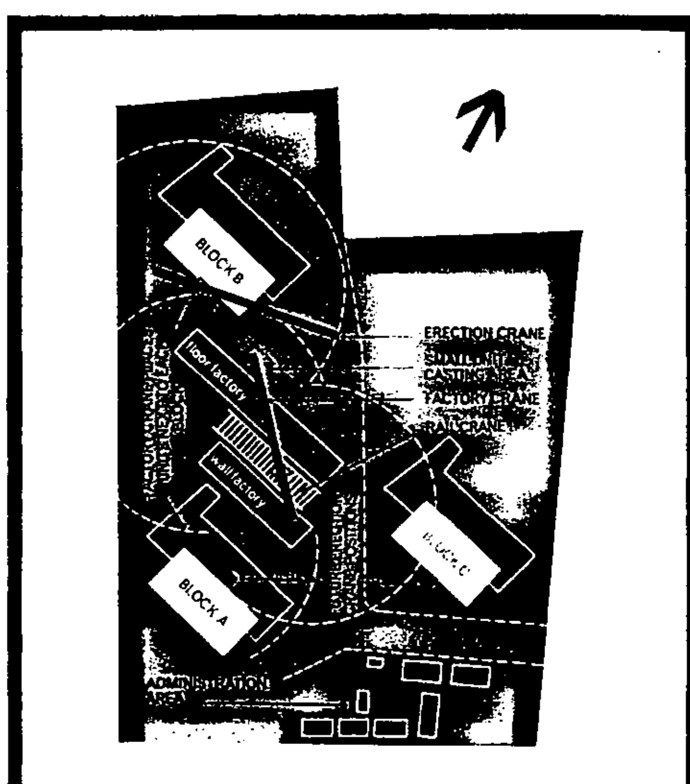
A portal crane and tower crane working in combination on the on-site factory at Feltham



Adjustable steel moulds are used for floor units, shown here with conduits being cast in



Layout of three 21-storey blocks of flats for Leyton Borough Council



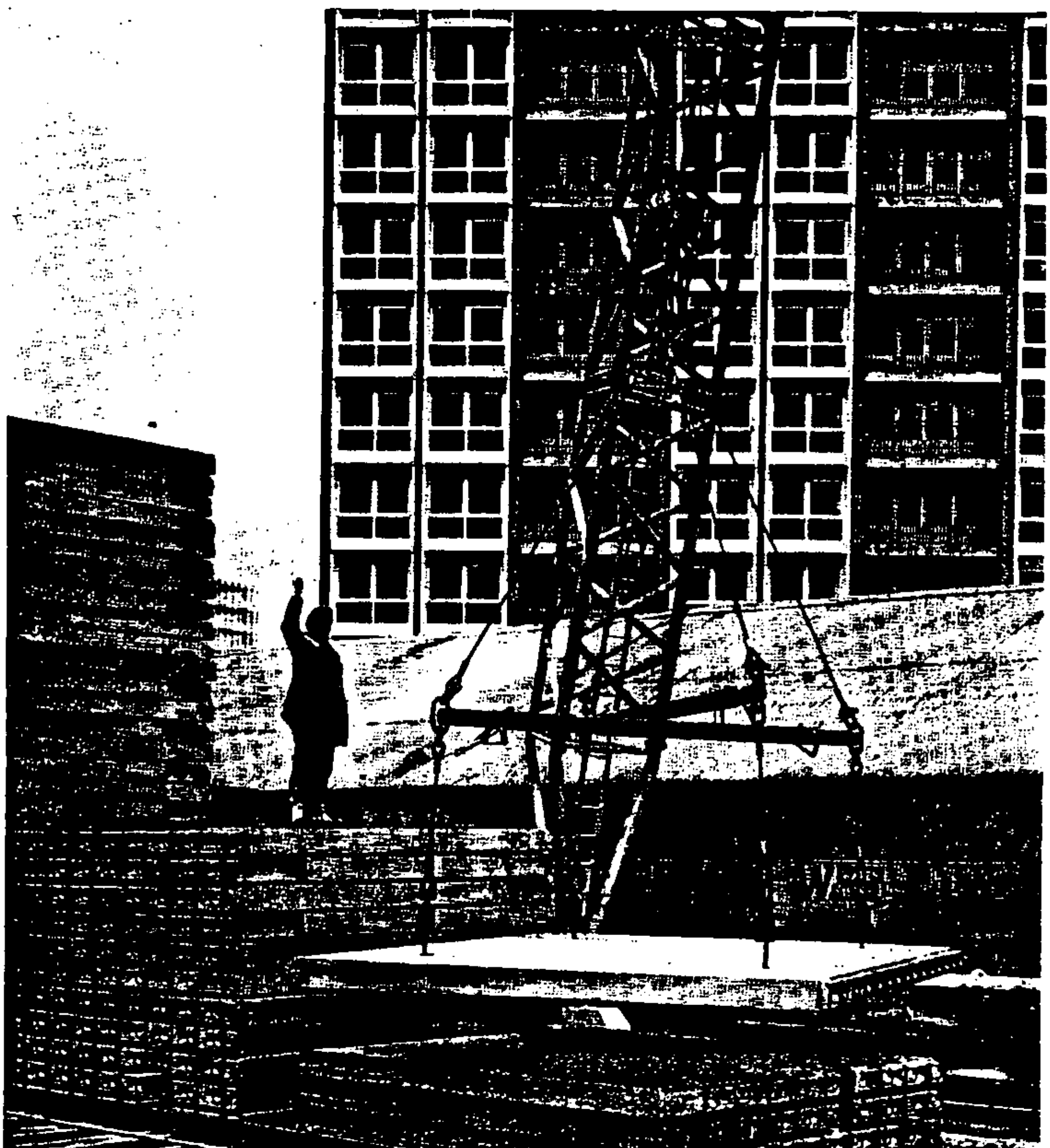
Operational layout for the same site showing the site factory and crane positions produced are carefully assessed. The lifting equipment used in the site factory is generally the same type as used for erection, which allows us a high degree of flexibility and interchangeability with the various types of plant. We were the first to use tower cranes in this country and we have now pioneered the use of portal cranes on building sites, not only in the site factories but also for the erection of low-rise blocks in system.

4 Superstructure
One of the basic principles of our system is to produce the largest possible components within the capacity of the lifting equipment. In this way we combine economy of moulds with optimum weights and keep construction joints to a minimum.

Floors are solid, 6½in. thick, with an insulating floor finish complying with Grade I Insulation Requirements in Code of Practice C.P.3. 1960. All units are smooth finished in the moulds so that no screeding is required.

Structural walls are 7in. thick and smooth finished ready to receive decoration.

Floor units being handled by the portal crane in one of the on-site factories



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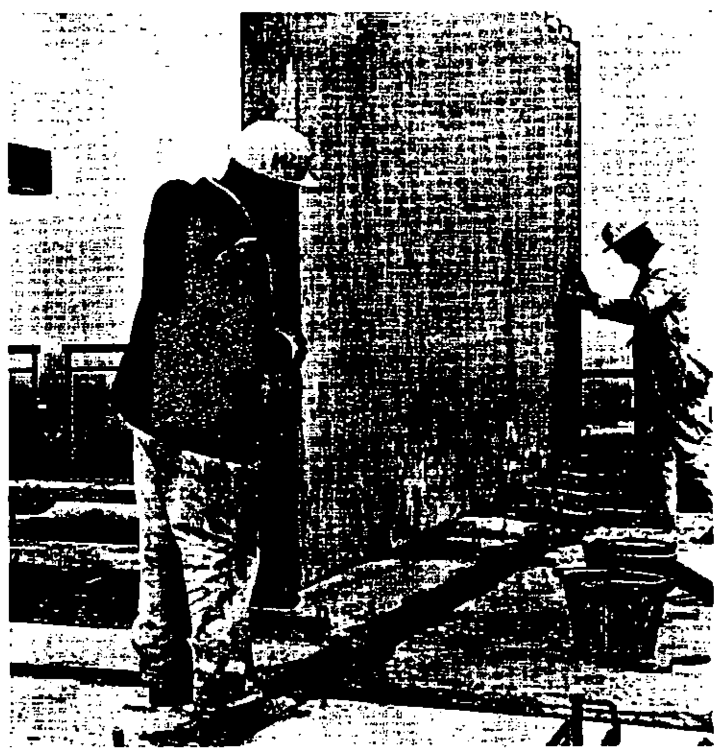
Non-structural partitions are 2¾in. thick dense concrete panels, precast in the factory in precisely the same way as the structural walls. They are not easily damaged and provide a very high level of sound insulation between rooms.

They are placed in position by the tower crane during the erection process and wet work is eliminated, thus reducing the building cycle both in time and man hours. This also means that there is no mixture of different surface finishes within the dwelling.

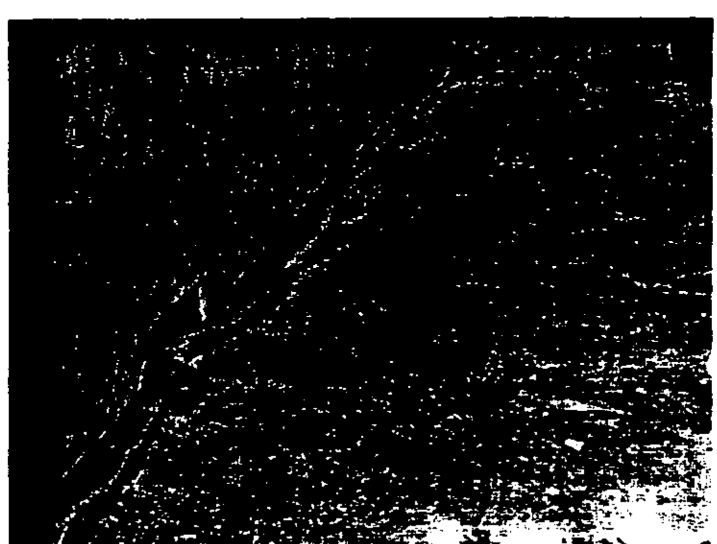
Load-bearing cladding. We use a standard 7in. concrete wall with a 1in. polystyrene sandwich and a 4in. external facing. The external skin is lightly reinforced and tied back through the polystyrene insulation to the internal skin with non-ferrous ties. This provides a "U" value of at least ·20.

Finishes available cover a very wide field. The choice of finish, which is largely dictated by cost, includes many varieties of exposed aggregate, bush hammering, ceramic tile and mosaic, profiled concrete and brickfaced panels.

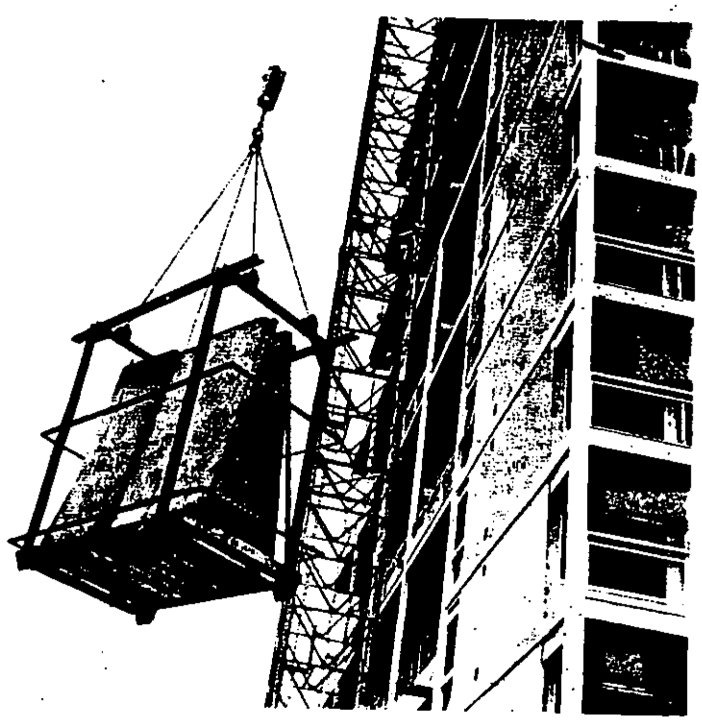
Seven-inch load-bearing crosswall being lowered on to levelling bolts



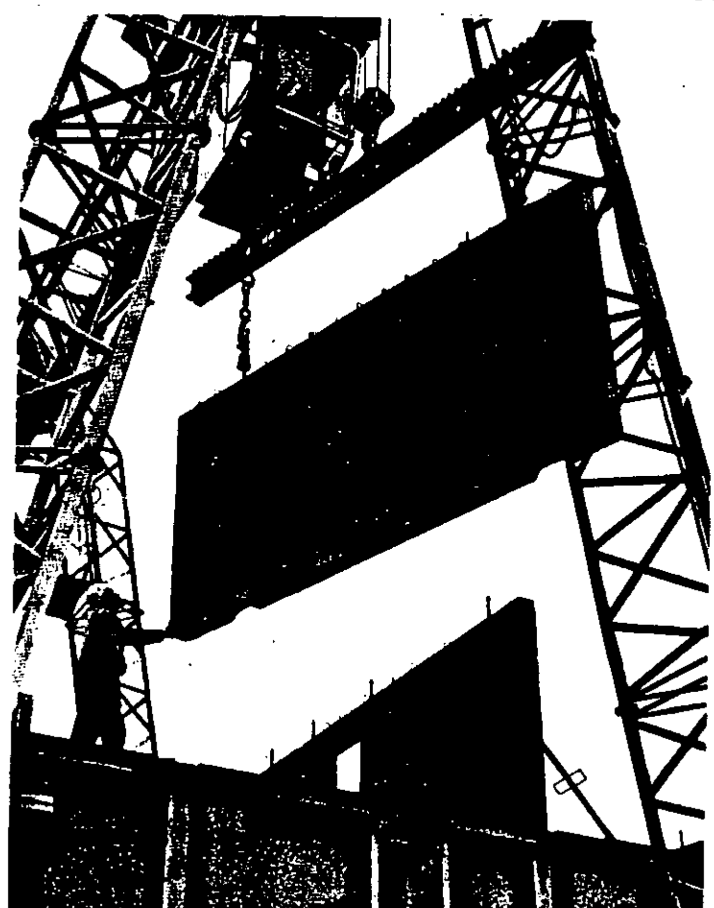
Crosswall lowered into high-grade mortar bed. Squeezed out mortar is trowelled off and no dry packing is necessary



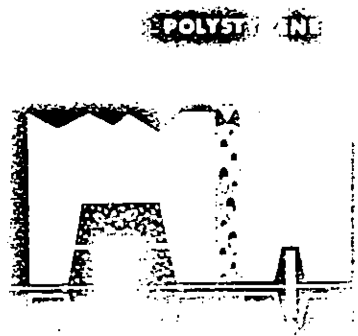
Battery cast concrete partition units being hoisted for erection at Brindley Road Paddington

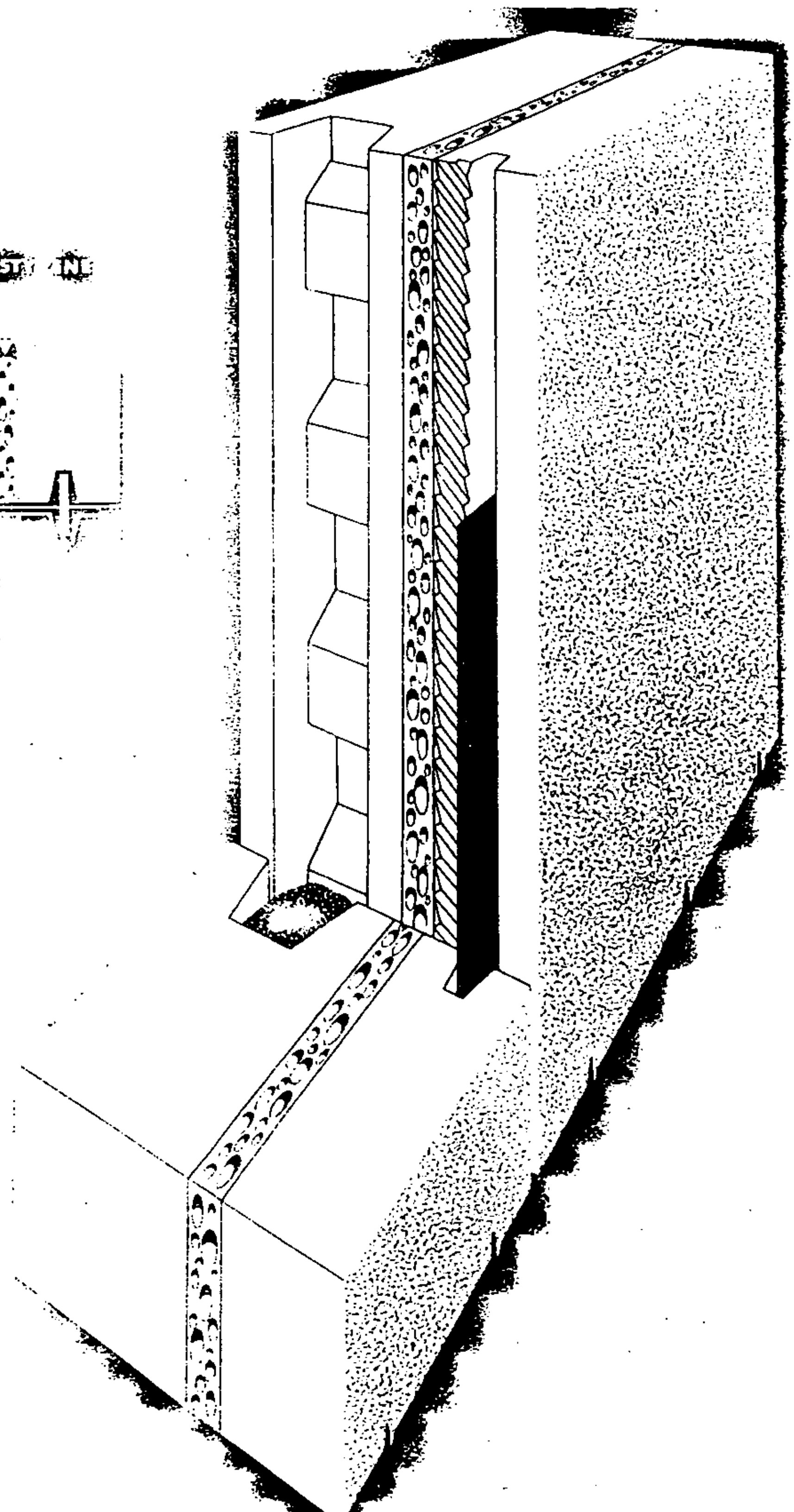


Load-bearing crosswall unit being lifted into position on low-rise blocks at Highfield, Feltham



External vertical wall joint





10

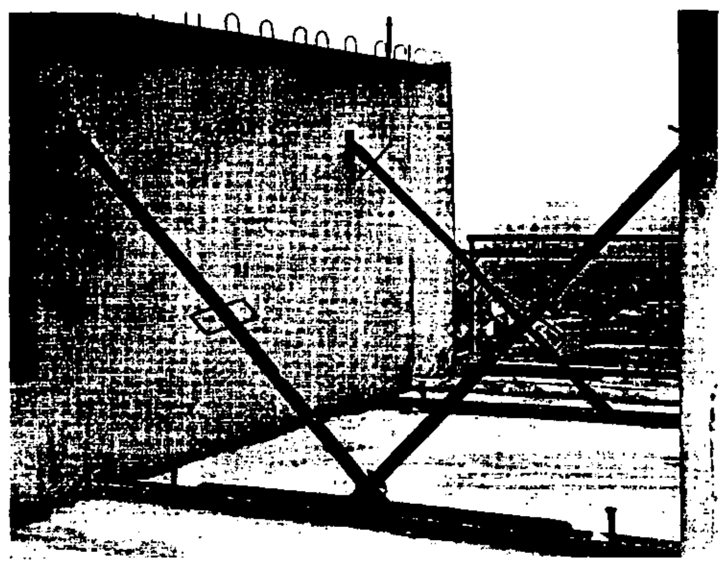
We have also introduced some interesting new processes which are revolutionising the use of plain concrete finishes.

We have paid special attention to the problems of weatherproof jointing on external faces. On our cladding we use a vertical joint drained at each floor and sealed with a neoprene strip.
"Cold bridges" and the associated condensation problems are avoided by separating all perimeter edges of the concrete elements from the cladding by 1in. polystyrene insulation.

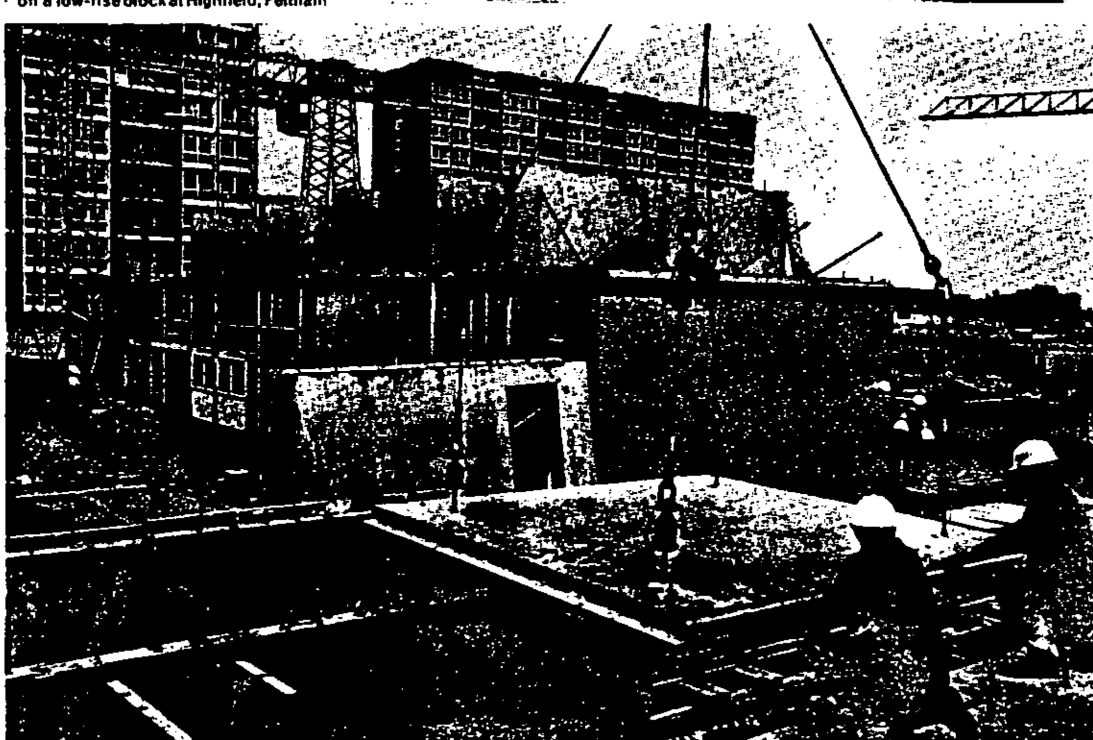
Non-load-bearing cladding. We give technical and cost advice on the wide variety of solutions available since whatever is chosen must comply with the requirements of standardisation and prefabrication.

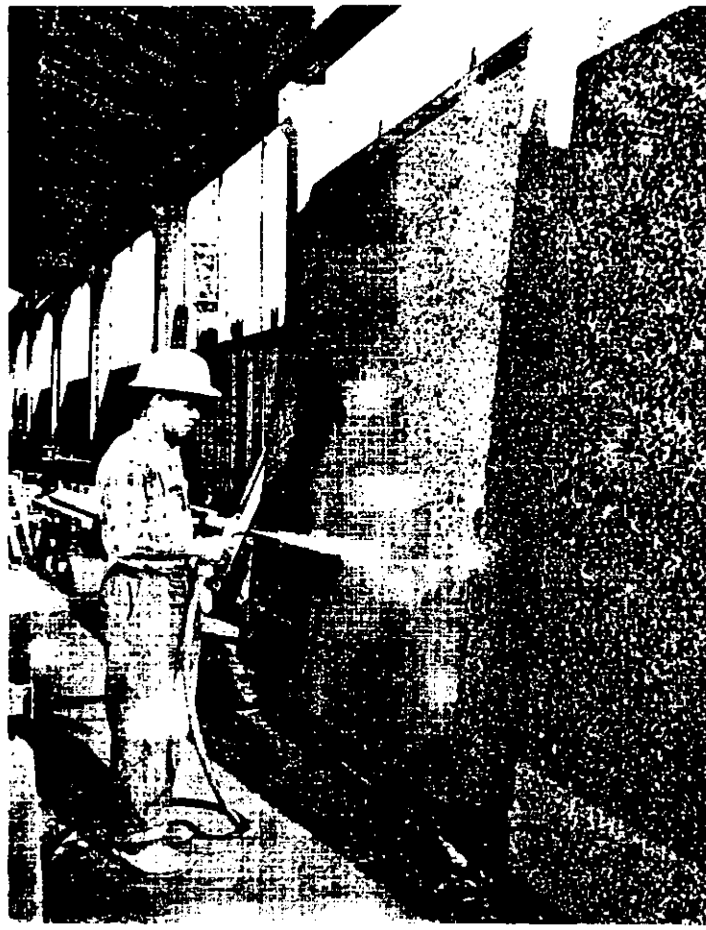
There are two methods we recommend as being most easily incorporated in industrial construction based on standard details. One is a prefabricated timber storey-height panel, spanning between structural walls, and incorporating insulated under-window panels. They are pre-finished either at the works or in

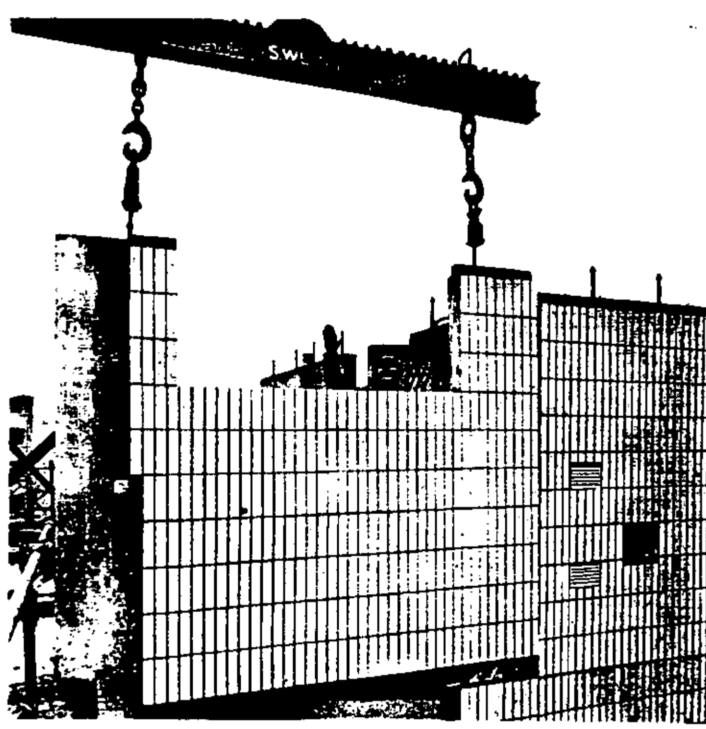
Crosswalls being supported during erection by adjustable props



Floor slab being lowered into position on a low-rise block at Highfield, Feltham







a painting shop on site before being hoisted and fixed.
The other is in concrete, either in the form of a spandrel panel of sandwich construction with a timber or metal framed window over, or as a complete cladding panel pierced with a window, painted, glazed and cast into the unit.

We attach great importance to the problems of cladding and have developed a number of interesting solutions; for example a heavily profiled "picture frame" unit in superfine white concrete.

The detailing of junctions and joints between the various components and the structure ensures proper weather-tightness and adequate insulation.

All staircases, balconies and storey-height refuse chutes are also precast on site.

Handling. Normally we work within the 3 to 4 ton range of units because this weight can be handled efficiently and economically over the width of a point or slab block by the normal range of tower cranes. On some schemes we find

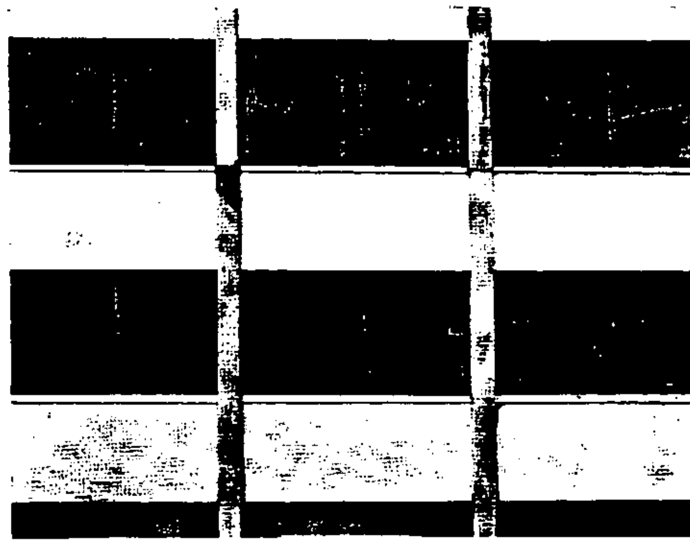
A load-bearing cladding unit, with the insulation incorporated in the internal skin, being positioned

it necessary to introduce larger cranes, capable of handling heavier units. These units are likely to occur on low-rise developments for which we have our portal cranes designed to handle loads up to 6 tons.

Erection of the structure with speed and accuracy is the keynote of our ability to undertake large scale industrialised building projects. This work is carried out by a small group of experienced erectors using specially designed jointing, plumbing and levelling methods and equipment. We have a training scheme for such men and a full operating manual for the procedures involved. The specially designed levelling methods ensure that the crosswalls are accurately plumbed and levelled into position, the joint is made simultaneously, and dry packing is thus eliminated.

Construction times will obviously depend on the size of the project, degree of repetition, the complexities of the substructure and external works. As a general guide, with a contract for 500 dwellings on a reasonably flat site we

Spandril-type elevation as used on the Whitehawk development at Brighton



Profiled surround in superfine white concrete cast in the on-site factory at Highfield, Feltham, and hoisted into position complete with glazing and infill panels

should expect to start handing over in 6 to 8 months at the rate of 8 to 10 dwellings a week, and to complete in 20 months.

5 Services
Heating. Most types can be used in the Wates System, including central boiler plants, gas and electric space heating. We have found the most acceptable and economical is a gas-fired warm air unit and where this is used a storey-height prefabricated flue unit is installed. The fan-assisted offpeak electric storage heater is a suitable alternative.

Lighting. We offer, in all cases, the recommendations of the Parker Morris Report related to a particular client's requirements. It is not difficult to accommodate the conduits and points within the structural components. Close collaboration during design ensures maximum rationalisation of the runs, points and connections.

Power. The ring main is incorporated within a 3½in. by 1in. pre-finished box

The Highfield profiled units in position on the block

Two types of infill units at Warwick Crescent, Paddington. A storey-height timber window unit and an exposed aggregate concrete unit with cast-in windows above

skirting. This is an extremely neat self-finished fitting and offers an infinite variety of positions for socket outlets. The cables are accessible and the ducts can be used for telephone installation if required.

5 Finishings

The doors are prehung in the frames at the factory and the composite architrave and frame is designed so as to mask the joint with the wall. This unit is fixed at the very latest possible stage to avoid site damage.

Prefinished kitchen units, wardrobes and other joinery items are manufactured complete at works and require only hoisting and fixing on site. We use a carefully phased ordering and delivery programme and the maximum use of standard components is all-important.

We can help the architect substantially by making our standard details available. This makes the task of scheduling and detailing joinery items very much less onerous.

Pre-hung door assembly about to be fixed into position

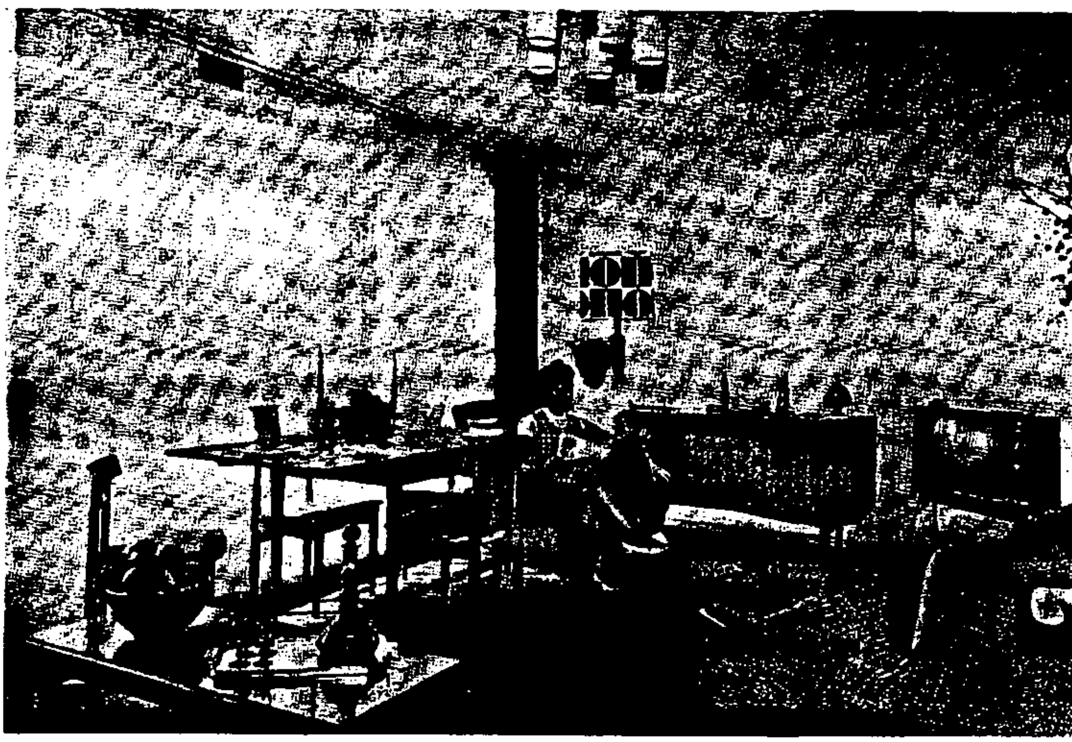
The standard of finish is such that decoration direct to concrete surfaces is not only acceptable but achieves a finish substantially better than plastering standards. A spray textured plastic finish is used on the ceilings and wallpaper is used on the general wall surfaces.

In the kitchen and bathroom a washable or vinyl coated paper is used, combined with plastic or glazed tile splashbacks. We have carried out careful surveys and tests of the floor finishes available and as a result are currently using two particular vinyl floorings in sheets laid direct on to the structural floor, the units of which have been smooth finished in the mould. Alternatively, there are a number of wood block floors or a prefabricated timber floating floor which can be used at additional cost.

7 Lifts

The accelerated rates of erection and completion of blocks of flats in the Wates System require a substantial

A living-room of a completed flat at Oliver Close, Leyton. Wall paper was applied directly to the concrete surface



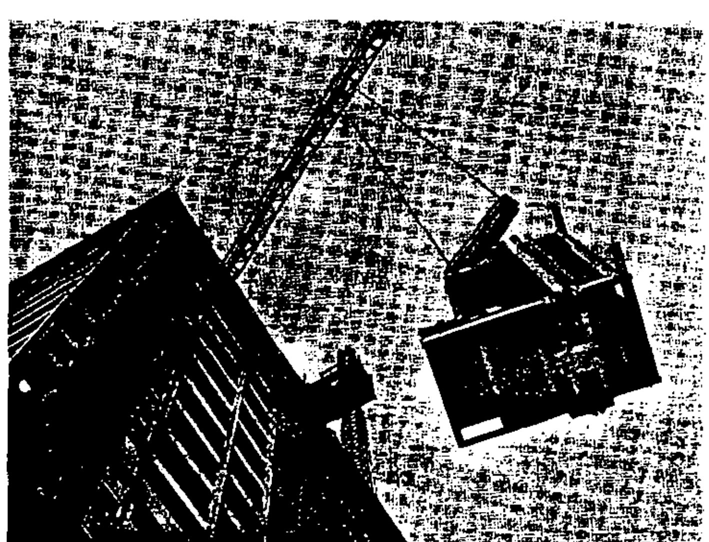
A section of the pre-finished skirting forming a duct for the ring main

A prepainting shop for preparing window frames and doors is set up on the site

speeding up of the lift installation. This is achieved by isolating the threshold and door frames for the hoist motor and gearing at roof level. By prefabrication of the lift car, the site assembly processes are reduced in time by some 50 per cent. The car and motor are installed by means of the tower crane immediately before completion of the precast roof structure. The precision of line and dimension obtained in the lift shaft construction allows work to commence at an earlier stage. This is particularly important on very tall blocks.

8 Public areas

The finished flats have a high standard of comfort and amenity and we believe that this can be reflected in the entrance halls and lobbies. We have studied the design of these areas with the aim of providing the appropriate atmosphere through the large variety of finishes available. Some part of the cost savings offered by the Wates System could usefully be directed to this end.



Completely prefabricated lift being hoisted ready to lower directly into the lift shaft at Oliver Close, Leyton

Other public areas form a reasonable continuation of the initial impression.

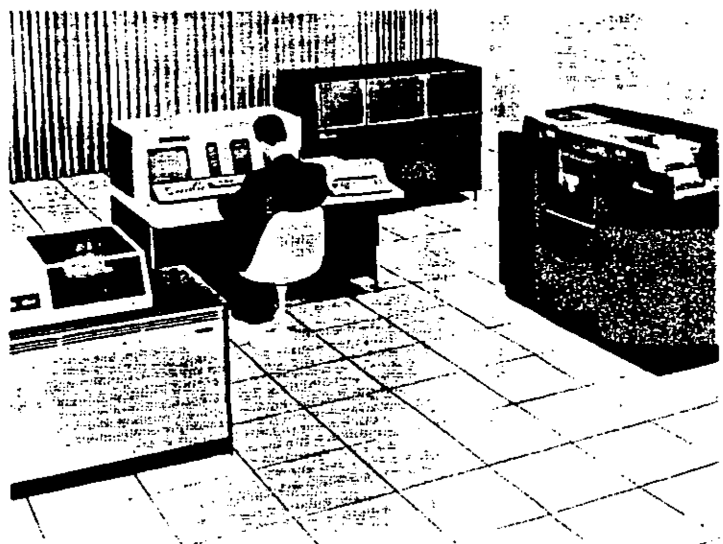
The standard stair flights are pre-finished either in grano or with integral tile inserts. Walls and ceilings are ready for immediate decoration with sprayed plastic or glazed cement finish.

Balustrading is prefabricated in standard panels and placed in position immediately after the erection of the structure.

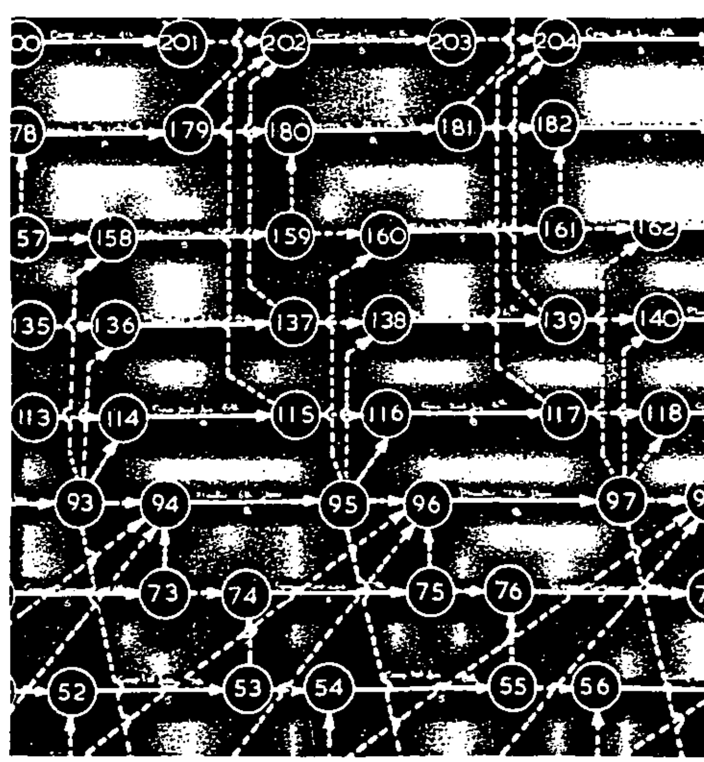
• Reduction of man hours

Throughout the sequence of a job we look for savings in time and effort wherever possible. A great deal of site work is eliminated by preplanning. Services like plumbing are rationalised into storey-height prefabricated sections. By work study comparisons we know we have in fact reduced man hours by more than 50 per cent compared with conventional building methods—and the standard is continually rising.

An IBM computer is used for monitoring [illegible] programme



A section of a typical Critical Path Method network



Wates Care

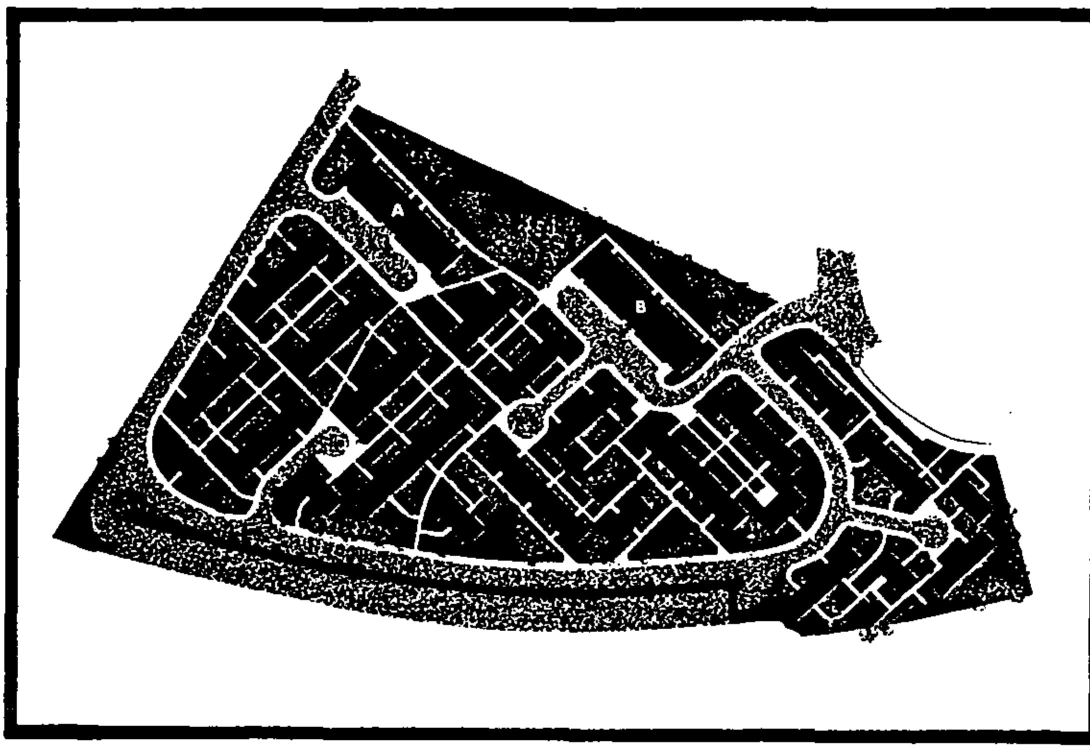
Industrialisation to some people sounds inhuman, but we believe the human element to be of vital importance. In the final analysis our people build homes for other people to live in. We use scientific planning, extensive mechanisation and systemised components, but we never lose sight of the human scale.

We care about the job we are doing; about meeting the client's requirements; and we care about the solid evidence we leave behind us when we move off site.

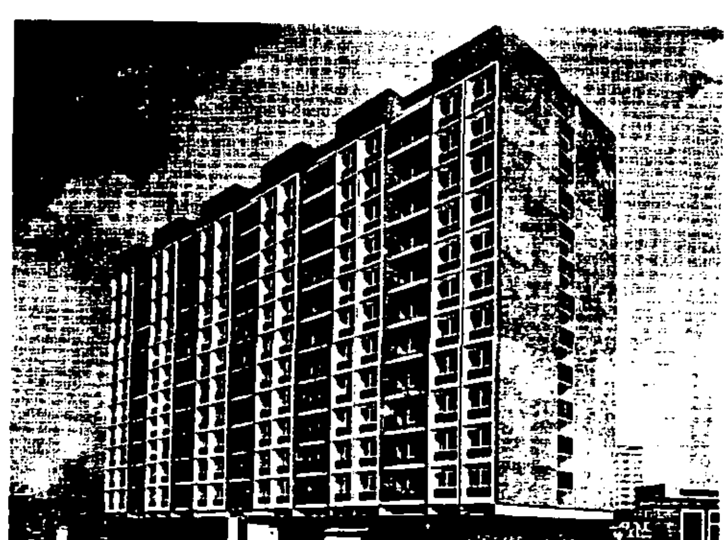
We care about our men, because we depend upon them, and they appreciate it. We have full staff conditions for at least half our operatives—continuity of employment, additional sickness benefits, three weeks' holiday with full pay—the same work terms in fact as for our office staff.

With improved site amenities and working conditions generally, each of our men can have a good hot meal in a pleasant canteen, use hot and cold water for

Layout of the Highfield development at Feltham which gives a total of 438 dwellings in the 2 twelve-storey blocks and 23 three-storey blocks.



One of the 12-storey blocks of flats on the Highfield development at Feltham

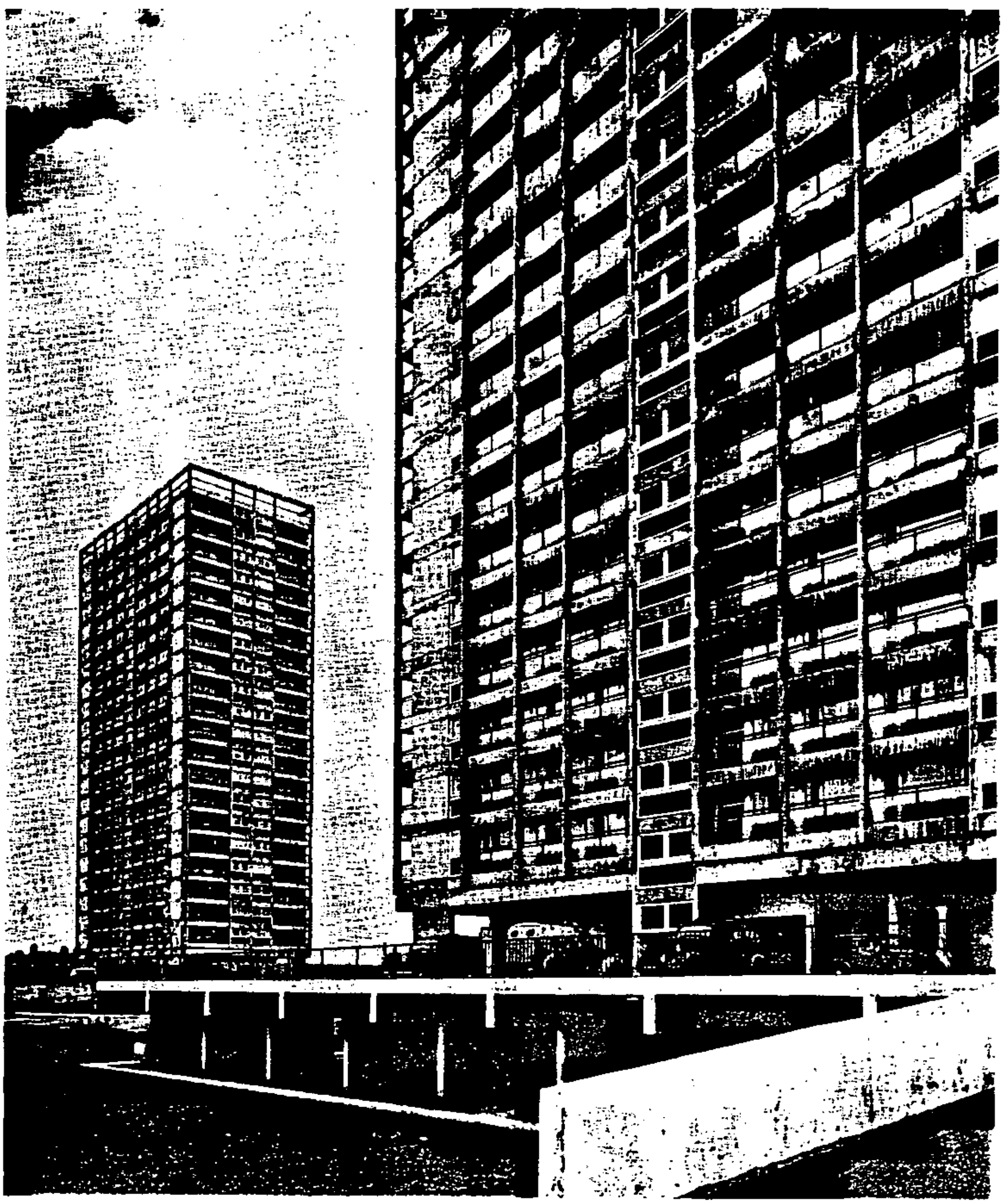


washing and have his own separate cabinet to keep his clothes clean and dry. More than that, we spend a lot of time and effort on improved safety measures.

The status of building as a worth-while job is rising at last and system building is vastly accelerating the process. Men can be proud of the work they do and the projects with which they are associated.

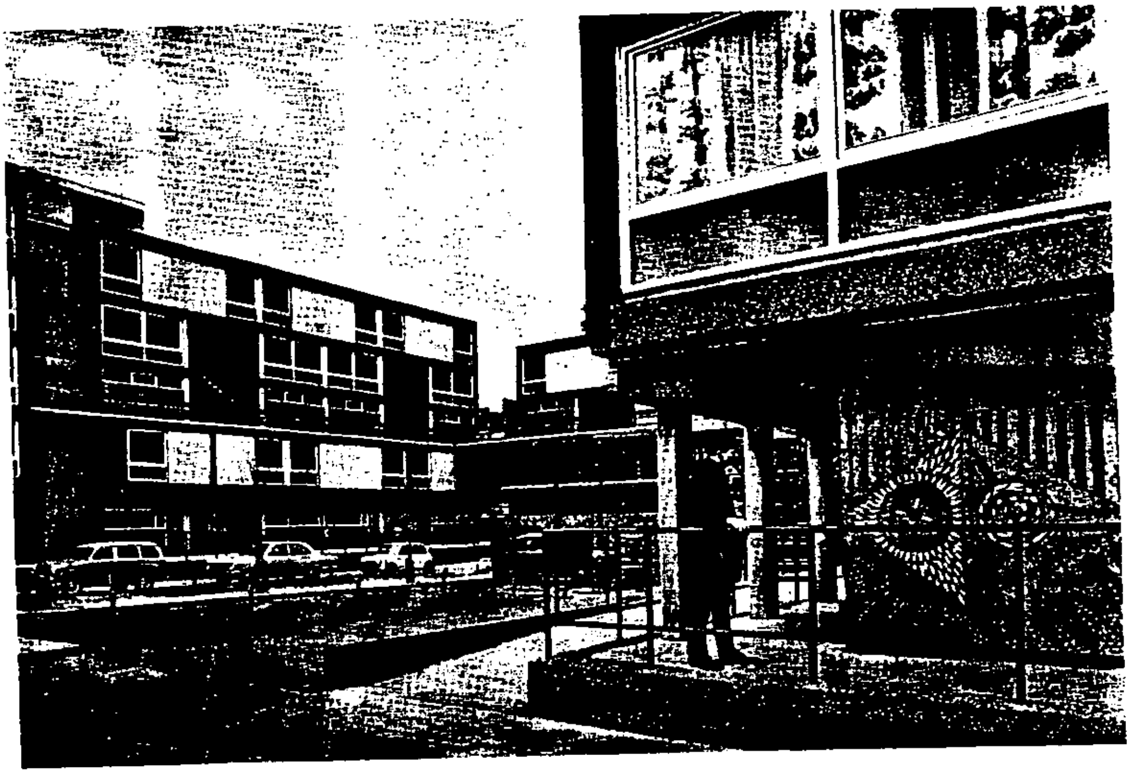
We respect such men and can have confidence in them.

Two of the three 21-storey blocks of flats built for the Leyton Borough Council at Oliver Close



This 11-storey block of flats at Bramley Hill, Croydon, took only ten weeks from ground floor to completion. It is one of over twenty similar blocks built for the Borough of Croydon

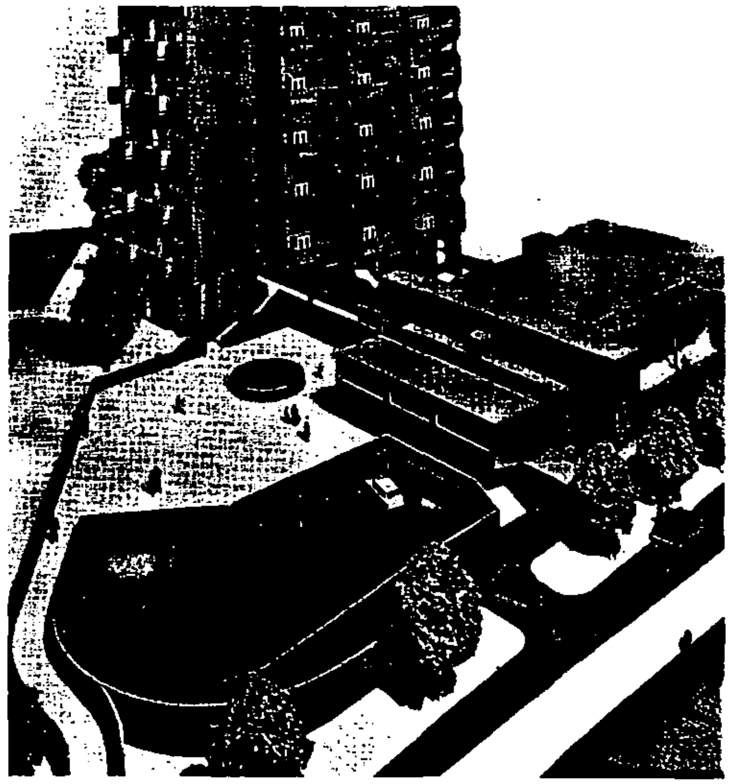
Hackney development for the GLC which includes two 23-storey blocks of flats and 24 five-storey blocks joined by pedestrian bridges at third floor level



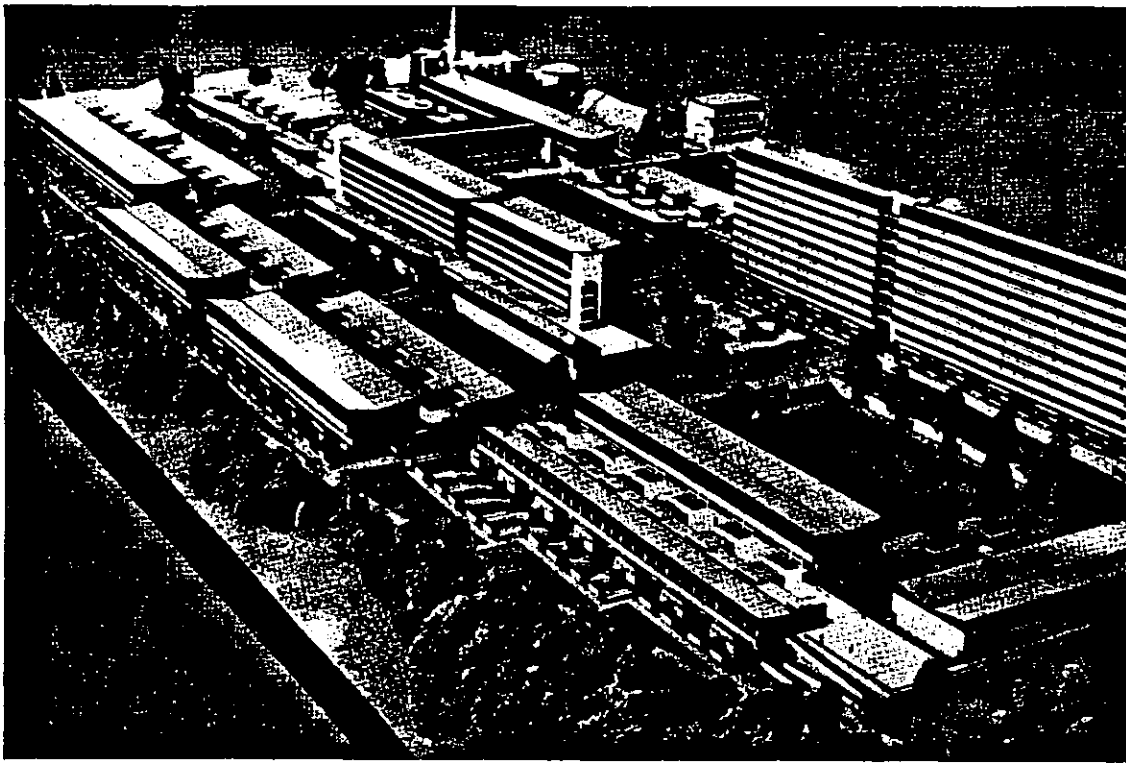
Low-rise blocks in System on the large Winstanley Road development at Battersea

The Rush Green maternity unit at Romford which provides 140 beds, operating theatre, labour wards, child care unit and administration

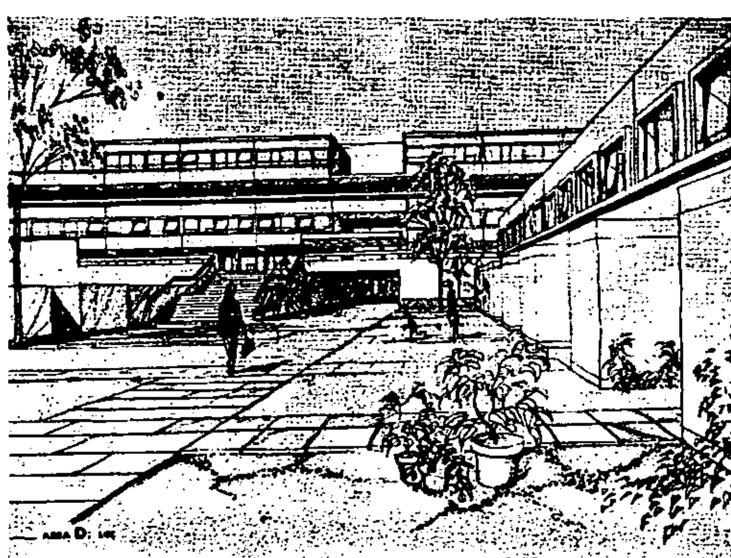
25



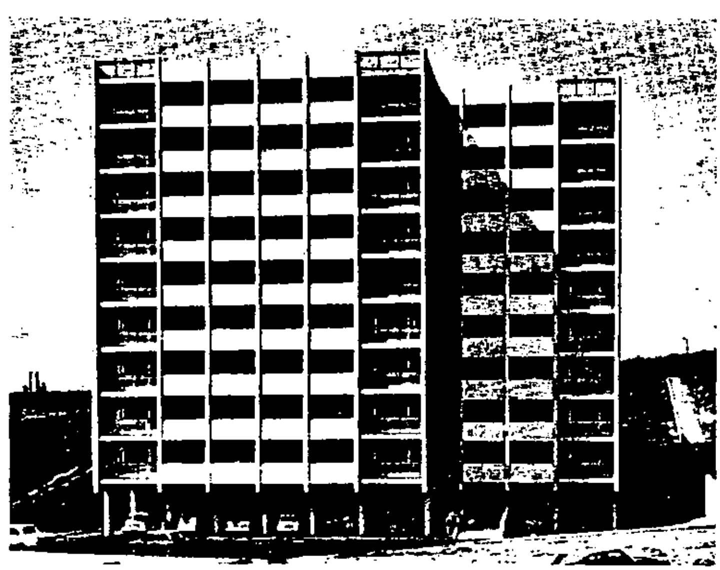
Model of the development at Broadmead Road, Woodford, which provides 604 dwellings for the London Borough of Redbridge: 484 dwellings in six 12-storey blocks and the remainder in 4-storey blocks



The Croydon Airport development which will provide 1,300 dwellings in one 11-storey block and 46 low-rise blocks for the Greater London Council



An impression of a pedestrians-only area of the Croydon Airport development



Conclusion

A lot has been written and spoken on the national need for industrialised building and there is a staggering number of systems on the market. But a system is only as good as the organisation behind it and the ability of the system to give the client what he wants. It must be able to produce buildings of architectural merit which will stand the test of time. It must be economically viable.

The Wates System is certainly able to satisfy these requirements. The flexibility of the 12in. module allows the architect the necessary freedom of design.

The system is economically viable essentially because we put the factory on site and there are no transportation costs, no extra handling costs and damage to units is, therefore, also limited. But maybe the most important fact is that the Wates System is an established system, a system in being. It has been designed specifically for the British market and can now be seen on any number of sites.

If you require any further information on the system, if you would like to see the system at work, or if you would like to know how we can co-operate, telephone us at Pollards 5000 or write to 1260 London Road, Norbury, London, S.W.16.

LIFECYCLE COSTING

life

The word on the street is...

Life Cycle Costing

The momentum of this evolving trend and requirement in project procurement is gathering pace, but just how aware is the industry of the benefits it delivers?
Stuart Bell of CIT asks the question.

The advent of PFI in particular has promoted Life Cycle Costing as the next level of project costing. The question remains, what are the and considerations to make when looking at the whole life costing of a project?

Peter Wells, senior consultant at Precept Programme Management has developed a fresh and sequential approach to Service Life Planning, the process detailed below is one refined from an earlier model built when in the position of senior building economist for the contractor Carillion.

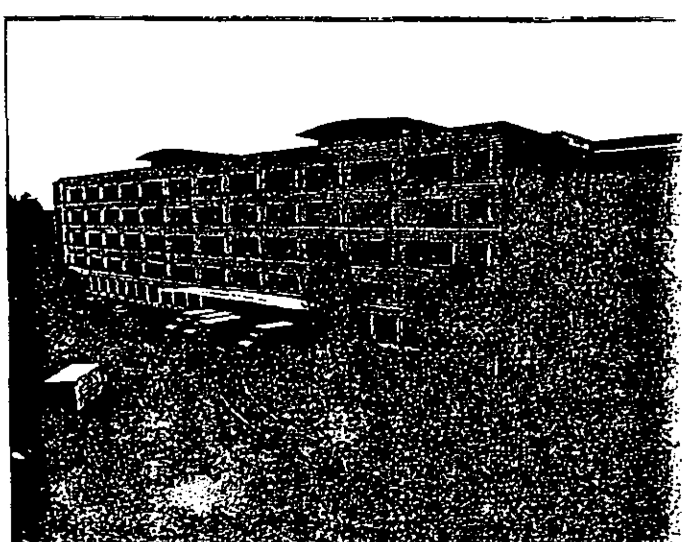
For those of you asking, 'what does it all mean?' Wells explains, "Service Life Planning is an umbrella term developed by the BRE to encompass both Life Cycle Costing and Life Cycle Assessment, i.e. the commercial and environmental costs of a building throughout its life." He continues, "through technical and business knowledge these assessments can be combined in order to derive improved value for the client by informing and guiding a project team such that whole life costs are optimised in relation to the clients profit and loss account."

Why should contractors sit up and take notice? David Benson, a Carillion Building Director (who's responsibilities include lifetime asset management) explains, "Carillion aims to lead radical improvement in construction in value for money and reliability through demonstration and dissemination of best practice and innovation, our aim is to achieve continuous improvement in life cycle costs, both in their prediction and impact on future revenue."

Moving forward, Benson believes that Carillion have the infrastructure and resources in place to succeed in this area of whole lifetime cost management. "The prediction of product life cycles and maintenance requirements is becoming critical to our ability to service our clients", he says, "where optimum solutions are being sought for the whole life of a project and not just for the initial construction period. This means that through close communication with manufacturers and designers we must evolve our knowledge and records of material life expectancy and behaviour".

So what are the key considerations? Wells documents, "the industry must understand the following aspects if we are going to help client realise their value ambitions...

- Capital Cost
- Routine Maintenance Requirements
- Capital Replacement Requirements
- Obsolescence
- Energy Use
- Operational Costs
- Disposal
- Environmental Impact



Where these key parameters can be understood, assessed and optimised within a financial model for the project."

The generic process for Service Life Planning can be summarised in four main stages, brief, model, design and solution as follows:

The Brief

Initially starting at a high level, the briefing process defines the required service life for the building and therefore the design life requirements for each element of the building. Based on BS 7543:1992, the brief will identify the following for each element, or component of the building:

- its design life
- its Lifelong, or, Replaceable, or Maintainable category
- If replaceable or maintainable, the required actions over the buildings life and timings for each action
- required maintenance regimes
- potential risks upon component failure

The level of detail will increase as the design progresses, where the starting point of the brief may be as basic as:

- Primary Structure
- Envelope
- Finishes
- Mechanical Services
- Electrical Services

Model, Design, Solution

After the initial briefing, the design team will commence the design following the normal stages of Concept, Scheme, Detail and Production Information. It is during these stages, particularly during concept and scheme design, that the SLP service must test, guide, support and inform the design team in developing the optimum solution.

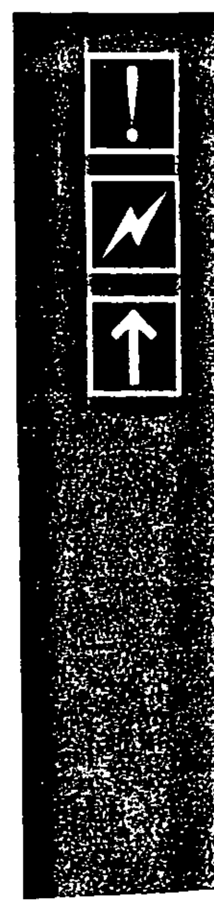
Where Wells believes that the optimum solution should provide the maximum required performance for the minimum cost, i.e. the best value. The result being:

- Compliant and superior projects in terms of design quality and building performance
- The best value for the client
- The most competitive project in terms of whole life costs
- Significant improvements in business returns for all project stakeholders

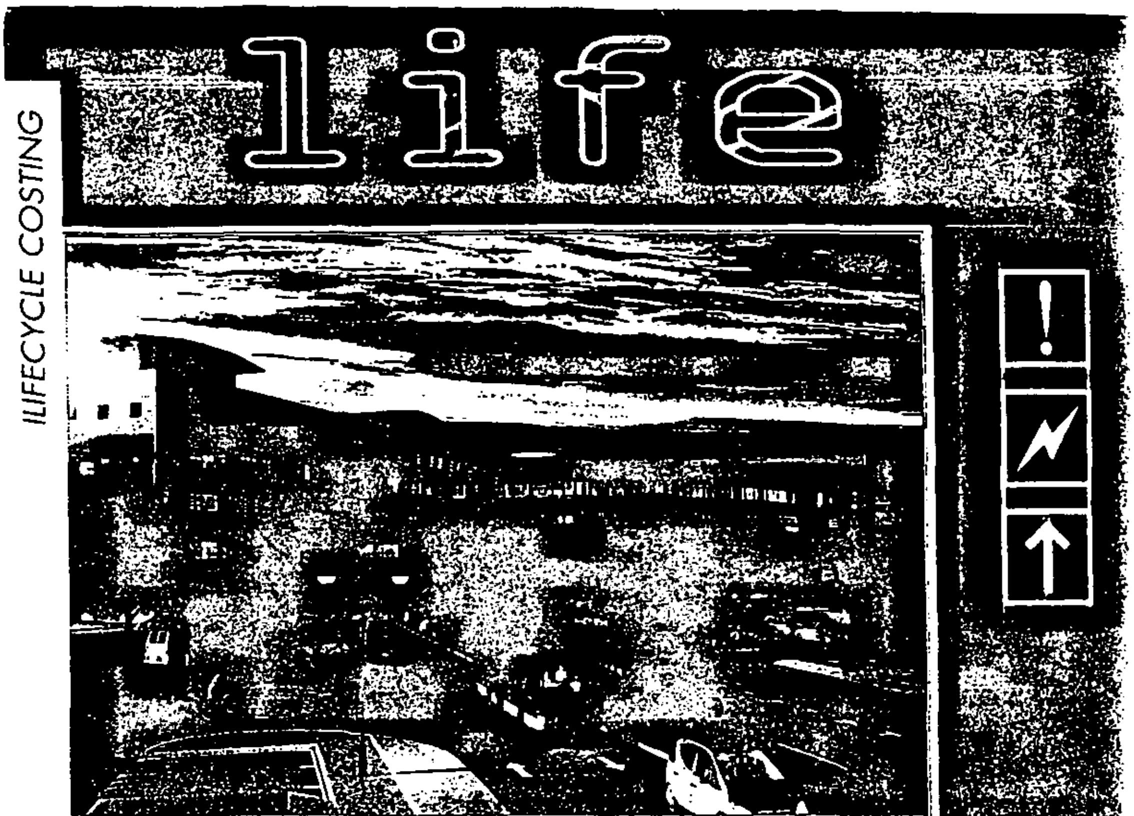
An approach to this may be the Initial Assessment - Target - Model process developed by Peter Wells which allows the project team to evolve the design against clear guide lines which are then used to test and optimise the project solution.

Initial Assessment: Costs per m2 GFA or Residual Valuations used to establish bid project guidelines at the earliest stages of the project (prior to any design).

Life Cycle Target: Developed from the initial assessment in conjunction with the design and precept's 'Component Selection' process, the target establishes the commercial, environmental and technical parameters for the optimum solution, the project and, therefore, the design.



LIFECYCLE COSTING



- Thorough risk and sensitivity analysis and consideration
- Cash flow 'smoothing'
- Analysis with 'What if?' scenarios
- Adequate Data, be it cost, action or occurrence
- Capturing both tacit and explicit knowledge

But, above all, Wells points out that what the industry needs is a pragmatic, logical and traceable approach!

The existing provision of proprietary spreadsheet and database applications do not fully capture the rigorous detail required. The industry needs a new breed of solutions to facilitate the whole life cost management process. Benson concludes. "Life Cycle Planning requires a tool that allows better analysis and balance between capital expenditure and operational expenditure.... we need a tool to help us achieve the optimum solution."

...visualisations of the Princess ... Hospital, Swindon - one of ... Life Cycle Costing projects

Wells has been involved in the detailed specification of the revolutionary solution, 'Life', launched this month by CIT. "Utilising I.T. and consulting best practice with a flexible software solution, that allows the capture and analysis of whole life costs will move the industry forward at a faster rate", he enthuses. "the benefits of this approach are too significant to be ignored!"

MAINTENANCE WORK PLANNING

INTRODUCTORY NOTES AND START-UP PACK

PRE-PLANNING AND ORDERING PROCESS AND PROCEDURES FOR TOTAL MAINTENANCE OF BUILDING, EQUIPMENT, PLANT AND FITTINGS

ISSUED TO: ALL INTERNATIONAL CITIES DIVISION MANAGERS

YHA (England and Wales) Ltd.
Registered Office: Trevelyan House, Dimple Road, Matlock, Derbyshire, DE4 3YH
Tel: 01629 592600 Fax: 01629 592702 web: www.yha.org.uk
Company No. 282555 A Company limited by guarantee
Registered Charity No: 306122

HOSTELLING INTERNATIONAL

Youth Hostels Association (England and Wales)

INTERNATIONAL CITIES DIVISION

YHA

PLANNED PREVENTATIVE MAINTENANCE .

LOG BOOK

QUICK CONTACT LIST

YOUTH HOSTEL
'PHONE NO
EMAIL

ITEM	SERVICE ENGINEER	PHONE NUMBER	**NAME**	MAKE OF EQUIPMENT
BOILER 1				
BOILER 2				
PASSENGER LIFT				
GOODS LIFT				
SEWAGE LIFT				
EMERGENCY LIGHTING				
FIRE EXTING -UISHERS				
FIRE ALARM SYSTEM				
VENTILATION PLANT				
AIR CON PLANT				
CATERING EQUIPMENT				
EMERGENCY GLAZIER				
ELECTRICIAN				
PLUMBER				
SHOWER VALVES				
CCTV				
ROOF AND GUTTERS				
DRAIN CLEAR				

Note: Amend list to specific requirements as agreed with Buildings Manager

HOW TO USE THIS MAINTENANCE PROGRAMME

Please remember that the purpose of this programme is to enable you to carry out the maintenance of the building in the easiest possible way whilst ensuring, at the same time, that the building is fully and efficiently operational.

In the same way that a vehicle has a maintenance log book which tells the owner how and when service and maintenance should be carried out (e.g. every year of 10,000 miles etc) to prevent breakdowns, or unnecessary wear, on components;, so does each building need regular and systematic maintenance scheduled to reduce deterioration. Thus this log-book can be considered as similar to a vehicle maintenance log.

Unlike vehicles which are designed and tested to enable minimum but regular servicing of many components to be carried out at one visit to a service centre or garage, buildings are virtually all different. Not only are the buildings different in their external appearance and construction, but even similar buildings may contain very different components internally. For this reason each individual building requires an individual maintenance schedule.

PROGRAMME OF ACTION.

A Complete the Data Collection sheets with every item of maintenance work that you can find! This is best done by walking around the building and considering the various suggested items shown on the sample sheets included in this programme. Remember to include only maintenance, not desired improvements.

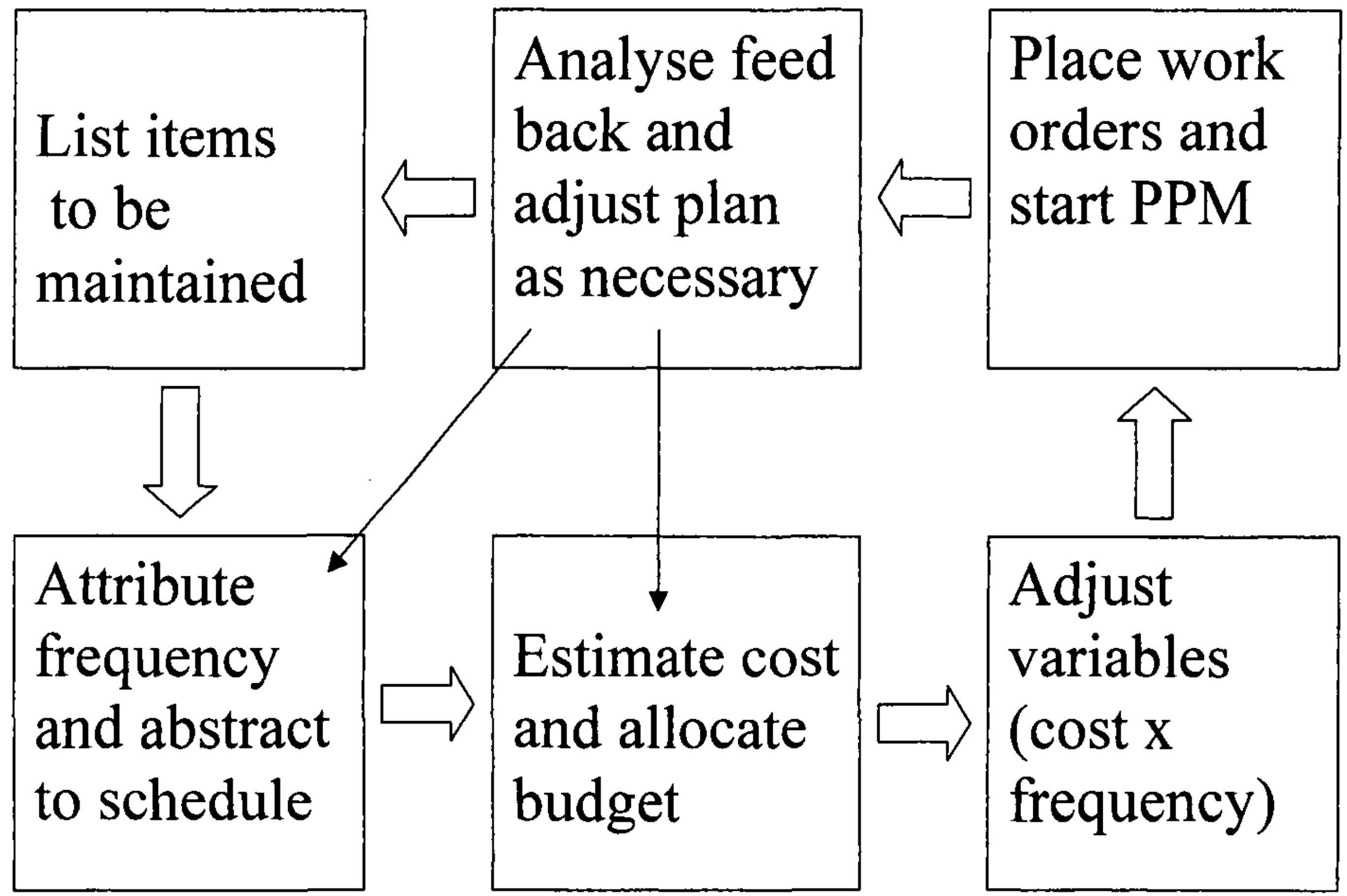
B Put a tick in the frequency box on the right hand side of the sheet, to correspond with your estimation of necessity and frequency. You can decide if an item requires maintenance, and how often. If you are not sure, ask the Buildings Manager.

C Abstract the items from the collection sheets onto the Action sheets. (Maintenance check list) to produce your weekly, monthly, 3 , 6, and 9 month and yearly action plan. Include every item of maintenance, if an item is only carried out every 3 years, include 1/3 each year. Furniture replacement is not included in the current programme details, but is being prepared to be added in during the next year.

D Allocate budget as necessary. Contracted out services, such as Boiler maintenance, will have a known cost, and estimates for other activities, such as emergency glazing, need to be made and used only for that purpose.

E Greater efficiency in using maintenance funds will enable further improvements in the future, and as alterations are made they must be added to the maintenance programme.

SYSTEM S DIAGRAM



SUGGESTED SERVICE FREQUENCIES
ADD/DISCARD ITEMS TO SUIT BUILDING REQUIREMENT

ITEM	SERVICE FREQUENCY PER YEAR	PROGRAMMED DATE 1ST VISIT	PROGRAMMED DATE 2ND VISIT	CONFIRMED SERVICE COMPLETED	
				DATE 1ST VISIT	DATE 2ND VISIT
BOILER 1	2 TIMES				
BOILER 2	2 TIMES				
PASSENGER LIFT	4 TIMES				
GOODS LIFT	2 TIMES				
SEWAGE LIFT	2 TIMES				
EMERGENCY LIGHTING	2 TIMES				
FIRE EXTING -EXUISHERS	2 TIMES				
FIRE ALARM SYSTEM	2 TIMES				
VENTILATION PLANT	2 TIMES				
AIR CON PLANT	2 TIMES				
CATERING EQUIPMENT	1 TIME				
EMERGENCY GLAZIER	AS REQUIRED				
ELECTRICIAN	1 \TIME & AS REQUIRED				
PLUMBER	1 TIME & AS REQUIRED				
SHOWER VALVES	1 TIME (2 visits x ½)				
CCTV	2 TIMES & AS RQUIRED				
ROOF AND GUTTERS	2 TIMES				
DRAIN CLEAR	1 TIME				

CONTRACT SERVICE VISIT PLANNING CHART.

INSERT ITEM TO BE SERVICED /MAINTAINED AND DATE					
MONTH	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5
JANUARY					
FEBRUARY					
MARCH					
APRIL					
MAY					
JUNE					
JULY					
AUGUST					
SEPTEMBER					
OCTOBER					
NOVEMBER					
DECEMBER					

SAMPLE OF COMPLETED PLANNING CHART

INSERT ITEM TO BE SERVICED/MAINTAINED AND DATE					
MONTH	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5
JANUARY			GOODS LIFT		
FEBRUARY	Passenger Lifts Ventilation	Fire Alarm & Extinguishers & Emergency Lighting	Catering equipment		
MARCH	Sewage Lift Pumps		Boilers 1st		
APRIL		Shower valves			
MAY	Passenger Lifts				
JUNE				GOODS LIFT	
JULY			Ventilation systems		
AUGUST	Passenger Lifts		Fire Alarm & Extinguishers & Emergency Lighting		
SEPTEMBER	Sewage Lift Pumps				
OCTOBER	Boilers 2nd	Shower valves	Roof gutters (dependant on leaf fall)		
NOVEMBER	Passenger Lifts				
DECEMBER					

PLANNED MAINTENANCE DATA ABSTRACT SHEET. SHEET NO OF

WEEKLY MAINTENANCE CHECK LIST

Date	Code	Item	Cost	Compl eted by	Manager to Sign confirm
		Public areas			
		Check carpet for chewing gum and remove			
		Check signs and notice boards, remove redundant notices			
		Replace defective lamps, including emergency lights.			
		Bedrooms			
		Replace defective lamps, including emergency lights.			
		Check waste plug in basin			
		Check lamps and replace, incl. Bunk and basin lights			
		Washrooms			
		Check for loose or broken WC seats and rectify			
		Replace defective light bulbs			
		External			
		Lights checked and bulbs replaced			
		Paths swept clear of debris and leaves			
		Grass/lawn areas cut and edges trimmed			

PLANNED MAINTENANCE DATA ABSTRACT SHEET SHEET NO OF

1 **1 MONTHLY MAINTENANCE CHECK LIST**

Date	Code	Item	Cost	Compl eted by	Manager to sign confirm
		External			
		Set timing controls correctly for time of year			
		Water drain off points cleared			
		Loose gravel and skid material cleared			
		Dead leaves swept clear of grass (November – March)			
		Soil water waste gullies cleared of Fat and waste deposits			

PLANNED MAINTENANCE DATA ABSTRACT SHEET SHEET NO OF

3 **3 MONTHLY MAINTENANCE CHECK LIST**

Date	Code	Item	Cost	Completed by	Manager to sign confirm
		External			
		Set timing controls correctly for time of year			
		Water drain off points cleared			
		Loose gravel and skid material cleared			
		Dead leaves swept clear of grass (November – March)			
		Soil water waste gullies cleared of Fat and waste deposits			

PLANNED MAINTENANCE DATA ABSTRACT SHEET SHEET NO OF

6 **MONTHLY MAINTENANCE CHECK LIST** (replaces alternate 3 monthly maintenance)

Date	Code	Item	Cost	Completed by	Manager to sign confirm
		External – low level			
		Set timing controls correctly for time of year			
		Water drain off points cleared			
		Loose gravel and skid material cleared			
		Dead leaves swept clear of grass (November – March)			
		Soil water waste gullies cleared of Fat and waste deposits			
		Securely fix any loose fittings, cables etc			
		Drive checked for pot-holes and all filled			
		Loose kerbs and edgings repaired			
		Rainwater gullies cleared of leaves and debris			
		Timber sheds etc.			
		Floor supports clear of base and not rotting			
		Roof felt securely fixed and repaired as necessary			
		Sides cleaned and coated with preservative			
		Door locks and hinges oiled			
		Surplus stored rubbish sent to tip			
		External –high level			
		Clean out guttering around buildings			
		Visual check on chimney pots, order repair if necessary (orn)			
		Visual check on chimney stacks and flashing. (orn)			
		Visual check on hip and ridge tiles (orn)			
		Visual check on slates and tiles. (orn)			

PLANNED MAINTENANCE DATA ABSTRACT SHEET SHEET NO OF

YEARLY MAINTENANCE CHECK LIST (Replaces alternate 6 month maintenance)

Date	Code	Item	Cost	Compl eted by	Manager to sign onfirm
		External			
		Set timing controls correctly for time of year			
		Water drain off points cleared			
		Loose gravel and skid material cleared			
		Dead leaves swept clear of grass (November – March)			
		Soil water waste gullies cleared of Fat and waste deposits			
		Securely fix any loose fittings, cables etc			
		Drive checked for pot-holes and all filled			
		Loose kerbs and edgings repaired			
		Rainwater gullies cleared of leaves and debris			
		Paint outside of fittings, posts etc.			
		Remove young trees that may cause root damage to foundations			
		Defective inspection covers replaced			
		Inspection covers and gully gratings painted with Bituminous			
		Timber sheds etc.			
		Floor supports clear of base and not rotting			
		Roof felt securely fixed and repaired as necessary			
		Sides cleaned and coated with preservative			
		Door locks and hinges oiled			
		Surplus stored rubbish sent to tip			
		Sides cleaned and coated with preservative			
		External –high level			
		Clean out guttering around buildings			
		Visual check on chimney pots, order repair if necessary (orn)			
		Visual check on chimney stacks and flashing. (orn)			
		Visual check on hip and ridge tiles (orn)			
		Visual check on slates and tiles. (orn)			

PLANNED MAINTENANCE DATA ABSTRACT SHEET SHEET NO OF

☐ **MONTHLY MAINTENANCE CHECK LIST**

Date	Code	Item	Cost	Completed by	Manager to sign confirm

PLANNED MAINTENANCE DATA COLLECTION SHEET. SHEET NO. A4

HOSTEL NAME	COMPILED BY	DATE	TITLE
SAMPLE	Keith Farmer	/ /	EXTERNAL

MONTHS

REF.	LEADER	ITEM OF MAINTENANCE WORK	1/4	1	3	6	12
	Lighting	Lights checked and bulbs replaced	√				
		Set timing controls correctly for time of year		/			
		Securely fix any loose fittings, cables etc.				/	
		Paint outside of fittings, posts etc.					1/3
	Surfaces	Drive checked for pot-holes and all filled				/	
		Loose kerbs and edgings refixed				/	
		Water drain off points cleared		/			
		Loose gravel and skid material cleared		/			
		Paths swept clear of debris and leaves	/				
		Grass/lawn areas cut and edges trimmed	/				
		Dead leaves swept clear of grass (November – March)		/			
		Remove young trees that may cause root damage to foundations					/
	Bounds	Timber fences repaired and coated with preservative					/
		Wire fences checked and repaired					/
		Brick/stone boundary walls repaired/repointed					1/3
		Hedges and shrubs cut back from paths etc					/
	Sheds etc	Floor supports clear of base and not rotting				/	
		Roof felt securely fixed and repaired as necessary				/	
		Sides cleaned and coated with preservative					/
		Door locks and hinges oiled			/		
		Surplus stored rubbish sent to tip				/	
	Drains	Rainwater gullies cleared of leaves and debris				/	
		Soil water waste gullies cleared of Fat and waste deposits		/			
		Defective inspection covers replaced					/
		Inspection covers and gully gratings painted with Bituminous					/
	Roofs	Visual check on chimney pots, order repair if necessary (orn)				/	
		Visual check on chimney stacks and flashing. (orn)				/	
		Visual check on hip and ridge tiles (orn)				/	
		Visual check on slates and tiles. (orn)				/	
		Clean out internal roof valleys of leaves and seeds etc.		/			
		Clean out guttering around buildings				/	

PLANNED MAINTENANCE DATA COLLECTION SHEET. SHEET NO.

HOSTEL NAME	COMPILED BY	DATE	TITLE
CLONE	Keith Farmer	/ /	INTERNAL

MONTHS

REF.	LEADER	ITEM OF MAINTENANCE WORK **PUBLIC AREAS**	1/4	1	3	6	12
		Check carpet for chewing gum and remove	/				
		Clean carpets and fix loose edges etc.			/		
		Check signs and notice boards, remove redundant notices	/				
		Check damage to decoration and make good and touch up.		/			
		Check and adjust heating levels		/			
		Check and adjust locks and closers, OR		/			
		Ditto and oil locks, hinges and closers , check intumescent strip			/		
		Replace defective lamps, including emergency lights.	/				
		Replace ALL high level lamps requiring scaffolding					/
		Check and adjust window stops and locks			/		
		Clean outside of window glass			/		
		Redecorate ceilings and wall surfaces					1/2
		Redecorate windows, doors, skirtings etc.					1/2
		BEDROOMS					
		Remove chewing gum	/				/
		Deep clean carpets					
		Check and adjust heating levels.		/			
		Check and adjust curtains and curtain tracks			/		
		Redecorate walls and ceilings					1/2
		Redecorate woodwork and radiators					1/2
		Check waste plug in basin	/				
		Check lamps and replace, incl. Bunk and basin lights	/				
		WASH ROOMS INCL. EN-SUITE ETC.					
		Clean ventilation grill		/			
		Apply approved drain cleaner		/			
		Descale shower head		/			
		Check for loose or broken WC seats and rectify	/				
		Check floor welds and seals and order repair		/			
		Service shower mixer valves				/	
		Service extract fans and ducting			/		
		Check and adjust heating levels.		/			
		Replace defective light bulbs	/				
		Replace broken coat hangers etc.			/		