A communication system approach to the management of quality in construction

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A COMMUNICATION SYSTEM APPROACH TO THE MANAGEMENT OF QUALITY IN CONSTRUCTION

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A thesis submitted in fulfilment of the requirements of the Council for National Academic Awards for the degree of Doctor of Philosophy

SOUTH BANK UNIVERSITY

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A COMMUNICATION SYSTEM APPROACH TO THE MANAGEMENT OF QUALITY IN CONSTRUCTION

By: Ayodele Bamisile

ABSTRACT

An understanding of the factors surrounding the achievement of specified quality requirements is imperative and hence a prerequisite for effective management of quality by the construction team. To this end, the research is concerned with identifying, with a high degree of certainty associated with the data, the cause and effect of quality problems directly related to the site production process and to establish, quantitatively, the relative importance of the factors.

Six hypotheses were postulated and their verification was based on balanced and honest conclusions drawn from the data analyses. Five of the six hypotheses are supported by the data. Therefore, they become explanatory theories for the management of quality in construction.

As part of a literature survey, a critical review of the previous works was made and the current state of the art was identified. Based on the knowledge gained from the literature survey, three detailed case studies were made of construction projects in the South East of England, utilising different procurement methods.

The case studies, in conjunction with the literature review, were used to develop conceptual models which in turn were used for structuring a detailed questionnaire intended to extend the research throughout England in order to achieve a sufficiently large category proportion. The responses to the questionnaires were scientifically analysed and statistically validated.

The data analysis results in the identification of 30 factors which are expressed as the causes of non-conformance to specified quality requirements. The relative importance of each factor was established. Therefore, a large cloud has been removed and the construction team can now direct their limited resources effectively. The second objective of the research was accomplished with the successful development of a new Quality System entitled "Quality Communication System" (QCS).

The implementation of the QCS approach to the management of quality in construction will result in achieving conformance to specified quality requirements at first attempt, lower costs and increased productivity in the construction industry. The research outcome is a significant contribution to the management of quality in the construction process. The outcome is perceived to represent an advance in knowledge associated with construction management.
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2. All those who took the trouble to respond to the questionnaire.

3. The two construction companies which allowed their projects to be used as case studies.

4. The co-operation and help of Ken Fletcher (formerly of BRE) and Dr. Ian Corner of BRE in fulfilment of BRE's role as a collaborating establishment.

My special thanks and gratitude go to my wife and friends for their encouragement.

Last, but not least, my very special thanks and gratitude go to my son, Omololu, who I have not been able to give the necessary fatherly care and attention when he probably needed it most. I love you.
DEDICATION

To my family....
My parents, Ojo and Modupe Bamisile;
My son, Omololu Bamisile;
and with special affection to my wife,
Busola K. Bamisile.
CHAPTER 1
THE RESEARCH AIM AND SCOPE

1.1 INTRODUCTION

The achievement of specified quality requirements by the construction team has long been a problem. Great expenditure in time, money and resources, both human and material, are wasted each year because of inefficient or the non-existence of a co-ordinated quality management system in the construction industry. This Chapter is based on preliminary reading and discussions held with some specialists in the industry. It reviews the need for research to identify the difficulties facing the construction team (excluding the design team) in achieving conformance to specified quality requirements at the first attempt with a view to using the concept of "soft" systems thinking methodology to develop a viable solution.

The reasons why one should bother about the quality of buildings are outlined and the aim, objectives and the hypotheses of the research are defined. The definitions and assumptions on which the research is based are described, together with the relative significance of the research. The Chapter is intended to set out the framework upon which the research is carried out.

1.2 THE NEED FOR THE RESEARCH

For the last thirty years there has been much debate between the professional groups within the construction industry and clients' organisations in this country concerning the performance of the building industry. The debates have resulted from defective buildings and the continuous increase in building maintenance costs. Clients have also become more aware of the quality standards required in the buildings they commission. A research need identified in the report of a survey carried out by the Building Research Establishment (BRE) (1) in 1978 was the
investigation and improvement of site organisation procedures which affect the cost and quality of buildings. In 1979, the BRE and the Chartered Institute of Building (CIOB) organised a joint symposium at BRE, Garston (2) to discuss ways of achieving, on site, acceptable standards of quality in construction. Arising from the symposium was the need for research into the "exploration of the manner in which quality standards are established and communicated on site." This was linked to the roles and responsibilities of all participants in the building process for the quality which emerges.

In 1981, Professor Bishop (3) said:

Bluntly, many clients and, perhaps, the public at large, believe that the industry fails to offer value for money; building projects are said to cost too much, take too long to complete and are too prone to failure and to rapid failure at that.

A joint meeting of the Institution of Structural Engineers and the Chartered Institute of Building was held in April 1987 to discuss the topic of "Realising Quality - Checking, Inspection, Training and Assurance (4). In November 1987, a summit meeting of 60 industry leaders was held at the Chartered Institute of Building Service Engineers (CIBSE) headquarters (5). It brought together consultants, contractors, manufacturers and public sector clients to face up to the challenges of quality assurance and contract conditions.

Appendix A highlights some of the headlines in the daily newspapers concerning public dissatisfaction with the performance of the Construction Industry. In 1972, Davis (6) of the Department of the environment (DOE) said "Unsuitable low quality will be associated with short life and high maintenance costs," In his editorial comment in BRE News (7) Burt asserted:

The main pressures for improvement of quality in construction come from two sources. The first is the increasing cost of maintenance compared with first cost . . . The second is the increasing social and legal pressure, including the European Economic Community draft directives on product liability and on building products.
In 1987, Building Maintenance Information Limited (8) produced a Building Maintenance Cost Trends which identified a continuous increase in the maintenance costs of buildings in the UK since 1980. The cost trends were supported by the "Housing Revenue Account Statistics" published by "The Chartered Institute of Public Finance and Accountancy" (9) in the 1983/84 fiscal year; 23% of the total expenditure on housing in England and Wales was spent on repair and maintenance of the existing housing stock. These costs rose to 27% in the 1988/89 fiscal year; representing an increase of 4% within the five year period. This could be the trend in the other sectors of the UK Building Stock and the increase could probably be attributed in part to an increase in defective buildings. However, an investigation will be required to confirm this assertion. The figures above for the housing sector are an indication that action is required.

The problems of the construction industry have also been the subject of numerous reports since 1946. The reports have taken many different forms. A few are the considered views of individuals, the Emmerson Report (10) for example. Some are the outcome of comparisons based on overseas visits, especially to Canada and the United States; for example the "Productivity Team Report on Building" (11) by a European productivity mission to the USA in 1950 and the study "UK and the US Construction Industries" (12) published in 1978. Others have been the work of Committees of Enquiry appointed by Ministers of Works or, more recently, by the National Economic Development Office such as the Banwell Report (13), the Phelps Brown Report (14) and the Wood Report (15). Others have been commissioned by the industry, sometimes to deal with mainly institutional matters, as, for instance, the Harper Report (16). In addition to the above, many current reports are also referred to in the text. These reports point out the unsatisfactory performance of our industry and they all called for improvement.

The application of quality systems terminology to the production of buildings shows that the process can be considered under two main headings:
1. The Design Quality: This is the quality determined by consultants on behalf of the client. It is the quality standard required by the contract and described in the appropriate documents.

2. The degree of conformance to specified requirements: This is the extent to which a building or part of a building conforms to the requirements of the client as contained in the production information issued to the contractor.

This definition implies the extent of the contractor's responsibility to comply with specifications and other production information in fulfilment of his contract to the satisfaction of the client. The definition of "quality" for the purpose of this research is item 2 above: "the degree of conformance to specified requirements."

From the various debates and reports, there appears to be a general consensus that there is a need to further improve the performance of the industry. With increasing competition from firms in other advanced countries (e.g., Japan, USA, Germany and France), there can be no place for the wastage of time and effort involved in any failure to achieve required standards of work at the first attempt. Quality has an essential part to play in improving the performance and competitiveness of the industry. The production of the quality required at the first attempt is not a question of academic interest, it is of vital importance to satisfying client needs.

The trend in the building industry at present is that all or most of the work on site is carried out by subcontractors. They are also, in one way or another, responsible for supplying to site most of the labour and materials. Subcontractors also contribute substantially to the design of buildings.

At the end of 1987, the Co-ordinating Committee for Project Information (CCPI) published (17) a set of conventions intended to produce general improvements in
documents used for the procurement and the construction of buildings in terms of their technical content, effectiveness and co-ordination between these aspects. Among the summarised problems being addressed by the guide to the convention was:

The nature of the building industry had been subject to change. Specialist design consultants were found to be used more frequently and construction work was extensively sub-contracted. Because of this, the process and co-ordination of the two phases of building production had become more important in maintaining required quality standard in a completed building.

Pateman (18) said "We live in the world of the subcontractor. Visit any building site and you'll see him there in a wide variety of guises . . ." In April 1987, A. Charlett (19) said:

Regrettably, as far as control is concerned, more and more contractors are tending to use subcontractors and it has been noticed that quality has started to decline.

The main contractor today organises and co-ordinates the activities of subcontractors who in turn engage the services of their direct employees or mainly self-employed operatives to carry out the works. In this respect main contractors differ little from management contractors. In addition to the references given above, the points are supported by the report of a study titled, "Faster Building for Commerce"(20).

From observation, it appears that quality problems are often associated with the manner in which quality standards are established. Other important factors include the timely communication of project information to site, and the roles, and responsibilities of all participants in the building process. In 1983, the National Economic Development Office (NEDO) published a report "Faster Building for Industry" (21) based on BRE and other research. One of its key findings is that work on site must be based on full information, communicated clearly and in good time. Pateman (22) points out that the achievement of quality assurance in relation to construction management relies among others upon "clearly specifying to the work-force the desired standards of quality in their performance." There are also
difficulties associated with the integration of design and construction and the coordination of subcontractors which often results in increased costs which in some cases have quality implications.

Current professional practice tends to encourage fragmentation of design and construction with a consequence that problems relating to communication and coordination are encouraged. These difficulties have a direct bearing on the quality and functional performance of buildings. Hence, the research aims to address the difficulties facing contractors in achieving conformance with specifications, at first attempt.

1.3 WHY ARE WE CONCERNED ABOUT THE QUALITY OF OUR BUILDINGS

Quality in construction in its widest definition affects everybody. Poor or bad design, non conformance to the specified requirements and bad or inadequate maintenance all come under the heading of levels of quality in our buildings. Below are some of the possible reasons why various parties should be concerned about the quality of our buildings:

Clients
- loss in value of the building
- disruption to users
- increase in maintenance and repair costs
- loss of profits/rents

Contractors
- waste of time due to rework
- disruption of management procedures
- loss of profit
- loss of bonus by operatives
- low/loss of morale
- low productivity
- liquidated/ascertained damages
- loss of market share/goodwill

Designers
- loss of market share/goodwill
- payment of compensation
- legal fees
- increase in insurance premium

Construction - loss of public confidence

Industry - loss of bargaining power
- loss of international market to competitor

General - nuisance/inconvenience

Public

This list is by no means exhaustive, however, it demonstrates that there is no room for complacency.

1.4 THE AIM OF THE RESEARCH

The research proposes to explore the nature of the current construction process in order to establish the difficulties that contractors may encounter in achieving conformance to specified quality requirements on building sites and to develop a viable solution for overcoming the difficulties.

1.4.1 The Research Objectives

1) The first objective

To identify the factors (difficulties) influencing the achievement of conformance to specified requirements during the construction of a building and to establish the relative importance of the factors.
2) **The second objective**

To use the concepts of the "soft" systems thinking methodology to develop an effective solution for overcoming some of the difficulties facing the construction team in achieving conformance to specified quality requirements.

**1.5 THE RESEARCH HYPOTHESES**

Having stated the aims and the attendant objectives, the objectives are then viewed through logical constructs called hypotheses. An "hypothesis is a logical supposition, a reasonable guess, an educated conjecture which may give directions to thinking with respect to the problem and thus aid in solving it" (23). Leedy also noted that hypotheses are necessary because (a) the researcher needs to have some points around which the research may be oriented in terms of searching for relevant data and b) they allow us to comprehend the research project and the motives of the researcher.

The term "hypothesis" can bewilder many people hopelessly unless they understand that it has two entirely different meanings in the literature of research. The first of these two meanings is limited to a statistically – oriented hypothesis. When one comes across the phrase "test of hypotheses," this refers to a statistical hypothesis, commonly known as the null hypothesis. The null hypothesis postulates that there is no statistically significant relationship between the variables. If a relationship does occur and the magnitude of the relationship is such as to exceed the possibility of its having been caused by random error or pure chance, then we conclude that some intervening variable(s), aside from the factor fortuitousness of nature is energising the data and, in consequence, we reject the null hypothesis. "It is this comparison of observed data with the expected results of normative values that we call testing the hypotheses, or perhaps more accurately, testing the null hypothesis" (23).
The second meaning restricts the word hypothesis to a research-objective-oriented hypothesis. Schvaneveldt and Adams (24) point out that:

The second style is frequently referred to as a directional hypothesis. In the second meaning, a hypothesis exists because the research problem or the sub-objectives issuing from it arouse a curiosity in the researcher's mind which, in turn, results in the position of a tentative guess relative to the resolution of the problematic situation.

Leedy also asserted that the purpose of a research-objective-oriented hypothesis is a very practical one. It provides a tentative objective, an operational bull's eye, a logical construct which helps the research look for the data. Based on the conclusions to which the data force the person, the researcher must either confirm or deny the hypotheses as posited. "This style is commonly used when previous research has demonstrated the possibility of a directional relationship between two or more variables" (24).

In constructing the hypotheses for the research, the author has opted for research-objective-oriented hypotheses because, previous studies (1), (25), (26), (27), (28) in the research area and the author's practical experience has demonstrated the possibility of a relationship between the stated variables. The hypotheses developed after the preliminary reading and initial discussion with some specialists in the industry are:

1. The degree of conformance to specified quality requirements tends to be positively influenced by identifiable factors which have different magnitudes.
2. The establishment and timely communication of specified quality requirements by the construction team tend to have a high degree of influence on the achievement of conformance to specifications.
3. The development and introduction of a specific system to guide achievement of conformance by the construction team is more likely to provide an effective solution than a general, non-directional, concern "for doing well" all tasks.
The above hypotheses were later refined and expanded in the light of the information and knowledge gained from the literature review described in chapters 3 and 4. Hence, the following are taken as the research hypotheses:

HYPOTHESIS A1

The achievement of conformance to specified quality requirements on construction sites tends to be positively influenced by a number of identifiable factors.

HYPOTHESIS A2

The factors influencing the achievement of specified quality requirements are more likely to have an order of relative importance.

HYPOTHESIS A3

The accuracy of production information defining the required quality standards tends to be an inherent part of the factors influencing conformance on construction sites. Hence, elimination of subjectivities and ambiguities in specifications by contractors through establishing the required quality with the client representatives, will have a high degree of influence in achieving acceptable quality at first attempt.

HYPOTHESIS A4

Lateness in issuing production information by clients representatives and subsequently by contractors often causes quality problems. Hence, the timely communication of specified quality standards by a contractor to other members of the construction team will have the highest relative importance in achieving conformance to the specification at first attempt.
HYPOTHESIS A5

The application of "soft" systems thinking methodology is more likely to provide clues for developing an effective solution to overcome some of the difficulties facing construction teams in achieving quality at first attempt than any "hard" system approach.

HYPOTHESIS A6

The development and implementation of an evolutionary quality system to guide achievement of conformance to specifications at first attempt by the construction team is more likely to provide an effective solution than the existing non-systematized quality measures.

References to the research hypotheses in the text are those of hypotheses A1 to A6 which now supersede the original 3. The extent to which the research data confirms or denies these 6 hypotheses will be evaluated in Chapter 11.

1.6 THE DELIMITATIONS

There are various areas directly or indirectly related to the topic of quality in construction. The topic is wide and subject to varying interpretations. It will be totally unrealistic to assume that the research will cover all the relevant areas. Therefore, it is imperative to indicate the areas contiguous to the problem which are expressly ruled out of the investigation. Leedy (23) asserts that:

Delimitations would be clearly set forth. It is well for all who read the research to know precisely how much area the research endeavour occupies. Without any equivocation the lines should be drawn to demonstrate exactly what areas relevant to the problem will not be studied.

The following areas are ruled out of the investigations:
1. The study will not evaluate the contribution of client's brief to the overall functional performance of buildings.

2. The study will be limited to "conformance to specified quality requirements" and not the quality of the design.

3. The study will not evaluate the possible effect of government policies on the quality of the construction industry products.

4. The study will not evaluate the motivational and behavioural aspects of siteworkers.

5. The study will not evaluate the quality of maintenance as it affects the overall functional performance of buildings.

1.7 THE RESEARCH ASSUMPTIONS

By definition, to assume is to take for granted, to pretend to take upon oneself or to claim something to be true or untrue. Certain basic assumptions underlie the statement of every problem. So basic are assumptions that without them problem(s) could not exist. This is illustrated by the research assumptions stated below. If the author cannot assume these, then there is no problem, for it is upon these assumptions that the research objectives rest.

Leedy (23) points out that:

Assumptions are what the researcher takes for granted. But taking things for granted may be the cause of much misunderstanding. What I may assume, you may never have thought of. If I act upon my assumption and in the final result such action makes a vast difference in the outcome, you may face a situation that you are totally unprepared to accept. To know what is assumed is, therefore, basic to a course of action.
If we know the assumptions a person makes, we are then better prepared to evaluate the conclusions that result from such assumptions. Leedy (23) noted that many students by stating assumptions could be stating the obvious, but because in research nothing is left to chance hence the prevention of any misunderstanding, all assumptions which have a material bearing upon the problem should be openly and unreservedly set forth. To do so helps to provide a setting for appreciating the problem more fully. In view of the above, the research assumptions are:

1. **The first assumption**: In the view of the debates between the professional groups within the construction industry and the client's organisations in UK, there appears to be a general consensus that there is a need to further improve the performance and competitiveness of the industry.

2. **The second assumption**: The achievement of specified quality standards by contractors has an essential part to play in improving the performance and competitiveness of the industry.

3. **The third assumption**: The achievement of specified quality standards at the first attempt is not a question of academic interest but of vital importance to satisfy clients needs.

4. **The fourth assumption**: The current structure of the construction industry which tends to encourage fragmentation of design and construction will continue.

5. **The fifth assumption**: Despite the works already done by the coordinating committee for project information (CCPI), the problems associated with production information issued for construction by the
design team will remain applicable for a considerable number of years.

1.8 THE RELATIVE SIGNIFICANCE OF THE RESEARCH

There have been some research studies in the focal area of the study. However, the establishment of the relative importance of the factors affecting the achievement of specified quality standards are yet to be fully explored. Various points have been identified as the causes for non-conformance to quality requirements in construction. For example, site management or contractor's organisation problems have previously been mentioned (1) (25) (26) (27) (28). However, the component parts of these causes have yet to be identified and a solution proposed. The factors perceived to date are in broad terms and are not good enough. All participants in the construction process demand to know the primary causes in order to direct their limited resources effectively. No attempts to quantify the relative importance of individual factors have so far been made.

The identification of the influencing factors and the establishment of their relative importance would potentially bring to the attention of contractors, the important issues to be addressed if the specified quality requirements are to be met at the first attempt.

Equally important is the fact that senior site representatives are responsible for communicating the specified quality requirements to operatives through the contractual chain. However, there is no system for them to carry out this significant role. One of the research needs identified in a BRE report (1) is the "preparation of complete, correct and timely project information; communication and compatibility between design and construction." No work in this area has been published. The development and introduction of a "quality system" for contractors should go a long way towards solving the problem.
Both these proposed research outcomes should prove a significant contribution to the knowledge in construction management as they will push back the frontiers of our knowledge about achieving quality in construction.

1.9 ABBREVIATIONS EMPLOYED IN THE THESIS

Some words have been shortened in an attempt to make the thesis compact without losing its readability. Some of the abbreviations are not commonly used in the construction industry, therefore it is imperative that their meanings are set out at a very early stage in the report to aid readers. Below are the abbreviations which readers may find unfamiliar in the text.

QCS Quality communication system
QRM Quality review meeting
QCWS Quality communication warning system
QCCD Quality communication control document
IRS Information release schedule
RD Root definition

1.10 ORGANISATION OF THE REMAINDER OF THE STUDY

The remainder of the thesis is organised in a sequential order, under ten chapters (ie chapters 2 to 11). Each chapter covers a specific area of the research. While chapter 2 describes in detail the methodology of the research, chapter 3 deals with issues of quality culture in the UK construction industry. The findings of a review of previous studies in the area of quality in construction are reported in chapter 4. The rationale for the selection of projects as case studies, the approach and the findings are described in Chapter 5. A detailed report of the individual case studies is dealt
with in Appendices D, E, and F. Chapter 6 explores the concept of stages 1 to 4 of the "soft systems thinking methodology" with a view to examining some of the problems facing contractors in achieving conformance to specified requirements. Chapter 7 describes the research questionnaire.

The main data analysis is covered by Chapter 8. The chapter also covers some of the quantitative aspects of the data required for the development of a quality communication system. The discussions and evaluation of the research findings in terms of its practical applications are described in Chapter 9. Chapter 10 is exclusively the domain of stages 5 to 7 of the soft systems thinking methodology and of the new "quality model" entitled "Quality Communication System". Chapter 11 covers conclusions and recommendations.

The appendices contain supplementary aids which are valuable information to understanding the text material more completely but which are not absolutely essential to following the argument developed in the body of the report. Apart from Appendices D, E and F, the appended data are largely numerical values, scores, statistical computations and other similar data, so that if the reader might wish to check the statistics of the study to confirm their accuracy.

The last section of the thesis, is the bibliography. It contains the reference material that was consulted during the course of the study. Should anyone wish to read further in the area of the research or in corollary areas, the bibliography items provide that opportunity.

1.11 SUMMARY

This chapter has set out the aim and scope of the research. It has also identified the need for the research and its relative significance in the light of the state of the
art in the field of quality management in construction. The next stage is the research methodology.
CHAPTER 2

THE RESEARCH METHODOLOGY

2.1 INTRODUCTION

The research methodology described in this Chapter is based on the framework set out in Chapter 1 and the discussions held with some specialists in the construction industry. The methodology is discussed under the five distinct phases in which the research was carried out. They were undertaken as a strategy for an integrated approach to resolving the aims and objectives and hypotheses of the research. These were executed within the context of the assumptions set out in Chapter 1. The sequence, logic and interdependence of the strategy is shown diagrammatically in Table 2.1. This Chapter describes also the rationale for adopting the research methodology and the computer software selected for the statistical analysis of the questionnaire.

2.2 STRATEGY

The research objectives, hypotheses, delimitations, assumptions and their relative significance were determined prior to establishing the strategy for gathering and interpreting the relevant data. This enabled the author to arrive at factually based conclusions and recommendations set out in Chapter 11. The intention was to establish a methodology for the treatment of data which would be appropriate to the nature of this study.

Leedy (23) asserted that it is important to recognise the fact that data and methodology are inextricably interdependent. For this reason, the research methodology must always consider the parameters and nature of the data. Adams and Schvaneveldt point out that:
A research design refers to a plan, blueprint or guide for data collection and interpretation, sets of rules that enable the investigator to conceptualise and observe the problem under study. The purpose or intent of a study defines the type of design that should be used.

The research is exploratory, in that the case studies are observations which the research generates directly. This is derived from the nature and objectives of the research. As Adams and Schvaneveldt (24) stated, "These explorers were seeking new information and new insights." This study is seeking new information about the difficulties facing contractors in achieving conformance to requirements. The research is analytical in nature as a result of the first objective which seeks to establish the relative importance of the factors influencing the achievement of conformance to requirements. Therefore the research data must be exploratory and analytical in character.

The research was carried out in five distinct phases.

1. Literature review. This includes an investigation into the quality culture in the construction industry and a review of previous studies in the area of research.

2. Direct field observations: case studies.

3. Development of a "conceptual model" based on root definitions formulated for the contracting sector of the construction industry.

4. Development and analysis of a questionnaire to obtain quantifiable data.

5. Comparison of the conceptual model with reality.
2.2.1 Literature Review

The main goal of the literature review was to develop a knowledge and understanding of previous work and activity in the field of quality management in construction. This was set within both a general context and the particular issue of conformance to specified requirements by contractors. The literature review was also important because it raised the author’s awareness of the main findings, trends, areas of debate, controversy and neglect. Suggestions for additional research as well as refined possible hypotheses were also considered relevant to the state of the art. Adams and Schvaneveldt (24) noted that a basic way of relating research to that of others is through a literature review that builds and weaves in with other research. This point was supported by Phillips and Pugh (25). The review of literature helped to assure that the newly generated results would be fitted and cemented into the "wall of knowledge and theory." It helped to determine the direction of additional research on the topic of conformance to specified requirements in construction and indicated specifics to be considered for measurement. Thus the review helped to assure that the research was well focused on the main objectives of the study. Without this integrative feature in the research study, the likelihood of the study being an isolated piece of work was considered to be high. In this event, the new "brick of data" is unlikely to be integrated into the "wall of knowledge" rather, it is expected to be the foundation stone on which a whole wall may be built in the future. For the purpose of this research, literature is considered to be all information in printed or oral form which is available on the topic of quality management in construction as well as on other subjects related to the research methodology.
A computer assisted search was carried out. A prerequisite to the computer assisted search was that the research topic had to be described in subject terms. The following subject terms were identified:

- Quality control in building or construction.
- Quality in construction.
- Quality in building.
- Quality assurance in building or construction.
- Conformance to specifications/requirements in construction.
- Quality standards in construction.
- Systems thinking.
- Systems practice.

The use of the above subject terms in a computer assisted search resulted in over two hundred sources. The sources were followed up.

2.2.2 Case Studies

Field observations and interviews were carried out as case studies on three selected building projects. Direct observations were considered more reliable than "what people say" in many instances. The approach was intended to be in-depth and comprehensive. It has been successfully used in the field of construction, social work, law, economics and medicine. As part of the data required for the research objectives, the case studies were intended to:

1. Provide a means for direct site observation during the construction of each building with a view to establishing statements of facts as to the faults and defects which actually occur on each site.

2. Establish anomalies resulting in faults and defects.
3. Find how the faults and defects could have been avoided.

4. Provide clues to the difficulties (factors) that the construction teams face in achieving conformance to specified quality requirements.

5. Provide opportunities to obtain first hand practical ideas/opinions that would assist the discovery of a viable solution.

The case studies do not attempt to provide a complete solution to the main objectives of the research. However, the ideas and opinions gathered at this stage would be used as one of the instruments for structuring the questionnaire, developing the conceptual model and act as a check on the results obtained from the responses to the questionnaire. The facts derived from the case studies are recorded objectively prior to being qualitatively analysed.

2.2.3 Conceptual models

After the completion of the case studies and prior to the development of the questionnaire, a conceptual model was developed. The conceptual mode was developed through the application of stages 1 to 4 of the soft system thinking methodology. The model was examined by the author and, subject to some amendments, the conceptual model was accepted as a working hypothesis based on the root definition. This formed a major part of the instrument used for the development of the questionnaire.

2.2.4 Questionnaire

The following were used for the development of the mail questionnaire:
1. Results of the literature review.
2. Findings of the case studies.
3. The conceptual model.

The ideas and opinions identified in the above instruments were translated into specific questions.

The responses to the questionnaire marked the final stage of gathering data for the research. The next stage of the study was the analysis of the data. Various methods were available in the literature for carrying out the analysis. In order to select the most appropriate statistical method, the goals to be achieved with the analysis were set out and used as a guide. A review of alternative statistical approaches was carried out before specific methods were adopted. In the review each method was tested as to its appropriateness for achieving the research objectives. Chapter 8 gives a detailed description of the methods used and section 2.4 briefly describes the computer software used for the analysis.

2.2.5 Comparison of the Conceptual Model with Reality

The comparison of the conceptual model with the real world represents Stage 5 of "soft" systems thinking methodology. The prime objective of adopting this approach is to enable the author to compare the conceptual model (notional system) with what exists at present in the contracting sector of the construction industry. The comparison was to lead into the identification of feasible and desirable change(s) that would be instrumental in developing viable solutions to the problem of achieving conformance to specified requirements in construction.

Finally the research data and its analysis have been critically evaluated in the context of the "state of the art" of quality management by the construction team. The evaluation provided the basis for firming up the relative significance of the
research, refuting or supporting the research hypotheses and for drawing conclusions and recommendations.

2.3 RATIONALE FOR THE RESEARCH METHODOLOGY

Prior to gathering any data for the study, there was a need for a literature review. The literature review derives its function from a fundamental position among researchers that the more one knows about peripheral investigations germane to one's own study, the more knowledgeably one can approach the problems indigenous to one's own area of investigation. Undoubtedly this statement is relevant to this research.

Having identified the research objectives as a result of the preliminary reading, the road was set for the first step in the literature review. As a prelude to the literature review, the author had discussions with some specialists in the research subject area. Appendix B shows the persons consulted. A balance was struck between those consulted. These included industrialists, academics and researchers. After detailed consideration, it became apparent that the following were key factors in the data required for the study:

1. The methodology which should involve direct contact with contractors to achieve an in-depth and comprehensive study of specific projects. This would lead to first hand information on the difficulties facing contractors in achieving their quality goals.

2. The nature of the data should be analytical. Hence it should be quantitative in order to explore by statistical means the possibility of achieving the research objectives.
3. The database collected should be large enough to enable the generalisation of findings and conclusions hence to refute or confirm the research hypotheses.

While factor 1 requires a case study approach, factors 2 and 3 necessitate what the literature refers to as a survey approach. The three factors aligned appropriately with the method required for obtaining both the exploratory and analytical types of data envisaged for this study. With the above points in mind and coupled with the research objectives and the hypotheses the author began to search the relevant literature to find the appropriate data collection method.

The literature revealed an overwhelming support for case studies as the most appropriate method for collecting hard information. The case study approach would provide the opportunity for direct contact with contractors thereby allowing an in-depth and comprehensive study of building projects during the construction phase.

The next phase was to find a method of gathering data that would be quantitative in nature and large enough to enable generalisation of findings. The options available in the literature were:

1. To carry out more case studies spread over the country with structured interviews.
2. To carry out personal interviews.
3. To carry out telephone interviews.
4. To carry out mail questionnaires.

After careful consideration, a decision was made to adopt the mail questionnaire method because of its advantages over the other methods and its relevance to the research objectives. The advantages of the mail questionnaire are:
- Reduction in biasing error
- Greater anonymity
- Considered answers and consultations
- Accessibility
- Lower cost

In addition to the above advantages, various discussions with potential respondents revealed the fact that they would find it more convenient to respond to a carefully developed mail questionnaire rather than give interviews face to face or over the telephone.

The following were seen to be disadvantages of the mail questionnaire method:

- Requires unambiguous questions
- No opportunity for probe
- No control over who fills out the questionnaire
- Low response rate

Efforts were made to mitigate the effect of the above constraints. The questionnaire comprised straightforward questions which could be comprehended solely with the help of printed instructions. An attempt was made to control who filled in the questionnaire by addressing the cover letter to identified senior site representatives. This was done also in order to improve the response rate. The idea worked extremely well as shown on the analysis of the response rate in chapter 8. In view of the above, the potential constraints of mail questionnaires did not adversely affect the research data.
2.4 COMPUTER SOFTWARE FOR STATISTICAL ANALYSIS

Quantitative analysis of the questionnaire was done by computer. However, some aspects of the analysis were carried out manually. The reason for this is fully explained in Chapter 8. The following computer software was considered for the analysis:

1. Minitab (Extensive statistical analysis)
2. Genstat (General statistics)
3. SPSS-X (Statistical package for the social sciences)

After careful consideration of the capability and flexibility of each software package and their comparison in relation to the intended analysis, the SPSS-X was selected. The software is available on the main frame of the Polytechnic computer facilities.

SPSS-X was used in the data analysis for the following reasons:

1. The logic and syntax of the software are suitable and flexible for analysing the data.

2. The system provides statistical procedures and data management facilities tailored to the particular needs of social type research.

3. The software's subcommands are computationally efficient.

4. The package has been in use since the early 60's. It has been tested and found to be efficient for the type of analysis required for the research.
5. The package is continuously being updated to take account of new developments in statistical analysis (as the case from SPSS to SPSS-X version 2.1 and the current version is 3.1.)

2.5 SUMMARY

The research methodology was carefully considered and the strategy established was found to be appropriate in the light of the objectives, hypotheses and the relative significance of the study as set out in this Chapter. The sequence and logic of the strategy were designed to show clearly the relationships and interdependence of the five distinct phases of the research. The goals of each phase were highlighted. Each phase was carried out from the contribution made by its preceding phase. Hence the methodology formed an integrated approach to resolving the research objectives and to provide data to test the hypotheses. This assertion is supported by the scientific rationale given for the adoption of the methodology.

Three computer software packages were evaluated for the quantitative analysis of the questionnaire. The evaluation resulted in the selection of SPSS-X as the most appropriate software for the analysis. The methodology provides a strong scientific base upon which the research was carried out.

Having set out the research methodology, the next chapter describes the current quality management process in the building industry and the application of soft systems thinking methodology to achieving conformance to specified quality requirements.
CHAPTER 3

QUALITY CULTURE IN THE CONSTRUCTION INDUSTRY

3.1 INTRODUCTION/PHILOSOPHY

As outlined in chapter 2, the first phase of the strategy for the research methodology is the literature review. The review is in two parts. The first part described in this chapter includes an investigation into the nature of current quality management in the construction industry. The investigation was carried out by a detailed review of all information in printed or oral form which is available on the topic of quality management in construction as well as on the subject of systems methodology for resolving ill-structured problems. The main goal of this part of the literature review was to develop a knowledge and understanding of the way in which quality management is being carried out in the construction industry and to find the appropriate systems methodology for resolving the quality problems that often arise.

The review has provided the author with sufficient knowledge and understanding required for the next stages of the research. The knowledge gained from the review was used in carrying out the case studies, to make the conceptual model and as part of the instruments required for developing the questionnaire.

3.2 THE APPROACH

Quality can be measured by clearly laid down requirements. Newlove (30), Pateman (31) and Cornick (32) use the concept of conformance to requirements as the definition of quality in construction. Oakland (33) argued that quality is simply fulfilment of requirements.
Achieving conformance to specified requirements is attained through effective management by all project participants and through every phase of a project. There are "customers" who have requirements and "suppliers" who must conform to such requirements. However, in the construction industry, the ultimate customer is the client and the ultimate supplier is the project team. The review of quality culture in the construction industry is carried out under the following headings:

1. The development of quality standards in construction.

2. The Client's brief which must accurately define the Client's requirements and the procurement method.

3. Quality of the design phase.

4. Quality management during the construction phase.

5. Quality assurance and the construction team.

6. Quality management in the manufacture of building materials and components.

7. The systems approach to solving world problems.

The review will be carried out in the context of the existing quality management activities in the industry.

3.3 DEVELOPMENT OF QUALITY STANDARDS IN CONSTRUCTION

Building regulations and standards in building did not have a separate or distinct entity earlier than the beginning of this century. Today standards in building and
By 1918, the Engineering Standards committee was incorporated in the British Engineering Standards Association whose activities were mainly related to the engineering industry. Therefore 1926 saw the first licence issued permitting a manufacturer to use the Kitemark; and by 1929 when a royal charter was granted to the Association, about one hundred standard specifications for building were in existence (36).

In 1931, when a supplementary charter was granted, the terms of reference were enlarged to cover industry as a whole and the name of the Association was changed to the British Standards Institution (BSI). Since then, there has been a steady rise in the number of British standards published, so that there are now in the region of 10,000 (37).

The 1965 report (38) of "The Ministry of Public Building and Works" (MOPBW) Committee on Agreement identifies the need to establish a national authority for testing and assessing new building methods and materials. In 1966 the Agreement Board was set up as an independent Company Limited by Guarantee. In 1968, the then Ministry of Technology appointed the Mensforth Committee to review national arrangements for attainment of quality in the engineering industries. The work of the committee led BSI to publish in 1972, BS 489: "A Guide to Quality Assurance" (39).

The first International Laboratory Accreditation conference (ILAC) was held in 1977 in Copenhagen; and the BSI introduced a "System for the Registration of Test Houses of Assessed Capability." In the same year BSI set up the Quality Assurance
Division at Hemel Hempstead. BS 5750: "Quality System" was issued in 1979. Also in 1979, BSI started its Registered Firms of Assessed Capability scheme and issued a consultative document titled "The Quality Assurance Council of BSI - its present and future Role." In 1982, the Agrément Board became the British Board of Agrément. BS 8000: "Workmanship on building sites" was issued in 1989 and when completed it will comprise of fifteen parts covering all site operations from excavation to hot and cold water services.

While British Standards (BS) were the first key influence on quality in construction, the second key factor was the Building Regulations and Codes of Practice (COP). An early objective of such regulations was to prevent the spread of fire and to enhance health and safety of the inhabitants (34). But matters relating to quality were soon introduced.

The Building Act 1984 made no mention of quality; its provisions, through frequent reference to British Standards and a still somewhat cautious reference to quality assurance, is and will, as its predecessors did, continue to have a strong influence on the quality of construction. The Act was used for the preparation of Building Regulations 1985 (40). The 1990/91 revised edition of the Building Regulations is currently in use.

The existence of BS, COP and building regulations is of little value in itself unless they are known, recognised and in constant use. The practical use of BS in the day-to-day work in an industry such as construction is an essential requirement to raise efficiency, ensure quality and give genuine productivity. The construction industry is characterised by the extreme diversity of its output and the complex co-operative efforts needed to meet the varied demand.
3.4 THE CLIENT AND THE BRIEF

The first fundamental of quality as defined by Crosby (41) and Mortiboys (42) is the definition of the customers needs and expectations which must be translated into clearly defined and measurable requirements for construction projects. Often, there were conflicting views between a client and their designers. Pateman (31) states

Clearly, the building user (client) perceives quality in terms of "degrees of excellence." In the eyes of the designer, quality is related to the needs of the users.

In some cases where there were conflicting views in their understanding of quality, the client often ends up with an unsatisfactory building.

The briefing stage demands active co-operation of the client. A Building EDC booklet published in 1985 (43) suggested seven steps to success in commissioning a building by clients. BRE publication (28) stressed the importance of the clients involvement in all phases of a building project and provide a checklist as a framework for developing an initial brief.

Equally important to clients in achieving a satisfactory building is the procurement and tendering process. Although NEDO publication (20) asserted that there is no proof of a best procurement method, the tendering process is still a problem in the industry. The comprehensiveness of tender documents, the time allowed for preparing a tender and the selection of tenderer are some of the key issues that required change and new ideas. The Building Quality Workshop (44) held in 1985 at the University of Reading concluded that prequalification of bidders or evaluation of bid proposals should not be based on money but on more fundamental points that are equally relevant to achieving conformance to requirements. Lack of coherent responsibility for quality is apparent in the industry. BRE/IOB Symposium (4) concluded that "other factors which affected quality included lack of clarity in allocation of responsibilities between consultant, contractors, subcontractors and labour." One of the key areas which have
fundamental flaws said Sir Clifford Chetwood (45) is that "project teams are fragmented in a number of "warring tribes" where no-one is in charge. Contractual arrangements encourage confrontation and adversarial attitudes." In the author's opinions, these inadequacies have their root in the "form of contract," "contract conditions" and attitudes generally prevailing in the industry.

Clients are now becoming more aware of their needs and expectations. They now increasingly employ advisers to help in the preparation of their brief. Some of the clients have commissioned construction projects abroad and now demand the same quality standards that they often obtain outside UK. Apart from the British Property Federation's (BPF) "form of contract," some clients now have their own "form of contract" tailored to their particular needs. Ashley (46) states that "clients will increasingly demand greater value for money." Clients are now coming together (more than before) under different bodies to make their views known and to influence both the construction industry and the government on issues concerning construction facilities. Some of the larger clients are working toward the BS 5750 quality system. PSA being the largest single client organisation and the first to obtain third party certification of its quality system led the way. This will put more pressure on the project team to adopt formal quality system.

3.5 THE DESIGN PHASE

The advancement and changes in the roles of the clients have not been matched with the same improvement by the designers. The object of design and the preparation of "production information" is to express client requirements. In recent years, the use of specialist design consultants has become more frequent. Therefore, because of the greater number of people involved in both the preparation and use of "production information" there is an increased risk of misunderstanding and oversight. The quality and co-ordination of the production information has become more important. Inadequacies in production information
have been identified by a number of studies and reports among which are (1) (26) (28) (47)

The production information is the key communication of the client’s quality requirements to contractors. In order that clients may obtain satisfaction from their buildings, the production information must be right and presented in such a way that compliance can actually be checked. Pateman (31) points out that "you must be able to measure quality. If you can't, you'll never know whether or not you've got it."

Despite all the discussions and campaigns, there are few formalised quality assurance systems similar to BS 5750 in design practices; and awareness and interest have generally been slow to emerge. This may change as more clients become interested in quality assurance and may procure design consultants together with other professional services on the basis of them having full certification.

Huntley (48) asserted that:

> Good design embraces such things as getting a proper brief, ensuring the design matches the client's requirements, prescribing the best material for the job and making sure that what is inked on the drawing board can be built on the site.

This sounds good, but the reality in the industry is still far from the picture painted by Huntley.

The study published in 1981 by the York Institute of Advanced Architectural Studies (47) revealed that the design process is inherently complex with uncontrollable delays which is further complicated by having to work on different stages of different projects at the same time. Equally important is the shortage of time which often resulted in a) only a small proportion of the available relevant written information was consulted, reliance being placed on memory and experience; b) design decisions were poorly recorded, so that it was often difficult to

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backtrack or pick up the threads when a job had been delayed; c) drawings and
other documents prepared by junior staff were not checked before issued for
construction. The findings of the study seem consistent with the BRE studies (1)
(28) The frequent lateness and poor co-ordination of information and the
difficulties of getting prompt answers to site queries are made more understandable
by the results of the studies.

3.6 QUALITY MANAGEMENT DURING THE CONSTRUCTION PHASE

In the majority of cases, the complete construction implications are not known at
the tender stage due to the scant level of information issued in tender documents.
Also the time allowed for the tendering process is often very short. Subcontractors
usually have an even shorter space of time to consider these implications when they
submit their bids. Ambiguous items in the tender documents are often not clarified
by both the contractors and their subcontractors which often results in a contractor
not allowing sufficient money in the tender to cover the perceived quality
requirements and the necessary overheads required to carry out the project.
Alternatively it may add disproportionate amounts to cover his risk resulting in
inflated tenders. On site, quality management is seen by many participants as issues
of control and inspection. However, what little inspection there is, is unplanned and
irregular. They are often too late and fail to detect faults. Newlove (30) states:

Only the contractor has the responsibility and power to achieve
specified standards. Experience suggests that the contractor's
inspection and control arrangements are rarely sufficient on any
contract of any kind . . . casual inspection methods are not likely to
be effective and could leave large section of defective work until a
time is reached when it becomes unreasonable to remove them.
Planned inspection routines, coupled with the use of checklists will
help to obviate the risk of missing out work which needs to be
inspected.

Clients are being represented on site by Clerks of Works / Job Architects or
resident engineers. However they have no sufficient authority to enable them to
carry out their supervisory roles despite their undoubted practical experience.
Much of their time is consumed in answering contractor's site queries due to inadequacies in the production information issued for construction. As a result, they are left with very limited time to actually control quality on site. Ashford (49) points out:

While responsibility for complying with specifications is firmly placed with the contractor, the unspoken assumption is made that unless the client maintains his own representative on the site to watch and supervise the works the resultant structures or buildings will not be in conformance.

The subcontracting nature of the construction industry makes quality control of individual operative's work extremely difficult and "lowest cost" targets continually force down workmanship standards. Efforts are being made to select subcontractors of proven ability for each site operation. Also, as part of their quality control, some contractors have devised a feedback method of assessing subcontractor's overall performance on previous projects. This method is based on asking project managers to assess subcontractors on a range of items and to award marks on a scale of very good to poor. The records are kept and updated from time to time. This helps contractors to continue to use subcontractors of proven ability and to stop sending enquiries to those that had failed to perform to the specified requirements. Huntley (48) points out:

In this respect, Simons will have to carry on as before, judging subcontractors on their standards of performance on previous jobs. West says: "If they don't perform to the standards or the speed we expect of them, they will not work for us again. It is as simple as that."

There seems not to be a formal procedure or an orderly method of communicating the clients requirements by the contractor to other project participants. Hartstern (50) said "The single most important item in assuring effective quality during construction is communication." Effective communication is lacking in the industry. Maiden (51) said

It is fashionable to bemoan the decline in craftsmanship in building but it is not the root cause. Truly it is lack of communication. Nobody today knows exactly what standard is required ...Granted that the right quality is a desirable aim, it must be clearly stated and fully understood.

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Mackman (52) asserted that "Another key to our success was the major effort we put in to communicate our objectives to all those employed on the project ... ". Pateman (22) asserted that "A lack of communication is the greatest problem to impede the implementation of quality assurance."

The idea of "snag" lists had become a prominent part of quality control by the client representatives. This method may have some impact on the finishing trades, however, its effectiveness in structural, cladding and roofing elements will be minimal. This again demonstrates the fact that there is no formal procedure for managing quality on site both by the contractor or client representative. In the author's opinions, we cannot continue this "crisis management" that tend to characterise our management of quality on sites.

3.7 QUALITY ASSURANCE AND THE CONSTRUCTION TEAM

The need for quality assurance is an indictment of the many inefficiencies in quality control. Problems in buildings, the consequential occurrence of protracted litigation, all result in a loss of professional, commercial and public standing of the building industry. 'Quality Assurance' which encompasses 'all activities and functions concerned with the achievement of quality' (BS 4778) has only come to the fore within the construction industry during the second half of the 1980's, although concern for quality dates back much earlier in a small number of complex, high value and high-risk projects, primarily in the nuclear and power industries and in offshore and petrochemical engineering where reliability and safety are paramount.

With the introduction of BS 5750, there has been considerable disparity of opinion over what quality assurance seeks to achieve. However, there has been a demand-pull by both the private and public clients. Many large private clients now compile tender lists of contractors operating a quality system. The Property Services Agency
(PSA) is moving towards the use of contractors with quality management systems for all its projects. From this demand - pull, it is clear that if for no other reason, contractors need quality assurance systems for survival and for commercial interests.

The principles of quality assurance can be demonstrated in three different types of quality system. The three types are as follows:

1. First Party Assessment. This involves setting up a quality system, documenting the structure and procedures and subsequently notifying the client that a quality system has been implemented. Some small contractors and subcontractors have started this type of quality system.

2. Second Party Assessment. This involves developing a quality system and inviting the client to collaborate in its development to fulfil the requirements for quality as specified by the client. Alternatively, a client may carry out an assessment of an employee's QA system. This type of quality system is not common with contractors or subcontractors operating in the building sector of the industry.

3. Third Party Assessment. Third party or full independent certification being the most detailed. This type represents therefore, the highest level of quality systems implementation. This is independent "full" certification (assessment and registration) under the guidance of BS 5750: "Quality Systems." Some medium and large contractors have started operating this type of quality system. Few subcontractors are working towards this goal.

Many organisations do not require such detailed quality systems or full certification to secure the benefits of a quality management system and therefore, implement
only the intermediate stages of a full certification programme. The level of
assessment to which an organisation aspires is, in real terms, influenced by its needs
and commitment, in fact it remains an organisational prerogative. Any organisation
seeking third party certification must develop their quality assurance system beyond
the first two levels of detail, and become registered with an independent
certification scheme accredited with the Government through The National
Accreditation Council for Certification Bodies (NACCB)

With all certification schemes it is important to appreciate that assessment of a
quality assurance system is based upon "the observation" of an organisation's overall
implementation of management and production procedures, for example a periodic
cross-sectional view of the quality system. These observations may not always
represent a true picture of the day to day application of quality assurance within the
company. The implementation of a quality system itself does not guarantee quality
or insure against inadequacy or failure within construction, but provides only an
assessment of the organisation's ability to work to high standards of quality.

Huntley (48) points out that:

But West is under no illusion about how the BS 5750 system will
affect the end-product. He makes it very clear that attaining
registration will not necessarily improve the quality of their
construction, nor will it ensure the work is done right first time.

It remains to be seen, if those companies operating BS 5750 quality systems are
using it with the right attitude and training as a management tool to improve
performance rather than to get on clients tender lists. Some of the construction
industry's employer organisations and professional institutions are campaigning for
the industry to embrace the ideas of BS 5750 and ISO 9000 quality systems in order
to improve the industry's performance.


In the manufacture of building materials and components, standard specifications now provide an essential basis for quality control of all activities within the factory. They include:

- Operations at each stage of the production process from receipt of the raw material to delivery of the finished products to the building sites.

- The designs for the products in the factory.

- The designs for the machinery and equipment used in the manufacture.

- Requirements for the site assembly of the products and their use and maintenance in the completed building.

The application of standard specifications is normally the responsibility of the design and quality control departments. "The effectiveness of quality control of production operations, based on standard specifications, depends on sound inspection operations" Martin (35). The majority of manufacturers of building materials and components now have trained personnel to carry out inspection and testing. Inspection at each stage of the production process with the object of avoiding rejects has an inherent advantage over the old system of inspection of the finished component which often led to rejects of finished goods.

There are a number of third-party quality assurance schemes currently in operation with specific relevance to building materials and components. The most commonly known schemes are the BSI "Kitemark" scheme and the certification scheme of the British Board of Agrément (BBA). The BSI Kitemark awarded to manufacturers
assessed, approved and licensed by BSI indicates that samples of their product have been independently tested against the appropriate British standard and certifies that the product meets with those standards. The British Board of Agrément tests, assesses and certifies new products or the new and innovative use of existing products. Many building materials and components are being manufactured under the above quality assurance schemes. There is no doubt that progress has been made over the years but there is still a need for improvement to reduce the 10% of quality defects attributed to materials and components by the BRE (66).

3.9 THE SYSTEMS APPROACH TO SOLVING WORLD PROBLEMS

The argument presented in chapter 1 to support the need for the research coupled with the inadequacies identified as a result of the investigation into the nature of current quality management in construction reveal that there are quality problems. Therefore, there is an urgent need for effective solutions. Hence, a literature search to find out the appropriate system to solve the quality problems prevailing in the UK construction industry was carried out and described in this section.

Cursory inspection of the world suggests that it is a giant complex with dense connections between its parts. René Descartes (53), the 17th century scientist, emphasised, not the facts of science but the scientific way of thinking with a view to solving world problems. He gave four rules for "properly conducting one's reason." It is the second rule which is most significant, however, since it encapsulates a prime characteristic of the scientific way of thinking as it has been practised for three centuries:

The second rule was to divide each of the difficulties examined into as many parts as might be possible and necessary in order best to solve it.

A recent study by Ree (54), usefully pays more attention to Descartes physics and the thinking underlying it. The core of Descartes' approach to science, he points out, was reductionist in the sense that "science" should describe the world in terms
of "simple natures" and "composite natures" and show how the latter could be reduced to the former. Here is the principle of analytical reduction which has characterised the Western tradition for years.

The failure of the scientific approach to make much progress so far in its application to the process of management can usefully be examined by looking briefly at the example of operational research (OR) which is the closest management science comes to having a hard scientific core. McCloskey and Trefethen's (55) account of the origin of OR points out that all its definitions emphasise its scientific nature and of course its origins lie largely in the attachment of professional scientists to wartime groups responsible for military operations. What has happened historically is that OR has concentrated most of its efforts on refining its quantitative tools and developing them for specific situations in the belief that problem situations recur. This outlook was expressed by Wild (56) and Churchman et al (57) respectively.

Checkland (58) and Bieshon (59) respectively point out that the crucial problem which science faces is its ability to cope with complexity. Checkland (58) also noted that:

The principle most central to scientific practice assures that the division of a problem into many parts will not distort the phenomenon being studied. It also assumes that the components of the whole are the same when examined singly as when they are playing their part in the whole or that the principle governing the assembling of the components into the whole are themselves straightforward.

The application of scientific methodology to real world situations has not yet been satisfactorily solved although some progress has been made. The solution to a complex problem as is often the case in the real world, cannot in the main be achieved by a reductionist approach or by adopting quantitative tools such as OR methodology. Ackoff (60) recently summarised the situation in a paper the title of which alone conveys the message: The future of Operational Research is Past.
The biologist Ludwif von Bertalanffy (61) formulated the theory of "open systems" which described the process of exchange between a living organism and its surrounding environment. These principles have been successfully applied to project management whereby the project environment can be shown to interact and influence the control of the project. The corollary to the open system is the closed system which generally has a state of equilibrium characterised by maximum entropy. Although it is important to consider all options carefully, the solution to any problem will eventually follow a certain plan with a defined line of thinking. Jackson (62) emphasises that it is difficult to argue against reductionism without a better alternative. Reductionism and expansionism can be conceptualised by identifying those problems which have the greatest influence on the system. Wilson (63) asserted:

Therefore the systems approach must have the ability to decompose complex phenomena into elements while similarly conceptualising and identifying the relations of varying intensity among the elements of the system. From this point of view the system approach lacks methodology and hence there is the tendency to solve each problem in its own right.

3.9.1 HARD SYSTEMS THINKING

The comparison by systems thinkers eg. Checkland (58), Wilson (63), McLoughlin (64) of the scientific approach to problem solving with engineering and technology approaches results in the concept of the "hard" systems thinking theory. Hard systems thinking is based on goal seeking schematic which are utilised to solve problems. Checkland (58) states that hard systems thinking is goal-directed in the sense that a particular study begins with the definition of the desirable goal to be achieved. He also noted that:

Hard systems thinking makes use of the kind of thinking which is natural to design engineers whose role is to provide an efficient means of meeting a defined need. The design engineers exercises his professionalism in a situation in which WHAT is required has been defined and he must examine HOW it can be provided.
This approach is well suited to well structured problems which have clear identities.
Checkland (58) points out that the relevant point about the design engineer's problem is that it is a structured one. He argued that there is a gap to be bridged between the desired future state and the present state; how to bridge it, he said, is the problem. These points are supported by Wilson (68) and Jenkins (65). They all asserted that the hard systems approach tends to break down when the problem to be solved is ill-structured such as, for example, what should be done about the problems in the UK construction industry, or the rising increase in building maintenance costs and the dissatisfaction of clients regarding the quality and performance of their buildings.

3.9.2 "SOFT" SYSTEMS THINKING

The basis for broad systems thinking is eclectic, that is, it draws on many different methods, methodologies, concepts and techniques in its efforts to help us understand real-world systems. As a result of nine studies carried out by Checkland (58) and his colleagues in 1969-72, a different methodology was evolved and has been subsequently tested and modified in more than a hundred studies since then. Such work yields, beyond the action in specific situations, a cumulative account of the nature of the human activity system concept. Checkland (58) called the methodology "soft systems thinking" which is capable of dealing with ill-structured problems, such as "cause and effect" of non-conformance to requirements by the Construction team. Checkland (58) points out that:

In the methodology, the situation in which the perceived problem lies (rather than the problem itself) is "expressed" and this is done, not in systems terms, but by using the concepts "structure" and "process" and the relation between the two.

The successful application of soft systems thinking methodology to ill-structured problems makes it more appropriate (than any other methodology) for solving the difficulties facing construction teams in achieving conformance to requirements.
The application of "soft" systems methodology to the research objectives is described in chapters 6 and 10.

3.10 SUMMARY

A critical review of the quality culture in the industry was made with a view to gaining sufficient prerequisite knowledge for data collection. The review focused on the development of quality standards, clients brief, the design and construction phases, QA and the construction team, and finally, quality management in the manufacture of construction materials and components.

Various BS and COP have been published over the years. The two most current BS relevant to quality management in construction are BS 5750 and BS 8000. Building Regulations are being constantly updated to take into account new developments and experience gained in their application. The 1990 / 91 revised edition of Building Regulations 1985 is currently in use. Progress has been made in the development and presentation of clients brief. However, there is still a lot more to be done in terms of its technical accuracy, the methods of procurement, the quality of tender documents and the time allowed for tendering.

The quality of the design phase is seen as a key factor in communicating the client’s requirements to contractors. The design sector of the industry is slow in operating any formal quality management system. There has not been much significant improvement in the overall quality of the production information, especially that prepared by architects. There is a lack of co-ordinated approach to quality management by contractors. More importantly, there is no formal system or orderly method for establishing and communicating the client’s requirements by the contractor to his team. Some large and medium size contractors have started to operate BS 5750 Quality Systems. Its contribution to achieving conformance to client quality requirements remains to be seen. Quality management is in existence
in the manufacture of construction materials and components. This could be one of the reasons why there are fewer quality problems attributed to materials.

A review of the systems approach to resolving problems was carried out. The soft systems thinking methodology was identified as the most appropriate approach to finding a solution to the difficulties that the construction team may encounter in achieving conformance to specified quality requirements. Part 2 of the literature review is described in the next Chapter.
CHAPTER 4

THE REVIEW OF PREVIOUS STUDIES

4.1 INTRODUCTION

This Chapter is a critical review of selected previous studies carried out in this country and abroad. The rationale for the selection of each study is outlined. In all, fifteen previous studies were examined. However, only nine of the fifteen studies satisfied one or more of the criteria underlying the rationale. Hence, only the nine were critically reviewed and described in this Chapter. The nine represent 60% of all the previous works identified in the literature search. The aim was to raise the author's awareness of previous main findings, trends, area of neglect and suggestions for further research. These were required to focus the present research as well as to refine the research objectives and hypotheses if the need arises. The review described in this chapter helped the author to develop the sequence of the case studies.

4.2 THE RATIONALE FOR THE SELECTION OF PREVIOUS STUDIES

Since the early part of the 1970's, several organisations, institutions and individuals have carried out studies concerned with the quality and functional performance of buildings in this country and abroad. The studies have attempted to identify types of faults and defects, their causes and to provide recommendations for improvements. One cannot deny the fact that progress has been made, however, some key issues still remain unresolved. A critical review of nine previous studies was made in order to demonstrate that the author has a full professional grasp of the background theory and practices in the subject of quality management in construction.
The rationale for the review and inclusion in the thesis of each previous study was based on the following:

1. The relevance of the study to the core of this research in terms of its aim, objectives and hypotheses.

2. The knowledge that could be gained by examining its methodology and comparing it with this research.

3. To select studies that include investigation into general construction as well as housing.

4. To include studies from other countries in order to gain experience that would help in understanding the subject better in the UK.

5. Finally to include the most relevant PhD studies because of their general approach to investigation that could be used as a yardstick for this study.

4.3 BRE: 1975 - FAILURE PATTERNS AND IMPLICATIONS (25)

4.3.1 Scope and method

During the period 1970-1974, the Building Research Advisory Service made detailed investigations of over 500 defective buildings. The data collected was analysed to discover the faults most likely to be encountered and to identify ways in which the incidence of building defects might be reduced. It was published in April 1975 as BRE DIGEST No.176. The investigation involved physical inspection of buildings in use.
4.3.2 Results and Observations

The study was a direct field observation made with a view to identifying faults and defects that might exist on buildings in use. This approach should have provided first hand information on real faults and defects. However, the approach would not be appropriate to establish the primary causes of the defects. The author believes that the investigators recognised this limitation and as a result, the causes of the defects identified were only outlined in general terms. They were unable to give details of the real causes of the defects. However, the study was a worthwhile one as it raised our awareness regarding the general issues of faults and defects in building and their causes in broad terms.

One of the results that is directly relevant to the present research was that a higher standard of supervision was found to be necessary if the more glaring instances of poor workmanship and omission of important details are to be avoided. "Something other than the present system of spot checks may be necessary in critical areas of the construction . . ." (25). The protection of materials and the works was also emphasised.

4.4 ABBOTT, W.W: 1976 - QUALITY CONTROL IN BUILDING WITH SPECIAL REFERENCE TO WORKMANSHIP AND SUPERVISION (26)

4.3.1 Scope and Method

The research was concerned with factors influencing the achievement of the degree of conformity to the requirement of the client during the construction of buildings. The purpose was to identify these factors, to establish their relative influence and to assess the extent to which a typical system for achieving quality is able to exert effective control so that persons concerned with the achievement of quality may find the results of the research of some assistance in meeting their objectives.
The work was carried out under four main headings into which groups the various factors influencing quality were perceived to have broadly fallen:

- Supervision and inspection of building work.
- Building operatives work.
- Specifications and communications.
- Contractual obligations of the contractor.

A discursive study of the factors was made and surveys were carried out in order to make quantitative evaluation of the relative contribution of the factors to overall quality achievement. The data for the research was collected by a survey of opinions of Contractors, Architects, Clerks of Works and Craftsmen based on questionnaires. The data analyses were carried out manually and were purely descriptive, based on frequency, percentage distribution and index.

4.4.2 Results and Recommendations

While the author accepted the aim and scope of the research, the thesis failed to justify the rationale for its selection. There was strong support in the literature for the development and testing of hypotheses in this type of study. The research contained no hypothesis. Surprisingly, there was no mention of the rationale upon which the research methodology was based and it was never described. The author of the study failed to describe how the population sample and the respondents were selected. The sample and the overall responses were very small. This made the generalisation of the findings and recommendations based on the data and the analysis questionable.

The method by which the questionnaires were circulated does not provide a proof that the intended respondents actually completed the questionnaires. Finally the
data were not tested for reliability. Although a Spearman’s Rank correlation coefficient was calculated for part of the data there was no overall test for validity of the research data. In spite of the above constructive criticism of the research, the author felt that the study had contributed to the knowledge base on the topic of quality in building, especially when one viewed the study in terms of knowledge of the topic in 1976. The study was the only PhD Thesis recorded in Alsby in the topic area between 1960 and 1988 in England.

Figure 4.1 illustrates the major factors identified as adversely affecting the quality of buildings. It must be noted that the factors were actually put forward to respondents for them to express their degree of agreement or disagreement. It was not their directly expressed opinion. If the respondents had been asked to express their own opinion directly, the results might have been different. The total incidence of unacceptable quality of work was 16% attributed to architects, 58% to contractors and 26% was attributed to operatives.
<table>
<thead>
<tr>
<th>Contractors, Architects &amp; Clerks of Works</th>
<th>Craftsmen</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Quality of operative</td>
<td>24</td>
</tr>
<tr>
<td>Quality of supervision</td>
<td>13</td>
</tr>
<tr>
<td>Site management</td>
<td>9</td>
</tr>
<tr>
<td>Shortage of skilled operatives</td>
<td>8.5</td>
</tr>
<tr>
<td>Design &amp; Information</td>
<td>8.5</td>
</tr>
<tr>
<td>Quality and supply of materials</td>
<td>8.5</td>
</tr>
<tr>
<td>Payment systems</td>
<td>7</td>
</tr>
<tr>
<td>Irresponsible attitudes</td>
<td>6.5</td>
</tr>
<tr>
<td>Tendering methods</td>
<td>5</td>
</tr>
<tr>
<td>Short contract periods</td>
<td>4</td>
</tr>
<tr>
<td>Subcontractors</td>
<td>3</td>
</tr>
<tr>
<td>Labour only subcontractors</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 4.1  Major Factors Adversely Influencing Quality of Building Work
Source (26)

The relative influence of the factors relating to quality shown in figure 4.1 in percentage terms cannot be taken seriously because it is simply a descriptive analysis without any validation or inferential statistical analysis. A more coherent and defensible method should have been used for the analyses. However, some of the findings and the recommendations are reasonable and still hold today.
4.5 BRE: 1982 - TRADITIONAL (MASONRY) HOUSING - A BRE STUDY OF QUALITY (66)

4.5.1 Scope and Method

The investigation into the technical quality of housing was prompted by general concern about the prevalence of failures in performance which has resulted in very substantial sums of money being spent annually on maintenance and repairs which should not have occurred. The aim of the study was to establish objectively the extent of the problem by identifying the full range of underlying faults in material or components, those introduced in design or during construction which could later give rise to failures and to assess how and why such faults occur. Such information was visualised as the basis for guidance aimed at improving quality generally and, more particularly, at helping people to avoid repeating the faults found.

The research team observed 12 public sector and 3 private sector housing projects under construction with a view to identifying where codes, standards or authoritative advice have not been followed. Such contravention were defined as faults. Faults of site origin were defined as departure from design requirements where these were not themselves at fault. The investigation was supplemented by a brief review of the organisational arrangement for quality in the building industry and in two other industries (Shipbuilding and Civil Aviation).

4.5.2 Results and Observations

The definition given in the report for faults of site origin confirmed the author's second definition of quality as "the degree of conformance to specified requirements." The most significant finding of the study that is relevant to this research was that "there was no evidence of any prior agreement on acceptable standards of site work, except for the perfunctory sample facing brick panel." (66)
It was reported that, on average, the cost of a faulty design detail plus its subsequent remedy was about three times the cost of a fault-free detail. The observers suggested the following as productive subjects for specific investigation:

1. Required quality should be established before tenders are accepted.
2. Closer liaison required between designers and site workers.
3. Designers consciously leave problems for the site to resolve.

These assertions undoubtedly supported this research's hypotheses nos 2 and 3. Nearly 50% of all faults found in the study originated from inadequacies in site practices by the contractors. Items ascribed to design were slightly fewer and materials and components the least.

Interestingly, the study did not rely mainly on physical observation of houses but also on consulting the working drawings and specification. Conflicting views were resolved by discussion with all parties and re-examination of the production information. The author believes that the methodology was scientifically sound and relevant to the objective of the study. Hence, the author has learnt a great deal about site observations which could be found of good use in developing the method and sequence of the case studies in this research. Despite the fact that the study comprises of an investigation of a small sample of sites, the author believes that the number of dwellings observed (1725 dwellings) was large enough for generalisations about the findings. The findings address some of the major issues relating to quality in construction and some of the conclusions and recommendations made are still relevant today. Many of the findings are similar to those identified in the 1987 study by EDC/BRE (28).
4.6 CIOB: 1983 - HOW IS QUALITY DETERMINED ON SITE (67)

4.6.1 Scope and Method

At a meeting of the CIOB Eastern Region Practice Committee, current standards of workmanship and quality in building were discussed. A central concern was communication among members of the building team. The Committee decided it would try to establish the importance of communication upon quality by means of a small survey, the results of which provided an interesting insight to the problem. Questionnaires were devised in order to obtain information at three different levels in the construction management communication chain. The levels are: contract management, site management and supervision.

4.6.2 Results and Observations

The interesting thing about the study was that it was instigated by men in the industry who had a common concern for the problem facing not the Eastern Region alone but the UK. The development and presentation of the questions within the questionnaires was practical. Hence it addressed some of the major issues regarding communication of the client requirements within the construction team. No explicit justification was given for adopting the questionnaire approach for collecting the data and for the structure of the questions. There were also no direct site observations or discussion with other members of the construction team outside the Committee. The author believes that field observations would have provided more hard information to complement the results of the questionnaires. The questionnaires were based purely on the practical experiences of the committee members.

In spite of the above limitations, the following findings are found to be directly relevant to the research:
1. Client's requirements were not adequately passed to contractors by the consultants. Therefore some improvements are required.

2. The contractor's senior site representatives often failed to inform their supervisors and tradesmen of the standards required. There is an urgent need for a formal procedure for establishing and communicating the required quality standards to all participants.

3. In the majority of cases, consultants did not adequately describe the standards of quality which would be acceptable. The production information remained ambiguous, poor, and open to subjective interpretation.

4. There was no evidence that consultants were informed by the contractors of what was possible. This reinforces the need for a progressive movement towards integration of design and construction with the earlier involvement of contractors in the design phase.

5. 100% of contract managers and site managers and 97% of supervisors (foremen) considered that communication contributes a lot to the quality of the finished buildings. This assertion strongly supports hypotheses no. 2 and 3 of this research.

It was obvious from the responses to the questionnaires that a gap exists between on the one hand:

how standards of quality within the established practice of the construction industry are defined (ie. by consultants in the form of specifications with a heavy reliance upon Codes, BS and manufacturers)

and on the other:

58
how standards of quality are established in the site situation.

It would appear from this investigation that site supervisors establish standards and that their decisions are highly arbitrary. Supervisors own experience and supervisory ability therefore determine the level of quality that occurs. This subjectivity may lead to the contractor providing a greater standard than is required or it may create the need for rectification of work because the quality was below what was ultimately found to be acceptable. The "acceptable" standard of quality is again often highly subjective with the standard of the final quality being to a large extent dependent upon the strength of the Clerk of Works, Architect or Client.

The gap between the definition of standards and the actual achievement of standards was accomplished by a series of breakdowns in communication which appeared throughout the whole construction process. The foundations for good channels of communication would seem to exist as there seems to be a high level of stability of relationships within most firms. What appears to be wrong is the lack of written communication with a subsequent reliance upon verbal communication.

4.7 SWEDEN: 1984 COSTS OF QUALITY FAILURE IN BUILDING CONSTRUCTION (68)

4.7.1 Scope and Method

The question of quality in Swedish building construction has been paid considerable attention in recent years. This interest was encouraged by the new series of quality standards ISO 9000 which had focused attention on assurance of quality. A greater responsibility with respect to quality has also been given to building clients through the Swedish building legislation's new planning and building code. Intensive work on improving the quality of supervision is being carried out by all the participants in the building process (68).
Figure 4.2: The reasons for quality failures, totally and for given functions.
Source (68)
<table>
<thead>
<tr>
<th>Type of Failure</th>
<th>Failure Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erroneous workmanship</td>
<td>16%</td>
</tr>
<tr>
<td>Defects in products</td>
<td>14%</td>
</tr>
<tr>
<td>Weaknesses in work preparation</td>
<td>9%</td>
</tr>
<tr>
<td>Erroneous construction</td>
<td>8%</td>
</tr>
<tr>
<td>Incomplete planning</td>
<td>7%</td>
</tr>
<tr>
<td>Disturbances in personnel planning</td>
<td>4%</td>
</tr>
<tr>
<td>Delays</td>
<td>4%</td>
</tr>
<tr>
<td>Alterations</td>
<td>3%</td>
</tr>
<tr>
<td>Setting out failures</td>
<td>3%</td>
</tr>
<tr>
<td>Design coordination</td>
<td>2%</td>
</tr>
<tr>
<td>Other</td>
<td>3%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 4.3: Failure cost distribution for different types of failure
Source (68)
Figure 4.4: Costs of failures distributed according to origin
Source (68)
As a result of the above, the purpose of the study was to stimulate improvements by indicating those situations in the building process where preventive measures are most effective. This aspect formed the basis of the research work presented in the report. The intention was to achieve the aim by elucidating the costs arising from quality failures and analysing their cause, nature and origin. A major study was performed continuously at a large building site. The study was confined to those situations which can be identified from the activity on the building site and relate to quality failures that appear on the building during construction works. By failure it was meant deviation from what was intended. By cost it was meant the sacrifice of one or more resources irrespective of who bears the cost. In order to illustrate the general validity of the results of the in-depth study of the large site, 21 complementary studies were conducted. In all, 1460 quality failures were registered.

4.7.2 Results and Recommendations

The data and its analyses could be judged to be reliable in its own right. However, the study was confined to a particular area of Sweden. How the results were assessed to be a reliable representative of the Swedish construction industry was not explained. 8% of the faults were not treated at all. The result could be compared with the NEDO (28) report described in section 4.8 of this chapter in which no solution was applied to approximately 5% of the quality related events. This illustrates some consistency between UK and Swedish quality problems in terms of resolution of the identified faults. The same pattern emerged with the UK studies in that the cost of failure attributed to design, site management (construction) and materials respectively reflected the fact that quality problems were more associated with contractor's activities than with design related items. The problems associated with materials and components are the least of the three major problem headings.
The allocation of causes to the quality failures was very subjective. This limitation was recognised and the report suggested that the results presented in figure 4.2 should be interpreted with care. One wondered why an accurate assessment of the cause of failures could not be made despite the fact that the observers were present continuously on sites. Having said that, the study is relevant to the topic in the UK and there is a lot to learn from its findings within the constraints of its limitations.

Failure costs for the most extensive types of errors are shown in figure 4.3. Figure 4.4 illustrates the costs of failure distributed according to their origin. A larger part of the costs (approximately 54%) was attributed to the contractor. Again this study emphasises the importance of communication in achieving conformance to requirements (13% of the total factors.) Motivation raising measures at all levels were suggested as a way towards quality improvement and in particular to cover lack of commitment and carelessness. The results of the 21 shorter studies were such that the in-depth study could be considered to be representative of the Swedish construction industry. From the studies, the project group plans to develop materials for internal company education schemes. We await its publication to find out if it would be useful in the UK.

4.8 BRE: 1987 - ACHIEVING QUALITY ON BUILDING SITES (28)

4.8.1 Scope and Method

Appreciating the recurring problems of defects in buildings which have been costing hundreds of millions of pounds annually and the fact that the Government is a major sponsor and client of the construction industry, the National Economic Development Office (NEDO), was concerned with the need to improve levels of performance and quality in UK buildings. The current research studies addressing quality in building were undertaken for NEDO by the Building Economic Development Committee in collaboration with BRE.
The research was designed to identify why and to what extent the quality achieved on some typical one-off building contracts failed to match the expectations of the client, professionals and contractors involved. The research objectives were "to suggest improved methods of quality control for building works by identifying the extent to which quality achieved falls short of expectations and by assessing the contribution of management procedures, project information, site supervision and inspection to standards achieved" (28).

The method adopted for gathering the data was by direct observation of the quality control processes in action on some 50 sites. The observations involved three separate studies each with the emphasis on specific issues. The projects observed were all "one-off" spanning the public and private sectors and using a wide range of procurement and contractual procedures.

4.8.2 Results and Observations

The report was the most comprehensive piece of work on quality management in construction carried out in the UK in recent time. It had served two major purposes: firstly it had filled the gap that had long existed and secondly it had raised the awareness of parties regarding the issues of quality management in construction. In general terms it could be said that the study had achieved its aims and objectives. However, the number of sites included in the second and third surveys was too small to provide representative samples and the conclusive evidence to substantiate some of the hypotheses. The report highlights that in most contract forms the contractor is responsible for the execution of "good quality" work in accordance with the specifications. This responsibility falls to his representatives on site, usually the senior site representative. While this fact was recognised, the report asserts "There are no formal procedures which the site agent can follow in carrying out his responsibility" (28). Apart from the hypotheses formulated and the recommendations the report failed to propose or identify a new formal procedure.
to obviate the difficulties presently facing contractor's agents. It must be noted that one of the objectives of the study was to "suggest improved methods of quality control." Among other things this is an area in which the present research aims to contribute significantly to the knowledge of quality management in construction.

The report points out:

On all the good quality projects, regular meetings between the contractor and the various subcontractors were set up well before the individual subcontractor started work on site. This approach was also used with suppliers where the supply of some items was critical to the success of the project. The intention was to make sure that everyone knew what work was to be undertaken when a subcontractor arrived on site and that the subcontractor knew who in the contractor's organisation to approach in the event of difficulties.

The author considered the above approach as one of the ingredients required for the development of a formal procedure. How this could be carried out in practice is a major concern for the present research. The report asserted:

If information is incomplete or erroneous at time of tender, tenderers have little chance to assess the resources required and price accordingly.

The report suggested that the client's principal adviser should co-ordinate the contributions from all the design specialists. However, the author believes that there is a major role for the tenderers as well and this will be explored in this research. Quality related events were divided into two broad aspects within which particular causes of quality problems were emphasised as illustrated in figure 4.5.
Figure 4.5: Survey 1: Causes of all 501 quality-related events and the effectiveness with which they were resolved. Source (28)
4.9 SANI, A: 1988 - AN INVESTIGATION INTO THE INFLUENCES UPON AND DETERMINANTS OF ACHIEVING PERCEIVED QUALITY IN THE MANAGEMENT OF CONSTRUCTION PROJECTS BY MULTIVARIATE ANALYSIS (69)

4.9.1 Scope and Method

The principal concern of the study was to provide building designers and site management with a theoretical framework from which potentially useful indicators could be derived for the understanding and enhancement of quality achievement in building construction. The aim was to reach conclusions, quantitatively, about the relative importance of each of the independent variables that determine the achievement of quality of work in construction projects. The methodology involved a series of initial interviews with a number of Housing Associations in Edinburgh to explore the key issues. The information collected was used to develop the research hypotheses and the selection of variables for the study. This was followed by the development and distribution of two sets of questionnaires for pretest purposes. The sample was drawn from lists of housing projects currently under construction in Scotland. Respondents were designers and contractor's agents. The final versions of the questionnaires were developed in three main parts and directed to clients, designers and contractors.

4.9.2 Results and Observations

Although the research described the rationale for adopting the so called quantitative method, there was no mention of the concept and rationale for the overall methodology of the study. For example, there was no justification for the population from which the sample of respondents to the questionnaires was drawn. The absence of this information made constructive assessment of the study and its
findings difficult. Despite the fact that the study was wholly concerned with housing in Scotland, its findings could be seen to shed some light on construction in the area in general, as various studies (BRE 1981 and 1987 and Griffith 1989) show there to be a similar pattern between housing and general construction. However, the study followed the same data gathering techniques as Abbott (26) Hence, it was based mainly on discussions and questionnaires. The questionnaires were not based on hard information that could be obtained through direct field observations or the use of the results of previous field observations such as the BRE (28) 1987 Study. The data were collected from a small sample of sites. The report recognises this as one of its limitations.

While the study utilises the advantages of quantitative analysis methods, the present research intends to utilise both quantitative and qualitative methods through the case studies and questionnaires envisaged for the study. Various findings and recommendations in the study positively support objective 2 and the hypotheses of the present research. Although there was no specific mention of a new procedure, the study recommended a quality control system which must foster the transfer of information on quality requirements in the contract to the workers. It also suggested the development and improvement of existing management procedures with well defined roles. The study failed to come up with specific solutions although, in fairness, this had not been included in the intended scope of the study. This research will attempt to find a viable solution that could address some of the recommendations in the study because, at the same time, they are also directly relevant to the research aim and objectives.

The proportion of variance explained by the core variables were: design 22.3%, operatives/management relationship 36.2%, supervision 35% and the final contribution was made by role strain and role clarity. A summary of the standardised regression weights of the independent variables on the dependent variable (quality achievement) is depicted in figure 4.6.
Figure 4.6: Standardised Regression Weights of the Independent Variables on the Dependent Variable (QA). Source (69)
4.10 GRIFFITH, A: 1989 - BUILDING PERFORMANCE AND QUALITY OF TIMBER-FRAMED HOUSING (70)

4.10.1 Scope and Method

The application of timber-framed housing in the form in which it has developed in recent years is not conventional within UK house building and demands considerably different design criteria and site practices from those required for traditional forms of construction. Griffith (70) asserts that:

"It is through recognising these differences that doubts have been expressed at the performance, quality and long-term reliability of timber-framed house construction. This concern had been encouraged, largely by the inadequate performance of other non-traditional construction used throughout the 1960's and 1970's and also, through recent evidence from other countries that problems of performance with the timber-framed form are emerging."

The above background coupled with the fact that there was no current research study on the topic, make an investigation a must. The specific objectives of the study were to:

1. Make quantitative assessment of building faults in the sample.
2. Identify the nature of the faults.
3. Establish the origin of the faults.
4. Assess the severity of faults and consider their defect potential.
5. Examine the influences upon performance and quality.

The data were based on building faults and defects which actually occurred in timber-framed houses currently in use. Therefore they could be perceived to be a factual indicator of current performance in timber-framed houses, rather than a predictive illustration. Information was collected from two sources, first from home owners who had reported problems with their dwellings to the contractor under the
NHBC Warranty Scheme and second from the detailed survey of three individual houses.

4.10.2 Results and Observations

The author felt that the method used in gathering the data was suitable for the objectives of the study. Despite the fact that the sample was small, the results were indicative of the problems that could be found in a larger sample. There was no coherent logic for the data analysis. This shortcoming led to subjective assessment of some of the faults in terms of their origins. However, the categories to which the origin of the faults were attributed may be accepted for the formulation of hypotheses for a more detailed and large sample survey in the nearest future. Various aspects of site practices that led to the faults attributed to the construction phase were not highlighted. It would have been interesting if the study had examined the specific roles played by NHBC representatives in order to form a view on how the organisation could perform its roles better in the future. In general, notwithstanding the limitations imposed on the study by the subjective assessment of the origins of the faults and defects, some conclusions could still be drawn from its findings. The distribution of origin of the faults indicates that 46% of all faults result from site causes. In fact it is likely that more than half of all faults originated from this source, as an undetermined proportion of faults resulted from design and construction factors (16%), half of which could be site based. The origins of all the faults are shown in figure 4.7. The study shows that there were considerable similarities between the origins of faults in both timber-framed and masonry construction; 46% (or say 58%) in timber-framed houses and 48% (66) in masonry housing.
Figure 4.7: The origin of the faults

Source: (70)
4.11 SIOHOLT, O: 1990 - NORWEGIAN QUALITY MANAGEMENT
SYSTEM (71)

4.11.2 Scope and Method

As a result of the national and international need for the concept of "right first time" in the Norwegian construction industry, the study aimed to stimulate the concept of "Total Quality Management" as an overall management approach. A process of continuous improvement within a firm/project was seen as a necessary basis for any implementation of quality systems. The "Norwegian Quality Management System" was created as a reference model appropriate in the building industry to all kinds of firms and projects and perceived to be applicable also in other countries.

Back in 1985, the Norwegian Building Research Institute (Byggforsk) set up a quality management group to work with construction companies in Norway and other countries. The experience gained over the years was formulated into a "five step quality development programme." The steps are shown in figure 4.8. The programme was based on small increments of development and the steps are overlapping. Having worked out the programme, Byggforsk organised companies into co-operating groups for its implementation. The main task of the Byggforsk management group was to work out and monitor such a quality programme for the execution of quality improvement in each company. Groups consisting of 6-8 companies were used during a 30 month period, guided through the five-step programme.
1. Working out a Quality program

2. Initiating improvements

3. Analysing current procedures

4. Developing the Quality System

5. Integrating and supervising the Quality System

Fig 4.8: Five step quality development program
Source (71)
4.11.2 Results and Observations

The study was based on an evolutionary (ie. developing from within a firm) system rather than revolutionary approach (ie. imposition by external forces.) The study was carried out by developing and formulating cultural procedures within individual company. The author believed that the approach would generate debates and direct participation by all parties right from the grass root to the top executives. The system followed closely the Japanese system of "quality circles" which is people oriented within each firm with less emphasis on external forces (71) Another interesting point to note is that the five step quality management system was developed specifically for the building industry based on experience gained over the years of the structure and processes of the industry. The approach is likely to gain more acceptance from workers than the imposition of a system which is subject to interpretation.

The sample of 50 companies used in the study was reasonably large to be taken as representative of the Norwegian building industry; provided it was nationwide. This was absolutely necessary in order to present a defensible system based on a national character and not on a sectional or regional culture.

BRE Studies (1) (28) had emphasised that lack of care causes bad workmanship rather than lack of skill. The author believes that before adequate care can be taken by all participants in the building process, attitudes and procedures must change. This study clearly demonstrates that success depends on the methods for changing attitudes rather than the content of the system developed. It was pointed out that:

Where improvement in a company's efficiency is the main objective, the development process tends to proceed in an evolutional way - primarily based on changes that get people involved.
This approach is illustrated by the horizontal axis in figure 4.9 which shows on the left the basic quality improvement activities concerning people, and these proceed towards the more formal activities involving paperwork on the right. The study asserts that:

Where formalised demands to fulfil quality standards dominate, the process will primarily be "paper work revolution" - yielding no sustained improvement in quality.

Therefore, for a national strategy for promoting improved quality in building, the study recommended that focus should be on the principles of total quality management based on existing cultures rather than purely on quality assurance procedures and that certification of quality systems should not be seen as the principal driving force.

The study has contributed significantly to the knowledge on quality management in the Norwegian building industry. As a result, many companies are taking up the "five step" approach to quality management. The report points out that other countries are also taking part. There is a lot to be learned from the system and the extent to which the system could become widely used within the EEC and other countries will be seen in a few years time.
Fig 4.9: An evolutionary implementation progress is recommended.
It is appropriate and desirable for a researcher to be aware of the relevant previous research and studies carried out in his area of study. However, it is not necessary that a researcher should carry out a critical review of all the studies. Hence a rationale was formulated for the selection of relevant studies for review in this research. In all, nine studies were reviewed and they all satisfied one or more of the criteria laid down.

Some of the studies lack rationale or justification of the methodology used. Also, some of the analyses are very basic (descriptive statistics). This may preclude a proper interpretation and understanding of the data. None of the studies undertook both field observation and a questionnaire survey as a combined approach to the collection of their data as envisaged in this research.

The findings of all the studies followed a similar pattern with the majority of quality problems attributed to the construction phase followed by the design phase. Materials and components were credited with fewer quality problems. In certain instances, the perceived causes of the faults and defects identified were judged subjectively by the individual authors. They did not represent the industry’s opinion per se. Often there is no defensible rationale advanced for the selection of the perceived causes/factors with which respondents were asked to express agreement or disagreement. The primary causes of non-conformance to client’s quality requirements were not established by any of the studies. All attempts to quantify the relative importance of the factors identified have also not been very successful.

Various points were raised in the studies (eg. that clients quality requirements are not adequately passed to contractors) and improvement called for. However they failed to develop any improvement actions (be it procedure, method, system, mode of changes) that could be implemented to overcome some of the difficulties.
identified. It is in the areas of these shortcomings of the various studies that this present research will try to provide answers within the context of the objectives, hypotheses and the assumptions outlined in chapter 2.
CHAPTER 5

THE CASE STUDIES

5.1 INTRODUCTION

The substantial completion of the literature review provided the knowledge base required to carry out the case studies. Three detailed case studies were carried out of new building projects in the South East of England utilising different procurement methods. This chapter describes the reasons for the selection of each building project for the case studies. Efforts were made to identify the primary causes of faults/defects through inspection of the actual buildings during construction, through the study of project documents and through interviews with all participants. The sequence and method adopted for the case studies are described in the body of this chapter. The detailed reports of the case studies are contained in Appendix D, E and F. The chapter concludes with the analysis and findings of the case studies. The findings were instrumental to the development of the conceptual model and in structuring the questionnaire. They also provided a check on the results obtained from the responses to the questionnaire.

5.2 THE FOCUS OF THE CASE STUDIES

Building contractors provide management links to effect an exchange between men, machines and materials on one hand and the client plus money on the other hand. That is, building contractors possess management skills to build which they sell to clients. They assume the risks of the building process in return for profit. Therefore, it is this management skill which needs to be examined when the quality of conformance fails to equal the specified requirements.
Sir Clifford Chetwood (72) points out that:

We have quite enough technical knowledge to enable us to maintain high standards of work. Our difficulty is to make sure that this know-how is effectively applied where and when it is needed. This is a management function and management efforts start at the top.

Newlove (30) states:

Any problem with the achievement of quality in construction can be seen to be ethical rather than technical, administrative rather than operational.

In view of the stated need, the method adopted for the case studies was to observe contractor's management systems noting any difficulties/inadequacies that might have a direct bearing on the quality of a building during construction. The observation technique entailed examining project documents, roles and responsibilities and physical inspection of buildings during construction in order to identify faults and defects and their primary causes. Interviews were carried out to identify specific difficulties facing the project team in achieving specified quality requirements.

To identify the difficulties facing contractors in achieving specified quality requirements and to be able to analyse them in terms of their origin and the degree of their impact on the quality of completed buildings requires the selection of projects for the case study to be based on a pre-determined rationale.

5.3 REASONS FOR PROJECT SELECTION

The following points were considered important for the selection of each case study:

1. Clients
2. Type/size of project
3. Design
4. Procurement method
5. Client's representatives
6. Contractor
5.3.1 Clients

A mix of projects from both the private and public sector of the economy were considered desirable for the research. About 40% of the construction industry turnover is from public sector projects (73). This percentage should be reflected in the selection of the projects for the case studies. Some clients use existing buildings as samples of the quality they require in their proposed buildings. This shows that the specific quality requirements in those instances are achievable. An example of this was found in case study No 3. The project will be very useful in that the difficulties facing the contractor in not achieving what was achievable will be established.

Clients of large organisations often seem to know precisely the quality standards required for their proposed buildings. They own large freehold and leasehold properties and they commission buildings regularly. They often have building departments manned by experienced building professionals. In view of the above, one can assume that the specifications for their proposed buildings will be explicit and be adequate for the purpose of quality control and inspections. These factors were considered essential to the selection of projects for the case studies.

5.3.2 Type/size of Project

All building projects are unique. However, some "one-off" types of projects call for unique design, co ordination, programming and integration of various materials unlike prototype buildings such as housing, factory buildings, warehouses and schools. These types of building projects were considered more appropriate for the case studies. The proportion of refurbishment to new building projects is becoming an important factor. About 40% of the industry's turnover in 1989 (73) was refurbishment. Therefore to be representative, projects for the case studies should
be for new build as well as for refurbishment work. However, the number of new build projects will be more than those of refurbishment in order to reflect their proportion in terms of the industry turnover. Equally important is the author's practical experience over the years of new building projects which was considered a valuable asset for the investigation.

The majority of new building projects are within the value of say three and twenty million pounds sterling. Hence small to medium size projects are more common than one-off large projects. Therefore, projects for the case studies were selected from projects within the above band.

5.3.3 Design

A building can be designed either by private consultants, client's in house designers or the contractor. Communication, responsibilities, and quality of production information will vary slightly under the above design routes. This could have some direct affect on the quality of the completed building. Choosing at least one project from each route for case study will provide an opportunity to develop a solution that can be widely used for the production of buildings that conform to requirements. Hence the research findings will be valid across the board and not tied to any specific design method. In fact, contractors require management tools that can be used on a variety of projects because contractor's personnel often move from one type of project design route to another.

5.3.4 Procurement Method

Procurement method and forms of contract have a direct bearing on responsibilities, communication, authorities and sub contractors, all of which can have an impact on the quality standards achieved on site. The current trend in the
industry is that two thirds of all building projects are procured using traditional forms of contract while other forms of contract such as design and build, management contracting or package deal account for the remaining one third. It is assumed that the trend will continue for the years to come. Hence, selection of projects for the case studies in the above ratio (2:1) is seen as a good mix because it reflects the reality of life at the moment and for the foreseeable future.

5.3.5 Client's Representatives

For three long years the British Property Federation representing private clients worked on a plan to streamline building procurement by traditional methods. The results were published in June 1984 in the form of a complete revised system which will require its own contract. The role of a client's representative is a key factor of the system (74).

The appointment of a project manager (other than the project architect) as a client representative is seen within the building industry as a positive step towards successful completion of a project. The author's experience also shows that the selection of a senior and professionally qualified person within the client's organisation could be an added advantage for the successful completion of building projects.

The BRE research entitled "Achieving Quality on Building Sites" published in 1988 highlighted the strong position of the Clerk of Works in the successful completion of building projects (28). In-house Clerks of works tend to know the quality standard required and hopefully specified by their organisation. This puts them in a better position than other Clerks of works.

Selection of projects that have the above stated features for the case studies will provide opportunities for assessing and re-establishing the positive effect of the
roles of client's representatives in providing a viable solution to the difficulties in achieving specified quality standards on building sites.

5.3.6 Contractors

There are many contractors in the UK. They vary in size, geographical location and type/sizes of projects engaged in. However, the majority of them are General Building contractors (73). They could be classified as large, medium or small contractors; international, national, regional or local contractors. The "big boys," the large contractors, tend to dictate/initiate management procedures in the industry. The turnover of the top 100 UK construction firms is about 30% of the industry’s turnover (73).

In view of the research objectives and the reality of life in the industry; it was believed that a viable solution that could be used by all contractors is desirable. Hence, investigating projects carried out by large and medium size contractors will satisfy the need for developing a viable solution to the difficulties facing contractors in achieving specified quality. Therefore projects for the case studies are to be selected from those carried out by large and medium size contractors.

5.4 FINAL DECISION FOR THE SELECTION OF CASE STUDIES

Based on the above factors, permission was obtained from two contractors in order to use their building projects for the case studies. Before the final selection of the individual projects was made, consideration was given to whether full access to all relevant documents and the unbiased co-operation from the project team would become available. Both were seen as equally important in the successful completion of the case studies.
As a starting point, three building projects were identified for the case studies. The initial intention was to increase the number further if the need arose to ensure successful accomplishment of the set objectives. However, the analysis of the three case studies resulted in substantial findings which were considered sufficient to be used, in conjunction with the results of the other instruments, for the development of the research questionnaire. Hence there was no need to extend the case study approach to more projects. The three projects displayed all the characteristics which were considered important for the case studies as shown in table 5.1. Having obtained permission to use a project for the case study, formal notices were sent to all relevant parties/individuals. Each notice contained a brief description of the investigation and its objectives. The sources of information used for the case studies are shown in Appendix C.

5.5 CAUSES AND SOURCES OF FAULTS AND DEFECTS

The diagnosis of the faults represent the impartial assessment of all the data available and were not as Eldridge noted "a means of confirming an opinion already formed" (75). In simple terms, the causes and related factors that were responsible for each fault were determined by relating the answers from many and varied searching questions to the known behaviours of the materials involved. Consequently, the quality of the questions asked and the answers to the questions were important determinants.

One of the most difficult aspects of any diagnosis is that very often more than one cause may be responsible for the defect, although in most cases it is possible (and indeed necessary) to identify the primary cause. For example, movement may have initially been responsible for the cracking of part of the brickwork/blockwork. The crack(s), if external, could then make rain penetration possible and the water penetration would manifest itself as dampness. In this case there would have been no dampness if there had been no cracks. But, equally important, the mere
<table>
<thead>
<tr>
<th>Item</th>
<th>Important Points</th>
<th>Client</th>
<th>Type / Size of Project</th>
<th>Designers</th>
<th>Procurement Method</th>
<th>Clients’ Representatives</th>
<th>Contractor</th>
<th>Building and Civil Engineering Consultant</th>
<th>Project Managers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No</td>
<td>Public</td>
<td>Commercial 115.0 m</td>
<td>1) in house Architects</td>
<td></td>
<td></td>
<td></td>
<td>Building and Civil Engineering Consultant</td>
<td>Med size national</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Private</td>
<td>Office / Showroom 63.8 m</td>
<td>2) in house Consultants</td>
<td>2) in house Consultants</td>
<td></td>
<td></td>
<td>Building and Civil Engineering Consultant</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>3) Private services Engineers</td>
<td>3) Private services Engineers</td>
<td></td>
<td></td>
<td>Building and Civil Engineering Consultant</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2) Private structural Engineers</td>
<td></td>
<td></td>
<td>Building and Civil Engineering Consultant</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1) in house Project Manager</td>
<td></td>
<td></td>
<td>Building and Civil Engineering Consultant</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2) in house Clerk of Works</td>
<td></td>
<td></td>
<td>Building and Civil Engineering Consultant</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1) in house Project Manager</td>
<td></td>
<td></td>
<td>Building and Civil Engineering Consultant</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.1: Projects for the case studies
<table>
<thead>
<tr>
<th>Item</th>
<th>Important Points</th>
<th>Case Study No 1</th>
<th>Case Study No 2</th>
<th>Case Study No 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td><strong>Contractor Appointments</strong></td>
<td>Selecting Tendering</td>
<td>Selecting Tendering</td>
<td>Two Stage Tendering</td>
</tr>
<tr>
<td>8</td>
<td><strong>Contract Duration</strong></td>
<td>52 weeks contract duration.</td>
<td>11 months overrun.</td>
<td>6 weeks.</td>
</tr>
<tr>
<td>9</td>
<td><strong>Information</strong></td>
<td>Poor.</td>
<td>Generally uncoordinated.</td>
<td>Generally uncoordinated.</td>
</tr>
<tr>
<td>10</td>
<td><strong>Client Participation</strong></td>
<td>The client had a team of in-house professionals.</td>
<td>They manage approved at the construction period.</td>
<td>The development was based on the ideas generated during construction.</td>
</tr>
<tr>
<td></td>
<td><strong>During Construction</strong></td>
<td>The client received minimal client input during construction.</td>
<td>The contractor and project team received very little input.</td>
<td>The project included very little input from the project team.</td>
</tr>
<tr>
<td></td>
<td><strong>Information Assessment of Production</strong></td>
<td>Good and the production information was generally good but the information was issued for construction.</td>
<td>The design and build information was often inaccurate.</td>
<td>Generally the production information was not very co-ordinated.</td>
</tr>
<tr>
<td></td>
<td><strong>Duration</strong></td>
<td>141 weeks. The construction period was 66 weeks.</td>
<td>141 weeks. The construction period was 66 weeks.</td>
<td>141 weeks. The construction period was 66 weeks.</td>
</tr>
<tr>
<td></td>
<td><strong>Multiple</strong></td>
<td>There were multiple consultants.</td>
<td>There were multiple consultants.</td>
<td>There were multiple consultants.</td>
</tr>
<tr>
<td></td>
<td><strong>Input</strong></td>
<td>The input from the client was minimal.</td>
<td>The input from the client was minimal.</td>
<td>The input from the client was minimal.</td>
</tr>
</tbody>
</table>

Table 5.1: Projects for the case studies (contd)
<table>
<thead>
<tr>
<th>Item</th>
<th>Assessment of Site</th>
<th>Assessment of The Client Overall Performance</th>
<th>Important Points</th>
<th>Case Study No 1</th>
<th>Case Study No 2</th>
<th>Case Study No 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Impressed and impressed with the client's performance</td>
<td></td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The experience of the client was very positive</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Very low morale due to lack of communication and respect</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Strong control by the client's team</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Information from the client's team was very good</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Strong cooperation with other projects</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>The quality of workmanship is average</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>The client has a strong lead throughout</td>
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<tr>
<td></td>
<td></td>
<td>The client's satisfaction was high</td>
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<td></td>
<td></td>
<td>The client was satisfied with the professional relationship with the team</td>
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<td></td>
<td></td>
<td>The project was handed over on time</td>
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<tr>
<td></td>
<td></td>
<td>A strong lead throughout</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>A high programme gave a rest</td>
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<tr>
<td></td>
<td></td>
<td>Simultaneous progress in both</td>
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<tr>
<td></td>
<td></td>
<td>There was a lot of</td>
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<tr>
<td></td>
<td></td>
<td>Strong control by an experienced contractor</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Progress ahead of schedule</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Seven day working for much of the time</td>
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<tr>
<td></td>
<td></td>
<td>Continued use of the existing programme</td>
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<td></td>
<td></td>
<td>Building during construction</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>A satisfaction job</td>
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</tbody>
</table>

Table 5.1: Projects for the case studies (cont'd)
existence of a crack and the appearance of dampness do not necessarily mean that
the crack has provided the means of ingress for the water. In some cases the two
defects are not related although both will have to be remedied. Nothing was taken
for granted. Efforts were made to identify the primary causes of the faults and
defects through inspections of the actual buildings, project documents and
interviews.

5.6 INTERVIEWS WITH EACH PROJECT TEAM (including subcontractors)

The aim was to find as much information as possible about what went wrong and
the lessons to be learned. There was no preference as to who should be interviewed
first. However it was decided to interview all the contractor's team first then the
subcontractors and later the client's representatives. The decision to follow the
above procedure was taken in order to present a full account of the contractor's
views to the client's representatives. The procedure worked well and it reduced the
number of times that each member of the project team had to be interviewed face
to face or on the telephone. Before the date of each interview the list of defective
operations to be discussed, together with the chart shown in figure 5.1, were sent to
each interviewee in order to prepare them for the interview. The chart was always
tabled as a guide for the interview. The interviews were conducted by discussing
each operation in turn.

Tape recordings were used with the permission of the interviewees. This helped the
author to listen attentively to what was being said by the interviewees. Important
points were noted. The recording also helped in checking the wording of any
statement to be quoted and to check if notes taken were accurate. On average,
each interview lasted approximately two hours. The conversations were guided by
the author onto new topics from time to time. The method allowed respondents to
talk at length in their own words and at their own level of understanding.
Discussion ranged freely to include topics that emerged spontaneously and were not foreseen as relevant. The information collected from the case studies was analysed individually and thereafter collectively by using qualitative methods.

5.7 RESOLVING CONFLICTING VIEWS

There were some conflicting views between the various parties. For the findings of the case studies to be unbiased, the conflicting views were thoroughly assessed and resolved. The interviews brought out considerable agreement between the parties. The procedure adopted for resolving the conflicting views was to find evidence from the project documents to support one party's view or to find evidence that could disprove a view.

The following steps were taken:

1. To re-examine the project documents and to carry out further inspections of the finished works. The available documents were very useful in this regard.

2. The necessary data obtained from the documents was extracted and sent by post to the relevant parties.

3. A few days later, the documents were followed up with telephone conversations. At this stage some of the conflicting views were resolved. The unresolved conflicting views are recorded in the report under the heading "DISAGREEMENTS" in Appendices D, E and F respectively.

93
IDENTIFY DEFECTIVE OPERATIONS

Preliminary Discussion
WITH SITE MANAGER

Preliminary Discussion
WITH CLIENT REPRESENTATIVE

Defective Operation Confirmed

Examine Project Documents

Inspect Defective Operation

Arrange for Interviews

Conduct Interviews

Re-examine Project Documents

Re-inspect Defective Operations

Resolve Conflicting Views

Analysis / Findings

Figure 5.2: Sequence of Case Studies
In spite of the fact that there were still some disagreements between the parties, the disagreements were not fundamental to preclude making reasonable deductions as to:

1. What the faults and defects were.
2. What the symptoms were.
3. What went wrong.
4. The origin of the faults and defects.
5. The influencing factors of non-conformance.
6. The lessons to be learnt.

The deductions were based on:

1. The agreements between the parties.
2. Evidence obtained from project documents and the physical inspection of the buildings.

There were some minor variations in the sequence of the case studies, however figure 5.2 shows the general sequence of the case studies. Specific steps taken for each case study are discussed under the introduction to each case study.

5.8 CASE STUDY NO. 1

The author is in the employment of a large construction company. As a result, some of the construction projects that the author has been involved with recently were considered for selection as case studies. Two of such projects satisfied the criteria underlying the selection of projects for the case studies. Equally important is the fact that the case studies are meant to be an in-depth and comprehensive field observation of construction projects. Hence, the selection of projects in which the author has direct involvement was perceived to be an advantage because of the in depth knowledge that could be gained as a participant observer. this was seen to be beneficial. therefore the two projects which met the criteria were selected as case study No. 1 and case study No. 2 respectively.
5.8.1 Identify Faults and Defects to be Investigated

Case study No. 1 commences with a brief discussion with the SITE MANAGER to confirm the occurrence of the defects to be investigated. The outcome of the discussion was the confirmation of defects which are relevant to this study. It also became more evident that there would be sufficient data for the investigation and hopefully the objectives of the case study could be achieved.

A brief discussion with the CLERK OF WORKS was also conducted. The result was also positive. Having confirmed the occurrence of faults and defects, the availability of data and the necessary co-operation required from members of the project team, the case study proper could commence.

The examination of relevant documents and the physical inspection of the completed works were carried out concurrently by taking each defective operation in turn. That is, look at the relevant production information issued for construction and compare it with the finished work. The SITE DIARIES and METHOD STATEMENTS helped to confirm what actually happened each day during the erection or installation of each operation.

The aims at this stage were:

1. For the author to re-familiarise himself with the details of the production information and the works.

2. To take note of critical details on the drawings.

3. To take note of any discrepancy in the production information.
4. To take note of dates when information were requested/received by the contractor.

5. To take note of dates when works were done.

6. To examine methods of working (ie. the sequence of work, plant used, hoisting and site transportation of materials.)

7. To take note of remedial works done.

8. To confirm who pays for the remedial works.

9. To find out how decisions affecting the final standard of the operation were made.

10. And finally to prepare points for discussion in the interviews.

Comprehensive notes of the above information were taken. The notes were subsequently used as facts for probing the interviewees.

The case study started in January 1990 (ie. 3 months after the last phase of the building was handed over.) The defective operations which were subject of investigation in this case study are:

1. MASONRY
2. CARCASSING TIMBER/DOORS
3. CLADDING/COVERING
4. PAVINGS
5. VENTILATION
A detailed report of the investigation is shown at Appendix D.

5.8.2 Those Interviewed

The following position holders were interviewed:

**Contractor's Team:**
- Site Team: Contract Manager
  - Site Manager
  - General Foreman
  - Site Engineer
  - Senior Quantity Surveyor
- Office Supporting Staff:
  - Construction Director
  - Chief Purchasing Officer
  - Estimator

**Subcontractors:**
- Flat Roof Subcontractor: Foreman & Contract Manager
- Carpentry Subcontractor: Senior Partner (site rep)
- Ventilator Subcontractor: Foreman & Senior Designer
- Door Supplier: Sales Representative
- Door Frame Supplier: Managing Director

**Client's Team:**
- Project Manager
- Project Architect
- Senior Clerk of Works
5.9 CASE STUDY NO. 2

The author was a full-time member of the construction team on the project used as case study No. 2. The author, in his capacity as the PROJECT PLANNER, started work on the project four weeks before the commencement of site activities. During the four weeks the author took part in various design, co-ordination and planning meetings between the construction and the design team and some major subcontractors. The author was a participant-observer from day one to the end of the project. The author's roles and responsibilities gave him direct access to all information necessary for the successful completion of the case study.

5.9.1 Identify Faults and Defects to be Investigated

A weekly assessment of the site operations was made to identify any quality problem. The assessment was carried out as follows:

1. Observation of site operations and noting any quality problem(s)
2. Discussion with other members of the construction team as to what they have identified as quality problems up to date.
3. Discussion with both the Design team and the Client's representatives to obtain their comments on the work already carried out.

Immediately it became apparent that there was a quality problem, investigation as to the cause(s) was commenced. The defective operations which were subject to investigation in this case study were:

1. IN SITU CONCRETE / LARGE PRECAST CONCRETE
2. MASONRY
3. CLADDING / COVERING
The full report of the investigation is shown at Appendix E.

5.9.2 Those interviewed

The following position holders were interviewed:

**Contractor's Team**
- Site Team
- Design and construction Manager
- Site Engineer
- General Foreman
- Office Supporting Staff
- Project Engineer
- Design Manager
- Purchasing Officer

**Subcontractors**
- Brickwork/Blockwork subcontractor
- Roof covering
- Profile metal sheet supplier
- Senior partner (Site foreman)
- Contract supervisor
- Production manager

**Client's Team**
- Project Manager

5.10 CASE STUDY NO. 3

Unlike the two other case studies, the author was not a member of the construction team on the project used as case study No. 3. Therefore a slightly different approach was adopted for the investigation.

5.10.1 Identify Faults and Defects to be Investigated

The following methods were used in order to identify the faults and defects that were the subject of investigation in this case study:
1. The author visited the site at least once in a month to carry out inspection of site operations in order to identify any quality problem.

2. During each site visit, the author held discussions with both the Contractor's Team and the Client's representatives (i.e., Resident Engineer and Architect.)

3. A critical examination of the project documents was carried out regularly each month.

The monthly site visits started during the fifth month of the site activities and lasted for eight months. During the eight months, various quality problems were identified. The identification of each quality problem was followed by an in-depth investigation. The quality problems which were the subject of investigation in Case Study No. 3 were:

1. R.C SLAB AND R.C WALLS
2. REINFORCEMENT
3. BRICKWORK / BLOCKWORK
4. MORTAR FOR BRICKWORK
5. CAVITY INSULATION

The full report of the investigation is shown at Appendix F.

5.10.2 Those Interviewed

The following position holders were interviewed.
**Contractor's Team**

Site Team  Project Manager  
Section Managers  
Brickwork Foreman  
Senior Engineer  
Planning and Resources Manager

**Subcontractors**

R.C Frame Subcontractor Foreman  
Brickwork Subcontractor Foreman and Senior partner

**Client's Team**

Resident Engineer  
Resident Architect  
Visiting Architect

**Supplier**

Rockwool Insulation Supplier Sales representative

### 5.11 ANALYSIS AND FINDING

A qualitative analysis of the information collected from each case study was made and presented in tabular form. The approach was to allocate each fault and defect to a specific group and to relate each group to the factors influencing the achievement of specified requirements obtained from the responses to the questionnaire. The allocations were carried out after all conflicting views had been resolved and were based on an objective assessment of the facts of each detailed investigation described in Appendix D, E and F. The following definitions were used in assessing the group to which each fault or defect belongs:
Design Faults:  Deficiencies in production information. Where construction had been carried out as per the design but faults still occur for which the contractor cannot be held responsible.

Construction Faults:

Departure from design requirements where these were not themselves at fault. See BRE 1982 (53).

Component and Material Faults:

Where the right materials or components were specified but the wrong ones were delivered to the site and subsequently incorporated into the works OR unexpected behaviour of materials and components.

Unexpected User's Requirements:

These are faults which could not be attributed to the three groups above but were brought about as a result of unexpected user's requirements. This group could also be linked to inadequacies in the client's brief.
### Table 5.2: The Faults / Defects and their Group Origin

<table>
<thead>
<tr>
<th>CASE STUDY NO 1.</th>
<th>GROUP</th>
<th>FAULTS &amp; DEFECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CASE STUDY NO 1.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1. BRICKWORK/BLOCKWORK</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Cracks in blockwork</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii) Rough brickwork</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iii) Uneven mortar beds/perpends</td>
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<td></td>
</tr>
<tr>
<td>iv) Brickwork &amp; blockwork not within specified tolerance</td>
<td></td>
<td></td>
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<tr>
<td>v) Patches of mortar, mud &amp; dirty</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. FLAT ROOF</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Drips of water from the roof</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. DOOR FRAMES &amp; DOORS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Twisting of door frames</td>
<td></td>
<td></td>
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<tr>
<td>ii) Twisting of doors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iii) Cracks in door lippings</td>
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<td></td>
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<tr>
<td>iv) Poor workmanship</td>
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<tr>
<td><strong>4. EXTERNAL BRICK/SLAB PAVING</strong></td>
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<tr>
<td>i) Undrained surface water</td>
<td></td>
<td></td>
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<tr>
<td>ii) Cracks in mortar joints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iii) Broken paving slabs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iv) Poor workmanship</td>
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<td></td>
</tr>
<tr>
<td><strong>5. SMOKE VENTILATORS</strong></td>
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<td></td>
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<tr>
<td>i) Drips of water from the vent</td>
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</tbody>
</table>
### Table 5.2 (contd)

<table>
<thead>
<tr>
<th>CASE STUDY NO 2.</th>
<th>FAULTS &amp; DEFECTS</th>
<th>GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DESIGN</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>1. REINFORCED CONCRETE LIFT PIT</td>
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<tr>
<td>1) Water ingress into reinforced concrete lift pit</td>
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<tr>
<td>2. BRICKWORK/BLOCKWORK</td>
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<td></td>
</tr>
<tr>
<td>1) Brickwork &amp; blockwork</td>
<td></td>
<td></td>
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<tr>
<td>not within specified tolerance</td>
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<td></td>
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<tr>
<td>2) Variation in width of perpends</td>
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<tr>
<td>3) Chipped &amp; damaged bricks in walls</td>
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<td></td>
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<tr>
<td>4) Patches of mortar &amp; stains on walls</td>
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<td></td>
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<tr>
<td>5) Mortar dropping into brickwork cavities</td>
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<td></td>
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<tr>
<td>3. ROOF COVERING SHEET (COLOUR)</td>
<td></td>
<td></td>
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<tr>
<td>1) Variation in colour of roof sheet</td>
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</tbody>
</table>
### Table 5.2 (cont)

<table>
<thead>
<tr>
<th>FAULTS &amp; DEFECTS</th>
<th>GROUP</th>
<th>DESIGN</th>
<th>CONSTRUCTION</th>
<th>COMPONENTS &amp; MATERIALS</th>
<th>USER UNEXPECTED REQUIREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CASE STUDY NO 3.</strong></td>
<td></td>
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<tr>
<td><strong>1. R.C. SLAB &amp; R.C. WALLS</strong></td>
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<tr>
<td>i) R.C. slabs out of tolerance</td>
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<tr>
<td>ii) R.C. slabs out of positional tolerance</td>
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<tr>
<td>iii) Large variation in R.C. wall thickness</td>
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<td><strong>2. REINFORCEMENT</strong></td>
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<tr>
<td>i) Wrong reinforcement was used to cast plant room conc. slab</td>
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<tr>
<td><strong>3. BRICKWORK/BLOCKWORK</strong></td>
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<td></td>
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<tr>
<td>i) Efflorescence &amp; staining</td>
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<tr>
<td>ii) Missing DPC</td>
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<td>iii) Mortar dropping</td>
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<td>iv) Missing insulation tie clips</td>
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<tr>
<td>v) Bad workmanship &amp; tolerances</td>
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<td><strong>4. MORTAR</strong></td>
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<tr>
<td>i) Compression strength of mortar far below specified strength</td>
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<td></td>
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<tr>
<td><strong>5. CAVITY INSULATION</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>i) Rockwool complete fill cavity slabs</td>
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</tbody>
</table>

- **Contributory Group**: A
- **Main Group**: •
Figure 5.3: Frequency distribution of primary cause of non conformance in the three case studies.
Table 5.2 shows the group to which the faults and defects identified in each case study were allocated. The distribution of the primary causes of the faults and defects into the major factors influencing the achievement of specified requirements is shown in Table 5.3. The frequency of occurrence of the primary causes of non-conformance in terms of the major factors is shown in figure 5.3.

5.12 SUMMARY

Three construction projects were selected for detailed field investigations with a view to finding the primary causes of non-conformance to specified requirements and the lessons that could be learned. The investigations provide useful findings which were sufficient for accomplishing the objectives set out in Chapter 2.

The approach and method adopted for the investigations had been used successfully by BRE (66). Its success had once again been demonstrated in this research by the first hand information it provides which would be used in the next stages of the research. The next stage of the research is the application of stages 1 to 4 of soft systems thinking methodology to quality management by contractors.
CHAPTER 6

THE APPLICATION OF A "SYSTEMS THINKING METHODOLOGY" TO ACHIEVING CONFORMANCE TO SPECIFIED REQUIREMENTS IN CONSTRUCTION

6.1 INTRODUCTION

This Chapter discusses and demonstrates the application of Stages 1 to 4 of soft system thinking methodology to the topic of quality management by contractors. Stages 1 and 2 represent the assembly of an initial expression of activities relevant to achieving conformance to specified quality requirements. It was carried out by way of preliminary reading, discussion with specialists, literature review and case studies as described in the previous Chapters. With the completion of the case studies, a rich picture was built up of quality management by contractors within the context of the current construction process.

Stage 3 entailed the development of root definitions from which the one most relevant to improve the quality problems was selected. A conceptual model was made from the root definition. This represents Stage 4 of the methodology. It comprises four sub-systems. The conceptual model is defensible because it complies with the criteria set out for a formal system as defined by Checkland and it was supported by practitioners in the UK construction industry. The model was used in conjunction with other instruments as a base for ordered questions posed by the questionnaire as described in Chapter 7 and analysed in Chapter 8.

6.2 APPLICATION OF SOFT SYSTEMS THINKING METHODOLOGY

The idea of "systems practice" implies a desire to find out how to use systems concepts in attempting to solve problems. It was argued in Chapter 3 that "soft"
systems thinking is the most appropriate method. The author will demonstrate in this Chapter the application of stages 1 to 4 of the "soft" systems thinking methodology to make a conceptual model geared towards identifying the inadequacies and possible changes required in quality management by contractors.

Figure 6.1 illustrates a chronological sequence of the seven main stages in using the methodology. In applying the seven stages to achieving conformance to specified quality requirements at first attempt by the construction team, the author draws upon the works of Checkland (58) Wilson (63) and Jenkins (65). The methodology contains two kinds of activity. Stages 1, 2, 5, 6 and 7 are "real world" activities, necessarily involving people in the problem situation, while stages 3, 4, 4a and 4b are "system thinking" activities which may or may not involve those in the problem situation depending upon the individual circumstances of a study.

6.2.1 Stages 1 and 2: Assembly of an initial expression of achieving conformance to quality requirements in construction

In these stages, the concern is to find out about the situation surrounding the nature of the current construction process and to build up a rich picture of the current state of achieving conformance to specified requirements. Checkland (58) points out that:

... this initial analysis should be done by recording elements of slow-to-change structure within the situation and elements of continuously-changing process, and forming a view of how structure and process relate to each other ...

Elements of structure are defined as those features related to physical layout, power hierarchy, reporting structure and the pattern of formal and informal communications. Process is related to the basic activities of deciding to do something, doing it, monitoring both how well it is done and its external effects and taking appropriate corrective action. The function of stages 1 and 2, Checkland (58) points out is to display the situation so that a range of possible and, hopefully,
relevant choices can be revealed. The key issue to a successful completion of these stages as recommended by Checkland (58) is by holding back during the course of the initial analysis and being prepared to collect as many perceptions of the problem as possible from a wide range of people with roles in the problem situation and by a determination not to press the analysis in systems terms at all.

The assembly of initial expressions of achieving conformance to requirements was carried out by way of preliminary reading, discussions with specialists, literature survey and case studies. Typical organisational structures showing the power hierarchy, reporting structure and the pattern of communications at site level are recorded in the case studies. Figure 6.2 shows a typical organisational structure at company level. The basic activities of transforming resources into construction facilities, including monitoring and decision-taking and controlling, were examined and recorded in the case studies. Sufficient time (19 months) was allowed for stages 1 and 2 and efforts were made to collect as many perceptions of the problem of achieving conformance to requirements. The analysis of the three case studies together with all the other supporting information revealed a rich picture of the problem situation giving a firm base to build on for proceeding with the methodology.
1. The problem situation unstructured

2. The problem situation expressed

3. Root definitions of relevant systems

4. Conceptual models
   - 4a. Formal system concept
   - 4b. Other systems thinking

5. Comparison of 4 with 2

6. Feasible desirable, changes

7. Action to improve the problem situation

Real world

Systems thinking

Figure 6.1: The methodology in summary (after Checkland, 1975)
6.2.2 Stage 3: Root Definitions of Relevant System

This stage involves the development of root definitions (RD) which will subsequently be seen to be relevant to improving the problem situation. The author developed several root definitions based purely on the data collected to date from which a selection of a few most relevant ones was made. This was necessary in order to avoid an attempt at an ideally perfect but impracticable analysis. From the selected few, the following root definition was proposed for the conceptual models:

A professionally-manned system concerned with the engagement of various resources to transform client's requirements into physical construction facilities which satisfy the requirements defined by the client's professional advisers.

If later stages reveal that this proposed root definition is lacking insight, irrelevant or infertile then other viewpoints will be tested. In fact, the root definition was tested by looking ahead to stages 4, 5, and 6 to see what kind of model would follow and what kind of changes would be likely to emerge when the models are examined alongside what presently exists in the UK construction industry. Checkland points out that:

To propose a particular definition is to assert what, in the view of the analyst, taking this to be a relevant system, making a conceptual model of the system, and comparing it with present realities, is likely to lead to illumination of the problems and hence to their solution.

He went on to recommend the CATWOE test of root definitions. The inclusion of all CATWOE elements in a root definition indicates that it is well formulated. The basic transformation (T) which this system brings about is evidently to engage various resources as inputs to generate construction facilities that will satisfy the client. The actors (A) in the systems are the professionals mentioned in the RD and the system client, beneficiary or victim (C) is clearly the owner and associated clients. A typical construction company is the system owner (O) since it is the company which could decide to abolish this system and get rid of these particular "actors." The main environmental constraint (E) which this system has to take as
Figure 6.2: Typical organisational structure of a medium size construction company
given is the accuracy of the client requirements as defined in the production information. The Weltanschauung (W) implicit in the RD is that a construction company engaging in the contracting sector of the industry is operating in a world in which the design and manufacture of its products are often carried out by different organisations. It must be noted that the author is not saying: "This is what the contracting sector of the construction industry should be but this is what the author shall take things to be in this analysis."

6.2.3 Stage 4: Making Conceptual Models

While the root definition is a statement of what is the system, stage 4 is to make a model of the activity system needed to achieve the transformation described in the definition. The conceptual model is an account of the activities which the system must do in order to be the system named in the definition. Checkland (58) noted that the activities to be included should be the minimum necessary at a particular resolution level. Modelling in this case thus becomes a question of asking: what activities, in what sequence, have to occur in order to make the transformation of construction resources into a construction facility that satisfies the client. In building the conceptual model, the author used those activities which are minimally necessary to ensure that satisfactory construction facilities (e.g. an office block) pass from the contractor to his client in return for an agreed fee.

Figure 6.3 shows the general structure of the system described in the root definition. Shown in figure 6.4 is the basic structure required by the root definition and its CATWOE. The first sub-system is the tendering process which must be carried out in an orderly and professional manner to ensure that contracts are won at prices that would enable the company to carry out the works to the clients satisfaction.

These considerations lead to the structure shown in figure 6.5, while the "selection of subcontractors/suppliers" sub-system is shown separately in figure 6.6; the
"preparation" sub-system in figure 6.7 and "execution of the works" sub-system in figure 6.8. Adding the four sub-systems together gives the final model in figure 6.9. For each activity in the model, the question was asked: What action is required that will aid the achievement of the stated objective. Each activity is examined thoroughly after formulation before it is finally included in the model. Every concept in the root definition finds expression in the model and the model hopefully reflects all aspects of the root definition.

Once the conceptual model was built, a formal systems check was made to ensure that it included all the necessary characteristics and that it was not fundamentally deficient. Although not strictly a validation in terms of an operational research model, it is possible to check the conceptual model against a general model of any human activity system which Checkland (58) refers to as a "formal system" model. Checkland asserted:

There are not valid models and invalid ones, only defensible conceptual models and ones which are less defensible.

A system is a formal system if, and only if, it possesses:

1. An on-going purpose or mission.
3. Decision-taking procedures.
4. Connectivity between the components.
5. Boundary within which the decision-taking procedures act.
6. Resources.
7. A position in a system hierarchy.
8. Has guarantee of continuity and
9. Exists in a wider system and/or environment.
Figure 6.3: Phase 1: The general structure of the system

Figure 6.4: Phase 2: The construction system modelled in more detail (Temporary system)
This list is taken from Checkland (58). The "formal system" model enables questions to be formulated which, when asked of the conceptual model, would reveal inadequacies either in it or in the root definition which underlies it. The author checked the conceptual model against points that make a "formal system" through well formulated questions and found that the model includes all necessary characteristics. It was concluded therefore that the conceptual model is not deficient and that it has been validated as a systems model i.e. as a defensible conceptual model.

6.3 SUMMARY

Soft system thinking methodology developed for resolving ill-structured problems, was found to be applicable to the search for a solution to the difficulties that contractors may encounter in achieving conformance to specified quality requirements. The application of stages 1 to 4 of the system has been demonstrated in this Chapter. It resulted in a relevant root definition and the development of a conceptual model. The next stage in gathering the research data is to use the conceptual model in conjunction with other data for structuring a questionnaire with the objective of generating a database. This should provide the indicators to the possible changes which might be introduced in order to solve/alleviate some of the problems facing the construction team in achieving conformance to specified quality requirements.

Stages 5 to 7 of soft systems methodology will be discussed in Chapter 10 as part of the preparatory stages of the new system to be developed for the management of quality by the construction team.
Figure 6.6: Subsystem L2: Selection of Subcontractors & Suppliers
Figure 6.8: Subsystem L4: Execution of the Works
CONTAINS PULLOUTS
Figure 6.9: Conceptual Model for Quality Management in Construction (Part 1)
CHAPTER 7

QUESTIONNAIRES - A Survey of Contractors

7.1 INTRODUCTION

A detailed mail questionnaire intended to produce a sufficiently large sample of contractors for their responses to be statistically valid is described in this Chapter. The questionnaire approach was designed to include in the research leading contractors spreading throughout England. The Chapter describes the way in which the questionnaire was developed, the rationale for the selection of its population, method of its distribution and the actual respondents. The development of the questionnaire was based on the results of the literature review, the findings of the case studies and the conceptual model made in Chapter 6. The contribution of the questionnaire to the research goals is also outlined. The method of distributing the questionnaire was successful in yielding a large response from all over England. An account of its analysis is in the next Chapter. The large sample size made the questionnaire the major part of the research data.

7.2 THE AIM OF THE QUESTIONNAIRE

In Chapter 2, reasons were given for the use of the "mail questionnaire" as a major instrument for gathering the research data. Also given was the expected contribution of the questionnaire to the overall aims and objectives of the research. It is anticipated that the questionnaire will:

1. Provide quantitative data required for resolving the research objectives and hypotheses.
2. Provide the opportunity to obtain an adequate sample of data to enable generalisation of the research findings to be made.

3. Generate databases which are required in order to carry out the comparison of the "conceptual model" with the real world in preparation for the development of a system model.

A full account of its development is given in this chapter. The questionnaire is shown at Appendix I. The chapter is presented under the following headings:

1. Development of the questionnaire.
2. The rationale for population selection.
3. The respondents.

7.3 DEVELOPMENT

The questionnaire was structured and presented under five sections as follows:

1. SECTION 1 - Objective questions regarding respondents and company background.
2. SECTION 2 - Questions concerned with the importance of communications for achieving quality.
3. SECTION 3 - Questions to assess the importance of QRM.
4. SECTION 4 - Questions relating to the adoption of QCS.
5. SECTION 5 - Questions relating to factors influencing the achievement of quality.

Over one hundred questions were first initiated. Questions were retained subject to their relevance to the research problem, that is, what information each question will
provide for solving the research problems. After three reviews of the draft questionnaire, a decision was made to pilot the questionnaire before developing the final version.

7.3.1 Questionnaire - The Pilot Version

Ten senior site representatives were approached from three construction companies for the pilot survey. Initial contact was made over the telephone during which the purpose of the survey was made known to the potential respondents. Appointments were made to see each of the respondents on their respective sites.

After completion of the questionnaire and the necessary comments by the respondents, general discussions were held on the structure and the potentiality of the questions to provide adequate information for solving the research objective. All the respondents approached for the pilot study took part and there was a general consensus that the structure of the questionnaire was useful. There was a strong belief that the questionnaire addresses the issues relating to the research objectives.

7.3.2 Questionnaire - The Final Version

After the pilot survey, the discussions held with the respondents and their comments were taken into consideration in the development of the final version. The final draft was further reviewed by the author. The review led to the final version of the questionnaire shown in Appendix I. It comprises 61 questions. Indeed there was not much difference between the pilot and the final version of the questionnaire. In view of this, the ten responses obtained in the pilot survey were included in the main data analysis.
7.4 THE RATIONALE FOR POPULATION SELECTION

The top 100 building contractors in England were selected as the population for the questionnaire. The selection was based on the following reasons:

1. Geographical spread.
2. Turnover in relation to the industry turnover.
3. Type/size of building projects.
4. Influence/bargaining power.

7.4.1 Geographical Spread

The research intends to develop a solution that could be used by the majority of contractors in England and possibly worldwide. In view of this, the data for the research were collected over a wide geographical area. The significance of the top 100 contractors in England is that they are spread all over the country. The majority of them are national or international contractors. They carry out works in all parts of England and they have regional or area offices in key towns in England.

7.4.2 Turnover

The volume of construction works carried out by the industry is reflected in their annual turnover. In 1990, the new orders obtained by contractors in Britain was £44,694 million out of which £39,189 million was in England. In 1990, the output of the top 100 contractors was about £11,757 million. This figure compared with the total new orders for the same period in England shows that about 30% of the industry output was carried out by the top 100 companies (73).
7.4.3 Type/size of Construction Projects

The type of construction projects being carried out by the top 100 contractors in England is very varied. The majority of these companies have a General Works division, a House Building division, a Specialist Project division and a Civil Engineering division. These divisions reflect the various sectors of the industry. This makes them more important for this type of research which involves general problems affecting quality of work. Views and opinions expressed by the top 100 contractors tend to reflect the views of the industry as a whole. One of the contributing factors to this is the size and type of projects being carried out by the companies.

7.4.4 Influence/bargaining power

There are various bodies and organisations representing the construction industry. Some of the organisations are:

- The Building Employers Confederation.
- The Federation of Civil Engineering Contractors.
- The Chartered Institute of Building.
- The Federation of Master Builders.
- The Construction Industry Council.

These organisations are the voice of the industry and the majority of their executive committees are made up of representatives from the top 100 contractors. A survey carried out among the top 100 contractors would tend to represent the voice of the industry. Therefore for a solution to work or any recommendation to be taken seriously, it would require their support. More importantly, they can influence the Government to pass legislation that would make a solution workable or enable them to comply with research recommendations.
The above points were considered the key factors in the selection of the population for the research survey.

7.5 THE RESPONDENTS

The research aim relates to the difficulties facing contractors in achieving conformance to specification. Apart from the activities at the tender stage, conformance to specification relates to site activities. Therefore respondents to the questionnaire are to be contractor's senior site representatives (e.g. Project Manager, Site Manager or Agent.) These position holders are responsible for achieving the specified quality and more so, they are responsible for the management of the whole project. The senior site representatives tend to have the authority to carry out their task. The above points make them more suitable as respondents than other members of the construction team. In view of this, it was unanimously agreed by the author and his supervisors to send the questionnaire to contractors' senior site representatives.

7.6 METHOD OF DISTRIBUTION

7.6.1 First Stage

Before the senior site representatives could be approached to complete the questionnaire, permission was required from their offices. Appendix G shows the letter written to the top 100 contractors in England. Their names and addresses were obtained from the contractors file published in the NEW CIVIL ENGINEER (76) issued on 15.2.90. The letters were marked for the attention of the Chief Executive of each company. Each letter was sent together with a copy of the draft questionnaire, address form and self addressed envelope for the return of the addresses of their senior site representatives. Responses were received from thirty
seven companies who sent names and addresses of their senior site representatives. The number of names sent varied from two to six.

7.6.2 Second Stage

A list of one hundred and sixty two site representatives was compiled from the responses from the thirty seven contractors. The final version of the questionnaire was sent out in April 1991 with the covering letter shown in Appendix H. Also enclosed was a self-addressed envelope for the return of the completed questionnaires. Ninety three respondents completed the questionnaire and returned it within three weeks. The responses came from thirty four companies out of the thirty seven that responded to the first stage. Two questionnaires out of the ninety three returned were not included in the data analysis because they were not properly completed.

7.7 SUMMARY

An account of the development, population, respondents and the distribution of the questionnaire is given in this chapter. It shows the reasoning that underlies the development and management of the questionnaire. This marked the end of the research data gathering process. The next stage is the analysis of the questionnaire.
CHAPTER 8
MAIN DATA ANALYSIS

8.1 INTRODUCTION

This Chapter is an account of the analyses and validation of the responses to the questionnaire. The object of the data analysis is to provide answers to the research objectives, and to form the basis on which to develop a new quality system, also to provide information to support or refute the research hypotheses. Tests for reliability and validity of the responses were considered desirable in order to enable generalisation of the findings to be made. The rationale for the data analysis is discussed under each section of the analysis. All relevant statistical methods were tested and the most appropriate ones selected for the data analyses.

The Chapter concludes by providing answers to the research objective, information to support the hypotheses in addition to providing the necessary data to carry out stages 5 to 7 of soft systems methodology and to develop the new quality system.

8.2 THE AIM OF THE ANALYSIS

The goal is to present the research data in a legitimate manner and to argue logically its importance in achieving the research objectives. To this end, the analysis of the data was to provide answers to the following research objectives:

1. Univariate Analysis for evaluation purposes.
2. Test for Reliability and Validity of the research data.
3. Establish the factors influencing conformance to specification.
4. Determine the relative importance of the influencing factors.
5. Determine the coefficient values of QCS variables in terms of the influencing factors.
6. Determine the relative importance of:
   - each level of QCS
   - QCS variables
   - QCS actions

Bearing in mind the fact that every computer software has its own way of handling data, it was considered desirable to describe the method by which the responses to the questionnaires were prepared and entered in the computer for the analyses.

8.3 DATA INPUT

8.3.1 Code Book

The first step was to create a computer file that lists each respondent's answers to each question. To do this, a code book was created. Appendix J show the code book for the data. It itemises all the important information about what is in the data file, For example, it specifies that each respondent's information required 2 records (for all 106 variables), the physical location of each variable (that is, beginning and ending column numbers), what the variable was called, and the description of each variable name and values. The code book comprises of the following headings:

- Variable name
- Origin of the question
- Description (Variable label)
- Response code/value
- Format record/columns
- Missing value

The code book shown in Appendix J formed the basis upon which the questionnaire responses were input into the computer ready for the analysis.
8.3.2 Missing Values

When the questionnaires were returned, it became clear that not all respondents had answered every question. In view of this, it was necessary to tell the computer what to do when there is no valid response. It is indicated in column 6 of the code book that the author would use a value of "9" to indicate missing information. Missing Value Command was therefore used to remove codes associated with certain attributes of a variable(s) from the analysis.

8.3.3 Data List

Appendix K shows the record and column to which each variable was recorded in the computer file. For example, the variable named PER1 is in column 5 of record type 1 while the variable named Fac2 is in column 6 of record type 2.

Having described in detail the preparation of the data for computer analysis, the next stage is to carry out univariate analysis of the data.

8.4 UNIVARIATE ANALYSIS OF THE QUESTIONNAIRE

In order to ensure that the data as input into the computer is clean (ie. does not contain errors) the analysis will begin with univariate analysis. Jendrek (77) points out that:

"Researchers must be sure the data are clean before beginning data analysis. Once the data are clean, most researchers like to know the characteristics of each individual variable".

Bailey (78) noted that in a descriptive study, especially an exploratory one, the researcher may be more concerned with describing the extent of occurrence of a phenomenon than with studying its correlates. Not only was the author concerned
about the frequency of occurrence of the variables, but it was directly relevant to the research objectives.

The aim of the research clearly show that the study is an exploratory one, hence there is a need to find out more about the frequency of occurrence of the variables defined in the study. Equally important is to check the legitimacy of data codes before embarking on a more detailed analysis. The following reasons make it objectively important to carry out univariate analysis:

1. To check the legitimacy of data codes - referred to as data cleaning.

2. To become familiar with the variables. It makes little sense to talk about a relationship between 'cost constraint' and 'conformance to specification', if we do not know the sample's 'cost constraint' distribution. "Careful researchers know the characteristics of individual variables before examining relationships between variables" (77).

3. To provide definite information to support or refute the findings of the Literature Survey and case studies.

4. To provide a statistical base for the description and discussion of the variables for the new quality system to be developed and to draw conclusions and recommendations at the end of the research.

The most basic form of univariable statistic is the frequency. A frequency distribution counts how often each attribute on a variable occurs.

SPSS-X subcommand titled 'FREQUENCIES' produces a table of counts, percentages, measure of central tendency and bar chart for the named variable(s).
The subcommand was used with relevant specifications for the univariate analysis. The resulting printout is shown in Appendix L with the variable name and variable label shown on the top of each analysis. The value label column represents the response code used for each variable. For example, the variable named PER1 has the following value labels: "contract manager," "project manager" and "site manager or agent."

Some people claim that a picture is worth a thousand words. The author supposes that these same people may think that a graph is worth a thousand numbers. To this effect, the frequency distributions of the research data are provided as bar charts. The length of each bar corresponds to the frequency of that attribute as shown at Appendix L.

A careful examination of the printout revealed that the data was clean, that is, there were no illegitimate codes. The next stage of the analysis was to test the reliability and validity of the data.

8.5 RELIABILITY AND VALIDITY

Regardless of the procedure by which a measurement is taken, the issue of quality of the procedure has to be resolved before statistical manipulation is useful or interpretable. The quality of measures is usually phrased in terms of two questions: (a) is the procedure reliable? (b) is the procedure valid? The research measuring instrument (the questionnaire) must be evaluated satisfactorily for reliability and validity before any statistical analysis can be interpretable and before the scientific community can willingly accept the research work.
8.5.1 Reliability

The problem of reliability refers to the stability of the measurement process itself when applied under standard conditions. It was required to find out if the questions used in the research, when applied repeatedly by other researchers or at different times, will produce the same results. In other words, reliability refers to consistency between independent measurements of the same phenomenon. Smith (79) asserts this:

"Thus a minimal requirement for any science is that it yield consistent measurement confirmable by independent observers - that it be independently reliable. Science requires reliable indicators or data. It is rare for researchers to obtain perfect reliability between independent measurements. Lack of consistency in measurement is therefore a very real problem which researchers must take into account".

As a basic step in any scientific problem, it is necessary to determine the extent to which measures are dominated by reliable variance or by measurement error.

8.5.2 The Reliability Coefficient

A very useful measure of reliability is obtained by correlating the scores on alternative forms of a measure. If alternative forms of a test exist, the two tests can be administered to a group of subjects. Each subject will then have a score on each test, and it is a straightforward matter to correlate the two tests with the regular equation. The resulting correlation is called the reliability coefficient. Nunnally (80) points out that:

"If reliability coefficient is 1.00, there is no measurement error at all in either of the alternative forms. People are ordered exactly alike on the two forms, scores are entirely repeatable, and one can generalise with perfect accuracy from one test to the other. At the other extreme, if reliability coefficient is zero, the theory of reliability leads to the conclusion that both measures are entirely unreliable, in which case the distributions of scores are distributions of pure errors".
Of course reliability is usually somewhere between 1.00 and zero. The size of the reliability coefficient is a direct indication of the extent of reliability. "The better, commercially distributed tests typically have reliability coefficients ranging between .80 and .95" (80).

8.5.3 Estimating the reliability coefficient

There are a number of ways to test measurement reliability, each of which has its own advantages and disadvantages. The methods to be discussed here are (i) Test-retest (ii) Alternate-form, (iii) split-half and (iv) Internal consistency method.

8.5.4 Test-retest method

In the test-retest method, two measurements on the same population are taken with the same instrument used at different times. The correlation between the two sets of measurements will be an estimate of the reliability coefficient. The higher the agreement between these measurements, the higher the reliability is judged to be. Unfortunately, there are two important disadvantages to using the retest method. The first is that the obtained reliability coefficient will reflect little of the error due to the sampling of content. The second is that the individual's memory of the answers given on the first test administration is quite likely to influence the answers given on the second. Memory works to make the two sets of test scores correlate highly, and consequently the reliability coefficient is usually an overestimate when determined by the retest method.

The present research methodology does not call for the questionnaire to be sent out to the same respondents twice. This was not found to be necessary in solving the research problems. Even if it had been necessary, it would have had to be done within an interval of a few months and individuals' memory would have caused
spuriously high reliability. While the content of the questionnaire is an issue, the need to measure the repeatability of the answers is not an issue.

Based on this argument, the test re-test method of estimating the reliability of the research measuring instrument was found not to be appropriate.

8.5.5 Alternate - form method

Instead of using the same test on two occasions, some researchers often found it appropriate to use two alternate forms. That is, instead of making up only one test form, two forms could be constructed which are very much alike. The correlation between the scores obtained on the two forms represents the reliability coefficient of the test. "Alternate forms are useful in follow-up studies, or in investigations of the effects of some intervening experimental factor on test performance" (81).

The research questionnaire is not a follow-up study nor is it an investigation of the effects of some intervening experimental factor on test performance. In view of this, this method was not appropriate in estimating the reliability coefficient of the research data.

8.5.6 Split-Half method

From a single administration of one form of a test, it is possible to arrive at a measure of reliability by various split-half procedures. In such a way, two scores are obtained for each person by dividing the test into comparable halves. To find split-half reliability, the first problem is how to split the test in order to obtain the most nearly comparable halves. This method is not ideal for the questionnaire administered for the research, hence this method of estimating reliability was not appropriate for the data.

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8.5.7 Internal Consistency Method

A fourth method for finding reliability, also utilising a single administration of a single test is based on the consistency of responses to all items in the test. The method involves the administration of a single measure and no extra effort on either splitting the component items or repeating items in a test is required.

The most generally useful equation for estimating reliability on the basis of internal consistency is by coefficient alpha and by the Kuder-Richardson formula 20, referred to as KR-20. While the coefficient alpha is used for polychotomus items (multipoint items), KR-20 is used for dichotomously scored items (items having only two categories e.g. yes or no). Nunnally (80) points out that:

"These equations usually provide good estimates of the reliability obtained from correlating alternative forms. Methods based on item correlations are superior to methods based on subdivided tests because there are so many different ways of subdividing a test. The reliability estimates obtained from these different approaches frequently differ appreciably from one another. Essentially, the methods based on item correlations estimate the average of the reliability coefficients that would be obtained from all possible ways of subdividing the items on a test, which obviously means that the methods based on item correlations are superior to any particular method based on subdivided test".

The internal consistency method has a lot of merit over the other methods as described above. In addition, its application of a single form of test make it more appropriate for this research. Therefore, it was used in estimating the reliability coefficient of the research data.

8.5.8 Internal Consistency Reliability for the Research Data

The data reliability coefficients were statistically computed by using SPSSX command titled 'Reliability'. All variables in the questionnaire were included in the analysis. Out of the 61 questions in the questionnaire, only 2 questions were
Table 8.1: Reliability Analysis Scale (ALL)

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<th>ITEM-TOTAL STATISTICS</th>
<th>SCALE</th>
<th>SCALE</th>
<th>CORRECTED</th>
<th>SQUARED</th>
<th>ALPHA</th>
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<td>IF ITEM</td>
</tr>
<tr>
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<td>IF ITEM</td>
<td>CORRELATION</td>
<td>CORRELATION</td>
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</tr>
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<td>10346.0778</td>
<td>.0769</td>
<td>.9719</td>
<td></td>
</tr>
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<td>-.1658</td>
<td>.9021</td>
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<td>.0862</td>
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**Reliability Coefficients**

108 Items

Alpha = .9017

Standardized Item Alpha = .9630
dichotomous items. The remaining 59 questions were polychotomous items. As mentioned in Section 8.5.7, coefficient alpha is appropriate for polychotomous items, therefore the data reliability was assessed by using the coefficient Alpha equation. SPSSX recognises the advantages and popular demand for coefficient alpha to the extent that it uses it as its default statistic for computing the reliability of data.

While de Vaus (82) stated that a reliability coefficient of .70 is satisfactory for an exploratory research instrument, Nunnally (80) has suggested a reliability coefficient of .50 as acceptable. Table 8.1 shows the output for the computed reliability coefficient of the research data. The alpha coefficient for each item range from .89 to .97. The overall Alpha was .90 and the standardised item Alpha was .96.

Table 8.1 shows that the reliability coefficients for all items satisfy the .70 acceptable level. The overall coefficient 'Alpha for the research data also satisfies the .70 acceptable level. This means that the data is 90 per cent reliable and that it contains only 10 per cent measurement error. The conclusion to be drawn from the above is that the research data has satisfactory internal consistency reliability. In other words, the data is reliable.

8.6 VALIDITY

A test may be highly reliable and yet not be a valid measure of anything. A crucially important phase in the development of a measuring instrument concerns learning whether or not the instrument is useful for any purpose. This phase is usually spoken of as determining the validity of an instrument. "Validity is defined as the degree to which the researcher has measured what he set out to measure" (79). Nunnally (80) states that validity is a matter of degree rather than an all-or-none property, and validation is an unending process.
The more notable methods in the literature for determining the validity of a measuring instrument are (i) content validity, (ii) criterion-related validity, and (iii) construct validity. The three methods were critically evaluated in order to justify the appropriateness of the selected method.

8.6.1 Content Validity

Content validity refers to the degree to which a measure covers the range of meanings included within the concept. In other words, content validity assesses the adequacy with which a specified domain of content is sampled. Content means the theoretical substance constituting the concept.

One difficulty with content validity is that of adequately sampling the item universe. Anastasi (81) has noted that:

"The behaviour domain to be tested must be systematically analysed to make certain that all major aspects are covered by the test items, and in the correct proportions".

Content must therefore be broadly defined to include major objectives. The plan is to randomly sample from a specified domain of content and, if most persons in positions of responsibility agree that the plan was sound and well carried out, the test would have a high degree of content validity.

It is inconceivable to think of any part of this research for which there is an agreement upon the domain of content relevant to the concept under investigation. In other words, there is no agreed criterion for determining the extent to which any measure in this research has attained content validity.

8.6.2 Criterion-related validity

Criterion-related validation procedures indicate the effectiveness of a test in predicting an individual's behaviour in specified situations. For this purpose,
performance of the test is checked against a criterion, i.e. a direct and independent measure of that which the test is designed to predict. Primarily, it consists of correlating scores on the predictor test with scores on the criteria variable. The size of the correlation is a direct indication of the amount of validity. For example, the validity of a written test employed to select college freshmen is determined, in this sense, by the relationship between the scores people get on the test and their successful performance in college. The criterion in this case would be the grade-point average obtained over four years of college.

The above description shows that, a requirement for undertaking criterion-related validation is the existence of some relevant criterion. A careful assessment of this research revealed that there are no relevant external criteria against which any measure in the research can be precisely validated.

8.6.3 Construct Validity

Finally, construct validity is evaluated through determining the degree to which certain explanatory concepts (constructs) account for performance of the measurement. In other words, studies of construct validity are based on the way a measure relates to other variables within a system of theoretical relationships. This is carried out by investigating whether or not the instrument confirms or denies the hypotheses predicted from a theory based on the constructs. Nunnally asserts that:

"Typically a researcher questions by examining the interrelationship of the scale items rather than examining whether they can predict other behaviours. Items measuring the same thing should be interrelated"

Variables must be measured before they can be related to one another in experiments, and for statements of relationship to have any meaning, each measure must, in some sense, validly index what it is purported to measure. Because constructs concern domains of items, logically a better measure of any construct would be obtained by combining the results from a number of measures of such items than by taking any one of them individually. Similarly, the combined scores
from a number of measures of items in the domain can be thought of as having a
degree of construct validity for the domain as a whole.

This method of determining the validity of a measuring instrument is more in tune
with the research measuring instrument, hence it is explored here further.

8.6.4 Construct Validity of the Research Measuring Instrument

All the items employed in the questionnaire were new and specifically designed for
the research. Nunnally (80) points out that:

"The way to test the adequacy of the outline of a domain relating to a
construct is to determine how well the measure of items "go together"
in empirical investigation".

He also pointed out that in studies of individual differences, the first step is to
obtain scores for a sample of individuals on the items. An analysis of the resulting
correlations provides evidence about the extent to which all the items tend to
measure the same thing. "The degree of association between two variables can be
assessed by a statistic called a correlation" (24).

The research is within the term ("studies of individual differences") used by
Nunnally, therefore his suggested approach for construct validation of the
measuring instrument will be pursued. The questions in the questionnaire were
individual items for which scores have been obtained as the first step towards the
approach mentioned above. The next step is to find the correlation between the
items.

The questionnaire comprises five sections. Each section represents an item of
measurement. In addition, within section two, there was a main item (question 22
of section 2) which measures the factors influencing the achievement of quality. The
responses to the question will be treated as a separate section in the correlation
analysis.
To establish the degree to which the questionnaire items have measured what they were set out to measure, the SPSSX subcommand titled ‘CORRELATION’ was used to determine the correlation matrix for each section of the questionnaire. Correlations range from -1.00 to +1.00.

Three possible conditions can occur. There can be no observed association between two variables. That is, variation or change in one variable is unassociated with variation in the other. Correlation of this type are close to zero. A positive association can occur when variation in one variable is high and variation in the other variable is high. This association can range from +.01 to 1.00. Finally, a negative association can be observed. This association means, as variation increases in one variable it decreases in the second variable. This statistical association can range from -.01 to -1.00. Also, the stronger the positive or negative correlation, the closer the statistical value will be to + or -1.00.

An examination of the resulting correlations revealed that all the items in each section were correlated with each other. The correlation coefficient in each pair range from approximately +.01 to +.98. This statistic indicates the degree of association between the research measuring instrument. The results show a high degree of association between the items.

There is strong support in the literature for measuring the statistical significance of questionnaires (or social science research) at the .05 level. Significance at the .05 level (P < .05) simply means that the probability of a relationship as strong as the observed one being attributed to sampling error alone is no more than 5 in 100. Table 8.2 show the value of the correlation between the research items at the .05 level. The values used in the table were obtained from the statistical analysis of
<table>
<thead>
<tr>
<th>Section</th>
<th>Variables</th>
<th>Total number</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>19</td>
<td>49</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>19</td>
<td>49</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>289</td>
<td>289</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>E</td>
<td>4</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>F</td>
<td>5</td>
<td>155</td>
<td>155</td>
</tr>
<tr>
<td>G</td>
<td>6</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>H</td>
<td>7</td>
<td>930</td>
<td>930</td>
</tr>
</tbody>
</table>

Table B2: Test for Validity of the Research
correlation between the items. The percentage of pairs at the .05 level range from 34 per cent (questionnaire section 2) to 100 per cent for question 22 of section 2. The overall analysis shows that 67% of all the questionnaire items have strong relationships with each other at the .05 level. Therefore, these statistics provide evidence of a high degree of internal construct validity of the research measuring instrument. In other words, the statistics have proved that the research measuring instrument has achieved its purpose by measuring what it set out to measure. That is, the data has construct validity.

The next stage of the analysis is to identify the factors influencing the achievement of specified quality standards.

8.7 TO IDENTIFY THE FACTORS INFLUENCING THE ACHIEVEMENT OF SPECIFIED QUALITY REQUIREMENTS

The research objective No.1, is intended to identify the factors influencing the achievement of specified quality requirements and to establish their relative importance. The data required for resolving the first part of objective No.1 comprises of the findings of the case studies and the responses to the questionnaire. Having used the outcome of the case studies as part of the instrument for developing the questionnaire, the resolution of the first objective will be analysed solely on the responses to the questionnaire. However, the relevant responses will be validated against the case study findings. The information which is directly relevant to resolving the objective are contained in question No.22 of Section 2 and in Section 5 of the questionnaire.

Question 22 contained in Section 2 of the questionnaire was developed to serve two purposes. Firstly, to provide data for validating responses to Section 5 of the questionnaire and secondly, to give the respondents the opportunity to express their personal opinion regarding the factors influencing conformance to specified quality
requirements. The question was included in Section 2 to enable the respondents express their opinion before responding to Section 5. The respondents used their own words to express their opinions. The responses do not necessarily reflect the words used in Section 5 of the questionnaire. This confirmed that the method and the structure of the questionnaire has face validity. In spite of the fact that the respondents used their own words in answering question 22, there was a pattern in their answers. In other words, they were saying the same thing in different words.

The responses to question 22 were very encouraging and, as a result, a decision was made to base the resolution of the research objective No.1 on the responses to this single question. The decision was based on the following key points:-

1. It embraced all the issues raised in section 5 of the questionnaire.

2. Additional factors beyond those mentioned in section 5 were identified.

3. While section 5 requested the respondents to express their degree of agreement or disagreement with stated views; their responses to question 22 contained in section 2 strongly reflect what they considered to be major causes of non-conformance.

4. Free use of their own words which reflected their experience rather than what they were asked to express opinion about.

5. The overall response represents the opinion of a larger population directly involved with the problems. This was considered more important than the opinion expressed to section 5.

In the event that the response to question 22 had not been encouraging, the research objective one would have been resolved using the answers to section 5 of
the questionnaire. In which case the findings and recommendation that would have been drawn from an analysis based purely on Section 5 would have been interpreted with great care. From the above it became clear that, the responses to question 22 were a more reliable guide for resolving the research objective one than responses to section 5 alone. This gives the research a reliable base for resolving the other objectives and testing the hypotheses.

8.7.1 Analysis of question 22 of section 2

From the literature, it was identified that SPSSX subcommand 'MULTI RESPONSE' could be used for the analysis of the responses to question 22. All attempts to use the subcommand failed. The author therefore decided to carry out this particular analysis manually.

A preliminary examination of the responses to question 22 revealed that the answers given could be itemised and grouped. Therefore, the most commonly used words by the respondent were used to group the factors. The factors were defined as variables V1 to V30. The question specifically asked was what is it that respondents consider to be major causes of unacceptable quality of works listed in order of importance. Therefore, it was assumed that the respondents had presented their answers to this question in their order of importance with the most important listed as no.1. It must be noted that during the piloting of the questionnaire, respondents did not find it difficult to put their responses to this question in their own order of importance. With this in mind, there is a need to put weight against the responses. This was done by adopting the following method.
5 points were given if a respondent put a factor as the most important
4 points were given if a respondent put a factor as 2nd important
3 points were given if a respondent put a factor as 3rd important
2 points were given if a respondent put a factor as 4th important
1 point was given if a respondent put a factor as 5th important
No points were given if a respondent did not mention the factor

The responses to the question are shown in Table 8.3. The returned questionnaires were numbered from 1 to 101. With the respondents number on the top of the table and the responses on the left hand of the table (V1 to V30), the weights of each answer to the question are tabulated as shown. The total weighted value of each respondent's answer to the question is given under the column titled 'Total'.

A total of 30 factors were identified from the answers to the question as the major causes of unacceptable quality of works. The factors were validated by the responses to questions in section 5 of the questionnaire. The validity analysis is shown in row H of Table 8.2. Hence it could be deduced that the 30 factors identified from the responses to question 22 are the factors influencing the achievement of specified quality requirements in the UK construction industry.

8.8 TO ESTABLISH THE RELATIVE IMPORTANCE OF THE FACTORS INFLUENCING THE ACHIEVEMENT OF QUALITY

Having identified the factors influencing the achievement of specified quality requirements, the next stage is to establish their relative importance. It is an obvious thing to say, that the factors cannot be equally important. It is prudent, therefore to establish the relative importance of the factor, because it will help the construction industry focus, direct or re-direct their resources as necessary, towards getting it right at the first attempt.

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The method adopted in establishing the relative importance of the factors is to find the proportional average value of each factor. That is:

\[ W_j = \frac{100 \times S_j}{T} \]

where \( W_j \) = relative importance of factor \( j \)
\( S_j \) = weighted value of factor \( j \)
\( T \) = grand total of the weighted values

The above equation was used to calculate the relative importance of each factor and the values are depicted in Table 8.4. The 30 factors are shown graphically in figure 8.1. For example, the factor titled 'poor supervision by subcontractors' is named variable V9 with frequency distribution of 49, weighted value \( S_j \) of 157 and relative importance of 12.8. Variable V9 has the highest proportional average value and therefore it is the most important factor. Variable V21 has the lowest proportional average value and hence the least significant of all the identified factors.

8.9 THE MULTIPLE REGRESSION ANALYSIS OF VARIABLES FOR THE NEW QUALITY SYSTEM

The purpose of multiple regression analysis for the research is to determine the coefficient value of the variables for a new quality system. The coefficient values are required for calculating the relative importance of:

1. Each level of the new quality system to be developed in Chapter 10.
<table>
<thead>
<tr>
<th>Factor considered by the New Quality System</th>
<th>100</th>
<th>1000</th>
<th>1250</th>
<th>1500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedback of the wrong forecast by computer</td>
<td>0.1</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Forecast of the wrong forecast by computer</td>
<td>0.1</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Forecast of the wrong forecast by computer</td>
<td>0.1</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Forecast of the wrong forecast by computer</td>
<td>0.1</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

**Table 5a: Relative importance of factors**

<table>
<thead>
<tr>
<th>Influencing factor(s)</th>
<th>100</th>
<th>1000</th>
<th>1250</th>
<th>1500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training of operators</td>
<td>0.1</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Training of operators</td>
<td>0.1</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Training of operators</td>
<td>0.1</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Training of operators</td>
<td>0.1</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

*Note: Values are indicative and do not represent actual percentages.*
Figure 8.1: Relative importance of factors influencing the achievement of quality in construction.
The first stage of the multiple regression analysis, is to decide on the relevant dependent and independent variables. The new quality system is to be developed for the purpose of giving the construction team a co-ordinated system that will aid them in achieving conformance to specified requirements at the first attempt. Therefore, the dependent variables are automatically the factors influencing quality. These factors are variable named V1 to V30 as identified in section 8.7.1 and 8.8. It is not possible to include all 30 factors in a multiple regression analysis, the reason being that not all the 30 factors identified can be forecast. Since there are no relevant independent variables from the questionnaire for all the variables, only 20 out of the 30 factors were used in the multiple regression analysis.

Independent variables are those variable in the questionnaire that are relevant to the development of a new quality system. Therefore, each question in the questionnaire was critically examined and a selection was made based on their contribution to the development of a new quality system as depicted in the conceptual model. Only variables with significant coefficients are included in the analysis. Variables which give coefficients of zero or negative (-) were also excluded from the equation (with one exception). Table 8.5 shows both the dependent and independent variables used in the regression analysis and their regression coefficients.

SPSS-X procedure titled REGRESSION was used for the regression analysis. Having selected the dependent and independent variables, the next stage was to write a programme for the analysis by using the relevant subcommands. After careful consideration, the following subcommands were found to be the most appropriate for the regression analyses:

1. MEAN SUBSTITUTION: for the treatment of missing values from the data.
2. **CRITERIA**: the Criteria subcommand was used in the analyses to set variable entry/removal limits. Entry was set at 0.05 and removable at 0.10 with the tolerance set at 0.0001.

3. **ORIGIN**: the subcommand was used to request the regression through the origin and to suppress the constant terms which are not required in the analyses.

4. **STEPWISE**: this subcommand was used to construct the equations.

The figures relevant to the analysis are the 'unstandardised regression coefficient' (B) and the XTX matrix for the variables. Table 8.6 shows a typical example of the multiple regression print out and column 3 of Table 8.5 shows the coefficient "B" for each regression equation. Various verifications carried out reveal that the regression analyses meet all relevant "Regression Assumptions." Detailed description of the tests carried out are found not to be very important in the text of this thesis, hence they are not included.
<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Independent variables correlated to dependent variables</th>
<th>Regression model</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>Fac3 Imp2 Imp3</td>
<td>0.37977 Fac3</td>
</tr>
<tr>
<td>V2</td>
<td>Fac3 Fac1 Imp2 Imp6 BSI2 BSI4 BSI6</td>
<td>0.60616 BSI6</td>
</tr>
<tr>
<td>V3</td>
<td>Imp2 Imp3 Fac3 Imp1</td>
<td>0.53897 Fac3</td>
</tr>
<tr>
<td>V4</td>
<td>Fac5 Imp2 Com4 Imp3 Fac3</td>
<td>0.42003 Fac5</td>
</tr>
<tr>
<td>V5</td>
<td>Imp2 Fac3 Imp1</td>
<td>0.71974 Fac3</td>
</tr>
<tr>
<td>V6</td>
<td>Imp6 Imp3 Imp4 Imp5 Fac1 Imp6 Imp7</td>
<td>0.77711 Imp6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.15260 Imp7</td>
</tr>
<tr>
<td>V7</td>
<td>Com1 to Com4 For1 to For8 BSI2 to BSI4 Imp5 Fac5</td>
<td>0.85675 For7</td>
</tr>
<tr>
<td>V8</td>
<td>Fac1 Fac3 Imp6 BSI2 BSI4 For2 For3</td>
<td>0.80299 BSI4</td>
</tr>
<tr>
<td>V9</td>
<td>For7 For6 Fac5 Fac3 Com4 Fac6 Fac7</td>
<td>0.84021 Fac6</td>
</tr>
<tr>
<td>V10</td>
<td>Fac5 For6 For7 For8</td>
<td>0.47107 For7</td>
</tr>
<tr>
<td>V11</td>
<td>Fac10 Fac11 Fac8</td>
<td>0.43195 Fac10</td>
</tr>
<tr>
<td>V12</td>
<td>Fac15 Fac2 Fac5</td>
<td>0.75721 Fac15</td>
</tr>
<tr>
<td>V13</td>
<td>Fac1 Fac12 BSI1 BSI3 BSI4</td>
<td>0.66584 BSI4</td>
</tr>
<tr>
<td>V14</td>
<td>Fac12 to Fac17 Com1 Com2 BSI4 For1 For5 Fac2</td>
<td>0.61600 Com1</td>
</tr>
<tr>
<td>V15</td>
<td>Fac10 Fac19 Fac20 Fac5 Fac13</td>
<td>0.44994 Fac5</td>
</tr>
<tr>
<td>V16</td>
<td>Imp2 Fac5</td>
<td>0.46164 Fac5</td>
</tr>
<tr>
<td>V17</td>
<td>Imp2 Imp1 Imp4</td>
<td>0.51664 Imp4</td>
</tr>
<tr>
<td>V18</td>
<td>Imp2 BSI1 Imp4</td>
<td>0.42907 Imp4</td>
</tr>
<tr>
<td>V19</td>
<td>Imp2 Imp4</td>
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</tr>
<tr>
<td>V20</td>
<td>Fac5 Fac1 Imp6</td>
<td>0.45644 Fac5</td>
</tr>
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</table>

Table 8.6: Variables used in the regression analyses and their coefficients
MULTIPLE REGRESSION THROUGH THE ORIGIN

Equation Number 1  Dependent Variable:  V1  SIZE OF CONTRACTOR STAFF

XTX Matrix

<table>
<thead>
<tr>
<th></th>
<th>FAC3</th>
<th>V1</th>
<th>IMP2</th>
<th>IMP3</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAC3</td>
<td>1.00000</td>
<td>-.33412</td>
<td>-.77900</td>
<td>-.59978</td>
</tr>
<tr>
<td>V1</td>
<td>.33412</td>
<td>.88836</td>
<td>-.05041</td>
<td>.01505</td>
</tr>
<tr>
<td>IMP2</td>
<td>.77900</td>
<td>.05041</td>
<td>.39317</td>
<td>.18612</td>
</tr>
<tr>
<td>IMP3</td>
<td>.59978</td>
<td>.01505</td>
<td>.18612</td>
<td>.64026</td>
</tr>
</tbody>
</table>

Variables in the Equation

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>95% Confidence Interval</th>
<th>Beta</th>
<th>SE Beta</th>
<th>Correl</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAC3</td>
<td>.379768</td>
<td>.107128</td>
<td>.167228 - .592308</td>
<td>.334124</td>
<td>.094253</td>
<td>.334124</td>
<td></td>
</tr>
</tbody>
</table>

Variables not in the Equation

<table>
<thead>
<tr>
<th>Variable</th>
<th>T</th>
<th>Sig T</th>
<th>Variable</th>
<th>Beta</th>
<th>Partial Tolerance</th>
<th>VIF</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
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<td>.0006</td>
<td>IMP2</td>
<td>-.128227</td>
<td>-.085305</td>
<td>.393166</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IMP3</td>
<td>.023513</td>
<td>.019962</td>
<td>.640261</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Collinearity Diagnostics

<table>
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<th>Cond Variance Proportions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index FAC3</td>
<td>1 1.00000 1.000 1.00000</td>
</tr>
</tbody>
</table>

End Block Number 1  PIN = .050 Limits reached.

Table 8.6: Multiple Regression Through The Origin
8.10 TO FIND THE RELATIVE IMPORTANCE OF THE ACTIONS REQUIRED FOR THE QUALITY SYSTEM

Having determined the regression coefficient for the variables, the next stage of the analysis is to use those coefficients to work out the relative importance of the Actions. However, there are various steps involved.

STEP 1
The first step is to calculate the relative importance of each regression coefficient in terms of the weighted value of the factors influencing quality. Table 8.7 show the calculations with a total value of 47,000.

STEP 2
The second step is to use the values found in column 4 of Table 8.7 to work out the relative importance of the four levels that will make up the new quality system as shown in Tables 8.8 and 8.9.

STEP 3
The third step is to determine the relative importance of the variables. The printouts for the multiple regression equations show that several independent variables are correlated with each dependant variable. However, because of the intercorrelations between variables, for each dependent variable an adequate regression model can be based on a single independent variable (with the exception of V6.) For example, Table 8.5 shows V1 as the dependant variable with Fac3, Imp2 and Imp3 as independent variables which correlate with it. However an adequate
<table>
<thead>
<tr>
<th>Quality Determinants</th>
<th>Wj</th>
<th>dj</th>
<th>Wjdj</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>3</td>
<td>4 2 x 3</td>
</tr>
<tr>
<td>V1</td>
<td>1.00</td>
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<td>0.3796</td>
</tr>
<tr>
<td>V2</td>
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<tr>
<td>V4</td>
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<td>0.42003</td>
<td>0.3780</td>
</tr>
<tr>
<td>V5</td>
<td>7.70</td>
<td>0.71974</td>
<td>5.5421</td>
</tr>
<tr>
<td>V6</td>
<td>3.40</td>
<td>.777107 - .152602</td>
<td>2.1233</td>
</tr>
<tr>
<td>V7</td>
<td>9.80</td>
<td>0.85675</td>
<td>8.3961</td>
</tr>
<tr>
<td>V8</td>
<td>4.80</td>
<td>0.80299</td>
<td>3.8544</td>
</tr>
<tr>
<td>V9</td>
<td>12.60</td>
<td>0.84021</td>
<td>10.7547</td>
</tr>
<tr>
<td>V10</td>
<td>0.82</td>
<td>0.47107</td>
<td>0.3846</td>
</tr>
<tr>
<td>V11</td>
<td>3.30</td>
<td>0.43195</td>
<td>1.4254</td>
</tr>
<tr>
<td>V13</td>
<td>3.10</td>
<td>0.75721</td>
<td>2.3474</td>
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<tr>
<td>V15</td>
<td>1.20</td>
<td>0.66584</td>
<td>0.7104</td>
</tr>
<tr>
<td>V16</td>
<td>4.40</td>
<td>0.61600</td>
<td>2.7104</td>
</tr>
<tr>
<td>V17</td>
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**Table 8.7 Relative Importance of each regression coefficient**
## Influencing Factors

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<th>Independent variables 2</th>
<th>wj dj Level 1 3</th>
<th>wj dj Level 2 4</th>
<th>wj dj Level 3 5</th>
<th>wj dj Level 4 6</th>
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<td>Fac3</td>
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<td>11.3509</td>
<td>4.4119</td>
<td>8.9901</td>
<td>22.2475</td>
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</table>

Sum = 47.000

Therefore relative value of each level = Total x 100
\[
\frac{\text{Sum}}{\text{Total}}
\]

**Table 8.8** : Allocation of the relative importance of each regression coefficient to the four levels of a new quality system
<table>
<thead>
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<th>Total x 100 Sum</th>
<th>Percentage (when constant = 1)</th>
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<td>1</td>
<td>11.3509 x 100</td>
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<td>47,000</td>
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<td>2</td>
<td>4.4119 x 100</td>
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<td></td>
<td>47,000</td>
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<tr>
<td>3</td>
<td>8.9901 x 100</td>
<td>19%</td>
</tr>
<tr>
<td></td>
<td>47,000</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>22.1619 x 100</td>
<td>47%</td>
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<tr>
<td></td>
<td>47,000</td>
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</tr>
<tr>
<td>Total</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 8.9: Relative Importance of the four levels of a new quality system
Table 8.10: Correlation Matrix for New Quality System (CQS) Independent Variables
model can be constructed with Fac3 as the sole independent variable, with a coefficient "B" of .379768. The correlation matrix reveals that Imp2 and Imp3 are highly correlated with Fac3 (with correlation coefficients 0.7790 and 0.59978.)

This does not imply that, because the regressions can generally be represented in terms of a single independent variable, other variables have no effect. Rather, their effects are felt indirectly by the fact that they are related to the independent variable used in the model equation. In view of this, the relative importance of each independent variable is the proportional average of their correlation with the main variable in each equation. The example given above with V1 as the dependent variable shows that the coefficient value of .379768 was brought about by the three independent variables with the proportional average of 1.000 for Fac3, .77900 for Imp2 and .59978 for Imp3. Table 8.10 shows the multiple regression correlation matrix for all the variables used in the regression analyses. The addition of the figures in each row gives us the total correlation value of each independent variable as shown under the column titled 'Total' in Table 8.10. The sum is the grand total of all the correlation value in each level.

The relative importance of each independent variable is therefore calculated as follows:

Relative importance = \( \frac{\text{Total}}{\text{Sum}} \times \) The relative importance of each level

eg \( \text{Imp1} = \frac{2.2735 \times 24}{22.2512} = 2.5 \)

The calculation for each variable is shown in Table 8.11.

STEP 4

The fourth step is to use the relative importance of the independent variables calculated in step three to determine the relative importance of the Actions. Before
the calculations are carried out, it is prudent to mention other methods that could be used in obtaining values for the Actions. The alternative methods are:

1. To ask the potential users of the new quality system to rank the Actions in each level in their perceived order of importance and then allocate values to each from the total relative importance of the level. That is 24% for level 1, 10% for level 2, 19% for level 3 and 47% for level 4.

2. For the author to extend the research methodology to include interviews with relevant persons within some construction companies to ask them to rank the Actions in each level in their perceived order of importance and then use the figure obtained from such an exercise to allocate value to each Action within the total value of the relevant levels.
<table>
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<th>Percentage</th>
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<td>Sum</td>
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</tr>
<tr>
<td>Imp1</td>
<td>(2.2735/22.2512) x 24</td>
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</tr>
<tr>
<td>Imp2</td>
<td>(6.9325/22.2512) x 24</td>
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<td></td>
</tr>
<tr>
<td>Imp3</td>
<td>(2.3034/22.2512) x 24</td>
<td>2.5</td>
<td></td>
</tr>
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<td>Imp4</td>
<td>(3.2959/22.2512) x 24</td>
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<td>(1.0492/22.2512) x 24</td>
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<tr>
<td>Fac3</td>
<td>(6.3958/22.2512) x 24</td>
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</tr>
<tr>
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<td>24%</td>
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<td></td>
</tr>
<tr>
<td>Level 2</td>
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</tr>
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<td>Fac20</td>
<td>(0.8544/16.4835) x 10</td>
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### Table 8.11: Relative Importance of variables (Part 2)

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<td>Imp6</td>
<td>(4.4940/26.0618) x 19</td>
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<td>(0.8710/26.0618) x 19</td>
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<td>BSI4</td>
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### Table 8.11: Relative importance of variables (Part 3)

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47%
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</tr>
</tbody>
</table>

**Table 8.2:** Variables and their contribution to a new quality system.

- **Variables:**
  - Temporary protection requirements
  - Access, tools, plants & equipment
  - Cost
  - Comparison
  - Tender program/contract duration
  - Site visit/proposed organization/structures
  - Contractor/Subcontractor Query List
  - Receive subcontractor query lists
  - Update 2 Send ALL Ebury documents
  - Prepare ALL Ebury documents
  - Prepare query list 5_send to consultants
  - Contractor internal CRM
  - Attend department to submit comments
  - Send out notice of CRM to consultants
  - Issue tender document to each department

**Summary:**
- **Level 1:** Percentage/Sum (see figure B.1)
- **Total:**
|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |(24,389),(956,984)
<table>
<thead>
<tr>
<th>4.7%</th>
<th>1.3%</th>
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<tr>
<td>0.0%</td>
<td>0.2%</td>
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<tr>
<td>1.5%</td>
<td>0.3%</td>
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<tr>
<td>1.3%</td>
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<tr>
<td>9.8%</td>
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**Actions**

<table>
<thead>
<tr>
<th>4.5</th>
<th>4.4</th>
<th>4.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review meeting</td>
<td>Progress and quality</td>
<td>Checkers and issues flagged</td>
</tr>
</tbody>
</table>

**Notes**

- 4.4: Can't open instruction.
- 4.3: Frequency of use.
- 4.2: Average standard.
- 4.1: Video related works/Exert
- 4.0: Other similar works/Exert

**Total Score**

- 4.4
- 4.3
- 4.2
- 4.1
- 4.0
3. To use a mail postal questionnaire to request for ranking of the Actions by contractors and then use the results to allocate values to the Actions within each level.

4. For the author to use his many years of practical experience in the construction industry to rank the Actions as to what he perceived to be their order of importance. If this method had been used, it could have lead to some justifiable criticism from fellow professionals.

The above alternatives were given careful consideration before they were dropped in favour of the following method. Alternative 1 would have led to criticism and alternatives 1 to 3 would have been too abstract. That is, they would not have contained sufficient information to enable respondents to put the whole issue of quality in construction into perspective as they did for the research questionnaire. The only way in which any of the alternatives 1 to 3 could have yielded a reasonable result would be to include it as part of a comprehensive questionnaire that will enable respondents to put the issues into perspective after having been made aware (in other sections of a questionnaire) of other issues relating to quality in construction. The author considered this as a possible further area of study.

The method used in calculating the relative importance of each Action is to 'average out' the value of each variable into the number of Actions with which they have a relationship. The strategy is as follows:

1. To examine each variable and determine from practical experience their relative contribution to each Action.

2. If a variable has any contribution (however small or large) to a particular Action, a tick is made in the column of the variable under the row of the Action. For example, Impl has a contribution to make in carrying out
Actions no. 1.3, 1.4 and 1.7 as shown in Table 8.12. That is, Impl1 has relationships with three Actions and they are all in level 1. Imp2 has relationships with all the fifteen Actions in level 1.

3. The number of rows ticked in each column is added up as the sum for each variable.

4. The relative importance of each variable (as calculated in step 3) is divided by the sum for each variable. For example, Impl1 has a relative importance of 2.5 with a sum of 3. Therefore the ratings for Actions 1.3, 1.4 and 1.7 as a result of the variables Impl1 relationship with them are 2.5/3 = 0.83. This calculation is carried out for all the variables and the Actions as shown in Table 8.12.

5. The relative importance of each Action is the addition of the values in their row. For example, Action no 1.1, has a total rating of 0.95 which is the addition of 0.50 contributed by Imp2 and 0.45 contributed by Fac3.

6. The total ratings for all the actions in a particular level are then added up which must equal the relative importance of the level as calculated in step two and shown in Table 8.9.

The "average" method is considered appropriate in this instance, because it does not overload one Action at the expense of other Actions. At the same time, it does not under-value any Action because any discrepancies in the average ratings tend to cancel each other out, thereby giving an overall rating that is practically comparable with the order of importance of each Action. This brought the data analysis to a conclusive end.
8.11 SUMMARY

The various aspects of the research covered by the main data analysis has been set out. This was followed by a description of the preparations made in order to input the responses of the questionnaire into the computer ready for analysis. Univariate analysis was carried out in order to find out the frequency of occurrence of the variables defined in the study and to check the legitimacy of the data codes.

Before any statistical manipulation of the data was embarked upon, tests were carried out in order to find out the reliability and validity of the data. Appropriate methods were used for the tests and the results show that the data has satisfactory internal consistency reliability and construct validity.

The primary factors influencing the achievement of specified quality requirements were identified from the opinions expressed by the respondents. The factors were supported by the findings of the three case studies. The factors were based on the free use of respondents' own words which reflect their experience as Line Managers rather than what they were asked to express an opinion about. The identification of the factors was followed by the establishment of their relative importance. This has removed a large cloud from the topic of quality management in construction. Hence, the research has produced new evidence to enable the construction team to direct and/or re-direct their limited resources as necessary towards the ultimate aim of achieving the specified quality requirements at the first attempt.

Identified in the analyses is the relative importance of each level, variables and actions required as instruments for the development of a new quality system for managing quality by the construction team. In order to determine the relative importance in a scientific manner, the coefficient values of the variables were determined by multiple regression analysis. It was carried out in terms of the primary factors already identified in the Chapter. The analysis involved a logical
and sequential four step approach which was successfully carried out. It provides the necessary quantitative data required for developing a new quality system. However, before the development of a new quality system could be embarked upon, the next chapter will deal with a general discussion and evaluation of the research findings in terms of their practical implications.
CHAPTER 9

DISCUSSIONS AND EVALUATION OF THE RESEARCH FINDINGS

9.1 INTRODUCTION

It is now necessary to present a balanced and honest discussion of the principal conclusions to be drawn from the findings as well as their practical implications. The first stage was to compare the methodology and findings of the research with those of the previous studies that were critically reviewed in the thesis. The contribution of the three case studies to the research objectives was once again revisited to enable conclusions to be drawn.

The discussion is further explored under the four headings to which a new quality system will be developed in the next chapter. The discussion will embrace all the principal findings that will contribute to the development of the new system and conclusions are drawn. The future trend of quality management in construction is examined under the headings: (i) Integration of design and construction, (ii) The Management of Construction Facilities and (iii) Total Quality Management. The evaluation and discussions are carried out as a prelude to the application of stage 5 to 7 of the "soft" system thinking methodology and the development of a new quality system.

9.2 THE RESEARCH COMPARED WITH THE PREVIOUS STUDIES

The findings of the research support some of the results of the previous studies. For example, 59% of the influencing factors are attributed to the construction phase while 19% is due to design, 3% to materials and components and 19% outside the direct control of the industry. This is similar to the BRE (1), (25), (66), NEDO (28), Abbott (26), Hammerlund et al (68) and Griffith (70) Reports. While the
previous studies had attributed the causes of quality problems to design, construction and materials, this research has found that there is a fourth group. 19% of the factors influencing the achievement of quality are outside the direct control of the industry as shown in column 9 of Table 8.4. The previous studies had adopted either direct field observations (case studies) or only questionnaires. However this research utilised both direct field observations and the questionnaire. This approach has given the research greater strength than previous studies. This is demonstrated by the detailed data obtained for the research which is sufficient to resolve the research objectives and to support or refute the hypotheses.

While the previous studies had relied mainly on descriptive statistics for their analysis, this research has moved further by using appropriate inferential statistics in the questionnaire analysis. Equally important is the fact that the data was found to have internal consistency reliability and construct validity. Unlike the data of the previous studies (with the exception of (69)) which were not tested for either reliability or validity. The reliability and validity of the data enables generalisation of the findings to be more tenable and defensible than the results and recommendations of the previous studies.

9.3 CONTRIBUTION OF THE CASE STUDIES TO THE RESEARCH OBJECTIVES

The main contribution of the case studies to the research goals is to provide the first hand information used in conjunction with the knowledge gained from the literature review to develop the conceptual model and in structuring the questionnaire. It was also used to support or refute some of the responses to the questionnaire.

In spite of the differences in design, form of contract, contractor's organisation, location and time of the three projects, there were defects with brickwork and, in particular, mortar deposits into cavities. The failure could result in cold bridge.
dampness and rising damp in the buildings. Also found on all the projects was a lack of adequate protection of works and materials. The level of subcontractor's supervision was never adequate on any of the projects. These findings support the results from some of the previous studies and call for immediate action to improve the situation. Not only are there common causes of defects/failures but they are equally supported by the responses to the questionnaire. Therefore it can be argued with strong conviction that the findings of the case studies validate the responses to the questionnaire and vice versa.

There were no identifiable differences in the management of quality relating to the three case studies that could be attributed to procurement method. The conclusion which could be drawn is that procurement method has no significance in the achievement of specified quality requirements. Although there were some peculiarities in the way the project used as case study no. 2 was run. Amongst others, the following actions were taken by the contractor which in many ways contributed to the successful completion of the project with fewer quality problems:

1. Well defined job description for contractor personnel.
2. Selection of subcontractors that the contractor had successfully worked with on previous projects.
3. Well trained and experienced contractor site team.
4. High client involvement.
5. Design input by contractor site team.
6. Major elements of the building were designed by subcontractors.
7. Proper material control (i.e. ordering, delivery and handling)
8. Strict control of flow of production information.
9. Orderly and professional sequencing of the operations (the only exception being the roof cladding, perimeter brickwork and curtain wall).
10. Regular site meetings between:
The importance of the above points was emphasised by the respondents in their comments to Section 5 of the questionnaire.

The conclusion to be drawn is that the findings of the case studies have achieved its intended objective by providing first hand information upon which the subsequent stages of the research were based.

9.4 TENDER PROCESS TO AWARD OF CONTRACT - RIGHT FROM THE START

It has become evident from the responses to the questionnaire that assumptions are often made by contractors about tender documents, rather than seeking clarification from the client representatives. In many instances this could preclude contractors and subcontractors from having adequate knowledge of the quality requirements. Hence, tender prices, tender programmes and methods of construction may not reflect the quality requirements perceived by the client and his representatives. Opinions will be divided as to the required quality between client's representatives on the one hand and the contractor on the other. The acceptable quality standard will become a serious question. Is it the quality perceived but not accurately specified in the tender documents or the quality assumed and priced by the contractor and subcontractors. This reinforces the issue of contractor/consultant/subcontractor quality review meetings starting from the tender stage through to the construction phase of a project. 91% of the respondents agreed that it is important that the contractor and client representative should agree prior to commencing on site a STANDARD against which conformance to

- contractor site team
- contractor site team and design team
- contractor site team and subcontractors
- contractor site team and client representatives
While NEDO (20) found that unrealistic contract time could affect the successful completion of a building project, the report did not find time as a key factor. In contrast to the report, this research has found that time constraint is ranked very high (no. 5) in the relative importance of the factors influencing the achievement of quality on site. 95% of the respondents agreed that the duration allowed for the execution of each element of a building project and the sequence in which they are carried out are essential factors in order to achieve the right quality at first attempt. The tender programme which determines the overall contract duration can only be as good as the information and time available for its preparation. Planning of site activities is important if operatives are to carry out their work safely and achieve the quality at first attempt.

Financial constraint is ranked ninth in the order of importance of the factors influencing quality. Hence, 90% of the respondents agreed that each element must be accurately priced at tender stage and sufficient money must be allowed in the bid to cover execution. Time and money are both determined at tender stage, often based on sketchy and ambiguous tender documents. The problems attributed to the above factors could be reduced (if not totally eliminated) if a co-ordinated approach to quality management is implemented.

If a contractor manages the tender process as outlined in the new quality system and wins the contract, the next most pressing task is the selection of subcontractors and suppliers to carry out the works. This must be carried out in a professional manner and all relevant factors taken into consideration as discussed in the next section.
9.5 SELECTION OF SUBCONTRACTORS/SUPPLIERS

94% of the respondents agreed with the fact that there is a need for the adoption of formal procedures for the selection of subcontractors. In their own words, the respondents emphasise the importance of vetting subcontractors. Therefore, it could be concluded that a procedure is required by contractors which will cater for the key issues for the selection of suitable domestic subcontractors and suppliers for each element of construction projects. Client advisors also required procedure for the selection of nominated or named subcontractors and suppliers. It may be possible to use the same procedure for both domestic and nominated subcontractors.

Unrealistic subcontractor's prices have been identified as one of the key factors influencing quality on building sites. This should not be surprising in the light of the current process in the industry. While contractors could be allowed 3 to 5 weeks to submit a tender for a £6m - £50 m project, subcontractors are often given a lesser period to submit their quotations to contractors. In certain instances, subcontractors are given less than one week. It is not surprising that they are unable to get the prices right when the tender documents are often inaccurate and there are no QRMs between the relevant parties.

Subcontractors and suppliers may find it difficult to comply with obligations which are not made known to them at tender stage. They might be right to refuse additional obligations which may not give them any compensation or fair return on their investment. Hence, contractors must make their requirements (such as temporary protection, checks and checklists, inspections, supervision etc,) clear at a very early stage to enable subcontractors and suppliers to allow for them in their prices. It is no good for contractors to assume that subcontractors will co-operate with their quality system if it is not made known to them before they arrive on site. The author sees this issue as one of the reasons why respondents identified
"subcontractor's attitude" to quality and contractors as a key factor in achieving quality on site. Contractors must realise that subcontractors are the people actually doing the work and that they are in business to make profit and survive as well as the contractors. Some contractors may probably think that they need to be secretive in order to remain competitive in the volatile commercial environment of the construction industry. There is no justification or moral sense in attempting to remain in business at the expense of subcontractors thereby leaving clients with unsatisfactory buildings. Contractors must act positively in a professional manner and become passionate with their subcontractors and suppliers for the good image of the industry. The implementation of a new quality system will surely help contractors to reduce the problems associated with the selection and management of subcontractors and suppliers.

The selection of a suitable subcontractor is the second step in ensuring that the specified quality will be achieved at first attempt. Often, there are various activities that need to be carried out on and/or off site prior to commencement on site. The level and duration of such activities depends on the operation. Such activities (preparations) required for a curtain walling operation are more intensive and differ greatly from for example painting operations. However, each must be monitored and carried out in an orderly and professional manner. Some of the principal factors at this stage of the construction process are discussed in the next section.

9.6 PREPARATIONS - ON/OFF SITE ACTIVITIES PRIOR TO THE COMMENCEMENT OF AN OPERATION ON SITE

The selection of a suitable subcontractor or supplier must be followed by the issue of complete production information relevant to the subcontractor's operations. The production information issued at this stage must be clearly marked "issued for construction." The information relating to all the interfaces of the operation must
be issued to the subcontractor. The research identified five separate factors under the design group as key influences on achieving acceptable quality of works. In order to ensure that the problems associated with production information are resolved prior to start on site, new quality system will identify the principal activities required.

Having issued production information to the subcontractor, the contractor must insist that the subcontractor studies the documents and raises queries as necessary to be discussed with the design team. Once queries are raised and discussed during QRM(s), the contractor must ensure that the design team amend their drawings and schedules to incorporate the comments and points agreed in the QRM. The contractor must issue the most current production information to the subcontractor at all times.

Before materials and components are delivered to the site, the contractor must ensure that the subcontractor submits samples or evidence that the items will comply with the specification. Had this been carried out in case study no. 3, the wrong cavity insulation would not have been installed. 90% of the respondents agreed that this activity must be carried out for all materials and components before they arrive on site.

Another principal activity at the preparation stage is on the one hand the handling and moving of material/components and on the other, their storage and protection. All the respondents considered these activities as important in the management of quality in construction. The issues must be discussed and agreed by the contractor with the suppliers and subcontractors.

While 54% of the respondents stated that quality standards are sometimes being explicitly communicated to tradesmen, 51% stated that inadequacies in communicating the required quality to tradesmen will have an effect on their work
with regards to conformance to specifications. There is overwhelming support for a system of "planned communication" which will contribute significantly to the achievement of specified quality requirements. There is also a strong correlation between these opinions and what the respondents considered to be major causes of unacceptable quality of work.

80% of the respondents believed that QRM ("planned communication" is a major part of QRM) is important in communicating the client's quality requirements down the contractual chain to the point of erection. In the majority of cases, QRMs had been initiated by the contractor. It is interesting to learn that contractors are beginning to realise the importance of the QRM although it is still being carried out in an unplanned and unco-ordinated manner. In spite of the importance of the QRM expressed by the respondents, 77% of whom indicated that their companies are operating a formal quality system, 32% had not actually attended a QRM before. This aspect makes the author (and hopefully others) feel concerned about the whole structure, attitude and implementation of BS 5750 by contractors at present.

It is important that subcontractors submit to the contractor for joint review, a detailed method statement, staff and labour level for each operation. This must be carried out before the operation commences on site. 97% of the respondents agreed with this view because of ignorance of correct method, inadequate subcontractor's supervision and lack of skill by operatives. Supervision by subcontractors has been identified as the most important factor influencing the achievement of specified quality requirements. Hence, the level and experience of subcontractor's supervisory staff must be discussed and agreed before each operation commences on site. It may be difficult to agree on the skill and competence of every tradesman to be employed on site. However, if the quality required is known and discussed with the subcontractor at tender stage prior to start on site, the subcontractor may be able to allow in his quotation for employing the
right calibre of tradesmen to carry out the operation.

The preparation stage will lead into the site execution of each operation. More care and attention given to the activities at this stage will pay dividends during the actual execution of the operation.

9.7 THE SITE EXECUTION OF THE WORKS

A competently produced construction programme will make allowance for a "learning curve." It is a reality of life on site that learning takes place at the beginning of each operation, hence the specified quality in all respects (including workmanship) must be communicated to the operatives. This could be carried out in different ways. Suggested methods are to be outlined in Chapter 11 of the thesis.

A STANDARD (ie. control samples) for measuring conformance to specified quality must be agreed by all parties before any major part of the operation is carried out. Agreement is required to remove subjectivities from the unmeasurable clauses in the production information.

Not only is supervision by the subcontractors of their own operations important, but also adequate supervision of the whole project by the contractor. It has been identified in the case studies that the minimum level of supervision being carried out at present is unplanned and unco-ordinated. This consists more of rejection of non-conformance rather than ensuring compliance at first attempt. Supervision by contractors ranked no. 7 in the table of factors influencing quality on site. Therefore it is not surprising that 90% of the respondents agreed with the view that the contractor and the client's representatives should agree and formalise the procedure and frequency of planned inspection, checking, testing and methods of resolving unforeseen events.
The provision and subsequent use of proper tools, plant and equipment by operatives is a key factor. For example, in the three case studies, mortar was found in the brickwork cavities as a result of not using cavity battens by the bricklayers. In case study no. 2, the subcontractor complained about the inadequacy of the scaffold provided by the main contractor. The operatives must be provided with safe, adequate and proper access, platforms, working space and the environment must be conducive for achieving the specified quality at first attempt. Over 90% of the respondents see these factors as important.

Bad workmanship ranked 8th in the hierarchy of factors influencing quality on site. From the data, the cause of this problem could be attributed to the following:

1. Lack of care by operatives and subcontractor's attitude to quality. These factors are also individually identified as key factors. The findings of the case studies reveal that where inadequate care has been taken by operatives, the result is always bad workmanship.

2. Bearing in mind that the majority of site operatives (self-employed in many cases) are now being supplied by subcontractors: it is becoming increasingly important that the contractor's supervisory staff should be able to control the subcontract works undertaken if the right workmanship is to be achieved. This view is supported by 89% of the respondents.

3. Continuity of work for site workers. The construction industry cannot remain as the dumping ground for labour force that has been rejected by other industries. The stop and go economic policy of central government is having a great impact on the level of employment, training and re-training of site workers. The industry labour force requires stable, secure and continuous employment in order to give its best. This level of certainty is required to attract and retain the right
calibre of men and women in the industry.

4. Lack of adequate skill is a key factor. More new materials, components and construction methods are now being used in the industry than any other time in this century. This development has resulted in skills being replaced by multi and flexible skills to meet the present and future demands. Existing tradesmen need re-training and new apprenticeships must be geared towards the use of new tools, materials and construction methods if acceptable workmanship is to be achieved at first attempt.

5. The case studies highlight what could happen if materials and works are not properly protected from other trades until final clean down and handover. The finding was strongly supported by the respondents to the extent that adequate temporary protection was ranked 15th in the hierarchy of the 30 factors influencing the achievement of quality. Bad workmanship will remain with us as long as we do not protect materials and work coupled with the other factors discussed above.

9.8 INTEGRATION OF DESIGN AND CONSTRUCTION

A major factor which makes the contracting sector of the building industry unique is the separation of design and construction. The design quality and the production information is a very important factor in achieving the client's requirements. Without this, the quality management of contractors will be jeopardised. The stage at which contractors are brought in to the development of a project is often too late. Gray (83) noted that details within the design were very difficult and, in some cases, impossible to construct. On interview it was clear that the majority of design teams had not considered the problems which the contractor had to face. There is a growing awareness that the contractor can make a valuable practical contribution to
the brief and the design stages of a building and that the resulting simplification of
the site work will produce better buildings for the clients. The contractor's
contribution must be made from the initiation of the design, within stage A and B of
the RIBA Plan of Work, to obtain most benefit. The construction contribution
should include the skills of specialist subcontractors, manufacturers and suppliers.

Most procurement methods are such that the design is unable to benefit from an
early involvement of the contractor's skills. Therefore, systems need to be
developed to include and reflect the input of these skills during all design phases, in
particular, during the initial phase. The British property federation system (74)
published in 1983 has as one of its views that attitudes must change and that many
practical aspects of design are understood by contractors just as well as by
designers. The BPF system, design-build and project management procurement
systems attempt to bring together or closer the design and construction phases of
building with the main objective of better buildings at reduced cost and built on
time. The author foresees an increased trend toward these forms of building
procurement in the years to come. It is good for the clients and the construction
industry.

9.9 THE MANAGEMENT OF CONSTRUCTION FACILITIES

The upkeep, maintenance and repair of existing building stock is being carried out
by the construction industry directly or indirectly. The quality and functional
performance of our cars or aeroplanes does not depend solely on the design or the
model or the manufacturer but equally on the quality and frequency of
maintenance. This is equally true of our building stock. We can no longer rely on
the design and construction of our building for its quality and functional
performance over its life expectancy. Upkeep, maintenance and repair must be
planned and regularly carried out under a quality system. In fact, as buildings
become more technologically complex including more sophisticated systems for
heating and ventilation, communication and service supply, so the requirements for maintenance management or facilities management is recognised.

A form of quality management should, at the completion of the total quality loop, embraces facilities management in a formalised policy of upkeep, maintenance and repair. Interest in this area has started to emerge slowly; it will continue and in the nearest future be a major part of quality consideration in our buildings if the functional performance requirements are to be achieved.

9.10 TOTAL QUALITY MANAGEMENT (TQM)

Total Quality Management is an approach to improving the effectiveness and flexibility of business as a whole. It is essentially a way of organising and involving the whole organisation, every department, every activity, every single person at every level. For an organisation to be truly effective, each part of it must work properly together recognising that every person and every activity affects and is, in turn, affected by others (33). TQM is a method for ridding people's lives of wasted effort by involving everyone in the process of improvement; improving the effectiveness of work so that results are achieved in less time. The methods and techniques used in TQM can be applied throughout the construction organisations.

TQM embraces all aspects of quality assurance and goes beyond its present role. TQM is an "organisation demand-pull" and not a client demand-pull. Hence, an organisation will investigate its present processes and procedures with a view to developing improvement methods towards effectiveness and flexibility of business as a whole. It is not subject to interpretation or geared towards a specific rigid standard. The benefit of quality assurance certification has already been mentioned. Small and middle sized contractors and subcontractors have not been taking up the advantages of quality management system because of the emphasis on third party certification which has been termed a "revolutionary" approach (71). In
the rest of Europe it would appear that an "evolutionary" approach is more favoured with QA systems growing from within the firm, rather than being imposed, and third party certification considered as very much optional. As a result the changes stand a better chance of being internalised and so self-maintaining and the focus remains on what really matters - better or more consistent quality work (84).

"This is not to say that the UK approach to quality management is wrong but, in this writer's view, it is fair to say that the UK approach is not right or best or leading the field." (84)

Third party certification will be appropriate in some circumstances and inappropriate in others.

A situation where many firms have to contort themselves to suit FQA has not resulted in widespread adoption. In the next few years Quality Assurance will have to adapt or die!" (84)

Hopefully adaptation will occur and the present situation will be seen in years to come as first step in the right direction, a phased development in which quality assurance becomes an important issue, a symbol of the desire to work consistently high standards.

9.11 SUMMARY

A comparison of the research methodology with those of the previous studies was made. The research methodology shows a greater strength over the previous studies in identifying the causes/effects of quality problems in the site production process. The contribution of the three case studies to the research objectives was assessed. Its findings are found to have achieved the intended objective by providing adequate first hand information upon which the subsequent stages of the research were based. Both the findings of the case studies and those of the questionnaire were discussed under the four main headings to which a new quality system is to be developed.

The research data supports the opinions identified in the literature review about the importance of the integration of design and construction and the management of
construction facilities. While the first is seen as a necessary goal towards a long
term approach to the procurement of construction projects, the second is seen as a
means of improving the functional performance of the existing building stock.

Finally, the relevance of TQM to the construction team was briefly discussed. The
research methodology has adopted an evolutionary approach as argued by TQM
thinkers. As a result of which the difficulties facing the construction team have
been identified and their relative importance established. Hence, a new quality
system can now be developed in the next chapter based on the inadequacies and
their practical implications as identified in the research.
CHAPTER 10

THE QUALITY COMMUNICATION SYSTEM

10.1 INTRODUCTION

In this chapter the author discusses and demonstrates the quality communication system approach to quality management in construction through the application of stages 5 to 7 of the soft systems methodology as it evolves from the research data. Recommendations for change to improve the current quality problems are made based on comparing the conceptual model with the real world. The method adopted for carrying out the comparison is fully discussed. Based on the inadequacies identified in the comparison, and the need for change, coupled with the results of the literature review, the findings of the case studies and the detailed analysis of the questionnaire, a new quality system entitled "Quality communication System" was developed. The aim and the objectives of the new system are outlined. The key documents and personnel required for the implementation of the new quality system are described in Appendix N.

10.2 APPLICATION OF STAGES 5 TO 7 OF SOFT SYSTEMS METHODOLOGY

Chapter 6 describes the application of stages 1 to 4 of soft systems thinking methodology to the topic of achieving conformance to specified quality requirements. This section will discuss and demonstrate the application of stages 5 to 7 to identify the inadequacies currently existing in the UK construction industry and the possible changes that may be required in the management of quality by the construction team. This is done in order to develop, in the next section, an effective solution for overcoming some of the difficulties facing the construction team in achieving conformance to specified quality requirements.
At this stage, the conceptual model built as Stage 4 in Chapter 6 will be compared with the real world. The comparison is between the activities of the conceptual model stating what needs to be done and the activities in the real world which show how it is being done. As recommended by Checkland (58) the comparison will be a general one asking what activities of the conceptual model are especially different from the real world and why. Checkland (58) points out that:

Studies of different kinds have seemed to call for different ways of carrying out the comparison and, in a variety of experiences, four ways of doing it can be identified. . . . In Airedale this was done by using the models as a source of questions to ask of the existing situation. . . . This method of using the conceptual models as a base for ordered questioning in the problem situation has subsequently been much used in many later studies. It will always be one possible way to proceed in any study.

He went on to explain how the fourth method was carried out:

For the comparison, after completing conceptualisation based on the chosen root definition, we made a second model, this time of what exists. . . . With this method, direct overlay of one model on the other then starkly revealed the mismatch which is the source of discussion for change. . . . In any particular study it may be useful to adopt any one of them or to carry out several comparisons using different methods.

The author carried out two methods of comparison. Firstly, the conceptual model (figure 6.9) was used as a base for ordered questioning in the questionnaire described in Chapter 7. The questionnaire was structured with the object of generating debate about possible changes which might be introduced in order to alleviate some of the problems facing construction teams in achieving conformance to requirements. Secondly, the author developed a second model, this time of "what is perceived to exist." The draft copy of the second model was based on the literature review and the findings of the case studies.

After drawing up the initial version of the second model, a pilot study was conducted with a view to establishing its potential to act as a true reflection of
quality management in the UK construction industry. Although the first conceptual model was piloted indirectly through the small-scale study carried out for the questionnaire, it was decided to table it too for discussion together with the second model. This was deemed necessary in order to re-assess its level of acceptance as a formal system and to generate more ideas.

Prior to the pilot survey of the two models, a preliminary comparison between the two models was carried out. The comparison revealed some major involvement not only by the contractor's team but also by the design team/client's representatives, subcontractors and suppliers. As a result of this the decision was taken to include in the pilot survey at least one member of each group mentioned above. It was also decided to exclude from this pilot survey the contractors that had taken part in the pilot study of the questionnaire and those that had responded to the questionnaire or had taken part in the case studies. This was perceived to be beneficial in order to avoid internal validation of the conceptual models and also to increase the number of contractors and individuals that participated in the research.

The pilot survey of the conceptual models involved detailed discussions with the following position holders:

**Design Team/Client's Site Representative**

1 Design architect
1 Site architect
1 Resident structural engineer
1 Building services engineer
1 Clerk of works
Contractor

5 Project managers - 2 of whom are from contractors operating BS 5750 "quality system"
2 Quality assurance managers
1 Estimator
2 Planning and resource managers
1 Purchasing officer

Subcontractors

2 Trades with subcontractor design input
1 Trade without subcontractor design

Each participant in the pilot survey was selected from a different company. This brought the numbers of main contractors that took part in the research to 45 (11 in this pilot survey and 34 respondents for the questionnaire) plus 3 subcontractors and five members from the client's team. These participants were additional to those participating in the case studies.

All the respondents with the exception of one project manager found the models appropriate and saw them as right steps in moving towards achieving quality at first attempt. The project manager who disagreed with the models argued that they laid too much emphasis on the management system, procedures and communication rather than skill and motivation of site personnel. While his points are reasonable and concern essential factors in achieving conformance to specified quality requirements, the area suggested by the project manager is outside the main focus of this research as outlined in section 1.6 of the thesis.
Bearing in mind that only the minimum number of required activities need to appear in each model, a balance had to be struck between the diverse comments and suggestions made by the participants regarding their practical implications. Therefore, only those comments and suggestions that had the greatest support among the participants have been incorporated into the development of the final version of the second model which is shown in figure 10.1. This final version is taken for the purpose of this research to reflect the essential quality management activities that exist in the real world of the UK Construction Industry.

The direct overlay of the conceptual model (first model) on the model (second model) of what is perceived to exist in our construction companies precisely revealed the mismatch shown in figure 10.1.1. The most obvious thing to notice in figure 10.1 is that fewer activities relating to quality management are being carried out at present in the UK construction industry. Some of the most important activities (eg. QRMs, control samples, review of subcontractor's method statement etc) are not being carried out. Where some of the activities are carried out, they often tend to be one off and did not occur on a regular basis. This is evidence that the quality management procedures existing at present are un-coordinated, non-systemised quality measures which have failed in the attempt to get the specified quality right at first attempt. Hence a need for a systemised quality measure as outlined in the first conceptual model in figures 6.5 to 6.9.
L3.1.1 Same as L2.3

L3.1.3 When an operation is to be carried out by directly employed labour of a contractor, there are no comments requested or made regarding the quality of the work by the trade department concerned.

L3.1.4 Lack of QRM prior to starting on site of a directly employed labour operation.

L3.1.4 No QRM between contractor's team prior to commencing operations on site. Ditto L3.2.1, L3.3.1, L3.4.5, L3.5.7, L3.6.4, L3.7.4 and L3.8.3.

L3.1.5 No QRM between contractor and consultants.

L3.1.6 As a result of lack of QRM between contractor and consultants prior to commencing each operation on site, there was no opportunity for consultants to incorporate contractor's buildability ideas into the production information. Ditto L3.2.3 and L3.3.3.

L3.1.7 Submission and review of method statement and staffing/labour level & both by the subcontractors, suppliers and directly employed labour force was lacking. Ditto L3.2.2 and L3.2.4, L3.3.3 and L3.3.5, L3.4.11 and L3.4.12, L3.5.12 and L3.5.13 and L3.6.5 and L3.6.6.

L3.7.1 There is a need for a material review meeting before selection of a domestic supplier and immediately on appointment of a nominated supplier. Ditto L3.8.
L3.7.2 Suppliers to submit statement and evidence that material and components supplied or to be supplied by them comply with specification prior to site delivery. Ditto L3.8.3.

L3.7.5 The contractor should agree with the supplier and client representative, a method for measuring compliance of materials and components to specification. Ditto L3.8.4.

L3.7.6 Contractors should obtain from their suppliers methods for handling and protection on site of all materials and components prior to site delivery. Ditto L3.8.6.

Sub-system 4 - Execution of the works

L4.1A NO method by which the required quality standard could be communicated to tradesmen on site. Ditto L4.1B and L4.1C.

L4.3 Contractors should agree measuring standard of conformance to requirements with client representative.

L4.4 There was no agreed formal procedure for planned inspection, checking, and testing and no method of resolving unforseen events.

L4.8 Carry out planned inspection, checking and testing and keep proper record.

L4.10 NO QRMs during the execution stage of each operation.

L4.13 68% of the respondents agreed that client's representatives should issue a "certificate of conformance" at the completion of each operation or at stages.
L4.14 For the benefit of all parties to the construction process, there should be a feedback mechanism regarding what is achievable or what is not and the experience gained on the use of materials, plant and methods of work.

The comments and suggestions made on the first conceptual model by the participants in the pilot survey are to be included in the development of the activities required for the new quality system. Hence, Table 10.4 is more comprehensive and logical than the first model. While the first conceptual model remained as a working hypothesis, it is now superseded by the activities required for the new quality communication system as shown in Table 10.4.

The new activities identified in the pilot survey which are not in the first conceptual model but included in the QCS are:

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Item No</th>
<th>Action Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.2</td>
<td>Send out notice of QRM to consultants.</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>Each Department to submit comments to estimator.</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>Prepare query list and send it to consultants.</td>
</tr>
<tr>
<td></td>
<td>1.8</td>
<td>Update and send out enquiry documents.</td>
</tr>
<tr>
<td></td>
<td>1.9</td>
<td>Receive subcontractor query lists.</td>
</tr>
</tbody>
</table>

| Level 2 | 2.1     | Define scope of subcontract and request comments from all departments. |
|         | 2.2     | Each department to submit comments to buyer. |
|         | 2.5     | Answer subcontractor queries. |

| Level 3 | 3.1.2   | Receive subcontractor query list. |
|         | 3.1.4   | Notify consultants regarding subcontractors queries. |
3.1.5 Ensure that consultants amend production information accordingly.

3.1.9 Obtain updated version of the method statement.

3.2.3 As 3.1.2

3.2.2 As 3.1.9

3.3.1 Define scope of the order and request comments from all departments.

Having incorporated the above activities into the new quality management system (QCS) the first conceptual model no longer required amending diagrammatically in this research. However, it must be noted that the above activities are some of the instruments required by future researchers (including the author) in order to reform the first conceptual model. This becomes important in our continuous effort to find the best system for the management of quality in construction.

10.2.2 Stage 6 and 7: Recommendation for Change

The comparison carried out in Stage 5 had drawn attention to inadequacies and possible changes. Checkland (58) points out that changes of three kinds are possible: changes in structure, in procedures and in "attitudes." The inadequacies and possible changes identified in this study indicated "procedural change" rather than a structural or complete change of attitude. Given the prevailing attitudes and the unwillingness in the part of some workers to contemplate any change, the aim is to design a procedural change which will arguably be systemically desirable and culturally feasible.

Although change in "attitudes" is not specifically called for in the comparison carried out in Stage 5, it must be remembered that any change that involves people would have some element of attitudinal change, co-operation and willingness to carry out the new procedure without force. The recommendations of Sani (69)
regarding site organisation behavioural variables and on-site motivational processes will be of great value to companies who intend to implement the proposed procedural change for managing quality in construction. The proposed procedure will be a new system entitled "Quality Communication System" (QCS) with the aim of establishing and communicating in time the required standards of quality for a project by a contractor to other members of the construction team.

The introduction of the QCS may so change quality management in construction that, although the originally identified inadequacies would be eliminated, new problems may emerge. Any emerging problems may also be tackled by means of the "soft" systems thinking methodology adopted here, thereby starting the circle again. The new procedure should be seen as a means to an end and not an end in itself. It is a learning process which should be adopted with great flexibility to suit each company and be continuously updated in line with contract conditions and the prevailing environment in which each company operates. The QCS is described in detail in the next section.

10.3 QUALITY COMMUNICATION SYSTEM (QCS)

This study has identified the major primary factors influencing the achievement of specified quality requirements and their relative importance. Equally important is the successful application of the "soft" system thinking methodology to quality management in construction. These points not only support the research hypotheses but also confirm some of the findings of the previous studies and opinions expressed by individuals in the industry. They all reveal an urgent need for a CO-ORDINATED APPROACH to the management of quality in construction and, in particular, the establishment and timely communication of quality requirements by contractors to other members of the construction team. Hence, it is desirable and feasible for contractors to adopt a co-ordinated system entitled "quality communication system" (QCS) for the management of quality in order to
achieve at first attempt conformance to specified quality requirements.

In view of the above, the Quality Communication System will set out in a professional and practical manner the major ACTIONS that should be carried out by the construction team for the successful management of quality in building projects. It must be noted that QCS is NOT intended to catch out somebody, but TO ENSURE that the necessary actions are carried out. An important part of QCS is the control and monitoring process by an assessor to ensure that actions are carried out at the right time. QCS will provide the long overdue system for contractors' senior site representatives to effectively carry out their work and perform their role of establishing and communicating the specified quality requirements to the best effect.

While 39% of the questionnaire respondents state that their company is operating the BS 5750 quality system, 76% are only operating a company made formal quality system (not to BS 5750.) One of the companies used in the case studies is currently operating BS 5750. Hence it could be concluded that all contractors require QCS. It would improve a company's BS 5750 quality system because it would form a major part of carrying out their quality goals. For those companies not operating BS 5750 or any formal quality system, QCS will represent a First Party Assessment and it will enhance their chances of achieving the specified quality at first attempt and all the advantages that would accomplish it.

The application of QCS will commence right from the tender stage to the practical completion of construction projects in general and, in particular, building projects. As pointed out in section 10.2.2, there is no evidence that the existing structure of construction companies could not carry out the necessary actions required to achieve the right quality at the first attempt. Therefore QCS is based on the assumption that resources are available within each company to implement the system and that changes to the structural organisation will not be required.
However, there may be some instances where additional resources, training and/or re-training may be required for the successful implementation of QCS. Each company should examine their existing structure and resource level to determine whether changes are required to enable them to implement QCS.

10.4 THE AIM AND OBJECTIVES OF QCS

The aim of the Quality Communication System is to:

Provide a system for establishing and articulating the specified quality requirements of a project and its timely communication by contractors to other members of the construction team.

10.4.1 The Objectives

The objectives of QCS are:

1. To enable both the main contractor and subcontractors to submit competitive and realistic prices at tender stage.
2. To enable them to agree and resolve ambiguities and subjectivities in the production information at a very early stage of each operation.
3. To be aware of the specified quality requirements at the various stages of the construction process.
4. To establish prior to commencing each operation the method to be used to ensure that the specified quality requirement will be achieved safely at first attempt.
5. To establish a STANDARD (ie. control sample of a permanent nature) for measuring conformance to specified quality requirements for each operation.
6. To monitor and control the works at various stages of the construction process and to take prompt corrective actions where non-conformance is identified.

7. To provide a feedback mechanism of "quality management data" for future use.

10.5 THE DESIGN OF QCS

The design of the Quality Communication System (QCS) is based on the following:

1. Literature review.
2. Findings of the case studies.
3. Analysis of the questionnaire.
4. The changes identified as a result of the comparison of the "conceptual model" with the real world in the UK construction industry.

The intention is to provide a sufficient common framework for the QCS in a manner that will enable each construction company to develop and implement their own QCS. This is done by developing the necessary documents, describing their preparation and usage, personnel and the interdependence of its parts. Figure 10.2 shows a QCS map which outlines the major components of the system and the relevant feedback mechanism. Based on this map, the QCS framework is presented under items A to H below.

A There are four operational levels as follows:

1. Tender stage to award of contract.
2. Selection of subcontractors/supplier to carry out each operation on site.
3. Preparation stage (ie. Activities required on and/or off site prior to effective commencement of each operation on site.)
4. Execution of each operation on site.

B At each operational level, there will be "actions" which must be carried out in order to achieve the relevant quality objectives. The sequence, date and duration of each action will be detailed in the relevant Quality Communication Warning System (QCWS). A QCWS should be prepared and used at the tender stage for all building projects. If a contract is awarded, a project QCWS will be developed for the construction phase. Each action in the QCWS will be made the responsibility of a particular member of the contractor's team and such a person must be clearly made aware of his responsibilities. Tables 10.1 and 10.2 show examples of each QCWS required for the implementation of a QCS.

C Evidence will be required to show that each action has been adequately carried out. Hence, having carried out each action, the person responsible for the action will provide the Quality Assessor/Auditor with evidence that the action has been carried out and that the intended objective has been achieved. The Quality Communication Control Document (QCCD) shown in Table 10.4 will be used by the person responsible for each action. He will input YES or NO for each action and the document that he will produce to the Assessor as evidence that the action has been carried out. The evidence required for each action must be clearly set out and agreed by all parties. Column 4 of Table 10.4 gives some useful guides as to the evidence that could be used for QCS. The evidence must be relevant to the quality objective of each action. This is important because each piece of evidence will form the basis for measuring the performance level of each action towards the ultimate achievement of the specified quality requirement.

D Someone other than a member of the project team (ie. Quality Assessor/Auditor or visiting manager) will be responsible for examining the
evidence at regular intervals. If the Assessor is satisfied with the action carried out and the evidence provided to support an action shows that the objective has been achieved or would be achieved, he will award the appropriate mark(s). Where necessary the Assessor will make remarks and suggest remedial actions. The results of the audit will be plotted on graphs. Each graph will represent an operation on the QCWS. Table 10.3 shows a hypothetical graphical presentation of a Quality Communication Assessment for PLASTERING AND SCREED (ie. operation no. 10 on Table 10.2.) The graph shows what the target mark is and the actual mark awarded would be plotted against it to show how far (behind or on target) the communication of the quality requirements for the specific operation have been achieved. The graph will show whether improvement is required or not and if the target marks are not obtained then the possible consequence can be predicted from the graph. The target mark for each action will be as determined in Chapter 8. However, each company could apply their own rating to each action within the context of the total relative importance of each operational level as determined in Chapter 8.

At each operational level, the Assessor will calculate the NET CONFORMANCE RATING for each operation and recommend remedial actions that may be necessary to improve communication at the next operational level. The recommendation of remedial actions will require input from relevant members of the construction team (this includes subcontractors and operatives.)

On completion of each operation, a TOTAL NET CONFORMANCE RATING (TNCR) will be calculated. The figure will show in quantitative terms how effective the quality management of the operation was.
The Assessor will calculate the AGGREGATED CONFORMANCE RATING (ACR) at levels 2, 3 and 4 for each operation. All the calculations will be recorded on the QCS CALCULATION MODE of a computer software as shown in Table 10.5. While the TNCR shows how the quality management of each operation has been carried out, the ACR will show the quality management of each operation in the context of the whole project.

At the end of the project, the ACR's will be used to determine the TOTAL CONFORMANCE RATING (TCR). The TCR will be the quantitative assessment of the degree of conformance to the project's specified quality requirements. The TCR will be compared with "Snag list(s)" and "non-conformance notes" issued by the contractor to subcontractors or by the client's representatives to the contractor.

The results of the comparison will be used by the Assessor and the contractor's senior management team to recommend "improvement actions" for on-going and future projects. The recommendations may require amending or updating some aspects of the QCS. Hence, experience gained from using QCS must be fed back into the system to start the circle again.

10.6 UPDATING QCS DOCUMENTS

Having developed a project QCWS and kept it running by carrying out the actions, it is equally important that the chart should be kept alive. Hence, its initial development is not the end of the story. It must be updated in the light of relevant events regarding the project. The events that could lead into updating a project QCWS are described in section N2.2 of Appendix N.

The actual updating of the chart could be carried out manually. However, this would be time consuming and an ineffective way in this era of high information
technology. Therefore, where possible, a project QCWS should be computerised along with the QCS documents. Various software has the potential to be developed in order to handle it effectively, for example, the "Project Orientated Evaluation Method" (POEM) developed by South Bank Polytechnic is a typical software system which could handle the computerisation of QCS documents. Lotus 123 will handle QCS documents effectively. The author successfully carried out a test run of updating QCWS shown in Table 10.1 and 10.2 on Lotus 123.

10.7 SUMMARY

The conceptual model developed in Chapter 6 and used in structuring part of the questionnaire has been compared with the respondents' opinions expressed in the questionnaire. It was also compared with another conceptual model made to represent activities currently being used in the management of quality by the construction team. The result of the two comparisons is the identification of inadequacies in the existing procedures. This has led to the recommendation for changes in the existing procedures to be backed up by cooperation and support by all construction personnel and, in particular, the site team.

The results of the two comparisons coupled with the remaining part of the research data have been used to develop a QCS which, if implemented as a management tool within the context of a suitable organisation structure, would enable the construction team to overcome some of the difficulties facing them in achieving conformance to specified quality requirements at the first attempt.
<table>
<thead>
<tr>
<th>Action No.</th>
<th>Action Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Define scope of subcontract and request comments</td>
</tr>
<tr>
<td>2.</td>
<td>Each department to submit comments</td>
</tr>
<tr>
<td>3.</td>
<td>Contractor internal QRM</td>
</tr>
<tr>
<td>4.</td>
<td>Prepare and send out subcontract enquiry doc.</td>
</tr>
<tr>
<td>5.</td>
<td>Answer subcontractor's queries</td>
</tr>
<tr>
<td>6.</td>
<td>QRM with potential subcontractor</td>
</tr>
<tr>
<td>7.</td>
<td>Scheme review meeting</td>
</tr>
<tr>
<td>8.</td>
<td>Issue production information to subcontractor</td>
</tr>
<tr>
<td>9.</td>
<td>Receive and examine subcontractor query list</td>
</tr>
<tr>
<td>10.</td>
<td>Contractor/subcontractor QRM</td>
</tr>
<tr>
<td>11.</td>
<td>Subcontractor to submit drawings for approval</td>
</tr>
<tr>
<td>12.</td>
<td>QRM/comment on subcontractor's drawings</td>
</tr>
<tr>
<td>13.</td>
<td>Subcontractors to re-submit drawings for approval</td>
</tr>
<tr>
<td>14.</td>
<td>Approval of drawings by consultants</td>
</tr>
<tr>
<td>15.</td>
<td>Notify consultants of subcontractor queries</td>
</tr>
<tr>
<td>16.</td>
<td>Ensure consultants amend their drawings</td>
</tr>
<tr>
<td>17.</td>
<td>Obtain and submit samples/evidence</td>
</tr>
<tr>
<td>18.</td>
<td>Obtain method statement from subcontractor</td>
</tr>
<tr>
<td>19.</td>
<td>Quality/method statement review meeting</td>
</tr>
<tr>
<td>20.</td>
<td>Obtain updated version of method statement</td>
</tr>
<tr>
<td>21.</td>
<td>Obtain and review method for handling materials</td>
</tr>
<tr>
<td>22.</td>
<td>Start manufacture</td>
</tr>
<tr>
<td>23.</td>
<td>Progress manufacture</td>
</tr>
<tr>
<td>24.</td>
<td>Site measure (if req'd)</td>
</tr>
<tr>
<td>25.</td>
<td>Work visit</td>
</tr>
<tr>
<td>26.</td>
<td>Interim progress</td>
</tr>
<tr>
<td>27.</td>
<td>Confirm start date</td>
</tr>
<tr>
<td>28.</td>
<td>Final checks/pre-start meeting</td>
</tr>
<tr>
<td>29.</td>
<td>1st delivery</td>
</tr>
<tr>
<td>30.</td>
<td>Start on site</td>
</tr>
<tr>
<td>31.</td>
<td>Communicate the specified quality to operative</td>
</tr>
<tr>
<td>32.</td>
<td>Establish standard for measuring conformance</td>
</tr>
<tr>
<td>33.</td>
<td>Agree and formalise procedure for 'T', 'C' &amp; 'T'</td>
</tr>
<tr>
<td>34.</td>
<td>Carry out 'T', 'C' &amp; 'T'/progress &amp; QRM</td>
</tr>
<tr>
<td>Item No.</td>
<td>Action Mode</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>1.1</td>
<td></td>
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<td>1.2</td>
<td></td>
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<td>1.3</td>
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<td>1.7</td>
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<td>1.8</td>
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<tr>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>1.10</td>
<td></td>
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</table>

Table 10.4: Quality Communication Control Document
<table>
<thead>
<tr>
<th>Remarks 2</th>
<th>Deadline</th>
<th>Evidence of Action Taken</th>
<th>Action Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Accepted</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No</td>
</tr>
</tbody>
</table>

**Level 2: Selection of Subcontractors**

<table>
<thead>
<tr>
<th>Actions</th>
<th>Tagger Award</th>
<th>Minutes of the Meeting</th>
<th>Subcontractor CM with Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yes □ No □</td>
<td>Yes □ No □</td>
</tr>
</tbody>
</table>

**Comments**

- Telephone conversation
- Include records of answers
- Keep accurate copy of the document
- Prepare & send out subcontract enquiry doc
- Subcontractor to reply

**Remarks**

- All comments from all subcontract & request
- Distribution list showing
- Define scope of...
- Yes □ No □
<table>
<thead>
<tr>
<th>Actions</th>
<th>Remarks &amp; Additional Details</th>
<th>Record of Action Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Level 3.1**: Labour & Material Package without design responsibility.
<table>
<thead>
<tr>
<th>Remarks &amp; \nTarget Award</th>
<th>Comments</th>
<th>Evidence of Action Taken</th>
<th>Action Mode</th>
<th>Action</th>
<th>Item</th>
</tr>
</thead>
</table>
| [Image of the table with content]

Level 3.2: Labor & Material package with design responsibility.
<table>
<thead>
<tr>
<th>Remarks</th>
<th>Target Award</th>
<th>Actions Taken</th>
<th>Action Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Evidence of Action Taken, Item 3.3: Material/Component supply only</td>
<td>Actioned</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Approval of sample, Order &amp; external sample</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proof record of the document</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minutes of the meeting</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Approval of sample, Order &amp; external sample</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oeien materials comply with spec</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oeien method of handing</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Delivery of materials</td>
<td>No</td>
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Legend:
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CHAPTER 11

CONCLUSIONS AND RECOMMENDATIONS

11.1 INTRODUCTION

The report of the research is brought to a conclusive end in this chapter. The first section of the chapter is the evaluation of the research hypotheses. The evaluation was carried out with a view to assessing whether the research data confirms the hypotheses. The evaluation reveals that five hypotheses are confirmed by the data. Suggestions for further research and recommendations are made on the basis of the evaluation and the practical implications of the research findings. This was done within the limitations of the research data which is also described in this chapter. Finally, the achievements of the research are discussed within the context of the existing knowledge of quality management in construction.

11.2 EVALUATION OF THE HYPOTHESES

Six hypotheses were postulated for the research. The hypotheses helped in the search for the relevant data. However, it must be stated that the data gathering process was geared towards current quality management in construction and not within the limited focus of the hypotheses or the research objectives. Hence, the data is wider in its scope and comprehensiveness than the objectives and hypotheses set out in Chapter 1. Therefore, it is within the wider context of the data that evidence will be drawn to confirm (support) or deny (refute) the hypotheses.

It must be emphasised once again that the research hypotheses are objective-oriented hypotheses and not statistically-oriented hypotheses. Hence, the evaluation of the hypotheses will be based upon balanced and honest conclusions
drawn from the analysis of the research data. This is NOT a "test of hypothesis" as in statistically-oriented hypotheses normally referred to as the "null hypothesis."

While the findings of the case studies are facts obtained through direct field observations, the respondents to the questionnaire represent a small sample of the UK Construction Industry. In view of this, tests were carried out in Chapter 8 in order to find out if the data collected from the questionnaire were reliable and valid. Appropriate methods were used for the tests and results show that the data has satisfactory internal consistency reliability and construct reliability. The internal consistency reliability means that if the questions used in the research are to be applied repeatedly by other researchers or at different times, it will produce the same results. As for validity, 67% of all the variables have strong relationships with each other at the .05 statistical significance level. This result proved that the questionnaire has achieved its purpose by measuring what it set out to measure. In addition to the reliability and validity tests, the relative importance of the factors influencing the achievement of specified quality requirements at first attempt was statistically established. It was also validated by the findings of the three case studies. The conclusions drawn from the analyses for the evaluation of the hypotheses are within the background of the statistical reliability and validity of the research data as briefly described above and in detail in Chapter 8.

HYPOTHESIS A1

The three case studies were carried out with a view to identifying, with a reasonable degree of certainty, the primary causes of non-conformance to specifications during the construction phase of building projects. From the direct site observations, it became obvious that it is possible to identify the causes and effects of quality problems on site. The site observations adopted an approach which enabled the cause(s) of each quality problem to be traced back to its origin. The approach produced a high degree of agreement between each of the project participants as to
the cause(s) of the quality problems. Table 5.3 and figure 5.3 outline the items identified in the three case studies as the factors influencing the achievement of conformance to specified quality requirements on the projects.

Question no. 22 of section 2 of the questionnaire was structured in an attempt to find out if there are identifiable factors influencing the achievement of specified quality requirements. From the opinions expressed by the respondents, it became clear that the causes of unacceptable quality of works can be identified. The analysis of the opinions resulted in the points now called "the factors influencing quality in construction" as shown in Table 8.4 and figure 8.1. The 17 factors identified in the three case studies are among the 30 factors identified in the responses to the questionnaire.

Therefore, it can be concluded that hypothesis A1 as stated on page 10 is supported by the research data. With this new information the industry can now address the key issues in order to achieve quality at first attempt.

HYPOTHESIS A2

Hypothesis A2 is based on the assumption that the factors influencing the achievement of specified quality requirements in construction have an order of relative importance. Question 22 of section 2 of the questionnaire specifically asked the respondents to state in order of importance what they considered to be major causes of unacceptable quality of works. The analysis of the respondents answers to the question provides the quantitative data which confirms that the influencing factors can be ranked in their order of relative importance as perceived by some contractor's senior site representatives. The data is shown in Tables 8.3, 8.4 and Figure 8.1. Hence the research data supports hypothesis A2. Participants in the construction process who are concerned with quality management can now direct their limited resources more effectively towards essential targets.

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HYPOTHESIS A3

The clients quality requirements are perceived to be accurately defined in the production information and, in particular, the specification. However, previous studies (1) (26) (28) (68) have identified poor or inaccurate design /production information as one of the major causes of quality problems. The findings of this research positively support the previous studies in this regard. The analysis of the questionnaire revealed that respondents ranked poor production information (see Figure 8.1) as No. 2 in the order of relative importance of the 30 factors influencing the achievement of acceptable quality of construction works. In the case studies, specifications were found to be ambiguous, subjective and in many cases were at variance with the manufacturer's instructions and the code of good practice for construction works. In addition to poor production information, respondents also ranked "impractical details and specifications" as No. 10; "designers specifying wrong materials" as No. 14 and "lack of co-ordination of design" as No. 19 in the order of relative importance of the 30 factors as shown in Figure 8.1.

In view of the above, it became evident that contractors should establish and/or re-establish precisely the required quality with the client's representatives (eg. architect, Clerk of Works or resident engineer etc.) This must be carried out at every stage of the construction process to enable contractors to achieve an acceptable quality at first attempt. This could be done through dialogue (QRMs) and contractors could offer practical suggestions where necessary about buildability, safety and lower cost. The conclusion to be drawn from the above findings is that hypothesis A3 is positively supported by the research data.

HYPOTHESIS A4

One other aspect of production information which has been identified as a cause of quality problems is its lateness in reaching the end users (contractors,
subcontractors, suppliers and operatives.) NEDO (28) identified that site management has to spend too much time chasing late drawings and other project information which inevitably reduces the time available for quality management with the consequence of unacceptable quality of the works being done. In case study No, 1, the contractor rightly alleged (with written evidence) late information for the "smoke ventilation," builders work holes in the roof, "details of the cleaning equipment" and details of the chiller house. This late information led to work done "out of sequence" which resulted in the quality problems outlined in the findings of the case study.

The respondents to the questionnaire ranked "late information" as No. 20 and poor communication by contractors as No.4 in the order of relative importance of the 30 factors mentioned as the major causes of unacceptable quality of work.

The above points are perceived to be conclusive evidence that late production information has considerable influence on achieving acceptable quality. However, the research data did not show late production information as having the highest relative importance on achieving conformance to specified quality standards at first attempt. Hence it could be concluded that hypothesis A4 is not fully supported by the research data.

HYPOTHESIS A5

In recent times, management theorists and systems practitioners had emphasised the open systems approach to problem solving. Soft systems thinking methodology was identified from the literature search as the most appropriate open system to resolve the complexities/difficulties facing construction teams in achieving conformance to specified quality requirements at first attempt. The application in this research of stages 1 to 4 of the soft systems thinking methodology resulted in the development of a defensible conceptual model which was subsequently used in
conjunction with other data for structuring the questionnaire.

As part of the soft systems thinking methodology, a second conceptual model was developed to represent what is perceived to exist in the UK construction industry. The pilot survey and the incorporation of the suggestions and comments from the industry line managers into the second model and the activities required for QCS, gave the soft systems a strong backing as an appropriate system.

The responses to the questionnaires and the comparison of the two models provide indicators (clues) to the changes that construction teams must face in achieving conformance to specified quality requirements. Thus, hypothesis A5 is seen to be supported by the research data.

HYPOTHESIS A6

Hypothesis A6 is based on the study carried out by the Norwegian Building Research Institute (Byggforsk) (71). The outcome of the study shows that the best way to solve quality problems in construction is to develop a system (or systems) based on company procedures. However, the author perceived that an understanding of the difficulties facing project teams is a prerequisite to developing an effective solution, albeit new or involving changes to existing procedures. This view is supported by stages 1 and 2 of the soft systems approach. This methodology is termed the "evolutionary approach" which is currently being used in some Scandinavian countries (eg. Norway.)

The research objectives were geared towards an evolutionary approach to the management of quality in construction. Based on the research data, a new quality system (QCS) has been developed. The new system contains activities and quantitative values for the management of quality in construction which, if properly
carried out, will reduce some (if not all) of the difficulties currently facing construction teams. Interestingly, some of the activities and the monitoring procedure included in the new QCS are not even being implemented at present by contractors operating BS 5750 "quality system." The positive outcome is attributed to the application of the soft system methodology and the evolutionary approach adopted in finding an effective solution to the quality problems.

From the direct contacts that the author has had with various groups in the construction industry, it could be deduced that the general impression in the industry is that BS 5750 "quality system" is a client demand - pull, general and a marketing "gimmick". Although it is generally recognised that it has raised the industry awareness about quality management. While BS 5750 "quality system" emphasises auditing of a project quality plan/procedure in general terms and at random, QCS emphasises monitoring through dialogue and continuous auditing of all activities to ensure that each activity is clearly understood and carried out at the appropriate time.

Although QCS is yet to be tested, the data and its analysis clearly show that its implementation with the right attitudes and within the right environment will provide an effective solution to some of the quality problems identified in the study. Hence, the data is perceived to support hypothesis A6.

While hypotheses A1, A2, A3, A5 and A6 are supported by the research data, hypothesis A4 is not fully supported. Therefore, the hypotheses supported by the data can no longer be taken as unproven. They are no longer propositions assumed without proof. The five hypotheses have been proven by the research data and they must be taken seriously by the construction industry. The hypotheses can now serve as explanatory theories for academics to pass on to their students.
Based on the findings of this research, the following areas appear to suggest further investigation:

1. The production information which is supposed to define the client's quality requirements has been found in this research (as well as many previous studies) to be inherently part of the difficulties facing the construction team in the management of quality. Since the establishment of "The Co-ordinating Committee for Project Information" (CCPI) in 1979, it has published many guidelines with the objective of bringing about a general improvement in the documents used for the procurement and construction of buildings. Research studies are required to find out how widely CCPI publications are being used in the design sector and what effect (if any) are they having. If not being used, why not. The application of "soft" systems thinking methodology may be useful for the design sector.

2. While one can not over emphasise the effect of financial and time constraints, assumptions being made by contractors and unrealistic subcontractors prices, their impact cannot be ignored. Therefore, further studies should be conducted to determine the minimum tender documents and the average time which is required by contractors and subcontractors to submit competitive prices for a whole range of building projects.

3. The method used in this research to calculate the relative importance of the QCS actions is appropriate and defensible. However, it is by no means the best. Therefore a further study is recommended to
determine from a larger population what the precise relative importance of each QCS action is. When it is determined, each contractor operating QCS must update their records accordingly.

4. While it will be recommended that each contractor implementing QCS should monitor its progress and usefulness in practice, however further studies should be conducted by way of direct field observations of QCS in practice with a view to updating the system through the application of "soft" systems or any other appropriate theory.

5. Poor supervision by subcontractors of their own trades has been identified as the most important factor of non-conformance to specified quality requirements. Studies are required to find out why this is the case and ways to bring about improvements.

6. In contrast to the NEDO (28) Report, this research has found that lack of skill by operatives causes more difficulties than lack of care. While lack of skill is ranked third in the hierarchy of the 30 factors, lack of care is ranked twelfth. Individuals in the industry have stated that lack of skill is not the real problem. The findings of the present research suggest further studies into the importance of the existing skill and how the problem could be resolved.

7. The findings of the research do not suggest that those contractors operating the BS 5750 quality system are immunised from the difficulties facing the contracting sector of the industry in terms of quality problems. Hence, further studies are recommended to determine the effectiveness of the BS 5750 "quality system" in the management of quality in construction.
11.4 RECOMMENDATIONS

In addition to the various actions outlined as part of QCS, the following general issues are strongly recommended as a means of overcoming some of the quality problems facing the industry:

1. A communication system approach (as outlined in QCS) to the management of quality in construction is presented as a viable solution to the major problems facing the construction team in achieving the specified quality requirements at first attempt. It is therefore recommended to all contractors and subcontractors.

2. When QCS has been proved to be workable and useful in practice, it will be recommended to clients and consultants as a means of assessing the probability that a contractor will achieve conformance at first attempt.

3. As a means of overcoming the problems of poor/inadequate supervision by contractors and subcontractors, the level and experience of potential supervisory staff should be discussed and agreed with the client prior to signing construction contracts. A PC sum may be allocated to cover the provision of the required supervisory staff. Contractors should apply the same procedures to their subcontractors.

4. Subject to the conditions of a particular construction project and the prevailing environment, the following are recommended as a means of communicating quality directly to tradesmen:
i) Approved work samples  
ii) Video presentations  
iii) Visit to/examining similar works  
iv) Unambiguous specifications written on durable plastic cards that tradesmen can put in their pockets  
v) Combinations of any of the above

5. Total quality management that evolves from within each construction company is recommended rather than the revolutionary approach of quality assurance. In the long run, TQM will be the best for the industry.

11.5 LIMITATIONS

Efforts have been made to get systematic, valid and reliable data because the aim is to understand and interpret correctly to enable generalisation of the research findings. In spite of the efforts, there are some limitations of the research which must be brought to light in this section.

The data collected from the case studies are sufficient for its contribution to the overall objectives of the research. However, the author considered the three case studies to be a small sample. By and large, the results of the case studies are validated by the larger sample of the questionnaire.

The top 100 construction companies in England were selected as the population for the Questionnaire. In actual fact, only 34 companies returned their own copies of the questionnaire. Hence, the data analysis and the findings are based on the opinions expressed by 101 respondents from 34 contractors in England. While the top 100 contractors could be acceptable as typical of the underlying population, 34 of them could not be accorded the same recognition.
A communication system developed as a result of the findings of the research has been recommended to contractors for implementation. It must be noted that the QCS is new and yet to be tested. It must be tested on real live projects before its significance can be fully understood. Therefore, contractors must recognise this fact and bear it in mind during the early stage of its introduction into their organisation for the management of quality in construction.

The above limitations are not considered as imposing a cautionary note on the generality of the research findings and recommendations but they are highlighted here for readers to bear in mind when interpreting the research.

11.6 ACHIEVEMENTS

The traditional approaches and awareness of quality management in the contracting sector of the UK construction industry are inadequate and unco-ordinated. The current QA slogan is revolutionary and is perceived to be good for the industry. However, an evolutionary approach (such as QCS) to the management of quality in construction is perceived to be the best long term solution. The concept of evolution is for the industry (and in particular each construction firm) to examine its roles and responsibilities within the context of the built environment with a view to establishing the difficulties facing it in order to achieve conformance to specified quality requirements at first attempt. Hence, to develop and operate systems that will enable the difficulties to be overcome. This is important because of the unique characteristics of the UK construction industry.

Working towards an evolutionary approach, the research has identified 30 factors (difficulties) representing the causes of non-conformance to specified quality requirements. The relative importance of each factor has also been established. Unlike the previous studies which have identified contractor's organisation as a
factor, this research has identified the primary causes associated directly with site production process. Both achievements have removed a large cloud from the management of quality in construction. Therefore, construction teams can now have the potential to direct their limited resources more effectively.

Through the application of "soft" systems thinking methodology, a new quality communication system has been developed. The implementation of the QCS approach to the management of quality in construction is perceived to be an effective solution that will result in achieving conformance to specified requirements at first attempt, lower costs and increased productivity. Equally important is the fact that the outcome of the research has produced the long awaited system required by senior site representatives for communicating the quality requirements to operatives. The research outcomes make a significant contribution to knowledge in construction management in the continuing process of pushing back the frontiers of our knowledge about achieving quality in construction.
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APPENDIX A
Glasgow faces £7.25m repair bill for children's hospital

DEFECTS in a £4 million children's hospital in Glasgow, which opened in 1971, would cost £7.25 million to put right, according to a Common committee report.

Bridge demolition reveals missing tendons

Several prestressing tendons were discovered missing when the damaged span of a 20 year-old M50 motorway over-bridge near Ross-on-Wye was dismantled last weekend.

M6 tests may lead to legal action

THE Department of Transport will consider taking legal action against the designer and builder of “spaghetti junction” - the M6 Gravelly Hill interchange in Birmingham - if tests on bearing beddings prove negligence.

Cladding fails away from Surrey block

THE entire north elevation of Surrey House, the 50m high Sutton tower block occupied by IPC Business Press Ltd, is to be scaffolded while the area is inspected for structural defects.

Corrosion fears on M26 bridge

Gunite repairs have been made to defective concrete in the M26 near Sevenoaks, Kent.

Writs likely over Braidley bridge cable problems

A civil action for damages against the designer and builder of Bournemouth's Braidley Road bridge is being prepared by legal counsel for Dorset County Council following replacement of the structure's external prestressing cables.

Police seek £4m damages for HQ

WRITs for damages of more than £4 million are to be served on the architect, engineer and a construction company involved in the building of the Scotland Yard headquarters in Victoria, London.

Deaths cause: no supervision

Lack of supervision was blamed for an accident in Skegness when a wall collapsed into a covered market killing two and injuring 14 others.
APPENDIX B

In addition to the intensive discussions that the author had with his supervisors, the following people were consulted:

1. K. Fletcher: Head of quality Assurance Section at BRE. He is also the author’s external adviser.

2. Dr. C. McLeish: A researcher at BRE with many years of experience in the topic area.

3. T. Cornick: A Research Fellow/Lecturer in construction Management at Reading University. Also an international consultant in "quality in construction" and author of a book on the topic.


5. J. Pateman: Quality Assurance Director, Kyles Stewart Ltd. An author of many articles on the subject. Under his supervision, his company is the first UK construction firm to obtain third party certification for Quality Assurance system in accordance with BS 5750.

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6. R. Rowsell: Regional Quality Assurance Manager, Laing Chiltern (A Region within the building Division of John Laing construction Ltd.)

7. John B. Dalton: Head of the product Development section, Quality Assurance Unit, Property Services Agency.
APPENDIX C

SOURCES OF INFORMATION FOR THE CASE STUDIES

a) all relevant drawings:
   - architect’s drawings
   - structural engineer’s drawings
   - subcontractor’s drawings

b) specifications

c) architect’s instructions

d) contractor’s site diary

e) Clerk of Works’ site diary

f) Contractor’s drawing register

g) information release schedule (IRS)

h) construction programme

i) query sheets

j) site record sheets

k) subcontractor’s enquiry documents

l) subcontract documents

m) order forms

n) site progress photographs

o) confirmation of verbal instructions (CVI)

p) physical inspection of the works

q) terms and conditions of relevant form of Contracts

r) construction method statements

s) minutes of site meetings

t) correspondence between:
   - client’s representatives and contractor
   - contractor and subcontractors
   - client’s representatives and subcontractors

C-1
u) contractor’s internal memos
v) interviews
w) Clerk of Works or RE site instructions
# CASE STUDY NO. 1

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APPENDIX D

D.1 CASE STUDY NO. 1

D.1.1 Project Description

The project was for the extension/modernisation of existing public sector property in a town in the south East of England. The major parts of the project are:

1. Main Building:
   - car park
   - trading & ticket office
   - offices
   - basement
   - concourse
   - first floor

2. Footbridge

3. Canopies

4. Ticket office within existing multi-storey car park.

The project was to raise the status of the station to one of the best in Europe and to meet the needs of the public in the 1990's and beyond.

D.1.2 Client

The project was conceived by a government owned national company. However, after the award of the contract, majority of the fund for the project was to be provided by an arm of the company that is being run on a commercial basis. The arm is a distinct organisation from the government owned national company.
D.1.3 Design Phase

The precise start date of the design was very difficult to determine. However, the project architect started work full-time on the project in 1983. The design phase was well into the construction phase. In fact, the design was not completed until early 1989.

D.1.4 Contract Details

Contract sum at tender stage: 7.6 million.
Contract sum at handover: 11.0 million.
Contractor selection: selective tendering.
Construction start date: February 1987.
Contract duration: 96 weeks (ie November 1988 for handover).
First handover: January 1989.
Time overrun: 11 months.

D.1.5 Client Representatives

Architect: In-house architects.
Structural/Services Engineers: Private consultants.
Clerk of Works: In-house staff.
Project Manager: In-house staff.
Quantity Surveyors: In-house staff.
Figure D.1 : Contractor’s Organisational Structure
D.1.6 Contractor

Area of Business: General building contractor.
Size: Medium size nation contractor.
Head Office: Midland.
Subcontractor/Supplier Selection: Through head office.
Presence in the project area before contract: None.
Contract(s) won in the project area during construction: One.
Contract(s) after the project: None.

D.1.7 Organisational Structure

Figure D.1 shows the contractors organisational structure for the project.

D.2 MASONRY

The affected operation was the brickwork/blockwork of the project. The defects identified were at various locations on the project. The construction phase of the operation was between January 1988 and February 1989. Cracks in blockwork became known in September 1988 while cracks in plastering manifested in April 1989.

D.2.1 Selection of Subcontractor

Two domestic subcontractors were selected after one another for the operation. The first subcontractor was selected out of five quotations received by the contractor of which the LOWEST PRICE was selected. When the first subcontractor left, the second subcontractor was selected by negotiation.
contractor negotiated with two subcontractors; and finally selected the LOWEST PRICE out of the two. The first subcontractor determined its contract four weeks into the subcontract. The second subcontractor was sacked by the contractor (see reasons below). Both subcontractors had never worked for the contractor before.

D.2.2 The Quality Problems

The workmanship was generally poor. Notable incidents are:

1. Cracks in blockwork.
2. Rough brickwork.
3. Uneven mortar beds/perpends.
4. Brickwork/blockwork out of specified tolerances (say ± 8mm), patches of mortar, mud, stains and paint on finished brickwork (facework).

D.2.3 What Went Wrong

1. Blockwork:

The cracks in the blockwork were attributed to the following:

a. Lightweight blocks were specified (subsequently used) where a higher strength type of blocks were required. (2.8 N/mm² blocks were used). "A 4.0 N/mm² blocks would be better" said the architect. The decision to use the lightweight blocks was as a result of financial constrains.

b. The original blockwork design did not allow for piers. There should have been provision for block piers, columns or returns for blockwork where the length of walls are over 8 meters. However, block piers were later introduced during the construction phase where they would not impact the aesthetic intention of the architect.
c. 100 mm thick blocks were specified (and subsequently used) where 150 mm thick or 200 mm thick blocks should have been used.
d. Blockworks were generally about 4.5m high and there were no provision to restrain the walls at the top (ie, at blockwork/beam or slab junctions).
e. There were suggestions that the doors and its frames were too heavy for some of the blockwork.
f. The strength of the mortar used for some of the blockwork may not be appropriate. That is, the mix design specified may not have been used. This was alleged by the architect but strongly disagreed with by the contractor. The only way to clear this contentious view is to carry out a test to determine the strength of the mortar at certain points in the building (this is outside the scope of this research). Wide variations in the strength of mortar and blocks could have resulted in differential movements which could cause the blockwork to crack.

As a result of the above mentioned points, when the doors were hanged and put into use, cracks begin to occur in both plastered and fair faced blockworks.

2. Brickwork:
Rough brickwork at corners, arise and copings were as a result of the use of cut bricks in place of special shaped bricks (non-standard shape bricks). The reason why bricks were cut are:
a. There was a disagreement between the client team and the contractor as to the bond required for the 'waiting area' within the car park in the basement of the building. The clerk of works said he gave the site manager a verbal instruction that the brickwork in the area shall be in English bond and not stretcher bond like other parts of the building. The site manager denied ever receiving the verbal instruction from the clerk of works. The contractors site diary did not show any record of the instruction and the verbal instruction
was never confirmed in writing (as required by the contract) by the architect.

Therefore, special shaped bricks for the area was ordered to suit stretcher bond. During construction, the architect required the waiting area brickwork to be built in English bond. The special shaped bricks now delivered to site for the area were not suitable for English bond. The architect therefore issued instruction to the contractor to cut and glued bricks on site to achieve the required shaped bricks.

b. Some of the details for special shaped bricks at junctions, returns and cappings were not buildable. This was due to bad detailing by the architectural technicians working for the architect (evidence of lack of proper checking of drawings by the architect before drawings were issued for construction). The architect accepted responsibility for the faulty details and therefore issued instructions to the contractor to cut and glue bricks to achieve required shaped bricks.

The Architect decided to accept cut and glue bricks because it will take minimum of 20 weeks to get the proper shaped bricks.

To wait for 20 weeks for the bricks would have a great impact on the overall project duration and cost. The architect was under a great pressure not to allow the project to be delayed further due to the lack of production information required by the contractor.

Two things were at stake:
- the practicality of cutting bricks and using glues to join them to make a special shaped brick on site and;
- the appearance of the finished work in relation to its immediate surrounding.
The brickwork, ends up being rough at spots where cut and glued shaped bricks were used.

3. Uneven mortar beds and perpends were mainly due to the type of bricks used. However, poor workmanship have contributed to the unsatisfactory appearance of some of the brickwork.

There was a wide variation in the dimensions of the bricks. Variation of 75 mm in a length of 3m brickwork were experienced. Not only the length and height of the bricks that were problem but the shape. "Some are like bananas" said the clerk of works. To achieve a true even mortar beds/perpends was very difficult with the specified bricks. The architect recognised the problem and prepared to accept straight perpends at every fourth course of brickwork. The contractor tried to comply with this requirement but that did not really help the appearance of the brickwork.

4. Brickwork/blockwork out of specified tolerances and patches of mortar, mud, stains and paint on the finished brickwork were attributed to poor workmanship.

The poor workmanship was as a result of:

a) Changes in brickwork/blockwork subcontractors. The first subcontractor determined his contract because there were no sufficient information to enable him progress the works in such a way that he could make enough profit. In view of the fact that there were construction boom in the country at the time, the subcontractor felt he could make more money somewhere else.
Another subcontractor was selected for the brickwork/blockwork. This contract was later determined by the contractor because his performance (progress) was not satisfactory both to the contractor and the architect.

b) Lack of care by the bricklayers. When the second subcontractor left site, the contractor decided to engage the services of self-employed bricklayers on a daily/weekly basis. Bricklayers, like any other craftsmen in the construction industry will like to work on site where there is bonus scheme in operation. This will enable them to earn more money above their weekly guaranteed earning which in many cases were very poor when compared with people in the manufacturing industry. The bricklayers employed directly by the contractor to complete the work were paid on 'Day work'. That is £x per day regardless of the output/quality of work per day. The amount paid per day affected the moral of the bricklayers as some of them told the author.

c) Shortage of competent bricklayers because of the boom in the south east of England during the period of the operations.

d) Lack of proper supervision. While less competent bricklayers were used, and no 'bonus scheme', supervision of the brickwork/blockwork was not sufficient. "The total quantity of bricks/blocks to be laid make it absolutely important that a full-time bricklayer foreman should have been employed" said the General foreman.

The site manager requested for one bricklayer foreman from the Construction Director through the contract manager but there was late response. When response was made, a self employed bricklayer foreman was engaged. Also, there were requests for section foreman and a finishing foreman. Appointment to these positions were never effectively made.
By and large the contractor because of financial constrains could not engage the services of experienced and capable staff to supervise the works.

e) Lack of protection to finished brickwork. The brickwork were not protected.
- against mortar dropping during brick laying.
- against mud, paint, dust and stains as other trades were being carried out within the vicinity of the completed brickwork.

D.2.4 Agreement Between All Parties

- Concrete blocks should have been used (say 4/7 N/mm²) instead of 2.8 N/mm² lightweight blocks.
- The thickness of some of the blockworks are not sufficient.
- Lack of head restraints to blockwork/brickwork could have contributed to the cracks.
- Changes in the clients requirement regarding bonding of brickwork had affected the appearance of the finished work.
- Bad details had also contributed to the appearance of the finished work.
- The variations in size/shape of bricks make it more difficult to achieve better appearance.

D.2.5 Disagreement Between The Parties

- The contractor alleged that more brick piers were required. The client representatives do not agree with the contractors view. The Building Control Officer for the council issues a letter to the client confirming that the brick piers provided comply with Building Regulations.
- The contractor strongly disagreed with the architects suggestions that the specified mortar mix might not have been used on some of the blockwork.
- There was no unanimous view regarding the suggestions that the doors and its frames were too heavy for some of the blockwork.

D.2.6 How It Could Have Been Avoided

1. The designer of the blockwork should have made provision for:

   a) Sufficient block piers
   b) Blockwork/brickwork head restraints
   c) Specified concrete blocks (say 4/7N/mm²)
   d) Buildable details at returns, junctions and copings
   e) Thickness of blockwork should have been properly explored.

2. The contractor should have envisaged and made provision for the required bricklayers to be employed to achieve the specified workmanship. The specification stated that the contractor shall ensure that no mortar encroaches on face of brickwork when laying. Conformance to this requirement required the contractor to protect the brickwork as laying progresses. An action which the contractor never carried out and this omission resulted in dirty brickwork.

3. A competent bricklayer foreman directly employed by the contractor should have been engaged to supervise the works.

4. The finished brickwork should have been properly protected using materials such as gauge 1000 polythene nailed to the brickwork with timber battens.
D.3 CARCASSING TIMBER/DOORS

The affected operations were the timber door frames and the doors.

D.3.1 Selection of Suppliers

The specification called for 'Door sets' (ie, frames and door complete) to be supplied by a nominated supplier. For its own interest, the contractor negotiated with the architect for a change in the above requirement. The contractors request was, to be allowed to order the doors from the nominated supplier and the timber frames from a domestic supplier. The architect approved this arrangement.

Therefore, the doors were ordered from the nominated supplier. The selected domestic timber frame supplier happens to be a subsidiary joinery firm of the contractor.

D.3.2 The Quality Problem

1. Door frames were found to be twisted
2. Doors became twisted
3. Cracks in door lippings
4. Poor appearance at ironmongery fixing spots
D.3.3 What Went Wrong

1. Inherent damage to door frames. Some of the frames were sent back to the supplier because they were found to be twisted on delivery. Two major reasons were attributed to the twisting of the frames:
   a) Lack of sufficient temporary bracing to the frames pending the fixing of doors.
   b) Possibility of the timber used for the frames to contain high moisture content. (This can only be proved by carrying out a moisture content test on the frame. That type of exercise is outside the scope of this research).

2. "Doors and frames were not properly stored on site," said the clerk of works and the joinery subcontractors. This fact was never disputed by any of the contractors team.

3. Changes in the sizes of structural openings resulted in some of the doors having to be cut on site to suit the new opening sizes. The doors were not supposed to be cut and re-made after they had left the factory.

4. Doors suffered a great variation in temperature after they had been hanged. That is, the doors were unknowingly subjected to high temperatures for many weeks because of heating units in operation without the chiller working to keep the temperature down to acceptable level.

5. Poor workmanship. The frames and doors were fixed by self employed craftsmen working for a labour only joinery subcontractor. There were no strict demarcations between first fix carpenters and second fix carpenters. The carpenters were also at a stage engaged on a 'day work' basis like the
bricklayers. "Some of the craftsmen lack sufficient skills to produce an average standard work" said the general foreman. When the senior partner for the subcontractor was asked to comment on the statement made by the general foreman, he simply said "a contractor will get what he paid for". The contractors chief purchasing officer agreed with the subcontractor, but would not construe the statement to mean that the contractor had not paid enough money to get competent carpenters for the project.

6. Insufficient supervision: Although the subcontractor maintained a full-time foreman on site throughout his works, all he does was to allocate works to his craftsmen and to sort out materials and production information. He was left with little or no time to supervise the works that were being carried out in terms of workmanship. Another weak point was that the contractor did not have an effective finishing foreman.

7. The lippings on the doors were not properly fixed. The door supplier accepted some responsibility in putting right the cracks in the lips. The cost of remedial works to the doors were shared between the contractor and the door supplier at a ratio of 1:3 respectively.

8. "The type of lipping used on the doors was not desirable" said the general foreman. He suggested an alternative type of lipping which the architect found convincing.

D.3.4 Agreement Between All Parties

- The need for sufficient temporary bracing on the frames.
- Cutting down and re-making doors on site was not desirable.
- Door lippings were not properly fixed.
- The high temperature that the doors were unknowingly subjected to had contributed to the cracks in the door lippings and perhaps the twisting.
- A work visit to the suppliers workplace would have helped the quality of the components.

D.3.5 Disagreement Between All Parties

- The view that the door frame contained high moisture was not unanimously accepted. At any rate the frame supplier strongly denied the suggestion but he could not produce any document that stated the moisture content of the timber used for the door frames.

D.3.6 How It Could All Have Been Avoided

Frames:
1. There should have been a requirement from the contractor to his supplier to ensure that all frames are properly braced before delivery.
2. A more competent joinery firm should have been selected for the frames.
3. A sample of the timber to be used for the frames should have been tested for moisture content and certificate kept by the contractor.
4. Considering the large number of frames required for the project, a visit to the suppliers factory by an experienced carpenter within the contractors organisation is desirable.

Doors
5. Experienced and competent second fix carpenters should have been employed to fix the doors and the ironmongeries. This action would have improved the standard of workmanship achieved.
6. The type of lipping suggested by the general foreman should have been specified for the doors because it is more integrated into the door than the
one used.

7. Same as for frames, a visit to the suppliers factory was desirable by an experienced carpenter within the contractors organisation. Maybe, the defects in the door lippings could have been detected before manufacturing is completed.

8. If the contractor could accept the use of less skilled carpenters by the labour only subcontractors, he should have balanced the equation by providing effective supervision of the works.

D.4 CLADDING/COVERING

The affected operation was the insulated trocal flat roof of the building. The roof was constructed between January 1988 and September 1988. Defect became known in November 1988.

D.4.1 Selection of Subcontractor

The specification for this section of the project contained names of three flat roof subcontractors, from which the contractor is obliged to select one. These named subcontractors were approved by the roof material manufacturers as competent firms capable of erecting the trocal membrane satisfactorily.

After the necessary pre-subcontract arrangements, the contractor selected one of the three named subcontractors to carry out the "supply and fix" of the flat roof.

D.4.2 The Quality Problems

1. Drips of water from the ceiling at various locations.
2. Dampness of ceiling tile at various locations.
3. Dampness of the insulation (lagging) to heating pipeworks.

D.4.3 What went Wrong

D.4.3.1 Investigation

Ceiling tiles at various locations on the first floor were taken down to gain access to the ceiling void to find out what cause(s) the aforementioned symptoms. The inspections were carried out jointly by both the contractor team and the client representatives. The inspection revealed the fact that the symptoms mentioned were as a result of leaks from the flat roof.

When the defect was brought to the attention of the flat roof subcontractor, the company wrote to the contractor saying that the work had been carried out in a professional manner and that all architect's instructions and relevant parts of the specifications had been complied with. The company therefore do not accept any responsibility. However, due to high level involvement from the contractors organisation, the flat roof subcontractor agreed to carry out remedial works at no extra costs to the contractor.

The same gang of operatives that carried out the original work were sent to site to carry out the necessary remedial works. Their terms of reference were:

- to locate where the dripping of water were;
- to trace the water from the dripping points to source(s) of the leak in the flat roof;
- to repair the leaks and stop water ingress into the building.
The operatives carried out intensive inspection of the ceiling void, junctions, services penetrations and laps in the roof membrane. They were able to locate some points perceived as the sources of the leaks. The points were subsequently repaired.

The remedial works carried out by the subcontractor did not stop the dripping of water from the usual locations and even additional dripping of water were later identified by the project team.

The project team carried out their own investigation as to the location of the leaks. Various points were agreed as the source(s) of the leaks. Therefore the subcontractor was called back to carry out necessary remedial works to stop the roof from leaking. During this second visit the subcontractor carried out more extensive remedial works. To the projects team disappointment, the leaks still persist. It would be too conservative to suggest that there were reductions in the leaks as a result of the remedial works. At this point, the subcontractor informed the contractor that they had done everything within their contractual and moral obligations and that they are not prepared to carry out any further remedial works without extra costs.

D.4.3.2 Observations

It was very difficult to locate the points of the leaks in the roof because of its construction. If water enters the roof at a point, it could have travelled a long distance through the steel deck until it found an exit into the ceiling void. Not only that it is difficult to locate the leak points, it is also not economical.
D.43.3 Design Concept

The design of the whole flat roof (main building and footbridge) and the connection details were never fully explored by the design team. The specification stated that the materials for the flat roof shall be installed in accordance with the manufacturers recommendations. However, the architect drawings would not allow the manufacturers recommendations to be adherent to. For example, the manufacturer of the trocal membrane requested for a minimum of 150mm upstand everywhere around the flat roof including around service penetrations. In some instances, architect details show upstands less than 100mm. When these discrepancies in the drawings and the specification were brought to the attention of the architect, he instructed the contractor to forego the aspects of the specification which called for manufacturers recommendations to be complied with and to fix materials to their requirements as shown on architect drawings. These requirements in the contractors opinion were wrong.

"The original design of the roof was never that of flat roof but a 'Lean to Roof'" said the architect. However, due to (1) change of client, (2) financial constraint, (3) time overrun at the design stage; a corporate decision was made by the design team to go for a total flat roof. This was a compromise between various design factors and the social factors mentioned above.

D.43.4 Roof Membrane

The roof finish membrane was a single layer material (1.5mm thick). The membrane is open to damage not so much by foot traffic but by any nail, screw, sharp metal or any similar materials. Even if someone goes over it with stones in his feet, it will puncture the membrane. The designers recognised this problem and provisions were made in the roof construction for permanent walkways (trocal type
WBP for walkways). However, the walkways went in too late, therefore they were not used during construction.

D.43.5 Services Penetrations

There were some large size holes required for services through the roof, the details of which were not available to the architect to pass onto the contractor. As a result of this, the flat roof was constructed without the services holes. When the details became available, the architect issued instructions to the contractor to cut holes through the finished flat roof for the services.

D.43.6 Penthouse - Plantroom to house the chiller

"The requirement for a penthouse was forgotten by the designers" said the clerk of works. The Contractor’s records show that the information for the penthouse was requested from the architect and it was never made available for it to be constructed before the flat room. Subsequently when the information finally came through, it showed a large hole (5mx6m) to be cut through the roof. The construction of the penthouse involved erection of about 10 tonnes of steelwork, and metal cladding materials. This was a major operation and the work did not help the flat roof to perform as intended.

D.43.7 Kobi Tracks - (cleaning equipment)

Over 200m steel channels were erected within the roof area after it had been constructed. The channels were to support cleaning equipment. The drawings show the channels connected to the main steelwork by the use of bolts and nuts and the roof membrane flashed into it providing the necessary upstand and watertight joints. Since the tracks did not want in before the roof as it should (shown on the
contractors programme preceding flat roof construction) they were connected to the structural steelwork through the roof membrane and mastic put around the connection bolts. (A potential source of leaks). There was a change in the type of cleaning equipment which affect the track required. The late change in the client's requirements affected the design, procurement and erection of the equipment. The architect did not agree that any delay had been caused due to client change of requirement.

D.43.8 Rain Water Outlets - (RWOs)

The subcontractors shop drawings show a number of RWOs. The number shown on the drawings were actually constructed but were later found to be insufficient. The architect purely relies on the expertise of the roofing subcontractor to provide sufficient RWOs. There were ponds of water at various locations on the roof. This was evidence of the limit of the experience of the subcontractor in designing the covering of this type of large roof.

D.43.9 Required fall for the roof

The subcontractor's drawings show a 10 degree fall for the roof. However, due to technical factors such as stability of the roof structure and services, a corporate decision was made to go for the minimum fall that could be achieved. The roof ended up being erected to nearly a nil degree fall. The idea being that water will always find its way to the RWOs.
D.4.3.10 Works carried out "out of sequence"

Due to the fact that the architect could not issue the necessary production information (penthouse details, services penetrations) to enable the works involved for the whole roof to be carried out in a professional manner as programmed by the contractor; the architect instructed the contractor to continue to carry out work where they could. As a result of the instruction, works were carried out 'out of sequence' which meant going back over the finished roof again and again to carry out late instructions. The contractor wrote several letters to the architect informing him that some of the details and instructions issued were bad practice. That is, less of a professional work. The response was that the works must proceed. The response from the architect was motivated by various factors mentioned above as social factors.

The contractor owed the client both the professional and moral obligations to draw to his attention anything that could lead to defective work. Having done what was required of him under the contract and the common law and having satisfied themselves that they could not be made liable for problems that may arise as a result of the points mentioned above, the contractor therefore carried out the works accordingly working 'out of sequence'.

D.4.3.11 Observations

Considering the fact that the various operations (services penetrations, penthouse and kobi tracks) that were carried out on the roof were scattered all over the roof and not close to the walkways, the roof would have to be trod on in order to gain access to and from the place of those works. However, the contractor should have provided some temporary protection to the roof to take care of the foot traffic and points for stacking materials. The cost of the temporary protection could have been
charged to the client as a result of late production information. The cost of any temporary protection would (I would imagine) be a fraction of the money spent in doing the remedial works to the roof up-to-date. The leaks seem to have stopped in the areas of the main building but there were still leaks on the footbridge two years after its erection.

D.4.4 Agreement Between All Parties

- The symptoms were caused by the leaks from the roof.
- The roofing subcontractor was not liable for the leaks.
- The type of roof membrane not appropriate for the project.
- Fall not adequate.
- Late information regarding some large services penetrations and the penthouse.
- More rain water outlets required.
- Some upstands less than 150mm recommended by the manufacturers.
- Foot traffic could puncture the roof membrane.
- Materials stacked on the roof could damage the roof.
- Conflicts exist between specification and drawings (resolved by the issue of architect instructions).
- Architect relied on subcontractors expert to determine the number and position of RWOs but without any design responsibility (what a flop on the side of the design team).

D.4.5 Disagreement between all Parties

- Architect does not agree that there was late information regarding the procurement and erection of kobi tracks.
While there was agreement as to late information regarding some large services penetrations and the penthouse (both were erected after the roof), the client representatives did not agree with the contractor that late information caused the works to be carried out 'out of sequence' (what a contradictory view).

While the client representatives blame the contractor for stacking materials on the roof and for the foot traffic, the contractor attributed the main cause of the leaks to bad design and poor connection details.

D.4.6 How the leaks could have been avoided

The quality problems that arise as a result of the leaks from the flat roof could have been avoided if and only if the following actions were taken at the design and construction stages:

1. The roof should have been designed by a specialist that is more knowledgeable in the requirements and behaviour of the trocal material. The specialist should also have design responsibility.

2. If 1 above was not feasible for any reason, then the designer should have ensured that his design enabled the roof materials to be constructed in accordance with the manufacturers recommendations.

3. The roof should have been designed together with all the necessary services penetrations, penthouse and the connections resolved before the installation commenced.

4. In view of the number of services penetrations scattered on the roof, materials that could take the required foot traffic (for maintenance) should have been used and not the single layer of trocal membrane.

5. More rain water outlets should have been provided.

6. Sufficient fall (say 15 degree) should have been provided so that rain water could easily "self drain" off the roof to the RWOs.
D.5 PAVING/PLANTING/FENCING

The affected operation was the external brick and slab pavings. It was constructed between January and April 1989. Defects became apparent about March 1989.

D.5.1 Selection of subcontractors

The operation was carried out by four different gangs. The first contractor determined his contract because of losing money on labour due to the fact that works could not proceed in an orderly and professional manner. This was as a result of inadequate information. The second subcontractors could not resource the operation to meet the official opening of the building. As a result of which, some of the self-employed bricklayers engaged for brickwork/blockwork were diverted to build the brick pavings. The third subcontractor was appointed mainly for supply and fix paviour type B. All the subcontractors were selected because of their lowest quotations.

D.5.2 The quality problem

1. Undrained surface water
2. Poor appearance/uneven surface
3. Cracks in mortar joint of type A pavours
4. Broken concrete slabs

D.5.3 What went wrong

1. Lack of adequate production information. The drawings and details issued for the construction of the external pavings were very sketchy. "The external
works drawings, just like other drawings issued on the contract were inadequate" said the site engineer. This view was shared by all the contractors team. The available document supported the statement. The inadequacies in the production information were:

a) Formation and finish levels not properly co-ordinated. This shortfall led to a considerable length of time being spent by the contractor, subcontractors, the architect and his clerk of works in resolving problems relating to levels on a daily basis. It resulted in work being carried out 'out of sequence' and some concrete slabs laid were later taken out and re-laid to levels not shown on drawings but agreed to by the architect.

b) Finish levels did not provide sufficient falls for surface water to be self drained into gulleys provided.

2. The appearance of the pavings were not satisfactory to the architect. It felt short of the clients requirements as contained in the specification. The factors which led to the above were:

a) The operation was carried out by different gangs employed by different subcontractors as stated under the heading titled 'selection of subcontractors'.

b) Lack of adequate care by the operatives. The operatives did not take adequate care in setting out the type A paviours in such a manner to achieve equal and even mortar joints.

c) Lack of adequate supervision. Much time were spent by the contractor and clerk of works in sorting out levels and details. In view of this fact, they were left with little or no time to actually inspect and

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control the workmanship of the works.

d) There was no protection to the pavings already laid. Walking on areas already laid with shoes full of mud from other parts of the site did not help the appearance of the pavings. As a result of the constant walking on the areas already laid with mud, it became very difficult to clean the pavings to a satisfactory appearance before and after handover.

3. The pavings were designed mainly for foot traffic and light duty vehicles. However, there was one access route for emergency vehicles. Other than emergency vehicles, the client and her tenants allowed heavy lorries to be driven all over the pavings. The pavings were not designed to take the weight of articulated and heavy delivery lorries now constantly being driven all over the pavings. This had resulted in cracks and broken concrete slabs and the pavings. Also some manhole covers were replaced as a result of damage done to them by the lorries.

D.5.4 Agreement between all parties

- "Production information could have been more adequate and co-ordinated" said the architect. This statement buttress the contractors argument regarding inadequacy in the drawings issued for the pavings.
- The number of subcontractors and the sequence in which the works were carried out had affected the final appearance of the pavings.
- Operatives' lack of adequate care had affected the setting out of the type A paviours.
- Supervision not adequate.
- Temporary protection desirable.
Heavy vehicular traffic had caused the cracks in the pavings and the damage to manhole covers.

D.5.5 Disagreement between all parties

The client representatives did not agree that:
1. The inadequacy in production information causes the determination of subcontract by the first subcontractor.
2. Works had been carried out 'out of sequence'.

D.5.6 How they could have been avoided

1. The pavings together with all external features should have been conceived and designed in one package.
2. Formation and finish levels should have been properly worked out and coordinated with other features such as gulleys. Had this been done, sufficient falls would have been provided so that surface water will be self drained into the gulleys.
3. Adequate production information should have been issued to the contractor to enable his subcontractors to plan, resource and carry out the works in a professional and orderly manner. If this was the case, the first subcontractor may not have legally determined his contract with the contractor.

This would have improved the morale of the operatives and as a result, bad workmanship may not have occurred. Also, the action would have improved supervision.
4. Protection of the pavings should have been carried out by the contractor even if it would have resulted in extra costs which could be negotiated with
the client.

5. Heavy vehicles that could damage the pavings should not have been allowed onto the pavings. The client should have brought it to the attention of his tenants that the pavings were not designed for heavy vehicles (total weight of vehicles to be allowed on the pavings to be stated).

D.6 VENTILATION

The affected operation were the smoke ventilators in the main concourse of the building. The installation of the ventilators was between March and April 1988. Erection of cleaning equipments adjacent to the ventilators was carried out between December 1988 and January 1989. The defects mentioned below became known in February 1989.

The smoke ventilators were designed and installed to operate automatically in case of fire. That is, to open and allow smoke to escape from the building in the event of fire. The ventilators were made of stainless steel and aluminium. They were in pyramid shapes.

D.6.1 Selection of Subcontractor

The subcontractor was nominated.

D.6.2 The quality problem

The trouble spot is the main concourse area of the building. Soon after the kobi tracks were erected, there were drips of water from several points within the smoke ventilator area onto the terrazzo floor within the building.
This resulted in:
- corrosion of connection bolts and nuts
- discolouration of terrazzo tiles
- nuisance to tenants and passengers

D.63 What Went Wrong

D.63.1 Investigation

During the early part of the design stage, the idea was to nominate a specialist firm such as COLTS for the complete package of the design, supply and fixing of the ventilators and its adjacent areas. As a result of the reduction in cost requested by the new client, the design was carried out by three different bodies. That is, the structural support for the ventilators was designed by the project structural engineers, the interface such as the flat roof around the ventilators and the kobi tracks were designed by the architect while the ventilators (only) was designed by a specialist subcontractor. This later scheme was not entirely the same as the early design intention of the architect.

The drip points were located and joint efforts were made by the project team to trace the drips back to its origin. After a considerable inspection of the smoke ventilators and its adjacent areas, leaks were detected to be coming through:

1. connection points of the ventilator louvres and the main structure.

2. connection points of the kobi tracks through trocal membrane to the main structure.

These connections were made of bolts and nuts.
D.63.2 Nomination of Subcontractor

The structural steelwork in the concourse area was designed with a view to put in smoke ventilators within the construction time. "Nomination of a specialist subcontractor was late," said the contractor. (A view not shared by the architect). The contractor advised the architect that a specialist firm for the job should be called in at an earlier stage so that necessary requirements for the ventilators could be incorporated into the structure as soon as possible.

D.63.3 Level and other requirements of the ventilators

When nomination of a specialist subcontractor was made, its requirements was that the smoke ventilators should be installed prior to any other item in its vicinity. Upstands were to be provided so that the ventilators could be independent of the main structure. This requirement was also necessary for the provision of drainage channels to drain rain water from the ventilators.

The ventilators would need to be installed at the appropriate level and flashed onto the upstands. The manufacturer was to manufacture and install them to take in water and drain it onto an open area in the roof so that it could find its way into the drainage channels to be provided.

The level at which the ventilators were to be installed was determined by the structural engineer (this should have been by the specialist subcontractor). The contractor requested that the level given by the structural engineer for the ventilators be raised a little higher (contractor was advised by the specialist subcontractor to request for raising the level of the ventilators). At that point "structural stability of the structure preclude raising the level of the ventilators", said
the architect. At the stage where the subcontractor was brought in, the structural steelwork was being fabricated. The design team decided not to stop the fabrication of the steelwork and hope they could find alternative solutions to the requirements of the ventilator subcontractor.

D.63.4 Interface between flat roof and the ventilators

The flat roof in the vicinity of the ventilators was installed before the installation of the ventilators. The ventilators were installed directly on the structure without the manufacturer's recommended upstands. Bolts for connecting the ventilators to main structure passes through the trocal membrane with mastic seal around the bolts (potential source of leaks).

D.63.5 Raising the level of the ventilators after installation

When erected, the ventilators failed the necessary test required to put them into operation. Also there was no provision to drain water from the ventilators area. The reason given by the subcontractor for the test failure was that the ventilators were installed at the wrong level. Also, without making the smoke ventilators independent of the structure there will be no way of providing drainage channel to take away rain water from the area. As a result of the above, the ventilators had to be raised and the architect issued instructions to the contractor accordingly. "Simply a bad design" said the clerk of works.

The raising of the ventilators was carried out manually by jacking the ventilators up and supporting it with steel chims. The practicality and the cost preclude the contractor from using a mobile crane for raising the ventilators. The ventilators were raised twice before it passed the commissioning tests. At this stage, the ventilators were independent of the main structure with about 75mm upstand. This
upstand now allowed drainage channels to be provided.

D.6.3.6 Kobi Tracks: (Cleaning equipment)

The kobi tracks in the areas of the ventilators were erected after the flat roof and ventilators had been erected. The sequence of these three operations in an ideal world would be:

- ventilators to be erected first
- kobi tracks to follow the erection of ventilators
- flat roof and necessary flashings after the kobi tracks.

The sequence above was unanimously agreed by the project team. The three operations could not be carried out as per the above sequence because of the following:

- late nomination of ventilator subcontractor.
- kobi tracks not ready for erection before the flat roof.
- in order to make the building watertight, the flat roof was erected before the kobi tracks.

Same as the ventilators, the kobi tracks were connected to the main structure with bolts passing through the trocal membrane with mastic seal around the bolts.

D.6.3.7 Remedial Works

Immediately it became apparent to the architect that there were leaks from the smoke ventilators area, marked up drawings were sent by the architect to the contractor asking the contractor to put the work right. On receipt of the architects letter and the marked up drawings, the contractor wrote back to the architect saying
that the ventilators and the associated works in the area had been carried out in accordance with architects instructions.

The architect acknowledged the fact, that works had been carried out as per AIs and drawings. Therefore, he issued instructions for the remedial works at the clients expense. The remedial works was by making the bolt connection points watertight using mastic sealants. Also expanding foams were put in to seal the gaps and mastic on top.

D.63.8 Observations

By definition, if the architect does not accept responsibility for the leaks, he would not have issued instructions for the remedial works at the clients expense. In spite of all the remedial works carried out in the ventilator areas; the leaks were yet to be stopped. On the 22.1.90 while on inspection of the project, the author saw operatives with their mastic guns trying to seal off the leak points.

D.6.4 Agreement Between All Parties

- The sources of the leaks, ie leaks were coming from the connection points in the area.
- The level at which the ventilators were first installed was wrong.
- The contractors original sequence of works in the ventilator area (information not available at the right time to follow the sequence) was right.
- Bad design.
- Despite the fact that the designers could not produce production information on time the client still required the project to be completed on a stipulated date (maybe because of the royal opening). This led to a rush in the project, the repercussion of which is evidence today by the number of making good
still being done at the clients expense one year after the royal opening.

- A complete package of the works in the ventilators area to one specialist firm would have produced a better job.

- The architect did not agree that nomination of subcontractor was late but agreed with the contractor that the subcontractor should have been brought in early (what a contradictory sentence on the part of the architect).

- A better method of raising the ventilators should have been used rather than the manual jacking of the ventilators.

D.6.5 Disagreement Between All Parties

- The contractor alleged late information for the kobi tracks. The clients representatives disagree. The first drawing for the kobi track was issued by the architect on the 12.5.88. However, the contractor 'INFORMATION RELEASE SCHEDULE' states that the contractor required the drawings by 7.8.87 (nine months difference). "If the drawings had been issued in August 1987, we would have been able to procure the tracks for erection before the roof covering went in" said the site manager.

D.6.6 How the leaks could have been avoided

1. The smoke ventilators should have been installed at the right level in the first instance.

2. Upstands should have been provided as recommended by the manufacturer to enable the ventilators to be independent of the main structure and for the provision of drainage channels.

3. When it became evident that the kobi tracks could not be erected before the flat roof, a more satisfactory connection details for the tracks should have been devised by the designers bearing in mind the new sequence of work to
be adopted.

4. Early involvement of the ventilator specialist firm would have helped the structural engineer to design the steelwork accurately (level).
CASE STUDY NO 2

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APPENDIX E

CASE STUDY NO 2

E.1.1. PROJECT DESCRIPTION

The project is a European facility for the demonstration of the client’s graphics product systems and services to dealers and consumers, and training in their use and applications. The project when completed should fulfil the visitor’s expectations of a large multi-national company.

BUILDING: Two floors with plant room on the roof. Total area per floor is approximately 1000 m².

LAYOUT: Ground floor comprises Reception and Working Showroom.
First floor comprises function areas, hosting, classrooms and traditional product training workrooms.

E.1.2 Client

The client is one of the world leading international companies in the field of photographic products and equipment. The client is a large organisation and a regular customer of the Construction Industry. It has a Building/Maintenance Department. In view of its constant construction works, the department had compiled a list of General Building Contractors and Trade Subcontractors. The list includes all firms that have worked directly or indirectly for the client in the recent years.

The client has a Company Engineering Standard to which all its contractors must comply together with all other necessary statutory regulations. The firms on the
client's list are very familiar with the Company Engineering Standards.

E.1.3 The design phase

Being a design and construct project, the contractor was responsible for the design and construction of the building. The design of the proposed building was carried out by the Design Department of the contractor.

The design (proper) was based on the employer's requirements and the contractors proposals which were the contract documents.

The following elements were fully designed by subcontractors (with design responsibilities)

- Structural frame
- Roof cladding
- Curtain wall
- Demountable partitions
- Lift
- Suspended ceiling
- Raised flooring
- Revolving door
- Entrance canopy

Although drawings were vetted by the Design Team, that do not relief each subcontractor of it design responsibility to the contractor. This means, each of the subcontractors was responsible to the contractor for the design and installation of its element. This did not relieve the contractor of his total responsibility to the client for the design and construction of the building.
The client's scheme was based on 1000 mm module. During the cost reduction exercises, the client decided to change the planning module to 1200 mm. This significant change lead to the design team to undertake re-planning of the building. The decision to use 1200 mm module was made on 7/7/89. Therefore the actual design of the building effectively started on 10/7/89 (i.e. seven weeks before construction was due to start on site).

E.1.4 Contract Details

Contract sum at tender stage: £3.2 million
Contract sum at handover: £3.8 million
Contractor selection: Two stage selective tendering
Contract start date: 29 August 1989
Contract duration: 61 weeks (ie. October 1990 handover)
Time overrun: none

E.1.5 Client Representatives

The project was conceived in October 1988. The client appointed an In-house Representative (Project Manager). The Project Manager developed (with the help of various departments within the client's organisation) the project brief. The brief was approved by the client's top management executive. After the approval of the project brief, a team of experts (client's team) was appointed. The client's team were:
The Client's Team prepared the tender document (Employers Requirements). Part 4 of the Employer's requirements comprises of A3 schematic drawings (very sketchy).

E.1.6. Contractor

Area of Business: General Building Contractor
Size: A region within the Building Division of a large International Contractor.
Turnover (Region): 68 million 1988/1989
Head Office - London
Subcontractor/supplier selection: Through the Regional Office. Site is approximately 20 miles from the office. Site Team always play considerable role in the rituals/decision for selections.
Presence in the Project Area before contract: 4 current projects.
Contracts won in the Project Area during construction: 3.
Regional Managing Director

Construction Director

Regional Manager Design & Build

Design & Construction Manager

Senior Q.S.

Site Q.S.

Planning & Resources Controller

Design Manager

General Foreman (for the last 9 months)

Structure

Architecture

M & E Services

Sub-contractor's Operatives

Figure E.1: Contractor's Organisational Structure
E.1.7 Contractor organisational structure

Figure E.1 shows the contractor’s organisational structure for the project.

E.2 IN-SITU CONCRETE/LARGE PRECAST CONCRETE

The affected operation was the in-situ reinforced concrete lift pit in the centre of the building. The concrete was cast in September 1989 and defect became known in October 1989.

E.2.1 Selection of subcontractor

The Subcontractor was selected from three potential Subcontractors that submitted quotation for the ground works on the project. Some of the prices in the "mini Bill of Quantities" prepared by the Subcontractor was negotiated and agreed by the contractor with the subcontractor. The usual comparison of the subcontractors performance on other projects was carried out, but the ability of a subcontractor to start on site within a short notice greatly influence the selection.

There were some internal political reasons within the client’s organisation which required the project to start on site at a specific date. The selected subcontractor was able and willing to start on site within a very short notice (say one week).

OBSERVATION: The subcontractor employed a very experienced setting out engineer. There were 48 column bases on the project and all were cast to within the specified tolerance. No other defective (except the water getting into the lift pit) works was found on the operations carried out by the subcontractor. This could be attributed not entirely to the contractor’s supervision but also to the competence...
and commitment of the subcontractor's foreman who was also doing all the setting out, lining of formwork and reinforcements. As it could be seen in figure 6.2, there was only one setting out engineer employed directly by the contractor on the project.

E2.2 The quality problem

Water ingress into reinforced concrete lift pit causing approximately 500 mm depth of ground water.

E2.3 What went wrong

There has always been water in the lift pit since it was formed with reinforced concrete in September 1989. The concrete was cast as part of the foundation for the building. During the eight months (September - April 1990) there were instances when the lift pit was filled with approximately 500 mm depth of ground water. During the construction of the column bases, water was encountered in the ground despite the fact that the geotechnical report of the site stated that the water level was far below the formation levels for the foundation.

None of the project team take any serious notice of the water in the lift pit between September 1989 (i.e. when the pit was formed) and April 1990 (i.e. when the roof cladding over the pit was completed). However, the contractor's setting out engineer recorded the fault in his contribution to the October 1989 Site Manager's monthly report as shown in figure E.2. There was no immediate follow up of the engineer's report regarding the possible cause of the water ingress.
Immediately the roof cladding was completed, the water in the lift pit was pumped out and the pit properly cleaned out of mud and debris. At this stage, the building has been made water-tight, therefore no water was expected in the pit. However, three days later, small quantity of water was found in the pit from there onwards, the quantity of the water kept increasing. It reached a level of approximately 75 mm depth.

"It was at this stage that we knew that something is wrong" said the Design and Construction Manager. The Contractor’s Structural Engineer was asked to comment on the water getting into the lift pit. The Engineer has this to say

"firstly, the C.35 concrete mix that I specified for the lift pit, if properly cast and well compacted will resist any ground water. Secondly, since the client’s geotechnical report for the building site did not show water level to be above the formation of the pit, I see no reason to tank the pit. Thirdly, there is no likely hold that water could get into the pit through the sump created in the pit, if the designed concrete mix has been cast properly. In view of the above, I do not accept that the ingress of water into the lift pit is as a result of design fault".

The Subcontractor was called upon to investigate and carry out any necessary remedial work that may be required to stop water getting into the pit. The Subcontractor was no longer on site because all the ground works has been completed. A labourer was sent to site by the subcontractor to pump out the water and properly clean the pit out. After these operations, the pit was dried up by the use of a heater. These actions did not stop the water. The subcontractor could not investigate the problem further before the firm gone into receivership. The receivers were not prepared to carry out any outstanding works on behalf of the subcontractor.
By this time, the lift installation has commenced. After the second week of the installation, the lift subcontractor formally wrote to the contractor saying it was unacceptable for his men to continue with the lift installation while there was water in the lift pit. The subcontractor insisted that the water must be stopped before the lift can be completed and commissioned.

In view of this the contractor decided to investigate the problem. A physical examination of the pit revealed the fact that the level at which water was getting into the pit was about 300 mm above the pit floor. Therefore, it was assumed that water must be getting in through the joint between the kicker and the pit wall. The contractor’s general foreman proposed that the whole floor of the pit should be screeded with a 300 mm upstand along the four sides of the pit. This view was supported by the Planning and Resource Controller (the author) but the Design and Construction Manager did not support the idea because of cost (say £75 - £150). After a considerable discussion involving the site Quantity Surveyor, the Design and Construction Manager decided to allow the General foreman to proceed with his proposed remedial action. The General foreman’s proposal was as a result of his experience with water ingress into basement of a recent project by the same contractor. The screed was to be a quick setting waterproof leak stopper, mixed and used as recommended by the manufacturer.

The concrete surface was smooth and it was decided to hack the surface to provide a key for the Screed/Rendering. The hacking was carried out by the use of a gango. While this operation was in progress, water burst out through a hole in the wall. A careful examination of the hole revealed that the hole was formed by spacer tube used to get bolts through the concrete to hold the two sides of shuttering together while the concrete was being cast. The level of the hole found was checked on the remaining sides of the pit and two more holes were found and when broken into, water burst out.
These holes were the ones referred to by the contractor's engineer as "shuttering tie holes" (see fig E.2). The record was not referred to when the water problem became more apparent. If that was done, time and effort would have been saved because the course of the ingress of the water would have been found straight away from the report and appropriate remedial action taken.

The subcontractor's foreman in charge of the operation when the works was carried out has been moved to another site when the defect became known. A copy of the Engineer's report (figure E.2) was issued to the subcontractor's new foreman for him to carry out the suggested remedy. As it could be seen the form was not signed to show that remedial action was taken by the subcontractor at the time.

The water was pumped out and the pit dried out completely. The pit floor was therefore screeded as proposed by the General Foreman but the 300mm upstand waterproof rendering was omitted. Instead, the shutterbolt holes were grouted up with waterproof cement mortar. These operations effectively stopped the water getting into the pit.

The holes (shutter-bolt holes) formed by spacer tubes in the formwork were not made good with mortar as stated in the specification after formwork was striked. The holes were not visible because they were partially covered by mud and mortar dropping from the above when the lift shaft was being constructed. It was the responsibility of the subcontractor to grout up the shutter bolt holes immediately the shuttering was striked. It is purely negligence of duty by the subcontractor. There was no formal procedure followed by the operatives to ensure necessary actions were taken.
The above investigation also revealed that the necessary inspections and supervision of the works were not carried out by the contractor during the execution of the operation.

**E.2.4 Agreement between all parties**

The subcontractor that carried out the defective work was no longer in business, therefore it was not possible to obtain its final say on the problem. "The cost of the remedial works will be contra charged to the Account of the subcontractor. This will be deducted from the retention money of the subcontractor still in our possession" said the site quantity surveyor. "We should have inspected the works better than we did" said the Design and Construction Manager.

**E.2.5 Disagreement between all parties**

None - as a result of E.2.4 above

**E.2.6 How it could have been avoided**

Immediately the formwork to the pit was struck, the tie holes should have been grouted up with cement mortar as stated in the specification. If the setting out Engineer's report had been followed-up, the problem would have been overcome sooner and with little effort. (The engineer was moved to another site in January 1990 and the problem became more apparent in April 1990).

**E.3. MASONRY**

The affected operation was the brickwork/blockwork to the perimeter of the building. Construction was between November 1989 and February 1990. Faults
became known in December 1989 and March 1990.

E3.1. Selection of subcontractor

Enquiries were sent to five potential Brickwork Subcontractors. Four out of the five submitted quotations for the operation. Three of the four prices were within the contractors budget for this particular operation. The fourth subcontractor (i.e. the highest bidder) was eliminated from the indepth performance comparison of the subcontractors. A work visit was arranged with the favourite subcontractor. The purpose of the work visit was to enable the contractor obtain an up to date physical examination of the workmanship of the subcontractor on a recent job. The work visit was carried out by the Design Manager and Design and Construction Manager. Both men were satisfied with the performance of the subcontractor on the project they visited. In the words of the Design and Construction Manager, "I am pleased with the work I saw been carried out by their bricklayers. Also, in the interview I had with the partners, they seem to know what they were talking about. Anyway, having seen their work, I was totally convinced that the job should be given to them".

Before the favourite subcontractor could be shown the green light, the Contractor's Regional Managing Director instructed the Purchasing Officer and the Design and Construction Manager that the job should be given to different subcontractors. Hence, a subcontractor outside the four that submitted quotations for the operation was nominated by the Regional Managing Director. Enquiry was sent to the subcontractor along with the other four but it failed to submit quotation when the others did. When asked why there was no response from the firm when invited to submit quotation, one of the partners said "we never received the enquiry documents. We are interested in doing the job".
The rates and the overall cost of the operation was negotiated with the subcontractor. The two partners that owned the firm were trained by the contractor. After their training, they both worked for the contractor as direct employed bricklayers. Years later, they were told by their employer (the contractor) to set up a brickwork subcontractor's firm and that they would always be put on Brickwork/Blockwork enquiry list. Since they set up the firm 15 years ago, they had carried out works for the contractor on various projects.

Why the sudden nomination of this subcontractor by the Regional Managing Director even before the firm submitted a price for the job? This was a question the author put to the purchasing officer for the project. "I tell you why .......... has not got any work at the moment and being a close associate of our region, I think our boss felt it is more reasonable to give them the job than to a one off subcontractor. Mind you, some of the senior project managers and site managers in this region are close colleagues of .................".

E.3.2. The quality problems

1. Brickwork/blockwork found to be out of specified tolerances.

2. Variation in width of perpends (it ranges from 6 mm to 20 mm).

3. Chipped and damaged bricks in the walls.

4. Patches of mortar and stains on finished brickwork.

5. Mortar dropping into brickwork cavity - cold bridge and water penetration.
E3.3. What went wrong

1. **Brickwork/Blockwork found to be out of specified tolerance**

The problem mainly occurred in the perimeter walls of the building. Setting out of the brickwork/blockwork was the responsibility of the brickwork subcontractor. The setting out was carried out by the subcontractor's working foreman. (i.e. one of the two partners that owned the firm). The foreman was a very experienced bricklayer with over 20 years of experience to his credit. The setting out carried out by him were later checked by the contractor's setting out Engineer. In more than two instances, setting out of the openings for curtain wall were found to be inaccurate. "Hence the primary source of some of the perimeter brickwork/blockwork been outside the specified tolerance", said the Engineer.

When asked, whether every dimensions for the curtain wall openings were checked by the Engineer. The Engineer said, "I did not checked every openings for dimensional accuracy. However, I checked two thirds of the openings". A proper record of the checks carried out by the Engineer was not kept. Therefore, it is very difficult to know whether the openings found to be outside specified tolerance were the ones not checked by the engineer. Again, the engineer has this to say "I found some of the openings that I checked to be between 10 mm and 20 mm over the permissable deviation. Where two or more courses of bricks had been laid before I found out the inaccuracy in the setting out, the Brickwork Foreman would not accept to take it down. His argument was that the difference will be made up as the brickwork/blockwork progresses".

When asked, if his findings were brought to the attention of the Design and Construction Manager, the engineer answer was "yes, I did drawn ..... attention to it and he promised to take it up with the Brickwork Foreman. Whether he did, I
never know ......... is capable of setting out the brickwork accurately but he is always in a hurry to get the job done, leaving no room to check his own work. He needs to take his time when carrying out setting out'. (Observation: setting out was never approved by any one as required by the specification).

The obvious defect as a result of the brickwork been outside the permissable deviation was that the gap between the brickwork piers and the curtain wall range from 3 mm to 40 mm. The gap ought to be 15 mm in the extreme cases for mastic pointing. The inconsistency in the gaps make the brickwork unsightly when the building is viewed from a close range. Follow-on trades were seriously affected as a result of exceeding the permissable deviation in brickwork/blockwork construction. The most noticeable was plastering and pelmets along the curtain wall sections of the building. Blockwork has to be dumped out to take off the inaccuracy in the walls. The permissable deviation for straightness was ± 10 mm and dumpling out of 35 mm in some instances was carried out by the plasterer to straighten out walls to enable follow-on trades, such as 2nd fix joinery, demountable partitions and suspended ceiling to be erected accurately.

2. Variation in the width of brickwork perpends

The defect was directly related to the problem of tolerances and setting out. The perimeter brickwork comprises of 12 courses of bricks from the strip footings to the point at which brick panels and piers were formed. The perpends up to that level range from 6 mm to 12 mm (standard perpend should be 9 mm). "The variation is not noticeable because on average, the perpends look 9 mm wide", said the Design Manager. The height of the openings for curtain wall was 7.2 m. Variation in the widths of the perpends became noticeable half way through the 7.2 m with progressive widening as the brickwork goes up as shown in figure E.3. The subcontractor's foreman attributed the cause of the fault to scaffold problem. He
has this to say:

"The scaffold platforms made available to us was not erected purposely for our brickwork. It was erected for the roof cladding subcontractor and later adapted for our use. We complained strongly about this issue to ......, but we end up having to use what we were offered. You can not expect good brickwork if proper access to place of work is not provided. In this case, it is the main contractor’s responsibility to provide us with adequate and proper access to carry out our works. The contractor failed in his responsibility. Now you see the end result. Again, our works was never inspected for tolerance or verticality but only for quantity and positioning of dpc. Why was this problem not picked up by the contractor when the first brick panel was built. The problem only came to light when brickwork was completed and scaffold taken down".

The brickwork foreman refused to accept that the variation in the width of the perpends were a deliberate action by him to off-set the inaccuracies in his setting out.

Two of the bricklayers were interviewed and in their opinion, good workmanship required patient and proper care. The first bricklayer said, "Bricklayers got to take their time when laying bricks or blocks. Despite the fact that we are on DAY WORK (i.e. basic weekly wages regardless of number of bricks or blocks laid) on this project, we are still under indirect pressure to laid 300 bricks per day. Apart from the scaffold problem, another major problem on this job was the weather. There was a lot of rain and heavy wind during the course of our works on this site". When asked if they have not taken the necessary care required for a good workmanship to be achieved, the second bricklayer said "No, I wouldn’t say that; but I believed we could have taken more care".

3. CHIPPED AND DAMAGED BRICKS WERE FOUND ON THE FINISHED WALLS

When perimeter access scaffold was dropped, it became known that chipped and damaged bricks had been used in the construction of the brick walls.
Figure E.3 Variation in width of brickwork perpends
Bricks delivery:
Bricks were delivered to site on pallets and well wrapped in polythene sheets. Delivery truck has lifting devices. Therefore, loading and off-loading were by the lifting device mounted on the truck. All bricks used on the project was delivered by same driver using the same truck. Some chipped and damaged bricks were found during deliveries. The number of bricks found chipped was very insignificant for the contractor to make official complaint to the brick supplier. However, the driver was informed of the damaged bricks and proper care was demanded of him. He did not accept that damages might have occurred during his transportation of the bricks. "Damages might have occurred in the supplier’s yard" said the driver. The bricks were stacked on site three pallets high.

Handling of bricks of site
Handling of the bricks on site was by fork lift. Both horizontal and vertical movement of the bricks from stacked position into the building was by fork lift driven by an experienced driver employed by the brickwork subcontractor. Bricks were moved horizontally within the building by pallet truck. There was no time during the construction of the brickwork that sufficient bricks were not available on site from which unchipped and undamaged bricks could be selected. The following record confirmed the point:

- Brick Delivery Schedule
- Brick Delivery tickets
- Monthly Manager's Report

The arrangement for the delivery of materials (including bricks) was the direct responsibility of the Planning and Resource Controller (i.e. the author).
The contractor’s Buying Department wastage allowance for bricks was 9% and the actual wastage recorded on site was 4% of the wall constructed. The type of brick used was very fragile and therefore vulnerable to damages. Hence the 9% wastage allowed by the contractor. "Since only 4% was recorded as actual wastage on site, it could be concluded that loading, off-loading, stacking and site handling has been carried out properly" said the Project Purchasing Officer.

The Design and Construction Manager said "The only conclusion at this stage is that the bricklayers has used chipped and damaged bricks in constructing the walls". The subcontractor’s foreman responded to the above as follows,

"We tried to select unchipped and undamaged bricks while laying the bricks but we can not rule out the possibility that few chipped bricks would not have been used due to human error. My men should have been more careful in selecting bricks. However, it can not be ignored that bricks could have been damaged by scaffolders and other follow-on-trades".

4. PATCHES OF MORTAR & STAINS ON FINISHED BRICK WALL
The finished fair faced brick walls were never protected despite the fact that sufficient gauge 1000 polythene sheet and timber battens were ordered and delivered to site for temporary protection of the brick walls. Temporary protection of the walls were the responsibility of the contractor.

Patches of mortar was as a result of mortar dropping while bricks above were being laid. The brickwork foreman pointed out:

"My men always wipe down the freshly laid bricks as work proceed. However, you can not but get some mortar dropping on the wall. More importantly, mortar will drop on walls far below where bricks are being currently laid and bricklayers will not go in to clean down walls at that level because scaffold board would have been removed. Hence, the need for covering the wall as construction progresses"
When asked why protection of the brick walls were not carried out, the Design and Construction Manager has this to say

"As you know, we have got the materials on site to protect the walls but we forgot to instruct the chippies to do it due to pressure of other more important things".

Specification stated that scaffold boards should be turned back at night and during heavy rains. This section of the specification was never complied with by the subcontractor and no attempt was made by the contractor to see that the specification was complied with. In spite of heavy rain during the months of January and February 1990, the time which majority of the brickwork was carried out; no protection of the walls was ever done. That simply tells us that the Clause in the specification which called for keeping the faced work clean during construction and until practical completion was not complied with by the contractor.

Observation: The specification was drafted by the Design Manager (engaged by the contractor) for the Design and Construction Manager's comment(s). Therefore one can say without much argument that the specification was a brain child of the contractor. One will wonder what the future hold for the industry if a contractor can not get its subcontractor to comply with its own specification talking less of specification written by consultants on behalf of a client.

5. **MORTAR DROPPING INTO CAVITY OF BRICKWORK / BLOCKWORK**

There were instances of mortar dropping into the cavity of the brickwork and blockwork. The perimeter brickwork/blockwork was constructed with 50 mm wide cavity. The wall was insulated with 25 mm thick polystyrene insulation bats. Therefore the cavity was left with 25 mm wide gap which should be kept free from mortar. The specification specifically called for battens or other suitable means to
be used in stopping mortar dropping into the cavity. This was never carried out by the bricklayers. The foreman said: "I don't read the specification. We should have been verbally instructed on site to use timber batten. We only use it where the contractor insisted we should use it". The Design and Construction manager said:

One thing I regret most on the project was the late arrival of a foreman. I should have requested for a foreman with trade background at the beginning of the brickwork construction. He could have been able to carried out the necessary inspections".

E.3.3 What went wrong

From the investigation above, what went wrong which resulted in the faults were:

1) Inaccurate setting out of brickwork/blockwork by the subcontractors’ foreman.

2) No planned and adequate inspection of the brickwork/ blockwork construction.

3) Access Scaffold was not properly erected for the purpose of brickwork. The adaption of existing scaffold was not carried out to suit brick-laying.

4) Rain and heavy wind affected the brickwork construction.

5) Lack of protection of the finished brick wall during the construction and against damages from follow on tradesmen.

6) Lack of adequate care by the bricklayers which resulted in wider variation in width of perpends, mortar dropping and selection of chipped and damaged

E22
bricks for incorporation into the works.

7) Timber battens were not used by bricklayers to protect cavity from mortar dropping during the course of the brickwork construction.

E.3.4 Agreement between all parties

1. Inadequate inspection of the brickwork/blockwork construction by the contractor’s team.

2. Access Scaffold could have been erected in a more suitable manner for brick laying.

3. Care by the bricklayers was inadequate.

4. Lack of protection of the finished work.

5. The weather was a contributory factor.

6. Timber batten should have been used.

E.3.5 Disagreement between all parties

1. The subcontractor did not accept inaccuracy in its setting out of the brickwork.

General Observation: Gauge boxes were never used in measuring aggregates for the mortar used on the project. Sand and cement were arbitrarily shovelled into mixer as witnessed in Case Study No. 3. The specification for this project did not
call for sample test of mortar to be carried out. If this was the case, then interesting results would have been obtained.

E3.6 How the defects could have been avoided

1. Inaccurate setting out could have been avoided if the brickwork foreman had taken more care and patience in carrying out his role.

2. Continuous checking of dimensions should have been carried out by the brickwork foreman.

3. All brickwork setting out should have been approved by the Contractor (e.g. by the contractor's setting out engineer) when first course of bricks/blocks were laid.

4. Planned inspection of the operation should have been arranged, resourced and properly carried out.

5. The operations along the perimeter of the building (i.e. brickwork/blockwork, roof cladding and curtain wall) should have been sequenced properly to allow sufficient access scaffold to be erected for the bricklayers.

6. Temporary protection of the brickwork should have been carried out.

7. More care should have been taken by the bricklayers in carrying out their works. This could have reduced (if not eliminate) mortar dropping, selection of chipped and damaged bricks and the wide variation in brick perpends.
8. Timber battens should have been used to stop mortar dropping into the cavity (also see Case Study No.3).

E.4. CLADDING/COVERING

The affected operation was the profile metal sheeting used as the roof covering for the building. Erection was between January and April 1990 and fault became known in February 1990.

E.4.1. Selection of subcontractors

Four firms were invited to submit quotation for design, supply and erection of all cladding to the pitch roof. The selected subcontractor had worked before for the contractor. The firm was also on the client's list of Trade Subcontractors.

Selection was not based purely on price but on the contractor's comparison procedures. The comparison procedure include assessment of price and scores obtained from assessment of the firm's performance on other projects. The "performance report" included the following headings:

(1) pre-site progress
(2) quality of work
(3) supervision
(4) Adherence to programme
(5) cooperation
(6) settlement with Q.S.
Ratings are:

   i) Unsatisfactory
   ii) poor
   iii) adequate
   iv) good
   v) very good

E.4.2 The quality problem

Colour variation (top sheet of the roof cladding). Colour variation evident on at least three elevations of the building when viewed from the ground. One colour was light grey while the other colour was dark grey. Noticeable variation depends on light conditions. The problem was identified by the Client's Project Manager.

E.4.3 What went wrong

During the first inspection of the roof, the sheet supplier commented that the colour variation evident on the top roof sheet is unusual with Goosewing grey panels. The supplier confirmed that material (coil) supplied by the steel producer was HP200 Goosewing grey, though more than one coil had been used. These comments were based on visual inspection. Detailed record checks was therefore required.

The supplier detailed record checks revealed the fact that two different batches of steel were mistakingly used by the supplier and subsequently delivered to site. The supplier's record checks include:

- check the details on order placed with steel producer.
- check batch no. with order no. and the colour of the batch.
- check batch(es) issued for processing (cut to sizes for the project).
The checks confirmed the following points:

- The order placed with steel producer spelt out in details the colour required;
- The material supplied by steel producer comply fully with colour required;
- More than one batch of steel were used for the project. Hence, the colour variation;
- Both colours evident on the project were within BS 10 A 05 acceptable colour tolerance for Goosewing grey. Therefore, to achieve a consistency in colour, the steel producer always supply material (coil) for each project from one batch of steel. The implication was that if materials were used from one batch of steel for a specific project, there would be no colour variation.

The supplier's factory normally works two shifts per day. Each shift uses the same production line. Therefore, work commenced by men on day shift but not yet completed will be carried on by the night shift. Works commence on the material for this project by the "Day Shift" workmen. They started to use material from the batch of steel supplied specifically for the project. They were unable to complete production (cutting to sizes) of the sheet required for the project; When the "Night Shift" workmen came in to continue where the "Day Shift" left the production process. They used material from a different batch of steel. The Supplier's Production Manager said:

"A mistake was made as a result of inadequacies in our production procedures. This type of problem has happened before and I think it is time we do something to stop it happening again".
E.4.4 Agreement between all parties

1. The client's requirements regarding colour was clearly stated. However, the project manager was not aware of the wide in colour variations of the chosen Goosewing Grey C1000. To this effect, the project manager made the following comments:

"We perceived conformance to our requirements to be the light grey colour because the sample panel approved by us was the light grey colour. However, we would have accepted the dark grey colour in lieu of the light grey for the whole roof. What we do not accept is the light and dark colours appearing together on same elevation of our new building".

2. The colour required was correctly and timely communicated to the subcontractor.

3. The subcontractor placed order for the right colour.

4. The order placed with steel producer was for the specified colour.

5. The steel producer supplied material (coil) of the right colour to the supplier.

6. Supplier mistakenly used material from two different batches.

7. The supplier accepted responsibility for the fault and fully prepared to renew all top sheets to North and West elevations and re-use light sheets to ensure that South and East elevations are consistently light. All dark sheets were removed.
E.4.5 Disagreements between all parties

None.

E.4.5 How the colour variation could have been avoided

Bearing in mind that the material was delivered direct to site by the supplier, there was very little the subcontractor and the contractor could have done to stop the problem from the source. Work visit by either the contractor or the subcontractor's representative would not have stopped or identified the problem at the source (i.e. the supplier's yard). The sizes of the sheets and the restriction on site (i.e. very limited access and space on site) do not permit inspection of the sheets to be carried out before erection started. Even if such inspection was carried out, the colour variation would not have been seen. The Design and Construction Manager pointed out:

"This type of problem can be avoided, if we carry out planned inspection of work done regularly. The inspection ought to be carried out at least twice in a day. If we have done that, we would have been able to stopped further erection of the wrong colour. Despite the fact that I wanted the building to be water-tight as soon as possible, I could have instructed the subcontractor to cover the whole roof with the base lining sheet while we wait for the right colour for the top site."

The subcontractor's proposed action to avoid re-occurrence of the problem as described by the firm's contract supervisor is as follows:

"We will prepare a checklist to be used on our projects. The checklist will comprise all items that could affect the final quality of our works. Various inspections will be carried out by our erectors as highlighted in the checklist. The checklist will be signed by our Contract Supervisor after his own inspections. The checklist will have a column for the main contractor's inspection. The inspections will be planned in accordance with
our works programme. Should we have done these on this project, we would have been able to stop erection within few days; because our planned inspection would have enabled us to identify the variation in the colour of the top sheet when it first happened".
CASE STUDY NO 3

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F.1 CASE STUDY NO.3

F.1.1 Project description

The project comprises a 258 bedroom extension to an existing hotel owned by a private sector client at London Heathrow Airport. The works comprises: minor demolition works including breaking up existing slabs, site clearance, linking the extension with the existing building, a five storey reinforced concrete framed building, bedroom block extension, fully air-conditioned and fitted out to a four stair "plus" standard, together with associated external works including new canopy structures and car parking area.

F.1.2 Client

The client is one of the leading companies in the UK hotel business. The client has 2 hotels at the Heathrow Airport. It was one of these two hotels that was been extended to cope with the demands of the 90's and beyond.

The client is a regular customer of the building industry. The company was able to develop the brief for the project in-house with inputs from it directly employed building professionals.

F.1.3 Design phase

The overall design and the specification for the project was virtually completed before tenders were invited. Of the various elements that make up the project, only the following were fully designed by the clients consultants: drainage, in-situ
concrete, mechanical and electrical services. However, the M&E contractors produce their own installation drawings.

Only outline drawings and material specifications were issued for the remaining elements, for example, precast concrete stair dimensions and reinforcement sizes were given by the structural engineer but no reinforcement schedules were given. The contractor has to produce his own reinforcement schedules. The schedules were required to order the required reinforcements and for the precast concrete subcontractors use.

**F.1.4 Contract details**

- **Contract sum at tender stage:** £14 million
- **Contract sum at handover:** £14.30 million
- **Contractor selection:** selective tendering
- **Form of contract:** The Articles of Agreement and conditions of contract were those issued by the Association of Consultant Architects and described as the "ACA form of building agreement 1982" 2nd edition 1984.
- **Construction start date:** 24th July 1989
- **Contract duration:** 59 weeks (ie for handover in September 1990)
- **Time overrun:** None

**F.1.5 Client representatives**

- **Architects:** Private consultant
- **Structural/Services Engineers:** private consultants
- **Clerk of works:** private consultant
- **Quantity Surveyors:** private consultant
F.1.6 Contractor

Area of business: As case study no.2
Size: As case study no.2
Turnover: As case study no.2
Head office: As case study no.2
Subcontractor/supplier selection: As case study no.2
Presence in the project area before contract: none
Contract(s) won in the project area during construction: none
Contract(s) after the project: one

F.1.7 Contractor's organisational structure

The chart in figure F.1 shows the contractor's organisation structure for the project.

F.2 IN-SITU CONCRETE/LARGE PRE-CAST CONCRETE

The affected operation was the structural reinforced concrete slab and walls. Construction of the operation was carried out between September 1989 and January 1990. Fault became known between the same period.
Figure F.1: Contractor's Organisational Structure
F.2.1 Selection of subcontractor

The following played a great part in the selection of the subcontractors for the superstructure in-situ concrete frame:

- Time - tight programme
- Method of construction
- Type of formwork
- Competence in the use of the chosen formwork

The contract duration makes the superstructure more critical in completing the project on time. This operation was the key to achieving the contract date. Therefore, the contractor decided to use a method of construction that could speed up the operation. The method of constructing the in-situ concrete frame (walls, columns, beams and slabs) dictate the type of formwork that could be used.

Being a five storey building with identical floors, a proprietary formwork that could be used on a repetitive job was chosen. The number of subcontractors that could use the chosen formwork were very limited (about 5 subcontractors in the whole of UK). The five subcontractors were invited (separate ie, each one at a time) for pre-tender interview with the contractor. References were obtained on the 5 potential subcontractors. After careful consideration of the results of the interviews and the references, 3 out of the 5 potential subcontractors were invited to submit quotations for the operation.

One of the 3 was finally selected. The price of the selected subcontractor was the 2nd highest. The references obtained on the subcontractor was the best. Also, the formwork manufacturer recommended the selected subcontractor. And more
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**Figure F.2 Variation in Slab Level**
importantly, the subcontractor was ready and willing to work to tight programme
that was required to carry out the works, so that follow-on operations could be
started as programmed for ultimate completion of the project on programme.

"The subcontractor is to be responsible for all setting out, lining and plumbing, from
the basic information provided by the contractor, i.e., grid lines and datums only.
The subcontractor shall be entirely responsible for the correctness of all the setting
out and dimensional accuracy, in relation to the subcontract".

It is the responsibility of the sub-contractor to ensure that the formwork is
adequately constructed so as to achieve the tolerances, concrete surface finish and
other requirements stated within the specification clauses. The contractor will
require the opportunity to inspect all formwork prior to the concrete being placed.
This check will not absolve the sub-contractor from any of his responsibilities".

F.2.2 The quality problem

1. In-situ concrete slab fall outside specified tolerance. A level survey of the
level 2 concrete floor slab show that several areas of the slab fall outside the
tolerance laid down in the specification. Being a finished floor, the specified
tolerance was ± 6mm. The survey of the slab is shown on Figure F.2.

As it could be seen, there were several areas of the slab which falls outside
the ± 6mm tolerance laid down in the specification.

2. Reinforced concrete (R.C.) walls were outside the specified positional
tolerance. Of the 72 no. survey readings taken on 25/9/90, 26 No. R.C. walls
were found to be outside the positional tolerance of ± 5mm specified.
Therefore, the safety factors of such walls would be reduced.
3. Large variation in R.C. wall thickness. The figures found on site were: 158mm, 165mm, 161mm, 177mm - Noting that these walls were designed to be 150mm thick. One R.C. wall was found to range from 175mm thick at the top to 225mm at the bottom. A wall was cast as 150mm instead of a 175mm thick wall (this had to be knocked down).

4. Apart from the above mentioned faults, many R.C. walls, and kickers were broken out and recast - (time and money wasted).

Among others, the above defective works would affect the following on trades such as:

a) plastering/rendering thickness could be too much in some locations and less than specified thickness in other locations.

b) Suspended ceiling grid would be affected. This could lead into an unsightly ceiling layout.

c) Room sizes would be adversely affected with a knock-on effect on room layout.

d) Preformed and off-site fabricated items would not fit. A typical example, was the pre-made toilet/bathroom pots for the whole project which were made in Sweden.

e) Time and money would be wasted in trying to sort out other finishing trades.
F.2.3 What went wrong

F.2.3.1 Method Statements

There was a requirement in the specification for the contractor to submit for approval his methods of dimensional setting out, construction and checking of concrete members.

While the contractor was responsible for setting out grid lines and datums (as per subcontract document) the subcontractor became responsible for setting out and accurately, positioning formworks, shuttering and reinforcements. This was a critical role been delegated by the contractor to the sub-contractor.

In the method statement submitted by the contractor for the whole project, there was a section on setting out and checking. The subcontractor also submitted a method statement for carrying out the in-situ concreting. No official record to confirm whether approvals were given to both method statements by the architect. As long as there was no query from the architect, the contractor assumed the method statements were approved. None of the two method statements stated clearly the procedures for dimensional setting out, and checking of the in-situ concrete. However, the subcontractors method statement stated how the in-situ concrete are to be constructed in terms of type of formwork, shuttering, propping and curing.

F.2.3.2 Setting-out engineers

The contractors organisational chart shown in Figure F.1 indicated that there were ten setting out engineers on site working directly for the contractor when the above
defective works were carried out. According to the subcontract clauses, these engineers were to set out grid lines and datums for the subcontractor. In the other hand, the subcontractor has only one man to perform the role of a setting out engineer. This same person was responsible for the following:

- setting out formwork, shuttering and reinforcements
- allocating works and supervising the following trades:
  - steel fixers
  - carpenters
  - concrete gang
  - labourers
- order/call off materials
- clerical works such as
  - record keeping
  - completing time sheet for his men
  - writing letters and confirmation of verbal instructions
- attending site meeting with the contractor.

For the size of the project and the tight programme, the role of the subcontractors supervisor should have been performed by three or four men with setting out background. The supervisor have no sound setting out background.
F.2.3.3 Setting out Formwork, Shuttering and Reinforcement

On the 28th September 1989, the contractor wrote to the subcontractor regarding the 26 no, R.C. walls found to be outside the positional tolerance. In a reply to the letter, the subcontractor stated that the tolerance specified was exceeded in only 15 cases of the 72 readings in the survey and not 26 as alleged by the contractor. He also attributed the fault to both his men and the contractor engineers. He did not propose any immediate remedial action but suggested that the contractor should wait until all first fix trades are completed to the affected areas before ascertaining what "if any" remedial work is necessary to meet the satisfaction of the architect.

The subcontractors supervisor stated that reinforcement and formwork were set out by his steel fixers and carpenters in conjunction with the contractors engineers. Despite the fact that the subcontract documents clearly defined setting out responsibilities, in practice it does not work. The reason being that the subcontractor has not got any capable person to carry out its contractual role of setting out and lining reinforcements and formworks. In response to this, the subcontractors supervisor has this to say:

"we rely on the contractors setting out engineers to set out accurately the grid lines and datums for our steel fixers and carpenters to fix their reinforcement and erect formworks respectively. And for the engineers to check our works before we pour concrete".

F.2.3.4 Setting out Equipment

Latest setting out equipment were used on the project, therefore, inaccuracies cannot be attributed to equipment said the senior setting out engineer.
F.2.3.5 Supervision

It was noted that formwork to beams and slabs were struck too soon than the stipulated period stated on the structural engineers drawings. A survey of the slab soffit shows a considerable drop in the concrete. This would affect mechanical and electrical installations because ceiling void would have been reduced. Also floor finishings above would be affected.

On the 6th October 1989, the Resident Architect sent a memo to the contractor regarding - concrete being placed prior to the completion of reinforcements. This showed lack of adequate control/supervision by the subcontractors supervisor and the contractors team. This lack of control/supervision was reiterated by the clients representatives in the October site progress meeting. The minute of site progress meeting of the 11/10/89 contained the following sentences in the quality control section:

"Structural engineers and architects were very concerned that there was not adequate supervision of the groundworks and frame subcontractors by the contractor, particularly placing of reinforcement and concrete casing. The structural engineers table a list of points, some of which needed serious remedial work. A special effort was needed to get the right quality".

F.2.3.6 Protection

On the 1st December 1989, the Resident Architect issued the following instruction to the contractor - "Break out and recast all kickers poured on 30/11/89. The very minimal protection given was insufficient to withstand temperatures -5°C and subsequently this concrete has not achieved any proper degree of initial set".

Query sheet No.53951 issued on the 6/10/89 by the Resident Engineer stated that
no protection/curing was applied to concrete as stated in the contractors method statement and the specification.

From the above indepth investigation, it could be concluded that the defective works occur due to the following:

1. Lack of competent setting out engineer employed by the frame subcontractor.
2. The role of the frame subcontractors supervisor was too much that there was no time left for him to carry out proper inspection and checking of reinforcement and formworks.
3. Contractor delegated setting out and lining responsibilities to a sub-contractor that was not capable of doing it.
4. Having delegated a critical part of getting the concrete right first time to the sub-contractor, the contractor did not back it up with proper and adequate supervision by its own staff.
5. Being a fast track project (£14M in 59 weeks), time was not at the side of the contractor and its subcontractors. To this effect, there were instances when operatives (steel fixers, carpenters and concreting gangs) worked for 15½ hours per day with only three ½ hour breaks in between. Site normally opened 7.30am and closed 11.00pm. This happened during the months of September-January. Though quantity were achieved but this long hour working by the same operatives did not help the quality of the works.
6. Newly poured concrete was not properly protected against freezing temperature.
7. Some of our engineers were no good said the contractors project manager.
F.2.4 Agreement between all parties

The points raised under the heading "what went wrong" were unanimously agreed to by all parties involved in the structural frame of the project.

F.2.5 Disagreement

None

F.2.6 How it could have been avoided

1. All starter bars should have been checked before and after concrete pours and prior to kicker construction so that any discrepancies can be dealt with before the kickers are cast. (This was contained in a memo from the Resident structural engineer to the contractor as a means of improving the appalling quality of concrete works on site).

2. Setting out of reinforcement and formwork should not have been delegated to a sub-contractor who cannot provide experienced setting out engineers to perform the role.

3. The sub-contractor should have been asked at the time of submitting quotation for the job to include an identified sum of money for setting out. A clause should have been included in the subcontract that payment of the setting out money would only be made where the subcontractor employed a competent setting out engineer(s) for the works.

4. The contractor should have ensured that adequate protection/curing of concrete was carried out as per specification and method statements.

5. Effective use of the contractors ten setting out engineers and three section managers could have avoided the occurrence and re-occurrence of the defective works.
6. The sub-contractor should have employed more working supervisors. They are more appropriate than contractors section managers. However, they are not supplementary to them but complementary.

7. At the critical stages of the project, the contractor should have considered two shifts of working periods. This would have reduced unnecessary stress from the operatives and supervision staff which would have led to reduction in defective works.

F.3 IN-SITU CONCRETE/LARGE PRE-CAST CONCRETE

The affected operation in this case was the fixing of reinforcement mesh in the plant room concrete slab. The work was carried out in January 1990 and the fault became known shortly after. The affected area was approximately 105m².

F.3.1 Selection of subcontractor

As F.2.1

F.3.2 The quality problem

It was found that wrong reinforcement steel was used in casting part of plant room concrete floor slab. That is, bottom layer of mesh to level 6 concrete floor slab was put in as A193 and not as B385. The significant affect of the faulty work is that the affected floor area could no longer receive the designed future loads.

F.3.3 What went wrong

The building comprises 6 floors. Ground floor to/and including the fourth floor are accommodation levels, while the fifth floor is the plant room. The loading
requirements for the accommodation floors were the same. Therefore, the
type/sizes of reinforcements for the suspended R.C. slab for the accommodation
levels were the same. The loading requirements for the fifth floor, been a plant
room differ from the accommodation floors. Therefore, the type/sizes of
reinforcement for this floor differ from those designed and ordered for the
accommodation floors.

The contractor was responsible for ordering all reinforcements. The correct
type/sizes of reinforcement were ordered and delivered to site on time for the R.C.
slabs including the plant room slab. The reinforcement was delivered to site one
week before fixing on level 6 was due to commence (this was confirmed by the
'delivery record book' kept on site by the resources manager.

The method statement submitted by the sub-contractor did not state how correct
reinforcements are to be identified from stock and placed into the works. The fault
was brought to the attention of the Structural Engineer by the contractor. The
structural engineer confirmed that the reinforcements used were adequate to carry
the present plant loads but not adequate for the anticipated future development.
The design of the plant room has taken into account future development that would
require heavier plants to be installed. In view of the advanced stage of the project,
the client do not want the slab to be taken down. The remedial action proposed by
the structural engineer was for the contractor to provide spreader beams left loose
in the affected floor areas for future use. These were provided by the contractor.

On the 16th October 1989, the contractor wrote a letter to the subcontractor
regarding breaches of safety regulations. A sentence in the letter read "loose
materials not stacked but scattered all around the slab". On the 4th December 1989,
the contractor wrote again to the subcontractor. The second paragraph of the letter
read:
"It is your responsibility to ensure that all reinforcements are stored in responsible/methodical manner to suit the agreed pouring sequences and in suitable positions for the location of the work. At present there is reinforcement scattered all over the site".

The fact that wrong reinforcement has been used was picked up by the contractors senior project engineer during one of his routine checks. But it was too late as concrete has been poured.

The structural engineers drawings showed the reinforcement layout for accommodation suspended R.C. slabs. All previous R.C. slabs (ie levels 2 to 5) were constructed to the reinforcement shown on drawing No. A 193. Structural engineers drawing No.B385 showed the reinforcement type/sizes and layout for the plant room R.C. slab. Two copies of the drawings together with two copies of reinforcement schedules for the slabs were issued to the subcontractor. "We are in possession of all the necessary drawings and schedules" said the subcontractors supervisor.

The first suspended floor slab (ie level 2) was cast in September 1989. The plant room slab was cast in January 1990. The subcontractors supervisor said "Having cast four different levels of suspended R.C. slabs in the past five months and using the same type/sizes of reinforcement, when it came to casting the fifth suspended slab, we forgot that the reinforcement for the slab differ from the accommodation floors. It was a mistake on my part. I should have checked the drawings before my steel fixers started fixing the reinforcement. We were pleased not to be instructed to pull it down".

When pressed to admit the fact that reinforcement scattered on site could have led to using wrong reinforcement in the plant room, the sub-contractors supervisor has
this to say - "No, if we had looked at the drawings we would have found the right reinforcement somewhere on site. You know, this was the only situation where we used the wrong reinforcement".

F.3.4 Agreement between all parties

1. Subcontractor was in possession of all relevant drawings.
2. The appropriate reinforcements were available on site.
3. Reinforcements were not stacked in the order in which they were to be used. They were scattered on site.
4. The sub-contractor operatives did not consult the relevant drawings before fixing reinforcement, despite the fact that the drawings were issued to them by the contractor.
5. Control and supervision by the subcontractors supervisor was not adequate.

F.3.5 Disagreement between all parties

None

F.3.6 How it could have been avoided

1. Reinforcements should have been stacked by the sub-contractor in an orderly manner and not scattered on site.
2. Having stacked reinforcement in an orderly manner, stock control was required by a competent person such as one suggested in the subcontract documents. He should check drawings with work to be carried out to ensure that reinforcements taken out of stock were used in the proper place.
3. The contractor staff should have checked the reinforcement before concrete was poured.
4. The sub-contractors supervisor should have checked that the steel fixers were always using drawings. He should have checked the steel with the proper drawings before concrete was poured.

5. Labelling of reinforcement by the suppliers required attention. At present, reinforcements were being delivered to site with paper label identifying schedule/drawing nos. These paper labels can not withstand site environment. Therefore, a more durable material such as plastic or the paper labels to be enclosed in a visible plastic is required. Some of the present labels would have teared off even before the steel arrived on site. This made it more difficult to identify each type/sizes of steel for specified locations.

6. The sub-contractors method statement should have stated clearly how correct reinforcements would be identified from stock.

F.4 MASONRY - Brickwork

The affected operation was the brickwork/blockwork with various faults as outlined in section F.4.3. The operation was carried out between December 1989 and April 1990. Faults became known between January 1990 and April 1990.

F.4.1 Selection of subcontractor

Four subcontractors were invited to submit quotation for the brickwork/blockwork on the project.

The four had worked previously for the contractor on other building projects. One of the four was selected. The subcontractor selected had just completed the brickwork/blockwork on a large office block for the contractor. The contractor (and hopefully the client) were satisfied with the subcontractors performance on the
recently completed office block.

The subcontractor was therefore, selected on the basis of:

1. The previous performance on other projects for the contractors.
2. The subcontractors ability to resource (personnel),the job to achieved the contractors programme.

The price submitted by the selected subcontractors was not the lowest out of the four quotations received by the contractor.

An extract from the subcontract document is as follows:

"The subcontractor is responsible for protection of the works with polythene and will be required to clean down completed works to the main contractors satisfaction, until the handover has been agreed in writing by the main contractor".

F.4.2 The quality problems

1. Efflorescence and staining on external brickwork
2. Damp proof courses not properly positioned - water penetration and dampness.
3. Mortar dropping (bridging the cavity) - cold bridge and water penetration (dampness).
4. Rockwool insulation tie clips not properly positioned - reduction in thermal performance of the walls.
5. Bad workmanship and tolerances - aesthetic, reduction in thermal performance of the walls, water penetration and dampness.
F.4.3 WHAT WENT WRONG

F.4.3.1 Efflorescence and staining on brickwork

1. Selection of Brick by the Architect

When the type of brick to be used on the project was selected by the Architect, the Contractor brought it to the Architect's attention the possibility of efflorescence occurring on the bricks. The contractor have experienced great difficulties with occurrence of efflorescence on other projects where the same type of brick selected for this project was used.

Despite this warning by the contractor, the Architect insisted that the selected brick shall be used on the project.

Correspondence

Brickwork construction started on 18 December 1989. On the 8 January 1990, the Resident Architect issued a memo to the contractor warning him of the potential problem of efflorescence. He also outline some of the actions required to avoid efflorescence generally on the facing brickwork.

On the 10 January 1990, there was a meeting on site between the Architect, Contractor and Brick Supplier to discuss the problem of efflorescence and variation in size of bricks. In the meeting, the brick manufacturer highlighted guidelines regarding efflorescence with emphasis on keeping the bricks as dry as possible in accordance with the building codes of good practice. It was also confirmed that the bricks stored at works have been covered and will be delivered shrinkwrapped.
The minutes of site progress meetings between the client, consultants and the contractor always contained a section for quality control. The section on quality control in the minutes of site progress meeting of 31 January 1990 contained the following sentences:

"It was noted that the bricks contain soluble salts which would appear on the face as efflorescence. This was temporary and not harmful. Every action possible was being taken to minimise it. The contractor had a new General foreman to supervise brickwork. Architect asked that more care should be taken to clear cavities".

Below is a memo sent to the contractor by the resident Architect on the 19 February 1990.

RE: FACING BRICKWORK QUALITY

"In spite of numerous verbal requests and subsequent instructions the top of cavity walls are not always protected. Practically all window sills on LvLs, 1, 2, 3 of south side of block one were left unprotected for over the week 17 - 18 of February during which period there were several spells of rain. As a result there was heavy staining caused by water ingress on the inside face of block walls and heavy efflorescence on the outside brick face generally.

Please instruct your subcontractor to maintain the required degree of protection of brick cavity walls at all times. In addition, please ensure that your own supervisory staff exercise their control continually and effectively over the bricklayer subcontractor to avoid the above or any other negligences to happen in the future. The R.A's office regularly make photographs to record and monitor quality and progress".

As a follow-up, the contractor forwarded the memo to the subcontractor with a cover letter re-emphasising the fact that protection of all the brickwork was the responsibility of the subcontractor.
Once again, on the 20 February 1990, the Resident Architect sent a memo to the contractor. The content of the memo is as follows:

**RE - BRICKWORK QUALITY**

"Following our repeated request to protect all exposed, horizontal surfaces of brickwork including window sills we have another quality control item to bring to your attention: On our inspection today - south side block 1, it was apparent that large areas of brickworks under window sills had severe staining. Apparently from water collected inside poured over the window sills. This excessive amount of water once it saturated, not only the bricks bringing out efflorescence but the lime as well from the mortar. This later one could cause a permanent staining. Therefore your urgent/ immediate investigation and treatment/remedying is requested".

Architect Instruction No. 140 was issued on 9 March 1990, instructing the contractor to carry out treatment of the efflorescence and staining on the affected area by adopting the brick manufacturer's recommendations.

**F.4.4.2 Why efflorescence and staining appeared on the brickwork**

As stated in the brick manufacturer's technical notes, three conditions are required to produce efflorescence:

1. Water soluble salts have to be present.
2. Water must be present in sufficient quantity and for sufficient time to dissolve these salts.
3. The form of construction must allow the salts bearing solution to reach the surface.

These three conditions must be present before efflorescence can occur.

The three conditions were allowed to be present in the following ways:
1. The investigation revealed the fact that soluble salts were present in the bricks used on the project. Hence, bricks had contributed to the cause of the efflorescence.

2. Water was present (possibly) in sufficient quantity and for sufficient time to dissolve the salts in the bricks. Water was able to get into the brickwork as a result of lack of/or inadequate protection of the brickwork during construction. This was purely the fault of the Brickwork sub-contractor.

The affected part of the building was built between December 1989 and April 1990 during which there was rain and severe wind in the southern part of England.

3. The form of construction was the external perimeter of the building with small eaves. The detail allowed the water soluble salts in solution to be brought to the surface of the brickwork and were deposited these by evaporation. Therefore, design has contributed to the efflorescence problem.

Also, from the brick manufacturer's Technical notes, one of the most common causes of cementitious stains is lime leaching from mortar joints and weep holes. The mortar used on the project contained lime.

From an independent technical expert's point of view, it was the presence of water in sufficient quantity due to lack of or inadequate protection of the brickwork during construction that causes the efflorescence. Especially non protection of horizontal surfaces as recorded in the correspondent's from the Resident Architect to the Contractor. The selection of the brick was made after the contract had been awarded to the contractor. The contractor's estimator only allowed in his price for
standard protection of brickwork during construction.

Despite the fact that the Brickwork sub-contractor was aware of the type of brick to be used, he did not allowed in his price for protection of the brickwork than what is normally the general practice. The investigation revealed that the minimum protection allowed for by the sub-contractor in his price was never carried out adequately and efficiently on site.

The tender enquiries sent to the sub-contractor did not call for price to be included for brickwork protection than what could be reasonably assumed by the subcontractors.

F.4.4 Agreements between all parties

1. The bricks contained water soluble salt.
2. Lack/inadequate protection of the brickwork worsen the efflorescence and staining problem.
3. The construction detail was a contributory factor to the problem of efflorescence.

F.4.5 Disagreement between all parties

While the contractor accepted the fact that more protection of the brickwork should had been carried out, the contractor's team did not accept the fact that the efflorescence and staining on the brickwork were mainly caused by the lack of protection. In the contractor's project manager point of view, the bricks contained too much (above average) water soluble salts that could cause efflorescence from driven rain after the building had been handed over. This could be proved or disproved in few years time if other areas not affected at present developed
F.4.6 How the efflorescence and staining could have been avoided

1. For the type of prestigious building, bricks containing high content of water soluble salts should not have been used.

2. From the contractor's experience of the type of brick, additional money should have been requested from the client through the Architect to provide proper and more effective protection of the brickwork during construction. The contractor's project manager believed that, if they have put in claims for additional money to cater for the protection, there would have been a lot of talking between the respective Q.S's but there is no harm in trying.

3. Item 2 above also apply to the subcontractor. That is the subcontractor should have applied to the contractor for additional money to provide effective protection to the brickwork. Not to had allowed for the necessary protection was not a tenable excuse that unacceptable work has to be carried out.

4. When both the contractor and the sub-contractor did not actually applied for additional money for the required protection, it implied that they have allowed in their prices to cover the required protection. And this should have been carried out satisfactorily to reduce (if not eliminate) the efflorescence.

5. The Contractor's Brickwork General foreman and other section Managers should had won the cooperation of the bricklayers and the labourers so that they could be motivated to protect the work every time.
6. Stacks of bricks should had been properly covered. They should had been stacked off ground on pallets not to allow it to be buried in mud.

F.4.7 Damp proof courses not properly positioned

On the 27 February 1990, it was noted by the visiting Architect that vertical and horizontal damp proof courses (DPC) at bottom corners of windows were not overlapping in some cases. One was found to be on the wrong side.

The Contractor and its sub-contractor attributed the non-overlapping of the dpc to poor details. It must be noted that the contract documents stated that the contractor should provide necessary details to supplement those issued by the client's Architects. Therefore, it could be concluded that the excuse given by the contractor was not invalid.

F.4.8 Mortar dropping

During a site inspection on the 1 February 1990 by the Resident Architect, he found that the cavities of the level 1 brickwork were filled with mortar droplets and debris from the blockwork above.

Again during a site inspection by the visiting Architect on the 27 February 1990, he found lumps of mortar bridging cavity of brickwork at various locations in the building.

The mortar dropping into brickwork cavities was unanimously attributed by all parties to:

1. Bad workmanship by the bricklayers.
2. Lack of adequate care by the bricklayers
3. Cavities were not protected during brickwork/blockwork construction by using cavity battens (cavity battens were not provided neither by the sub-contractor or the contractor for the bricklayers to use).

F.4.9 Rockwool insulation tie clips not properly positioned

At a site visit on the 23rd February 1990, the visiting Architect noted that the positioning and securing of rockwool insulation material in the brickwork cavity on block 1 (south) of levels 4 and 7 was sub-standard. At level 4 where bricks were been laid, the rockwood was in poor condition. The edges of the rockwool were broken and could not be held by the tie clips. Consequently, the rockwool was sagging and catching mortar droppings. "It appears that the rockwool had not been fixed in accordance with the specification", noted the visiting Architect.

On the 27th February 1990, when the same visiting Architect visited site, he found rockwool not held by tie clips and sagging in various locations in the building. He also found tie clips been spaced 1m horizontal (the requirement in the specification was for maximum of 600 mm horizontally). He found some tie clips missing altogether.

F.4.10 Bad workmanship and tolerances

During the site visit on the 27th February 1990, the visiting Architect recorded the following faults:

1. 100mm empty gap of top of insulation which leave the area uninsulated.
2. Cavities in brickwork varies from 80 mm to 100 mm wide These was above the limit for wire ties specified for the required 75 mm wide cavity. Also this
would affect bearing of bricks upon lintel supports (2/3 of brick width should be supported).

3. Cavities were found not closed at side of openings as shown on Architect drawings. These would lead to water penetration into the completed building.

4. On the 1 March 1990, the Resident Architect had this to say:
"On inspection of Stainless Steel lintels installed on block 1, the distance between the face of brick and the edge of stainless steel angle is irregular and therefore unsightly. The distance should be uniform and parallel".

5. Brickwork was found to be outside the specified tolerance. This was more obvious at the junction of brickwork and enamel panels. It makes it very difficult to fix the enamel panels. Some would not fit the opening left for it. Time and money were wasted in having to re-fabricate other panels to fit the brickwork built outside specified tolerance. It was later found that the wind posts (dummy fixing rail) were not positioned accurately by the contractor's engineers.

The subcontractor foremen and the contractor's team attributed the faults above to lack of care and bad workmanship by the bricklayers.

F.4.11 Agreements

1. Insufficient details of dpc were issued by the contractor to the subcontractor.

2. Inaccurate setting out and positioning of wind posts had contributed to the problem faced with the junctions of brickwork/enamel panels.

3. Cavity batten is a necessary tool to stop mortar getting into brickwork cavities. The subcontractor should have provided it.
F.4.12 Disagreements between all parties

1. While some of the bricklayers accepted bad workmanship for mortar dropping into cavities, missing and wrong positioning of insulation tie clips; variation in cavity width; and other brickwork defects, they blamed the subcontractor’s foremen on his failure to issue them with all necessary drawings. Some of the drawings issued to the subcontractor never get to the bricklayers.

2. The bricklayers also attributed defective works to:
   a) payment by result system adopted on the job.
   b) The environment in which they carried out the works.

F.4.13 How the defects could have been avoided

1. The Contractor’s Architect should have provided supplementary details for the dpc to be installed properly by the bricklayers.

2. The subcontractor’s foremen should have made drawings directly available to bricklayers.

3. If drawings were made available to bricklayers, efforts would also be required by the foremen to ensure that the drawings were used.

4. Standard/buildable details that could be easily understood by an average bricklayer should have been issued for construction.
5. Timber cavity battens should have been made available to the bricklayers to protect brickwork cavities from mortar droppings. If battens were provided, the foremen should had ensures that the bricklayers used them efficiently at all times.

6. Setting out and positioning of wind post should had been carried out accurately by the Contractor's Engineers.

7. The causes of lack of care by bricklayers (and other tradesmen) which often preceed bad workmanship should be greatly considered more objectively by everyone in the industry.

F.5 MASONRY - mortar

The affected operation was the sand and cement mortar for the brickwork/blockwork on the project.

F.5.1 Selection of subcontractor

As F.4.1

F.5.2 The problem (defect)

Compression strength of mortar were found to be far below the specified standard:

1. The mortar cube test certificate M18/ABC of 6 April 1990 showed 0.2 - 0.25 N/mm² 7 day compression strength.
2. The mortar cube test certificate M19 failed the 28 day compression test. The three cubes tested had an average compression strength of 1.7 N/mm\(^2\) rather than 2.5 N/mm\(^2\) as required by the specification. (i.e. BS 5628).

The defects that could result from the above, as stated by the Structural Engineers are:

a) Since the mortar has not reached the specified strength in compression, which indicate a reduced flexural strength, important for resisting wind loads on the brickwork panel.

and more importantly

b) A chemical analysis of mortar cubes M18 indicates a lack of cement in the mortar which will result in a reduced durability and deterioration, suggesting a long term maintenance liability in the aggressive atmosphere adjacent to Heathrow Airport.

F.5.3 What went wrong

F.5.3.1. Material Supply

Wall type F24/1, 2 and 3 were facing brick walls. Group 3 mortar was specified for these types of walls. The mortar selected in the group was option 2. That is, 1 part of cement to 5-6 parts of premixed lime and sand. The proportion of lime to sand being 1:6. The lime and sand were mixed off site and delivered to site in 8 tonne skips. The use of mortar skips, reduces the risk of premixed stuff been contaminated by mud and others. Each skip of the premixed lime and sand were used within seven working days.
Cement was delivered to site in 50 kg bags. They were delivered to site in approximately 10 tonnes on 1 tonne per pallet. The cement were normally used within four weeks of it been delivered to site. Each bag of cement used on the project carried BS No.12 mark. Both the cement and the premixed lime and sand were supplied by the Brickwork Subcontractor.

**F.5.3.2 Protection of materials**

Good practice and BS 8000: part 3 required the premixed lime and sand skips to be normally covered with tarpaulin or polyethylene against rain, snow, excessive drying out, wetting and loss of fine particles of lime and pigments. On the project, there were instances when the skips were not covered. This could had resulted in the premixed stuff to be affected by any/or all of the above adverse conditions. The cement were not stored under cover in a dry conditions as recommended by BS 8000: part 3. They were left on pallets in the open area on site. This is not unusual, however, good practice required the cement to be protected from elements by covering it with water resistance materials such as polyethylene. This method of protection were used but none of the men interviewed could denied the possibility that there could not had been instances when the cement were not covered.

**F.5.3.3 Mixing of Mortar (Batching)**

The Brickwork subcontractor was responsible for mixing the mortar. Concrete mixers were used for mixing the mortar. The sub-contractor assigned one of his labourers to carry out the role of mixing the mortar. The particular labourer had performed this same role for the subcontractor on other projects for over five years.
The sub-contractor’s foremen and the labourer could not say whether they had worked on other building projects where mortar was subjected to regular testing as it happen on this project. The specification do not state specifically how materials were to be batched. The method adopted was to gauge the material by volume using shovel or Timber Gauge Boxes.

F.5.3.4. Sample for Testing

Mortar samples were taken at random to make cubes for compressive test. The mortar samples were taken by the contractor and the cubes made from the samples were subsequently sent to independent testing authority as required by the specification.

F.5.3.5 Test results

The results of the tests were submitted by the contractor to the client’s structural engineers. The Mortar Cube Test Certificate M18/ABC of 6 April 1990 showed 0.2 - 0.25 N/mm² strength; which is far below the expected standard 7 day strength of 1.7 N/mm². A chemical analysis of mortar from cubes M18/ABC indicated a lack of cement in the mortar. A similar chemical analysis carried out from mortar cubes M19 also indicated lack of cement.

The content of a letter written by the contractor on the 5 April 1990 to the Brickwork Subcontractor are:

"We have recently received a test result on the black mortar taken on the morning of 26 February 1990. The 28 day cube result reached 19 N/mm² which is 8 times the required strength. We would ask you to review your batching methods so that this does not occur again".

From the above investigation, the defective mortar could be attributed to:

F-34
1. Possible use of contaminated cement
2. Batching method
3. Human error

1) **Contaminated Cement**

To achieve the specified mortar strength, cement that had 'gone off' or contaminated should not be used. It is most likely that the cement used for the mortar had 'gone off' or contaminated. This was never proved because samples of the cement used were not taken for chemical analysis. (This should have happen anyway). However, this was a possibility because the cement were not stored in a dry, weatherproof, frost-free, enclosed shed or building with a dry floor as recommended by BS 8000: part 3 1989. Also, bags of cement were not stacked so that consignments can be used in order of delivery.

When asked if the labourer often checked cement for deterioration, his response was negative. Therefore, lumpy cement might had been used.

2) **Batching Method**

Batchings on site were done manually by volume. The contractor provided Gauge Boxes for this purpose. Instead of using the Gauge Boxes all the time, the Labourer chosen to shovell the premixed lime and sand from the skip into the mixer and adding cement direct from its bags. These procedures happened in approximately 75% of the batching period.

Despite the fact that the specification do not state specifically the batching method(s), good practice required batching to be carried out under a proper control
by volume using Gauge Boxes or mechanically by weight.

In order to achieve the specified mortar strength a proper control of batching method was required. As it could be seen, neither of the above batching methods were properly used, hence, achieving the specified strength was left to chance. Therefore, the probability that the proportion of cement added to the premixed lime and sand shovelled into the mixer by the Labourer was less than the specified ratio was very high.

3) Human Error

In February 1990, the result of a 28 day mortar cube test reached 19N/mm² instead of 2.5 N/mm². The most obvious reason for that there was - 'too much cement in the batch'.

In March 1990, mortar cube test failed the 7 day compressive test and in April 1990, another cube test failed the 28 day compressive test. The chemical analysis of mortar cubes from the March and April samples indicated a lack of cement in the mortar. Therefore, if the cement used had not 'gone off' or contaminated, then less cement or too much premixed 'lime and sand' must had erroneously been put into the batches from which samples were taken for the tests. That is to say, the proportion of cement to the premixed lime and sand does not comply with the specified 1 part of cement to 5 parts of premixed lime and grade G sand or 6 parts of premixed lime and grade S sand.

1 part of cement to 6 part of premixed lime and sand was the intended batch ratio used by the Labourer. The subcontractor foremen did not take note of the requirements in the specification which stated that 5 parts of grade G sands shall be used. They did not even know what grade of sands were been used for the mortar.
The subcontractor decided to use 1 part of cement to 6 parts of premixed lime and sand because the table in the specification called for 1 part of cement to 5-6 parts of premixed lime and sand. The subcontractor did not read the section of the specification which stated the proportion of sand to be used with a particular grade of sand.

F.5.4 Agreement between all parties

1. Cement was not properly stored.
2. Less cement must have erroneously been used.
3. Good practice of batching had not been used.
4. There had been lack of control/supervision of the batches by both contractor's team and subcontractor's foremen.

F.3.5 Disagreement between all parties

The contractor's Project Manager did not agree with the Structural Engineer that the defect could result in a long term maintenance nor would the flexural strength of the building be affected. The Project Manager's point of view was never supported by any technical or research data. However; in principle, he agreed that the specified requirement for the mortar had not been met.

F.5.6 How it could have been avoided

1. The cement should have been stored as recommended by BS 8000: part 3 1989. This would have prevented the cement from becoming lumpy (i.e. gone off) or contaminated.
2. Mixer with a loading hopper and a weight batcher mechanism should had been used. This type of mixer should had been provided and a strict instruction given to the Labourer to always use the loading hopper. This would had stopped the arbitrary loading of the mixer. Human error in counting nos of sand shovelled into the mixer would had been eliminated, thereby required proportion of cement would always had been added to each mortar mix.

If this method had been used, to achieve the specified mortar strength would not had been left to chance.

3. Each delivery ticket for the skips of premixed lime and sand should always be examined to identify the grade of sand in the mix. This is required to determine whether 5 or 6 parts of the premixed stuff is required to 1 part of cement.

4. More care should had been taken by the Labourer.

5. Both the subcontractor's men and the contractor's team should had taken proper steps to ensure that every relevant sections of the specifications were read, understood and complied with.

6. Skips of sand should had been adequately protected as recommended by BS 8000: part 3 1989.

7. More control/supervision of the Labourer by the subcontractor's foremen should had identified and stopped the arbitrary loading of the mixer.
F.6 BUILDING FABRIC SUNDRIES

The affected operation was the rockwool cavity insulation to the perimeter brickwork/blockwork walls. The affected areas (800 m²) were constructed between 15/1/90 and 28/2/90.

F.6.1 Selection of subcontractor

As F.4.1

F.6.2 The problem (defect)

Type of cavity insulation used was at variance with specification. That is, Rockwool complete fill cavity slabs were used in the perimeter brick/block walls instead of the specified Rockwool partial fill cavity slabs.

F.6.3 What went wrong

Design Criteria:

The walls comprise:-

- 100 mm thick outer skin of brickwork.
- 75 mm wide cavity with 50 mm thick insulation slab.
- 100 mm or 150 mm thick inner skin of blockwork.

50 mm thick Rockwood partial cavity fill slabs was specified to allow the insulation to be fixed in the cavity for thermal insulation and the remaining 25 mm gap to be left unobstructed for sound insulation. The type of insulation used up to 28 February 1990 was not suitable for partial cavity fill because it tend to sag which
could lead to it been drop off the blockwork into the cavity leaving the blockwork un-insulated. In the other hand, the specified partial fill Rockwool slab is stronger and it would withstand sagging. This would make it stay in place if installed with sufficient tie clips.

Information

The 'supply and fix' of the cavity insulation slabs was included in the brickwork subcontractor's package. Therefore, the subcontractor was responsible for placing the order for the material as per information issued to him by the contractor. All the relevant sections of the specifications regarding the cavity insulation were forwarded to the subcontractor as part of his subcontract documents. The subcontractor confirmed been in possessions of the necessary information to order the specified insulation.

The insulation material was mineral fibre batts to BS 6676: part 3. According to the specification, the insulation was marketed under the firm called Rockwool and the proprietary brand name by which the insulation could be identified was 'partial fill cavity slab'. The manufacturer and reference name were correct as confirmed by one of the insulation suppliers.

The subcontractor placed an order with a Rockwool Supplier. The order read 'supply 50 mm thick rockwool batts 900 mm x 600 mm'. The description in the order form did not contain the specified brand name by which the required insulation could be identified.

The insulation supplier said "for us to be able to supply the right material we require the following information"
1. The name of the firm under which the insulation is marketed;
2. proprietary brand name and/or reference by which the product could be identified;
3. size;
4. thickness;
5. quantity;
6. where possible, 'intended usage'

What happen when the reference name or intended usage are not given by a customer? This was a question the author put to the insulation supplier. He answered "we supply standard item. You know our sales staff are not technical experts. The more information a customer supply us the better".

Items 1, 3, 4 and 5 above were included in the order sent by the subcontractor to the insulation supplier. However, items 2 (critical) and 6 were not included.

The order form was written by one of the subcontractor's partners. As a response to a telephone call from one of the site foremen, the partner placed an order with a supplier over the telephone. He later sent out the order form as a confirmation of the order placed on the telephone. The partner confirmed that despite the fact that he had with him in the office a copy of the specification for the project, he did not check the specification before the telephone call. When asked why he did not check the specification before the order, the partner had this to say "well, you don't have to check specification all the time and especially when ordering materials such as rockwool batt that are commonly used by us. I don't think we would be able to make any profit on the job because this mistake of my had cost us a fortune". When the order was made over the telephone, did the supplier ask you the intended usage of the rockwool or the reference name? This was another question the author put forward to the subcontractor's partner. He has this to say - "No. Rockwool is used in
various locations in a building”. The contractor’s Project Manager said:

"It is difficult to differentiate between the partial fill cavity batt and the complete fill cavity batt. By looking at them you can not tell the difference. The only difference is when you touch them. The partial fill cavity batts are more stronger than the complete fill cavity batts".

Other members of the contractor’s team and the subcontractor’s site foremen thought the rockwool batts delivered to site were the specified type.

While the wrong insulation were being used, the contractor’s General Foreman (Brickwork) noticed sagging of the insulation batts. He therefore carried out checks of the tie clips to find out if the clips were positioned in accordance with the specification.

The general foreman found some tie clips missing but those missing were not sufficient to cause the insulation to sag as evidence on the project. The contractor therefore drew the attention of the Resident Architect to the problem (sagging of the insulation batts). The Rockwool manufacturer was invited to site to discuss the problem. It was during the site discussion between the Resident Architect, Contractor, and the Rockwool manufacturer that it became known (for the first time) that complete fill cavity slabs were being used instead of the specified partial fill cavity slabs (It was a pity that it took six weeks for this fact to be known).

REMEDIAL WORK

The contractor put forward a proposal for cavity filling where the wrong type of insulation had been installed. The proposal was to drill 16 mm diameter holes in the facing brickwork and blown RMC polybead insulation into the cavity to make it a complete fill cavity. The Contractor seek technical opinion from BRE and R & D
department of his company. The BRE and R &D department of the Contractor found the proposal technically sound and suitable. The Architect approved the proposal and the remedial work was carried out. The remaining part of the brickwork was built using the partial cavity fill insulation slabs in accordance with the specification.

**F.6.4 Agreement between all parties**

1. Subcontractor ordered wrong material.

2. Late identification of the wrong material by all parties lead to substantial quantity of the material to be used.

**F.6.5 Disagreement between all parties**

None.

**F.6.6 How it could have been avoided**

1. Specification should had been examined thoroughly before the insulation was ordered.

2. The insulation should had been checked by both the sub-contractor's foremen and more importantly by the contractor's team to ensure compliance with specification.

3. When in doubt, ask. The contractor's team should had consulted their company's R & D department for assistance in identifying the material when it was delivered to site.
4. Inspection of work carried out should include checking of specification with material used at very early stages of an operation. In this case, compliance with material specification should had been checked by the contractor's team not later than the first week of using the wrong type of insulation.

5. Item 4 above is also applicable to client's representatives especially the Architect and the clerk of works.
Dear Professor R Howes  

A Model for the Management of Quality on Building Sites - A Research Project

For the past thirty years the performance of the construction industry in this country has been the subject of much debate between professional groups within the industry and clients' organisations. Issues that gave cause for concern have often emanated from defective buildings and from the ever growing costs of building maintenance. Clients have also become more aware of the quality standards required in their commissioned buildings.

There appears to be a general consensus that there is a need to improve the performance of the industry, especially with increasing competition from firms in other advanced countries. Our perception is that quality management has an essential part to play in improving the performance and competitiveness of our industry. The production of the quality required at the first attempt is not a question of academic interest, but of vital importance to satisfy clients' needs and to ensure that each contractor can survive and remain a profitable organisation.

The Department of Construction Management has initiated and is sponsoring doctoral research aimed at investigating conformance to specified requirements which is the responsibility of the main contractor. The objective is to develop a "quality model" designed to assist construction companies to achieve their quality goals by providing them with a comprehensive framework for good practice.

A questionnaire has been designed which forms part of the study. The research is mainly concerned with the conformance to specified requirements on building sites. The specific objective of the questionnaire is to identify, with a high degree of certainty, the cause and effect of quality problems associated directly with the site production process.

To this end, we are approaching leading contractors drawn from the top 100 construction companies in this country with a request for their co-operation.
The questionnaire respondents are to be contractors' senior site representatives (eg. project manager, site agent or site managers). The value of the study would be considerably enhanced if you could provide us with the names and site addresses of several - up to six, say of your senior site representatives. This will enable us to approach them directly, and to seek their response to the questionnaires.

The questionnaire will be treated in the strictest confidence. The Department wishes to give you a clear assurance that it takes full responsibility for this aspect of the study.

Attached is a form for you to complete and return in the enclosed stamped, addressed envelope. A copy of the draft pilot questionnaire is included for your information only.

We would be grateful if the form could be returned at your earliest convenience as this will facilitate quick progress. Thank you for the courtesy of your assistance.

Yours faithfully

[Signature]

Professor R Howes
Head of Construction Management
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6. NAME: ____________________________________________
   SITE POSTER ADDRESS: ____________________________________________
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NOTE: WOULD YOU LIKE THE RESULT OF THE RESEARCH SENT TO YOUR
      GOODSELF? YES [ ] NO [ ]
APPENDIX H
Our Ref: RH/JL/AB

Date as Postmark

Dear [Name],

A Model for the Management of Quality on Building Sites - A Research Project.

The Department of Construction Management has initiated and is sponsoring research aimed at investigating the difficulties that may stand in the way of achieving conformance to specified requirements in construction projects which is the responsibility of the main contractor. The objective is to develop a "quality model" designed to assist construction companies to achieve their quality goals by providing them with a comprehensive framework for good practice.

The enclosed questionnaire forms part of the study. The research is mainly concerned with conformance to specified requirements on construction sites. The specific objective of the questionnaire is to identify, with a high degree of certainty, the cause and effect of quality problems associated directly with the site production process.

To this end, we have approached Mr. [Name] at your office, and he has given us the permission to seek your response to the questionnaire. The questionnaire will be treated in the strictest confidence. The Department wishes to give a clear assurance that it takes full responsibility for this aspect of the study.

The value of the study would be considerably enhanced if you could answer all the questions as frankly as possible. We are aware of the pressures under which you operate and the time constraints on your work, but I very much hope that you will spare a little of your time to complete the questionnaire. This would assist us greatly in the research project.

A stamped, addressed envelope is provided for the return of the questionnaire. We would be grateful if the questionnaire could be returned within a fortnight as this will facilitate early processing.

On behalf of my colleagues I would like to take this opportunity to thank you in anticipation of your assistance.

Yours sincerely,

[Name]
Project Researcher
APPENDIX I
directly with the site production process
the cause and effect of quality problems associated
The attached questionnaire is aimed at identifying

QUESTIONNAIRE

WANDSWORTH ROAD, LONDON SW8 2JZ
DEPARTMENT OF CONSTRUCTION MANAGEMENT
SOUTH BANK POLYTECHNIC
SECTION 2

2. How is important that a contractor should perceive the same quality standards as the client? 

Never [ ]
Sometimes [ ]
Often [ ]
Always [ ]

3. How often does your company make assumptions about tender documents without seeing certification from the consultant in submitting tenders?

Never [ ]
Sometimes [ ]
Often [ ]
Always [ ]

4. Allow this to happen? To which the present procurement systemsindicate the extent to which the present procurement systems

Never [ ]
Sometimes [ ]
Often [ ]
Always [ ]

5. What is your company's experience with the previous method of communication and the requirements for materials, components, and services provided?

Never [ ]
Sometimes [ ]
Often [ ]
Always [ ]

6. Has your company obtained a third party certification?

No [ ]
Yes [ ]

7. Does your company have in place a formal quality management system?

No [ ]
Yes [ ]

8. The nature of your company?

9. How long have you been working in the construction industry?

Less than 3 years [ ]
Less than 10 years [ ]
Less than 20 years [ ]
More than 20 years [ ]

10. How long have you held your current job title or role?

Never [ ]
Sometimes [ ]
Often [ ]
Always [ ]

11. Employer's details (e.g., name, address, phone number, email)

12. Currency and trade certificate (please state)

13. Your job is to...
comprehend, if any

AGREE

DISAGREE

STARKLY AGREE

STARKLY DISAGREE

This is seen as a key factor.

stage and sufficiently must be allowed to cover execution.

Experiences of building project may be considered failed and tender

3. CONTRACTOR'S BUDGET FOR EACH PROPOSAL
EVALUATE

comprehend, if any

AGREE

DISAGREE

STARKLY AGREE

STARKLY DISAGREE

standards on site,

essential understand to the achievement of specified

motivation and comprehend to producing acceptable work are

2. COMMITMENT TO THE WORK BY INDIVIDUALS ENGAGED ON A PROJECT
EVALUATE

comprehend, if any

AGREE

DISAGREE

STARKLY AGREE

STARKLY DISAGREE

for motivating construction to specified quality standards.

An adequate number of experienced the management staff and an

1. SIZE AND EXPERIENCE OF CONTRACTOR SITE MANAGEMENT TEAM
EVALUATE

Please answer all questions by Ticking your response column to each

factor in achieving specified quality standards.

For your deferral of progress or completion of these

under each factor and express your confidence on the improvement of this

site observation and factors to consider for the purpose of these

list below are a number of factors including the achievement of

SECTION 5.

AGREE

DISAGREE

STARKLY AGREE

STARKLY DISAGREE

its important that the main

1. CONTRACTOR'S performance to specified
criteria in the comparison of tender

and frequency for:

reaches the consideration are any and

is important that the site

material for a contrast of the quality

complements prior to delivery

to demonstrate the quality of specified

of the site management team, it is

it is important for supplier

to the delivery of
certificates of completeness and

PRETEND INJECTION

icient for delivery of

-Report for tendering

-Prepared estimate

-Prepared drawing

-Prepared specification

-Prepared programm

6. SCALE OF the management

So...
Any comments, if any

Disagree
Agree
Strongly Agree/Straight SQ
Strongly Disagree/Straight NG

Contractor's position is a significant factor in achieving
timeframe/writing to met to a & components on site.

11. Handling and Moving Materials and Components on Site.

Any comments, if any

Disagree
Agree
Strongly Agree/Straight SQ
Strongly Disagree/Straight NG

Standards are to be met/achieved.
Components on site is a very important to the specified quantity
Perpetual and adequate storage/pretreatment of materials and

10. Storing/ Pretreatment of Materials and Components on Site.

Any comments, if any

Disagree
Agree
Strongly Agree/Straight SQ
Strongly Disagree/Straight NG

Delivery is a key factor.
Through pretreatment of materials and components from the origin

9. Quality of Materials and Components.

Any comments, if any

Disagree
Agree
Strongly Agree/Straight SQ
Strongly Disagree/Straight NG

Inappropriate materials.
Involving the use of materials.


Any comments, if any

Disagree
Agree
Strongly Agree/Straight SQ
Strongly Disagree/Straight NG

As per deviation and experience/deficiency.

7. Inspection of Work on Site.

Any comments, if any

Disagree
Agree
Strongly Agree/Straight SQ
Strongly Disagree/Straight NG

and appreciation of vital duties are to be avoided.
Understand the correct form of materials and components.

6. Supervision of Site Operations.

Any comments, if any

Disagree
Agree
Strongly Agree/Straight SQ
Strongly Disagree/Straight NG

Subcontractors and suppliers for each element of the building project.
Formal procedures which address key factors for the procurement

5. Procedures for the Selection of Subcontractors/Suppliers.

Any comments, if any

Disagree
Agree
Strongly Agree/Straight SQ
Strongly Disagree/Straight NG

Correct and timely delivery of materials.

4. Performance and the Sequence of Site Activities.

Any comments, if any

Disagree
Agree
Strongly Agree/Straight SQ
Strongly Disagree/Straight NG

is under control so that failure may be prevented.
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Quality standards, the most important factor in protecting completed works is the management of the work site. The decision to carry out any work is a key factor. The protection of the site and the equipment used should be adequate. The provision of tools and equipment is a key factor. In order to achieve the expected quality standards, the site must be well organized. The management of the work site is crucial. The decision to carry out any work is a key factor.
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### Table Notes

- **Codeword**: The code assigned to each Facade.
- **2011** to **2019**: Specific data entries for each year from 2011 to 2019.

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**Mean** 2.099  **Median** 2.000  **Mode** 2.000

**Valid cases 101**  **Missing cases 0**

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**Mean** 4.220  **Median** 5.000  **Mode** 5.000

**Valid cases 101**  **Missing cases 0**

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**Mean** 1.306  **Median** 4.000  **Mode** 4.000

**Valid cases 101**  **Missing cases 0**
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**Mean**: 1.602  
**Median**: 2.000  
**Mode**: 2.000  
**Std dev**: 0.602  
**Range**: 2.000  
**Minimum**: 1.000  
**Maximum**: 3.000  
**Valid cases**: 99  
**Missing cases**: 3
### IMP2: Present Procurement System

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<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cum Percent</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>SOMETIME</td>
<td>1</td>
<td>37</td>
<td>37.8</td>
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<tr>
<td>OFTEN</td>
<td>2</td>
<td>43</td>
<td>43.9</td>
<td>83.7</td>
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<tr>
<td>ALWAYS</td>
<td>3</td>
<td>16</td>
<td>16.3</td>
<td>100.0</td>
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</tbody>
</table>

Total: 101

### IMP3: Frequency of Assumptions Made at Tender

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<th>Percent</th>
<th>Cum Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEVER</td>
<td>0</td>
<td>17</td>
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<td>16.6</td>
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<tr>
<td>SOMETIME</td>
<td>1</td>
<td>40</td>
<td>37.7</td>
<td>54.3</td>
</tr>
<tr>
<td>OFTEN</td>
<td>2</td>
<td>24</td>
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</tr>
<tr>
<td>ALWAYS</td>
<td>3</td>
<td>20</td>
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</table>

Total: 101

### IMP4: Stage at Which Respondent Involved With

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<th>Cum Percent</th>
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</thead>
<tbody>
<tr>
<td>COMMENCEMENT DATE</td>
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<td>21</td>
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<td>20.8</td>
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<td>POST TENDER</td>
<td>2</td>
<td>36</td>
<td>33.7</td>
<td>54.5</td>
</tr>
<tr>
<td>PRE-TENDER</td>
<td>3</td>
<td>44</td>
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</table>

Total: 101

### IMP5: Study of Production Info. Prior To Commence

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<th>Frequency</th>
<th>Percent</th>
<th>Cum Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>0</td>
<td>33</td>
<td>3.1</td>
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</tr>
<tr>
<td>LESS THAN 1 WEEK</td>
<td>1</td>
<td>30</td>
<td>29.4</td>
<td>32.5</td>
</tr>
<tr>
<td>LESS THAN 2 WEEKS</td>
<td>2</td>
<td>37</td>
<td>35.7</td>
<td>72.2</td>
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<tr>
<td>MORE THAN 2 WEEKS</td>
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<td>41</td>
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Total: 101

---

**Mean:**

- Frequency: 1.745
- Median: 2.000
- Mode: 2.000

**Valid Cases:** 98

**Missing Cases:** 3

---

**Mean:**

- Frequency: 1.110
- Median: 1.000
- Mode: 1.000

**Valid Cases:** 91

**Missing Cases:** 10
### Contribution of Planned Communication

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<th>Percent</th>
<th>P*6nt</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>LITTLE</td>
<td>1</td>
<td>20</td>
<td>19.8</td>
<td>19.6</td>
<td>100.0</td>
</tr>
<tr>
<td>A LOT</td>
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<td>3</td>
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<td>Missing</td>
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</tr>
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Mean: 1.796  Median: 2.000  Mode: 2.000
Std dev: 4.05  Range: 1.000  Minimum: 1.000

Valid cases: 98  Missing cases: 3

### Communicating Quality to Subbies, Suppliers

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<tr>
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<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>DONT KNOW</td>
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<td>1</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>NO</td>
<td>1</td>
<td>18</td>
<td>17.8</td>
<td>18.0</td>
</tr>
<tr>
<td>YES</td>
<td>2</td>
<td>81</td>
<td>80.2</td>
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<tr>
<td></td>
<td>Total</td>
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<td>100.0</td>
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</table>

Mean: 1.800  Median: 2.000  Mode: 2.000
Std dev: 4.24  Range: 1.000  Minimum: 0.000

Valid cases: 100  Missing cases: 1

### Specifications Tend to Rely on BS and C

<table>
<thead>
<tr>
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<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>DONT KNOW</td>
<td>0</td>
<td>1</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>NO</td>
<td>1</td>
<td>13</td>
<td>12.9</td>
<td>13.6</td>
</tr>
<tr>
<td>YES</td>
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</tr>
</tbody>
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Mean: 1.893  Median: 2.000  Mode: 2.000
Std dev: 1.26  Range: 2.000  Minimum: 1.000

Valid cases: 97  Missing cases: 4

### Possession of a Library of Current BS An

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<th>Percent</th>
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<td>1.0</td>
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<tr>
<td>NO</td>
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<td>13</td>
<td>12.9</td>
<td>13.6</td>
</tr>
<tr>
<td>YES</td>
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Mean: 1.801  Median: 2.000  Mode: 2.000
Std dev: 4.17  Range: 2.000  Minimum: 0.000

Valid cases: 101  Missing cases: 0
7-May-92 FREQUENCY DISTRIBUTIONS
19:56:28 SOUTH BANK POLYTECHNIC on BIG:
VMS V5.4

8513 RELATIVE VALUE OF BS AND COP

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<th>Value Label</th>
<th>Value</th>
<th>Frequency</th>
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<th>Cum</th>
<th>Percent</th>
<th>Percent</th>
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</thead>
<tbody>
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<td>1.0</td>
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<td></td>
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<tr>
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<td>46</td>
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<tr>
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<td></td>
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<tr>
<td></td>
<td>9</td>
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</table>

Mean 1.765 Median 2.000 Mode 2.000
Std dev 1.552 Range 2.00 Total cases 99

7-May-92 FREQUENCY DISTRIBUTIONS
19:56:28 SOUTH BANK POLYTECHNIC on BIG:
VMS V5.4

8514 FREQUENCY OF EXAMINING BS AND COP

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<th>Cum</th>
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<th>Percent</th>
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<td>SOMETIMES</td>
<td>1</td>
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<td>62.6</td>
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</tr>
<tr>
<td>OFTEN</td>
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<tr>
<td>ALWAYS</td>
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<td>6</td>
<td>5.9</td>
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<tr>
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<td>Total</td>
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Mean 1.424 Median 1.000 Mode 1.000
Std dev 1.241 Range 3.00 Total cases 99

7-May-92 FREQUENCY DISTRIBUTIONS
19:56:28 SOUTH BANK POLYTECHNIC on BIG:
VMS V5.4

8515 NUMBER OF BS AND COP AVAILABLE ON SITE

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<th>Cum</th>
<th>Percent</th>
<th>Percent</th>
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</thead>
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</tr>
<tr>
<td>LESS THAN 5</td>
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<td>28</td>
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<td>LESS THAN 10</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>MORE THAN 10</td>
<td>3</td>
<td>40</td>
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<td>40.6</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>9</td>
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<td>2.0</td>
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Mean 1.838 Median 2.000 Mode 3.000
Std dev 1.146 Range 4.000 Minimum 0.000 Maximum 4.000

Mean 1.838 Median 2.000 Mode 3.000
Std dev 1.146 Range 4.000 Minimum 0.000 Maximum 4.000

Valid cases 99 Missing cases 3

7-May-92 FREQUENCY DISTRIBUTIONS
19:56:28 SOUTH BANK POLYTECHNIC on BIG:
VMS V5.4

8516 POSSESSION OF OTHER ESSENTIAL DOCUMENTS

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<th>Cum</th>
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<tr>
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<td>93.9</td>
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<td></td>
</tr>
<tr>
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<td>3</td>
<td>1</td>
<td>1.0</td>
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Mean 1.939 Median 2.000 Mode 2.000
Std dev 1.261 Range 1.000 Minimum 1.000

Validate cases 99 Missing cases 3
### QRM1: Previous Attendance of Quality Review Meetings

<table>
<thead>
<tr>
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<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO</td>
<td>1</td>
<td>32</td>
<td>31.7</td>
<td>33.3</td>
</tr>
<tr>
<td>YES</td>
<td>2</td>
<td>64</td>
<td>63.4</td>
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</table>

**Valid cases:** 101  
**Missing cases:** 0

### QRM2: VMS Initiate the Quality Review Meetings

<table>
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<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
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</thead>
<tbody>
<tr>
<td>CLIENT</td>
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<td>5</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>DESIGNERS</td>
<td>2</td>
<td>10</td>
<td>10.0</td>
<td>15.0</td>
</tr>
<tr>
<td>CONTRACTOR</td>
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<td>36</td>
<td>35.7</td>
<td>50.7</td>
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</table>

**Valid cases:** 101  
**Missing cases:** 0

### QRM3: Frequency of Quality Review Meetings

<table>
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<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEVER</td>
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<td>9</td>
<td>9.9</td>
<td>9.9</td>
</tr>
<tr>
<td>SOMETIMES</td>
<td>1</td>
<td>45</td>
<td>45.9</td>
<td>55.8</td>
</tr>
<tr>
<td>OFTEN</td>
<td>2</td>
<td>36</td>
<td>36.7</td>
<td>92.6</td>
</tr>
<tr>
<td>ALWAYS</td>
<td>3</td>
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<td>9.9</td>
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</table>

**Valid cases:** 96  
**Missing cases:** 5

### QRM4: Importance of Quality Review Meetings

<table>
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<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>0</td>
<td>2</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>LITTLE</td>
<td>1</td>
<td>17</td>
<td>17.1</td>
<td>24.1</td>
</tr>
<tr>
<td>CONSIDERABLE</td>
<td>2</td>
<td>54</td>
<td>54.5</td>
<td>88.6</td>
</tr>
<tr>
<td>GREAT</td>
<td>3</td>
<td>26</td>
<td>25.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Valid cases:** 101  
**Missing cases:** 0

---

**Frequency Distribution Details:**

- **NO:** 32, 31.7%, 33.3%
- **YES:** 64, 63.4%, 100.0%

- **Never:** 9, 9.9%
- **Sometimes:** 45, 45.9%
- **Often:** 36, 36.7%
- **Always:** 9, 9.9%

- **Mean:** 1.647  
- **Median:** 2.000  
- **Mode:** 2.000  
- **Standard Deviation:** 0.474  
- **Range:** 45  
- **Minimum:** 1.000  
- **Maximum:** 75

---

**Frequency Distribution Details:**

- **CLIENT:** 5, 5.0%
- **DESIGNERS:** 10, 10.0%
- **CONTRACTOR:** 36, 35.7%

- **Mean:** 2.791  
- **Median:** 3.000  
- **Mode:** 3.000  
- **Standard Deviation:** 0.720  
- **Range:** 60  
- **Minimum:** 0.000  
- **Maximum:** 75

---

**Frequency Distribution Details:**

- **NONE:** 2, 2.0%
- **LITTLE:** 17, 17.1%
- **CONSIDERABLE:** 54, 54.5%
- **GREAT:** 26, 25.5%

- **Mean:** 7.00  
- **Median:** 2.000  
- **Mode:** 2.000  
- **Standard Deviation:** 0.60  
- **Range:** 75  
- **Minimum:** 0.000  
- **Maximum:** 75
### Joint Review of Method Statement

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<th>Value</th>
<th>Frequency</th>
<th>Percent</th>
<th>Percent</th>
<th>Cum Percent</th>
</tr>
</thead>
<tbody>
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<td>4</td>
<td>6.0</td>
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<td>4.0</td>
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<td>Agree</td>
<td>2</td>
<td>31</td>
<td>40.3</td>
<td>30.7</td>
<td>36.7</td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>3</td>
<td>64</td>
<td>80.6</td>
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<td>100.0</td>
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### Submission of Details of Staff and Trade

<table>
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<th>Value Label</th>
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<th>Percent</th>
<th>Percent</th>
<th>Cum Percent</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1</td>
<td>6.9</td>
<td>6.9</td>
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</tr>
<tr>
<td>Agree</td>
<td>1</td>
<td>31</td>
<td>35.1</td>
<td>30.7</td>
<td>61.8</td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>2</td>
<td>64</td>
<td>70.5</td>
<td>65.3</td>
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</tr>
<tr>
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### Obtain Evidence That Materials and Components

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### Frequency Distributions

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### Summary Statistics

- **Mean**: 2.297
- **Median**: 2.000
- **Mode**: 3.000
- **Std Dev**: 1.000
- **Range**: 3.000
- **Minimum**: 1.000
- **Valid Cases**: 101
- **Missing Cases**: 0

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### Summary Statistics

- **Mean**: 2.614
- **Median**: 3.000
- **Mode**: 3.000
- **Std Dev**: 1.000
- **Range**: 3.000
- **Minimum**: 1.000
- **Valid Cases**: 101
- **Missing Cases**: 0

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- **Mean**: 2.455
- **Median**: 2.000
- **Mode**: 2.000
- **Std Dev**: 1.000
- **Range**: 3.000
- **Minimum**: 1.000
- **Valid Cases**: 101
- **Missing Cases**: 0

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### Summary Statistics

- **Mean**: 2.297
- **Median**: 2.000
- **Mode**: 2.000
- **Std Dev**: 1.000
- **Range**: 3.000
- **Minimum**: 1.000
- **Valid Cases**: 101
- **Missing Cases**: 0

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### Summary Statistics

- **Mean**: 2.614
- **Median**: 3.000
- **Mode**: 3.000
- **Std Dev**: 1.000
- **Range**: 3.000
- **Minimum**: 1.000
- **Valid Cases**: 101
- **Missing Cases**: 0
### Frequency Distributions

**FOR5: Obtain Method of Handling/Protection of...**

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**Total: 101**

**FOR6: Agree Standard Prior to Commencing Each...**

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**Total: 101**

### Other tables...

### Notes...

- **Mean:**
  - 2.416
  - 2.212
  - 2.443
  - 2.303

- **Median:**
  - 2000
  - 2000
  - 2000
  - 2000

- **Mode:**
  - 2000
  - 2000
  - 2000
  - 2000

- **Std Dev:**
  - 572
  - 630
  - 677
  - 630

- **Range:**
  - 3000
  - 3000
  - 3000
  - 3000

- **Valid Cases:**
  - 99
  - 97
  - 99
  - 99

- **Missing Cases:**
  - 2
  - 4
  - 2
  - 2
### 7-May-92 FREQUENCY DISTRIBUTIONS

#### FAC1 SIZE AND EXPERIENCE OF CONTRACTORS TEAM

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### 7-May-92 FREQUENCY DISTRIBUTIONS

#### FAC2 COMMITMENT TO THE WORK BY INDIVIDUALS

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### 7-May-92 FREQUENCY DISTRIBUTIONS

#### FAC3 DURATION AND FREQUENCY OF SITE ACTIVITIES

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**Mean**: 2.464  
**Median**: 3.000  
**Mode**: 3.000  
**Std dev**: 3.000  
**Frequency**: 101  
**Valid cases**: 101  
**Missing cases**: 0
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Total 101 100.0 100.0

**Statistics:**
- Mean 2.394
- Median 2.000
- Mode 2.000
- Std dev 1.236
- Range 3.000

Valid cases 99 Missing cases 2

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### FACT 2: SUPERVISION OF SITE OPERATIONS

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Total 101 100.0 100.0

**Statistics:**
- Mean 2.394
- Median 2.000
- Mode 2.000
- Std dev 1.236
- Range 3.000

Valid cases 99 Missing cases 2

---

### FACT 3: INSPECTION OF WORKS ON SITE

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Total 101 100.0 100.0

**Statistics:**
- Mean 2.336
- Median 2.000
- Mode 2.000
- Std dev 1.236
- Range 3.000

Valid cases 99 Missing cases 2

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### FACT 4: METHODS AND PROCEDURE FOR ORDERING MATERI

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Total 101 100.0 100.0

**Statistics:**
- Mean 2.394
- Median 2.000
- Mode 2.000
- Std dev 1.236
- Range 3.000

Valid cases 99 Missing cases 2
### FAC09 QUALITY OF MATERIALS AND COMPONENTS

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Total: 101 100.0 100.0

- **Mean**: 2.310
- **Median**: 2.000
- **Mode**: 2.000
- **Std deý**: .563
- **Range**: 3.000
- **Minimum**: 0.000
- **Maximum**: 3.000
- **Valid cases**: 101
- **Missing cases**: 0

### FAC10 STORAGE AND PROTECTION OF MATERIALS AND COMPONENTS

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Total: 101 100.0 100.0

- **Mean**: 2.535
- **Median**: 2.000
- **Mode**: 2.000
- **Std deý**: .523
- **Range**: 3.000
- **Minimum**: 1.000
- **Maximum**: 3.000
- **Valid cases**: 101
- **Missing cases**: 0

### FAC11 HANDLING AND MOVING MATERIALS/COMPONENTS

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### FAC12 SKILL AND COMPETENCE OF TRADESMEN

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- **Std deý**: .523
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- **Minimum**: 1.000
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- **Valid cases**: 98
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### FAC13. CONTROL OF OPERATIVES BY CONTRACTORS TEA

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**Valid cases**: 98, **Missing cases**: 3

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**Valid cases**: 98, **Missing cases**: 3

### FAC15. REMUNERATION TO OPERATIVES

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#### Frequency Distribution

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- **Std dev**: .676
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**Valid cases**: 99, **Missing cases**: 2

### FAC16. PROPER TOOLS, PLANT AND EQUIPMENT

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- **Median**: 3.000
- **Mode**: 3.000
- **Std dev**: .676
- **Range**: 3.000
- **Minimum**: 0.000
- **Maximum**: 3.000

**Valid cases**: 99, **Missing cases**: 0

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7-May-92 FREQUENCY DISTRIBUTIONS
19:56:30 SOUTH BANK POLYTECHNIC on BIG:: VMS V5.4

FAC13. CONTROL OF OPERATIVES BY CONTRACTORS TEA

FAC14. LACK OF CARE BY OPERATIVES

FAC15. REMUNERATION TO OPERATIVES

FAC16. PROPER TOOLS, PLANT AND EQUIPMENT
### FAC17 ACCESS TO PLACE OF WORK

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**Statistics**

- **Mean**: 2.634
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- **Maximum**: 3.000

**Valid Cases**: 101
**Missing Cases**: 0

### FAC18 PROTECTION OF WORKS DURING CONSTRUCTION

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**Statistics**

- **Mean**: 2.475
- **Median**: 2.000
- **Mode**: 2.000
- **Std Dev**: 0.521
- **Range**: 3.000
- **Minimum**: -1.000
- **Maximum**: 3.000

**Valid Cases**: 101
**Missing Cases**: 0

### FAC19 HUMIDITY AND TEMPERATURE CONTROL DURING

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**Statistics**

- **Mean**: 2.000
- **Median**: 2.000
- **Mode**: 1.000
- **Std Dev**: 0.521
- **Range**: 3.000
- **Minimum**: 0.000
- **Maximum**: 3.000

**Valid Cases**: 101
**Missing Cases**: 0

### FAC20 PROTECTION OF COMPLETED WORKS

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**Statistics**

- **Mean**: 2.350
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- **Mode**: 2.000
- **Std Dev**: 0.635
- **Range**: 3.000
- **Minimum**: 0.000
- **Maximum**: 3.000

**Valid Cases**: 101
**Missing Cases**: 0
N.1 PREPARATION OF QCWS - AT TENDER STAGE

The twelve actions listed in the ACTION column of QCWS at tender stage shown in Table 10.1 remained virtually the same for all projects. However, the requirements of each tender document may dictate the need for some alteration to the ACTION column. Where this is the case, the alteration should be done without altering the fundamental objective and sequence of the system.

The following factors will have a direct effect on the sequence, timing and linkage of the actions:

1. The time allowed to submit tender.
2. The value of each project will be a key factor.
3. The number of main elements of the project. That is, the various subcontract packages that the project are to be sublet or handled.
4. The adequacy of the tender document. This is a key factor and one of the points that top management will examine before a decision is made as to whether to tender for a project.
5. The number of estimators that will work on the project.
6. The level of involvement of other departments in the preparation of the tender.

The above factors must be carefully considered in the preparation of the "QCWS at tender stage." The sequence, timing and linkage shown in Table 10.1 is set out as a guide. It is based on a minimum of five weeks within which tender must be submitted. Often, tendering periods are shorter and this must be taken into
**N.2 PREPARATION OF PROJECT QCWS**

An important document required for the preparation of the project QCWS is the WORKS PROGRAMME. An outline programme submitted to the client at tender stage or as a works programme is not appropriate for the exercise. A detailed works programme is required. The programme should itemise all the operations required to complete the project. The programme must be produced before preparation of a project QCWS can start. All operations that make up the whole project must be included in the project QCWS.

In addition to the works programme, all materials and components required for the project must be identified and outlined for inclusion in the project QCWS. This will involve examining all available production information and discussion with the design team to identify their design intention prior to the issue of remaining production information. This is essential because all of the production information will not be available during the preparation of the project QCWS.

The notes given below under the title "Development of Project Quality Communication Warning System" are to be used as a guide for the development of a QCWS for a building project.

In the column headed "operations," sufficient space between subcontract packages and materials must be left for future use when new items require inclusion in the project QCWS. Also there must be space to include new items in the "materials" section of the column. These ideas are shown in the example in Table 10.2.
N.2.1 Development of Project Quality Communication Warning System

Described below is a guide for the development of a project Quality Communication Warning System by using Table 10.2 as an example.

1) **Operations:** In the column headed "operations" list all works that are to be carried out by different subcontractors or suppliers.

2) The date and project week no. rows run from the date of award of contract to handover date. The example shows a period of four weeks from award of contract to start on site of the first operation (foundations.) This is shown as week no. -4, -3, -2 and -1.

3) Extract the start date of each operation from the "Master or Works Programme" and enter it into the appropriate week no. in the QCWS chart. In the example, the first operation (foundations) starts on site in week no. 1, therefore Action 30 (start on site) was entered into week no.1.

4) Obtain from potential subcontractors/suppliers the lead-in period for each operation. The lead-in time should include:

   i) Latest date when firm order must be received by subcontractor.

   ii) Drawing production time: design and shop drawings (eg. 6 weeks)

   iii) Period for updating drawings after comments from consultants (eg. 2 weeks.)

   iv) Manufacturing period (eg. 11 weeks.)

   v) When/whether site measure is required.
Add onto the lead-in obtained from subcontractors:

a) The contractual or agreed time that consultants have to comment on subcontractor drawings (eg. 10 working days.)

b) The time required to prepare subcontract enquiry documents - Action mode no.s 1 - 4. A reasonable time must be allowed to enable actions 1 to 4 to be carried out efficiently (eg. 4 weeks.)

c) The time required for subcontractors/suppliers to submit prices - Action mode 5 and 6 (eg. 3 weeks.)

Therefore, the total lead-in time for a typical operation with design input from a domestic subcontractor will be as follows:

i. Time to prepare subcontract enquiry document 4
ii. Time allowed for subcontractors to submit price 3
iii. Time required for price comparison and final selection 2
iv. Scheme review period prior to subcontractor commence drawing production 5
iv. Drawing production time 6
vi. Update drawings 3
vii. Final approval of drawings or "no further comments" 2
viii. Manufacturing period 11

For example, item no. 13 of the QCWS entitled "Demountable partitions" required 36 weeks within which actions 1 - 29 must be carried out. In order to start the operation on site during project week no. 44, action no.1 should be carried out during project week no.8, action no.2 during week no.9 and so
on until week 43 when first delivery of materials will be made to enable the operation to commence as programmed for week 44.

Operation no.8 of the QCWS entitled "Brickwork/blockwork" is an operation which does not require design input by the subcontractor. Therefore, the lead-in will not include lead-in nos 4, 5, 6 and 7 as shown above for operations with design input.

The above examples show that production information for Demountable partitions is required by the contractor not later that project week no.7 while production information for Brickwork/blockwork is required not later than the third week after the award of contract.

5) A major factor in the successful implementation of a QCWS is the adequate and prompt issue of production information by the consultants. It is important that the contractor manage the issue of information very well. To this effect an Information Release Schedule (IRS) will help the contractor to monitor the issue of production information by the consultants.

6) In order to ensure the efficient implementation of QCWS, actions to be carried out by individuals (eg purchasing officer) must be spread as evenly as possible. For example, if a purchasing officer is to prepare and send out three major subcontract enquiry documents in a week, this may reduce his concentration and proper examination of the relevant information to be included in the enquiry. This could be a recipe for future quality or cost problems. This point must be taken into consideration during the development of QCWS. Also, allow for public and statutory holidays in the QCWS chart (although not shown on the example in Table 4.2).
7) Brickwork/blockwork operations start on site during week no 18 and during the same week, the specified quality requirement must be communicated to the operatives. Hence the (30/31) shown in week 18 for brickwork/blockwork. This means that action no 30 and 31 are to be carried out during week no 18. Also during week 19, Action no 32 and 33 need to be carried out for brickwork/blockwork.

Action no 34 (ie carry out inspections, checks and tests) for each operation are shown to commence during the third week into the erection or installation of each operation. This action is shown in the third week for clarity purposes only. The action will commence same week as action no 30 and continue during the course of the operation till completion. The frequency will be as agreed in action no 33 or in the contract documents.

The arrow lines show that Action No 34 will be carried out every week from start on site to completion of each operation. For example brickwork/blockwork operation required Action No 34 from week No 18 to week No 34.

8) There may be some operations that will last for a few days on site (possibly less than one or two weeks). In addition to Action 1 to 29 which need to be carried out before such an operation can start on site, some of the other (eg Action 31 to 33) may also have to be done before the start date. For example mat wells and blinds. This must be taken into account when developing QCWS.

9) Fewer actions are required for domestic suppliers of materials and components. Watch out for the following:
i) The date when the material/component is required on site
ii) The lead in period from supplier
iii) The latest date when production information must be received from the consultants.

It is absolutely important that the purchasing officer approach potential suppliers to obtain the lead in time. This method is better than to guess what the lead in could be. However, the experience and knowledge of the purchasing officer must be used as a guide in carrying out his Actions.

10) Nominated subcontractor and supplier

Where an operation is to be carried out by a nominated subcontractor or materials/components are to be supplied by nominated supplier, the contractor shall notify the Architect as to the date when nomination must be made. The Contractor should ensure that nominations are made at the right time to enable Actions 7 to 29 to be adequately carried out before the programmed start date of the operation. The first Action required for a nominated operation is the scheme review meeting. Item No 3 and 4 of the example show a typical nominated operation. This shows that nomination must be made not later than two weeks after the award of contract to enable all communication Actions to be carried out and the operations to start on programme during week No 27.

The person responsible for the development of QCWS may have to rely on his experience to determine the lead in time for an operation or material requiring nomination. He may obtain names of potential subcontractors from the consultant to enable him to approach them to confirm what the precise lead in time would be should they be nominated. I strongly suggest the
contractor approach potential subcontractors through the Architect to obtain accurate lead in time.

11) The column titled "subcontractor/supplier" is where the name of each subcontractor or supplier shall be recorded. In the example, AMOYO GROUP is the nominated subcontractor for both the Mechanical and Electrical services. The names shall be entered as nomination or selection are made for each operation.

12) The column titled "Action Mode" is where all Actions required for communicating the specified quality requirements for a project by a contractor to the construction team are listed in a chronological order.

On the left side of "Action Mode" column is the column titled "Action No.". The column gives the number for each action made. The numbers are then used in the body of the QCWS as shown in the example.

N.2.2 Updating project QCWS

Amongst others, the following events are considered factors which will lead to updating a project QCWS.

1) Late production information

If for any reason, production information is not issued as stated in the IRS, in most cases the Actions required for the specific elements will be pushed back.
2) **Actual progress of work on site**

If the actual progress on site is behind or ahead of programme, this will have a direct effect on the project QCWS.

3) **Variations**

During the construction phase of the project, there may be variations for omission or addition. Not all variations will lead to updating a project QCWS, but a significant variation may require updating a project QCWS.

4) **Extension of time**

If for any reason the contractor is granted an extension of time to the contract, this could be an event that would affect the issue of a revised programme which in most cases could lead to updating the project QCWS.

5) **Change of subcontractor or supplier**

A situation may arise in which the contractor may have to appoint another subcontractor or supplier. If this does happen, it may affect the project QCWS which could lead to it being updated.

N.3 **HOW TO USE QCCD**

The Quality Communication Control Documents (QCCD) shown in Table 10.4 are a key part of the system. It emphasis the need to produce evidence that a particular action has been carried out. The evidence is required to enable the assessor to rate the value of the actions in relation to the objective they were intended to achieve.
Not only that Actions must be carried out accurately and at the right time, but evidence must be produced to show how and the extent of the action taken. Without this, the Assessor will not be able to do his work efficiently. When an Action is completed, the person responsible for the Action will tick the "Yes" box in the ACTIONED column as an indication that the Action has been carried out.

In the column titled "Evidence of Action Taken" is a list of items that will be acceptable as evidence that the action has been carried out. However, this does not stop the Assessor from asking for more details if he feels it is necessary for him to award the necessary rate for the action taken. Therefore, it is important that the responsible officers keep records of their Actions.

The column titled "Comments" provides an opportunity for each individual responsible for carrying out the Actions to state any comments they may have relating to each Action. The comments could be any of the following:

1) Reason why an Action was not carried out
2) Reason why sufficient evidence cannot be produced
3) Reason why the Action taken was not effective for achieving the intended objective.
4) What Action is required at a later stage to correct the ineffective Action.

N.4 RATINGS AND REMARKS BY QUALITY ASSSESSOR

N.4.1 The Quality Auditor/Assessor

Another major factor in the successful implementation of a Quality Communication system is the assessment and award of marks for Action carried out. The person responsible for the task must possess the skills sufficient to enable him to do a good
job. Therefore, the following points must be considered before his selection:

1) He must have a good knowledge of the construction process and relevance of his Actions.
2) He must be trained as a quality Auditor and in more specific issues raised under Quality Communication system.
3) He must be aware of the evidence that is reasonable for each Action.
4) He must understand the objective of QCS.

N.4.2 Rating

The Quality Auditor or Assessor will examine all evidence produced in support of each Action and thereafter assess as to whether the intended objective has been achieved. If he is satisfied that the objective has been achieved or would be achieved, he will award the total possible mark.

If Action is not taken or the Auditor is not convinced that the Action carried out has achieved the intended objective, he will not award any mark for such an item. The Auditor could request for additional action to be taken or more evidence to be produced before he awards the mark. If the additional Action is taken or more evidence produced to justify that the intended objective has been achieved or would be achieved, the Auditor will then award the mark. Therefore if a mark is not awarded for an Action during a particular Audit session this does not stop the Auditor from awarding the mark at a later Audit session. The key rule is the achievement of the specified requirements at first attempt.

The Auditor will always award full mark. There is no part award of marks. That is, it is either the full possible mark awarded or no marks at all. This is very important in the successful running of the system. This is required to eliminate subjective,
inconsistent and indiscriminate award of marks.

Remarks

Against each Action, the Quality Auditor shall make comments in the remark column. The comments shall be his opinion for awarding or not awarding mark. The comments shall also include specific Actions that may be required to put things right at a later stage during the progress of the project. The comments are a key factor in preparing recommendations during and at the completion of the project.

N.5 WHO SHOULD CARRY OUT EACH ACTION AND RATINGS

N.5.1 QCWS At Tender Stage

ACTION BY:

QCWS at tender stage shall be monitored and be under the control of the project estimator. He shall carry out all the Action as described in the guidance notes. He shall ensure that all Actions required by the other people are carried out in an orderly and effective manner.

RATING BY:

Supervision and rating of QCWS at tender stage shall be the responsibility of a senior estimator (eg superintending / chief estimator). The person doing the rating must be in a capacity to attend the Settlement Meeting.
N. S. 2 PROJECT QCWS

ACTION NOS 1 - 6:

Actions Nos 1 - 6 of project QCWS shall be monitored and be under the control of the project purchasing officer. He shall carry out all the Actions as described above. He shall ensure that Actions required by other members of the contractors team are carried out in an orderly and effective manner.

RATING BY:

The rating of Actions Nos 1 to 6 shall be carried out by a Senior Purchasing Officer who is not involved with the project or by an Internal Quality Auditor.

ACTION NOS 7 TO 30:

The person responsible for the Actions, control and monitoring of the project QCWS Nos 7 to 30 will depend on the size of the project and its organisational structure. The most important thing is that a member of the contractor’s site team must be responsible for the Actions. It would be a good idea if it could be included in the job description of such an individual.

From the discussion, held with a number of contractors, the following position holders were identified as the right person to be responsible for the Actions.

i) Project Manager/site manager or agent
ii) Resources Manager
iii) Planner
iv) Assistant Project Manager/section manager
v) Project Administrator

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The selected person shall arrange all the necessary meetings and ensure that Action required by others are carried out promptly and in an effective and orderly manner. For example,

(1) he shall obtain written confirmation from subcontractors and suppliers that manufacture has commenced;
(2) progress manufacture;
(3) ensure subcontractors take site measure at the appropriate time
(4) Arrange work visit
(5) Carry out interim progress to ensure that the contractor or supplier is on course to meet the start date or delivery date.
(6) Send out Letter of Confirmation of start date to subcontractors
(7) Carry out final checks with subcontractors and suppliers and ensure a pre-start meeting is held before the start date.
(8) Ensure that other members of the site team are aware and preparations made to take delivery of materials

**ACTION NOS 31 TO 34**

The size of the project and its organisational structure will dictate who will be responsible for Actions 31 - 34. The likely people to be responsible are:

i) Project Manager/site manager/agent
ii) Construction Manager
iii) Section Manager / Engineer or Trade Foreman

The person responsible for the Actions shall work closely with the subcontractor supervisors or foremen and the Client's representatives such as site Architect,
Resident Engineer and Clerk of Works.

**RATING BY:**

The rating of Action Nos 7 to 34 shall be carried out by any of the following:

i) Regional / District / Contract Manager or Director

ii) Internal Quality Auditor

The person must be someone that is not directly involved with the day to day running of the project.