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THE MANAGEMENT

OF

ERROR

IN

CONSTRUCTION

PROJECTS

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Abstract

The "defects problem" has demanded considerable attention in recent years, with much emphasis given to the technical causes of failure. This research project examines the problem from a different point of view - that of human error. Taking as a starting point, technical publications in the construction industry, the research reviews human error literature from a variety of industries and perspectives and synthesises a model of error causation covering organisations in a construction project context. This model is then progressively tested in four studies, a general preliminary survey and three more detailed studies of house-building. Conclusions support the view that errors leading to failure in complex socio-technical systems often exhibit systems characteristics and involve the whole managerial structure. An improved model is proposed, which emphasises the importance of both project and general management errors.

Key words - Human error, defects, project management, failures.

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1

INTRODUCTION

1.1 THE DEFECTS PROBLEM

This report documents an investigation of the nature and cause of errors leading to defects in construction work. Although concentrating on error, the investigation started with an examination of the technical causes of defects. The literature concerning defects reveals considerable repetition, suggesting that a lack of technical knowledge (as represented by the mass of books, reports, guides and case studies of defects) is not their main cause. The problem is more one of conveying existing knowledge from technical literature to finished product; that is to say, not so much a problem of what to do, but how to do it. The investigation, therefore, became drawn towards the human causes behind implementing technical solutions, causes which turned out to predominate in defects and failures in several industries including some far removed from construction.

1.2 HUMAN ERROR

In contrast to an extensive literature on the technical nature of defects, there is a general absence of work in the construction area related to their basis in human error. However, recognition that "human error" and not "defects" are the key search terms opens a far wider range of sources, including psychology, sociology, management and engineering. These sources, whilst providing differing emphases, also reveal a large measure of agreement. Categories of common types of error begin to emerge and some authors arrange these categories in a systematic manner according to the proximity or remoteness within an organisation of the category from the perceived perpetrator of the error. Some propose models consist of layered hierarchies. At the base of the hierarchies are technical errors made by operatives, towards the centre are a range of managerial factors and at the top, wider contextual factors. Authors suggesting these models, coming by and large from outside the construction industry, are not concerned with errors related to defects, but rather accidents or major failures.

1.3 THE NEED FOR RESEARCH

The discovery of this rich literature and of the attempts at "model building" was instrumental in directing work in two ways. Firstly, it emphasised the importance of searching widely and not always in the most obvious places in researching the subject of human error, and, secondly, it revealed a possible gap in current thinking on the causes and cures of defects.

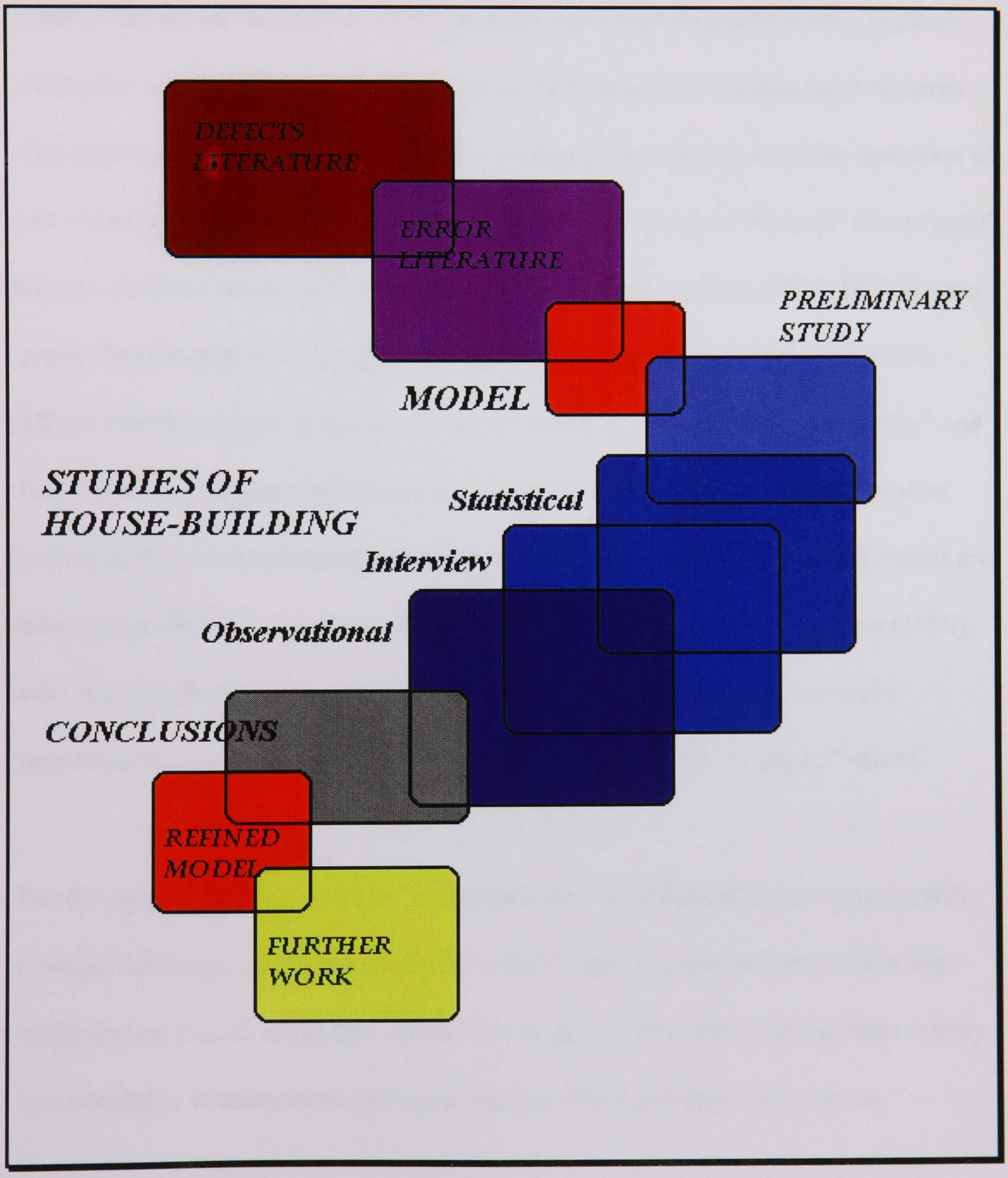
Regarding the first point, it is notable that authors writing on human error and coming from one of the sources mentioned above are often constrained by their own specialist knowledge to either ignore, or consider only in very general terms, other perspectives. This has the effect of the authors sometimes appearing to identify "the problem", but not to be able to propose the solution. The literature, with some notable exceptions, appears to sit in a series of separate "boxes" made from the specialist knowledge of the disciplines. A conscious effort at creative thinking is, therefore, necessary in order to identify all likely influences on the occurrence of errors and defects and, consequently, all disciplines likely to have a view on the problem. A further effort is required to understand sufficiently the content of the specialist disciplines identified in order to use their knowledge in further research. A final effort is necessary to search for common ground, or over-riding disciplines, which might link the disparate bodies of knowledge on human error.

Regarding the second point, it has already been mentioned that human error has received scant attention from the construction literature. Where it has been mentioned (generally in civil engineering and related to disastrous failures), the causes of and cures for failure are presented in such a cryptic or haphazard fashion that the human error component has to be searched for or implied. Apart from some attempts to apply human error models to construction safety, no systematic effort has been made to provide what is essentially a link between knowledge related to the subject in disciplines "external" to the construction industry or project based industries generally, or to defects (as opposed to accidents and major disasters). It was towards this gap that the research was drawn.

1.4 AN OUTLINE OF THE RESEARCH METHOD

By combining the wider literature and literature related more specifically to the construction industries an attempt was made at synthesising a model of error specifically related to construction projects. However, the volume of literature uncovered by applying the search terms to such a wide range of industries and disciplines, meant that it was necessary to continually revise the contents of the model in the light of new knowledge, even without the influence of the field work. The point at which a model was considered sufficiently "firm" to bring forward for further investigation, was therefore relatively arbitrary and revisions were anticipated at its conceptualisation. Field research took the form of an investigation consisting of separate steps, more or less building on each other. The contradictions sometimes evident between steps and the lack of perfect fit between conclusions from different strands of the research are evidence of the research process adopted - to build on knowledge as it was revealed either from literature, or from field research, to modify conclusions in the light of the building process and to carry out much of the work concurrently. An investigative methodology was thought appropriate to a research project which sought to synthesise knowledge from a wide spread of disciplines and apply it to another. The use of concurrency was, as with many construction projects, to save time. As with concurrency in other projects, its use in research carries the cost of engendering revision and rework and the marks of that are visible. Although at the outset, the research did not consciously follow a recognised methodology, the path of the research, as approximated in figure 1.1, is recognised in the literature on research design and methodology and is developed in Chapter 6.

FIGURE 1.1 - THE RESEARCH PROCESS



1.5 DEFINITIONS

Although the research adopts an inclusive approach to the study of human error, it is necessary to define boundaries. It could be argued that all errors are human in origin and any human action leading to an unwanted result should be considered a "human error". This would include the small proportion of errors that arise from completely unforeseen causes and, as a consequence are not amenable to human error research. Conversely, it would exclude "deliberate" errors, such as fraud, which by definition are not errors at all, but which clearly come within the definition of "human" if not "error". Many formal definitions of human error *imply* culpability, and thus include deliberate errors, by referring to externally moderated norms. For example, Stewart (1993) defines human error as "a human action that exceeds some limit of acceptability" and Bea (1994) as "a departure from acceptable or desirable practice on the part of an individual that can result in unacceptable or undesirable results". These definitions are more comprehensive than those, from for example the psychologist Lourens (1990), who consciously excludes culpability by framing the definition in terms of the perpetrators own intentions, excluding both "deliberate" and "negligent" errors.

For the purposes of this research, a restricted view would seem to be un-necessarily limiting. Although a dictionary definition might exclude deliberate acts, whilst logic might dictate that all errors are human, this study includes fraud, but excludes wholly uncontrollable consequences of human actions. Bea's definition of errors as "departures from acceptable or desirable practice", thus provides an adequate basis for investigation.

1.6 A MAP OF THE RESEARCH

The investigative nature of the research meant that it was not always possible to follow a clearly delineated path towards conclusions. In retrospect, however, it became possible to construct a map of the main research arena. The boundaries of "error", "non-error", their outcome and hence the scope of the research are illustrated in graphical form and are shown in Figure 1.2. To explain the figure, the central problem driving the research is defects. Defects imply a shortfall in terms of the product of an enterprise rather than a shortfall in terms of the process of production. A wider definition of failure would include the latter, which is often evident as "business" failures related to cost and time performance. A shortfall, in the form of accidents caused by either product or process failures, is an unfortunate, and usually avoidable, side effect of activities. They complete the "map" of the consequences of actions.

A map of the causes of failures can also be drawn. It will be demonstrated that these are overwhelmingly human in origin. However, some failures are either unforeseen or predicted as a normal process of wear and tear. These classes of action are called (rather inelegantly) "non-error" causes, as are frauds, which, whilst human in origin, are by definition not errors. The map is completed by dividing errors into two classes, manifest and latent. It is in this area of the map where the research is concentrated.

The figure shows in red the “path” of primary research interest centring on the error basis of defects, but using an investigative logic, the research draws in apparently tangential areas of study to provide insights or corroborate findings on the “primary path”. Human error related to accidents is a particularly active area of general research interest and this area, marked green in the figure proved relevant. Business failure, in terms of poor time and cost performance was also of interest and is marked in blue[1]. Also marked in blue is the converse of failure, success. Conformation of many findings uncovered in the study of error is found in the “success” literature related to general management, project management, quality assurance, and safety[2].

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[1] Oakland (1993) and ACSNI (1993)from the perspectives of total quality management and nuclear industry safety respectively suggest links between quality and safety and business performance.

[2] Whittington et al (1992), Harrison (1992) and Whiston and Eddeshaw (1989) draw links between safety, quality and defects. The first notes “"The most obvious effect of (programme pressures in the construction industry) is that (operatives) must increase productivity which in turn is likely to increase the defect rate. The parallels with the comments made by respondents in this research about time and financial pressures and their impact on safety are striking".

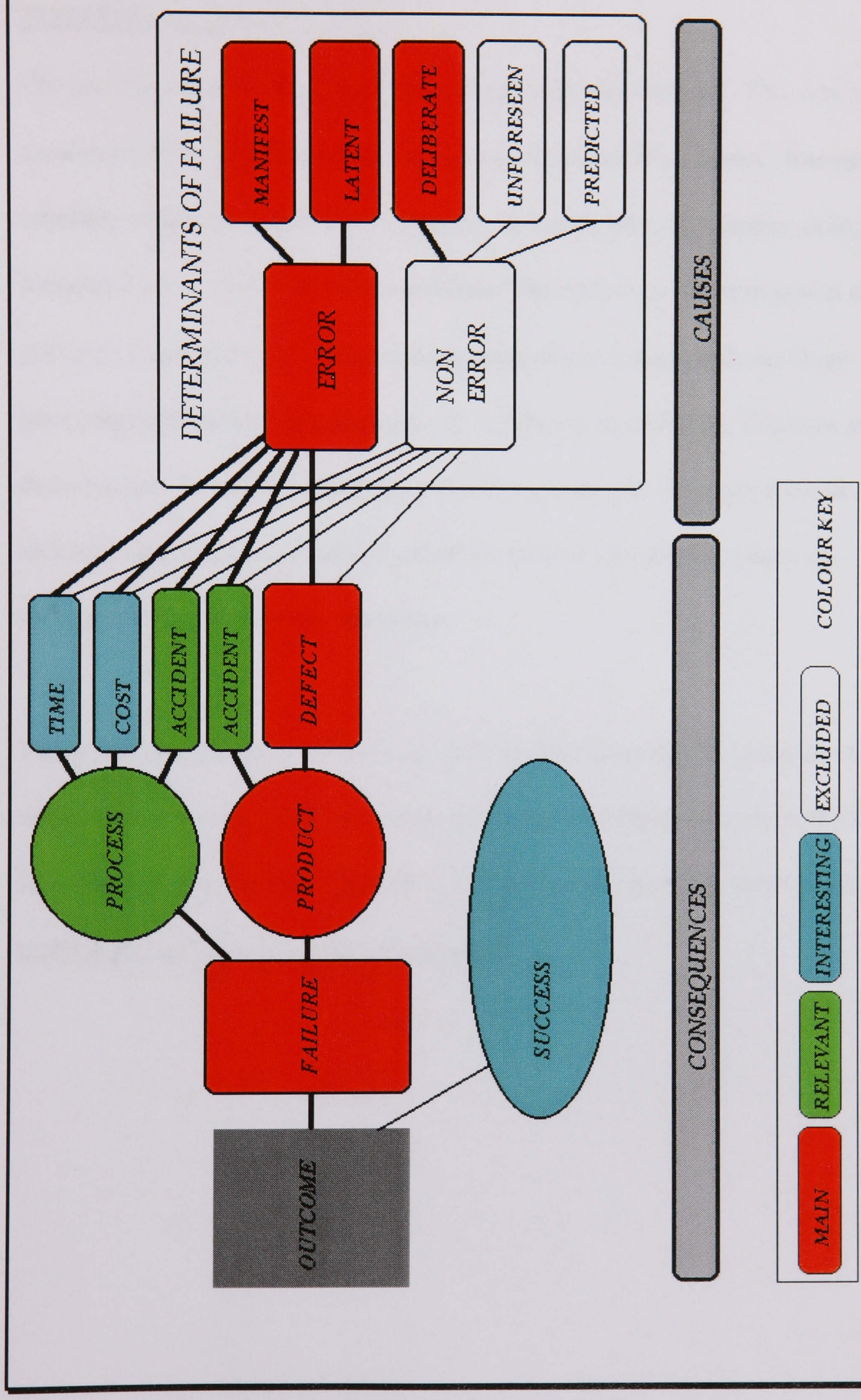

FIGURE 1.2 A MAP OF THE RESEARCH

1.7 THE RESEARCH STEPS

THE LITERATURE REVIEW

The literature, first concerning defects, then error was analysed. This was later supplemented by reviewing areas, such as quality assurance, project management, reliability engineering and systems safety - literature generally concentrating on successful performance, rather than failure. The review involved technical disciplines, primarily engineering, but also the disciplines of psychology and sociology. The latter gave particular attention to human error in relation to accidents, disasters and catastrophes. As well as covering several disciplines, the literature spreads over many industries including construction, minerals, nuclear, chemical engineering, transportation and marine engineering.

There was no clear point in the research at which reviewing the literature stopped and some areas are, at the time of writing, still being developed. However, the literature falls into and is presented (Chapters 2, 3 and 4) as three perspectives on error covering technology, social science and management.

MODEL BUILDING

After the review was substantially completed, the perspectives were reintegrated (Chapter 5) by extracting common themes, identifying differences in view and gaps in knowledge. From this process a model of the error process related to construction projects was conceptualised. This model forms the basis of subsequent field research, consisting of a preliminary study and three studies of house-building.

PRELIMINARY STUDY

The preliminary study (Chapter 7) sought responses to the model from the construction industry generally. For this purpose, a fairly wide section of informed opinion was surveyed by using a largely closed question type of postal questionnaire, but with an opportunity for respondents to supply additional comments.

STUDIES OF HOUSE-BUILDING

The studies were in three parts (Chapters 8, 9, 10):-

- A statistical study which assessed the impact of individual factors in the model on measures of error.
- An interview study to further assess the impact of factors and examine linkages between factors.
- An observational study to more closely examine errors as they incubated in a representative setting.

The conclusions from the studies of house-building are combined with those from the literature review and preliminary study in forming the findings from the research. The overall conclusions are, therefore, based on triangulating evidence.

2

A TECHNOLOGICAL PERSPECTIVE ON ERROR

2.1 INTRODUCTION

An analysis of literature from a technological perspective reveals several authors who have considered human error and its outcomes. Their writings can be loosely classified as follows:-

- **The forensic engineering and "disaster" writers**
- **Monographs particularly directed to human error**
- **Research reports and case studies on human error**

2.2 THE FORENSIC ENGINEERING AND "DISASTER" WRITERS

A number of authors have reviewed major disasters in the construction and use of buildings and engineering structures. Some are writing from the perspective of "forensic engineering", which has as its objects the analysis of the technical causes of failures, others from general interest.

McKAIG (1962)

The earliest author of failure monographs reviewed is McKaig who summarises reports of building and other collapses dating back to the nineteenth century. McKaig largely reports the technical causes of failure and the consequences in terms of human life and damage. In passing, he notes "human error" reasons for these failures, including lack of foresight, fraudulent practices and negligence related to both the design and construction of structures. He makes no attempt to define "human error" or systematically analyse the causes of these errors and is often not specific as to exactly who had erred, but does point in some instances to gross failures in **supervision and checking, confused responsibilities, unregulated changes, uncontrolled concurrent working**[1] and **financial pressures**. These "themes", it will be seen, repeat throughout much of the literature reviewed.

McKaig reports official recommendations in avoiding the repetition of failure that largely concentrate on controlling the identity of the individual. Thus, the report on the New York Coliseum collapse of 1956 recommended:-

- Licensed engineers should be used for critical areas of construction
- Contractors should be licensed
- Building control officers should be graduate or licensed engineers.

Similar recommendations were made in reports concerning collapses in 1911, 1915, 1922, and 1959, suggesting that deficiencies in the technical knowledge of practitioners of that time were considered more influential than wider managerial failures such as the division of responsibilities and control of changes.

[1] Concurrent working is where several stages of a project (for example, briefing, design, and construction) are carried out **concurrently** rather than **sequentially** (Morris 1994). This is usually done to save time.

FELD (1968)

Feld writes from the standpoint of the forensic engineer and also points out the need for practitioners to acquire technical knowledge and/or be licensed to practice. However, he also cites failures in supervision both at the design and construction stage and poor co-ordination and divisions of responsibilities between key construction players (particularly in standard forms of engagement). Feld particularly stresses the need for carefully delineated responsibilities between specialists in suggesting:-

> "...there is general agreement that a clear-cut division of the total responsibility to the owner and to the public is desirable and as yet is non-existent". (page 375)

He also notes that clarifying responsibilities by simply transferring them to other parties may be counter-productive, but a clear demarcation between design and construction and concentrating design in the hands of one designer was needed.

Feld notes the importance of communications in the form of properly co-ordinated drawings and the importance of controlling changes during construction (particularly by ensuring that significant modifications are made by issuing altered drawings and withdrawing the originals rather than by amendments to the originals on site). Finally, Feld notes the role of cost pressures in error, where he suggests that both cost pressure per se and fluctuations in pressures caused by a "boom and bust" business cycle can lead to discontinuities of resources and consequent mistakes.

KAMINETZKY (1976), (1991)

Following the format and approach of the previous two writers, Kaminetzky also concentrates on the technology of recent disastrous failures with some reference to the influence of human error. Kaminetzky points out the role in failures of lack of technical knowledge on the part of individuals, poor inspection and supervision procedures, poor division of responsibilities, lack of control over changes, the use of uncontrolled concurrent working, poor communications and pressures of time and cost.

Kaminetzky (1991) notes limitations of checking which he suggests:-

> "Can at best serve as a deterrent to flagrant contract and code violation. It may well also serve to prevent constant and continuous errors often caused by ignorance rather than by ill-intent". (Page 41)

He also emphasises the need to carefully define responsibilities and to assign duties to where he considers they are most effectively performed. Interestingly, Kaminetzky criticises the use of performance specifications in the USA in this respect, preferring the European practice of fully specified design:-

> "In Europe, engineers produce a complete set of drawings - every rebar is indicated, every rebar bend is specified. What the contractor gets is the complete story, allowing no deviation....Once the contractors are developing something which is not spelled out in the design (as in the USA), then they are, in fact, designing, and that is where the trouble starts". (page 567)

With respect to the role of communications in failure, Kaminetzky cites two instances, where poor formal communications were to blame. Firstly, a contractor mistook lines on a drawing and consequently left out the capitals to concrete columns (The result of this omission was a punching shear failure of the associated concrete slab). The second instance involved an interpretation error of a drawing, where the dimension on reinforcing steel of 1¼" was mistakenly read as ¼". This occurred because the drafter had written the figure 1 too close to a construction line. The error was not detected by checking or construction supervision and consequently the retaining wall was constructed using ¼" steel reinforcement and collapsed as soon as it was loaded.

Kaminetzky concludes by expressing, in common with many writers from different disciplines, a view that most failures in the construction industry are the product of multiple causes.

<u>ROSS (1984)</u>

Ross analyses reports of major construction failures from the USA construction journal Engineering News Record. In common with previous authors, he concentrates mainly on the technology of the failures, but also cites as causes of failure deficiencies in technical knowledge, fraud, pressures of time, poor inspection and supervision and poor division of responsibilities.

Ross reports the occurrence of fraud in constructing pipelines in Alaska, USA in 1975. However, he notes that frauds were largely **induced** by technical failures and pressure of time - an observation suggesting that errors may be driven by other wider or more remote factors.

As with Kaminetzky, Ross emphasises the importance of clear cut divisions of responsibilities. He quotes C H Thornton, president of Lev Zetlin Associates Incorporated (investigating forensic engineers) from an Engineering News Record report of 9/4/84 on the Hartford Coliseum (USA) roof collapse of 1978,:-

> "... that the incompatibility of building systems due to a lack of co-ordination among members of the building team are behind most exterior wall and enclosure failures" (page 297)

He continues by recommending better education of architects and engineers in the co-ordination of building systems.

SCOTT (1976)

Scott follows the format of the previous authors in analysing construction failures in the United Kingdom. Again, he concentrates predominantly on the technology concerned, but makes some reference to the human error cause of failure. Causes listed include lack of individual technical skill, lack of checking or inspection, poor division of responsibilities, the use of concurrent working, poor communications and pressure of time.

Scott also questions the effectiveness of checking, in suggesting that checks and inspections should be unannounced and random. In common with Kaminetzky, he notes confusions of responsibilities as a cause of specific failures and reports the recommendations of the committee examining the Ferrybridge C Power Station Cooling Tower collapse of 1972, which advocated:-

> "The establishment of clearly nominated areas of responsibility in future contracts between specification, design, and construction for each of the parties involved". (page 154)

Scott later comments on the practice of concurrent working, where normally sequential activities such as design and construction are allowed to overlap. He notes recommendations of the report into the Milford Haven Box Girder Bridge collapse of 1972, which included that:-

> "checks and designs (should be) completed before work starts". (page 149)

2.3 MONOGRAPHS PARTICULARLY DIRECTED TO HUMAN ERROR

Whilst also reviewing technological causes in many case studies of disasters, two authors from a technological background have paid particular attention to the role of human errors in failures.

PETROSKI (1985), (1994A) (1994B)

Petroski, in two major works (1985) (1994B) examines the nature of error in a civil and structural engineering context related mainly, but not exclusively to construction. In common with the "disaster" authors reviewed above, Petroski cites errors in connection with major failures, including poor checking, poor change control, concurrent working, poor communications, constrained costs and pressures of time. However, he provides a more detailed analysis of the considerations underlying these lapses.

Petroski stands out among engineering writers in pointing out that errors have a beneficial function in the development of technology. Examining the case histories of previous construction failures, he notes the role of error in innovation and quotes the 19th century engineer Brunel's view of the Royal Commission of 1847 (examining the use of iron in railway structures) as "the commission for stopping further improvements in bridge building". This Royal Commission was set up, after several bridge collapses, to suggest improvements to design by reducing the scope for error.

Petroski is also notable among technologists in distinguishing <u>latent</u> from <u>active</u> failures, a distinction noted independently by authors from the perspectives of psychology and safety engineering and to recur in this research. In discussing latent failure Petroski (1994B) points out:-

> "the absence of failure does not prove that a design is flawless, for a latent failure mode may be triggered by yet-unexperienced conditions" (page 160)

Coupled with this insight is Petroski's (1994A) observation that case histories of major disasters focused on technological and individual factors are often ineffective as they provide:-

> "lessons....(that are).... so specific as to seem hardly relevant to anything but a clone of the failed design" (page 52)

Exceptions listed by Petroski include the Space Shuttle "Challenger" investigations, which explored:-

> "in considerable detail the <u>management-engineer interface</u>". (page 52)

Petroski (1994B) does not decry measures of error control such as checking, but, as with earlier authors, notes their limitations. The problem of checkers making the same mistakes as the perpetrator of an error he expresses thus:-

> "It is the function of checking, whether by the original designer or by peers, to catch the omission of a critical calculation, the lapse in logic, the error in analysis, or the mistake in mathematics. But too often the process of checking - an integral component of the design process itself - is myopic. The original designer can continue to overlook the same errors of commission or omission, and the peer can nod at the faulty logic" (page 27)

On change, Petroski (1985) notes that a cause of the Hyatt Regency Hotel walkway collapse (Kansas USA, 17/7/1981) was an uncontrolled change to a detail of the construction (Petroski added that the original details were considered un-buildable and quotes the Engineering News Record report that "a detail that begs a change cannot be completely without blame when the change is made" (page 89) [2]).

Petroski later (1994B) summarises some of the key elements in change control in a review of Galileo's "Dialogues Concerning Two New Sciences" (Galileo 1954). Petroski quotes Galileo's story of the provision of an intermediate support to a stone column laid horizontally in storage. Differential settlement of the three supports led to the cracking of the column, contrary to the expectation that three supports would be an improvement. Petroski remarks:-

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[2] The same quote is also cited by Ross (1984) who attributes it to a letter published in ENR from John Peterson, Department of Civil Engineering, Oregon State University, Corvallis, Oregon, USA and dated 17/9/84

> "Good practice dictates that the checker discusses his proposed design change with his peers and superiors to be sure that he is not overlooking something in what seems to be a clear improvement, and good practice also requires that he has the change approved by the engineer in charge. He presents his proposed change to them, and they all agree it seems an excellent idea. Thus the third support is added". (page 37)

Presumably, had this procedure been followed in Galileo's example, the third support would <u>not</u> have been added. In relating the story of the marble column to current practice Petroski (1994B) adds:-

> "A knowledge of the story of Gallileo and the marble column and an appreciation of its implications for checking design changes might have alerted someone involved with the (Kansas) walkway design that here was a detail to be checked anew" (page 37)

Petroski (1985) cites pressure of time as a cause of error, but also quotes the view of the US House of Representatives Committee on Science and Technology (1983) that “fast track” construction was a "least significant factor" in preventing structural accidents from happening (“Fast track” construction is a technique for saving time by running some operations, particularly design and construction concurrently). The apparent contradiction between the view that pressure of time is a cause of error, but that fast tracking is not significant suggests that some other factor, perhaps related to how the concurrency involved in fast tracking is handled, intervenes to confound a direct relationship between time and errors. This possibility is addressed by authors of major interdisciplinary reports and quality assurance monographs[3] [4].

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[3] ACSNI (1993), Oakland (1993)

[4] The benefits of fast tracking remain contentious - see Tighe (1991) for a critique of the process.

In emphasising the importance of communications, Petroski (1985) again quotes the US House of Representatives Committee on Science and Technology (1983) who listed "communications and organisation in the construction industry" first among the six factors they considered critical in avoiding construction failures.

KLETZ (1985), (1992), (1993)

Kletz is a chemical engineer, writing about safety in the chemical and process engineering industries. In common with the construction based authors cited above, Kletz notes the role in errors of inspection, defining responsibilities, communications and cost pressures. Unlike some of the above authors, Kletz (1985) plays down the importance of the technical knowledge of the individual:-

> "Lack of knowledge is not the main problem (in accident situations). The main problem is that we do not use the knowledge we have. Accidents, with few exceptions, are not caused by lack of knowledge, but by a failure to use the knowledge that is available". (page 5)

He suggests that there are severe limitations in either changing the behaviour of individuals to avoid making errors, or in blaming operatives for many errors. Regarding the former Kletz (1985) notes:-

> "instead of trying to persuade people not to make mistakes, we should accept people as we find them and try to remove opportunities for error by changing the work situation, that is, the plant or equipment design or the method of working. Alternatively, we can mitigate the consequences of error or provide opportunities for recovery". (page 1)

Regarding the latter, Kletz (1992) tempers accusations of ignorance and lack of skills made by many authors. Of the operatives who designed and installed a temporary pipe that subsequently ruptured and precipitated the 1974 Flixborough disaster (which killed 28 people) he comments:-

> "The men charged with the task of making and installing the temporary pipe had great practical experience and drive....but they did not realise that the pipe and its supports should have been designed by an expert in piping design". (page 360)

Kletz noted that the underlying causes were un-controlled changes and lack of management support[5].

He also is one of few writers in the area of human error to consider the possibility of selecting individuals to remove “error inducing traits”, which he dismisses as being both impossible and undesirable. He notes that weeding out the forgetful might "leave people who cause accidents for another reason" quoting in support research by Swain (1973).

Although Kletz (1985) generally supports the value of checking, he also notes its limitations, in particular in connection with watching and checking for rare events. He reports an accident caused by a railway signalman's failure to confirm that a "train was complete by checking the tail lights":-

> "it is difficult for anyone to realise that an event that has never occurred in 25 years has in fact just happened". (page 53)

[5] In support of the contention that blaming failures on human errors is misleading, Kletz quotes Hurst (1976), who suggests that “real” pilot error is only to blame for 1-2% of aircraft accidents, not the 60% often quoted.

With respect to the role of communications in error, Kletz (1985) particularly stresses the importance of informal communications in reporting two specific failures, the collapse of the West Gate Bridge, Victoria, Australia (a box girder bridge) and the construction of the walls to a compressor house. For the former, Kletz wrote:-

> "No one told (the construction team) that (box girder) components must not be forced together, if they do not fit they must be modified. The consulting engineers made no attempt to ensure the contractors understood the design philosophy and that traditional methods of construction could not be used. Nor did they check the construction to see that it was carried out with sufficient care". (page 38)

The last sentence illustrates the close link between some failures of communication with failures in checking. In this case, checking appeared not to be to detect "culpable" errors, but to ensure that the construction team were adequately informed. The second instance reported was that of the walls to a compressor house being built <u>too strongly</u> to blow out in the event of an explosion[6]:-

> "In this case a construction engineer, not just a construction worker, failed to follow the design. He did not understand, <u>and had probably not been told</u>, the reason for the unusual design". (page 97)

Kletz (1985) also comments on cost pressures and conflicts between safety and profitability in process engineering. He notes contradictions between first cost and costs-in-use (in advocating greater capital expenditure to reduce errors and hence costs in maintenance) and records the instance of an explosion and fire occurring because of a desire to increase production by bypassing safety trips.

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[6] This is desirable in order to relieve pressure and reduce the impact of an explosion.

Finally, Kletz (1992) in common with Petroski, but unlike most technologists, proposes a model of accident investigation, which suggests that errors may have underlying or hidden causes:-

> "Accident investigation is like peeling an onion. Beneath each layer of causes and recommendations lie other layers. The outer layers deal with the immediate technical causes, the middle layers with ways of avoiding the hazards and the inner layers with the underlying weaknesses in the management system". (page 356)

This view of error formation, whilst unusual in literature from authors from a technological background, is echoed in writing, reviewed later, from psychology, reliability engineering and systems safety.

2.4 RESEARCH REPORTS AND CASE STUDIES ON HUMAN ERROR

Several authors, from a technological background, report research projects, case studies and their technical experience in human error and related subjects. The more significant of these are reviewed separately below, with the balance reviewed collectively at the end.

THE UNIVERSITY OF NEWCASTLE, AUSTRALIA RESEARCH

Mark Stewart and Robert Melchers, of the University of Newcastle, Australia have devoted considerable attention to the occurrence of human error in the design and supervision of reinforced concrete structural elements. From this work they suggest that the majority of structural failures are due to gross human error, with design and construction error as the dominant causes of these failures. Stewart (1995) adds, however, that most errors are related to reductions in serviceability and not catastrophic failure, thus, supporting the direction of this study in relating it to defects.

They give both a definition for human error generally:-

> "a human action that exceeds some limit of acceptability" (Stewart 1993, page 278)

And for human errors in a structural design context:-

> "A human error in the structural design context may be defined as an event or process that departs from commonly accepted competent professional practice". (Stewart and Melchers 1988, page285)

The main thrust of their work is directed to examining the effectiveness of checking. Melchers (1989) reports error rates on modelled structural engineering tasks of up to 14% without considering self checking effects and known design code ambiguities and Stewart (1994) notes that the cost of re-work amounts to approximately 5% of total construction costs. Stewart (1993), in attempting to quantify failure for various levels of checking, reports that the probability of failure with self checked design and unsupervised (by engineer) construction as 239 times higher than checked and supervised design.

Stewart (1993) also reports that errors remaining after engineering inspections of contractors work amounted to approximately 1.7% of the initial errors, thus confirming the effectiveness of independent checking of contractor's work. For design checking, Stewart noted that one check reduced errors by 80% and two checks by 95%. Stewart concluded by postulating that:-

> "It is reasonable to assume that a single (independent) design check and engineering inspections constitute a realistic error control strategy..." (Stewart 1993, page 290)

Both Stewart (1994) and Melchers (1989) note, however, limitations of checking with Melchers reporting that it was very likely that many errors were made in practice even in structures that do not fail.

Finally, Stewart and Rosowsky (1995) are two of very few authors within the construction industry to suggest a risk analysis[7] approach to hazard identification.

ALLEN (1976, 1986, 1992)

Allen, also writing from an engineering perspective, notes that human error predominates in the generation of defects and failings. His main theme is, by drawing on the work of DeBono (1971, 1976), to point out the inevitability of error in a structural and civil engineering context. He suggests that mistakes cannot be avoided because they arise directly from the way the mind works and also notes the roles of time pressures in errors. Allen (1986) gives an indication of the reason that time pressures cause errors:-

[7] Risk analysis involves systematic analysis of complex processes in order to identify weak elements. Two techniques are commonly used, fault trees, where a fault in a component or procedure is traced forwards to discover its consequences, and event trees, where an undesired event is traced backwards to identify all likely causes (see also Chapter 4, section 4.3)

> "A useful experiment to show up the errors in the thinking process is to try to do things in a great hurry. More mistakes occur because our actions are based on internal patterns triggered off by incomplete information - no time to puzzle over it and fully understand it". (page 4)

Finally, Allen (1986) notes unclear drawings and inadequate construction procedures as causes of error.

HADIPRIONO (1985) , HADIPRIONO AND TAHIR (1990)

Hadipriono (1985) in an extensive review of press reported failures of bridges, low rise and multi-storey building and plant and industrial buildings, found design and construction defects roughly evenly split, with defects in materials and maintenance as a much smaller category. "External" failures in use were also a substantial category, but only for bridge and plant/industrial building failures.

In reviewing these failures, he divides their causes into two broad categories, "enabling" as opposed to "triggering". The enabling cause is an event inherent in a structure due to design, construction, or maintenance deficiencies. The triggering cause is "an external event, such as a vehicle collision, impact or explosion, that could initiate a structural failure". This division of causes parallels the distinction made by Petrosky between active and latent error causes.

Both Hadipriono and Hadipriono and Tahir cite as causes of failures, errors in checking, including particularly design checking, together with failures of independent inspection of construction. In addition, cost pressures, poor communications and confusions of responsibilities are noted as causes. Hadipriono (1985) emphasises confusions of responsibilities at:-

> "Contractor - sub-contractor - construction manager - design engineer - architect - owner's representative, interfaces". (page 1478)

In avoiding such confusions, Hadipriono and Tahir (1990) advocate continuity of the design concept by the designer and owner.

Hadipriono (1985) also implicates changes, discontinuities, and losses of design concepts as causes of failure and gives the example of the 1978 Hartford, Connecticut, USA roof collapse, where a change in the bracing system to improve buildability caused buckling of truss members and consequently the collapse.

BROWN AND XIAOCHEN YIN (1988)

Brown and Xiaochen Yin also review press reported failures from a structural design perspective and in so doing note both the inevitability of error and that, for most major failures, more than one individual error is involved. They note the role in errors leading to failures of poor checking procedures, poor division of responsibilities, poor communications (particularly through the medium of drawings), inadequate funding of both fees and construction, compressed time schedules, the economic climate and social/cultural pressures.

On the last influence, Brown and Xiaochen Yin list amongst factors affecting the likelihood of errors occurring, human conditions, including social origin, cultural background and education. They also note factors "external to the building process of "the political system" and "social conditions".

In common with Petrosky, they suggest that there are benefits with errors and that, to a certain extent errors should be tolerated.

ELDUKAIR AND AYYUB (1991)

Eldukair and Ayyub also analyse press reported defects and failures and conclude that human error predominates in the generation of defects and failings. Whilst also citing individual factors, poor checking and supervision, poor communications (particularly between architects, engineers and contractors), costs and social constraints, they follow Petrosky and Hadipriono in proposing that errors can have latent and active elements. They extend their analysis to propose a multi-layered structure of error influences, dividing failure causes initially into natural and man made hazards, variations within common practices and departure from common practices. Later they attribute the causes of a large number of failure cases as shown in Table 2.1:-

TABLE 2.1 CAUSES OF FAILURE
(Eldukair and Ayyub 1991)

Personality	Percentage of failure cases
Project architect	3
Structural engineer	48.2
Resident engineer	31.1
Inspector	27.6
Contractor (head office)	3.8
Contractor (site staff/supervision)	59.6
Contractor (workmen)	17.4
Operator (e.g. crane)	2.8

(some overlaps involved)

Analysing the cause of failures further, the authors classify error into:-

Primary cause - covering the technical causes of the failure such as "poor erection procedures" These were cited in 54.3% of failures.

Secondary cause - covering managerial reasons for failure such as the "lack of supervision and control". These were cited in 36.6% of failure cases. These were cited as the possible underlying reason for failure.

They further report that deficiencies in the division of work responsibilities contribute to about 30% of cases. These deficiencies were the dominant "management" cause of failure. In addition, they implicate financial pressure in 11.6% of reported cases, noting that cost constrained maintenance programmes were cited in 52.3% of cases of bridge failures. Finally, they note that "environmental errors" were implicated in 56.1% of cases, within which political pressures influenced 10.4%.

DAOUD AND HAMDANI (1988)

Daoud and Hamdani report research into the incidence of mistakes in construction in the Gulf region and note problems of poor supervision and inspection procedures, inadequate division of responsibilities, poorly controlled changes in the form of variations and poor communications generally. In particular, they cite the lack of a clear understanding of the rights and responsibilities of each party to a project as a major sources of problems in construction. They also note "changes in personnel as the work progresses" and later in their paper they generally implicate failures in "quality assurance, checking/review systems, tolerance levels, related to variations".

ROLLINGS AND ROLLINGS (1991)

Rollings and Rollings are concerned with defects related to the construction of airfield pavements. They echo points made above concerning the preponderance of errors as the cause of defects and point out causes related to the individual (expressed as "ignorance", or "laziness, greed, fraud and pride"), poor checking, poor communications, constrained costs and time pressures.

They particularly cite inadequacies in formal communication tools, including the use of inadequate specifications, blindly lifted from past projects and including outdated materials. They comment that blindly following standard details, where an unexpected condition exists, can lead to error. With respect to cost pressures they note that:-

> "Poor quality work achieved at a cheap price is definitely a functional failure". (page 282)

JONES AND NATHAN (1990)

Jones and Nathan analyse the failure of a supermarket roof in Burnaby, British Columbia, Canada and quote extensively from the Canadian Government report on the failure (Government of British Columbia, 1988). They note that the collapse was the result of multiple causes and cite checking errors, concurrent working, poor division of responsibilities, lack of control of changes, cost and time pressures.

In common with other authors, including Petrosky (1985), they note the limitations of checking, in particular the fact that checkers in this instance made some of the same mistakes as the original perpetrators of errors. Jones and Nathan (1990) also cite, as a cause of the collapse, confused responsibilities:-

> "among owner, project manager, prime consultant, architect, structural engineer, and even tenant" (page 155)

They further note that the checking process, in itself introduced to reduce error, may actually have led to divided responsibility (by shifting some responsibility from perpetrator to checker).

Jones and Nathan (1990) also note the effect of change on the project, where an increase in concrete slab thickness contributed to the collapse of the roof, and problems of "obscure" communications. They report the Commission recommendations (Government of British Columbia, 1988) that engineering structural calculations be submitted with drawings and specification when applying for a building permit. These calculations would become a "public document", subject to review "for legitimate reasons" in order to "stiffen the standards of care of the poorly organised engineer". The recommendations have a parallel with the suggestions of writers from psychology reviewed later, that communication links should be visible.

On the subject of cost pressures, Jones and Nathan consider that bidding for professional services contributed to the collapse. They again quote the Commission findings, that structural engineers should be made to carry professional liability insurance and use a schedule of minimum fees.

BUILDING RESEARCH ESTABLISHMENT STUDIES

Since 1980, the United Kingdom Building Research Establishment has conducted a number of studies of defects arising on building sites, which give some insight to human error causes. Griffin (1990) in conducting a large survey of 116 Local Authorities, concentrates largely on technical causes, with only passing reference to error related causes. He does, however, note multiple occurrences of defects, implying a lack of knowledge transfer underlying their cause. He suggests that an increased number of defects occurring between the years 1983 and 1989 might similarly be because advice given in guidance publications was not being used. Finally, he notes the need for new working practices to meet the demands of changing technology, but without spelling out the desired practices.

Bonshor and Harrison (1982A, 1982B, 1982C, 1982D) report studies of 15 traditionally built housing projects in order to determine the origin of faults in construction. They adopt a classification of origin as follows:-

- Design
- Specification
- Materials
- Site
- Shared (design/site/specification)
- Other

Of these, site origins predominate. However, when design documentation as a whole is considered (design, specification and some shared causes), this was the largest category of cause. Bonshor and Harrison (1983A) estimate the cost of faults and report that the extra cost of a correct detail (in the first place) is on average only about one-fifth of the cost of an adequate (later) remedy for a defective detail. They conclude by commenting on the contributions to faults of skill, care, supervision and design/site interface problems. They link these contributions by noting that there is no single action which could remove the problem of faults in construction.

Harrison (1993) updates Bonshor and Harrison (1983A) in an observational study of 18 housing schemes. He uses the same classification as the earlier study and, in analysing 976 faults, finds a similar preponderance of those originating from site. Whilst faults originating from design and specification continued to form a large proportion of all faults, in this study the combined total of design, specification and other faults was still less than faults originating from the sites. Harrison suggests that this lower proportion of design faults compared with the earlier study may simply be because less sets of working drawings were examined. Much of the study concentrates on the technical causes of defects classified by element or by types of technical performance failure. In passing, however, he mentions the continuing occurrence of faults detected in the earlier study, suggesting that poor knowledge transfer is behind many faults. He also notes the need for greater care as a result of the greater complexity of modern building.

Bentley (1981) reports observational site studies of 27 non-housing construction projects, concentrating on observing the site activities of clerks of works and site managers. He recorded "quality related events" (events causing the "clerks of works, site managers, architects or tradesmen to pause in their work and consider the quality or 'rightness' of the building" (page 1)) These he categorises into 13 causes:-

Workmanship

- Lack of skill
- Lack of care
- Lack of knowledge
- Poor planning by tradesman
- Poor contractor's organisation
- No protection of completed work

Aspects of design or project information

- No co-ordination of design
- Difficult to build
- Design will not work
- Unclear/missing project information
- Low quality design
- Designer not understanding materials

Of these, lack of care by tradesmen and unclear/missing project information rank as the largest two categories, accounting for 42% of all quality related events. The categorisation mixes technical and managerial causes, but in further qualitative analysis, Bentley sheds some light on human error related causes. He notes that problems often resulted from more than one cause, that division of responsibilities and the associated roles adopted by project participants were important in avoiding problems and that time and cost pressures were influential. He notes that planning, inspection, checking and consultation were important functions of site managers on well run sites and suggests that:-

> "A co-operative clerk of works/site agent team could do much to maintain good quality, particularly where their combined technical knowledge and experience were a good match to the needs of the job" (page 4).

Bentley notes the importance of detailed inspection as an essential part of a quality control system, but suggests that it will, not of itself produce good quality work. Rather, he emphasises project management functions particularly related to communications. He further notes that on sites achieving satisfactory levels of quality the project culture was marked by commitment to the job and a high level of consultation between everyone concerned:-

> "Sites with acceptable quality standards tended to be characterised by a 'consultative' approach to problem solving - anyone on site could raise questions and many individuals could contribute to solutions" (page 6)

In contrast, Bentley reports a site with very poor perceived quality:-

> "On this site there was a lack of effective management coupled with extremely poor project information (often incomplete and sometimes incomprehensible). Everyone was performing strictly within the limitations of their formal role. The clerk of works was dealing with problems alone, with little consultation with

> trades' foremen or the agent. The architect was reluctant to visit the site. When he did he was inundated with queries arising from the drawings".

Bentley concludes by noting that in general, quality standards on site did not rely significantly on formal checking and acceptance or rejection of completed work. Rather they resulted from the efforts of site managers and clerks of works concentrating on an "environment where good work could and was likely to take place" (page 6).

OTHER AUTHORS

Several other monographs and reports of research projects or case studies consider human error from a technological point of view. These include Bartholomew (1987) who is concerned with the performance of smaller projects, Chadwick (1986), concerned with construction project quality, Dea and Gans (1986), concerned with procedures in improving project controls and several authors who are largely concerned with error in connection with either forensic engineering, defect analysis, or the performance of completed buildings[8].

In addition Mills, Denis Associates (1988A, 1988B), writing a restricted circulation report concerning building defects for the UK Association of Building Component Manufacturers, Korman (1991A, 1991B and 1991C), in editorials for the Engineering

[8] Including Addleson (1977, 1992), Blockley (1977), Ellingwood (1987), Ferry Borges (1990) Frangipol (1987), Freeman (1975), Garratt (1978),Gnaedinger (1987), Harris and Chaney (1969), Knoll (1982), Lamb (1985), Lew (1984), Matousek (1982, 1992), Nowak and Tabsh (1988), Patterson (1984), Porteous (1992), Peck (1981), Ransom (1994), Robson (1978), Sanchez-Silva et al (1996), Scott (1986) Smith (1976, 1977), Sowers (1993) Sriskandan (1986).

News Record, and an editorial for the ASCE (1978) journal "Civil Engineering" make several points related to human error.

Common contentions in these works, echoing points made above, include agreement that human error is involved in the majority of defects and failures (Blockley 1977, Frangopol 1987, Harris and Chaney 1969, Knoll 1982, Lew 1984, Matousek 1982, Nowak and Tabsh 1988, Peck 1981, Sowers 1993, Sriskandan 1986), that error causes can be divided into active and latent components and modelled in terms of primary and secondary factors (Chadwick 1986, Ellingwood 1987, Matousek 1992), that error occurrence is inevitable (Nowak and Tabsh 1988) and that failure has multiple causes (Sanchez-Silva et al 1996).

Sriskandan (1986) points out the role of selection of the individual in avoiding errors and Lew (1984), Ellingwood, (1987), Mills, Denis Associations (1988A, 1988B) and Ransom (1994) note the importance of checking.

Ellingwood (1987) repeats comments noted above that checking is only partially effective, particularly for gross errors. This is because they are too rare to be easily noticed and consequently likely to slip through the process. The similarity with comments made by Kletz (1985) reported above, from a chemical engineering perspective, is notable.

The ASCE (1978), Chadwick (1986), Ferry Borges (1990), Nowak and Tabsh (1988) and Lew (1984) repeat arguments that errors can to a certain extent be tolerated, with both Ferry Borges and Nowak and Tabsh suggesting a differentiated approach to checking. The latter suggests the use of sensitivity analyses to direct attention to the most critical elements of structures.

Poor divisions of responsibility are noted as a cause of error by Ellingwood (1987, Mills, Denis Associates (1988A), Ferry Borges (1990) Sriskandan (1986), Gnaedinger (1987), Robson (1978) and Chadwick (1986). An illustration of the problem of confused responsibilities is provided by Korman's report of a US Court case (Korman 1991B), concerning defects at the (then) newly constructed Stamford, Connecticut, USA train station (Wilbur Smith and Associates vs the US Justice Department). Confused responsibilities were given some prominence in the article. The divided responsibility between designers was particularly noted:-

- Concept design - Skidmore, Owings and Merril.
- Prime architect/engineer/program manager - DeLeuw, Cather, Parsons
- Designer of record - Wilbur Smith Associates
- Construction manager - Sverdrup and Parcel
- General contractor - O and G Industries.

Korman further quotes structural engineering witness C.H. Thornton, who was appearing on behalf of a defendant:-

> "When you take the person who conceived the design away from the shop drawing review you generally end up with a disaster". (page 9)

Change as a cause of error is cited by Chadwick (1986), Lamb (1985), Scott (1986), Smith (1976, 1977) and Sriskandan (1986). Chadwick (1986) advocates the use of “change control” namely requiring that changes have approval from the owner and engineer, according to the criteria:-

1 Would the change be cost effective and not delay work elsewhere?-

2 Would (any) related system operate safely (and in the nuclear power industry, would it be licensable).

Change control is a technique drawn from general project management (Archibald 1976, Morris 1994 - see Chapter 4) and its use in connection with construction errors is reinforced by Chevin (1993), who notes the value of controlling changes at the design stage of a project.

Ellingwood (1987) and Chadwick (1986) both note and criticise the practice of concurrency and make recommendations including the provision of detailed plans using critical path planning and work breakdown structures and adequate control points to assess completion of previous steps in construction programmes.

Problems concerning communications are noted by Bartholomew (1987), Lew (1984), Mills, Denis Associates (1988A 1988B), Korman (1991A 1991B), Ellingwood (1987), Porteous (1992) and Dea and Gans (1986). Lew (1984) notes the collapse of a cooling tower at Willow Island, West Virginia, USA in 1978, where no guidelines concerning erection of the tower were given by the design engineers to the contractors and the site foreman was left to make the decision of when to remove formwork. Korman (1991B), in reporting the US Court case mentioned above quotes the construction manager concerned, in criticising "flawed contract documentation".

Chadwick (1986), Bartholomew (1987), Robson (1978), Mills, Denis Associates (1988A) and Gnaedinger (1987) note the role of cost pressure in error occurrence and Mills, Denis Associates (1988A) and Korman (1991A, 1991B) also point out the role of pressure of time. Mills, Denis Associates (1988A) also point out pressure in the form of the excess demands of clients. They note that over half of claims brought against architects arise from the lack of a proper appointment contract and the consequent confusion over client expectations.

2.5 CONCLUSIONS

Some common themes are revealed in the above literature. Many authors including Kletz (1985), Allen (1986), Nowak and Tabsh (1988) and Stewart (1991) point out that human error causes predominate in failures in construction. Some suggest that errors are inevitable (Kletz (1985), Nowak and Tabsh (1988), or indeed beneficial (Petroski 1985).

Kaminetzky (1991), Harrison (1993) and Sanchez-Silva et al (1996) are examples of authors indicating that errors leading to failure have multiple causes and both Petroski (1994B) and Kletz (1985) further consider the **latent** and **active** components in error formation. Petroski in particular notes the value of considering the "management-engineering" interface in any failure investigations. Hadipriono (1985), Hadipriono and Tahir (1990), Eldukair and Ayyub (1991), Chadwick (1986) and Ellingwood (1987) are all authors who develop the concept of latent and active components of error formation in considering "enabling" or "triggering", or "primary" and "secondary" causes. This consideration ties in with the detailed analysis in the technologically based literature, where managerial causes including poor division of responsibilities and lack of control of changes are regularly indicted.

In examining the causes given for errors in greater detail, they can be grouped into three broad bands. Firstly, factors of lack of technical knowledge, fraud and negligence expressed in terms such as "laziness, greed, fraud and pride" (Rollings and Rollings 1991) are widely cited. To this can be added poor selection of technical personnel and lack of adequate self checking. These causes appear to be related to the identity and qualities of the individual error perpetrator.

Secondly, causes related to failures in detailed project management feature large in forensic engineering and case study reports. These failures relate to checking, poorly divided responsibilities, change, the use of concurrent working, and poor communications (both formal and informal).

Thirdly, causes related to driving factors of constrained costs and time are noted by many authors, with some also noting more general factors related to "cultural" (Brown and Xiaochen Yin 1988, Bentley 1981) or "societal" (Pepperell 1987) demands

3

A SOCIAL SCIENCE PERSPECTIVE ON ERROR

3.1 INTRODUCTION

The two social sciences most concerned with human error are psychology and sociology. Their main interest is related to errors leading to accidents and major failure, rather than defects and their work spans a range of industries where, generally, the consequences of error have been or could be seen to be extremely severe.

3.2 PSYCHOLOGY

A number of authors writing from the perspective of psychology have given particular attention to human error. Most notable in the field of cognitive psychology (summarised as the study of the thinking process of the mind (Eysenck and Keane 1990)) are Rasmussen (1983, 1987, 1990), Reason (1987, 1990, 1991), Norman (1988) and Lourens (1989, 1990). Contributions from behaviourism (centred on the study of stimuli and responses (Sutherland 1991)) include Duff et al (1993, 1994).

RASMUSSEN (1983, ET AL 1987, 1990)

Rasmussen's contribution to thinking on human error centres on the synthesis of a widely cited typology for error causes at the level of the individual. Rasmussen (1983) divides errors into three types:-

- Skill based slips and lapses
- Rule based errors
- Knowledge based errors

Skill based slips and lapses stem from the mechanism of the mind for dealing with routine activities. These operate at the automatic level of information processing within the mind.

Rule based errors stem from another mechanism for dealing with routine performance. For often repeated actions requiring some cognitive input, there is a tendency for the individual to apply rules that have worked in the past. Errors occur in situations of informational overload (where a wrong rule may be applied in panic), of the first "exception" to a rule which has always worked in the past (the so-called "strong but wrong" rule) and of rigidity (where an old rule may be applied inappropriately).

Knowledge based errors result from faults in the deliberate thinking process required for problem solving. Knowledge based thinking is very resource intensive and is restricted by such factors as limitations on the capacity of the mind as a processor (so-called workspace limitations), selectivity (where attention is selectively given to the wrong feature), inattention to unseen problems (so-called "out of sight, out of mind" phenomena) and overconfidence.

Rasmussen (1987) defines error with reference to internal goals as:-

> "an act that is counter productive with respect to the person's (private or subjective) intentions or goals". (page 293)

This contrasts with definitions from the technological writers, in that it relates errors to subjective and not to objective intentions such as the "commonly accepted competent professional practice" used as a measure by Stewart (1993). The effect of this more restricted definition is that Rasmussen tends not to consider as errors those which meet subjective intentions, but still fail to meet objective criteria (in other words, errors related to ignorance, fraud and negligence are excluded).

However, Rasmussen (1987[9], 1990) does give considerable attention to wider considerations than the internal workings of the mind. In common with Petroski (1994B), Rasmussen (1990) decries highly specific analyses of accidents in suggesting:-

> "we should be fighting types of accident causation, not these individual tokens". (page 1190)

He also gives reasons why managerial factors should be considered in error occurrence. He considers that an inadequate response from operators depends on conditioning taking place during normal work. The conditioning is performed by the conscious decisions made by work planners or managers, but, in the context of accident analysis, the actions and decisions of managers were easily missed. This

[9] Leplat and Rasmussen (1987)

demands that accident analysis should examine more closely the concept of responsibility for error and pursue errors further up the managerial hierarchy.

Rasmussen (Leplat and Rasmussen, 1987), in common with Stewart and Rosowsky (1995), suggests a risk analysis[10] approach to hazards, but later (Rasmussen 1990) tends to play this down by pointing out that modern workplaces are more dynamic than traditional work environments and involve more supervisory tasks, decision making, diagnosis and contingency planning - tasks which are not amenable to risk analysis techniques.

REASON (1987, 1990, 1991)

Reason (1990) draws on Rasmussen's (1983) typology of errors, but gives much more attention to wider causes. He provides a similar definition of error, again restricting errors to the unintentional, but he gives some attention to violations (classed as unintended, sabotage and partly deliberate). However, his definition still excludes deliberate frauds and negligence.

In common with Kletz (1985) and Nowak and Tabsh (1988), Reason considers that errors are inevitable and provides a psychological perspective of the benefits of error, complimenting that of Petroski (1985):-

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[10] See footnote 25 on page 104

> "Errors are the inevitable and usually acceptable price human beings have to pay for their remarkable ability to cope with very difficult informational tasks quickly and ...effectively". (page 148)
>
> "Human fallibility has its origin in useful and adaptive processes. In particular, they arise from a natural tendency to minimise cognitive strain". (page 148)

He repeats the view that failures are usually the result of multiple errors, and notes the converse that error avoidance relies on multiple measures.

Reason (1990) gives considerable attention to cognitive processes that impede error detection at the level of the individual. These include relevance bias, where the individual is selective in considering solutions, relying on partial explanations and desensitisation to discrepancies between the real "world" and "mental" model in the mind. Errors of omission figure large in surveys noted by Reason and forgetting intentions is a common form of lapse. To avoid errors, Reason suggests self-monitoring, training (especially training which allowed subjects to make errors) and feedback. However, he notes that training has limitations and comments that most errors, being an intrinsic part of mental functioning, cannot be eliminated by training.

Reason(1990) parallels Petrosky and Kletz in making a distinction between <u>latent</u> and <u>active</u> errors. Latent errors are those made in the design, management or supervision of a system, which, of themselves, do not serve to cause a failure, but which could contribute. Drawing on a review of industrial accidents, he considers that latent errors are assuming greater significance:-

> "Close examination of 6 case studies...indicate that latent rather than active failures now pose the greatest threat to the safety of high technology systems" (page xi)

Reason later develops this distinction between latent and active errors in proposing a "resident pathogen metaphor" - latent defects in a system waiting for a combination of circumstances to occur. In making the distinction, Reason (1991) (quoted in Bea 1994 at page 222) implicates managerial factors and emphasises the influence of more senior managers over error occurrence:-

> "The higher a person's position within the decision making structure of the organisation, the greater is his or her potential for spawning pathogens".

Although implicating managerial factors in errors, Reason, unlike the "technological" writers, is not specific as to exact cause. He notes the benefits of independent checking and suggests that some diagnostic errors are only detectable by others (diagnostic errors involve conscious processing analogous to construction design), and also criticises self checking in reporting research into nuclear power accidents by Woods (1984):-

> "Whereas half the execution failures were detected by the crews themselves, <u>none</u> of the diagnostic errors were noticed by the operators who made them. They were only discovered by 'fresh eyes'- nearly ¾ of all errors remained undetected". (page 164)

Later, however, Reason (1990), encapsulates in the phrase "the Catch 22 of Human Supervisory Control" the dilemma of trying to make human operators into rare event checkers, thus closely following points made by Kletz (1985) and Ellingwood (1987), that checking for rare or gross error can be ineffective. He also comments on financial pressure as a cause of error and suggests that senior management might put profits before safety because they are making choices between profit/safety on the basis that profits are relatively certain, objective and favourable, whereas safety investment was based on probabilities of outcome (an event may never occur), does not always involve objective assessment and incurs cost.

Reason gives some attention to institutional attitudes, cultural issues and social pressures and lists general failings of "incompetent management", "selective blindness", "conflicting goals", "reversed logic" and "fallible management structures". He quotes from Lord Justice Sheen's report on the Herald of Free Enterprise disaster[11]:-

> "the underlying, or cardinal faults lay higher up the company...from top to bottom the body corporate was infected with the disease of sloppiness". (page 193)

Reason later expands these points to discuss "organisational reasons for errors" and quotes Westrum (1988) in listing organisations as being one of three types, "pathological" (an error prone organisation), "calculative" (an organisation which performs adequately under normal conditions) and "generative" (an organisation which acts as a "responsive error neutraliser"). He lists "organisational responses" of "denial", "repairing" or "reforming", the last being considered less error prone than the former two types. Despite these analyses, Reason gives little specific detail of why certain organisations behaved in one or other way in error situations.

[11] Department of Transport (1987)

NORMAN (1988)

Norman reviews human error, from a psychologist's perspective, in the context of the design of artefacts. In common with authors cited above, he notes the inevitability of error and suggests measures for avoiding their occurrence, including self-monitoring, training (especially training which allows subjects to make errors) and feedback. He suggests, without spelling out detail, principles for "transforming difficult tasks into simple ones" including:-

- Making things visible
- Bridging the gulfs between execution and evaluation
- Getting the mappings right

Points related to visibility of actions and communications have parallels in comments made by technologists including Jones and Nathan (1990).

Norman cites a number of serious industrial accidents caused by design deficiencies, but also notes managerial pressures in the instance of the shooting down of a Korean Air Lines flight in 1983[12]. In this incident, the inertial navigation system of the airliner could not be changed in flight and the crew would have had to return to the departure airport to reset the system. However, a contributing factor to this accident was reported to be the threat by the airline's management to "discipline" the next crew that returned prematurely to base.

[12] The aircraft strayed into airspace controlled by the USSR

LOURENS (1989, 1990)

Lourens (1990) is concerned with traffic accidents and emphasises the importance of human error in that context. He notes that:-

> "In most analyses of industrial, air traffic, and road accidents, an error by one of the operators emerges as the main, causal factor". (page 1252)

However, Lourens (1989) also suggests that definitions of human error can be flexible:-

> "According to Singleton[13], almost any accident involving a man-machine system can with equal validity be traced to inadequate machine design, inadequate training, inadequate instructions, inadequate attention, and unfortunate coincidence of relatively rare events, or just human error" (page 420)

Lourens (1990) reinforces this "flexibility" in reviewing attribution theory[14]:-

> "An overall tendency has been found to attribute what happens to other people to their personal responsibility, but to place much more emphasis on the role of external circumstances, when explaining what has happened to oneself". (page 1257)

In common with Petrosky (1985) and Reason (1990), Lourens points out the benefit of error and implies a hierarchical view of error occurrence similar to that cited by other authors. Regarding road traffic accidents, Lourens (1990) implicates wider “systemic” factors thus:-

> "The evidence that a person causes an accident by making an error is often only circumstantial and might be given too much weight because of a possible bias towards blaming the victim. As a consequence, the "therapy" most often

[13] See Singleton (1973)

[14] See Heider (1958)

> chosen as a way to reduce the number and effects of human error is to try and change the person. Selection, training, and information campaigns are preferred to structural adaptations of the system, although the results of the former are often poor". (page 1252)

<u>DUFF ET AL (1993, 1994)</u>

Duff et al concentrate on improving the safety performance of the individual by applying behavioural techniques. Duff et al (1994) reports research evaluating the benefits of using goal-setting, feedback and training techniques in improving safety on UK construction sites. The results indicated that such techniques were effective, as measured using objective assessment of safety performance, but the researchers also made comments concerning the role of management in safety:-

> "Although no attempt was made, as an integral part of the research programme, to evaluate the effect of management commitment, it became apparent that this was probably having a significant impact upon some of the results.
>
> It was evident on some sites that the site management, despite support for the project from senior company management, were not fully committed to the research activity....
>
> While the evidence is not conclusive, it does suggest that management commitment is a factor which should be objectively measured, and its effect evaluated, during any extension of this research". (Page 75)

Duff et al (1994) identify the need for research into organisational safety climate, management style and organisational structure in future work. In a postscript to the paper, the authors also recognise the role of wider causes of safety problems of poor communications (in the form of an inadequate specification) and cost pressure.

THE PSYCHOLOGICAL WRITERS - CONCLUSIONS

The contribution of authors writing about human error from the perspective of psychology is largely centred on the internal thinking process as illustrated in Rasmussen's typology of errors as skill, rule or knowledge based and definitions of human error (Rasmussen, 1987, Reason 1990) which relate to internal reference points rather than externally moderated norms. However, all authors reviewed here consider wider factors and Reason (1990), in particular, follows other authors in emphasising the **active** and **latent** component in error formation.

Unlike authors from a technological background, however, psychologists do not, by and large, indict specific managerial failures. Reason (1990) makes some reference to the behaviour of organisations and Norman (1988) refers to the need for visibility in communications. They appear to recognise the limitations of cognitive psychology in explaining the wider causes of errors, but are unable to propose specific corrective measures. In contrast, the direct citing of factors such as the poor division of responsibilities, uncontrolled changes and uncontrolled concurrent working, by the technologists is refreshingly specific. Duff et al (1994) are an exception, in that, although working from a behavioural perspective, more detailed recognition of the role of management is apparent. This probably stems from the fact that the authors are based in a school of technology and include technologists.

Paradoxically, the emphasis on managerial measures to avoid errors may introduce another branch of psychology, that related to leadership, motivation and control in the workplace and generally classed as social psychology. That branch makes little direct reference to human error, but may be more influential in improved error performance.

3.3 SOCIOLOGY

The literature related to human error written from a sociological perspective is mainly concerned with the sociology of disaster, major accident or major economic failing. The more notable in the field include Turner (1978, 1992), Perrow (1984), Sagan (1993), Collingridge (1992) and Vaughan (1990). A contrasting perspective is provided by writers from the "High Reliability Organisation" school, including Roberts (1993), Rochlin (1993) and Schulman (1993). These write, in the main, not from a disaster perspective, but from the perspective of organisations which successfully avoid errors occurring. Wilson (1989) considers specifically the accident record of the construction industry from a sociological perspective.

TURNER (1978, 1992)

Turner's main contribution to the literature on human error is in his close examination of the social context of three major disasters, the Aberfan coal tip slip of 1966, the Hixon level crossing accident of 1968 and the Summerland fire of 1973 (Turner 1978). He acknowledges that errors can have multiple causes and notes generally that disasters are caused by social and administrative as well as technical factors, but expands on this to give specific failings. He cites comments of the Tribunal investigating the Aberfan disaster[15] concerning the culture of the coal industry as including:-

> "a pervasive institutional set of attitudes, beliefs and perceptions which led to a collective neglect of the problems of safety relating to tips by almost everyone concerned". (page 54)

The components of this collective neglect he lists as including:-

- A set of industrial beliefs which gave little consideration to tips.
- Few staff appointed to deal with safety in tips.
- Organisational practices oriented away from problems of tips towards those of mines.
- Literature on tip safety was neglected or not given wide circulation.

Consequently:-

> "when decisions about the siting of new tips were being made, little or no trouble was taken over this problem". (page 55)

Referring to the Hixon level crossing disaster[16], Turner notes:-

> "the central and most distinctive contributing feature leading up to the disaster was a failure on the part of a large number of individuals in British Rail departments, in the management of road hauliers concerned and in the Ministry of Transport to bring together creatively the information which they all had, or had access to in a way which would have made clear the danger of the new crossings to a long, slow moving vehicle which was already part of the way

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[15] HMSO (1966)

[16] Where a large, slow moving lorry carrying a transformer became stuck on a level crossing in the path of an express train (See HMSO 1968).

> across an automatic half-barrier crossing when it began to close" - this was a "failure in creative problem solving". (page 55)

According to Turner, Summerland was notable for a gap in the continuity of the project between the design and construction of the shell under one design team, and the design and furnishing of the building by the lessees, employing a second design team. Factors considered by the commission of enquiry[17] included the use of informal contacts and it concluded that the underlying factors were:-

> "many human errors and failings, and it was the accumulation of these, too much reliance on an "old boy" network and some very ill-defined and poor communications which led to the disaster" (page 57)

In summarising the similarities between the Aberfan, Hixon and Summerland disasters, Turner indicates some reasons for organisational failings. He lists these as including:-

<u>Rigidities in perception and beliefs in organisational settings</u>

For example the National Coal Board view of coal tips as external to the coal mining business and the reference to fire escape stairs at Summerland as "service stairs". Quotes from the Aberfan tribunal[18] illustrates the problem:-

> "Rubbish tips are a necessary and inevitable adjunct to a coal mine, even as a dustbin is to a house, but it is plain that miners devote certainly no more attention to rubbish tips than householders do to dustbins". (page 58)
>
> "We found that many witnesses, not excluding those who were intelligent and anxious to assist us, had been oblivious of what lay before their eyes. It did not enter their consciousness. They were like moles being asked about the habits of birds". (page 58)

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[17] Isle of Man: Government Office (1974)

[18] HMSO (1966)

Turner comments:-

> "Thus there is a possibility of a vicious, self-reinforcing circle growing up where it is generally believed that an area is not important or problematic. The staff employed, therefore, are not specialists in this area, and are not employed to look at it, so that the presence of new staff serves to reinforce the beliefs which placed the new staff there". (page 58)

The decoy problem

This organisational problem consists of issues, other than the one causing a failure, deflecting institutional attention away from an issue later to cause a disaster. The example given by Turner is the possibility that the Summerland complex may not have been seen by the regulating authorities as either a conventional large building or as a conventional theatre and the appropriate regulations were not, therefore, applied. Turner suggests an "initial response" to the decoy phenomenon as to:-

> "consider whether there may not be means by which organisations can scan the problems which they do in fact deal with, and then try and look behind them to see if they are obscuring potentially dangerous ill structured problems". (page 60)

Organisational exclusivity - disregard of non-members

This problem is seen by Turner as the "organisational view" that it only need take account of matters arising from within the organisation. Turner cites, as an example of the problem, the "fobbing off" of the Aberfan Council's anxieties about coal tips by the NCB with "ambiguous and misleading statements such as 'we are constantly checking these tips'".

Remoteness of top management

Again referring to the Aberfan disaster, Turner notes:-

> "The top management of the NCB had an idealistic view of what should have happened with regard to tip safety and tip siting, but they took no action to check on it, or to check that men of the right training were available". (page 63)

Turner gives some source "internal" reasons for organisational errors based on the concept of bounded rationality as propounded by Simon (1957). The concept proposes that the extent of searching for solutions to managerial problems is "bounded" by the impossibility of reaching an optimum solution. This in turn means that managers "satisfice" in making choices (that is they choose the <u>first available satisfactory solution</u>). Satisficing in itself can, thence, lead to error[19]. He further draws on work by Lawrence and Lorsch (1969) in pointing out conflicting organisational needs for integration and diversity. In resolving these conflicting needs, a hierarchy of authority can develop, which in turn fosters a culturally determined organisational outlook, practice and knowledge. He summarises this as follows:-

> "groups of decision makers are trying to behave rationally, judging their success by means of criteria which are approved within their organisation". (page 167)

Unfortunately this behaviour might not correspond with that necessary for the effective avoidance of certain errors.

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[19] The concept of satisficing is taken up by Reason J (1987)in "Collective planning and its failures" in Rasmussen et al (1987)

Turner further lists managerial requirements in avoiding disaster under a general heading of a "creative response". This response includes:-

- Awareness
- Opportunities for managers to examine problems
- Measures to deal with organisational bias and the decoy phenomenon
- Specific consideration of "strangers" to the organisation (e.g. the public using a site, but not part of the close site organisation).

In a later work (Turner 1992) expounds four general characteristics of a good safety culture:-

- A caring organisational response to the consequences of actions/policies.
- Commitment to this response at all levels, especially senior.
- Feedback of incidents to practitioners.
- Rules and norms for handling safety problems, supported in a flexible, non-punitive manner.

Turner (1978) gives specific attention to communications problems:-

> "In situations of 'disjunct information', the simple remedy of 'better communication' will not work unless resources are increased so that the problem is no longer ill-structured, or unless the problem defined is reduced to a size which can be adequately handled by the existing information net". (page 61)

He follows up by suggesting several reasons for communications failures including:-

- Non-receipt of information
- Distortion of information

- Ambiguity of information
- Overwhelming volume of information causing:-

  Overlooking important details

  Inadvertent disregard of relevant information
- Lack of an overview concerning communications

Turner further adds that a sub-class of disaster can arise because of the barriers to certain kinds of communication erected by social habit and routine intercourse. He suggests that patterns of communications are structured by:-

- Authority and division of labour
- Territorial considerations
- Formation of cliques

Finally, Turner (1992), in common with Rasmussen (1990) criticises the use of structured quantified risk analyses in avoiding errors and suggests:-

> "....most major systems failures arise as a result of ill-structured combinations of factors, whose dimensions become apparent only with hindsight (and) it is clear that such events cannot be well captured by means of highly exact anticipatory risk assessments". (page 190)

PERROW (1984)

Charles Perrow proposes a "theory of systems, of their potential for failure and recovery from failure" in his highly readable and widely cited monograph "Normal Accidents". He "focuses on the properties of systems themselves, rather than on the errors that owners, designers and operators make in running them" and in so doing brings a sharply contrasting perspective to that provided by (in particular) by the "technological" authors cited above. For example both Perrow and Ross (1984) report on the failure of the Vaiont Dam, Italy, on 9 October 1963. However, the latter concentrates on the technical reasons for failure, with passing reference to the prosecution and conviction of supervising engineers and managers, whilst the former ignores technical factors and reports the Vaiont technical board findings:-

> "the disaster was the direct result of bureaucratic inefficiency, muddling, withholding of alarming information, lack of judgement and evaluation and lack of serious individual and collective consultation". (page 238)

Perrow considers that "something more basic and important than (for example operator error) contributes to the failure of systems" He is scathing concerning the concept of "forced error" namely an error induced by the perpetrator him or herself. In reporting a mining accident where an operator was dragged into a conveyor belt whilst trying to keep the area below it clean he suggests that:-

> "if the operator did not keep the idler area clean, one strongly suspects he would be **forced** to look for another job" (page 247 - my emphasis)

Further related to mining accidents Perrow comments:-

> "As I have tried to indicate,...experience and training are perhaps less relevant than job pressures, careless management, and supervision, and above all, the inherent dangers of these enterprises". (page 249)

The central thesis of Perrow's book is the propounding of "normal accident theory". He defines a normal accident as:-

> "the interaction of multiple failures that are not in direct operational sequence". (page 23)

The elements of a normal accident are:-

- A large number of components (parts, procedures, operators)
- Two or more failures among interacting components.
- Tight coupling, comprising

  Very fast processes.

  Failed parts which cannot be isolated

  No alternative method of maintaining production

Perrow attributes these characteristics (summarised as a combination of interactive complexity and tight coupling) to a number of high risk industries including the nuclear industry, aircraft, air traffic control and shipping. Major accidents are considered inherent in these industries as compared with more loosely coupled, linear industries. Perrow summarises the difference between the types of industry thus:-

> "Loosely coupled systems are said to have 'equifinality' - many ways to skin the cat; tightly coupled ones have 'unifinality'" (page 94)[20].

Perrow compares air traffic control with shipping (both of which he considers to be tightly coupled and complex industries) and makes a distinction between their relative safety records. The good record of air traffic control he attributes to the high status and influence of victims, highly visible nature of accidents and the independent overall control of navigation by controllers. In contrast, shipping accidents involve low status anonymous victims and lack of independent control. In all industries Perrow reports that:-

> "we found rampant attribution of operator error to the neglect of errors by the Great Designers and the Centralised Managers" (page 351)

[20] Terms drawn from General Systems Theory (Bertalanffy, 1971) - see Chapter 4

He concludes by reiterating that the point of the book:-

> "is to see these human constructions as systems, not as collections of individuals or representatives of ideologies.....They are systems that elites have constructed, and thus can be changed or abandoned". (page 351)

Unfortunately, Perrow, in acting as a detached observer, gives little indication of how or in what direction any changes should be.

THE HIGH RELIABILITY ORGANISATION WRITERS

The writings of these authors stem from research work conducted from 1984 by a group of researchers at the University of California at Berkeley (Marone and Woodhouse 1986, La Porte and Consolini 1991, Roberts 1989 and Rochlin et al 1987), into the operation of what they called High Reliability Organisations. The thrust of their work is based on the premise that it is more productive in discovering the reasons for failure to study organisations, which although involved in high risk enterprises, manage to maintain a good record of error-free performance. From their observations, these researchers have extracted high reliability strategies, summarised as:-

- The use of duplication (or redundancy)
- Decentralisation of decision making
- A culture of reliability (using socialisation and training)
- Continuous operations and training (not sinking into "dangerous complacency")
- A capacity to learn and a belief in the effectiveness of learning

- Political elites and leaders who place a high priority on safety and reliability

The philosophy of the group and direction of their findings is summarised in a collection of writings edited by Karlene Roberts (1993). She acknowledges Perrow (1984), Turner (1978) and Vaughan (1990) (reviewed below) and the reported research is expressed to be complimentary to their analyses of failure.

Roberts outlines the HRO studies of the US Federal Aviation Authority Air Traffic Control, the Pacific Gas and Electric Company Nuclear Power Plant at Diablo Canyon, California USA and the US Navy's nuclear powered aircraft carriers. Rochlin (1993) summarises the definition and characteristics of HROs arising from the studies. HROs are involved with complex technology, require managed reliability and safety in order to avoid error and are supervising the technology involved. The distinguishing characteristics of HROs are that they:-

- Search continually to improve operations
- Set ambitious goals, without risking errors
- They do not rest even in quiet periods.

Rochlin emphasises the focus of the HRO research as being on the

> "static and dynamic characteristics of organisations that have not just 'avoided' failure through good fortune or the vagaries of probability, but actively who have managed to control and reduce the risks of technological operations whose inherent hazards make them prone to join the list of classical failures. In other words, these organisations have not just failed to fail, they have actively managed to avoid failures in an environment rich with the potential for error" (page15)

Rochlin adds, as a distinguishing point from the generally detached observational view of Perrow (1984):-

> "we note only that organisations cannot reduce risk by reducing external demands for services. Nor can they act to modify the socio-political environment in which they are situated. Therefore, their only choice is to seek to manage risk within the external framework in which both risk and demand are defined". (page 18)
>
> "The underlying belief, and the foundation of organisational reliability, is that only through its own performance and behaviour can the organisation control the (probability) coefficients; that it can continue to operate only if both the probabilities and, to some extent, the risks themselves are effectively managed and controlled through its own training, skills, and error detection and correction mechanisms. The alternative is probably the external imposition of intrusive regulation or increasingly stringent operational requirements, both of which are seen by our organisations as having a decidedly negative impact on safety". (Page 19)

Rochlin lists eleven observed characteristics of HROs:-

1. Errors are recognised as being omnipresent and eternal and vigilance the price of success
2. Sources of error are recognised as dynamic and thus monitoring mechanisms must be continually renewed/reinvigorated
3. The operating environment is considered a constant source of threat
4. No rationalising of the problem solving process into one best approach is possible or used.
5. Multiple simultaneous informal organisational structures exist
6. Anticipatory modes of dealing with problems are used.
7. Support is provided for organisational units searching for latent errors.

8 An unwillingness exists to "test the boundaries of reliability" (i.e. HROs do not use "trial and error" learning)

9 There are no "stopping rules" (i.e. rules limiting the extent of searching) in the search for self improvement

10 A tradition of adherence with formal rules (expressed as "going by the book")

11 Even when full analysis of errors is available, the organisation still perceives the need to search for error.

Douglas Creed et al (1993), in reviewing the HRO research methodology of analysing "reliability" returns to Perrow (1994). The object of reliability is to avert the 'normal accidents' that Perrow sees as inevitable due to the interactional complexity and tight coupling inherent in hazardous technologies. They assert that HRO researchers examine effectiveness as the goal rather than "ineffectiveness as the non goal" (p66) and focus on the cultural aspects of HROs. These are based, in the final analysis on individual adherence and inculcation of shared values coupled with a harsh and unforgiving punishment structure (which includes injury and death).

Hirschhorn (1993) in reporting a case study of a nuclear reactor, stresses the role of leadership and contrasts the concept of hierarchy with that of bureaucracy. The latter he considers dysfunctional and caused by organisational leaders not taking the risks of the enterprise. Hirshorn indicts punishment as a cultural force driving error and the use of "checks and balances", where one part of an organisation checks another, as a procedure based on a false analogy with the operation of Government (where, for example, the Judiciary checks the Executive). In High Reliability Organisations checks and balances should not be necessary - “a good baseball team does not have checks and balances” (page 143). He considers checking inverts authority by emphasising “rules rather than roles”, but without a system for backing up action where gaps in the rules are found. He sets out a four part model of effective organisation for high risk settings which includes:-

1 A hierarchical structure

2 Delegation which is broad and deep

3 Two classes of procedures

   a) Grounding procedures giving broad guidelines, which applies to a wide range of circumstances and is strictly applied.

   b) Detailed procedures where employees are free to vary precise steps as long as they fulfil intentions.

   Procedures under class (a) are analogous to a National Constitution and (b) analogous to the Common Law.

4 Emergency procedures to integrate (a) and (b)

In advocating a hierarchical form of structure, Hirschhorn makes the point that the hierarchical form derives from the military and the contingencies of battle. He considers that it remains a powerful social intervention for managing risk.

Weick (1993) analyses the Tenerife air disaster of 1978 and, in quoting La Porte and Consolini (1991) notes the importance of talk and inter-crew communications and the cultivation of inter-personal skills in the avoidance of future similar accidents. Weick also acknowledges and uses Normal Accidents Theory (Perrow 1984) but actively sets out methods (by training and forewarning of conditions of vulnerability) to avoid circumstances leading to the tight coupling and complexity. He notes:-

> "As we have suggested, any system, no matter how loose and linear it may seem, can become tighter and more complex when it is subjected to overload, misperception, regression and individual response" (page 191)

SAGAN (1993)

Sagan takes Normal Accidents Theory and contrasts it with HRO Theory in an analysis of nuclear weapons accidents in the USA from the end of World War Two up to the present.

He notes that errors leading to major nuclear incidents had not occurred, but that this appears to be by chance rather than design. He suggests that events related to nuclear weapons reveal two disturbing characteristics, firstly, that several potentially catastrophic accidents occurred and were not controlled in the way that HRO theory would suggest and, secondly, that accidents were covered up and mis-reported in such a way as to "turn the experience of failure into the memory of success".

Sagan concludes by supporting Normal Accidents Theory. He suggest limitations of the HRO approach by quoting March (1981):-

> "as long as we assume that organisations have goals and those goals have some classical properties of stability, precision and consistency, we can treat an organisation as some kind of rational actor. But organisation do not have simple, consistent preference functions. They exhibit internal conflict over preferences. Once such conflict is noted, it is natural to shift from a metaphor of problem solving to a more political vision". (page 46)

Sagan found organisational errors behind "human error" (meaning error related to the workface operative) and widespread mis-attribution of blame to operators. This attribution error was, itself, the cause of a lack of organisational learning:-

> "The common tendency to assign blame for accidents on operator errors, and thereby protect the interests of those who designed the system and the leaders of the organisation was also found to increase the likelihood of repeated mistakes" (page 246)

These observations echo those of Perrow and, from different perspectives, those of Reason (1990), Petroski (1985) and Kletz (1985). The problem with the findings appears to be that, in common with Perrow, Sagan is unable to propose ways of handling failures in risky systems.

<u>COLLINGRIDGE (1992)</u>

Collingridge examines six major failures, the space shuttle programme (<u>not</u> the Challenger disaster), nuclear power, North Sea oil, Videotex, large irrigation schemes in the developing world and high-rise system building in the UK. None of these failures was primarily related to loss of life, but rather involved economic or environmental considerations. He attributes the causes of these failures to inflexible technologies and centralised planning, interdependency and vested interest in a project's continuance.

These lead to the perpetuation or hiding of mistakes, eventually concluding with costly failures. With respect to high rise system building he notes:-

> "It is hardly newsworthy when some group of businessmen and bureaucrats make mistaken investment decisions because of over-confidence in the technology that it involves. Optimism is likely to be with us for some time to come. What is startling is not that mistakes were made, but that perfectly ordinary errors turned out to have extraordinarily high costs, which must be borne for decades to come by people who had no involvement in these decisions". (page 137)

In avoiding large institutionalised blunders, Collingridge proposes that projects, systems and technologies should be such that they allow trial and error learning and incremental improvement. On the use and value of such learning he notes that:-

- Errors should be kept to a minor nature. He notes that "effective trial and error can only happen when the errors which are bound to occur impose a modest degree of pain and suffering" (page 5).
- Not too much should be changed at once, allowing "incremental learning".
- Trial and error learning allows lessons to be learned quickly.
- Some mistakes should be allowed to occur as they are inconsequential.

Trial and error learning favours technologies with high operating and low capital costs with (using Perrow's terminology) loose coupling and a less dedicated infrastructure. The problems that Collingridge notes with his case studies of failures is that of inflexible technology leading to centralised choices, which in turn lead to centralised planning, interdependency, vested interests in a project's continuance, the perpetuation and hiding of mistakes and eventually costly failure.

He cites the economic failure of the space shuttle programme as being caused by:-

- Inflexibility with long lead times, capital intensive technology, very large unit size and a dependent infrastructure.
- Centralised choices with central public funding, a "monopoly of experience" and a lack of an independent view.
- A lack of incremental development.

Overall, he suggests that chosen technologies and methods of development can lead to large errors:-

> "The case studies show the astonishing blindness to error that organisations can show when their structure frees them from one of the normal embarrassments of organisational life, confessing that things did not work as well as they should have and calling for changes of some sort to be made". (page 157)

In common with Perrow and Sagan, Collingridge does not specify the means by which some error intolerant technologies can be changed to allow the trial and error learning proposed. In the case of high-rise building and irrigation schemes, alternatives may be obvious in the form of traditional low-rise construction and smaller irrigation schemes based on alternative or intermediate technology. In the case of the space shuttle or North Sea oil exploration, alternatives are less obvious. Indeed, this point is covered by the HRO writers, who contend (Roberts 1993) that trial and error organisational structures are totally inappropriate for high risk enterprises.

VAUGHAN (1990)

Vaughan (1990) extensively reviews the documentation related to the space shuttle "Challenger" disaster. She notes that the accident resulted from failure of technical components, of the organisation responsible for its production and use and the regulatory organisations designed to oversee the entire operation. She follows several authors reviewed above in commenting that the accident could not be explained by the failure of the technical system alone, but, apart from some comments concerning poor communications, lack of visibility of communications and pressures of time and cost, she takes a wide organisational view of the disaster.

Her central thesis is that the autonomy of regulators overseeing the development of Challenger, coupled with the symbiotic interdependence of regulator and regulated, predisposed the mission to failure. This thesis, whilst interesting, can be criticised in two ways. Firstly, Vaughan presents no direct evidence that the failure of the critical component causing the accident was caused by regulatory (rather than internal) omissions. This she admits in noting that:-

> "....no direct evidence exists that allows us to assert that these organizational patterns caused the accident" (page 254)

Secondly, she also is forced to admit the limitations of the "sociological" approach in noting:-

> "...both preventative strategies and post-accident attempts to correct the organizational contribution to technical system accidents are handicapped by out lack of skill at converting research findings into diagnostic recommendations for organizations" (page 255)

WILSON (1989)

Wilson draws on work by contingency theorists including Burns and Stalker (1961) and Lawrence and Lorsch (1969) who distinguish mechanistic from organic organisations. In suggesting that the construction industry consists largely of organic types of organisation, Wilson notes that most safety legislation is designed for more mechanistic types working in a "steady state". The legislation assumes, amongst other conditions, that working environments are controllable, that organisations can maintain relatively stable work forces, that the physical work place consists of a permanent factory or other facility and that stability of production allows the development of rules and procedures to minimise the scope for human error.

In arguing that these conditions do not exist in the organic construction organisations, Wilson itemises and categorises some factors that distinguish construction project work from process industries. Broad categories of environmental, organisational and individual factors are identified. Environmental factors include external influences such as the weather, the working environment and political influences. In construction projects, these influences are strong. Construction work takes place outside, using temporary structures and is characterised by improvisation. The construction industry is also susceptible to government economic manipulation and thus cannot easily predict future work or resources needed.

Wilson includes as organisational factors, project management functions of specialisation and control of projects, echoing problems (such as poor division of responsibilities and control of change) identified by technological writers. In contrast to more mechanistic organisations, construction projects are characterised by ad-hoc specialisation by sub-contracting, and control of projects (including the organisation, co-ordination, planning and supervision of quality) requiring a greater degree of delegation to site management and sub-contractors.

Individual factors particular to construction work are itemised as including discretionary power, experience and risk taking. Construction work is distinguished by a work force exercising a high degree of individual discretion, relying on experience rather than conscious education or training and being required and prepared to take higher risks.

Wilson concludes by emphasising training and education of both operatives and managers in safety and accident prevention. He places particular stress on the key role in construction of the site manager and consequently the importance of the formal training of this individual. However, whilst stressing that each site manager should undergo a formal course of training in safety, health and welfare, Wilson is less specific concerning what the manager should study within that course. He does not identify whether training should emphasise the mechanics of accident prevention as such or whether it should address some of the underlying causes of error centred on inadequate project management that Wilson had identified earlier.

OTHER AUTHORS

Other authors reviewed in this section include Clarke and Short (1993, Dombrowski (1991), Quintanilla (1987), Roberts et al (1980) and Higgin and Jessop (1965). Clarke and Short (1993) follow Sagan in commenting on ostensible "High Reliability Organisations", noting that they have very clear, well agreed upon operational goals and enjoy abundant resources. They suggest that the method of automation used on the USS Vincennes (ostensibly an HRO) had an affect on the accidental destruction of a civilian airliner[21]:-

> "..... cruisers like the Vincennes are automated in ways that thwart the human networks that produce reliability" (page 391)

They also note in case studies of the Challenger crash and the Exxon Valdez oil spill the factors of "locked organisational behaviour", "entrenched organisation", "vested interests" and "multiple goals" causing inadequate responses and inflexibility. Dombrowski (1991) espouses the view that errors stem from failures in personal judgement as opposed to failures in communications, procedures etc. However, it is not clear whether the failures in judgement are managerial or operational. Quintanilla (1987) proposes a hierarchical view of human error which follows authors from psychology and technology. However, he further criticises the

[21] The USS Vincennes shot down an Iran Air aircraft (flight 655) during the Iran - Iraq war

"psychological/engineering perspective" as engaging in "individualistic myopia". He later indicts the dynamics of change in quoting the view of Johnson (1980) that change is the "mother of trouble".

Roberts et al (1980) in a study of pilot error note the importance of error in invention and diffusion of knowledge, but also give attention to avoiding error by clearly defining responsibilities (giving an example of reduced accidents subsequent to the appointment of a squadron air safety officer covering air, industrial, driving and general accidents). They also consider the role of culture in the commission of pilot errors noting possible cultural biases that could cause errors. They report, firstly, that some mistakes made by pilots are considered serious by their peers even though they are minor in themselves. These mistakes are termed "diagnostic" because they indicate that a pilot who makes such errors is also capable of erring in much more serious contexts. Conversely they noted that some errors are considered by pilots as minor, but that <u>independent judges</u> consider them to be "high in danger" and they conclude:-

> "If the danger estimate is correct....there is a contradiction. There may be dangerous errors which have an element of positive affect and may not be judged too harshly by the system. These errors may be congruent with other values held in the larger system...." (page 19)

In other words, there may be a <u>culturally biased attitude towards certain errors</u>.

Finally, Higgin and Jessop (1965) in a study of communications in the building industry distinguish formal and informal communications and suggest that the main factor lying behind communications difficulties was the nature of relationships between the communicators. They identified a mismatch between the technical interdependence of industry resources and the organisational independence of those who control them.

THE SOCIOLOGICAL WRITERS - CONCLUSIONS

In contrast to authors from a psychological or technological perspective, Turner (1978), Perrow (1984), Sagan (1993), Collingridge (1992) and Vaughan (1990) examine error in the context of organisations as a whole. Insights revealed in their writings include the realisation that organisations are in themselves error-prone, that operations within the organisation rarely go according to plan and that conflict between individuals or sets of individuals in the workplace is the norm and often politically motivated.

Perrow, Sagan, Collingridge and Vaughan, however, whilst providing perceptive insights are relatively devoid of suggestions for improving the performance of organisations carrying out complex and dangerous activities. Perrow offers the "take it or leave it" option of not engaging in certain activities, whilst Sagan deplores accidents in nuclear weapons systems without suggesting alternatives to the nuclear deterrent theory of the 1950s and later. Vaughan frankly admits that translation from theory to practice is problematical. High Reliability Theory, though considered naive and deficient by these writers, is more helpful because it suggests improvements. It may be better not to engage in nuclear armament, nuclear power generation and space travel, but air transportation, shipping and large scale construction is necessary. If this contention is accepted, then Turner, the High Reliability Organisation writers, Roberts et al (1980) and Higgin and Jessop (1965) are more helpful. Turner, in particular, gives detailed indications of why three disasters took place and offers concrete proposals for improvement. These boil down to a caring and participative managerial system oriented towards both the operations of the organisation and other relevant activities. Roberts et al (1980) observation of the influence of cultural orientation as a factor influencing error outcomes is interesting in that it gives reasons for some serious mistakes by operators, not related to methods and systems, but to perceptions of a much wider society.

4

A MANAGEMENT PERSPECTIVE ON ERROR

4.1 INTRODUCTION

This perspective consists of a fairly heterogeneous grouping of literature with the common theme that they all relate in some way to managerial theories. Five sub-themes are identified as follows:-

- Total quality management and quality assurance, including construction quality assurance
- Reliability engineering and systems safety.
- Interdisciplinary reports and collected works
- Project management literature
- Systems theory

4.2 TOTAL QUALITY MANAGEMENT AND QUALITY ASSURANCE

A large literature exists on total quality management and quality assurance, which has implications relating to error, and this review covers indicative works. Authors reviewed from the general quality management literature include Oakland (1993), Bell et al (1994) and Stebbing (1993) and from a construction background several publications of the Construction Industry Research and Information Association (1988) Barrett (1992, 1994) and the ICE (1989).

THE GENERAL QUALITY MANAGEMENT LITERATURE

Literature from total quality management contains close parallels with some authors reviewed previously. For example Oakland (1993) and Bell et al (1994) both note that faults are not caused solely by the workforce and they emphasise the responsibility of management for quality. Bell et al quote Deming (1986):-

> "85% of quality problems are due to faults in the system rather than faults in the employee" (page 94)

They add:-

> "Thus blaming workers is de-emphasised, and responsibility for product or service quality is placed largely in the hands of management" (page 94)

The links between Turner (1978) and Oakland (1993) are particularly notable. Oakland stresses:-

1 **Participation.**

> "The emphasis throughout all stages of ....TQM implementation should be on the participation of all employees, especially those who will be directly affected by changes" (page 98)
>
> "Recognition and the chance to participate are the only effective incentives (towards the implementation of TQM)" (page 437)

2 **Orientation to outsiders**.

> "The House of Quality" (Total quality management system) is "a 'system' for designing a product or service, based on customer demands with the participation of members of all functions of the supplier organisation" (page 45).

3 **Consensus based effective leadership.**

> "Total quality management starts at the top". This includes "Visible management commitment" (page 41)

"Quality function deployment is consensus based and therefore promotes teamwork, creates communications and leads to a global view of the development process" (page 45)

4 **Fostering positive attitudes**

"Total quality management is concerned chiefly with changing attitudes and skills so that the culture of the organisation becomes one of preventing failure - doing the right things, right first time, everytime" (page 31)

Unlike Turner, however, Oakland does also stress individually based measures:-

"Total quality management is concerned with moving the focus of control from outside the individual to within" (page 31)

Terms such as personal commitment, personal development, acceptance, understanding and involvement are widely used. Personal responsibility for actions and self inspection are emphasised.

Other features of the TQM approach include advocating the careful division of responsibilities between parties and a systematic use of control and correction measures. Bell et al (1994), in particular, make several comments relating to detailed management, which strongly echo technological writers. They stress clear definition of responsibilities, the control of project changes and the control of concurrency (by using 'phase exit reviews' and 'concurrent engineering'[22]). Drawing on work by Shingo (1986), Oakland also notes the value of source inspections, short feedback cycles and fail safe systems. Thus, TQM, whilst it emphasises cultural and social aspects, includes

[22] Concurrent engineering is a body of knowledge devoted to managing the simultaneous development of several project stages. The Institute of Concurrent Engineering publishes a journal and a synopsis of the discipline can be found in Prasad (1993)

techniques and systems related to measures recognised by authors from other perspectives.

Oakland, in common with many other authors recognises the limitations of trying to change personal characteristics, but also suggests that the "culture" of an organisation is dependent on, rather than a determinant of, managerial factors:-

> "Many (TQM) change programmes do not work because they begin trying to change the knowledge, attitudes and beliefs of individuals. The theory is that changes in these areas will lead to changes in behaviour throughout the organisation..."
>
> "What is required, however, is virtually the opposite process, based on the recognition that people's behaviour is determined largely by the roles they have to take up. If we create for them new responsibilities, team roles and a process driven environment, a new situation will develop, one that will force their attention and work on the process. This will change the culture" (page 408)

Oakland (1993), Stebbing (1993) and Bell et al (1994) support checking in order to reduce quality problems, but distinguish checking of the output for defects and checking of the quality management system (in the form of quality audits, surveys, inspections and sampling). Oakland is scathing about checking as traditionally applied in British industry and notes:-

> "(The) ritual (argument between production and quality control) is associated with trying to answer the question, "Have we done the job correctly"...There is still a belief in some quarters that to achieve quality we must check, test, inspect or measure - the ritual pouring on of quality at the end of the process" (page 14)

Instead, Oakland advocated the use of (inter alia) self inspection, very short feedback control cycles, good communications and extensive training. The prevalent TQM view expressed by Oakland appears to be based on improved self correction rooted in co-operative and participative performance[23].

Oakland comments on the conflict between cost and performance by suggesting that a link exists between a low defect rate and improved economic performance:-

> "Time and money spent on quality-related activities are not limitations on profitability; they make significant contributions towards greater efficiency and enhanced profits" (page 24)

This suggestion, repeated later in major interdisciplinary reports (ACSNI 1993, Bea 1994), indicates that the relationship between cost and performance may not be direct, but influenced by the intervening variable of managerial performance (in this case related to Total Quality Management).

THE QUALITY MANAGEMENT LITERATURE RELATED TO CONSTRUCTION

There is a large literature concerning quality management in construction, mainly concerned with the implementation of quality management systems rather than examining the overall philosophy of total quality management. It concentrates on and stresses the importance of proper procedures, organisational charts, auditing, the keeping of records, and the production of manuals and detailed checklists (Duncan

[23] A view which is echoed by Morris (1994) in supporting the Japanese total quality management principles. The latter, he reports, are based on teamwork, catching errors before they are passed down the production line, full involvement of suppliers in achieving improvements and a product design process that integrates downstream production expertise into product design.

1989, Johnson 1989, Oliver 1990 1992, Hughes and Williams 1991). The role of legislation and third party certification is also stressed by many (Barrett 1994, Ashford 1989).

The importance placed in the general quality management literature on participation and co-operation is not reflected in construction industry writings. Certainly, the text of many publications mentions participation (Oliver 1992, Duncan et al 1990), attitudes (Johnson 1989), leadership and involvement (Chetwood 1989). However, the flavour of texts following exhortations to lead and participate, is one of imposition rather than participation. A quotation from Duncan et al (1990) illustrates the point:-

> "The introduction of a (quality management) system should be not by imposition, but by each manager....ensuring that there is a common understanding of management's procedural interpretation of requirements" (page 53)

In other words, by imposition!

The obsession of the construction related quality management literature with formalised rule based procedures, when compared with the analysis of previous literature concerning errors and quality management can be criticised on three grounds:-

1 **It does not follow the general quality management literature or is it based on research findings.**

2 **It is "rule bound" and generally downgrades the importance of "roles".**

3 It is reductionist in approach.

1 Failure to follow the quality management literature

The contention that quality assurance procedures are imposed within organisations from the top down is supported in that in none of the standard texts reviewed are there any formalised procedures for involving the workforce in determining the nature of the quality system, although consultation is sometimes offered in the implementation of a given system. There was generally no evidence of any research underpinning the literature relating to implementing quality assurance.

Indeed, an exception is research (Meyer 1994) indicating that a "bottom-up" process of implementing a quality system, supported by enlightened leadership, is more productive than the top-down process generally implied:-

> "If the leader wants to engage his subordinates he must first of all analyse his own attitudes and emotions as they come out through his actions. Then he must make sure that his subordinates experience that the quality system will help and empower them in their working situation. If the routines and checklists become an additional burden they will be sabotaged sooner or later" (page 90)

The bottom-up process of implementation involves delegation and participation. This theme is taken up by Barrett (1994) who also notes the human side of the organisation in construction quality assurance and stresses the need to achieve self management of workers who are motivated to achieve high quality. These two authors are very much the exception to an overall gap between quality management theories and applications. The gap is recognised by Juran (1988), a key quality management writer, who notes that:-

> "There is no evidence that a company using the ISO-9000 standards, or certified according to these, is any better quality-wise than other companies" [24]

2 Construction quality assurance is "rule bound".

The emphasis in the literature on manuals, procedures, checklists, organisational charts, records and auditing by third parties (Duncan et al 1990, Oliver 1990, 1992, Kettlewell 1989, amongst others) illustrates the importance of rules to the authors. The dangers of such an approach in high risks situations has already been pointed out by Hirschhorn (1993), but a few construction based authors also take up the theme. Sioholt (1991) emphasises the role of participation in forming positive attitudes to quality in the context of introducing quality management systems in house-building and points out the danger of focusing on paper systems rather than the quality of managers. Meyer (1994), in advocating participation, emphasises the role of the leader and Barber (1992) acknowledges the limitations of a rule based approach in pointing out:-

> "The diagnosis of faults and design cures cannot be entirely reduced to procedures. It is necessary also to allocate responsibility and authority to individuals, and to allow them sufficient freedom to pursue any matter to a satisfactory conclusion" (Page 82).

Finally, Seymour and Low (1990) inveigh against:-

> "Management and control procedures...treated as technical processes that are neutrally undertaken by robot-like functionaries who, book in hand...check the course of work against it" (page 21)

> "In essence QA rests on the belief that the probability of a firm's producing a good quality product - whatever it is - will be increased if distinct, formal and extensively documented procedures, administered by specialist quality managers, are used, The emphasis of QA seems to involve a shift from

[24] Quoted in Barrett (1992) page 6

> internally and organically generated concern with quality, by the actual producers, to a mechanically imposed set of procedures whose efficacy is guaranteed by external controllers and assessors" (page 25)

They conclude by advocating the resurrection of the notion of professionalism and re-emphasising such concepts as care, integrity and morality.

3 Construction quality assurance is reductionist in approach

Most writers (for example Duncan et al 1990, Oliver 1992) recognise the limitations of quality assurance when it is applied to construction, in that briefing, design, construction and commissioning are often separate and QA systems are designed to be "Firm" specific. The authors then proceed by proposing systems applicable within one or other of these construction divisions. The unspoken assumption appears to be that the combination of separate quality assurance systems will amount to the whole and that the links between them are sufficiently unimportant to be ignored. This reductionist assumption is criticised in the systems literature reviewed later (Von Bertalanffy 1971, Blockley 1992) and can be contested on logic grounds alone, where examples of potential interface problems can be imagined (examples would include "overlay" problems where specialists drawings do not "match up").

A few authors squarely address this criticism and propose alternatives to the usual "firm based" QA systems. Barber (1992) notes:-

> "Dealing with quality problems can pose special difficulty on projects where responsibility is split between more than one organisation. A defect affecting the work of one may be the result of a fault in the work of another. Quite

> commonly, there may be contributory faults in the work of more than one. In such situations, it is essential that there should be unified overall responsibility. Under conventional forms of construction contract, the final responsibility for the investigation of defects and approval of solutions has been allocated to the Engineer or Architect. The model (QA) standards do not address the difficulty" (page 83)
>
> "Suitable contractual arrangements are required in order to transcend the limitations of an individual organisation's quality system" (page 85)
>
> "For an overall project quality system, authority must cascade from the top. This can readily be achieved with turnkey projects as a single organisation has overall responsibility. A solution is provided in relation to nuclear installations by BS5882 through the client body having over-riding responsibility for quality. Another solution has been recommended by the Construction Management Forum under the title of "Project Control Plans" for application in conjunction with construction management contractual arrangements. There is, however, a general lack of provision for overall project quality systems in conjunction with other contractual arrangements. This is a significant gap in the existing International Standards and forms of contract, but the problem can only be overcome if contractual and quality management aspects are addressed together" (page 57)

Barber also notes with approval the French systems of latent defects assurance, which involves the appointment of independent agencies (Bureaux de Contrôle) to monitor design and construction overall.

Although the disadvantage of quality assurance systems operating only <u>within</u> separate firms in the construction process is recognised, the separation of quality as a business objective from other objectives is rarely recognised as dysfunctionally reductionist. Indeed, several authors (Johnson 1989, Duncan et al 1990, Oliver 1990 1992) actively advocate the separation of quality assurance from other objectives, by the setting up of QA departments and the making of QA appointments. However, elsewhere in Oliver's (1992) report, the author recognises that quality, cost and duration are all related; a theme which is repeated by McCaffer (1989), Langford and Ndili (1991) and Barber (1992). The interrelationships between business objectives are emphasised in several other places in the literature, but the effect of giving separate attention to quality in construction quality assurance literature is to ignore the fact that quality is dependent on good general management (and in a project context, good project management).

Thus, although several authors (CIRIA 1988, Lawrence 1989, Duncan et al 1990) note factors covered in earlier literature, such as responsibility definition, change control, control of concurrency (by advocating "hold points" etc.), planning, supervision and monitoring, few pursue these factors further. There is no recognition that good programming and cost control, by for example careful assignment of technical responsibilities, influences quality. This is so, even though the "forensic engineering" writers reviewed earlier have widely cited failings concerning these issues as causes of disaster, failure or defect.

THE TOTAL QUALITY MANAGEMENT AND QUALITY ASSURANCE WRITERS - CONCLUSIONS

In common with many authors reviewed previously, these authors stress the role of management in achieving quality. For the general quality management writers, the role should include participation, the use of consensus and the fostering of positive attitudes. Unlike many authors, particularly the sociological writers, quality management specialists also stress personal factors including individual commitment, involvement and acceptance of responsibility. Many general quality management proposals also echo conclusions from technological writers. Clear division of responsibilities, control of changes and concurrency are stressed. Checking is considered important, but of the quality system rather than the technical output.

The literature specifically covering construction quality management appears not to relate either the philosophy of general quality management, or the findings from the technological writers to the problem of quality in construction. This gap is partially filled by a small number of writers expressly recognising that it exists, but the overall sense is that construction quality assurance is both divorced from any theoretical base and tied into sets of rules and procedures in direct contrast to the recommendations of authors from other backgrounds.

4.3 RELIABILITY ENGINEERING AND SYSTEMS SAFETY

A large body of literature exists, which is particularly concerned with the reliable and safe performance of industrial processes. This literature hitherto has largely concentrated on the "dangerous" industries, where outcomes might have extremely severe consequences for society, but recently some publications have specifically covered the construction industry. Conclusions from this literature often closely match those from other perspectives covered earlier.

EMBREY (1992)

Embrey (1992), writing from the perspective of Probabilistic Safety Assessment[25] closely follows the psychologist Reason (1990) in analysing the events surrounding major accidents into active and latent errors. Latent errors, he further divides into operational (maintenance) errors and organisational (design, management or policy) errors. Embrey proposes a three level category of accident causation:-

- The actual "combination of latent, active and recovery errors that gave rise to the disaster"
- "Error inducing factors"
- "Higher level policy factors"

A further possible level of "other more global factors such as the general economic situation and the prevailing political philosophy" (pages 199-200)

Embrey synthesises the three levels of accident causation into a model with the object of incorporating managerial factors in probabilistic safety assessment. The result is MACHINE (model of accident causation using hierarchical influence network). The three levels of causation are labelled in MACHINE as direct causes, level 1 causal

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[25] For a detailed review of Probabilistic Safety Assessment and related risk analysis and human error identification techniques see Kirwan (1992). Kirwan gives a brief synopsis of the probabilistic safety assessment approach as:-

> "(The) approach...is to define a set of undesirable events...then identify what...failures...can lead to these events...(it) then quantify the likelihood of each failure and each failure combination and derive a prediction of how often the event will occur, along with estimates of its consequences (e.g. number of fatalities)". This results in the "risk picture" of a plant for use in deciding "whether the plant can be built or allowed to continue running" (page 300)

influences and level 2 causal influences. He also specifically notes factors leading to errors of confusions of responsibilities and poor communications.

HARRISON P I (1992)

Harrison P I (1992) reviews human factors in the use of quantified risk assessment and initially points out the importance of management in safety improvement programmes. He later refers to a "socio-technical pyramid" in proposing a hierarchical view of accident causation, with the accident as the tip of the pyramid, supported by factors of operator reliability and engineering reliability. These were, in turn, supported by factors of communications and feedback control, thence organisation and management and with the system climate at the base of the pyramid.

He expressly draws a link between quality management and safety and suggests improvements of better inspection during and after engineering construction (Quoting Kletz 1988), that organisations clearly and unambiguously define responsibilities and that project changes be better managed. Regarding the last Harrison notes, in the development of a "template" for the elements of a process safety management system, "The Management of Change". This management includes:-

- Written procedures to manage changes
- All plant changes should trigger some kind of plant review

Kirwan explained the use in risk assessment of fault trees, which start from a failure and trace backwards to possible initiating events, and event trees, which start from an event and trace forwards towards possible failures.

- All personnel affected should be informed
- Organisational changes should be controlled (i.e. staffing changes)

Harrison also notes the role of cultural attitudes in fostering safety and suggests key elements in process safety management systems (in the chemical industry) as including management attitudes and management organisation.

HURST ET AL (1991)

Hurst et al (1991) in a paper covering research into errors in process plant construction note that human error was the largest known direct contributor to 500 recorded incidents and also that human error was a cause of failure in preventative mechanisms. Only a 7.6% contribution to failure was classified as not recoverable (that is not attributable to human error). Hurst et al (1991) classify errors as "operating errors" or "socio-technical failures". The latter they define as "underlying causes of failure or the failure of a potential preventative mechanism"..."these are a function of the whole system". They later develop a hierarchical scheme with reference to pipework failures in process plants. Their scheme lists accident causation as including:-

1 Engineering reliability

2 Operator reliability

3 Communication, information and feedback control

4 Organisation and management

5 Systemic climate

WHITTINGTON ET AL (1992)

Whittington et al (1992) specifically research management, organisational and human factors in the construction industry. They record, in connection with construction accidents, that accidents often have multiple causes (for the accidents they studied there were between 3 and 15 causes and an average of 7 per accident). They note that strong parallels exist between safety as an objective and quality and that generic management problems have been highlighted by major accidents such as the Piper Alpha and Kings Cross disasters. Thus, they set out as the thesis underlying their research that poor management decision making together with inadequate or inappropriate controls make a major contribution to many accidents occurring on construction sites. In emphasising the importance of managerial solutions to safety performance they note the need to recognise the socio-technical context within which accidents occur. They also note that a managerial approach is particularly important in the construction industry, where the potential for highly engineered safety defences is low.

However, the research underlying their report indicates that construction accident investigations are often myopic. They draw a contrast between the more "systems-critical" approach of major investigations (including major construction accidents) and the "person-centred" approaches traditionally adopted. They note, in referring to DeJoy (1985), that supervisors favour explanations for accidents that are internal to the workers:-

> "Assigning responsibility to individuals absolves the supervisor and company from direct blame and typically leads to recommendations for behaviour change often through disciplinary approaches" (page 12)

Hence there is a failure to routinely carry out causal analysis in construction accidents. They also note the role of attribution in reporting that subcontractors are more willing to discuss the impact of planning and organisational failures on site safety performance than their personal failings.

Whittington et al divide accident causes into factors related to the <u>injured party and immediate work colleagues</u>, <u>site management issues</u> and <u>headquarters issues</u>. In their review of construction incidents, they report that approximately a quarter involve injured party factors, a quarter headquarters factors and one half site management factors. They expressly postulate a hierarchical model, which operates on four levels:-

1. Company policy level
2. Project management level
3. Site management level
4. Individual level

They report specific factors influencing accidents, echoing comments made by authors writing from a less specialist technological background, including poor supervision, remoteness of responsibility (caused by some procurement paths), uncontrolled changes, poor communications, cost and time pressures. With regard to the last two factors, they again indicate the hierarchical nature of error occurrence in project management by noting that financial and time pressures were seen to lead to a preference for short term contracting and to adversely affect safety performance by:-

- Diffusing responsibility
- Making it difficult to establish systems
- Reducing on-site supervision
- Making it difficult to maintain on-site standards
- Reducing investment in training
- Reducing the likelihood that safety will be dealt with early in the project life-cycle.

They note "cultural" factors in construction accidents including the fact that safety systems were perceived as not being "owned" by the site employees and point out features of organisational culture in the construction industry. These include that it "values initiative and flexibility" and that "risk taking is seen as endemic" in the industry.

Finally, in attacking what they saw as an inadequate planning strategy (including poor sequencing of work, unplanned variations, conflicts between safety and production, incorrect pricing of jobs, excessive programming pressure and poor co-ordination of work) they suggest that the corollary of many factors identified by technological writers might be good project planning. They advocate the use of more formal systems for proactively identifying risks, selecting appropriate methods of work and scheduling work to minimise hazards.

OTHER AUTHORS

Several other authors write from a reliability engineering or systems safety perspective including Billington and Allan (1992), Stix (1989), Gertman (1993), Hahn et al (1991), O'Conner et al (1993) and The Safety and Health Practitioner (1993). These advocate techniques such as risk analysis. From within the construction industry, the Health and Safety Executive (1985), Health and Safety Executive (1987) and the European Construction Institute (1992) use a similar approach. The recently enacted Construction (Design and Management) Regulations (HMSO 1994) have also given a clear impetus towards formalised risk analyses in construction design and planning.

The UK Health and Safety Executive (1985) stress the importance of managerial factors in reporting that only 9% of industrial maintenance accidents had human error as the direct and final cause. They add that workers were primarily responsible for 16% of such accidents between 1980 and 1982 (inclusive), but that managers were primarily responsible for 54% and contributed to a further 15%. More specifically, the European Construction Institute (1992) stress the role of the client in defining responsibilities in relation to safety, health and environmental responsibilities and the Health and Safety Commission (1992) note that interruptions to work activity are a frequent cause of accidents. Communications, participation and feedback are all emphasised in a paper by Zohar et al (1980) relating to encouraging workers to use ear protectors in noisy industrial plants. They found that timely feedback and participative management was far more effective than the alternative of disciplinary threats as a means of ensuring compliance.

Markku Mattila et al (1994) show a link between better budget performance and better safety performance in research with first line construction supervisors, thus reinforcing views from authors from a quality management perspective, amongst others. The intervening variable identified in their research relates to "management" factors of monitoring, feedback and improved communications. They note:-

> "Analyses of companies with successful safety programmes have shown that a high quality of management is linked with a higher level of safety" (page 86)

In contrast, Hinze and Raboud (1988) note a non-significant positive link between the relative cost of construction work and average injury frequency. This may explain an apparent contradiction in views concerning the influence of cost on error. **Relative cost** (i.e. whether a project is running under or over budget) may be directly correlated with error rates, but **absolute costs** not so clearly. In other words, trying to meet unrealistic budget targets may increase errors but both error rates and costs may fall when appropriate managerial measures are taken. However, the causality of the link between budget performance and error rates must be treated with caution in the light of the work by Markku Mattila et al (1994). If cost pressures do lead to errors, the link may be much more complex than indicated.

THE RELIABILITY AND SYSTEMS WRITERS - CONCLUSIONS

In common with many other writers, these writers emphasise human error as the cause of failures and, amongst human error, management errors. Accidents are seen to have multiple causes and these can be arranged in the form of a hierarchy with latent managerial and wider factors underlying more immediate and direct active errors. The view of error inducing organisations as "socio-technical" systems is widely voiced and the knock on pressure of cause on cause is illustrated.

Linked to this view of organisation is the emphasis from reliability engineers on risk analysis and more generally the view that risks can and should be identified and allowed for at the outset. This forward looking, if rather mechanistic view, maps on to the High Reliability Organisation literature and contrasts with Perrow's (1984) fatalistic Normal Accidents Theory.

Where detailed managerial measures are discussed, these authors repeat the technologists' emphasis on supervision, division of responsibilities, control of changes, control of concurrency, good communications and a participative culture. The role of cost and time pressure is also noted.

Some authors link safety and quality as common objectives and closely associated with this is the view that good performance in these objectives also brings benefits of reduced costs and times. A distinction is made between relative (Hinze and Raboud

1988) and absolute (Markku Matila et al 1994) measures of cost and time. Safety or quality performance is seen to worsen in line with poor relative (comparing planned with actual) cost/time performance. However, good management at the outset should reduce absolute costs and times and improve safety performance.

Finally, some authors suggest avoiding managerial problems of the division of responsibility, control of changes and the like by the use of better planning. The indication here is that planning may be an overall factor linking these separate factors.

4.4 INTERDISCIPLINARY REPORTS AND COLLECTIONS

The interdisciplinary nature of the study of human error is illustrated by a number of reports and edited readers from a variety of backgrounds. Four such works are reviewed here, comprising a special report on safety of nuclear installations (ACSNI 1993), a report on error in the US ship-building industry (Bea 1994), a UK Government report on the safety of concrete falsework (Health and Safety Executive 1976) and a reader edited by an engineer (Blockley 1992).

ACSNI (1993)

The Advisory Committee on the Safety of Nuclear Installations Study Group on Human Factors (ACSNI 1993) report, Organising for Safety, makes several comments paralleling authors reviewed above. It notes that accidents are seldom caused by the errors of a single individual and, conversely, that multiple measures are needed to reduce error.

In noting a shift in accident analysis away from what it calls an "Historical" approach (which concentrates on preventing unsafe acts and unsafe conditions of work by introducing rules and changes to technical conditions) and towards an analysis of management of the underlying error process, the study group follows themes developed by technologists such as Petroski (1985) and Kletz (1985) and psychologists (Rasmussen 1987, Reason 1990). They quote a study of accident in high rise construction by Andriessen (1978):-

> "Management has the highest influence on the degree of safety of the work behaviour, the group somewhat less. Of least importance are the personality factors - at least as far as they are studied here (page 84)

ACSNI (1993) point out several detailed managerial factors, which follow technological and other authors reviewed above. In particular they note the importance of the division of responsibilities, control of changes and good communications. They report research in the USA suggesting that the economic climate was among predictors of safety performance, but also point to other research, which indicates that a link may exist between a low error rate and <u>increased economic efficiency</u>. This research suggests that there may be a common factor related to management style. <u>Low accident rates</u> and <u>high economic efficiency</u> are both correlated to <u>job satisfaction</u>, a <u>democratic management style</u> and <u>increased worker responsibility</u>. This closely follows comments by Oakland (1993) from a Total Quality Management perspective.

ACSNI also make considerable reference to the role of organisational culture in fostering safety. They emphasise the importance of developing a "safety culture" the elements of which include the internal climate and organisation of the system, the need for every individual to "own" the actions being taken to improve safety (rather than seeing them as imposed from outside) and the development of a "proactive safety management". They note research which indicates that accident rates are lower when:-

- Resources are devoted to safety
- Participative relations exist between staff
- Visibility of senior management on the shop floor is high
- Production and safety is balanced
- There is a participative leadership style.

They point to recent UK transportation and offshore oil industry disasters that indict senior managers and quote research (Rees (1988), which notes the success of voluntary self regulation in the context of US construction company safety. In conclusion, they propose a definition of safety culture:-

> "The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's health and safety management. Organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventative measures" (page 23)

The emphasis on communications and participation in this definition has strong parallels with authors from total quality management (Oakland 1993) and sociology (Turner 1978, 1992).

Finally, ACSNI stress the "synergistic" nature of a safety culture, where cultural aspects have a beneficial effect disproportionate to the inputs required to produce them. Thus, orientation towards, in this case, safety is seen to have benefits in terms of better quality cost and time performance.

<u>BEA (1994)</u>

Bea reviews a wide range of literature in reporting, for the US Ship Structures Committee, the role of human error in the design, construction and reliability of marine structures. He repeats the view that human error predominates in failures (in this case, of marine structures) and quotes in support the UK P & I Club (1993) evidence that human error was responsible for 62% of major commercial shipping claims in 1993. He also quotes Sowers (1993) that only 12% of failures are due to "lack of technology" and succinctly summarised the point thus:-

> "The experience with non-marine structures indicates that the challenge of reducing human and organisational error in design and construction is not a problem of not knowing what to do. It is primarily a problem of not doing what we know we should not do" (page 80)

Bea provides definitions, both for individual[26] and organisational errors[27] and stresses the importance of the latter. He quotes Henriksen et al (1993), who, in relation to the "medical" socio-technical system, propose a four tier model of the error process. The tiers relate to <u>individual characteristics</u>, <u>the nature of work</u>, <u>the physical/social</u>

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[26] "....a departure from acceptable or desirable practice on the part of an individual that can result in unacceptable or undesirable results" (page 3)

[27] "....departure(s) from acceptable or desirable practice on the part of a group of individuals that can result in unacceptable or undesirable quality" (page 3)

environment and management factors. The first two tiers are labelled "active errors" and the latter two "latent" errors. Bea later develops his own hierarchy of organisational errors consisting of "upper level management errors", "front line management errors" and "design/construction/operating team errors".

In reviewing Henriksen (1993), Bea notes the importance of a systems perspective, in particular, the causal nature of many errors. He quotes Henriksen:-

> "A systems perspective leads one to suspect that the difficult to recognise latent errors that are made upstream by systems designers and organisational policy makers permeate the system and contribute to the downstream active errors made by technologists" (page 76)

Bea also comments on many of the detailed managerial reasons for error reported by other technologists including poor supervision, division of responsibilities, uncontrolled changes, poor communications, disregard of life-cycle costs and poor organisational culture.

In connection with checking he echoes comments by Ellingwood (1987), that checking can be ineffective and that both error tolerance and directed checking should be used in the design of ship structures. He comments thus:-

> "It would be desirable that QA/QC be very stringent for the error intolerant elements. Also, it would be desirable to configure or design the element or component so that it could be error tolerant for the highly likely types of design, construction and/or operators errors" (page 126)

With respect to the control of changes, Bea reviews a case study of Mitsubishi Heavy Industries VLCC[28] designs where second generation VLCCs had to be re-called after cracks were found in the cargo tanks of one carrier. The cracks stemmed from un-controlled design changes - the decision to change from the use of mild steel to high tensile steel in some structural elements.

Bea (1994) notes the importance of culture in interconnected series systems (such as ship-building or construction):-

> "The reliability of a multi-element series system can be improved by....human factors such as a consistent set of high quality individual, organisation, hardware and procedures factors that are allowed to permeate the entire design process. Organisational culture is likely the most important (overall factor conditioning this reliability)" (page 166)

Bea continues by suggesting that at the core of many organisation based errors lies a culture that does not promote quality and gives examples, related to failures of sea based drilling platforms, of a series of errors of judgement stemming from risk-prone management attitudes and a refusal to acknowledge mistakes. The parallels with Turner (1978) and Collingridge (1992), writing from a sociological perspective, are notable.

[28] Very Large Crude (oil) Carrier.

HEALTH AND SAFETY EXECUTIVE (1976)

The 1976 Health and Safety Executive report into the safety of falsework[29], prompted by a series of engineering collapses earlier in that decade, was notable for its recognition of the role of managerial actions in errors, predating most of the authors reviewed above. The report notes that technical factors were of relatively minor importance in the failures they reviewed and that latent factors (labelled "procedural" in the report) were of importance.

They also note that fraud was a relatively insignificant factor and that inspection and state regulation was of limited effectiveness in ensuring safety (Quoting in support the Robens Committee of Safety and Health at Work (Health and Safety Executive 1973)). They precede other authors (Kletz 1985, Ellingwood 1987) in pointing to the ineffectiveness of checking, suggesting that it is better to avoid error at the outset, and make several comments on detailed project management.

They indict poor division of responsibilities for the design of permanent and temporary works, and suggest the appointment of a temporary works co-ordinator (to co-ordinate specialists and allocate responsibilities for the design/erection of falsework). They also suggest the approval of falsework designs by a qualified engineer, checking of novel falsework features by an independent assessor and submission of falsework design calculations to the designer of the permanent works for comment.

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[29] Temporary work used to support concrete during the construction of engineering structures.

They combine comment on change control and poor communications by noting in their review that sometimes the need for changes are not communicated back to the designer and modifications are made on site which seriously weakened the structure. In this respect, the report recommends that modifications which introduce significant changes be referred back to the project engineer for acceptance (thus echoing comments by Feld (1968) and Kaminetzky (1991) in suggesting that significant modifications should be made by issuing altered drawings and withdrawing the originals rather than by amendments to the originals on site).

Regarding communications, the report notes:-

> "We are of the opinion that if adequate and proper attention were paid to communication of information which is already available somewhere, this could possibly be the greatest single contribution to improved standards of falsework construction" (page 38)

<u>BLOCKLEY (1992)</u>

Blockley brings together several authors (two of which (Turner 1992, Kletz 1992) have been mentioned above), writing under the general heading of Engineering Safety. Blockley's own contribution is one of combining separate monographs into a whole in the introduction and conclusions to the book.

He makes two points, which strongly echo comments from other authors. Firstly that a distinction has to be made between technical and human error causes of failure and secondly, that a distinction has to be made between individual mistakes and "organisational matters". Regarding the former he contends that:-

> "....we cannot talk in terms of engineering safety in technical terms only. Individuals, their organisations and groups and their cultures are all involved" (page 454)

He later distinguishes two cultures of engineering, the "technical tradition" and "problems of professional activity and business", and points out the over-emphasis, in engineering education, of technical knowledge at the expense of managerial skills.

Regarding the latter, he notes generally that there has been a tendency to attribute human error to individual mistakes and lapses, but that:-

> "Other writers, with other perspectives, have revealed that human factors in engineering failures are often much more subtle and relate to organisational matters" (page 7)

Blockley follows the widely reported distinction between latent and active errors in proposing a "balloon" model of latent pre-cursors to an accident, failure or disaster, corresponding to air being blown into a balloon. Subsequently, only a small trigger event, such as a pin or lighted match, would be needed to release the energy pent up in the system.

Matousek (1992) also implies a hierarchy of errors in promoting the use of systematic quality assurance. This, he contends, is necessary because building workers are no longer fully trained and cannot be relied on to produce careful workmanship in response to formal technical documents.

Matousek expands by indicating the sources of errors as including inadequate work specification, insufficient demarcation of areas of competence and responsibility, lack of information flow and insufficient co-operation. Blockley, in summarising this contribution, suggests:-

> "Quality assurance is a means by which we try to ensure that we reach our goals. An essential goal of any business is to satisfy clients and make a profit. It ought to follow therefore that quality assurance is good business. As safety is part of quality assurance then it should follow that the proper management of safety is good business too" (page 26)

Blockley concludes by emphasising the importance of leadership in relation to organisational culture. He charges management with the duty to develop a good corporate safety culture and suggested that this will lead not only to cost savings, but also to increased quality and worker satisfaction. These points have clear parallels with other authors reviewed and support indications above that cost, time and error rates may be <u>dependent</u> on managerial factors rather than effectively in conflict.

<u>INTERDISCIPLINARY REPORTS AND COLLECTIONS - CONCLUSIONS</u>

To a certain extent it is inevitable that these reports should echo the findings of earlier work reviewed, as the latter often forms the basis for the former. However, it is open to committees directing government sponsored reports to take a different approach. The fact that they do not take a different approach and the fact that an early report

(Health and Safety Executive 1976) contains many recommendations pre-dating modern research on human error gives strength to the links between the reports and other perspectives.

This literature repeats findings from elsewhere, that failures have multiple causes and cures and that managerial and organisational causes are more important than both technical and individually based errors. Regarding the latter, the finding (Health and Safety Executive 1976) that fraud was not a significant factor in their investigations, is paralleled elsewhere.

The view of errors having latent and active components and error induction exhibiting hierarchical characteristics is also repeated here. This view is shown to extend to industries as far from construction as ship-building and medical practice. Again, detailed managerial reasons for failures include poor supervision, division of responsibilities, control of change and communications.

The role of organisational culture is given some prominence and analysed as including components of participation, visible management and leadership. The possibility that a good organisational culture, as evidenced by appropriate levels of these components, will produce synergistic effects of superior cost, time and quality or safety performance, is promoted widely. This contention has echoes in both the High Reliability Organisation writings and Turner's (1978) work on UK disasters.

4.5 PROJECT MANAGEMENT

Poor division of responsibilities, control of changes and control of concurrency are cited as causes of errors by many authors from technological, social science and management perspectives. Project management, although it does not directly concentrate on error as a subject, is a discipline concerned with improving these factors and it is interesting that points made earlier are echoed by project management specialists. Archibald (1976) in an early project management monograph stresses, amongst other factors, the importance of proper division of the project manager's responsibilities in noting that:-

> "....division of the project manager's responsibilities is probably the most common cause of projects not achieving their objectives" (page 39)

He further stresses the importance of continuity of role for project management, which should:-

> "avoid the practice of 'passing the baton' for project responsibility as the project passes from phase to phase" (page 37)

The use of the expression 'passing the baton' is exactly the same as used 10 years earlier in the Tavistock Institute report on communications in the U.K. building industry (Tavistock Institute, 1966). Archibald also comments on the need to control changes and concurrency. Regarding the latter, he advocates a "design freeze point" corresponding to the "baseline design". Curtin et al (1991) follow Archibald's criticism of concurrency in noting that many clients consider it counter-productive to begin construction work too early and then have to accept variations. They further note problems of allocating responsibilities for design defects where management contracting is used. Their solution is for the client to allocate full responsibility for the design to a single organisation, which may be the architect or a management contractor. The points echo those from both a safety (Whittington et al (1992) and technological (Kaminetzky 1991) perspective.

Morris (1994) in reviewing the history of the management of projects, notes a number of project failures. Some of the case studies he reviews also show clear parallels with problems identified by other authors. For example, in referring to the failures of the channel tunnel project, Morris notes a key cause as:-

> "...that old problem of concurrency - of starting construction before the design is properly worked out" (page 176)

Morris attempts to define a theoretical base for project management and, in common with Kerzner (1995) and Walker (1989) (in a construction project management context), invokes general systems theory (Von Bertalanffy (1971) - see below). Stallworthy and Kharbanda (1983), imply a similar overall philosophy in stressing the need for a total view of the project management process. Several project management authors (Keller 1995, Archibald 1976, Kertzner 1995) imply a systems approach in stressing that the objectives of project management include the integration of time cost and quality. This is in sharp contrast to the "construction" quality assurance writers reviewed above, who concentrate solely on the management of quality.

The techniques of project management, covered in the above works and several other publications (Harrison F L 1992, Lock 1996, Meredith and Mantel 1995) provide detailed guidelines for controlling the problems which continually recur in the literature. Particular stress is placed on the division of responsibilities and planning and control to avoid the problems of concurrency and change. Morris (1994) describes the classic project management approach as including the techniques of work breakdown structure, organisational breakdown structure and task responsibility matrices (to plan and control the division of responsibilities between project participants), the use of resourced plans, prepared using critical path analysis techniques (to plan time, but also to allocate responsibilities), the use of earned value analysis to control both costs and progress, the use of milestone planning, design reviews and design freeze points to control concurrency and the use of change control. He summarises the approach thus:-

> "Careful definition, comprehensive planning, thorough risk analysis, better use of prototypes, careful progressing of development, thorough early testing, great care in managing concurrency/simultaneous development, stable but challenging relationships with suppliers, good communications, conflict managed as a source of ideas and development - all these painfully learned lessons are now generally accepted strategies for managing technology effectively" (page 228)
>
> Managing the development of the project definition, in a timely cost effective way, with minimum changes, towards ends that reflect the customer's real needs, is central to the management of projects" (page 230).

PROJECT MANAGEMENT - CONCLUSIONS

As a recently emerging discipline, project management is still struggling to identify its theoretical base and boundaries. It has adopted general systems theory, but still appears to concentrate on the detailed process of project management and the structures of project organisations, rather than taking a wider view and encompassing either sociological or psychological perspectives. Attempts are being made, by writers in the forefront of the discipline, to address this imbalance and Morris (1994), in particular, reveals links between detailed project management techniques and a wider view. Morris expressly makes links with three authors from a sociological perspective (Turner 1978, Perrow 1984 and Collingridge 1992) in indicating that:-

> "The lesson of all three authors are of a piece with those of this study; keep projects as small and modular as possible, fully assess the risk in advance, test before implementing, and have management attuned to the size and complexity of the system and the degree of turbulence associated with it" (page 228)

However, Morris is an exception and project management, as a discipline, does not generally acknowledge the sociological perspective. Project management's strength appears to be in providing a link between, on the one hand, the disjointed set of problems identified by the technological and psychological writers and the system wide, but generally disengaged writings of sociologists.

4.6 SYSTEMS THEORY

GENERAL SYSTEMS THEORY

Project management writers are exceptional in referring to general systems theory, although several authors reviewed earlier make passing reference to "systems" and explore systemic interrelationships between factors influencing error outcomes. Systems theory holds that certain phenomena, whether natural or artificial, cannot be explained by reductive scientific analysis. Von Bertalanffy (1971), an original proponent of the theory and referred to in project management literature (Morris

1994), gives examples (drawn from disciplines including biology, sociology, history and management) of tangible and intangible items, the operation of which cannot be explained by examining the individual components from which they are formed. An example of a systems view of history is noted by Von Bertalanffy thus:-

> "Earlier periods of history may have consoled themselves by blaming atrocities and stupidities on bad kings, wicked dictators, ignorance, superstition, material want and related factors. Consequently, history was of the 'who-did-what' kind - 'idiographic', as it was technically known. Thus the Thirty Years War was a consequence of religious superstition and the rivalries of German princes; Napoleon overturned Europe because of his unbridled ambition; the Second World War could be blamed on the wickedness of Hitler and the warlike proclivity of the Germans.
>
> "We have lost this intellectual comfort. In a state of democracy, universal education and general affluence, these previous excuses for human atrocity fail miserably. Contemplating contemporary history in the making, it is difficult to ascribe its irrationality and bestiality solely to individuals (unless we grant them a super-human - or subhuman - capacity for malice and stupidity). Rather, we seem to be victims of 'historical forces' - whatever this may mean". (page 6).

Interestingly, this theme is repeated by an historian, Travers (1994), in a re-appraisal of the 1915 Gallipoli campaign[30]. He argues that the blame for this disaster should not be laid at the feet of any one individual, rather the reasons for failure were systemic and structural. Two short quotations illustrate Travers's approach to the history:-

> "...most of the previous historiography has over-emphasised the role of Gallipoli personalities - whether Hamilton, Hunter-Weston, Birdwood, Stopford or Sitwell - rather than focusing on structural problems. All these individuals and their staffs were 'locked in' to a system that allowed little flexibility" (page 433)
>
> "Perhaps one other form of analysis of command at Gallipoli (and the Western Front) may be useful. A recent proposal for understanding large-scale industrial errors makes the distinction between <u>active</u> and <u>latent</u> errors. In the context of Gallipoli, there were *latent* errors in the rather rigid structure of the British

[30] A disastrous First World War attempt at landing troops in the Dardanelles.

> army system, where social and organizational imperatives often took precedence over change and flexibility. These *latent* or in-built errors made possible the *active* errors of officers and commanders in HQs and in the front lines...." (page 434)

Thus, Travers links history, systems theory and modern views on error incubation in one paper.

Von Bertalanffy contrasts the systems view with analytical procedures in science:-

> "The system problem is essentially the problem of the limitations of analytical procedures in science. This used to be expressed by half-metaphysical statements, such as emergent evolution or 'the whole is more than the sum of the parts', but has a clear operational meaning.....Analytical procedure depends on two conditions. The first is that interactions between 'parts' be non-existent or weak enough to be neglected for certain research purposes....the second condition is that the relations describing the behaviour of parts be linear....
>
> "These conditions are not fulfilled in the entities called systems, i.e. consisting of parts 'in interaction'." (page 17).

This theme is again taken up, in an error context, by a writer reviewed earlier. Blockley (1992), in criticising engineering education, propounds:-

> "It is essential that the academic and intellectual scope of engineering is widened immediately to provide academic support to the so-called non-technical activities that all engineers find are part of their work. This is the "social science" of engineering and the "philosophy of engineering", both of which must be turned into active academic subjects. Although there is some indication of the development of research into these matters and into project and construction management, this research is minute in comparison with the efforts in the "applied physics of engineering". The amount of research into a topic such as quality assurance is small. Indeed, one could imagine many people questioning the fact that any research could indeed be performed on such a subject - so constrained are they in thinking in terms of research being only "applied physics". Perhaps the practical way of developing these disciplines is through the developing ideas of the "systems approach" (page 456)

> "In simple terms a systems approach is the one that takes a broad view, tries to take all aspects into account and concentrates on the interactions between different parts of the problem. So what is the difference between the scientific method and the systems method and why is it relevant to engineering? The scientific method is an approach that characterises the world by assuming that natural phenomena are ordered, regular and not capricious. Following Descartes, it is a reductionist approach which takes a complex problem and breaks it down into component parts and tackles them separately. Systems thinking, alternatively, questions the assumption that the component parts are the same when separated out as when they are parts of the whole" (page 457)

The development of systems theory has emphasised the concepts of closed and open systems, synergy, equifinality and teleology. A closed system is one, which does not interact with its wider environment. Within the closed system concept, the field of Cybernetics has developed feedback theories of wide application to engineering, management and biology. Open systems theories use, for example, the operation of life forms in biology, which continually interact with the environment in maintaining a "dynamic equilibrium". Synergy is the property of systems to amount to more than the sum of their parts. Equifinality stems from the observation that many biological and social entities can achieve the same ends from different processes[31] and teleology is the phenomena observed in many living and social systems of directedness or ordered actions.

Thus, the reference to systems theory in project management and the critique of the reductionist approach in construction quality management can be related to systems

[31] Again, a point made by a writer in the literature review (Perrow 1984), without referring expressly to systems theory.

authors views that the sum is more than the parts and that the interactions between parts cannot be ignored.

THE OPEN SYSTEMS GROUP

The systems view has been applied by the Open Systems Group[32], who study failures in a systems context. The Open Systems Group (1981) defines a system as:-

> "a set of objects together with relationships between the objects and between their attributes connected or related to each other and to their environment in such a manner as to form an entirety or a whole" (page 12).

They describe a system as an assembly of parts where:-

1 The parts or components are connected together in an organised way

2 The parts or components are affected by being in the system and are changed by leaving it.

3 The assembly does something

4 The assembly has been identified by a person as being of special interest.

Within the group, Watson and Fortune (1984) set out a series of "systems paradigms" as theoretical frameworks for studying systems failures. The paradigms are system, control, communications, engineering reliability and human. Systems paradigms concepts include a view of systems as input-system-output mechanisms examined holistically by taking an overall view rather than following a reductionist approach.

[32] The Systems Group of the Technology Faculty at the Open University.

Systems are described as exhibiting hierarchical characteristics, where divisions can be made into (using progressively smaller units of analysis) systems, subsystems and elements, all existing in a wider system and thence the system environment. The system environment is distinguished from the wider system in that it consists of unconnected externalities[33]. The authors consider that a systems paradigm applied to failures is valuable as it "points up:-

- Deficiencies in organisational structure
- No clear statements of purpose from the wider system
- Performance deficiencies in sub-systems
- Poor sub-systems communications
- Poor sub-systems design
- Lack of accounting for the environment
- Imbalances in the systems - for example, between resources and quality assurance" (Page 21).

Fortune (1984), applies the systems approach to specific studies of failure. She defines failure as dissatisfaction, goals unattained, undesired outputs and sets out the central objective of a systems approach to failure in perceiving systems in situations from which failures have been seen to emerge. The systems concepts used in failure analysis are defined as:-

[33] In the context of the preceding review of technological literature, these might include such factors as cost, time and societal constraints.

- A performance judgement of whether failure has occurred.
- Conflicts of objectives (for example costs versus safety)
- Holism and emergent properties (for example synergy, negative synergy)
- Multi-disciplinary study.

Fortune considers the methodology in understanding systems failures to be exploratory and iterative, allowing objectives to be reviewed. A <u>failure investigation methodology</u> involves considering and adopting one or several failure paradigms, comparing these with the specific situation and interpreting differences and similarities.

Bignell and Fortune (1984) uncritically review several case studies of failures and the value of a systems approach to failure is noted:-

> "...one of the greatest values of using a systems framework to study failure is that it encourages a broad examination of both the failure itself and the context in which it occurred. Consideration of the systemic background of a particular failure will lead to a much greater understanding of all the influences and flows of both materials and information that existed in the situation. Of particular importance are the links between sub-systems and between the system and its environment, but even more than this, consideration of the whole system and its environment should prevent the narrow, blinkered approach, which has previously been a characteristic of many failure studies. Engineers have tended to look for technical problems, ergonomists have searched for human error or for mismatches between man and machine and, indeed, each expert has tried to seek justification for his own pet theory as to 'why things went wrong'....The systems approach to failure is not only a multi-disciplined one, but also one that demands an open mind". (page 165).

Fortune and Peters (1995) update much of the material covered above by examining several more recent case studies. They note points raised by other authors reviewed including a link between concurrency and failure and the reluctance of commercial organisations to look forward towards the possibility of failure. Regarding failures in project management, the authors also note:-

> "There is a whole literature of sets of techniques and methods for project management and project planning, but projects remain highly vulnerable to failure". (Page 33)

They quote research by Pinto and Slevin (1987) into the critical success factors for projects. These are categorised as:-

Aims - project goals are clearly defined

Organisation -

- Resources are sufficient
- Control mechanisms are in place and used
- Project has support of top management
- Communications channels are adequate
- There is capability for feedback
- Contractors are responsive to clients

People -

- Project manager is competent
- Project team is competent

Fortune and Peters (1995) review basic systems concepts including a definition of system as an organised whole, holism, environment and boundary and closed and open systems. With regard to the distinction between system and environment, the authors point out that the environment influences the system, but in their definition, the system cannot influence the environment. They formalise a systems failures method following Fortune (1984) and give some attention to failure analysis techniques.

They set out an alternative concept, "vulnerability" to that of "interactive complexity" (Perrow 1984) and the "resident pathogen metaphor" (Reason 1990). People, populations, plant or systems are prone to failure because of physical states, location and the like, which make them vulnerable to failure:-

> "For the moment, the concept of vulnerability seems to have more mileage than the concepts associated with complexity. Elderly people or babies may not be accident prone, but their physical state may make them more vulnerable to events. Similarly, a chemical plant may be complex, but the state of its repair may be the factor which renders it vulnerable to failure" (page 245)

The authors devote a section to failure avoidance, which can be directed to mitigating the impact of failure, or to avoidance from the start and quote Brearley's (1991) study of common themes in failure analysis:-

- Failure to manage change
- Communications failures
- Performance monitoring failures
- Failure to act on feedback information
- Failure to learn from past lessons
- Complacency
- Maintenance failures
- Manpower failures

- Violations
- Multiple failings
- External factors

Fortune and Peters conclude by outlining three approaches to avoiding failure, the reliability approach (based on reliability engineering, not on high reliability organisation theory), a "learning" approach and a "quality assurance" approach. The last they conclude is suitable for "easily definable lower level problems, using, for example, statistical process control" (page 252).

SYSTEMS THEORY - CONCLUSIONS.

Systems theory concentrates on the links between parts of an entity rather than analysis of the parts themselves. Thus a "systems" views of events in history (Von Bertalanffy 1970, Travers 1994) and failures (Watson and Fortune 1984, Fortune and Peters 1995), claims to play down the role of individual actors and emphasise interactions. In this, the authors reviewed above are only partially successful as it appears inescapable that analysis of any problem will tend to reductionism. Thus, Watson and Fortune (1984) could not escape analysis into five "paradigms", which have the appearance of existing as separate entities.

Nevertheless, the view of an entity as a system, or series of systems, appears useful. In the context of errors in construction projects, the "system" producing errors in buildings fits the Open Systems Group (1981) definition - it consists of connected parts, which are affected by being in the system and changed by leaving it. The system does something and is of interest in that it is this system which spawns defects and failures. However, the formal systems paradigm as propounded by Watson and Fortune (1984) does not fit easily with construction project work. It implies a single wider system (perhaps more suited to unified organisations), fails to integrate paradigms that the authors themselves identify and does not identify, or confuses factors relevant to project management. Thus, human relations factors are treated separately from control factors, even though other authors indicate that the two are related.

The overriding benefit of a systems approach is in defining more general concepts, the distinctions between closed, open systems and the environment, synergy, equifinality and the models of control. It encourages a broad examination of failure and context and prevents a narrow and blinkered approach to the study of failure (Bignall and Fortune 1984). In suggesting an "element", "sub-system", "wider system" and "environment" approach to systems, it provides a structure for the study of error, which could be focused on factors related to the individual, project and external pressures. Finally, several systems publications both identify factors (such as change, concurrency, communications and control) which have been reported by other authors, and give detailed guidance concerning how these factors operate.

The gap between systems theory as expounded in this section and applications in the current study lies in defining the exact components of the project as an error perpetrating system and in defining exactly how these components interact.

The view of error influences and outcomes as being systems driven also holds out one further possibility - that of the whole error commission or avoidance process in project systems being encapsulated in a model. The following Chapter identifies common themes in the literature and proposes a model for use in further empirical study.

5

INTEGRATING THE PERSPECTIVES

5.1 COMMON THEMES

Although at first sight it might seem that the wide range of perspectives reviewed in Chapters 2, 3 and 4 are irreconcilable, there are a number of points of agreement. Differences, whilst apparent, appear to fit together to form a complementary mosaic rather than a contradictory mess. Clear areas of agreement exist and these are collated to form themes, representing current thought concerning the nature of error. The themes are summarised as follows:-

THE IMPORTANCE OF ERROR

Widely expressed is the view that, in any technical failure, human error predominates. Figures for the percentage of failures which could be directly attributed to error causes vary, but 70-80% or more is usual.

THE INEVITABILITY OF ERROR

Writers from a background of psychology note that internal thinking processes are such as to make error commission inevitable and to a certain extent a necessary process. Other authors repeat this view or extend it to point out the beneficial role of error in learning. The implication from this view is that errors can not be entirely avoided, but rather should be managed.

MULTIPLE ERRORS

Writers from technological, psychological and sociological backgrounds all point out that, particularly for major failures, several errors are involved. Some authors attempt to quantify the number of errors per failure, with 7-10 being quoted in one instance (Whittington 1992).

UNDERLYING ERRORS

A number of independent sources make the distinction between latent and active causes of failure. In most instances, the latent causes of failure stem from errors by managers or external factors such as cost or time constraints. These causes predispose a system to failure, but would not normally directly induce failure. For that to happen, an active error would need to be made. Active errors are usually associated with people carrying out physical work and are conditioned by individually based factors such as knowledge, application and motivation.

THE SYSTEMIC NATURE OF ERROR CAUSATION

This view is gaining ground in writings from reliability engineering, sociology, quality assurance and historical analysis. Organisations committing errors leading to failure are considered socio-technical or organisational-technical systems, which have to be considered as a whole in analysing cause.

5.2 DIFFERENCES IN VIEW

Beyond these common themes, differences in perspective lead to different emphases in analysing the exact cause of error. In particular, writers from the perspective of sociology take a detached view of failures as stemming from organisational inadequacy, whereas writers from the perspectives of technology, reliability engineering and quality management are more specific. Points of contact between perspectives occur in the writings of (inter alia) Turner (1978), Petroski (1985), ACSNI (1993), Whittington et al (1992) and Harrison (1992).

Writings from the perspective of psychology recognise most of the common themes listed above, but are also not specific concerning underlying causes. Again, points of contact are made in reports such as ACSNI (1993) and Bea (1994) where the editors combine psychological and managerial thought. The over-riding impression in examining both psychological and sociological writings is that they are largely inadequate, the psychology by indulging in "individualistic myopia" (Quintanilla 1987) and the sociology by being overly long-sighted in treating organisations as a whole.

5.3 GAPS IN KNOWLEDGE

Where authors from any perspective are specific as to cause, there is a consistent repetition of problems of lack of checking and supervision, poor control of changes and concurrent working, poor division of responsibilities, poor formal and informal communications and poor organisational culture. To this could be added the influence of wider factors of cost, time and social pressures and the influence of factors internal to the individual related to knowledge acquisition and use.

Managing these problems, in the context of construction projects, is seen to be the subject matter of project management. It is, therefore, in the project management arena that attention should be directed. Not only directed to the separate causes, but, in following the majority of all authors reviewed above, directed to how they interact systemically in causing the unwanted result. In so concentrating on that area of middle ground, between the direct application of technology and wider sociological considerations, it is not necessary to discard either the psychological or sociological perspective, but rather answer some of the questions that they expressly (Vaughan 1990) or implicitly (Reason 1990) ask, but appear not to be able to answer - exactly what are the reasons for things going wrong.

It might have been possible to focus directly on the management of projects in reviewing the literature, but to do so would have been to fall into the reductionist trap identified in the systems literature and implied in several other writings. In retrospect it appears that many perspectives emphasise project related causes. Having identified a clear area of interest, it becomes apparent that little work has been done linking error inducing factors to project performance and that most authors have stopped at identifying the cause of a particular failure, without attempting to draw general lessons.

There appears to be a clear gap in research and the literature filled only by such partial studies as Hinze and Raboud (1988) covering a small portion of factors identified, studies of defects (Bentley 1981) not having a rigorous basis in error research, or case studies of failure (Watson and Fortune 1984) not specifically appropriate to construction project management. In order to direct efforts to the most effective methods of improving performance it is necessary to:-

- Confirm the importance of project related errors, in particular latent errors and to look behind obvious causes for further underlying factors.
- To investigate interactions between errors.

The literature reveals that this research has not, as yet, been done.

5.4 A MODEL OF THE ERROR PROCESS

CONTENT

To expand on project related errors, the literature indicates that these are related to a series of factors associated with active individual errors, but wider than implicit in a purely psychological perspective, a series of factors related to the organisation of work (in the case of construction, the organisation of construction projects) but more specific and detailed than implicit in a purely sociological perspective, and a series of wider environmental factors acting as external pressures on projects and those responsible for their execution.

Taking factors associated with individual errors first, error commission in projects, although dependent on wider factors, appears at least in part to depend on the knowledge of the individual. Elements such as the level of training, skill, application, as well as effective selection for tasks are seen by many authors as part of that factor. Study of the influence of this factor alone, in order to determine its exact importance in defects and failures might repay the effort, but in this research it is felt more productive to take a much wider and comprehensive view rather than specialise. The justification for a wider view being the relatively investigative, rather than confirming, nature of the work and the reported influence in the literature review, not of factors alone, but of the <u>links</u> between factors - in other words, the systemic nature of error incubation (Morris 1994, Kerzner 1995, Fortune and Peters 1995).

The factors related to the organisation of project work consisted of those causes of failure mentioned above that are so widely cited as to begin to rank as categories. They involved failures of <u>checking</u> (the subject of detailed study by Stewart and Melchers in Australia), division of <u>responsibilities</u>, control of <u>changes</u>, control of <u>concurrency</u>, and <u>communications</u>. Again, it might have been possible to study the influence of any one of these factors on the performance of projects (Hinze and Raboud 1988), but this would ignore the systemic aspects of error formation.

Wider factors related to pressures of <u>cost</u>, <u>time</u> and <u>society</u> are also regularly cited as causes of defects, failures and accidents. Project management is required to respond to these pressures and, additionally, project managers have to work within an organisational culture, however defined, which might influence performance.

FORM

Structuring of error influences has been attempted by several authors, starting from the basic division made by (amongst others) Petrosky (1985), Reason (1990) and Blockley (1992) of errors into active and latent. This distinction is developed by Hadipriono (1985), who considers enabling and triggering causes in detail and Eldukair and Ayyub (1991), who divide detailed causes into primary and secondary factors.

Those developing more complex models of error influences on several levels include Embrey (1992), who classify causes as actual errors, error inducing factors and higher level policy factors, Hurst et al (1991), who classify causes as Engineering and operator reliability, Communications, information and feedback control, Organisation and management and Systemic climate, and Bea (1994), who classify causes as Upper level management errors, Front line management errors and Design/Construction/Operating team errors.

OPERATION

The literature review indicates that multiple errors, active and latent are usually involved in both major and minor failures, but that these do not often act in isolation and are systemically linked. However, authors fail to demonstrate how the links between errors operate. Thus, in many respect, their models represent lists of independent factors, rather than unified systems interacting in the manner described by Von Bertalanffy (1971). Furthermore, many lists of factors are not specific to construction project work, or are related to safety and accidents, rather than defects and failures.

If the evidence from the literature is accepted, that the causes of error in projects are complex and not simply related to obvious individual failings, then some method, or framework for mapping causes and the links between them appears necessary in attempting to reduce their occurrence. In turn, this suggests a model of the nature of error in a project context, following authors mentioned above. Any model proposed at this stage would be tentative and subject to revision in the light of research, but a model of the nature of error in a project context, suitable for further testing, is proposed and is shown below.

5.5 MODEL OF THE NATURE OF ERROR IN A PROJECT CONTEXT
(Based on the literature)

GLOBAL FACTORS

Environmental factors

- Political pressures (Stix 1989, Brown and Xiaochen Yin 1988).
- Societal pressures (Pepperell 1987, Roberts et al 1980).
- Cost factors
  Intense competition (Robson 1978)
  Bidding based on cost alone (Jones and Nathan 1990, Hadipriono 1985)
  Skimping (Bartholomew 1987).
- Time factors (Allen 1986)

Organisational culture

- Inappropriate organisational orientation (Turner 1978).
- Unresponsive and inflexible organisation (Clarke and Shorte 1993).
- Remote management (Turner 1978, Reason 1990, Oakland 1993).

MANAGERIAL FACTORS

Checking strategy

- Checking procedures are not implemented (Stewart 1993)
- Poor supervision (Kaminetzky 1991)

Responsibilities

- Split responsibilities for tasks are evidenced (Korman 1991B)
- Divisions between tasks are not clearly delineated (Scott 1976, Feld 1968)
- Broken or loose links exist between initiation and performance (Kaminetzky 1991, Korman 1991A)
- Lack of "centralisation" of tasks exists (Robson 1978, Kaminetzky 1991, Roberts et al 1980)

Lack of change control

- Changes are not routed through responsible initiator (Feld 1968)
- Changed details are not checked (Sriskandan 1986)
- Excessive changes evidenced (Brown and Xiaochen Yin 1988)
- Discontinuities of personnel evidenced (Daoud and Hamdani 1988)
- Lack of written change control procedures evidenced (Chadwick 1986)

Concurrency

- No identifiable "control stops" to define stages in a project (Ellingwood 1987)
- No "freeze" points (Chevin 1993)

Poor communications

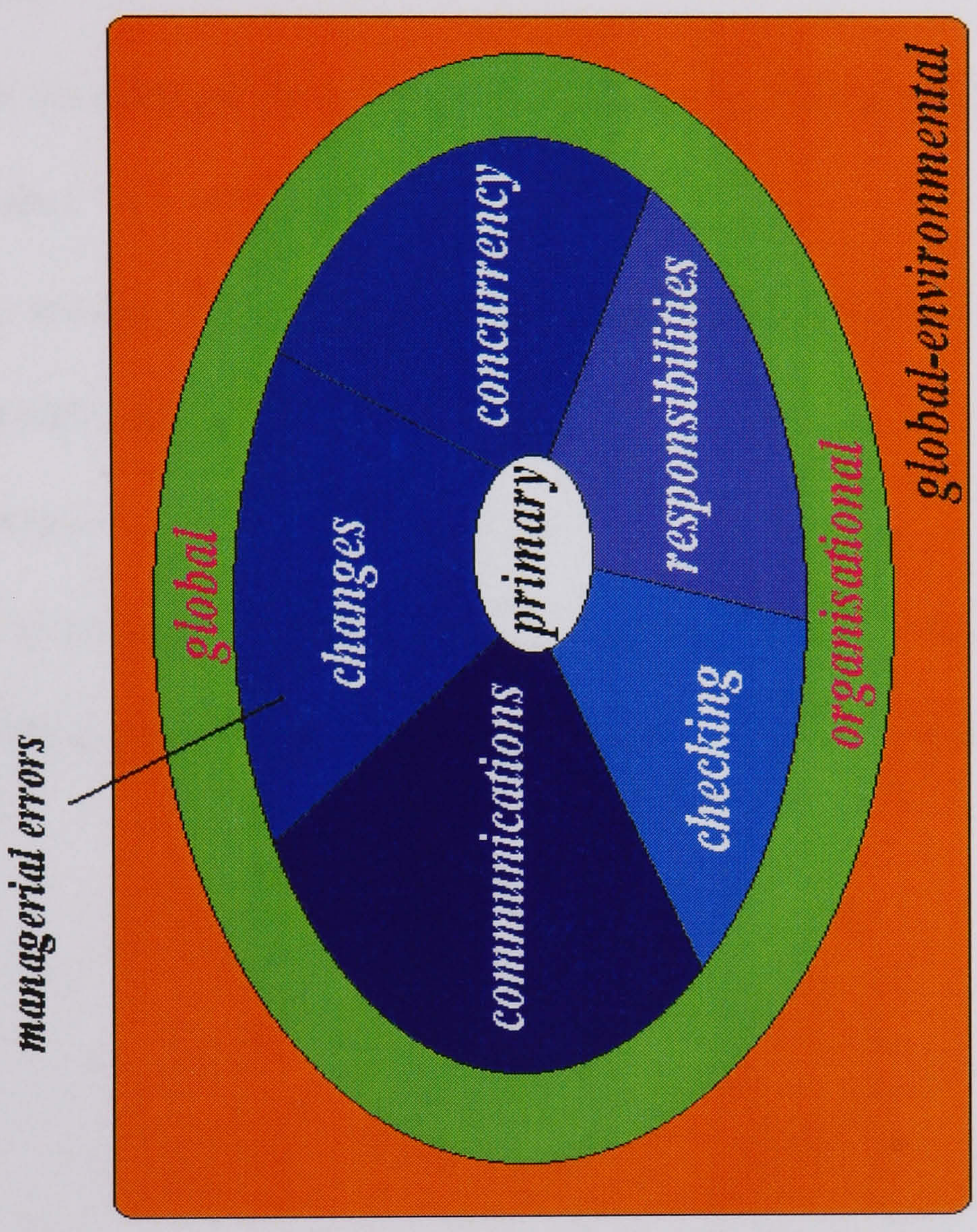
- **Poorly detailed formal communication tools evidenced**
    - Unclear documents (Allen 1986, Brown and Xiaochen Yin 1988)
    - Excessive "noise" in documents (irrelevant/tangential material) (Rollings and Rollings 1991, Turner 1978)
    - Conflicting documents (drawings/specification etc) (Korman 1991B)
    - Conflicting specialist documents (engineering/architectural/sub-contractor drawings etc) (overlay problems) (Kaminetzky 1991, Mills, Denis and Associates 1988A)
- **Lack of visibility in communications evidenced** (Reason 1990, Norman 1988, Jones and Nathan 1990)
- **No attempt made to explain details of documentation to construction personnel** (Kletz 1985, Lew 1984)

PRIMARY FACTORS

- **No strategy or policy exists for:-**
    - Systematic knowledge acquisition (Reason 1990, Ransom 1994)
    - Selection of knowledgeable personnel (McKaig 1962, Sriskandan 1986)
    - Self inspection of tasks (by requiring certification or confirmation etc) (Jones and Nathan 1990)

These factors are summarised in figure 5.1 overleaf.

FIGURE 5.1 - MODEL OF THE NATURE OF ERROR IN PROJECTS



MODEL PROPERTIES IN RELATION TO STUDIES

The three properties of the model, content, form and operation relate to the empirical studies reported in Chapters 7-10 in the form of specific questions as follows:-

1) **Form.**

   Is the structure of the model supported by empirical research?

2) **Content**

   What are the most important factors and are important factors represented at all levels?

3) **Operation**

   Do factors in the model operate to form an inter-related system?

The link between these questions and the studies is shown diagrammatically in figure 5.2 overleaf.

FIGURE 5.2 - MODEL PROPERTIES IN RELATION TO STUDIES

STUDY	**Preliminary**	**House-building**		
		Statistical	**Interview**	**Observational**
Property				
1) **Form** - the structure of the model				
2) **Content** - the importance of factors				
3) **Operation** - system effects				

6

METHODOLOGY

6.1 INTRODUCTION

This Chapter sets out the methodology and the underlying epistemology of the research. Methodologies in construction management have been vigorously debated in the recent past (1997-1998) and it is thus necessary to explicitly acknowledge the debate in detail. The first part of this Chapter, therefore, considers the debate within construction management research between the so called "rationalist" and "interpretivist" paradigms. It widens the debate to examine parallel arguments in the social science literature generally and it examines areas of agreement between the paradigms and routes to resolution of the rationalist/interpretive dichotomy. An alternative approach is proposed for applied technological problems, which is more relevant to the practical aims of this research, than either paradigm.

The second part of the Chapter considers the research methodology adopted in some detail, (with further detail being given in the respective Chapters covering the field research). The Chapter concludes with a diagrammatic representation of the methods used for verifying the propositions generated in the research.

6.2 THE CONSTRUCTION MANAGEMENT DEBATE

THE CRITIQUE

In 1995, Seymour and Rooke of the School of Civil Engineering, University of Birmingham introduced the argument that methodological assumptions held by construction management researchers had the effect of endorsing the status quo (Seymour and Rooke, 1995). These methodological assumptions they labelled the "rationalist paradigm", which they contrasted with an "interpretivist" approach. The latter was presented as an alternative, more appropriate methodology for the study of construction management. The authors gave considerable attention to their perception of the assumptions of the rationalist paradigm, the chief of which was a distinction made between subjective experience and objective reality. This distinction was considered invalid for social research, where researchers were presented with a world in which meaning was already made. Researchers were seen to assert their own interpretations of reality rather than investigating the interpretations of others. Developing from the distinction made by researchers between subjective experience and objective reality, was a critique of the employment of causal models and explanations by researchers. These were seen as dwelling exclusively on tools of control, ignoring the conventions of everyday life. Further, the tools legitimated control of some people over others by providing scientific justification for courses of action. They considered that there was no objective, value free point of view from which the rationality of a culture might be judged. The interpretivist alternative involved employing "verstehen" (Weber 1933) - defined as the understanding of another's point of view. Apart from Weber, three other sources of the interpretivist paradigm were identified, the Chicago School of Sociology, Blumer (1967) and Garfinkel (1967). The common theme of these sources was, again, the need to place the individual and his or her context at the centre of any research investigation. The authors took a polemical stance in their argument by supporting Garfinkel's methods as the only viable ones for social research. To them, the researcher's aim was to report the perspectives of the participants in particular settings, that is to reveal how people constructed their world, and not to report any single truth.

The authors applied their critique to a study of the determinants of quality in construction, which has parallels to the present research. Researchers in that study monitored constructional elements for defects and categorised the causes into "management controllable" and "operative controllable". The objective of the research was presumably to identify more commonly cited causes in order to direct future preventative action. The authors reported difficulties experienced in categorising causes in the research, where they identified ambiguities arising from the sequential nature of many construction tasks. These difficulties they interpreted as stemming from a need to apportion blame rather than merely identify the reasons for a defect arising. From these difficulties, the authors developed two criticisms, firstly, they asserted that the researchers were inappropriately required to take a normative stance in apportioning blame and categorising cause. This, they claimed, was not suited to a rationalist paradigm, which was ostensibly objective. Secondly, they concluded that a technical inability to attribute cause could only be addressed by an assessment of the whole texture of informal arrangements and tacit agreements that characterised the construction project. This could only be performed by those actively engaged in the work or a committed ethnographic researcher rigorously applying "verstehen". Whilst also recognising that accurate categorisation was possible, the authors maintained their philosophical standpoint of not distinguishing subjective experience and objective reality in asserting that there was no single, objective or neutral account to be had in the research.

In 1997, authors from the same source issued an express call for debate on the same research methodology theme (Seymour, Crook and Rooke, 1997). Little was added in this much shorter paper except that reference was made to grounded theory (Glaser and Strauss 1968), a theory which is directed towards generating abstract propositions. This was a modification of the philosophical position set out in the earlier paper. There was also some tentative recognition of the validity of causal research in that it was seen to have a subsidiary role compared with the primary role of defining meaning in interpretive investigations.

The call for debate and the earlier paper generated a limited response, the key points of which are reported below. In their reply to that response, the original authors (Rooke et al, 1997) again took a polemical stand in criticising the advocacy of "methodological liberalism", where rationalist methodologies were combined with interpretive ones.

They considered that such an approach was not conducive to developing rigour in construction management research and attributed difficulties suffered in sociology generally to its prevalence. The authors repeated their contention that "verstehen" understandings (sic) rather than causal ones should be the aim of social research. They succinctly set out their position as follows:-

> "First, the explication of inter-subjectively established meaning is the aim of social research. Second, such explication requires the researcher to refrain from constructing theoretical explanations (including causal ones), since these impose the researcher's meanings at the expense of those of the subjects of the research. Third, therefore, the final test of the validity of an analysis is if it can be demonstrated that such an analysis is the analysis which is used by the subjects of the analysis in analysing their own situation. Fourth, there is a tension between these academic principles and the further principle that the findings of research should be useful to practitioners, in the sense that fulfilling the first cannot guarantee the second, and vice versa. Fifth, this tension can be managed on the basis that all findings are produced in specific circumstances, for specific purposes. Sixth, the research should be capable of communicating a knowledge of how others in the construction process see that process in a way that is useful to practitioners (that usefulness to be judged by the practitioners themselves). Seventh, in addition, research should enable practitioners to reflect upon their own practices in such a way as to facilitate their attempts to improve those practices" (page 493).

This stance was again modified in a second reply (Seymour et al 1998) where the authors recognised that science "as it is understood by positivism" (page 112) was an academic discipline appropriate to the study of social conduct. However, they also wished to promote interpretivism as an equivalent academic tradition to positivistic science. The authors concluded that they did not wish to deny the possibility of causal explanations in social life, but saw such explanations as subsidiary.

THE RESPONSES

The responses to the call for debate noted above were of two types. Two papers (Raftery et al, 1997; Chau et al, 1998) presented a conciliatory stance. The first paper, in particular, largely interpreted the debate as a technical issue and advocated the multi-methodological approach later criticised by Rooke et al. Chau et al also attempted to reconcile the two paradigms by suggesting that interpretive methods could be used to provide information for identification and conceptualisation of problems, which were subsequently theorised for further rationalistic investigation. However, they also engaged the philosophical discussion by positing that there was a knowable order in nature, thus clearly distinguishing themselves from Seymour and Rooke. Likewise, their references to the need to understand the "real world", the need to formulate hypotheses and the need for generally applicable theory showed a philosophical standpoint that recognised objective reality. They criticised the interpretive approach which produced local situated knowledge on the grounds that, logically, it could only produce anecdotes relevant to the individual researcher.

A more robust, polemical stance was taken in two other papers (Runeson, 1997 and Harriss, 1998). The main thrust of both papers was to uphold science as a means of advancing knowledge. Science was seen as the development of causal theory and the authors saw the rejection of the rationalistic paradigm by Seymour et al as the rejection of science. Runeson suggested that not searching for casual relationships, generalisation and verification removed the purpose of science and the possibility of scientific progress. Harriss made a similar point that all scientific paradigms involved the production of theory. Drawing a distinction between inductivist and deductivist theory he noted the Popperian proposal (Popper 1959) of the development of theory through falsification. However, he contrasted theory development with the approach suggested by Seymour et al. He saw their approach as the rejection of theory and generalisation in favour of localised relevance. Although both authors strongly defended the view of scientific knowledge as the production of theory, both also acknowledged uses for an interpretivist approach. Runeson saw it as useful in adding valuable insights, building new theories and modifying existing theories and Harriss, whilst more dismissive of the paradigm, acknowledged its value in business consultancy.

As a side issue, both Runeson and Harriss considered the problem of defining construction management theory. Seymour et al had suggested, as a prelude to their critique, that construction management was based in the social sciences, hence the interpretive paradigm was relevant. Runeson and Harriss did not accept that there was a single separate theory that covered construction management and preferred the view that construction management was informed by several relatively unrelated intellectual disciplines. However, Runeson noted that a lot of research in construction management was normative, directed towards finding better work practices and the like, and not "science….in the positivist tradition" (page 300). As such, the measure of success for construction management research was effectiveness - "It is judged on results, and results alone" (page 300) and need not be informed by scientific theory.

Runeson's dismissal of practical research betrays a rather elitist view of science quite different from the rebuttal of interpretivism. A wider view might suggest that the unifying feature of construction management theory <u>is</u> its practical normative nature. This view might also suggest that construction management <u>does</u> use scientific theory (whether called positivistic or not), but its practical nature means that it is equally likely to draw on interpretivism. This view has not been aired and consequently the construction management debate remains both unresolved and shallow. However, before considering specifically the nature of construction management research and attempting to define construction management theory in relation to the current study, it is important to properly examine the actual and apparent differences between "rationalist" and "interpretive" paradigms. To do this, it is necessary to go beyond the construction management debate and examine similar discussions in related areas. For this purpose, the contention that construction management is a species of social science research can be accepted and the examination concentrated there. Appropriately, the discussion has also been most detailed in social research and, in particular, in sociology. Much of the following is drawn from this discipline.

6.3 THE WIDER DEBATE

A NOTE ON TERMS

The academics instigating the construction management debate introduced the terms "rationalist" and "interpretivist[1]" and drew a distinction based on the chief assumption concerning subjective experience and objective reality. They later referred to "positivistic science", a term also adopted by respondents to the debate. In a parallel debate concerning property research, Harris and Cundell (1995) issued a call without expressly collecting their criticisms under the umbrella of a single term, but Lizieri (1995) in response referred to "phenomenological", "reflexive", "feminist", "post-modernist" and "qualitative" approaches on the one hand, as opposed to "quantitative" approaches on the other. Green (1998), in a critique of construction process improvement, also referred to post modernism, but adopted a "critical perspective". When the debate is widened to directly include the social sciences, a similar plethora of terms is revealed. Thus, the "rationalist" approach is variously referred to as "positivist", "post-positivist", "realist", "scientific", "quantitative" and "based on the natural sciences", whilst the "interpretivist" approach includes "hermeneutic", "anti-realist", "naturalistic", "constructivist", "critical theorist", "qualitative", "new paradigm" and "action" research as well as several other terms. Importantly, these respective sets of terms are not synonyms. There are major differences in the underlying epistemology and methodology <u>within</u> as well as <u>between</u> the two divisions. Some of these differences will become evident below as the debate between the

[1] Seymour and Rooke originally used the term "interpretativist" and this in itself generated a minor debate. They later changed the term to the more generally accepted "interpretivist" used here.

divisions unfolds, but in order to economise on the use of terms, it is necessary to clarify some commonly used distinctions.

The term "rationalist" is little used in recent social science literature, the most commonly used alternative term being "positivist" or "positivistic science" and this term is generally used in the following discussion to label an epistemology based on a belief in the existence of objective reality outside the experience of interacting individuals. "Interpretivist" is a more widely used term and is generally taken to denote an epistemology based on a belief that reality is created by the interaction of individuals through the medium of language. Seymour et al identified this key distinction and much of the discussion in the social science literature is based on it. However, a distinction is also frequently made between quantitative and qualitative research in the same way. Thus, quantitative research is identified by many authors with a positivist and qualitative with an interpretivist epistemology. Logically, this distinction is less clear and this lack of clarity is reflected in the literature. The two terms appear to also refer to techniques of inquiry rather than underlying epistemologies, with both quantitative and qualitative techniques being consistent with either epistemology. The terms "quantitative" and "qualitative" are therefore avoided, unless demanded by the context, in the following discussion. Where inevitable, the epistemological definitions are adopted.

POSITIVISTIC SCIENCE

The roots of positivism in social science are found in the "positivistic philosophy" developed by Comte as a reaction to his perception of the negative aspects of the French Revolution and the anarchy pervading at that time (Ritzer 1996). Comte also founded "sociology" - a science based, according to him, on the systematic study of abstract laws which govern the social universe. These laws could be tested through the careful collection of data. The main "abstract law" that Comte developed was an evolutionary theory, which proposed that there were three intellectual stages through which the world has gone throughout history, culminating in the positivistic stage. In the positivistic stage, methods of science and empirical observation were the paramount means of advancing knowledge of the social world and only by the widespread adoptation of positivistic science would social harmony be achieved. This belief in "abstract laws governing the social universe" is still widely held among sociologists. Thus, Pugh (1983) expresses a "prior ontological belief that the organisational behaviourist universe is replete with regularities and a prior epistemological belief that we can manipulate our concepts so that the relevant data expose these" (page 47). Similarly, Hammersley (1992) reports that a "reality independent of the researcher whose nature can be known....is a philosophical doctrine on which much ethnography is founded" (page 43). Bryman (1988) sets out in considerable detail the features of positivism, summarised as follows:-

- It considers the methods and procedures of the natural sciences to be appropriate to the social sciences.

- It entails a belief that only observable phenomena can be counted as knowledge.
- It involves the accumulation of verified facts building towards theoretical knowledge.
- It involves the postulation of hypotheses as causal connections between entities, which are then submitted to empirical tests.
- It purports to be "value free" in both denying the validity of normative statements as they cannot be verified <u>and</u> requiring the scientist to take a disinterested neutral stance to research.

CRITIQUES OF POSITIVISM

Positivism has been attacked from a variety of directions within the broad grouping of interpretivist scholars. From the perspective of symbolic interactionism (see below), positivistic sociology is unsure, over-ambitious metaphysics, inaccessible to intelligent examination and holds incorrect views of social structure. Traditional positivistic sociology is considered to reduce actors to mindless robots on the societal level (Ritzer 1996). Denzin (1983) objects to positivism's use of the language of natural sciences and the search for causal paths, causal chains and causal antecedents, which he considers is detrimental to the study and understanding of lived experience. Guba and Lincoln (1998) provide a more detailed critique of the "conventional wisdom" of positivism, including that it strips data of its context, it excludes from consideration meaning and purpose, it inappropriately applies generalisations to individual cases, it fails to distinguish theories and facts and it fails to recognise the inter-relationship between researcher and the researched. Reason and Rowan (1981) criticise orthodox positivistic social science in a similar vein. Thus they see it as inappropriately treating people as isolable from their normal social contexts, as detaching the subjects of research from the underlying theory, as reifying the social world and as involving deception. Hammersley (1992) reports similar objections to ethnography based on survey and experimental research. This is seen as imposing the researchers' assumptions about the social world, as involving suspect generalisations from the experimental situation, as involving the inappropriate reliance on statements or observations, as invalidly reifying social phenomena and as inappropriately ignoring the creative role of cognition and group interaction. Miller and Crabtree (1998) in reporting clinical medical research attack "patriarchal positivism", which they see as a form of control through rationality involving inappropriate reductionism, emphasis on scientific rationality and the view of the body as a "biochemical machine" (page 294). Denzin (1998) makes a strong moral attack on positivism where he claims that "knowledge produced under the guise of objective science is too often used for purposes of social control" (page 315).

Several of these criticisms relate to methodological considerations, in that they are concerned with the <u>way</u> that conventional positivistic research is carried out. Indeed, this is recognised by Guba and Lincoln (1998) in that they make what they call "internal critiques" of positivism (page 197). These, they suggest, can be eliminated by the greater use of qualitative data. However, several criticisms relate to the inappropriate reification of social phenomena and are consistent with the views of Seymour et al concerning subjective experience and objective reality. If reification is seen to include the construction of theories and hypotheses, this appears to remove the scope for reconciliation between positivistic and interpretive epistemologies.

INTERPRETIVISM

The roots of interpretivism are less clearly defined that those of positivism. Schwandt (1998) groups the terms "constructivist" and interpretivist" as general descriptors of a "loosely coupled family of methodological and philosophical persuasions...which share the goal of understanding the complex world of lived experience from the point of view of those who live it" (page 221). One source of interpretivism is symbolic interactionism which is derived from the philosophy of George Herbert Mead (Ritzer 1996). Mead's philosophy is based on pragmatism, which holds that reality does not exist in the world, rather is actively created during individual actions. Mead was also influenced by psychological behaviourism - the view of the organism as responding to external stimuli. However, he modified the psychological view of behaviourism to allow social processes to intervene through language. Mead believed that consciousness was not lodged in the brain, but was a characteristic of the environment. This gave rise to the concept of "mind", which is created by social interaction through the medium of symbols (in the form of language). Ritzer (1996) summarises the basic principles of symbolic interactionism which includes the following points:-

- People can think and this differentiates them from the animals.

- Thought is shaped by social interaction
- Social interaction involves learning meanings and symbols used for human thought
- People are able to modify meanings and symbols on the basis of interpretation of the situation

As a consequence of the belief that thinking is shaped by social interaction, symbolic interactionists hold a relativistic view of the world. Different objects have different meanings for different individuals. The differentiation between subjective experience and objective reality drawn by Seymour et al appears to derive, at least in part, from the underlying philosophy of symbolic interactionism and a parallel strain runs through much interpretivist literature. Consequently, Denzin and Lincoln (1998) stress the socially constructed nature of reality, which Guba and Lincoln (1998) consider to be incommensurable with a belief in objective reality. Schwandt (1998) reports constructivism's belief that "knowledge and truth are created in the mind" (page 235). Bryman (1988) reports a wider range of sources underlying the epistemology of qualitative research. These include the symbolic interactionism noted above, but also phenomenology, "verstehen", naturalism and ethnogenics, most of which treat social knowledge as a matter of understanding - "social action must be examined by the social scientist in terms of the actors own interpretations of his or her actions and its motivational background" (page 51). The key features of qualitative research involve:-

- Seeing research through the eyes of the participants
- Providing detailed descriptions of social settings
- Examining social entities as a whole

- Taking a longitudinal (process) view of social life
- Adopting an unstructured, flexible approach
- Avoiding theory and conceptualisation as it is reification of social phenomena.

The underlying philosophy of interpretivism has consequences for methodology. This has been comprehensively illustrated in the approach to method advocated in "new paradigm" research (Reason 1981, Hammersley 1992). New paradigm research methods are directed to serving the needs of practitioners, which is the only means of ensuring relevant, valid findings not susceptible to unethical manipulation by researchers, or users of the findings.

CRITIQUES OF INTERPRETIVISM

Interpretivism, broadly defined, has been criticised from both within and without the paradigm on technical and philosophical grounds. In particular, within the paradigm, a number of authors have taken issue at a philosophical level with more literal interpretations in the form of radical deconstructionist or similar perspectives (Reason 1998, Greene 1998). To deal with technical issues first, several authors mention problems of ensuring internal and external validity, reliability and generalisability where techniques based on interpretivism are used (Hammersley 1992, Greene 1998, Bryman 1988). These problems range from the inability to generalise from single case studies to problems of validity where the participants also engage in the research. Bryman (1988) in particular reports a number of subjectivist ethnographic studies of the same groups of people by different researchers, which come to widely differing conclusions:-

> "Such sharp disparities should not be expected if ethnographers indeed base their accounts on native understandings and interpretations" (page 76)

Ritzer (1996) reports criticisms of symbolic interactionism for having "too readily given up on conventional scientific techniques" (page 363) and for employing vague and imprecise concepts such as "mind", "self", "I" and "me". He further notes criticisms of the paradigm for ignoring psychological and physiological factors such as the unconscious, emotions, needs, motives, aspirations and intentions, and for overly concentrating on everyday life. Greene (1998) from a generally sympathetic point of view criticises interpretivism for its inability to inform policy:-

> "qualitative evaluations as a genre…are destined to remain….beautifully responsive but, in being so, unable to assume a more proactive role in the social policy sphere. And so, because the evaluator as public scientist must be proactive, must him or herself become an active and accountable player in the policy arena, qualitative evaluation will not be enough" (page394)

Miller and Crabtree (1998), also from within the interpretivist paradigm, charges qualitative researchers with producing incomprehensible reports, published in a language and in places that benefit researchers and not participants. Hammersley (1992) points to the methodological inconsistency of qualitative researchers who reject realism at a philosophical level, but use a form of "naïve realism in assessing their own research" (page 125). Rose (1982) makes a similar point, with respect to the <u>behaviour</u> of researchers, thus:

> "All sociologists act as if they could apprehend and describe reality through the process of operationalisation and as if they could rely on absolute standards of scientific proof for their results to be evaluated….From this position, the supposed strong relationship of epistemology to research practice is something of a myth" (page 154).

The critique at a philosophical level centres on the relativism implied by the belief that all knowledge is socially constructed. Relativism is seen, if carried to its logical conclusion, as leading to an inability to transmit knowledge, or conduct any meaningful research, as leading to solipsism and as leading to an amoral outlook, which leaves the researcher unable to do more than reflect the views of participants whatever the views may be. Several of these points are made from within the broadly defined interpretivist paradigm (Schwandt 1998, Stanfield 1998, Kincheloe and McLaren 1998, Reason 1998), or from those sympathetic to the interpretivist approach (Atkinson and Hammersley, 1998, Greene 1998, Gill and Johnson 1997). Schwandt (1998) explains the problems of solipsism and relativism as follows:-

> "What is an adequate warrant for a subjectively mediated account of intersubjective meaning? In the absence of some set of criteria, such accounts are subject to the charges of solipsism (they are only *my* accounts) and relativism (all accounts are equally good or bad, worthy or unworthy, true or false, and so on)" (page 246)

This leaves the researcher "unable to critique the very accounts they produce" (page 246). Schwandt continues by arguing that the psychological claim that knowledge is socially constructed and is not simply the product of sense data on the mind is not problematical, but there are logical problems in holding to the epistemological claim that knowledge does not discover a pre-existing world outside the knower. He poses the question that if knowledge is only in the mind of the knower how is it that knowledge is available to individuals and is shared and transmitted. Similarly, Atkinson and Hammersley (1998) point to recent post modernist challenges to the objectivity of research in ethnography. These challenges have developed towards questioning the possibility of social science knowledge and suggesting that the accounts produced by researchers are themselves constructions. They describe these challenges as leading to scepticism, relativism and hence "debilitating nihilism" (page 252).

Bryman (1988) reports the problems posed by simply reflecting the views of participants when these views may be overtly immoral or marginalist (fascists or 'Jesus Freaks' are the two examples he gives). Greene (1998) notes that "Interpretivism justifies values in inquiry, but does not justify any particular ones" (page 394). Hammersley (1992) expands the critique to include problems of 'value relativism', which theoretically could render "us unable to condemn, or to justify action against the perpetrators of genocide" (page 77). A similar problem is reported, within the interpretivist paradigm, by the critical theorists Kincheloe and McLaren (1998), who suggest that critical theory is distinguished from interpretivism by providing "the post-modern critique with a normative foundation....Without such a foundation the post-modern critique is ever vulnerable to nihilism and inaction" (page 272). This theme is echoed by Reason (1998) in his critique of radical deconstructionalism. He considers the approach to be:-

> "over-intellectualised and thus both nihilistic and oppressive. Voices are just voices; they have no claim to truth, so the search for voice is seen as being the search for any old voice. And given current power relations on the planet, the first voices likely to be "deconstructed" are those of people already oppressed, the voices of the poor, of women, but also the voices of the body and of the earth itself." (page 281)

Consequently, Reason (although an instigator of 'new paradigm research') rejects a relativist ontology in favour of a more subtle combination of objective and subjective reality. This compromise seems to be inconsistent with the basic epistemological differences between positivism and interpretivism. Although the possibilities of rapprochement are held out at a technical level, with the exception of Reason and Hammersley, few authors reviewed consider this at the philosophical level. Nevertheless, Hammersley presents a persuasive argument for "subtle realism" and suggests that the apparent dichotomy between the two paradigms can be closed to the benefit of both. This argument is reviewed below in considering ways in which the debate can be resolved.

6.4 RESOLUTIONS

There is an large body of social science literature calling for the resolution of the dichotomy, showing how this can be and is being achieved, or pointing out that the dichotomy is false and that the two "paradigms" are not paradigms at all in the sense meant by Kuhn (1970). As with the arguments presented above, resolutions can be divided into methodological and philosophical (Bryman 1988), with the methodological being more easily illustrated. Accordingly, the arguments for resolution at this level are considered first.

Bryman (1988), in pointing out the difference between epistemological and methodological versions of the qualitative/quantitative debate notes that "The tendency to associate particular methods with particular epistemological positions is little more than a convention which took root in the 1960s" (page 125). From this point, Bryman goes on to illustrate that qualitative and quantitative approaches (methodologically defined) can be combined in any way that gives valid results. The point is taken up by Atkinson and Hammersley (1998), who note that participant observation is claimed by interpretivists, but is also used by positivists. Miller and Crabtree (1998) also advocate mixing and matching of methods, whilst noting interpretivists' fears of mixing on the grounds of not wanting to be seen to acknowledge a subservience of qualitative to quantitative paradigms. The authors, in overcoming their fear, expand on multi method approaches including concurrent, nested, sequential and combined designs. Fontana and Frey (1998), Gill and Johnson (1997) and Robson (1993) similarly support various combinations of methods to achieve required ends. Robson, in particular parallels Runeson and Chau et al in advocating inductive/interpretive research for theory building and deductive/quantitative research for theory testing.

Authors coming from an interpretivist background and advocating mixed methodologies, have also implicitly accepted some form of realist ontology, because the use of some methods necessarily requires the testing of abstract theory. It is this implication which appears to be behind the "purist" comments of Seymour et al and it is for this reason that mixing and matching may not be acceptable to all interpretivists. However, this dichotomization in itself leads to a resolution in the form of the two paradigms having clearly different subject areas of study. This resolution, which can best be described as the "horses for courses" argument, is both widely expressed and widely implied. For example, Hammersley (1992), in a critique of practitioner research, draws a distinction between, on the one hand, more general scientific research, carried out by specialist researchers and producing research of indirect and general relevance and on the other hand problem-solving and reflective inquiry, producing information that is of more specific and direct relevance to practice. He considers both forms of research valid, but require different methods of managing subject matter. Denzin (1998) also notes that positivist and interpretivist paradigms have different aims and gives details of what those aims are, with positivistic research being concerned with the "world of causes and effects" and constructivist/interpretivist research being involved in "interpretation of the subject matter at hand" (page 502). Greene (1998) takes a range of philosophical standpoints including post-positivism, pragmatism, interpretivism and critical theory and fits different research questions to each. For example, she fits questions concerning policy and macro decision making to positivism, whereas she fits questions concerning staff welfare and empowerment to interpretivism. Guba and Lincoln (1998), whilst generally critical of positivism, also acknowledge the differing aims of positivistic, constructivist and critical theorist research. Positivism is concerned with prediction and control of phenomena, constructivism with understanding and reconstruction and critical theory with critique and transformation. Rose (1982) notes the particular successes of participant observation and field work based on interpretivism thus:-

> "the major success of the (interpretive) approach seems to be in research on social organisations and on looser-knit social groups, where the focus of the

inquiry is the 'here and now' of group dynamics, the ideology or the world view of the group, or a specific process or experience" (page 129)

There is also a de facto correspondence between epistemological beliefs and subjects of study in much interpretivist literature (Schwantz 1998, Smithgate 1981, Torbert 1981A, 1981B, 1981C, Janesick 1998, Reason 1998, Miller and Crabtree 1998, Fontana and Frey 1998 Adler and Adler 1998, Hodder 1998, Harper 1998, Clandinin and Connelly 1998, Rist 1998, Checkland 1981, 1989). An example of the "horses for courses" argument is provided by Checkland (1981), who illustrates the specialist application of systems theory to "soft systems methodology" (a type of operational research based on interpretivism) as follows:-

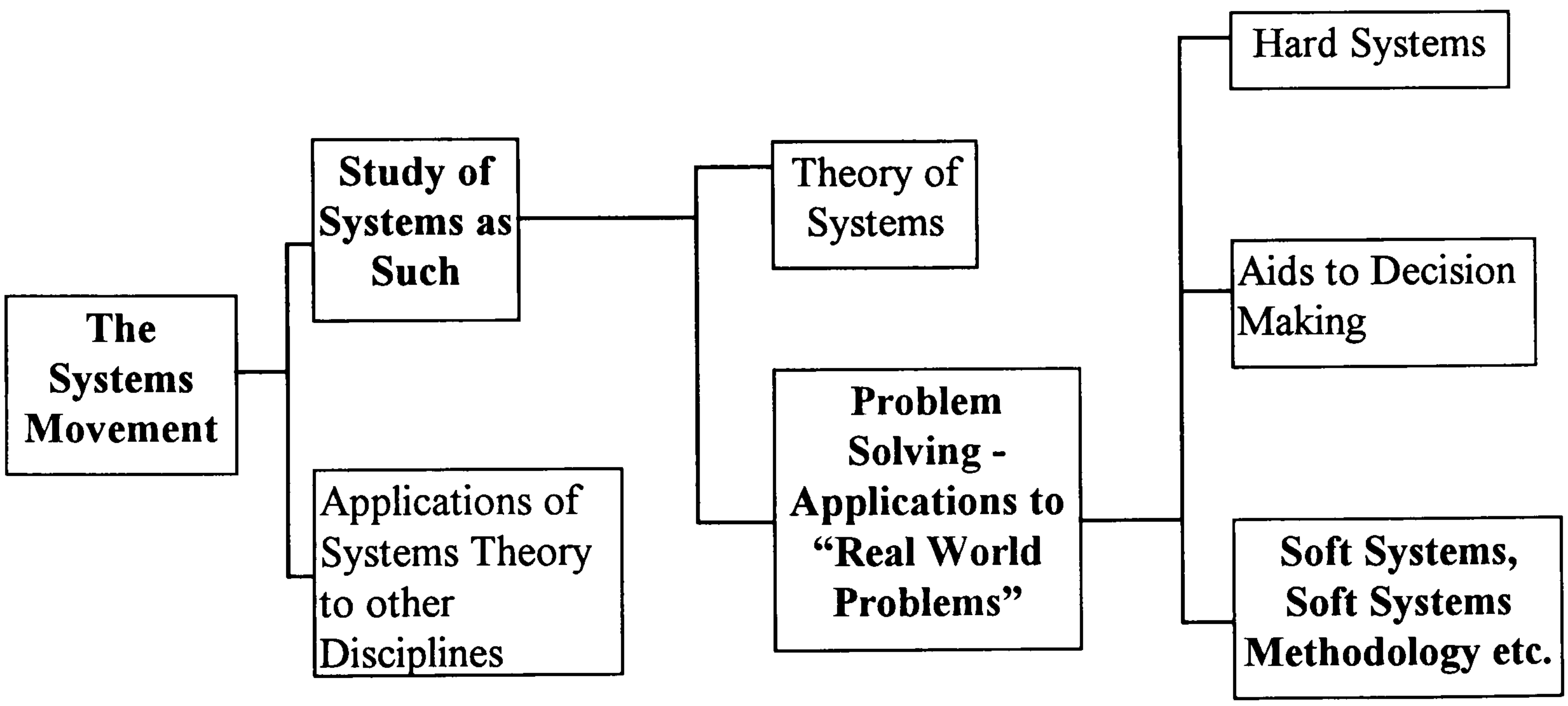


FIGURE 6.1 THE APPLICATION OF SYSTEMS THEORY TO SOFT SYSTEMS METHODOLOGY (Source - Checkland (1981) page 95)

Checkland applies soft systems methodology to problem solving applications "bounded by the organisational setting" (page 154) and not to the more general scientific research mentioned by Hammersley (1992).

With respect to the philosophical debate, Morgan (1983), in introducing a reader presenting both positivistic and interpretivist views, makes the same point as Thomas Kuhn (1970); that the propositions within a particular paradigm cannot be "proved, disproved, or evaluated on the basis of axioms within the (paradigm)" (page 15). Thus, conversion or consensus is required if the dichotomy is to be resolved at the paradigmatic level. Consensus has been appearing for several years, but the call for reconciliation by the interpretivist George Marcus (1998) shows that it has largely been achieved. Marcus comments on the over-reaches of interpretative science:-

> "I believe the major fear in the general reception to the now decade-long radicalization of tendencies....that have been present from the very inception of qualitative social science is that of transgression, of excessive skepticism, and of a paralyzing relativism - of a crossing of limits beyond which "anything goes"....and where even the possibility of communitas - of a shared discourse - among scholars has become imperilled" (page 403)

Marcus continues by citing with approval examples of ethnographic research which display a commitment to a return to objective knowledge in order to "re-invigorate a current exhaustion with the explicit rhetoric of the post-modern debates" (page 403). A similar call for consensus is made by Lincoln and Denzin (1998), who note that continual inter-paradigmatic criticism is of little relevance to active researchers. Historically, even where largely interpretivist methods have been advocated, forms of theorising have not been eschewed. Thus, even though Weber's "verstehen" is much quoted as the correct approach to social research, Weber himself de-emphasised methodological issues and was prepared to compromise between nomothetic and ideographic methods. To Weber, theories in the form of concepts never completely captured the empirical world, but could be used as heuristic tools for gaining a better understanding of reality (Ritzer 1996). Berger and Luckmann (1967) also expressly stated that they did not have a polemic intent in writing "The Social Construction of Reality", and they supported both positivistic science and the use of theory in pragmatic applications.

Three attempts to combine realist and anti-realist ontologies are Huberman and Miles's (1998) "transcendental realism", Reason's (1981) "perspective" and Hammersley's (1992) "subtle realism". It is difficult to see how Huberman and Miles's conception differs from any other "realism" given their belief that "social phenomena exist not only in the mind, but in the objective world as well" (page 433). Reason also implies prior knowledge in the mind in defining <u>perspective</u> as "a personal view from some distance" (page 241), which appears little different from outright realism. However, Hammersley gives considerable detail in promoting subtle realism. He considers that it is consistent to believe in the existence of phenomena independent of claims about them and to not assume unmediated contact with them. Consequently, "knowledge is belief of which we are reasonably confident" (page 50) and phenomena can exist independently of claims made about them. The aim of social research is the representation (not reproduction) of reality and it can accommodate different points of view:-

> "the fact that we have no direct access to reality, and thereby to knowledge that can provide a foundation of certainty for our understanding of the world, does not necessarily imply rejection of truth as correspondence. Nor does it undermine the idea that some methods are more effective than others in producing knowledge of reality, or the ideal that there are criteria by which we can judge empirical claims. These conclusions only follow if we assume that for claims to be called knowledge they must be known with <u>absolute</u> certainty, that to be of any value methods must <u>ensure</u> true findings and that criteria must produce assessments that are <u>beyond all possible doubt</u>....there is no reason to make these very strong assumptions" (page 61).

The validity of research is measured by its truth. It is true if it represents accurately the phenomena that it is intended to "describe, explain or theorise" (page 61). This is the "correspondence theory of truth" and Hammersley considers that adequate evidence of truth is not an absolute measure. In everyday life, it might be demonstrated "beyond reasonable doubt", or by use of "cost and value" calculations (page 69). For research seeking wider applicability, higher standards are required including submitting it to peer review among the specialist research community. These views on measures of truth correspond closely with both actual scientific practice <u>and</u> tests of authenticity demanded by interpretivist researchers. For example, Popper (1959) notes the uncertainty of science:-

> "the empirical basis of objective science has nothing 'absolute' about it. Science does not rest on rock bottom. The bold structure of its theories rises, as it were, above a swamp. It is like a building erected on piles. The piles are driven down from above into the swamp, but not down to any natural or given base, and when we cease our attempts to drive our piles into a deeper layer, it is not because we have reached firm ground. We simply stop when we are satisfied that they are firm enough to carry the structure, at least for the time being" (page 179 in Losee 1993)

Popper recognises the possibility of competing theories and proposes "verisimilitude" as a process of approximating towards the truth. Interestingly, exactly the same test of validity (verisimilitude) is referred to by several interpretivists including Lincoln and Denzin (1998) and Adler and Adler (1998). Given the apparent reconciliation of paradigms, it is appropriate that methods should begin to show common features.

Modern social science theory appears, therefore, to be able to accommodate both positivistic and interpretivist approaches. Some authors still take a "purist" interpretivist stand including Guba and Lincoln (1998)and an unmoderated positivist stand appears to be held by Harriss, but even these "extremists" appear prepared to recognise the value of the "opposite" paradigm in limited applications. Accommodation does not, however, necessarily mean that there are not substantial disagreements in detail and points related to, for example, unethical scientific study, or problems of generalisability with interpretivism, are well founded. Assuming that these problems can be adequately addressed by careful research design and execution, there is still the problem of correctly applying method to study objectives. Denzin (1998), Bryman (1988), Hammersley (1992), Greene (1998), Rist (1998) and Reason (1998, 1981) as well as several other authors have clearly demonstrated that different research objectives require different methods. If cause is being investigated, then some form of propositional research is justified. In order to make such research generally applicable, beyond the research setting, a certain degree of separation between researcher and researched and some use of quantitative techniques might be justified. If understanding is sought, or change from within desired, then a more inductivist approach following the interpretive pattern is appropriate. In relation to the current study, the choice of an applied research methodology, using a propositional approach will be argued in the following section.

6.5 AN APPLIED RESEARCH APPROACH

In his response to the call for debate in construction management, Runeson made reference to the heterogeneous grouping of subjects included under the banner of the discipline. Many of these he dismissed as "not science" in a manner which implied that the only "good" knowledge was a particular kind of scientific knowledge. Yet, even a cursory glance at the abstracts of papers in the major construction management journals, Construction Management and Economics, and Engineering Construction and Architectural Management, indicates that the majority of papers are of the applied type dismissed by Runeson. A further glance at active research programmes promoted through the United Kingdom Government also indicates that they are concerned to a large extent with applied research[2]. The ground upon which Runeson rejects such research as science - that it is concerned with bettering work practices and the like is supported by Bryman's (1988) definition of positivistic science, which denies validity to normative statements as they cannot be verified. The problem with this view is that, not only does it reject much interpretive research as "respectable knowledge", but all applied propositional research with a normative content as well. Weber (1948) attempted to avoid the problem of normative values in research by advocating a clear separation of both politics and personal values from science. He supported science thus:-

> "To affirm the value of science is a presupposition for teaching (in the classroom). I personally by my very work answer in the affirmative, and I also do so from precisely the standpoint that hates intellectualism as the worst devil..." (page 152)

Weber advocated the separation of values from science thus:-

> "I am ready to prove from the works of our historians that whenever the man of science introduces his personal value judgement, a full understanding of the facts ceases" (page 146)

However, Weber did not suggest that values had no place in the behaviour of scientists, merely that the normative questions relating to choice of subjects of study, the orientation towards "bettering work practices" and the like preceded the practice of science. Runeson's rejection as science practical management problems, and by implication his rejection as scientific the research methods of those working on such problems, betrays an un-necessarily strict positivist view that all research, including the selection of research topics must be strictly value neutral. This view was clearly not held by Weber. It also demands an examination of the nature of applied work in fields related more closely to construction management than economics or the natural sciences.

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[2] For an example of such a research programme, see the Department of the Environment, Transport and the Regions, DETR Construction Research and Innovation Programme: Compendium of Projects on the DETR Web site.

The first requirement in widening the debate towards applied knowledge is to examine forms of knowledge beyond scientific reasoning. It is interesting to note that Kuhn (1970) recognised both normative imperatives and different forms of knowledge in developing his paradigm theory:-

> "in fields - like medicine, technology and law...the principal raison d'être is an external social need (and these fields are not driven by) paradigm change". (page 19)

Further, Kuhn tested his own theory by the pragmatic standard of efficacy as follows:-

> "....one set of reasons for taking the theory seriously is that scientists do in fact behave as the theory says they should" (page 208)

In responding to a point raised by Runeson, that medicine depends upon positivistic science, Seymour et al also note the difference between science and medical practice:-

> "Apart from the scientific work that has gone into the formulation of the pills, the order of knowledge on which the doctor draws is entirely separate from the scientific. And what can we say about the surgeon's skill in wielding the scalpel? It represents more than the knowledge of anatomy" (page 110)

Seymour et al differ from Kuhn in linking "non-scientific" knowledge to interpretivism; a link which is also made by Hamilton (1998). Hamilton draws a distinction, taken from Aristotle, between theoretical and practical knowledge. He links the former to science and the latter to interpretivism. However, there is no reason to suppose that practical knowledge is based solely on interpretivism. The flaw in Seymour et al's point is that the general practitioner and the surgeon are just as likely to use abstract propositional reasoning as the scientist developing the drugs they use.

Ferré (1995), in discussing the philosophical roots of technology, also gives considerable attention to the differences between the forms of intelligence which underlie practical and theoretical reasoning. Drawing on Whitehead (1929), he notes that practical reasoning is outcome oriented, judged by its applicability to a problem, is of instrumental value and does not require explicitness - it only needs to produce results. In contrast, theoretical intelligence is disinterested, focuses on depth and precision, is judged by its means, is explicit and relies on linguistic abstraction. The mode of progress of practical reason is through invention. In contrast the language of theoretical progress is discovery or understanding. An important use of practical knowledge is the development of valuable applied concepts to produce inventions and innovations which work. It is not primarily concerned with discovery or understanding per se, unless these achievements are directed towards practical improvements. As the capacity to achieve abstract propositions is central to practical reasoning, in contrast to Hamilton, Ferré clearly adopts a realist position - objective reality is literally the "object" of invention or innovation.

Knowledge in applied technological fields like construction management is likely to involve practical reasoning and use propositional research (for example, of the kind mentioned in Miles and Huberman, 1994). It relies for validity on corroborative evidence much as the detective or medical practitioner uses in determining cause (Miles and Huberman 1994, Creswell 1998, Mintzberg 1973), but its over-riding imperative is, as Runeson correctly noted, that its products work. It is value neutral in its application, but, in line with Weber (1948) deals with values as a prelude (for example in the choice of topics of study). This model of reasoning finds support from the operation of the Law (Lloyd 1964, Farrar and Dugdale 1984, Holland and Webb 1996) and from many social scientists who consider the practical applicability of theory of paramount importance. These include Robson (1993) (who expressly invokes both a technological and a quasi judicial model of analysis), Hammersley (1992), Atkinson and Hammersley (1998), Heron (1981), Sanford (1981) Rist (1998), Gill and Johnson (1997) and Checkland (1981).

Keating (1997) articulates the approach (in relation to research into social work) thus:-

> "The test of theory is not only how well it explains what we are seeing, but also how well is serves particular interests and purposes" (page 7)

Further support is provided by Gill and Johnson (1997), who adopt a "pragmatic epistemological position" based on "explicit recognition that social theory is interconnected with social practice" (page 149):-

> "the truthfulness of any methodologically corroborated explanation or account would be ultimately available, or testable, only through practice. This makes it incumbent upon the researcher to provide a clear guide to the practical ramifications of the theory and the subsequent practices that would pragmatically test that theory....research should proceed at least to identify the practical ramifications of (an) account and, ideally, should also proceed to test that account through practical interventions into our world so as to get feedback from that external reality" (page 149)

To conclude this section, therefore, construction management is a practical discipline. A research paradigm appropriate to construction management should use an applied approach and be judged by the success of its discoveries as applied to practical inventions, whether abstract or physical. It uses all forms of knowledge, provided they are effective and these include both positivistic science and interpretivism. Its outcomes might be in the form of immediately applicable inventions, or in the form of more generally applicable guides to policy that in turn inform practical decisions. It is within this paradigm that the research presented in this thesis operates and accordingly adopts a multi-methodological design, but with a primarily applied propositional orientation.

6.6 THE RESEARCH

PREVIOUS STUDIES OF ERROR

Many studies of error and its outcomes consist of documentary reviews. These fall into three broad classes. Authors such as Turner (1978), Perrow (1984), Vaughan (1990), Sagan (1993) and Jones and Nathan (1990), review the published reports of major disasters and attempt to synthesise general conclusions from these, authors such as Eldukair and Ayyub (1991) and Brown and Xiaochen Yin (1988) review large numbers of press reports of failure, analyse their cause and draw conclusions and several authors including McKaig (1962), .Kaminetzki (1991) and Feld (1968) anecdotally collect and analyse reports of failures. Some authors including Rollings and Rollings (1991), Doud and Hamdani (1988), Dea and Gans (1986) and Kaminetzky (1991) extend their analysis to include lesser failures, as a series of case studies, often of a "forensic engineering" nature. The approach, however, is much the same as the documentary reviewers listed above - to analyse past mistakes, to generalise and learn lessons.

Field research is more limited, but includes the series of case studies of High Reliability Organisations reported by Roberts (1993). In these studies, the researchers attempt to get inside the organisations to observe their actions. Use is made of experiment by Mark Stewart (1993, 1994) and his co-researchers at the University of Newcastle, Australia, in attempting to measure engineering design errors and several researchers including Whittington et al (1992) and Sani (1988) use field surveys of organisations in constructing models of the error process or of quality assurance. Hinze and Raboud (1988) use a combination of the reported accident record of US contractors with an analysis of the method of construction planning used by those contractors to draw a conclusion that the better a site was planned, the lower was its accident record. Duff et al (1994) use field experiment in evaluating the effect of feedback and goal-setting techniques on the safety performance of construction operatives.

The UK Building Research Establishment use surveys and observational studies for their research reported in Chapter 4. For a general study of the technical causes of defects, Griffin (1990) uses a postal survey of 116 Local Authorities, the survey instrument being a structured questionnaire form. Both Harrison (1993) and Bonshor and Harrison (1983A) use observational studies of housing projects. The studies involved the observation, recording and analysis of faults as they arose during construction. Bentley (1981) uses a similar method of observation, but centres on two key personalities (the clerk of works and the site manager), rather than faults, in evaluating "quality related events". Bentley also supplements his numerical analysis of quality related events with interviews and detailed narration of case studies, which show both the pathology of error incubation and the ingredients that go into good quality construction.

ACCOUNT OF THE RESEARCH PROCESS

Introduction

The review of previous research gives the impression that it was possible to fully discover, document, analyse and criticise other researchers' attempts to improve the understanding of human error prior to commencing work. However, the research process was more organic, involving the discovery of literature (including that related to methodology) at the same time as some field work was carried out. The analogy proposed by Miles and Huberman (1994) of a criminal investigation, where propositions in the form of hunches are floated by a detective, tentatively tested and later modified, more accurately reflects the path of the research. In order to save time and take advantage of opportunities offered and (to continue the detective analogy) not to let the trail go cold, several tasks were carried out concurrently. Although there was a risk that this would lead to mistakes in choices of methodology, inconsistencies between studies and, possibly, abortive work, the risk was considered worthwhile in order to more comprehensively investigate the subject matter within a manageable timescale.

The studies

Literature review

The starting point for the research was a review of the literature as reported in Chapters 2, 3 and 4. The path of this review, commencing with the investigation of defects, was described in the Introduction. Much reviewing was conducted intuitively, based on the researcher's experience of investigating more specific construction problems. A deliberate attempt was made to widen the sources of information as far as possible - to consider all the possible leads that might have a bearing on the occurrence of defects. This "inclusive" approach involved the examination of several disciplines, but also involved looking at outcomes other than defects, such as accidents and business failures) and looking at the "success" side of outcomes, for example, in the quality assurance and safety literature (See figure 1.2 in Chapter 1).

Model construction

The process of integrating the various perspectives on human error reviewed in the literature led to the emergence of common categories. Certain authors had also indicated that errors in complex organisations could not be treated in isolation and should be considered as systems. Many authors had structured the causes of error into hierarchical models and this led to the tentative proposition that errors in construction could also be modelled. Drawing from literature related to errors in project based industries (for example, Whittington et al 1992), a model of error was proposed and is detailed in Chapter 5.

Preliminary study

Immediately the model had been formulated, a decision was made to attempt a preliminary verification in order to. more closely control the research and avoid setting off on false leads. The objective of the preliminary study was to investigate, primarily, whether the content and form of such a model was applicable to those most affected by construction errors - the participants in the construction process. This led to the decision to use a postal opinion survey and a largely closed question type questionnaire. The advantages of this type of instrument were seen as:-

- It allowed a sample of a cross-section of the population, thus allowing for some generalisability of results.
- It could be prepared and administered fairly quickly, thus providing rapid feedback in directing future work on errors.
- It comprehensively represented the model.

The method of sampling (for detail see Chapter 7) involved an opportunistic sample of students at a university combined with a "snowball" element, where students were asked to pass questionnaires to colleagues. The method of analysis involved largely statistically based quantitative techniques drawn from standard texts in the area (Bryman 1989, Coolican 1994, Howell 1989, Kinnear and Gray 1994). Coding and analysis of qualitative responses also followed standard texts in the area (Miles and Huberman 1994, Hamel 1993, Yin 1993, 1994, Strauss and Corbin 1990). On completion of the preliminary study, feedback was sought by submitting a paper for publication (Atkinson 1998).

Statistical study

In order to strengthen and develop the results from the preliminary study, a method of relating the content of the model directly to the occurrence of defects was sought. Analysis of data from High Court records of litigation related to defects was considered, but was unavailable, as was data concerning defects from a building guarantee company. Had such data been available, some form of documentary analysis or field experiment might have been devised. In the event a statistical study was devised to compare aspects of the model with levels of defects on 23 ongoing house-building sites (for detail see Chapter 8). The advantages of this approach were:-

- It attempted to relate the model directly to the level of defects.
- It provided data suitable for statistical analysis, thus improving reliability.
- Some information could be directly observed by the researcher
- It allowed some generalisation within a limited population

As with the preliminary study, techniques used in the statistical study relied on standard texts in the area.

Interview study

An early decision was made to supplement statistical analysis with interviews. This was because not all aspects of the model were amenable to statistical analysis, particularly those related to systemic effects, where one error could lead to another in a different category.

The collection of statistics involved a physical visit to sites and this provided an opportunity to combine the collection of statistics with an interview with the site manager. When combined with a further wider set of interviews of senior construction personnel and building guarantee company managers (for detail see Chapter 9) the responses could be used as corroborating evidence of the causes of errors and to provide information on factors not amenable to statistical analysis. It was at this point that it was realised that satisfactory investigation of all properties of the proposed model would rely on the <u>totality</u> of findings from several studies. Thus, the <u>triangulation methodology</u> encountered earlier in such works as Miles and Huberman (1994) was reviewed and became a conscious goal of the studies. The method used for the interview study was to conduct a largely undirected open interview as detailed in Chapter 9 following coding methods advocated in the standard qualitative texts mentioned above. The triangulation methodology also followed recognised writings on research methods (Miller and Crabtree 1998, Robson 1993, Bryman 1988, Winch 1990, Gill and Johnson 1997). In addition, triangulation followed Koch (1993), who specifically applied it to studies of error avoidance in High Reliability Organisations, illustrating the appropriateness of the technique in the current context.

Observational study

Researcher observation was used largely to complement the interviews and follow the pathology of errors as they arose. During the site visits and interviews detailed in Chapters 8 and 9, discussions were held on the possibility of closely observing one site in action. The advantages of such an observational study were:-

- It allowed for assessment of the pathology of errors as they arose, including examining links between underlying and patent causes.
- It allowed direct observation by the researcher rather than reliance on reporting by others in the Interview Study.
- It allowed factors that could not be measured in the statistical study to be considered.

Against these advantages is set the fact that any information would be local, from which it would be difficult to generalise beyond the situation. Research methods used again followed standard texts noted above (for detail see Chapter 10).

The rationale for each method is summarised in table 6.1 overleaf. This table is based on Mintzberg's (1973) justification for his research approaches as reported in Gill and

Johnson (1997) modified to suit the current work and with disadvantages drawn from the conclusions reported in Chapter 11 added.

TABLE 6.1 - JUSTIFICATION OF RESEARCH APPROACH (AFTER MINTZBERG 1973)

Method	**Applications**	**Advantages**	**Disadvantages**	**Appropriate use**
Wide literature review	General	Convenient	Time consuming..	Cover broad field of study.
Model Construction	Whittington et al (1992), Embrey (1992), Bea (1994)	Allows for complexity	Involves preconceptions	Conceptualise complex interacting system.
Questionnaire survey	Griffin (1990)	Generalisable, quick, comprehensive	Sample limitations, constraining.	Provide early feedback
Statistical field study	Hinze and Raboud (1988)	Generalisable, reliable, direct	Construct validity, data constraints	Provide link between propositions and defects
Interviews	Bentley (1981)	Allows for probing of causal links and pathology of errors.	Localised, selective induction, interviewee bias	Operation of model, including links between causes. Complement statistical study..
Participant observation	Bentley (1981), Harrison (1993), Roberts (1993)	Direct, reveals detailed pathology	Localised, time consuming	Examine causes and pathology.
Triangulation	Robson 1993, Bryman 1988, Koch (1993)	Provides corroboration	Requires multiple studies	Basis for overall findings.

An investigative research methodology

Table 6.1 shows a "methodological" precedent related to each of the field studies adopted. However, most precedents were "single studies" and were more vulnerable to methodological failings than multiple studies using a variety of methods. The current research, based on the use of multiple studies and triangulation, appears a more robust method for investigative research[3]. The key components of an investigative methodology arising from this research and suitable to applied research problems can be distilled, therefore, as follows:-

1) A detailed search of literature using as wide a source of information as is consistent with the research problem(s).
2) The formulation of propositions. In the current research this was in the form of a model
3) Preliminary verification of propositions to test for general applicability
4) Search for more detailed corroboration, refutation or modification of preliminary findings.
5) Further studies until sufficient evidence is uncovered to support corroboration. The measure of sufficiency might be the "beyond reasonable doubt" criteria proposed by Hammersley (1992).
6) Comparison of studies in a process of triangulation.

This methodology, although derived largely intuitively, is supported by Rose's (1982) ABCDE model of a suitable process for social science research. In constructing the

[3] Both the value of multiple studies and the need to allow subsequent studies to influence earlier ones is recognised by C Wright Mills (1970) with respect to sociology:-

"Good work in social science today is not, and usually cannot be, made up of one clear-cut empirical 'research'. It is, rather, composed of a good many studies which at key points anchor general statements about the shape and the trend of the subject. So the decision - what are these anchor points? - cannot be made until existing materials are re-worked and general hypothetical statements constructed" (page 222) model, Rose expressly recognises that theory is often reconsidered in the light of empirical findings, re-written and later re-tested in an iterative process:-

> "One important point is that, in most research reports which test theories, the author will normally reconsider the theory after the empirical findings have been described. The re-writing of theory (or at least parts of the theory) to take account of new findings is the most common result of theory-testing research: this comment applies whether the theory tested is confirmed or refuted" (page 46)

Rose's model involves five steps, A - generation of theory, B - generation of abstract propositions (in the current research the preliminary model), C - operationalisation of propositions, D - field work and E - results. Theory, propositions and operationalisation are linked to results with feedback links as follows:-

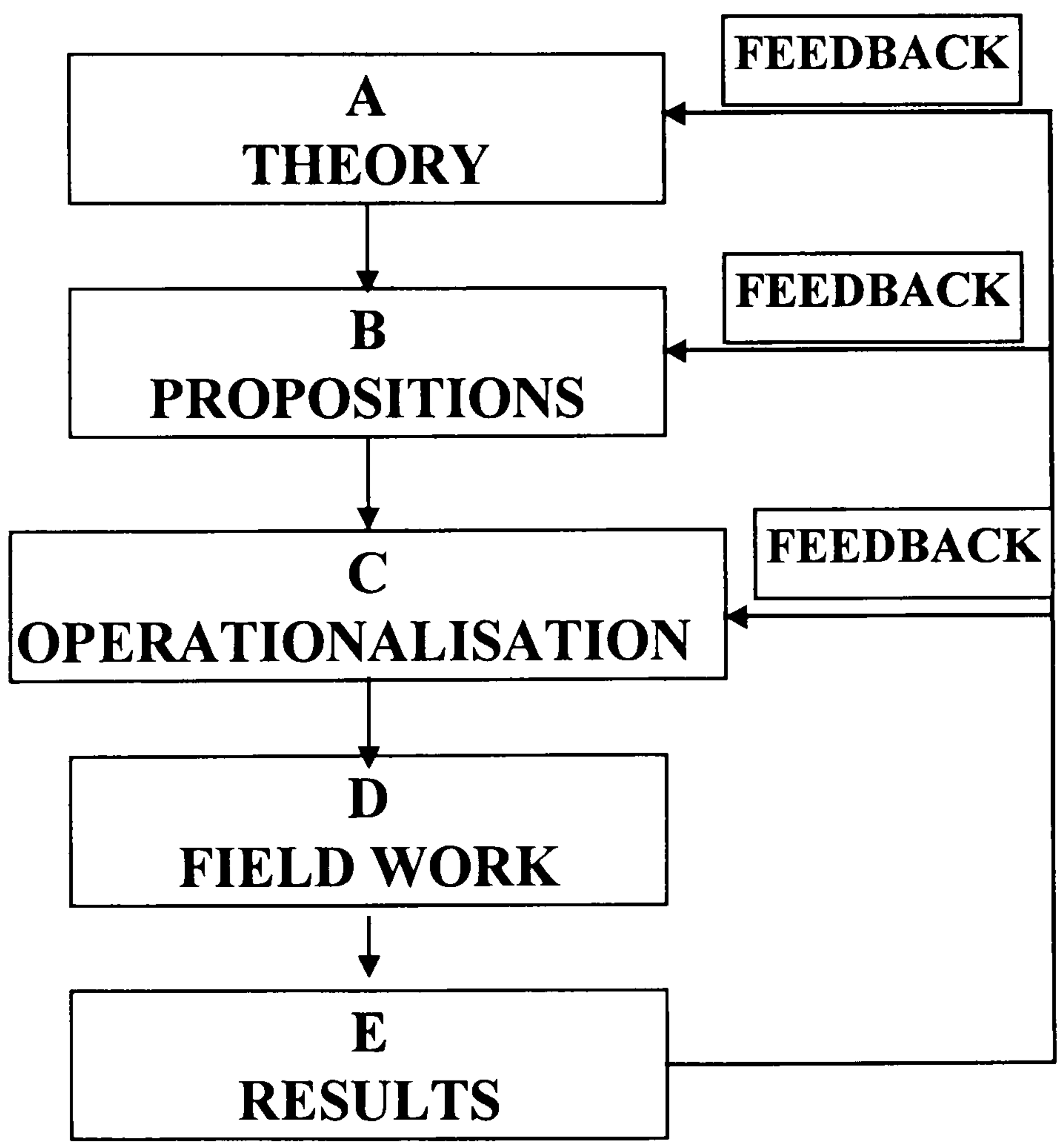

FIGURE 6.2 THE ABCDE MODEL (ROSE 1982)

A similar model is proposed by Gill and Johnson (1997) more specifically related to practical interventions:-

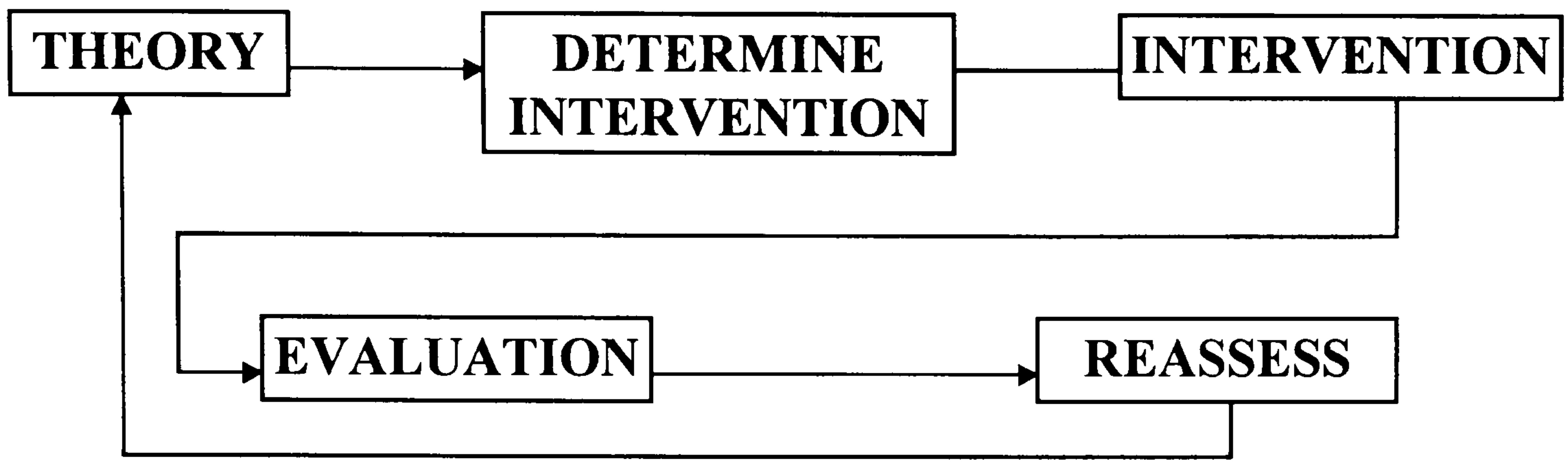

FIGURE 6.3 FEEDBACK MODEL OF RESEARCH - ADAPTED FROM GILL AND JOHNSON (1997)

The sequential nature of the studies in the current research allowed feedback and modification of the proposed model, much as envisaged by Rose, and Gill and Johnson. Applying Rose's ABCDE model (Figure 6.2) to the research process used gives a diagram similar to that shown in the Introduction (Figure 1.1), but with feedback links. This modification is shown in figure 6.4 overleaf.

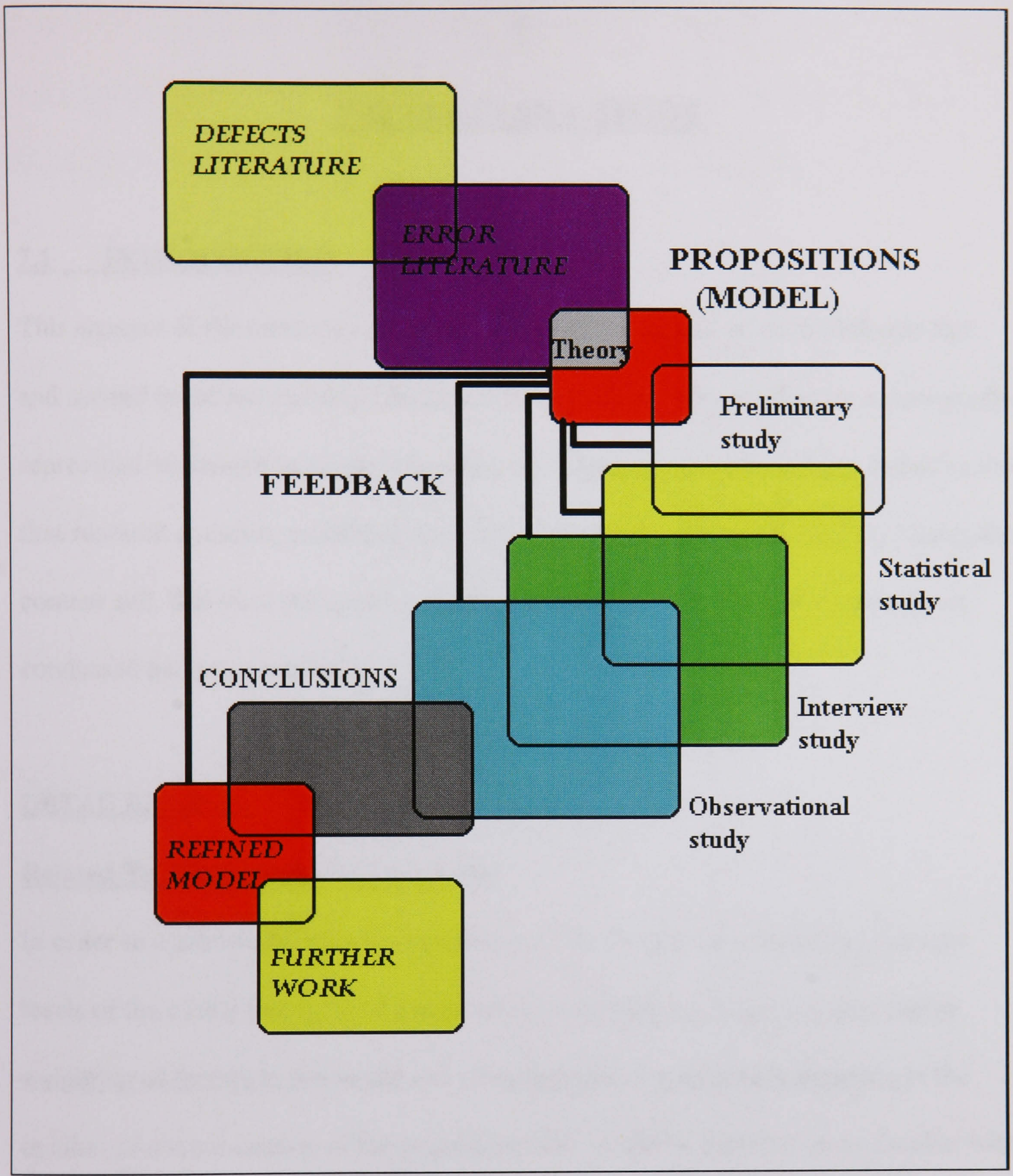

FIGURE 6.4- THE RESEARCH PROCESS FOLLOWING ROSE (1982)

7

PRELIMINARY STUDY

7.1 INTRODUCTION

This element of the research addresses the **form** and **content** of the model (the first and second questions identified on page 150 in Chapter 5) by conducting a survey of a representative sample of construction industry participants. Although presented as the first research question, examining the form of the model was easier after examining the content and, therefore the questions are reversed, with an analysis of content being conducted and presented first.

DETAILED OBJECTIVES

Related To The Content Of The Model

In order to establish the relative importance of factors and their weighting between levels of the model two detailed questions were formulated, what was the relative weighting of factors in the model and were these factors applicable generally in the opinion of a cross-section of the population who would be expected to be familiar with the intricacies of building projects?

With regard to the weighting of factors, the model placed emphasis on latent factors (classified as **managerial** and **global**) and confirmation of this emphasis was sought in the survey. If latent factors were emphasised in the survey, this would both act to confirm the assumption in the model that the pathology of error requires consideration of the whole "project system" rather than the most obvious active errors and give an opportunity to direct future research to elements within the model of greatest perceived importance.

With regard to the applicability of factors, it was necessary, in order to construct a set of error inducing factors applicable to most construction projects, to check for general agreement within a cross-section of the construction industry. Should differences between groups be apparent the reasons for differences should be explored and could be used to expand, or strengthen the model by providing more than one perspective.

Related To The Form Of The Model

The model in common with similar models drawn from the literature adopted two untested structural dimensions. It **categorised** the sources of error and it **layered** those sources into a hierarchy (also a form of categorisation). The principles of categorisation were based on analysis and synthesis of the literature and this research sought to test the categorisation by empirical research. Two questions were, therefore, posed - were the range of factors comprehensive and was the hierarchical structure of the model (with three separate layers - **global**, **managerial** and **primary**) a valid vertical categorisation?

7.2 METHOD

An opinion survey of a representative quota of construction industry practitioners was conducted.

TARGET POPULATION

Target population requirements were that the respondents were drawn from three groups:-

Commissioning, briefing, design and design checking sectors of the construction industry

The construction industry is exceptional in that design and construction are normally separated, with design being carried out by consultants or experts acting "in-house" to the client organisation (Tavistock Institute 1966). Including in a survey those responsible for the briefing and design process was considered important. These individuals might be expected to have a view both of their own role in construction projects and of the role of others, especially those in the construction side of the industry.

Constructors

Contracting and sub-contracting organisations are normally responsible for construction only, with design of all but minor details being performed by others. Managers within construction organisations have to avoid construction errors occurring, sometimes including design errors and they may well have views on other parts of the process. Including representatives from construction was, therefore, considered an essential part of the survey.

Neutral respondents

It was envisaged that a survey of designers and constructors might give strongly polarised views. In order to test for this, it was desirable to include relatively neutral respondents. If views between designers, constructors and the neutral respondents were reasonably correlated, it might be concluded that responses were not unduly polarised.

It was decided to target consultant or client based quantity surveyors as neutral respondents. It was recognised that consultant quantity surveyors are normally paid by the client (AQUA 1996) and are not strictly neutral, but they characteristically occupy a more detached position between the design and construction parts of projects than either the contractor or designer. In particular they:-

- Are not involved directly in the design or construction process. Although they typically evaluate work in progress and at completion, they specifically do not normally make deductions for defects, leaving this task to the designer (JCT 1980).
- Are required to take a neutral stance in matters of post-contract evaluation. This is also true, in traditional contracts of engineers, building surveyors and architects, but only for certain matters and their position is compromised elsewhere, where an

executive stance must be taken. Accordingly such designers were not thought to be as impartial as quantity surveyors[1].

SURVEY METHOD

The method

The sample consisted of construction industry participants recruited by and including final year students of quantity surveying, building surveying and construction management following day-release honours degree courses at the South Bank University. Also approached were a small number of other similar construction industry participants polled directly by the researcher.

The method used was to ask students to distribute several copies of a pre-prepared questionnaire (see appendix 7a). This method would not draw responses from a strictly random sample of the industry, but replies from the three broad groups noted above were expected. The strengths and weaknesses of this survey method were as follows:-

Strengths

1 *Availability.*

The target group was readily available enabling a fast turnaround time for distribution and receipt of returns.

[1] The neutral role of the quantity surveyor is illustrated by Higgin and Jessop (1965) who describe the QS's position as being "St Christopher assisting in the passage of the developing project rather than being planted on either (the professional or the commercial) shore" (page 23).

2 *Balance.*

A reasonably balanced return within the three groups identified above was expected.

3 *Return numbers.*

A relatively good return was expected. Normally returns of 10% or less are achieved with random postal questionnaires. This tends, in itself, to invalidate the "random" nature of the survey with only the "interested" responding. Here a return of 25% or more was expected and in the event achieved[2]

Weaknesses

1 *Randomness*

The sample would only be drawn from representatives of the construction industry known to, or associated with, the students. This quota might be expected to be more concerned with education and "day release" than the average for the industry. Respondents were also likely to be drawn more from established professional, client and construction firms, engaged in providing systematic education for their staff. Geographically, most responses came from the South East of England and may not be representative of the UK as a whole, or other countries. The student population directly represented those following

[2] In support of this method, Barrett (1989) quotes Moser and Kalton (1971), who note that survey non-respondents typically differ from those that respond and that a response rate of 60% plus is most desirable.

building surveying, quantity surveying and construction management. Architecture and engineering students were not directly approached, but several architects and engineers were included in the returns as colleagues or associates of the students. Trades-people were not directly represented in the student body and the survey largely included only managerial and professional staff. Some ex-trades-people are included in the eventual returns, but the weight of views can not be said to represent operatives in the industry. The method of sampling (see below), by asking students to pass questionnaires to respondents and to collect them when completed, might have affected the independence of responses[3]

2 *Ethics*

Using students as the target population would involve ethical considerations. In particular, the target groups of students were following units being taught by the researcher. Thus it was necessary to make clear that taking part in the survey was voluntary and in no way related to performance on the courses. For this reason, students were not specifically identified in the distribution of survey forms. The forms were un-numbered and the only method of follow-up (in order to increase the return rate) was by general exhortation. These points were presented to the targeted students in an introductory letter (see below).

[3] The method is a variant of "snowball sampling" (Coolican 1994 page 40). Examination of the completed questionnaires indicated that they were completed independently.

Detail of the method

Final year degree students (Year 5) of the part-time degree courses in building surveying, quantity surveying and construction management were targeted. Total numbers envisaged were approximately 125, but the eventual uptake was 105. The students were, as groups, initially solicited to help with the research and the general object of the survey was explained. They were told that they would be asked to complete a questionnaire and pass further blank copies to their work colleagues, superiors and other construction related acquaintances.

At a later date 105 questionnaire packs were distributed to the students out of a total prepared of 125. A few additional packs were distributed directly by the researcher to practitioners in the construction industry (those personally known to the researcher, or directly expressing an interest in the research). Each pack contained:-

- A covering letter (Appendix 7b) explaining the research and pointing out the voluntary nature of participation. The letter requested that students recruit 3 or more colleagues in completing questionnaires and that they complete one themselves.
- Four copies of the questionnaire.
- One example questionnaire showing how it should be completed, but emphasising that the actual scores were for illustration purposes only.
- A stamped addressed envelope for the return of questionnaires.

The numbers of questionnaire forms distributed and returned were as shown in table 7.1.

TABLE 7.1 - QUESTIONNAIRE RETURNS

Prepared for distribution	500
Distributed	420
Returned	107
Percentage return	25.5%

Survey instrument (Questionnaire)

The survey questionnaire is included at appendix 7a. It consisted of a 28 item three page "closed question" style instrument including fourteen questions asking for both a rating (out of 5) and a ranking of methods of avoiding errors leading to defects. Questions were generated directly from the model (pages 147-148) with minor changes of wording devised to simplify understanding. The respondent was asked to rate every method, but only rank the top five methods. The reasons for asking for both a rating and a ranking were to check for understanding of the questionnaire and to check for random completion (see below). The 14 questions covered the factors identified in the model of the nature of error. However, the questions were not structured in any way to reflect the hierarchical nature of the model.

In addition, one question invited the respondent to supply further factors he/she considered important in avoiding errors. Three blanks spaces were given for inserting factors and spaces for ranking/rating each additional factor. Other questions asked for information on roles and experience for use in analysis.

To avoid primacy effects[4] in completing the questionnaire, questions logically relating to primary factors were placed towards the end (The expectation being that factors such as training and selection might be scored unduly highly if placed first). To avoid recency effects (i.e. the last questions being given undue weight), the last pre-formatted question (Question 14) was placed immediately before the open-ended supply question (Question 15).

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[4] Primacy and recency effects were first identified by Ebbinghaus (1885). The primacy effect is where items presented early in a list are more likely to be recalled than those presented towards the middle. The recency effect is where items presented at the end of a list are more likely to be recalled than those towards the middle.

7.3 ANALYSIS

BACKGROUND INFORMATION

Roles

The roles of respondents, classified by their employing organisations are as shown in Table 7.2 (Returned under "Role of Organisation"):-

TABLE 7.2 - ROLE OF RESPONDENT

ROLE	NUMBER	PERCENT
Architect	4	3.7
Building surveyor	18	16.8
Engineer	6	5.6
Other designer etc.*	27	25.2
Quantity surveyor	25	23.4
Main contractor	21	19.6
Sub-contractor	6	5.7
TOTALS	**107**	**100.0**

*"Other designer etc." includes respondents classifying themselves as clients, clients representatives or project managers, or respondents having a general design or design checking role.

The roles of respondents were grouped for analysis purposes into three main categories as shown in Table 7.3

TABLE 7.3 - ROLE OF RESPONDENT IN MAIN GROUPS

ROLE	**NUMBER**	**PERCENT**
DESIGNER ETC.	55	51.4
CONSTRUCTOR	27	25.2
QUANTITY SURVEYOR	25	23.4
TOTAL	107	100.0

Supervisory position

Respondents were asked whether or not they supervised other staff within their organisation and 68% did so. The inclusion of a question allowing the division of the sample on the basis of supervisory position was made at a late stage in the development of the questionnaire and was not directly relevant to the model of the error process. The basis for including the question was that it might detect an "Attribution" or "Blame" effect. Attribution effects are drawn from psychology and suggests that the individual might blame external circumstances for his/her own failings, but blame the failings of others on their personal inadequacies (Lourens

1990)[5]. Blame effects are reported by Whittington et al (1992) in connection with construction industry accidents and might also distort the responses. Thus there could be a tendency to "hide" certain factors by deflecting blame elsewhere. A sufficiently large "blame" effect might have suggested modifications to the model.

Experience

Respondents had a mean of 5.8 years experience in their current role and 17.2 years in the construction industry.

THE ERROR QUESTIONS

The weighting of factors

Mean ratings

Respondents were asked to rate 14 statements, corresponding with the factors in the model (Appendix 7a). Mean ratings for the fourteen questions, in descending order of magnitude, are as shown in Table 7.4

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[5]Quoting Heider (1958) in defining attribution theory as "an overall tendency to attribute what happens to other people to their personal responsibility, but to place much more emphasis on the role of external circumstances, when explaining what has happened to oneself" (page 1257)

TABLE 7.4 - ERROR QUESTIONS, MEAN RATINGS

Question No	Mean	Std Dev	Valid N	Factor in model	Level in model	Question description
9	4.12	1.19	106	**Communications**	Managerial	Using clear communications
12	3.87	1.16	106	**Time**	Global	Having adequate time to carry out work
8	3.82	1.04	105	**Concurrency**	Managerial	Completing tasks fully before releasing work (controlling concurrency)
7	3.82	1.03	104	**Change control**	Managerial	Controlling changes properly (e.g. variations)
1	3.73	1.13	106	**Education and training**	Primary	Improving the education and training of individuals
4	3.69	1.09	105	**Checking**	Managerial	Independently checking all work
6	3.65	1.15	106	**Responsibility definition**	Managerial	Clearly defining work responsibilities
2	3.62	1.07	106	**Selection**	Primary	Being careful in the selection of individuals
5	3.34	1.04	105	**Supervision**	Managerial	Supervising the work of junior staff
10	3.29	1.07	106	**Culture**	Global	Having a positive culture in the organisation
3	2.99	1.04	104	**Self certifying**	Primary	Making individuals sign off work
11	2.96	1.06	106	**Economics**	Global	Having an economic climate that ensures an adequate return
14	2.95	1.04	106	**Client expectations**	Global	Having clients with reasonable expectations
13	2.31	1.13	106	**Political influences**	Global	Having a steady political climate

From table 7.4 it can be seen that all five managerial factors in the model (page 147-148) were within the top half of the ratings over the 14 questions, but, both the global factor, "time", and the primary factor, "education", were also highly rated.

Of the low scoring factors, the three least supported were the political climate, client expectations and the economic climate. All are grouped in the model as "external factors" under Global Factors - respondents appeared to stop short of blaming errors on the government and the customer.

Rankings

In order to test for random responses and understanding of the questionnaire, respondents were asked to provide a ranking of their view of the top 5 methods of avoiding errors. The mean rank of each method was computed and compared with the rating of each method as shown in Table7.5:-

TABLE 7.5 - ERROR QUESTIONS MEAN RANKINGS (Compared With Ratings)

FACTOR	RANKING OF RATINGS	RANKING
Communications	1	1
Time	2	2
Concurrency	3	4
Change control	4	7
Education and training	5	5
Checking	6	6
Responsibility definition	7	3
Selection	8	9
Supervision	9	10
Culture	10	8
Self-Certifying	11	12
Economics	12	11
Client expectations	13	13
Political influences	14	14

The two sets of rankings were compared using Pearson's r tests for the significance of correlation and the results were significant ($p<0.01$)[6]. Thus, although there are some discrepancies, the ratings were well represented by the rankings and statistically provided highly significant correlations. The spread of highly rated factors over the three major divisions in the model (global, managerial and primary) is maintained in the rankings and the low ranking for external global factors is the same as in the ratings.

Discrepancies can possibly be explained by some confusion evident in the returns and caused by the layout of the questionnaire, where ratings were presented alongside rankings. In a piloting of the questionnaire, this confusion became evident and it was felt necessary to include a sample of a completed form for guidance. Nevertheless, some confusion may have remained and caused the inconsistencies noted above. Judging by the large number of returned forms containing comments appended in question 15 (the supply question), showing that respondents had given some thought to its completion, it is thought unlikely that random completion was widespread.

The Applicability Of Factors

The rating returns were analysed in order to determine the extent of agreement between the main groups of respondent. Two sets of groups were identified at the outset. Firstly occupational groups of designer etc., constructor and quantity surveyor, separately identified for reasons outlined above. Examination of the returns was

[6] Also significant ($p<0.01$) using Spearman's Rho.

directed towards ensuring a reasonable level of correlation between these groups. Where this was not found, the reasons for differences were investigated. Secondly, two groups, those supervising and those supervised were also separately identified. This split allowed for any significant differences between the individual and the supervisor to be identified. The expectation was that each group might "attribute" errors to the other group by the supervised stressing managerial factors at the expense of primary and the supervisors stressing the opposite, primary factors at the expense of managerial. The formal hypotheses were that there would be no significant correlations ($p<0.05$) between the two groups of respondents.

Pairwise correlations between groups were based on the mean rating scores for each group for the 14 questions and the results are shown in Tables 7.6 and 7.7. Using Pearson's r tests for the significance of correlation, all results were significant at $p<0.05$[7]. The formal null hypotheses of no correlation can, therefore, be rejected (See appendix 7c for correlation charts). This indicates that, in responding to the questionnaire, a common view was taken of the relative importance of factors, both as between occupational groups and as between supervisory positions. These close correlations are, however, based on mean scores and they might disguise significant differences between groups of participants for particular factors.

[7] Also significant ($p<0.05$) using Spearman's Rho.

TABLE 7.6 - PEARSON CORRELATIONS BY OCCUPATIONAL GROUP

		Designer	QS	Constructor
Correlation	Designer	1.000	0.941	0.930
	QS	0.941	1.000	0.841
	Constructor	0.930	0.841	1.000
Significance	Designer	-	0.000	0.000
	QS	0.000	-	0.000
	Constructor	0.000	0.000	-
Number		14	14	14

TABLE 7.7 - PEARSON CORRELATIONS BY SUPERVISORY POSITION

		Supervisor	Non-supervisor
Correlation	Supervisor	1.000	0.904
	Non-supervisor	0.904	1.000
Significance	Supervisor	-	0.000
	Non-supervisor	0.000	-
Number		14	14

Differences between groups on particular factors

In order to detect differences between the two groups identified above on individual factors, two further sets of statistical tests were used. For the three-way occupational role split (Designer-QS-Constructor) a one way analysis of variance test was run. For the two-way split on supervisory experience an independent samples t-test was used. The formal hypotheses were that there was no significant difference ($p<0.05$) between samples.

Occupational role

Taking the occupational role variable of "Designer", "QS" and "Constructor" first, the results are as shown in Table 7.8 and 7.9[8]

TABLE 7.8 - DIFFERENCES BY OCCUPATIONAL ROLE
ONE-WAY ANOVA
Significant results ($p<0.1$) shown **bold**

Variable	Mean			Between groups sig
	Designer	QS	Constr	
Certifying (self)	2.96	3.21	2.85	0.459
Change control	**3.62**	**3.76**	**4.26**	**0.028**
Checking	3.58	3.84	3.74	0.607
Communications	**3.83**	**4.40**	**4.44**	**0.037**
Concurrency	3.66	3.80	4.15	0.142
Culture	3.31	3.12	3.41	0.615
Economics	**2.89**	**2.64**	**3.41**	**0.024**
Education	3.59	4.00	3.74	0.329
Client expects	2.89	2.96	3.07	0.753
Supervision	3.17	3.48	3.56	0.219
Political infl	2.39	1.96	2.48	0.196
Responsibilities	**3.46**	**4.08**	**3.63**	**0.083**
Selection	3.44	3.96	3.67	0.135
Time	**3.61**	**4.20**	**4.07**	**0.062**

[8] A check was made using a Kruskal-Wallis non-parametric one way ANOVA which also showed significant differences ($p<0.05$) for the factors "changes", "communications" and "economics"

TABLE 7.9 - DIFFERENCES BY OCCUPATIONAL ROLE
ONE-WAY ANOVA
Multiple Comparison Significance test (Games Howell)
Variables with between group significance ($p<0.1$) only

Variable	**Role**	**Role**	**Significance**
Change control	Designer	QS	0.774
	Designer	**Constr**	**0.020**
	QS	**Constr**	**0.058**
Communications	**Designer**	**QS**	**0.053**
	Designer	**Constr**	**0.073**
	QS	Constr	0.983
Economics	Designer	QS	0.613
	Designer	**Constr**	**0.076**
	QS	**Constr**	**0.030**
Responsibilities	**Designer**	**QS**	**0.031**
	Designer	Constr	0.806
	QS	Constr	0.200
Time	**Designer**	**QS**	**0.081**
	Designer	Constr	0.139
	QS	Constr	0.875

Supervisory role

Taking the division, between "supervisors" and "non-supervisors"(2), the results are as shown in Table 7.10[9].

[9] A check using a Mann-Whitney U non-parametric test confirmed this result

TABLE 7.10 - DIFFERENCES BY SUPERVISORY ROLE
INDEPENDENT SAMPLES T-TEST
Significant results (p<0.1) shown **bold**

Variable	Supervisor		Non-Supervisor		Sig
	Mean	Standard Deviation	Mean	Standard Deviation	
Certifying (self)	3.01	1.11	2.94	0.97	0.727
Change control	3.90	0.96	3.61	1.17	0.222
Checking	3.73	1.11	3.65	1.07	0.713
Communications	4.04	1.23	4.32	1.12	0.254
Concurrency	3.78	1.08	3.82	1.01	0.860
Culture	3.40	1.01	3.06	1.20	0.164
Economics	2.93	1.04	3.03	1.09	0.649
Education	3.74	1.13	3.74	1.19	1.000
Client expects	3.00	1.01	2.88	1.09	0.601
Supervision	**3.52**	**1.05**	**3.06**	**0.95**	**0.033**
Political infl	2.24	1.08	2.41	1.21	0.475
Responsibilities	3.63	1.13	3.74	1.19	0.677
Selection	3.72	1.09	3.47	1.05	0.267
Time	3.78	1.18	4.03	1.11	0.299

Discussion of the differences

Between roles

Differences of factor ratings between the roles of respondents was considered a possibility, but not predicted in the survey. Accordingly two-tailed tests of significance were used. The results confirm, firstly, the general agreement between groups revealed by the correlation tests. Little overall polarisation of views (expressed as a lack of significant differences) were evident between the three groups of respondent. Where significant (or near significant) differences were apparent, these were concentrated in the “managerial” and “global” areas of the model. The pattern of differences show that constructors rated all five significant (p<0.10) factors in table 7.8 higher than did designers, with significant ($p<0.05$) or near significant differences on three of those factors.

The constructors' positions as commercial concerns (as opposed to the more consultant roles of designers) may account for different perceptions of the influence of global factors of "economics and "time", but, given current pressures on fee income and public client market testing of services, this difference is, perhaps, surprising.

The constructors rating of managerial factors of "change control", "communications" and "responsibilities", more highly than designers could be because they place more emphasis on the management of projects. However, no corresponding significant emphasis by designers on other factors was noted. Constructors, as represented by contracting and sub-contracting firms, are much more involved than designers in the integration and control of diverse resources and it is this involvement that may account for higher ratings on significant factors. This might suggest that error management exhibits contingency features, where the importance of factors is dependent on the circumstances of the respondent.

Differences between quantity surveyors and constructors were notable in only two areas, "changes" and "economics" also indicating that constructors consider these factors more important and, perhaps reflecting their commercial background.

Between supervisors and non-supervisors

The highly significant difference between supervisors and non-supervisors on the factor "Supervision" was in the opposite direction to what might be expected. Supervisors rated this factor significantly higher than non-supervisors, tending to refute suggestions of a "blame" or "attribution" effect made in the literature. Similar differences were possible for primary factors of " education " and "selection ", where supervisors were expected to rate these factors higher than non-supervisors. These were not evident to the extent that there was an almost exact fit between distributions of scores for the groups on the factor "education". Factors relating to "external circumstances" (Lourens 1990) such as "communications" and "culture", might also have been scored more highly by those supervised, but this was not seen either.

The Range Of Factors

The questionnaire contained one question (15) asking the respondent to suggest further factors which they considered important in avoiding errors. In total 51 respondents answered this question (from a total of 107), with 74 comments being made (several respondents made more than one comment). The responses were classified as follows:-

A Responses suggesting a technological solution.

These included comments such as "using feedback from past projects" and "careful, practical design, in particular with regard to the relationship between components". In all, nine comments (from 74) of this type were made. Given the technological background of the respondents this was a very small number and indicated that the respondents were generally taking a "human error" approach in answering the question.

B Responses citing factors outside the model

Five respondents cited factors outside the direct control of participants in the building process (Briefing, design and construction). All were related to materials or components brought into the process and example comments were "introduce new materials very cautiously", "Careful selection of tried and tested materials for the building fabric" and "careful specification of components by the design team to ensure co-ordination and compatibility".

C Responses with no clear relationship to the research.

Two responses could not be categorised and are ignored in the analysis.

D Responses broadly fitting into the model.

Most other points fitted within the scope of the model and were classified as:-

1. Primary factors
2. Supervision and checking
3. Responsibility definition, changes, concurrency.
4. Communications

5 Organisational culture

6 Global factors (time, money and client expectations)

1 Primary factors

Approximately eight comments were made concerning primary factors such as the selection and knowledge of the individual. Comments included "Use qualified and skilled operatives on site", and "Ensure individuals carry out (their) own quality checks"

2 Supervision and checking

Four comments were made concerning this factor including "inspection of work before covering up" and "supervise all work". The relatively small number of comments corresponds with the modest ranking of checking and supervision in the rating survey. This contrasts strongly with the emphasis on checking and supervision revealed in the literature review. It appears that this factor was considered important by respondents, but only amongst others.

3 Responsibility definition, changes, concurrency.

Six respondents noted the importance of these factors, some by quoting the factor itself, others by mentioning planning or co-ordination. The latter two could be considered the means by which responsibilities are defined, changes controlled and concurrency avoided[10]. Combining managerial factors relating to defining responsibilities, controlling changes and controlling concurrency in one overall planning factor was adopted, for operational reasons, in the statistical study of house-building (see Chapter 8). Comments included "Having a statement of who is fully responsible for design" and "Carry out work in a planned logical sequence".

4 Communications

Eight comments were made in relation to communications including "Close liaison between design and construction staff", "Having contractor involvement at design" and "Good communications from client to his representative, to main contractor and through a system to the tradesmen (via supervisors etc.)".

5 Organisational culture

A few comments were made related to organisational culture including "Team culture - all working together as a project team", "Team building between contractor, client and professional team", "Having a good working relationship with all levels of site staff" and "Having a good project team".

6 Global factors (time, cost and client expectations)

Six respondents mentioned business factors of adequate time and cost to complete work. These included such comments as "Avoiding overloading staff with work",

[10] For a justification of this approach see Morris (1994)

"Executing work on a basis that gives emphasis on ability and track record rather than lowest-price-wins-job basis" and "adequate funding for project". Comments related to client expectations included "understanding customer requirements" and "clients being clear on standard required".

E Responses suggesting new categories, or modifications to the model.

Some responses referred to factors not expressly acknowledged in the model. These centred on two considerations, "systems" and "leadership and motivation".

Comments related to "systems" considerations included "Good user friendly management with regular review/systems updates", "A QA system properly followed and supported", "Implementing formal QA procedures" and "Using a QA system". Comments related to "leadership and motivation" included "Leadership by making sure that staff are motivated by defining and giving appropriate responsibility and trusting them", "Giving staff a sense of responsibility", "Good motivation within the workplace" and "Job satisfaction".

Although not expressed in the model, comments related to "systems" support the systemic aspects identified in the literature review consistent with the views of ACSNI (1993), Turner (1978), Oakland (1993) and Blockley (1992). They do not relate to new categories within the model but to the links between categories. They are recognised in the third research question, related to the **operation** of the model and considered in Chapter 8.

Comments related to leadership and motivation refer to the abilities and qualities of individuals in the roles that they act, rather than the procedures that they follow. This follows Hirschhorn (1993), who criticises the depersonalisation of functions (in connection with High Reliability Organisations), and several writing from a quality assurance perspective (Sioholt 1991, Meyer (1994, Barber 1992 and Seymour and Low 1990). Although not introducing new categories in the model, the comments suggest an alternative conceptualisation based on the identity of the actors in the construction process, as opposed to the managerial functions performed by the actors.

Conclusions from the consideration of "other factors"

Most responses to the supply question (15) fell into the categories of the model. Of 107 returns, 51 respondents made comment under this question and few made points that were not directly represented in the model.

However, the emphasis placed by some respondents on leadership and motivation touch on a contradiction in the literature review and resulting model. The model follows many modern writers on human error (e.g. Reason 1990, Kletz 1985), who consider that blame for error outcomes should not be placed on the individual perpetrator and that wider managerial factors are involved.

Logically, however, it is obvious that "to err is human"[11] (e.g. see Petroski 1985). The writers appear to be apportioning blame by implication to individuals, the managers of organisations rather than operatives. Managers are charged with defining responsibilities, controlling changes, ensuring adequate motivation, training and selection and instilling a participative, supportive organisational culture. The errors are still "primary" in nature, but relate to a different set of individuals and a different set of tasks. Following writers such as Hirschhorn (1993) and Seymour and Low (1990), who criticise the depersonalisation of managerial functions, perhaps some managerial factors should specifically acknowledge "leadership" factors. The importance of this acknowledgement is that "leadership" is a **primary factor** - only it depends on the selection, training and education of individual managers not front line construction workers.

The Structure of the Model

The possibility of more fundamental factors being behind the categories identified in the model was hinted at in the responses to the open question (15), where terms such as "systems", "culture" and "leadership" were mentioned. It was also possible that the statistical correlations between respondents to the questionnaire and the 14 factors would group on other underlying, or latent factors corresponding with the three-level hierarchical structure of the model and provide statistical support for its conceptualisation. In order to try and detect such grouping, the statistical technique of

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[11] Alexander Pope, 1688-1744, Essay on Criticism.

Factor Analysis employing the principal components method, was used. To allow for the possibility of latent factors "naturally" corresponding to the broad grouping factors in the model, the questionnaire intentionally did not include any indication of overall grouping of the questions.

Factor analysis is a technique used largely in the study of psychology to detect underlying latent variables as displayed by scores on manifest variables. The process involves:-

- Producing sets of correlation coefficients in matrix form for all the variable combinations in a data set. In the present case the variables are formed from the 14 factors as revealed in the main questions on the questionnaire.
- The extraction of latent factors, (known as principal components) represented by groups of correlations.
- The rotation of principal component axes in order to maximise the relationships between the variables and some of the factors (Kinnear and Gray 1994).

In order to avoid confusions between “factors” as used in the model of the error process and “latent factors” as used in the factor analysis procedures, the manipulated factors are called “variables” with the term “component” used for the underlying principal components. The analyses were carried out using SPSS for Windows

Following the a priori divisions of the model into primary, managerial and global levels, the analysis was restricted to three principal components and revealed loadings as shown in table 7.11 and illustrated in figure 7.1:-

TABLE 7.11 - FACTOR ANALYSIS
Rotated Component Matrix

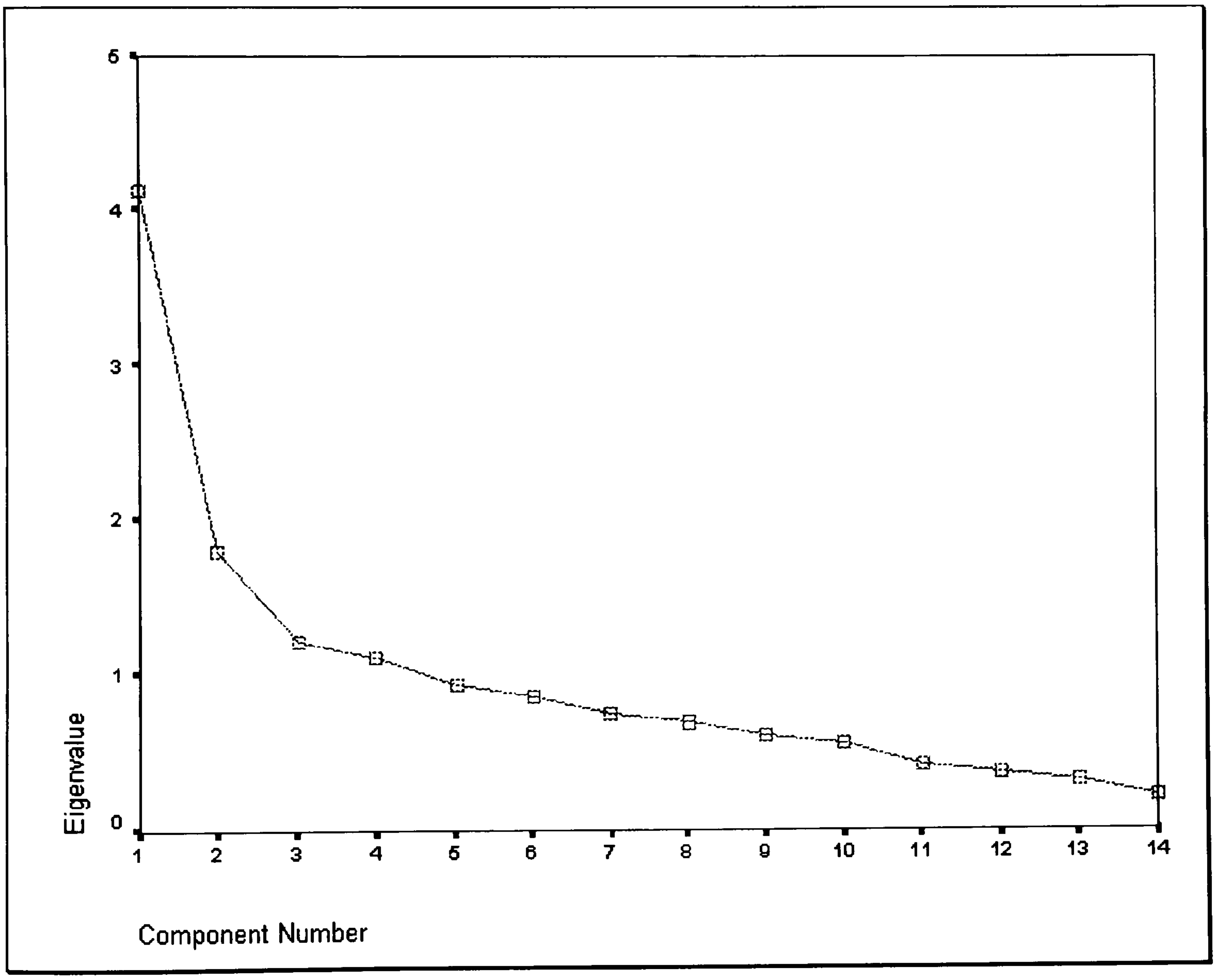
Element	Component		
	1	2	3
Making individuals sign off work to certify that they have checked their own work			.718
Controlling changes properly (e.g. variations)	.597		
Independently checking all work which might lead to defects	.521		
Using clear communications (Drawings/spec/BQs)	.835		
Completing tasks fully before releasing work (e.g. not starting construction until relevant drawings are complete).	.557		
Having a positive culture in the organisation.	.455		
Having an economic climate that ensures an adequate return for work		.831	
Improving the education and training of individuals	.728		
Having clients with reasonable expectations with regard to quality of work		.654	
Supervising/overseeing the work of junior staff			.509
Having a steady political climate within which to operate		.703	
Clearly defining work responsibilities	.716		
Being careful in the selection of individuals	.617		
Having adequate time to carry out work	.758		

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Rotation converged in 5 iterations.
Absolute values of less that 0.40 suppressed.

TABLE 7.12 - FACTOR ANALYSIS
Total Variance Explained

Component	Initial Eigenvalues			Rotation sum of squares loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.126	29.475	29.475	4.016	28.685	28.685
2	1.794	12.813	42.288	1.812	12.945	41.630
3	1.219	8.706	50.994	1.311	9.364	50.994

FIGURE 7.1 - FACTOR ANALYSIS
Scree Plot



Discussion of the Factor Analysis

Examination of the rotated component matrix shows a fairly clear split between most variables in the set as one component, three global variables of "economics", "expectations" and "politics" as a second component and the variables "certifying" and "supervising/overseeing the work of junior staff" forming a further component.

Some support is evident in this analysis for the division in the model between global elements and elements **internal** to the project (labelled in the model as managerial and primary respectively). The global variables of "economics", "expectations" and "politics" load on one fairly clearly defined component accounting for approximately 13% of the variance. However, the loading excludes the variables "time" and "organisational culture", which are grouped with the first component. Thus, the "fit" between the analysis and the model is not exact.

The division in the model between managerial and primary variables is not supported by the analysis in two respects. Firstly, both variables "education and training" and "selection" are grouped with the first component (containing mainly managerial variables) rather than forming a separate component. Secondly, the variable related to "self certification" is separately grouped in a third component with "supervising junior staff".

It is possible that the reason for the global variable "time" loading with managerial elements, was because respondents felt that the management of time was within their control (unlike other global elements). In this respect, it would be interesting whether re-presenting economic pressure as "**cost pressures**" would produce a similar re-grouping in that the latter would imply a more controllable element amenable to careful management.

Organisational culture is, perhaps, also grouped as a managerial element because it is considered within the control of managers. Some responses from question (15) supported this by emphasising the need to <u>engender</u> a positive culture, teamwork and co-operation. If organisational culture was wholly outside the influence of management, such manipulation would not be possible.

The isolation of "certifying" and "supervising junior staff" as a separate third component does not follow any logical pattern. One relates to individual action in avoiding errors, but the other relates to managerial control. However, both variables were rated as relatively less important in the returns and the significance of the component should not be over emphasised.

In conclusion, therefore, the factor analysis provides some support for a division in the model between managerial/primary and global components. The failure of factor analysis to distinguish between managerial and primary components is compounded by the isolation of a third component containing both primary and managerial variables.

7.4 CONCLUSIONS

To return to the objectives of this study, it sought to address the **content and form** of the model (the second and first research questions posed in Chapter 5) by considering four more detailed questions:-

- What was the relative weighting of factors in the model?
- Were the factors applicable generally?
- Was the range of factors comprehensive?
- Was the hierarchical structure of the model valid?

CONTENT

The Weighting Of Factors In The Model.

Certain factors were rated by respondents as more important than others and, in line with the literature, the importance of "latent" managerial and global factors was confirmed in the survey. Greatest emphasis was placed on the managerial factor "communications", followed by the global factor "time", the managerial factors "concurrency" and "change control" and then the primary factor "education".

The Applicability Of Factors

Significant ($P<0.05$) correlations on the mean of all 14 tested variables were found between the three main groups of respondent targeted in the survey. A similar significant correlation was noted between respondents supervising staff as opposed to those not supervising staff. This indicated that the model was reasonably representative of the construction industry as a whole (subject to the sampling reservations noted earlier).

Within this general agreement, some significant differences were noted for particular variables. The differences suggest mildly polarised views between designers and constructors on the importance of some managerial and global factors. In particular, constructors rated the top ranked factor, "communications" as significantly more important than did designers. The differences between designers and constructors <u>may</u> have been due to the greater involvement in managerial tasks of contractors and sub-contractors. Differences might also suggest that the importance of various factors is dependent on the circumstances of the different categories of respondent. Constructors are more involved in controlling managerial factors than designers and thus are more likely to emphasise these. A significant difference was noted between those supervising and those not supervising staff on the ratings for the importance of "supervising the work of juniors", but in the opposite direction to that predicted. This tends to refute a "blame" or "attribution" effect.

FORM

The Range Of Factors

The open question (15) gave respondents the opportunity to identify other factors important in avoiding errors. Several took this opportunity, but completely new factors were not identified. However, some respondents emphasised factors, which suggested modifications to the model. Some emphasised systems aspects, which although not explicitly incorporated in the model, were reflected in the third research question and were considered in the studies of house-building. Others emphasised leadership and motivation, aspects related to the individual, but at least in the case of leadership, at a managerial level. This emphasis suggested that the distinction between primary and managerial factors was invalid.

The Structure Of The Model

Factor analysis suggested some grouping of factors on other latent factors. An approximate division between two components in the analysis containing, respectively, managerial/primary variables and global variables was detected, but no distinction between managerial and primary variables was evident. Rather, a third component contained two low rated variables "self certifying" and "supervising junior staff", which were categorised as primary and managerial respectively.

8

STUDIES OF HOUSE-BUILDING 1

The Statistical Study

8.1 INTRODUCTION

This study addresses the **content** of the model (the second research question on page 150) by investigating whether there is any statistically significant relationship between factors in the model and the performance of construction projects. The use of statistical analysis has been developed in fields of study, such as public health and psychology, where the direct cause of an influence cannot be easily determined because the mechanism is unknown or invisible. In this study, cause is more easily determined, but is often very specific to circumstances and not easily generalised. Statistical analysis was used in order to improve the general applicability of any findings.

8.2 METHOD

THE FOCUS OF THE STUDY

Construction projects involve designing, assembling resources (materials, plant and labour), planning production, construction and commissioning. As any one part of the design-procurement-construction process might impinge on another, it is desirable to include the entire process in the study. However, the study concentrates on project rather than process industries. The materials supply industry and the early briefing and later use and maintenance parts of the process are, therefore, excluded. It also proved difficult to study both the construction and design processes in detail and the study largely concentrates on the former.

CONSTRUCTION OF A SAMPLE

The population under initial consideration was all construction projects, but, as full coverage was impossible, a limited sample was drawn. Initial restrictions were geographical, limiting the sample to the United Kingdom. The final sample was drawn from the South East and Midlands of England[1], thus further restricting the extent to which findings could be generalised.

As the effect of the factors in the model could easily have been swamped by technical differences between construction projects, an early decision was made to attempt to control for type and method of construction. Projects involving buildings of a similar scale using similar construction type were sought, and the group most readily available and fitting this criteria was housing. Speculative housing construction in the United Kingdom tends to use a relatively similar pattern of procurement with in-house designers working informally with in-house construction staff and sub-contract trades. Accordingly, housing type was further restricted to speculative, with a target of simple, two or three storey construction using standard house types. This target was largely achieved, with some exceptions in that a few projects involved more complex construction (later adjusted within the study).

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[1] For details of location see appendix 8b

As the subject matter of the research was sensitive, involving data on defects, costs, construction timing and errors, it was also decided not to attempt to recruit a sample by using postal or other impersonal communication techniques. An alternative of direct contact with fairly large speculative house-builders was used. In all, four house-builders were approached and one region from each of two builders agreed to take part in the study. Participation was later increased (by using direct persuasion) to include one further region from each of the two builders.

Both house-builders were well organised and involved in constructing a considerable number of units annually. They were both "premium" rated by building guarantee insurance companies[2]. Thus, they cannot be considered representative of house-builders as a whole and in particular of smaller, less formally organised companies. They do, however, represent the larger established house-building companies, which construct the bulk of speculative housing in Britain.

DATA COLLECTION

In order to use statistical analysis techniques, a sufficiently large sample of projects was required. Given the limitations on size of each of the regions within the two firms taking part in the study, it was possible to include 23 projects, representing all the on-going sites (autumn 1995) within the regions. The method of investigation chosen was, primarily, to use direct interview with the site manager for each of these projects and

[2] In the NHBC grading system (Using A1 to D4 classifications), both companies were graded as A1

this involved visiting each site, conducting an inspection and a one to two hour interview. Details of the sites, interviewees and research programme are given in Appendices 8a, 8b and 8c.

The reason for using the site manager as the primary target source was that much of the data required concerning the skills of site workers, managerial control of building production and the effects of such pressures as cost and time, in this type of construction, are available from this individual (speculative house-building projects being largely run from the site). Interviewing the site manager allowed economical extraction of most data required to complete the study. Other data collected in order to make sure sites were comparable were gathered by direct inspection, or from company managers. The advantages of a personal visit and interview (over less direct methods) were seen as:-

- An improved number of returns.
- Improved extraction of data because of face-to-face contact.
- The ability to extract qualitative as well as quantitative data as an alternative approach to using statistical analysis.
- The ability to corroborate/supplement returns from participants with researcher assessment of factors such as quality and complexity of construction and differences in specification.

The disadvantages of personal visits were the cost and time of visiting each site. These, and the resources of the organisations concerned, restricted the number of projects that could be included in the study.

SURVEY INSTRUMENT

Data were collected by using a two-part structured interview form (appendices 8d and 8e), the first part being completed in the presence of the site manager and the second part being completed at the end of the site visit by the researcher.

The first part of the form gave assurances of confidentiality and asked for general information concerning the site manager, the company and the site. It then asked questions covering the factors in the model, a qualitative assessment and an opportunity for the manager to respond to the research with comments.

IDENTIFICATION OF VARIABLES

In constructing the survey instrument it was necessary to identify the exact variables for use in statistical analysis. A full explanation of these variables and their construction is given in appendices 8f and 8g, and the link between the variables and the model of the error process is documented below. For ease of cross-referencing, the variable numbers listed in Appendix 8f are given in the variable title.

Dependent Variables

A measure for the level of error as revealed in the level of construction defects was sought as a dependent variable. However, quantifying either the level of underlying errors or the evidence in the form of the number of defects, gave rise to a number of problems as follows:-

1) Temporal

The errors causing defects occur during the construction phase of a building's history, but the defect may only manifest itself during occupation several months or years later. If measurements were taken during construction, only those detected would feature. Conversely, if measurements were taken during occupation, all those detected and corrected earlier would be excluded. A qualitative assessment was possible of the nature of post-occupation defects, but quantitative assessment was rejected as:-

- Inaccurate because some defects would not be reported by occupiers, rather they would be put right without reference to the construction team, or the Company concerned.
- Difficult because it would involve either surveying occupiers or some other method of collecting data.
- Incomplete because it would exclude pre and post occupation defects put right by the construction team.

- Time consuming because it would involve waiting for the construction and occupation of all units for all sites. This, in itself would lead to inaccuracies because of the time lag between commission of any errors and their appearance.

2) Seriousness of error

Numerical assessment of defects might not reflect the **gravity** of the underlying errors. A large number of defects related to a particular site or house might be of cosmetic significance only. Conversely, a small, low value mistake might have consequences which far outweigh either its numerical significance or the cost of its correction. Additionally, it was reported by some site managers and a building guarantee company inspector that recording of similar small defects could in some instances be treated individually, but in others, collectively. A trend was noted to record each defect for each unit individually in order to increase the "detection rate" of the building guarantee company. This could dramatically increase the recorded number of defects for some sites. Notwithstanding these reservations, it would be expected that differences would even out between sites provided that the sample size was sufficiently large. The limited number of sites in the study meant that any measure based on numerical assessment should be used with caution.

3) Access to data.

One Region of one Company was able to give cost data on post-construction defects, but this was extremely inaccurate as a result of lack of maturity of the data (some sites had been completed more recently than others and therefore had lower rectification costs). Access to data from the other regions was difficult to obtain.

4) Comparability of data.

This is related to problems of gravity of data and the temporal problem noted above. The cost of correcting defects potentially could have acted as a good measure of error and all Regions had maintenance budgets on a "per unit" basis. However, the budgets might be exceeded or under-spent because of factors totally unrelated to any defects/errors made. Factors would include:-

- Whether units were sold early in the site's history and most defects were corrected (as a matter of Company policy) by the construction workers rather than post-completion "correct and charge back" procedures.
- Whether the occupier corrected the defect without recourse to the company as noted above.
- Whether the defect was accepted as a Company problem or contra-charged to a "defaulting" sub-contractor.

5) Recording of data

Researcher observation of errors and defects as they occurred was not practical as it would have demanded an excessive amount of time and probably caused resentment from site workers. Some records of defects are kept by Building Guarantee Companies, but these are treated confidentially and are often incomplete (Open interviewee number 17 in the Interview Study reported that the inspector will routinely remove records of corrected defects in order to avoid "clogging up the files"). These records also ignore the gravity of the defect.

Measures used

In conclusion, although a limited amount of objective quantitative data on number of defects, their cost post-occupation and their gravity were available it was decided not use data in this form. Alternative, more robust, measures of the level of defects on each site were sought and eventually it was decided to make two assessments based on frequencies:-

1) Reported defects and error instances (variable 1)

The site manager was asked to report any instances of defects found or errors committed on the site. These were weighted:-

- To reflect the extent to which the site was complete.
- To reflect differences in size and complexity of sites (by dividing numbers of instances by estimated total costs of the sites).

Sites were divided into two categories (based on a split at the mean value), those with a high level of instances and those with a low level of instances.

2) Perceived quality (variable 2)

The site manager was asked to subjectively rate the quality of each stage of the construction process on the site. The reason for requesting a "quality rating" rather than a rating for the level of defects was that it is easier to persuade site managers to talk about the positive assessment of "quality" rather than the more negative assessment of "defects". The rating of quality was subsequently scored for each site and sites were divided into two categories (based on a split at the mean score) - "high perceived quality" and "low perceived quality" respectively.

Independent variables

Independent variables representing, as far as possible, the factors in the model of the nature of errors were constructed as follows:-

Primary factors

Relating to operatives

Skills of trades-people (variable 3)

The site manager was asked to rate the skills of individual trades-people and this rating was converted to an average score for the site. From this, sites were divided into two categories (based on a split at the mean score), "high skilled" and "low skilled".

Relating to managers

Variables related to the performance of the site manager as an individual were added as a result of responses in the preliminary study emphasising individual managerial qualities. Three variables were used:-

Experience of manager (variable 4)

Preliminary questions asked the site manager for an estimate of the number of years experience he/she had in the industry and as a site manager and sites were divided into two categories (based on a split at the mean value), those staffed by "experienced" as opposed to "inexperienced" managers.

Background of manager (variable 5)

The occupational background of the manager was recorded informally (i.e. there was no specific provision made for this in the questionnaire). and sites were divided into two categories, those staffed by managers from an operative background having later progressed into management (trades background) as opposed to those from a background as a managerial trainee or graduate manager (managerial background).

Qualifications of manager (variable 6)

The extent of formal qualifications of the manager was also recorded informally and sites were divided into two categories, those staffed by managers having formal as opposed to those not having formal qualifications.

Managerial factors

Communications

This was divided into two sub-factors, **informal communications** and **formal communications**, in line with comments from some authors in the literature review (Kaminetzky 1991, Kletz 1985, Turner 1978).

Informal communications (variable 7)

The site manager was asked how many contacts (visits/verbal communications) were made by non-line staff per month. From this, sites were divided into two categories (based on a split at the mean value), sites with a high as opposed to those with a low level of communications.

Formal communications (variable 8)

The site manager was asked to rate the quality of the project documents (drawings/specification) in three respects, their volume, clarity and buildability. The rating was later converted to a score and sites were divided into two categories (based on a split at the mean value), those with high quality and those with low quality formal communications.

Organisational culture (variable 9)

On the basis of literature equating culture of organisations with the extent of managerial "participation" (Oakland 1993, ACSNI, 1993, Turner 1978), the site manager was asked how many contacts (visits/verbal communications) were made by line managers. In addition, the site manager was asked how many formal company meetings he/she attended and how many sub-contractor meetings he/she held. The sum of contacts and meetings was used as a score representing the level of managerial participation. Sites were divided into two categories (based on a split at the mean value), those with a positive (high participation level) and those with a negative (low participation level) organisational culture.

Planning/programming (Representing the division of responsibilities, control of concurrency and control of change) (variable 10)

On the basis of the findings of the preliminary study and literature on project management (Morris 1994, Archibald, 1976, Meredith and Mantel 1995, Lock 1996, Kerzner 1995), together with earlier research (Hinze and Raboud 1988), it was decided to combine the separately identified factors of "division of responsibilities", "control of concurrency" and "control of change" into one overall planning factor. Hintz and Raboud had suggested that better project planning was linked to a lower construction accident rate and, similarly, better planning (representing better division of responsibilities, control of concurrency and control of change) might be linked to a lower error rate. The reason for combining the factors was operational in that it was considered easier to measure the level of planning than the levels of the three causes separately.

Site managers were asked how work was planned on three aspects, method of planning (Informally, bar chart or CPA), location of planning (central or local) and extent of updating. On the responses from these questions a 5 category division of the sample was possible. This was later reduced to four divisions as no sites were completely un-planned. For analysis purposes sites were divided into two categories - "centrally planned" and "locally plus centrally planned"

Checking

The site manager was asked to indicate how he/she checked the work of each sub-contractor, in terms of frequency and level of formality (e.g. whether a formal check list was used). In the event, no usable objective data was obtained from this question and a statistical assessment of checking in the research project was not possible. This was because all site managers used very similar checking regimes - they tended to walk round the site several times per day, to check especially carefully at the end of tasks or before payment, to give particular attention to certain trades (for example bricklayers and carpenters) and to only formally check at the overall "snagging" stage (the end of construction). This information gave very "flat" data, which could not be satisfactorily analysed.

Relating to project management factors generally

Intensity of project management (variable 11)

In order to assess the overall effect of the intensity of project management, as reflected in the weighting of factors, a combined score was constructed by taking the product of the raw scores for planning, informal and formal communications and culture. Sites were subsequently divided (based on a split at the mean score) into those with a high intensity of project management and those with a low intensity of project management respectively.

External factors

Cost pressure (variable 12)

The site manager was asked whether the site was pressurised in terms of cost on three divisions - not tight-normal-tight. For analysis purposes sites were divided into two categories, tight/not tight.

Time pressure (variable13)

The site manager was asked whether the site was pressurised in terms of time on three divisions - slack-normal-tight. For analysis purposes sites were divided into two categories, tight/not tight.

Societal pressure

The site manager was asked whether the quality of the project had been affected by the economic climate. In the interviews, all managers interpreted this question as the influence that customers were being able to exert on the project through market power. Additionally, most site managers commented on the pressures being exerted by increased market demands on sub-contractors. Thus, although the question was initially related to economic pressure, it was re-interpreted as less direct "societal pressure". In the event, no usable objective data was obtained from this question and an assessment of societal pressure in the research project could only be made qualitatively. The primary reason was that the data were too "flat" to allow a realistic division into categories.

Summary of dependent and independent variables

The variables can be summarised therefore as shown in table 8.1

TABLE 8.1 SUMMARY OF DEPENDENT AND INDEPENDENT VARIABLES

No	Variable Name	Number in questionnaire
	DEPENDENT VARIABLES	
1	Reported defects and error instances	31
2	Perceived quality	30
	INDEPENDENT VARIABLES	
3	Skills of trades-people	15
4	Experience of manager	7
5	Background of manager	6
6	Qualification of manager	6
7	Informal communications	18, 20, 21
8	Formal communications	25
9	Organisational Culture	19, 22, 23, 24
10	Planning/programming	17
11	Intensity of project management	17-25
12	Cost pressure	28
13	Time pressure	29

8.3 ANALYSIS

Each independent variable was compared with the two dependent variables for strength of association and tested using chi-square tests for significance computed with SPSS for Windows. The null hypotheses were that there would be no significant association between independent and dependent variables. Results are as shown in tables 8.2 and 8.3.

TABLE 8.2 - CHI-SQUARE ASSOCIATION - REPORTED DEFECTS
p<0.1 shown shaded

p=0.510		Skill level of trades-people		
		High	Low	Total
Level of reported defects	Low	6	6	12
	High	7	4	11
	Total	13	10	23
p=0.059		Experience of manager		
		Experienced	Inexperienced	Total
Level of reported defects	Low	4	8	12
	High	8	3	11
	Total	11	11	23
p=0.019		Background of manager		
		Managerial	Trades	Total
Level of reported defects	Low	8	4	12
	High	2	9	11
	Total	10	13	23
p=0.033		Qualifications of manager		
		Qualified	Unqualified	Total
Level of reported defects	Low	6	6	12
	High	1	10	11
	Total	7	16	23
p=0.855		Level of informal communications		
		High	Low	Total
Level of reported defects	Low	5	7	12
	High	5	6	11
	Total	10	13	23
p=0.057		Quality of formal communications		
		High	Low	Total
Level of reported defects	Low	10	2	12
	High	5	6	11
	Total	15	8	23
p=0.827		Organisational culture (level of participation)		
		High	Low	Total
Level of reported defects	Low	6	6	12
	High	6	5	11
	Total	12	11	23
p=0.049		Planning/programming		
		Local and central	Central	Total
Level of reported defects	Low	7	5	12
	High	2	9	11
	Total	9	14	23
p=0.007		Intensity of project management		
		High	Low	Total
Level of reported defects	Low	10	2	12
	High	3	8	11
	Total	13	10	23
p=0.304		Cost pressure		
		High	Low	Total
Level of reported defects	Low	9	3	12
	High	6	5	11
	Total	15	8	23
p=0.552		Time pressure		
		High	Low	Total
Level of reported defects	Low	4	8	12
	High	5	6	11
	Total	9	14	23

TABLE 8.3 - CHI-SQUARE ASSOCIATION - PERCEIVED QUALITY

p<0.1 shown shaded

p=0.072		Skill level of trades-people		
		High	Low	Total
Perceived quality of site	High	6	3	9
	Low	4	10	14
	Total	10	13	23

p=0.795		Experience of manager		
		Experienced	Inexperienced	Total
Perceived quality of site	High	5	4	9
	Low	7	7	14
	Total	12	11	23

p=0.431		Background of manager		
		Managerial	Trades	Total
Perceived quality of site	High	3	6	9
	Low	7	7	14
	Total	10	13	23

p=0.106		Qualifications of manager		
		Qualified	Unqualified	Total
Perceived quality of site	High	1	8	9
	Low	6	8	14
	Total	7	16	23

p=0.349		Level of informal communications		
		High	Low	Total
Perceived quality of site	High	5	4	9
	Low	5	9	14
	Total	10	13	23

p=0.435		Quality of formal communications		
		High	Low	Total
Perceived quality of site	High	5	4	9
	Low	10	4	14
	Total	15	8	23

p=0.265		Organisational culture (level of participation)		
		High	Low	Total
Perceived quality of site	High	6	3	9
	Low	6	8	14
	Total	12	11	23

p=0.183		Planning/programming		
		Local and central	Central	Total
Perceived quality of site	High	2	7	9
	Low	7	7	14
	Total	9	14	23

p=0.349		Intensity of project management		
		High	Low	Total
Perceived quality of site	High	4	5	9
	Low	9	5	14
	Total	13	10	23

p=0.435		Cost pressure		
		High	Low	Total
Perceived quality of site	High	5	4	9
	Low	10	4	14
	Total	15	8	23

p=0.675		Time pressure		
		High	Low	Total
Perceived quality of site	High	4	5	9
	Low	5	9	14
	Total	9	14	23

From tables 8.2 and 8.3 it can be seen that the null hypothesis of no association between dependent and independent variable can be rejected for the following associations:-

At P<0.05

- The background of the site manager and the reported level of defects (A managerial background is associated with a lower level of defects)(p=0.019)
- The qualifications of the site manager and the reported level of defects (Qualified managers are associated with a lower level of defects)(p=0.033).
- The level of planning and programming and the reported level of defects (More detailed planning is associated with a lower level of defects)(p=0.049)
- The intensity of project management and the reported level of defects (More intense management is associated with a lower level of defects)(p=0.007)

At P<0.10

- The quality of formal communications and the reported level of defects (Better quality formal communications are associated with a lower level of defects)(p=0.057)
- The experience of the site manager and the reported level of defects (<u>Inexperienced</u> managers are associated with a lower level of defects)(p=0.059)
- The skills of trades-people and the level of perceived quality (More highly skilled operatives are associated with higher perceived quality)(p=0.072)

DISCUSSION OF THE FINDINGS

Overall

The pattern of results overall gives some support to the findings in the preliminary study that managerial factors are influential in the avoidance or control of errors leading to defects. This support is clearly shown for the dependent variable measure of "reported defects", but is not repeated for the measure "perceived quality". Possible reasons for this discrepancy centre on differences in the level of objectivity of the two dependent variables.

"Reported defects" as a measure are subject to a certain amount of under and over reporting by the informant, but are rooted in objective and numerically assessable events. However, "perceived quality", although assessed in detail for each stage of construction, is based on internal perceptions of quality which might both differ from individual to individual and not be based on numerically quantifiable and objective events. Thus, differences in perception may confound the relationships between dependent and independent variables. An assessment of "perceived quality" could also (probably unintentionally) reflect factors other than the absence or presence of defects. Not only might this include an assessment of generally sub-standard work not amounting to defective, but it is also easy to include variations of business performance of the trade companies doing the work in the assessment. Thus, although guarded against in the design of the questionnaire, the skills of the operative become associated with the quality of his/her work and this, in turn, is reflected in a significant relationship found between trade skills and perceived quality. That relationship should, therefore, be treated with caution and more reliance should be placed on findings related to reported defects.

The pattern of results

Significant results related to reported defects were both concentrated on managerial factors and, within this set of factors, on those of a more tangible nature - formal communications, planning/programming, the experience, background and qualifications of the site manager and the overall intensity of project management. In contrast, a lack of significance for the less tangible managerial factors of informal communications and organisational culture was evidenced.

The measures used for these latter two factors may explain the lack of significance. These were based on a summation of contacts between non-line and line colleagues respectively and could be subject to the action of an intervening variable in the form of a contingency reaction to problems on the site. Thus, a greater degree of contact might have been needed where there were technical problems with the sites and the level of contact rose with the level of reported defects rather than falling. This phenomenon was referred to qualitatively by interviewees, who pointed out the need for more intense communications with difficult sites. Although technical complexity was controlled as far as possible in the selection of traditional speculative housing as the subject of the study, control over such details as siting and ground conditions was not possible.

Independent variables in the form of measures specifically related to the role of the site manager were added as a result of findings from the preliminary study and it is notable that these all had a significant association with the level of reported defects. The results show that the technically qualified manager and the manager from a managerial background was associated with a low level of reported defects.

However, there was also a very strong association between lack of managerial experience measured in terms of time and a low level of reported defects. This is contrary to what one might expect and could merely indicate that more experienced managers were more likely to report defects. Relative verbosity was not controlled in the study, but two related associations tend to refute this criticism. Firstly, senior managers interviewed in the following study informally identified a total of four "star" site managers (sites 3, 4, 21, 22), who they considered of above average ability. Of these four managers, three were classified within the "inexperienced" group, suggesting that lack of experience was <u>not</u> a constraint on performance. Secondly, by comparing the two independent variables, "experience of manager" and "qualifications of manager" it is clear that a straight relationship between experience and performance is confounded by the fact that qualified managers are concentrated amongst the less experienced (at p= 0.016). This is illustrated in table 8.4 and suggests that <u>qualifications</u> rather than experience determines performance on site.

TABLE 8.4 - CHI-SQUARE ASSOCIATION EXPERIENCE/QUALIFICATIONS OF MANAGER

p=0.016		Qualifications of manager		
		Qualified	Unqualified	Total
Experience of manager	Experienced	1	11	12
	Inexperienced	6	5	11
	Total	7	16	23

The lack of significance noted for global factors of cost and time pressure also echoed the findings from the preliminary study. It appears that the relative performance of the sites in terms of either reported defects or perceived quality was not affected by these pressures. Less clear is the lack of significance attributed to skills of trades-people when measured against reported defects, but the near significant result when measured against perceived quality. The latter appears to support the indication from the preliminary study that primary skills are important in avoiding error, but the limitations of the dependent variable "perceived quality" have already been mentioned and the result should be treated with caution.

8.4 CONCLUSIONS

This study, in identifying links between factors in the model and measures of error, provided support for the findings in the preliminary study in answering the second research question (page 150). When relatively objective measures of error were used (in the form of reported instances), it appeared that there was an overall relationship between a number of factors <u>related to the management of projects</u> and the performance of sites.

In isolation these results should be treated with caution. The sample upon which they are based is restricted geographically and in terms of type of project. The method of data collection related to both independent and dependent variables contains elements of subjectivity and the sample size itself is fairly small.

However, when combined with the preliminary study a strongly consistent pattern begins to emerge. That study clearly indicated that managerial factors were considered important in the avoidance of errors leading to defects and this is, at least partially, replicated in this study. It also suggested that some "global" factors were less important and the lack of association noted in this study supports this view.

Perhaps more important is the correspondence between views in the preliminary study emphasising the importance of <u>individually</u> based managerial factors and the significant associations in this study between levels of reported defects and the site managers' background, qualifications and experience. This supports the indication that underlying project management factors are the individual abilities and qualities of the manager.

This finding resonates with the literature, where some authors (e.g. Hirschhorn 1993) emphasise the importance of managerial roles rather than procedures in avoiding unwanted outcomes. It directs emphasis in avoiding error to improving the performance of the manager rather than by attempting to improve performance by the imposition of procedures. Procedures are important and this is evidenced by the significant associations between levels of defects and such factors as formal communications and planning, but the means of implementing these should be through individually based measures related, perhaps, to education and training. This also has interesting parallels with comments in the literature in connection with the construction industry quality assurance movement, where quality management is often seen as an impractical imposition of procedures rather than a process of educating the workforce and its managers (Seymour and Low 1990, Barber 1992).

9

STUDIES OF HOUSE-BUILDING 2

The Interview Study

9.1 INTRODUCTION

The Interview Study provides an alternative method of investigation to the statistical study in addressing the **content** of the model (the second research question posed in Chapter 5 on page 150). The study is also specifically directed towards addressing the **operation** of the model (the third research question). In detail, the study examined:-

- The relative importance of factors identified in the model of the nature of error, with a check on the classifications adopted.
- Any differences between sets of interviewees in order to confirm general agreement of this relative importance.
- Linkages as displayed by the interaction of one factor in the model on another.

9.2 METHOD

The method used was to conduct largely unstructured interviews of members of the organisations used in the statistical study as well as one further set of independent agents within the house-building industry and to analyse the content of the responses. The collection of interview data was conducted in two distinct parts.

In the first part, the site managers used for the supply of data for the statistical study (Chapter 8) were asked open questions at the end of the interview sessions (See questions 31, 32 and 33 in the Questionnaire - Appendix 8d). Question 31asked whether the site manager had experienced any particular quality problems relating to the project. The total number of instances recorded was used as a dependent variable in the statistical analysis (variable number 1 - reported defects and error instances). The content of these responses was further analysed in this study to enumerate all the identifiable causes of the defect, or error and to classify these causes in accordance with the model. Questions 32 and 33 prompted a more subjective response in that they asked the interviewee to give a general opinion of factors influencing the quality of the houses in the project (question 32) and for other general comments (question 33). The content of the responses to these questions was also analysed in terms of the model. For both questions, detailed narration of the pathology of particular instances was used to illustrate the interaction of one cause with another and so examine the systemic nature of error incubation (The third research question).

In the second part of the study, more senior managers within the two house-building companies used for the statistical study were interviewed as well as a foreman for a bricklaying sub-contract company on one of the house-building sites. These interviews were open and did not involve particular pre-identified questions (See appendix 9b - Open Interview Questionnaire). The interviewees were prompted with similar questions to that posed to the site managers, but not specifically related to any particular project. Responses revealed a similar mix of specific recollections of defects and error instances and more general comments, which were analysed in the same way as the site managers' responses.

Using the same method, a third separate set of managers within building guarantee companies was interviewed. These companies provide building insurance for new houses. The personnel interviewed were responsible for assessing the risk and inspecting the construction of housing sites prior to issuing insurance policies. The object of these interviews was to provide an external view independent of the reports from within the two companies. Full details of interviewees in the second part of the study are give in appendix 9c. In all, 40 interviews were conducted as summarised in table 9.1.

TABLE 9.1 - INTERVIEWEES

Source	**Number**
Site managers	23
Senior managers, foreman subcontractor	12
Building guarantee managers	5
TOTAL	**40**

Responses were recorded in detail and analysed in accordance with the model of the nature of errors in appendices 9a(i) to 9a(vii). The content of the responses was initially analysed in two categories:-

- Specific narration of errors either leading to defects or detected and corrected beforehand (appendices 9a(i-iii) - Record of errors).
- Narration of more general problems leading to, or (based on the interviewee's experience) known to lead to errors (appendices 9a(iv-vi).

The cause of each error or general problem was later identified using, where possible, the categories of the model. For many errors and problems, this involved the identification of more than one cause, a patent cause and one or more underlying causes. In the quantification of the causes of error, each identified cause was treated separately. A summary of this assessment is given in appendix 9a(vii). Text of narration was used later to examine the interaction between patent and underlying causes.

9.3 ANALYSIS

THE CAUSES OF ERRORS AND PROBLEMS

In total 220 causes of errors or general problems were identified and they could be readily categorised into the broad grouping of the model as shown in figure 9.1.

FIGURE 9.1 - THE CAUSES OF ERRORS/PROBLEMS BROAD CATEGORIES

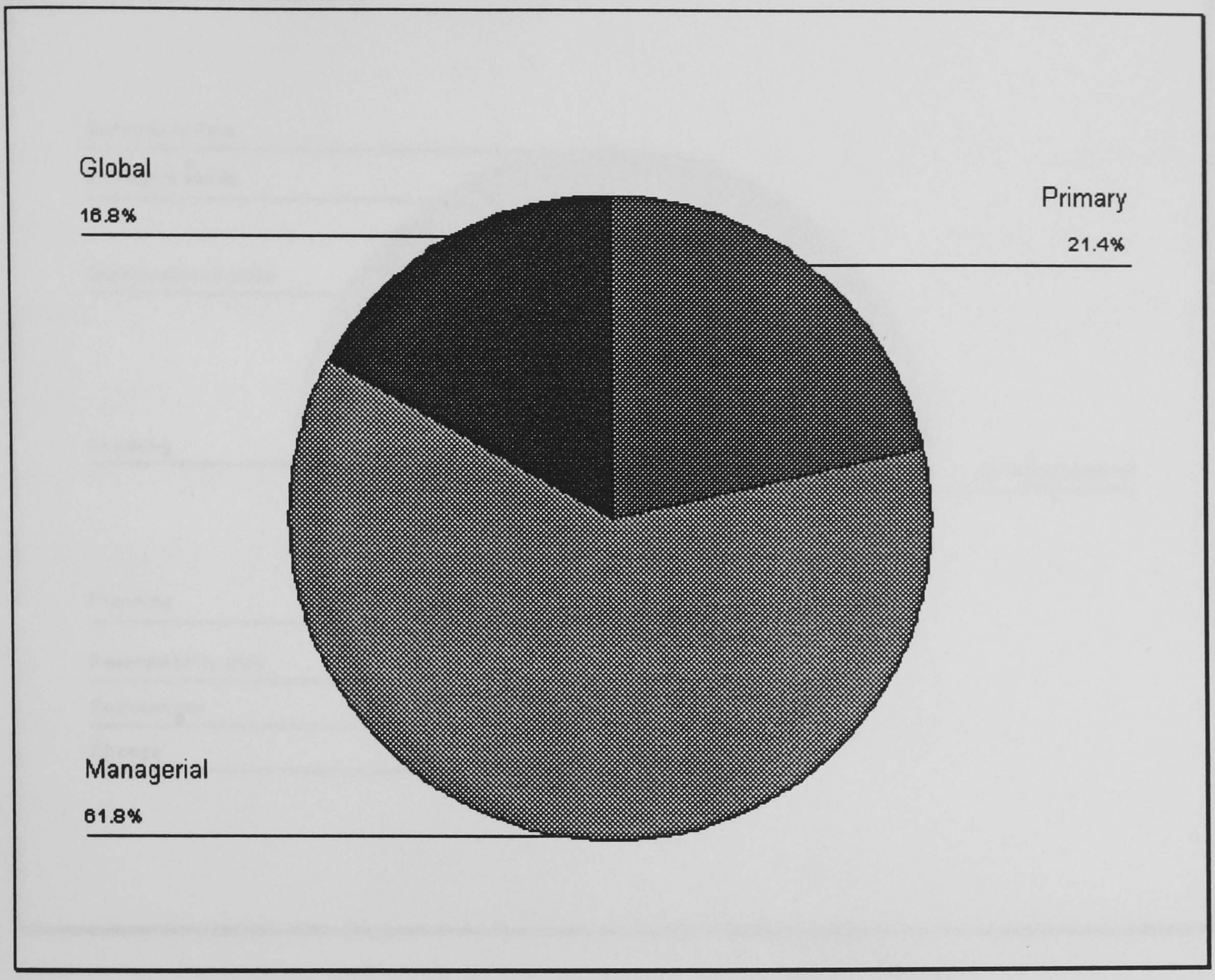
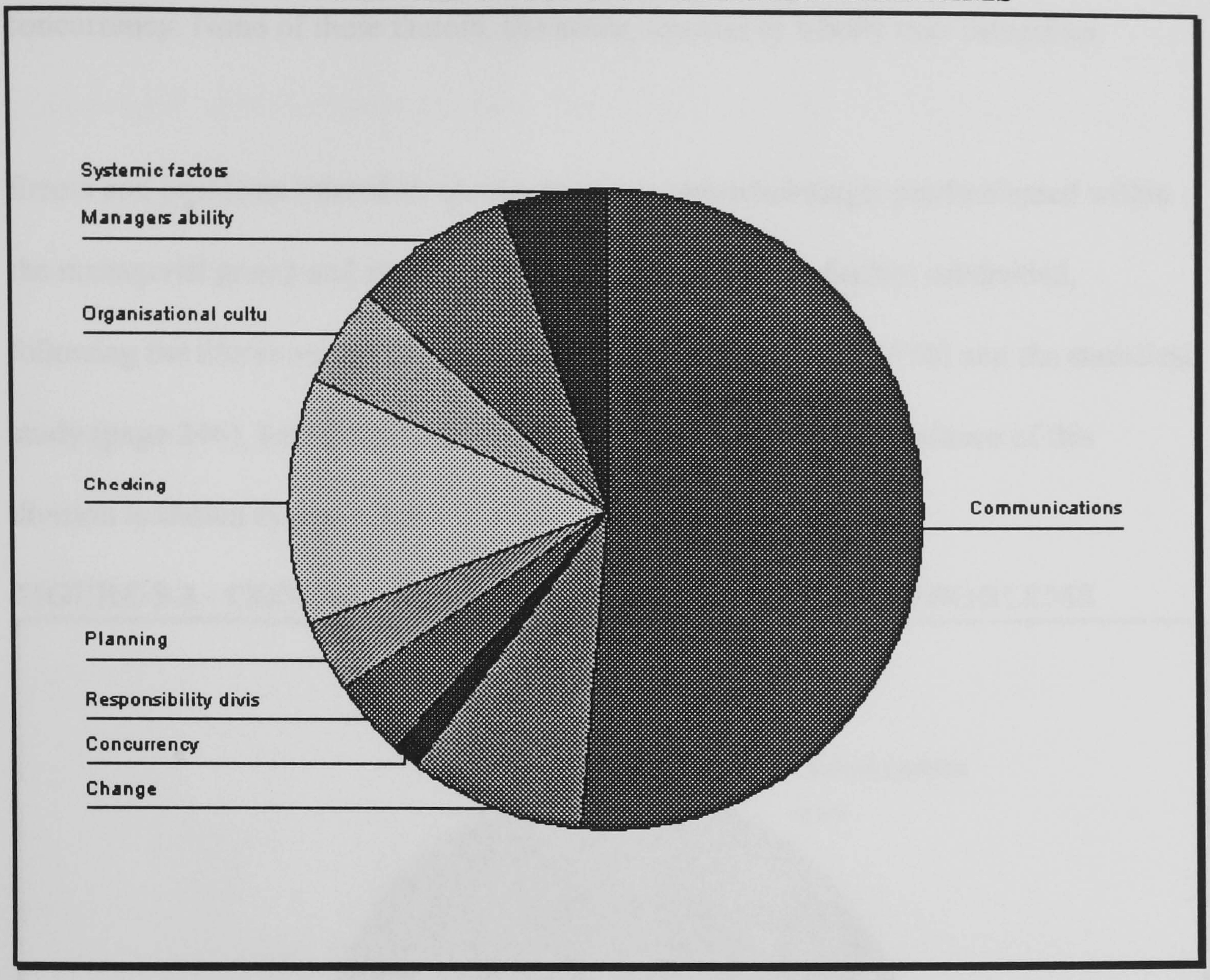


Figure 9.1 shows that managerial causes predominated in responses from all interviewees, with much smaller attributions to both primary and global causes. This balance of causes followed the preliminary study, where managerial factors were generally rated by respondents as important. When managerial causes were examined in more detail the breakdown shown in figure 9.2 was revealed.

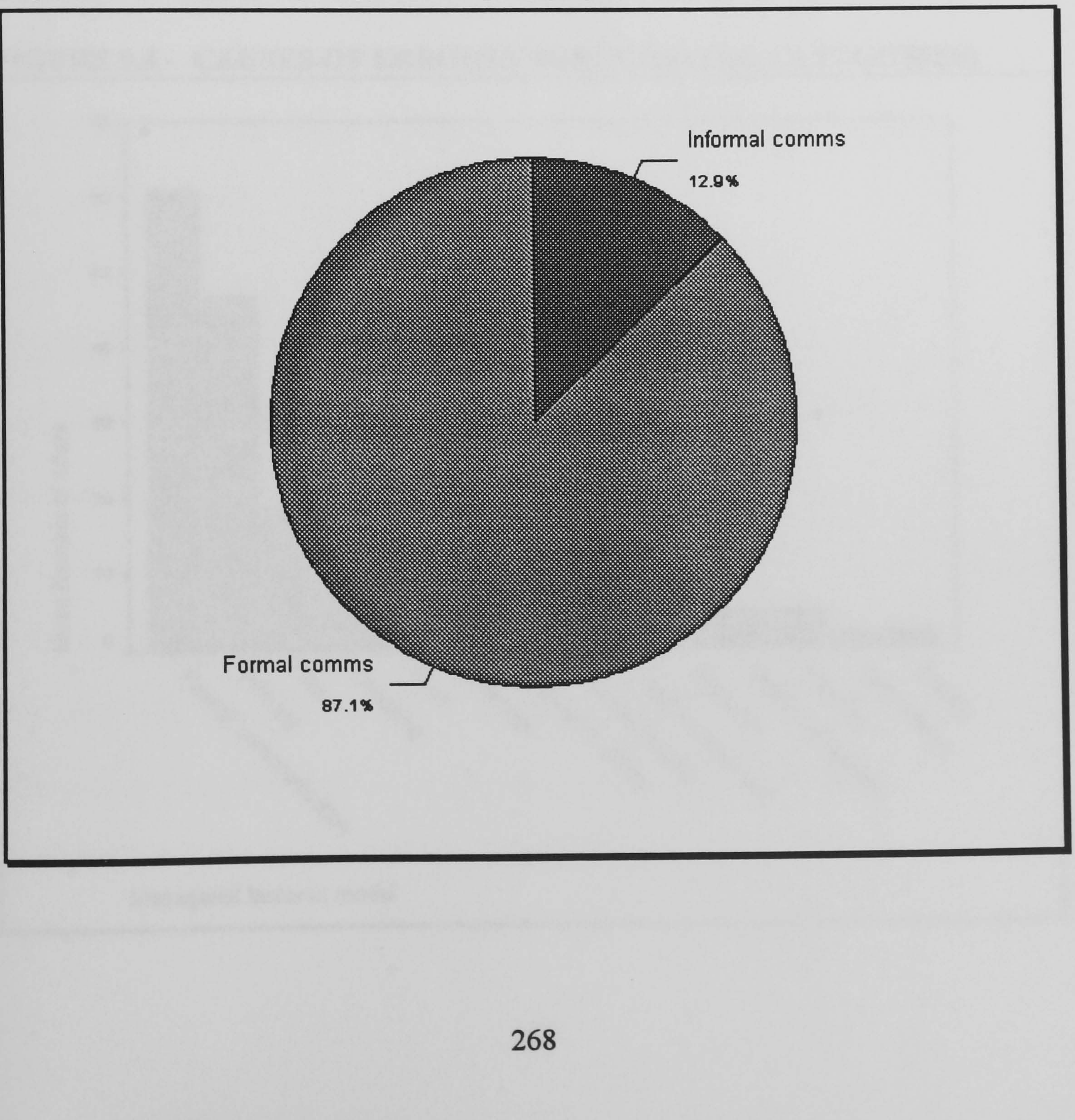
FIGURE 9.2 - MANAGERIAL CAUSES OF ERRORS/PROBLEMS



Again, the breakdown followed the model closely. It included three additional categories not explicitly shown in the model, "manager's ability", "systemic" and "planning". The classification "managers ability" followed the preliminary study, where it was suggested that the primary qualities of the manager might underlie managerial functions. The classification "systemic" also followed the preliminary study, where it was suggested that a "system" or "systems" linking factors were instrumental in avoiding errors. The classification "planning" followed the statistical study, where planning was identified (following Hinze and Raboud 1988) as the corollary of and taken as a proxy for the division of responsibilities, control of change and control of concurrency. None of these factors, therefore, amount to wholly new categories.

Errors and problems related to communications overwhelmingly predominated within the managerial group and responses within this factor were further subdivided, following the literature (Kaminetzky 1991, Kletz 1985, Turner 1978) and the statistical study (page 246), into <u>formal</u> and <u>informal</u> communications. The balance of this division is shown in figure 9.3

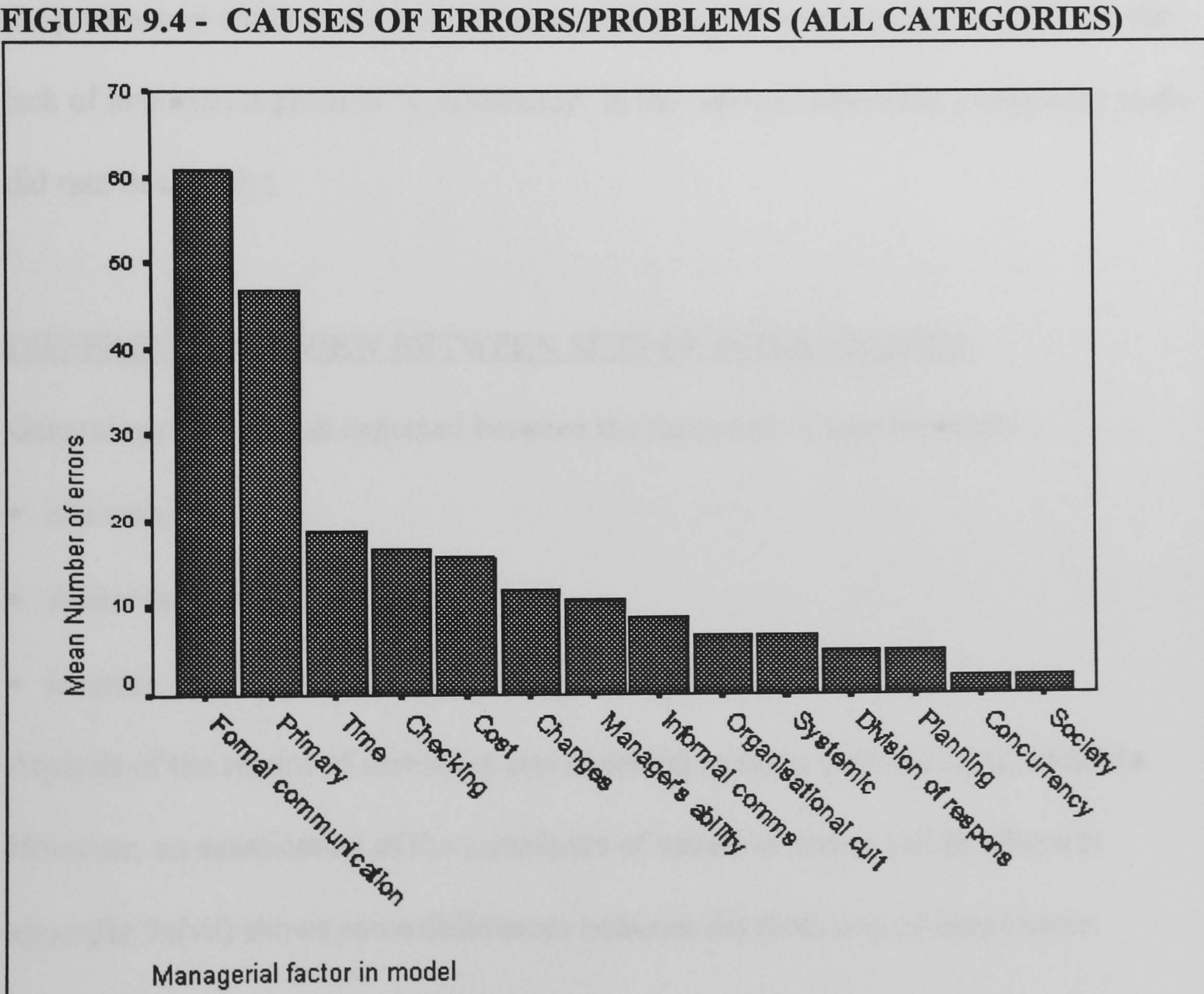
FIGURE 9.3 - COMMUNICATION CAUSES OF ERRORS/PROBLEMS



Thus, it could be seen, that of the most significant factor, communications, errors and problems related to formal communications overwhelmingly predominated. This corresponded with findings from the statistical study, where a significant association between the quality of formal communications and the level of reported errors was noted.

Taking the whole set of responses, ordered in term of frequency, a pattern was revealed as shown in figure 9.4.

FIGURE 9.4 - CAUSES OF ERRORS/PROBLEMS (ALL CATEGORIES)



This pattern followed closely, but not exactly, the ratings from the preliminary study (page 212). In that study, communications was also rated as the most important factor in avoiding errors and "time", "changes" and "checking" were, in common with this study, rated in the top six most important factors. Primary errors were represented in the preliminary study by (amongst others) "education and training", which was rated among the top six.

The most notable discrepancy between the reports of errors/problems and the preliminary study rankings was in the importance given to "costs" in the reports (where the preliminary study equivalent of "economic climate" was not rated highly) and the lack of importance given to "concurrency" in the reports (where the preliminary study did rate this highly).

DIFFERENCES IN VIEW BETWEEN SETS OF INTERVIEWEES

General agreement was expected between the three sets of interviewees:-

- site managers
- senior managers and
- insurers

Analysis of the record of narratives was expected to show converging conclusions. However, an examination of the summaries of causes of errors and problems in appendix 9a(vii) shows some differences between the three sets of interviewee.

Differences might be caused by an attribution (Lourens 1990) or blame (Whittington et al 1992) effect. This was examined in the preliminary study (page 214/215), where the effect was not detected. As with the preliminary study, it was possible that reported errors or problems in this study might be distorted by the interviewee under-reporting factors where blame could be attributed to him or her and, correspondingly, over reporting factors where blame could be attributed elsewhere. This effect was most likely to occur in reporting primary as opposed to managerial errors, the expectation being that site managers would emphasise primary, but not managerial, errors. Interviewing more senior managers and insurers provided a check on this as these managers were unlikely to stress primary errors if they felt that the site management was responsible for the error/problem.

To check for any such attributions a chi-square test of association was used comparing, respectively, site and senior managers' reports of errors classed as primary, or managerial. As the group "insurers" was small (5 No) they were combined with "senior managers" in the analysis. The formal hypothesis was that there would be no significant association between the two groups. The results are as shown in Table 9.2.

TABLE 9.2 - CHI-SQUARE ASSOCIATION - SITE/SENIOR MANAGERS' REPORTS

p=0.028		Manager		
		Site	Senior	Total
Number of errors	Primary	25	11	36
	Managerial	39	43	82
	Total	64	54	118
p=0.044		**Manager**		
		Site	Senior	Total
Number of problems	Primary	4	7	11
	Managerial	37	17	54
	Total	41	24	65

From table 9.2 it can be seen that the null hypothesis of no association between dependent and independent variable can be rejected for the two associations:-

- The locus of the manager as site or senior and the classification of reported errors as primary or managerial (A higher frequency of reports of primary errors is associated with site managers and a higher frequency of reports of management errors is associated with senior managers)(p=0.028)
- The locus of the manager as site or senior and the classification of general problems as primary or management (A higher frequency of reports of primary problems is associated with senior managers and a higher frequency of reports of management problems is associated with site managers)(p=0.044)

However, the table reveals that, although site managers reported significantly more primary errors than senior managers, senior managers reported significantly more general problems related to primary factors than site managers. The effect of summing both errors and problems is that one measure almost completely cancels out the other as shown in table 9.3

TABLE 9.3 - CHI-SQUARE ASSOCIATION - SITE/SENIOR MANAGERS' REPORTS (Both Categories)

p=0.487		**Manager**		
		Site	Senior	Total
Sum of errors and problems	Primary	29	18	47
	Managerial	76	60	136
	Total	105	78	183

It can be concluded from this that, although differences in detail existed between reports from site and senior managers, overall this was not significant.

SYSTEMIC INTERACTIONS

A considerable volume of literature (for example, Morris 1994, Blockley 1992, Bea 1994) has considered the systemic aspects of errors. The need for "systems" was referred to by some respondents in the preliminary study, and included in the model, but that study did not include a detailed examination of whether and how errors leading to defects involved systemic interactions. An object of this study and the following Observational Study (Chapter 10) was to conduct this examination by analysing the causes of the more obvious patent errors.

Types of interaction

Analysis of the reports of errors and more general problems in Appendix 9a revealed several types of interaction, which could be categorised into one of three types of error cause as follows:-

- Self contained errors
- Simple two-way interactions between causes
- Complex interactions between causes

1 Self contained errors

This type of error predominated in all reports and related mainly to formal communications (approximately 45 instances)and primary errors (approximately 35 instances). The next most frequent cited single cause related to changes, which occurred relatively infrequently (approximately 8 instances).

Simple primary errors were often related to the operative and presented as the cause of an actual defect. For example the site manager for site 1 cited poor quality brickwork involving missing wall ties, leaning piers and lack of frame ties and the site manager for site 5 cited an instance where a landscaper "turfed" over the top of manholes. In contrast, where formal communications or changes were cited as the single cause it was not always clear whether the error had actually caused a defect. For example, the citing by the site manager for site 3 of expansion joints in brickwork which did not match internal wall layouts did not make clear whether the work was actually built as designed and later corrected, or corrected in advance of construction. Where it was clear that a defect had arisen, for example in the instance quoted by the site manager for site 5 of an error in the design of floor joists resulting in post-construction strengthening, it was also clear that the operative constructing the work was not in error, but merely correctly following a detail.

The instance cited by the manager for site 13 of an error in positioning a window on a drawing being picked up by the bricklayers <u>before</u> being built into the work indicates that one difference between simple primary and simple managerial errors is that the former <u>give no chance for prior correction</u>, whereas the latter are sometimes <u>capable of being checked and corrected by operatives and their supervisors</u>. This suggests that, even where instances are presented as being from a single cause, the likelihood of errors actually materialising as defects depends on an interaction between different specialists.

This suggestion was supported by instances of primary operative error being cited, when the real cause could have been poor formal communications or even more remote global factors. Thus, the site manager for site 7 recorded the instance of operatives nailing pipes and causing house floods, where it was not clear whether drawings showing the location of the pipes were provided, or even whether the pipes were live and the leaks were immediately obvious (and capable of quick rectification). The site manager for site 12 noted that bricklayers incorrectly quoined the jambs on a knapped flint faced house. This error was classified as primary, but some architects provide drawings of elevational treatment and it was not clear whether this was the case here. A third example of such a disguised cause occurred in the report from the site manager for site 16, who cited the omission by operatives of carpentry details that, perhaps, should have been shown on drawings or in a specification.

These errors not only raise questions of classification and identification of underlying causes, but also question the necessary limits of knowledge of operatives at the "primary" level. Modern construction, even of traditional housing, has become complex and trades trained operatives are often not capable of allowing for details where not expressly shown. This extends to traditional details, such as the quoining of knapped flint, which are now used infrequently.

In summary, therefore, the reporting of an instance attributed to a single error may not have always been accurate or complete. Taking the two most frequently recorded single errors, primary errors and formal communications errors, the former directly resulted in defects, whereas the latter were modulated by the action of others, in one case cited, by an operative. Thus, even with apparently self-contained single errors, the eventual outcome appeared to depend on interactions of causes.

2 Simple two-way interactions between errors

In several narratives of errors and problems, the interaction of causes was expressly acknowledged and in most instances this interaction was simple, involving two errors or an error and a wider global or external factor. In all, 18 instances were recorded and classified as follows:-

- Related to primary errors
- Managerial - global
- Managerial - external factors

Related to primary errors

Primary - checking

Perhaps the most obvious interaction of errors leading to defects is that of the operative performing the work and the checker verifying the work. Three instances involved such an interaction. On site 3 it was reported that poor roofing was caused by insufficient trades supervision, which improved after threats from the NHBC (A building guarantee insurance company). Open interviewee 3 reported a notorious incident where a considerable number of houses were built without cement being used in the wall mortar. The causes cited were poor workmanship and lack of supervision. Open interviewee 17 also reported an incident of walls being built with insufficient mortar, attributing the defect to a "knowledge error by bricklayers and lack of supervision".

Primary - formal communications

This interaction has previously been noted in connection with simple errors, but express interactions were also noted. Open interviewee 17 reported the instance of subsidence being caused by operatives not allowing for the effect of a nearby Oak tree in digging foundations. However, the depth and design of foundations would normally be calculated by engineers in these circumstances and provided, either on drawings, or by direct instruction.

The more general complaint of formal communications not being provided and decisions being left to operatives on site was made in other instances. On site 3 it was reported that design errors were not corrected and "left to construction to correct". On site 21 it was reported that drawings "lagged building production and hence too much was left for site to decide" and open interviewee 8 reported that formal communications often <u>followed</u> operative actions rather than <u>preceding</u> them and commented that it is "far better that the detail is there than it is got over on site".

Primary - informal communications

One incident was reported of an interaction between poor operative performance and a failure in informal communications. On site 3 it was reported that poor brickwork quality was caused by the bricklaying firm operating at too great a distance from their office. The extended distance made communications difficult. Not expressly reported was the implication that this made control and checking of the operatives more difficult. Thus, this incident would probably have involved an interaction between <u>three</u> causes, communications, checking and primary factors.

Primary - change

One incident was noted related to change, where the manager for site 19 suggested that "change orders (were) not always passed on in the bricklaying firm". This incident, however, probably also included an interaction of three factors, <u>change</u>, <u>communicating the change</u> and <u>incorrect primary action</u>. In this respect, the operative is possibly the least culpable agent.

Primary - global factors (cost and time)

The tension between the performance of operatives and cost pressures was illustrated by two reports. It was reported on site 5 that the performance of an electrician was not up to standard and pressure built for the electrical engineering firm to be replaced. This faced opposition from the company quantity surveyor (who was charged with controlling costs). The interaction was put more generally by the manager for site 20 who complained that lack of money lead to "poor selection of trades and lack of qualified managers".

One report (site 15) related to an interaction between operative standards and time pressure, where poor bricklaying was reported as being "partly caused by speed of working".

Managerial - global

The interaction of the global factor, time with managerial factors was illustrated by two reports. Open interviewee 5 noted generally that the fast pace demanded by modern construction "required good organisation of men" and open interviewee 6 illustrated the interaction of time and concurrency by recounting problems related to the start up of site 23. Pressure of time, in turn caused by the demand for early sales of houses, meant that show houses were constructed in advance of site works leading to the situation where completed houses could not be occupied and piped/wired services were installed in houses, but could not be tested or commissioned. From this analysis it can be concluded that any primary errors in installing services would be greatly magnified by the inability to test them before covering up the work; a problem manifested as a primary error, but directly related to concurrent working, and the demands of the sales programme causing time pressures.

Managerial - external factors

Three reports related to interactions between formal communications and factors external to the model. The manager for site 19 cited poor ground conditions leading to design difficulties. The manger for site 21 similarly cited subsidence of an existing building leading to re-design. Open interviewee 11 reported a problem with one house, where negative pressure on a chimney stack was causing down-draughts in the flue and smoke to enter a room - a problem again not anticipated in the design.

These were not interactions within the model as such, but relate to the definition of "error". If such errors were completely unforeseeable (as was reported for the problem with the chimney stack), they would not come within the definition. However, designs should take account of existing conditions and it is harder to see how poor ground conditions or existing subsidence could be overlooked. These two interactions might, therefore, be hiding other causes, perhaps related to inadequate time and cost leading to skimping of pre-design investigations.

3 Complex interactions between causes

Although some reports of two-way interactions *suggested* more complex underlying causes, other reports *expressly indicted* these. Two types of interaction were illustrated, fairly specific instances of interactions within the building process caused by multiple errors and more general "systemic" problems driven "from the top" by senior managers.

Regarding the first type of interaction, open interviewee 16 reported two specific instances. On one site, parapet walls to gables of houses were built without damp-proof courses and poor mechanical fixings of coping bricks. This was reported as a design fault (formal communications) overlooked by the site manager (checking), but primary error was also indicted in that the need for a damp-proof course at parapet level should be known by a skilled bricklayer. The interviewee's interpretation of the causes of the defect was inadequately skilled operatives blindly following flawed formal communications and not being checked by the supervisor.

The second incident reported by open interviewee 16 related to a claim to a building insurance company for floor joist failure. The pathology of this incident showed how multiple errors can compound to cause failure. A bricklayer built floor joist hangars into a unit at too high a level. This could have been a primary error, but was also compounded by poor design detailing (formal communications). To reduce the joists to the correct floor levels, the carpenter excessively notched the joists over the hangars. This would weaken the joists, but the problem was compounded by electricians further notching the joists to accommodate cabling. The defects were not detected by normal supervision (and the normal supervisor had also been on holiday for some time). Finally, the failure was further compounded in that it was repeated in several other units. The cause for the further lapse was cited as lack of clear instructions to carpenters after the initial failure. Thus, in this one incident, an interaction can be demonstrated between:-

- **Formal communications (poor design detailing)**
- **Primary error (notching joists)**
- **Checking error (supervision inadequate)**
- **Informal communications (failure to instruct carpenters)**

More general "systemic" problems were illustrated by open interviewee 12, who reported problems with the show houses on site 11. These had "exhibited very high maintenance costs". The cause was attributed to too much haste in construction, with the comment that "we threw them up too quickly and reaped what we sowed". The reason for the excessively fast pace of construction was to consciously meet sales targets and the cause clearly indicates the systemic effect of some errors. The very high maintenance costs were caused by <u>primary errors</u>, driven by <u>lack of time</u>, compounded by a <u>lack of checking</u> and a management system that did not adequately <u>plan</u> for speed. In this instance, the primary errors were not really "errors" at all as the interviewee recognised and senior management planned for likely problems.

A similar pathology of causation was reported by open interviewee 6, who noted that the managing director for his region, concerned with maximising sales and hence profits, always wanted to "build out" all sites in order to have a product to show customers. Thus the need for profits (<u>cost</u> related) produced <u>time pressures</u>, which in turn caused <u>primary</u> and <u>checking</u> errors.

9.4 CONCLUSIONS

To return to the object of this study, it provided an alternative method to the Preliminary and Statistical Studies to addressing the **content** of the model and it addressed the **operation** of the model by investigating systemic effects.

THE RELATIVE IMPORTANCE OF FACTORS

Responses from interviewees in the study were readily categorised into the model of the nature of error and the balance of causes underlying reports from interviewees closely followed the findings from the preliminary study. Both studies classed communications as the most important cause of errors leading to defects and, of the top six most highly rated factors in the preliminary study, five also featured as the most frequently cited causes of errors and problems in the Interview Study. The findings of the two studies are compared in Table 9.4.

TABLE 9.4

COMPARISON OF PRELIMINARY STUDY RATINGS AND INTERVIEW STUDY RETURNS

FACTOR	PRELIMINARY STUDY RATINGS	INTERVIEW STUDY RETURNS
Communications	1	1
Time	2	3
Concurrency	3	
Change control	4	6
Primary♣	5	2
Checking	6	4
Responsibility definition	7	
Cost♠		5

♣ Education and training in the preliminary study.
♠ Economics in the preliminary study.

Communications were subdivided into "formal" and "informal" in this study and a preponderance of errors and problems related to formal communications followed the significant association noted in the statistical study between formal communications and error instances.

DIFFERENCES BETWEEN SETS OF INTERVIEWEES

As with the preliminary study, differences in view were examined in this study. In particular, it was possible that reports of errors from site managers might be distorted by a tendency to blame others rather than blame themselves. Thus, primary errors might be over-reported by site managers and errors attributable to site managers might be under-reported. This effect was detected when the frequency of errors classed as primary or managerial was analysed and compared with the locus of the manager (site or senior). However, the opposite effect was detected when the frequency of more general problems was analysed. The overall result was that, when errors and problems are taken as a whole there was no significant association between the classification of cause (primary/managerial) and the locus of the manager (site/senior).

LINKAGES DEMONSTRATING SYSTEMIC EFFECTS

The Interview Study demonstrated the systemic aspects of error causation by identifying three types of interactions between causes:-

- Self contained errors, where the cause of a defect appeared to stem from a single error. However analysis of some of these errors suggested some interactions with other causes. Thus, primary errors might **disguise** "upstream" managerial errors and errors related to managers might be **modulated** by the actions of others "downstream" to the error. In the former set of errors, causes are likely to be inaccurately attributed as primary errors rather than managerial and in the latter set of errors, several might never reach the stage of becoming a defect, if "picked up" by operatives and their supervisors. From this analysis, it seems that the operative is often the unsung hero of the building process - unjustly blamed for the mistakes of others, yet not credited when he/she detects these mistakes.

- Expressly noted two-way interactions of errors perpetrated by different actors in the project. Here, an operative might make a primary mistake, but his or her work might not be checked, a manager or operative might blindly follow poor formal communications, or the operative or manager might be pressured by time or cost considerations.
- Complex interactions between errors. Two types of complex interactions were noted. Firstly, series of errors caused by a triggering primary error or error in formal communications, which was then **carried through** the construction sequence and later repeated because of poor communications. Secondly, series of errors driven "from the top", perhaps consciously, leading to a generally high rate of defects. For the latter type, the initial "errors" are **"deliberate"** and engendered by **driving motivators**, such as profit, sales, or the need to meet year-end accounts.

Overall, this study corroborated the findings from the preliminary study and provided support for the content of the model. It showed that communications factors predominate in the pathology of errors leading to defects. That "communications" predominates does not mean that other factors are not important and highly rated factors were spread through all three levels of the model - "Primary" errors were ranked second in the frequency of citing of causes, followed by the "global" factor "time". Detailed examination of causes indicated that all factors can, either singly or collectively, contribute to defects. Examination also revealed that interactions between factors are an important feature of many errors leading to defects, giving support for the operation of the model. Interactions may relate to site activities or the design/development process, but it has also been demonstrated that errors can be driven from the top by wider business factors. Thus, the "systems view" advocated by Blockley (1992) amongst others, is supported in this study.

10

STUDIES OF HOUSE-BUILDING 3

The Observational Study

10.1 INTRODUCTION

The observational study primarily addresses the **operation** of the model (the third research question on page 150), by focusing attention on errors and their pre-cursors as they actually arose during the performance of a specific project. Additionally, observations allowed some recording of error instances, which was used to complement the other studies in addressing the **content** of the model (the second research question).

SPECIFIC OBJECTIVES WERE TO:-

1 Document and classify errors as they happened in accordance with the model.

2 Examine the links between causes by tracing the pathology of errors leading to potential or actual defects in buildings under construction.

10.2 METHOD

GENERALLY

The method adopted was to use participant observation of a construction project. The site based operation of speculative house-building was chosen as the focus of the study, for the same reasons as the statistical study. Speculative house-building in the

United Kingdom is relatively uniform, simple and key operations are concentrated in one place, the site. It was considered that significant events related to incipient and actual errors would be visible from the vantage point of the site and the site office <u>for this type of construction</u>. In addition, using speculative house-building allowed the study to be drawn from previous work. The study was based on one of the 23 sites used in the statistical and interview studies.

The time scale chosen for the study was one week. This was considered the minimum time for a cross-section of events to be evidenced sufficiently to complement the other parts of the research. It was considered that the project should be observed at a period where most construction activities were taking place (from excavating foundations to completing buildings). One of the advantages of traditional, two/three storey housing on green-field sites is that it is common for all phases to be under construction at the same time and this also influenced the choice of speculative house-building.

CHOICE OF PROJECT

The most convenient (in terms of daily access for the researcher) source of suitable projects within which to conduct the study was Region 1 of Company 1. Company 2 sites were generally not available as the Company was withdrawing from house-building and the involvement of a researcher was not encouraged. Region 2 of Company 1 was more remote from the researcher's base (see appendix 8a). Accordingly, the managing director of Region 1, Company 1 was approached to authorise access to a site. General authorisation was given and three sites were short-listed (9, 16, 23). Sites 9 and 16 were nearing completion, but site 23 was in a relatively early phase of construction, with all main activities being executed (with the exception of roads and sewers, which had been completed). This site was, therefore, chosen for detailed study.

METHOD OF RESEARCHER INTEGRATION

A visit was made to the site in the course of the statistical/interview study and the site manager was interviewed. At this stage the site was in the very early stages of construction with roads and sewers being installed. The site was thus identified as being suitable for the observational study, given that, by the time the study was to be carried out, construction was likely to span most activities[1]. The site manager's co-operation was sought and given and the nature and role of the researcher was explained as being one of observer. It was additionally stressed that the researcher would carry out any work tasks required by the site manager. As it was likely that the best vantage point to record the events of the site and those related to outside agencies was near the telephone, the researcher volunteered to carry out clerical tasks and answer the telephone, in addition to supporting the site manager and assistant site manager around the site.

[1] Activities on the site did, in fact, cover most normal construction stages. The site was divided into three parts. In one part, houses (including show houses) were nearing completion, in a second, houses were at "first lift" stages and in the third, footings were being excavated and concreted. One small part of the site had yet to be started.

Integration was evidenced by:-

- The researcher being given clerical tasks and answering the telephone as planned (10.45 Monday).
- The researcher being accepted by some of the sub-contract operatives in that the ground-workers took time to show the use of a laser level (15.45 Thursday) and the excavator driver gave the researcher "lessons" in driving a 360 degree tracked excavator (14.15 Friday).
- The researcher being asked to solve site-based problems in relation to changes in construction details (13.15 Thursday).

METHOD OF RECORDING DATA

Continuous recording using tapes or other mechanical means was rejected for two reasons, firstly it was felt to be too intrusive (causing resentment and withholding of information) and secondly it was considered that recording all information verbatim would include too much irrelevant data. Recording was, therefore, by writing timed entries in a rough note-book during, or as soon as possible after, the occurrence of an event[2].

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[2] The methodology followed Coolican's (1994) description of diary studies, with the diary being written up at the end of the day from notes "recorded where the opportunities have arisen" (page 102)

The intention was to record all events, other than the trivial, but it was recognised that some unconscious selection may take place. This eventuality was not allowed for, because the observational study was not the sole source of information. All events were reviewed at the end of each day and contemporary notes were added. In addition, some researcher notes were added to events as they occurred - these are identified in the diary. The diary was transcribed verbatim and further notes were added at the transcription stage. The text of the diary and the accompanying notes are given in appendix 10a and the following analysis should be read in conjunction with the text.

In order to maintain a chain of evidence from events as they occurred to the analysis reported here, times are given in brackets after the points considered. This follows literature (Miles and Huberman, 1994, Strauss and Corbin, 1990) on the method of presenting evidence in qualitative research.

10.3 ANALYSIS

DOCUMENTATION AND CLASSIFICATION OF ERROR INSTANCES

The text of the diary was analysed into a number of "error related events"[3]. Such events were problems reported and discussed in the site office, instances of actual errors occurring on the site, or tactics used to avoid errors occurring. Coding of instances to particular factors in the model of the error process was then carried out and the results are given in Table 10.1 and illustrated in figures 10.1 and 10.2.

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[3] Bentley (1981) recorded "quality related events" in his observational study for the BRE (see page 47)

Problems were experienced in carrying out this process, particularly related to the fact that many instances could be linked to either multiple or underlying causes. The figures should, therefore, only be treated as indicative of the relative importance of the factors. Notwithstanding these problems, however, it was possible to categorise all instances in terms of the model and new categories were not revealed in this study.

TABLE 10.1 - RECORD OF ERROR INSTANCES

FACTOR IN THE MODEL	RECORDED INSTANCE
GLOBAL	
Time	**2**
Cost	**13**
Societal	**6**
MANAGERIAL	
Checking	**5**
Communications	**22**
Concurrency	**3**
Changes	**12**
Responsibility division	**1**
Organisational Culture	**6**
PRIMARY	**8**

FIGURE 10.1 - RECORDED ERROR INSTANCES SUMMARY

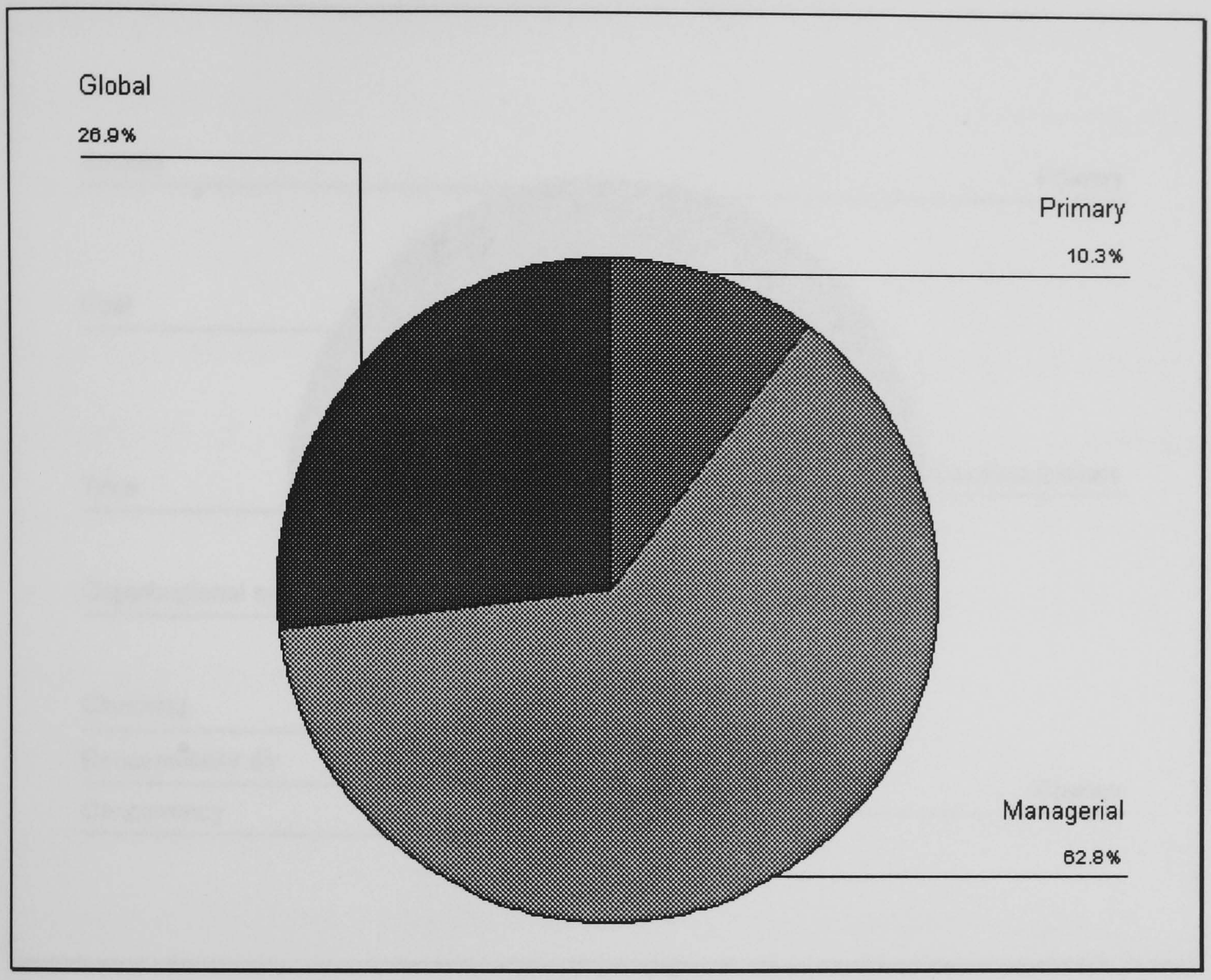
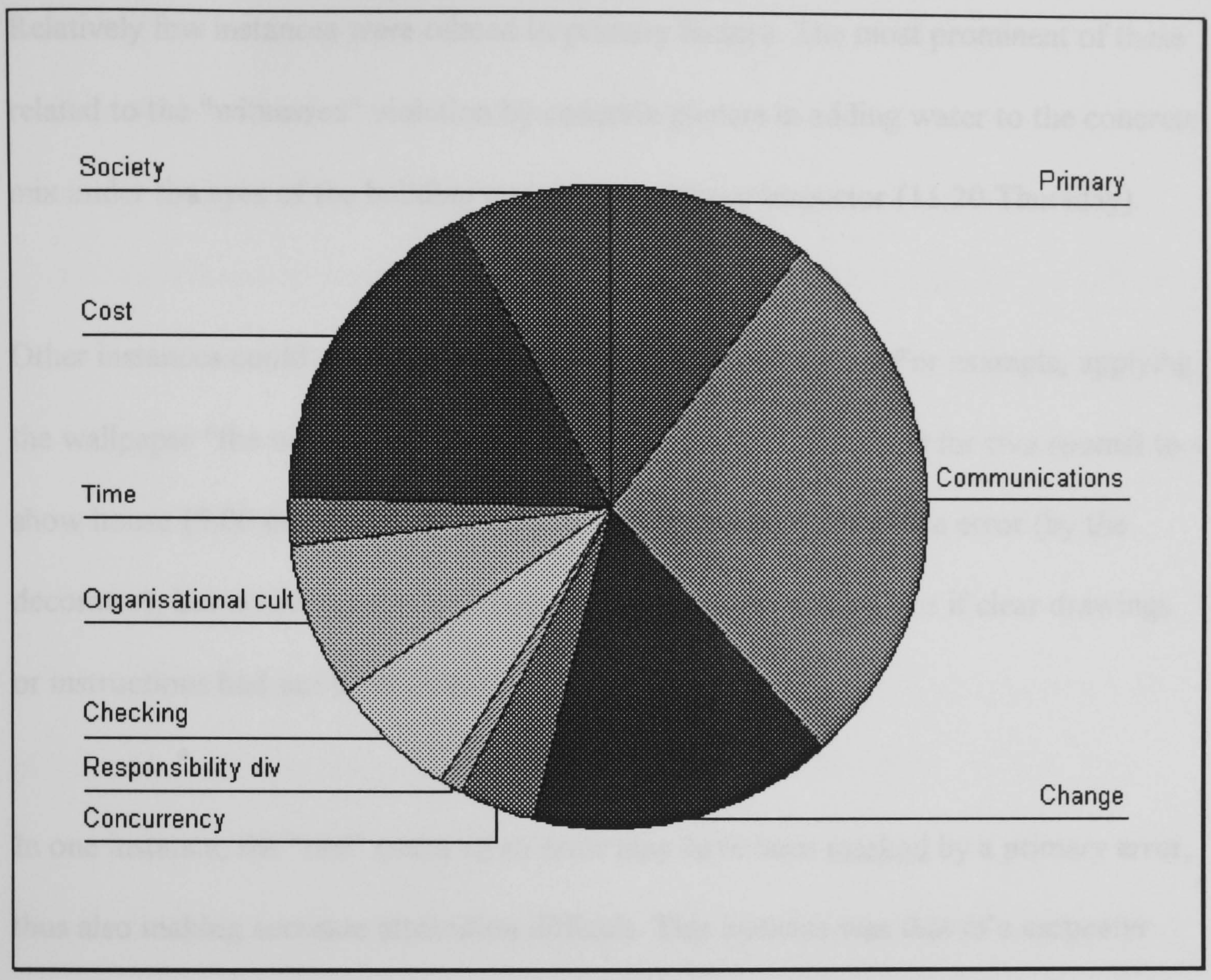


FIGURE 10.2 - RECORDED ERROR INSTANCES IN DETAIL



In addition to the above analysis, two instances were related to external factors beyond the control of the organisation.

It was apparent from this analysis that managerial factors predominated, followed by global then primary factors. The significance of managerial factors was in line with both the preliminary and interview studies, but events related to global factors were more prevalent than expected.

Primary factors

Relatively few instances were related to primary factors. The most prominent of these related to the "witnessed" violation by concrete placers in adding water to the concrete mix under the eyes of the building guarantee company inspector (11.20 Thursday).

Other instances could not be clearly attributed to primary error. For example, applying the wallpaper "the wrong way round" (exchanging the pattern/type for two rooms) to a show house (9.00 on Monday), could have been a primary operative error (by the decorator), but could equally have been an error in communications if clear drawings or instructions had not been given.

In one instance, the "real" cause of an error may have been masked by a primary error, thus also making accurate attribution difficult. This instance was that of a carpenter cutting up the wrong sized floor joists for a unit (9.05 on Friday). However, this error was induced by **changes** to the unit in turn driven by **economic forces** and **societal pressure**.

Examination of the Building Guarantee Company site file (13.05 Friday) revealed a similar ambiguity. Some defects could have been attributed to primary error (Brickwork bonding errors, laying foundations on slurry and adding water to concrete), but some could have been communications errors coupled with poor definition of responsibilities. Ambiguity arose because it was not clear whether the worker was expected to know, without prompting by drawings or other instructions such details of modern construction as the need for weep-holes over openings, the number of under-floor vents per metre of wall length, or the need for suspended floor slabs over deep fill. These questions, related to the “knowledge expectations” of operatives, echoed comments in the interview study and such ambiguities, particularly between **primary** actions and **formal communications** were common in that study.

A suspected instance of sabotage (8.01 Friday), where a WC pan may have been deliberately broken as an act of revenge, illustrated the limitations of some views of human error (Reason 1990, Kletz 1985). Most models of the error process based on psychology and some based on engineering ignore deliberate error.

It became apparent during the study that the site manager was relatively impotent with regard to the selection of operatives. This was in line with literature (for example, Kletz 1985) suggesting that workers should, to a certain extent, be accepted “as they were”. Two particular instances illustrated this impotence. The site manager was unable to have the electricians removed from the site (8.05 Thursday) for poor business performance and a similar problem with the fencing contractors remained unresolved (9.15 Tuesday, 9.50 Friday). Obtaining adequate workers appeared to have involved continual badgering of the sub-contractors' managers rather than removal of the firms. In contrast, the site manager had some power to employ general workers and used informal contacts to try and do this. This was illustrated in the approaches to a fork-lift driver on an adjacent site (15.00 Wednesday), to whom the site manager had offered a job.

Managerial factors

Communications

Instances related to problems with formal and informal communications were common during the study. Examples included the circuitous routing of payment cheques at Company level (10.50 Monday), incorrect sizing of steel beams in schedules/drawings (16.30 Monday), incorrect levels between houses and paths (wrong drawings or a lack of drawings) (8.45 Tuesday), foundations layouts not matching superstructure layouts (11.40 Wednesday), wrong patio door sizes being left in brickwork (10.35, 12.05 Thursday) and lack of information concerning retaining walls (8.50 Friday).

Change

Change was also regularly implicated as a cause of potential and actual errors. The most prominent agents inducing change during the week were "home-makers" - the facility given to purchasers to make adaptations to their prospective purchase. In some instances, the changes led to dismantling work. For example, changed door sizes (10.35 Thursday) required dismantling of brickwork.

Checking

Checking errors were not expressly implicated during the study, but were implicit in some primary errors reported above. Rather, checking featured as instances of pre-emptive avoidance tactics. For example, the site manager used a “passing” exhortation to a ground-worker to use adequate concrete in the bases for lamp standards <u>as the work was being performed</u> (8.45 Tuesday).

Concurrency

Problems of concurrency were noted, but generally as a consequence of other failings. For example, problems related to the installation of electrical and water services caused by cost factors (10.50, 15.00, Monday, 8.45, 10.00 Tuesday, 15.30 Thursday) were leading to concurrent working.

Organisational culture

Instances related to organisational culture featured on several occasions. In meetings between site sales and construction staff (12.50 Monday, 16.00 Friday), a cultural "gap" between site and head office personnel was illustrated. A conflict of cultures was illustrated by the differing orientations of top management and construction managers over the organisation of and payment for services installations (10.50, 15.00 Monday, 9.50 Wednesday) and the re-siting of the office and show cabin (12.36 Monday). The conflict was between profitability, cash flow or survival objectives (at overall company level) and performance on site.

The link between poor organisational culture and lack of participation was indicated by such comments as the "head office only letting you know when there are problems" (12.50 Monday) and reported gaps in senior management knowledge related to the problems being experienced with the project (16.00 Friday).

The organisational culture <u>within the site</u> appeared to be influenced by the actions of the site manager and assistant manager. The distinguishing features of this culture were:-

- ***High levels of participation***

  Both site manager and assistant would carry out tasks on site, by, for example, driving the fork-lift truck (15.15 Monday),or preparing working areas (15.30 Wednesday).

- ***Approach***

  The approach of the site manager was direct and abrasive as was illustrated by his handling of the electricians (8.05 Thursday) and the fencers (9.50 Friday). The site manager appeared to have a series of "rows" with sub-contractors and subordinates (for example with the ground-worker foreman - 8.50 Friday), but was equally prepared to acknowledge good work - as with the carpentry work to plot 34 (10.22 Friday). The assistant manager adopted a more conciliatory attitude and was privately critical of an abrasive approach. The overall impression given of the culture of the site was that of task-oriented, but active and participative management[4].

Global factors

Factors of **cost**, **time** and **societal** demands were seen by site personnel as being behind many of the problems experienced with the project. This was particularly the case with the "home-maker" scheme, where the site personnel saw problems of a "tight" economic climate leading to purchasers demanding more in the way of changes, but the company failing to respond adequately (10.00 Tuesday). Similarly tight costs, driven by economic pressures, were perceived to underlie the lack of services installations (15.00 on Monday), where non-payment of the water services bill was linked to year-end cash flow requirements.

The fact that both the site and assistant site managers frequently cited the home-maker co-ordinator in connection with home-maker induced changes suggests that labelling as global factors some economic or societal demands may be misleading. Both building and site manager reported (10.00 Tuesday) the need for better management of home-maker changes if they were to be allowed. Management would be in the form of a "technically qualified design/construction co-ordinator".

[4] One way of classifying this culture might be in accordance with the "managerial grid" of Blake and Mouton (1978), where it would fit somewhere between "team management" (9.9) and "authority-obedience" (9.1).

Similar ambiguities appear in the comments of the site manager concerning the problems with services (8.01 Friday). He implicated the "commercial director and surveyors" in the non-arrival of services rather than global factors. Global factors may therefore have been used to hide other causes of errors. The above comments suggest that the site management largely considered global factors a "given", beyond the control of the organisation, but which the organisation should "rise to"

THE SYSTEMIC NATURE OF ERROR INFLUENCES

The systemic nature of error influences was evidenced in the observational study in several unrelated incidents including:-

- Home-maker changes
- Problems with the supply of services
- Problems of lighting for decorators
- Problems with wallpaper paste
- Problems with cleaners starting work
- Problem of performance of electricians
- Problem of mis-positioned gutter outlets causing drainage revisions

Systems effects related to these incidents are summarised as follows:-

1) <u>Home-maker changes</u>

(8.00, 15.45 Monday, 10.00 Tuesday, 9.40 Wednesday, 8.30, 10.35 Thursday)

The causal nature of error factors

The provision of "home-makers" showed a "chain of cause" from <u>economic influences</u> leading to slow sales, through <u>societal demands</u> (purchasers were able to "pick and choose") to <u>changes</u>, <u>concurrent working</u> and <u>primary</u> errors leading to potential defects. Actual defects were not recorded in relation to home-makers, but changes increasing the span of floor joists and moving the position of internal load-bearing walls (plots 34-36) would predispose the construction to failure.

The hidden or latent nature of some error factors

Without a detailed knowledge of the history of a particular home-maker, it would be difficult, in some cases, to look beyond the primary error to the underlying cause. This was illustrated by the problems experienced by the carpenter in cutting up the wrong floor joists for use in an altered unit (9.05 Friday). Likewise, should problems of over-spanning joists occur, it would be difficult at a later date, to trace cause back to economic influences or managerial ineptitude in handling the required changes.

2) <u>Problems with the supply of services</u>

(15.00 Monday, 10.00 Tuesday, 9.50 Wednesday, 15.30 Thursday)

Multiple causes of error

Failure to provide an electrical supply illustrated several separate causes of error. Separate causes were the conflicting organisational and performance requirements related to payment, poor communications regarding payment and changes in the position of the sub-station. At the time of the study, no active errors had materialised from the services supply and further active errors would be needed for the latent errors noted here to have an effect in terms of defects.

The causal nature of error factors

Cost and time pressures, poor communications and changes had introduced the requirement for concurrent working for both water and electrical installations, which would, in turn, increase the impact of primary errors.

3) <u>Problems of lighting for decorators (for decorating internal bathrooms)</u>

<u>(15.30 Monday)</u>

Multiple separate causes

Multiple causes were again illustrated in this example. Failure to provide a fixed electrical supply, failure to realise that the lack of windows in internal bathrooms should be communicated to the sub-contractor and tight pricing by the sub-contractor had all combined to cause a problem.

4) <u>Problems with wallpaper paste for show houses</u>.

<u>(14.00, 14.45 Tuesday)</u>

Multiple separate causes

The fact that wallpaper required a ready-mixed paste was not communicated to the decorators and the decorators claimed that they had not priced or allowed for providing the paste. Obtaining paste was invoking difficult communications as local supply was prohibited by organisational procedures.

5) <u>Problems with cleaners starting work.</u>

<u>(14.30 Tuesday)</u>

The causal nature of error factors

This attempt at pre-emptive action - to warn cleaners that power, lighting and hot water were not available for their task, again illustrated the influence of wider causes on individual performance.

6) <u>Problems of performance of electricians</u>

<u>(8.05, 10.20 Thursday, 10.00 Friday)</u>

The causal nature of error influences

The intransigence of electricians in not doing as required by the site manager and, eventually, taking suspected sabotage action was explained by the poor price that they received for second fix work. The out-turn event of damaging equipment may have been exacerbated by the abrasive attitude of the site manager - a cultural factor.

7) Problems of mis-positioned gutter outlet

(9.20 Friday)

The hidden nature of some errors

The problem of "running outlets" to gutters on a block of houses being positioned incorrectly presented itself as a primary error by a plumber. However, it is likely that this problem was exacerbated by conflicting formal communications in that site and house-type drawings often do not correspond. House-type drawings would normally show the ideal position for gutter outlets, but site drawings, showing the drainage layout may show differing positions for the associated rainwater pipes, in order to allow for site characteristics (such as the fall of the ground in relation to the houses). The plumber possibly worked from house-type drawings rather than site drawings. In this case, two errors were made, one, a formal communications error at the design coordination stage and a more obvious primary error during construction.

Multiple consequences

The consequent revisions to drainage layout caused a more shallow fall to the drains than designed leading to a greater risk of blockages. In addition, the increased run of drains increased the cost and duration of construction. This provides an illustration of the inter-relatedness of the **effects** of error.

Further examples of systems effects

Further examples were evidenced in the ambiguity of the cause of the mistake of using the wrong wallpaper in the show units, (where the wallpapers to bedrooms 1 and 2 were reversed) and the mistake of fixing an extractor point in the wrong position (9.00 Monday). In both instances, error could be attributed to poor communications, or primary error depending on the circumstances.

The contingency response of the managers in matching checking strategy to type of task was also evidence of a systems approach to the handling of error. For some checking, continuous supervision was used (9.20 Thursday), elsewhere post-construction checking was used (10.22 Friday). The task involved with the first illustration was laying tarmac, a relatively irretrievable task. The latter task was fixing of upper floor joists, a task capable of easier later correction.

Communications were also often mixed with checking. This was the case with the building managers' inspection visits to the site (10.00 Tuesday). Here, the building manager:-

- **checked** work by walking around the site with the site manager,
- **communicated** information (for example concerning the Electricity Board "Wayleave" problems),
- **planned** the re-positioning of the sales unit and work to the first phase,

- **pre-empted** problems by giving a warning concerning the disposal of "muck" on the adjoining site.

In addition to illustrating a systems effect, this instance also emphasised problems of categorisation in the model, where the manager was performing a number of functions simultaneously.

10.4 CONCLUSIONS

In addressing the **content** of the model, a numerical analysis of the diary indicated that most error related events concerned **communications**, **cost** pressures, **changes** and **primary** factors (in that order). This analysis echoed findings from the preliminary, statistical and interview studies. The numbers are, however, misleading because of ambiguity of cause, or multiple and inaccurate attributions. For example, the number of causes attributed to cost factors may be misleading, in that there were several indications during the study suggesting it was not the external factor alone that caused problems, but also an inadequate **response** from within the organisation. Thus, the need for a technical co-ordinator to handle changes in design and other factors was stressed by the site and building manager.

This study addressed the **operation** of the model (the third question in Chapter 5) by illustrating inter-related and multiple causes of error, as well as inter-related effects in terms of quality, cost and time. It also illustrated "precursor" effects related to managerial or global factors. Some "active" defects arose during the study (such as the sub-standard concrete arising from over-watering and defects noted in the Building Guarantee Company files), but latent and active components suggested by Petrosky (1994), Reason (1990) and Blockley (1992) were also evident as "incipient failures". For the latent precursors to have materialised as defects, a primary error would need to be committed (for example, in the case of lack of a water supply, a poorly jointed pipe by a plumber) and this would have to lead to a measurable defect. The reported "modulating" effect of the operative noted in the interview study was, therefore, demonstrated in this study, with the probability of several latent problems <u>never</u> materialising as consequences and thus <u>never</u> causing a defect. They did, however, increase the statistical probability of a defect occurring.

11

CONCLUSIONS

11.1 INTRODUCTION

This research project was driven by the need to reduce defects in construction, by uncovering and investigating their underlying causes. The investigation was initially concentrated on an open review of literature which progressively pointed towards the role of error in failure. Literature covering errors from a wide range of sources indicated that:-

- Errors are behind most failures in industry.
- Errors are inevitable and therefore must be managed
- Failure often involves multiple errors
- Failure often involves underlying latent errors as well as obvious active errors
- Error causes are linked systemically

Several authors offered models of error in complex systems, without systematically verifying or practically applying these. However, the desire to thoroughly follow the trail of cause behind errors which lead to defects, led to an approach which went further than simply constructing a model. A tentative model (figure 5.1) related to the occurrence of defects in construction projects was proposed based on a synthesis of the literature. Subsequent field research of both an investigative and confirmatory nature set out to examine the model as proposed, but also contemplated modifications.

Thus, feedback from the preliminary study influenced the direction of later work, adding to the sophistication of the model

The empirical research involved four stages, a preliminary survey of practitioners in the construction industry and statistical, interview and observational studies of speculative house-building. These studies addressed the proposed model as illustrated in figure 5.2 and repeated below as figure 11.1

FIGURE 11.1 (5.2) - MODEL PROPERTIES IN RELATION TO STUDIES

STUDY	Preliminary	House-building		
		Statistical	**Interview**	**Observational**
Property				
1) **Form** - the structure of the model				
2) **Content** - the importance of factors				
3) **Operation** - system effects				

The investigative methodology behind the research led to a search for corroborating evidence of causes by triangulating between the studies.

11.2 FINDINGS FROM THE STUDIES

PRELIMINARY STUDY

The preliminary study, in addressing the **form** and **content** of the model introduced four more detailed questions as follows:-

Related to form

- were the range of factors in the model comprehensive?
- was the hierarchical structure of the model (with three separate layers - **global**, **managerial** and **primary**) a valid vertical categorisation?

Related to content

- what was the relative weighting of factors in the model?
- were these factors applicable generally?

Reference to a sample of construction industry participants gave some support to both the form and content of the model, but with modifications. With respect to the form, open responses indicated that the **range** of factors was reasonably comprehensive, but factors related to systems aspects and primary characteristics at managerial level were also relevant. With respect to the **hierarchical structure** of the model, factor analysis gave some support to a division between global factors "external" to as opposed to managerial/primary factors "internal" to the project. However, this division was not exact and factor analysis also indicated a third principal component containing variables representing the primary factor "self certifying" and the managerial factor "supervising junior staff".

With respect to the content, survey responses emphasised factors <u>across</u> the model. "Communications" was the highest rated factor, followed by "time", "concurrency control", "change control" and "education and training". The emphasis on communications and managerial functions of concurrency and change control followed literature from several perspectives. There was a lack of emphasis on more remote global factors of the political, economic and social climate. General agreement on the most important factors was noted from groups of respondents drawn from the design and construction sectors of the industry.

<u>STUDIES OF HOUSE-BUILDING</u>

<u>**Statistical study**</u>

The statistical study, also addressed the **content** of the model by investigating whether there were any statistically significant links between measures of factors in the model and the performance of projects. In relation to 23 speculative house-building projects, significant associations were found between reported levels of defects and the background (p=0.019), qualifications (p=0.033) and experience (p=0.059) of the site manager. The findings indicated that qualified site managers from a managerial (as opposed to trades) background were associated with sites having a lower level of defects. Less experienced managers were also associated with sites having a lower level of defects, but less experienced managers were also better qualified (p=0.016) suggesting that qualifications rather than experience determine performance on site.

Significant associations were also found between the reported level of defects and the level of planning and programming (p=0.049), the intensity of project management generally (p=0.007) and the quality of formal communications (p=0.057). The findings indicated that more detailed planning, more intense project management and better quality formal communications were associated with sites having a lower level of defects. An association was noted between the level of perceived quality of the site and the skills of trades-people, with more highly skilled operatives being associated with better perceived quality (p=0.072)

Whilst the size of the sample suggests that these results should be treated with caution, they correspond well with the preliminary study findings in supporting the content of the model. In particular, significant links between variables representing communications, planning and project management and levels of defects supports the emphasis placed in the preliminary study and much literature on managerial factors. The lack of a significant association between global factors and performance also echoes the low ratings for some of these factors in the preliminary study.

Factors related to the primary characteristics of the site manager were included in response to indications in the preliminary study that primary factors at a managerial level might be important. The statistically significant associations between performance and the background, qualifications and experience of the site manager justify this inclusion.

Interview study

The interview study addressed the **content** and **operation** of the model by interviewing 40 participants drawn from the house-building industry including the 23 site managers involved in the statistical study, their more senior managers and personnel from two house-building guarantee insurance companies. Regarding the content of the model, numerical analysis of interviews indicated that most error incidents related to **communications**, **primary factors**, **time**, **change control**, and **checking** in that order. The emphasis on communications provides strong support for both preliminary and statistical studies, particularly in view of the different method used for this study.

Regarding the operation of the model, analysis of the interviews revealed three "pathologies" of defect causation, self contained errors, two-way interactions of errors and complex interactions. It was notable that even for simple self contained errors, there was often an underlying cause effectively **disguised** by a more obvious patent error. For two-way interactions, the interplay of errors causing a defect was expressly acknowledged. Analysis of complex interactions revealed two types of pathology. One type involved a simple error being carried through the construction sequence and compounded by subsequent errors. The other type was consciously "driven from the top" by motivations, such as profit and sales, not related to the quality of the work.

Observational study

The observational study also addressed the **content** and **operation** of the model, but focused on errors as they occurred on a single site over a short time period. Regarding the content of the model, numerical analysis of observations indicated that most errors related to **communications, cost pressures, changes** and **primary factors** in that order. Emphasis on communications replicated findings from the preliminary, statistical and interview studies.

The operation of the model was illustrated by a series of incidents which emphasised the importance of **links** between errors and other driving forces. A causal chain was evident in some incidents showing how wider global factors, or managerial errors could drive and magnify primary errors. It was shown how the underlying errors could be disguised by the operation of a later active error and incidents having multiple causes and leading to multiple consequences were illustrated.

11.3 TRIANGULATING FINDINGS

By combining studies it is possible to triangulate findings. That is, converging findings are obtained from three or more sources before firm conclusions are drawn. In relation to the three research questions posed in Chapter 6, the clearest evidence of triangulated findings was in relation to the second and third questions related to the **content** and **operation** of the model and these are considered first. Findings related to the **form** of the model are less clear cut and are considered later.

CONTENT

The clearest finding from all studies was the importance attached to **communications**. This finding was supported by opinion in the preliminary study and by analysis of incidents in the interview and observational studies. The statistical study revealed an association ($p=0.057$) between high quality formal communications and low levels of reported defects.

Apart from the importance attached to communications, opinion and analysis supported a range of factors spanning all levels of the model. Primary factors (or their equivalent expressed as "education/training", or "skills") were ranked within the top five factors in the preliminary, interview and observational studies and an association ($p=0.072$) was noted between high levels of trade skills and high perceived quality in the statistical study. The control of change was also ranked within the top five factors in the preliminary, interview and observational studies and its proxy in the form of good planning, was associated (p=0.049) with a lower level of reported defects in the statistical study. The global factor "time" was emphasised in the preliminary and interview studies and "cost" was emphasised in the observational study, but other global factors did not feature in any empirical study.

Overall, analysis of the content of the model supports the emphasis placed by the literature on managerial factors and, correspondingly, a conceptualisation that expressly acknowledges these.

OPERATION

Both the interview and observational studies illustrated **links** between factors in the model which demonstrate that the model operates as a system. Three "pathologies" of causation were identified in the interview study, involving self contained errors, two way interactions between errors and complex interactions. Underlying errors disguised by subsequent primary errors were illustrated as well as outcomes involving multiple errors, or multiple consequences.

The findings from these two studies are supported by the literature (including Turner 1978, Reason 1991, Blockley 1992, Fortune and Peters 1995) which emphasises the "systems" and "socio-technical" aspects of error causation. Demonstrating **linkages** between errors justifies the contention in the literature that systems have to be treated as a whole in examining error causation and proposing remedial action in avoiding future errors.

FORM

Support for the division of the model into categories was evidenced in the preliminary study, where the **range** of factors was seen to be comprehensive. However, the categorisation was subject to two criticisms. Firstly some respondents in the preliminary study did stress factors (related to systems aspects and primary factors at managerial level) which were not expressly included in the model. Secondly, the observational study illustrated that several categories were "permeable" and not easily distinguished. Thus, there appeared a distinction, but no clear dividing line, between communications, checking and planning work.

Some support for the **hierarchical structure** of the model was evidenced in the preliminary study factor analysis. However, only two clear principal components were revealed - those "internal" and those "external" to the project. A third minor principal component based on variables representing factors of "self certifying" and "supervising junior staff" was also identified.

Some results from the statistical study also challenge the hierarchical distinction between primary and managerial factors in the model. In the statistical study, measures related to the primary qualities of the site manager were included and were found to be associated (p=0.019, p=0.033, p=0.059) with levels of reported defects. This set of associations suggests that there should not be a distinction between primary and managerial factors. Primary factors are important at a managerial as well as operative level and, perhaps the distinction should be based on individual roles and specialisms in project organisations. The evidence for an alternative based on roles can be summarised as follows:-

- Preliminary study indications in the "supply" question that primary factors (leadership, motivation), but at a managerial level are important in avoiding errors.
- Preliminary study indications in the factor analysis, where managerial and primary components were not clearly distinguished by separate principal components.
- Statistical study associations between primary factors (including the background, qualifications and experience of the site manager) and performance in relation to defects.

11.4 A REFINED MODEL

The research related to the form of the model indicates that a conceptualisation that categorises on the basis of a distinction between primary and managerial errors is not tenable. However, the distinction between **active** and **latent** errors widely made in the literature (Petroski 1985, Reason 1990, Blockley 1992) is supported by empirical research in the interview and observational study. Examining the **linkages** between causes in these studies has shown that some errors clearly predispose systems to failure, without directly causing the failure themselves. Other errors, usually made at the work-face, are necessary before an unwanted outcome will result. Thus, a division based on a split between **active** and **latent** errors can be maintained. As active errors are usually committed by operatives and as this research has shown that the individual characteristics of the manager are salient in performance in relation to defects, an alternative model might distinguish between the roles of those directly involved in performing physical work and the roles of the supporting managerial cast. "Primary" errors thus become "operative" errors and "managerial" errors thus become "manager" errors.

Apart from this re-conceptualisation, the strong emphasis placed in the literature and in all of the empirical studies on **communications** indicates that this factor should be given greater prominence and presented throughout the model. A distinction can be made between "operative" tasks and "management" tasks, but all are involved in communication and this should be more accurately illustrated. An illustration of a refined model based on the alternative conceptualisation is proposed below:-

FIGURE 11.2 - REFINED MODEL OF THE NATURE OF ERROR IN PROJECTS

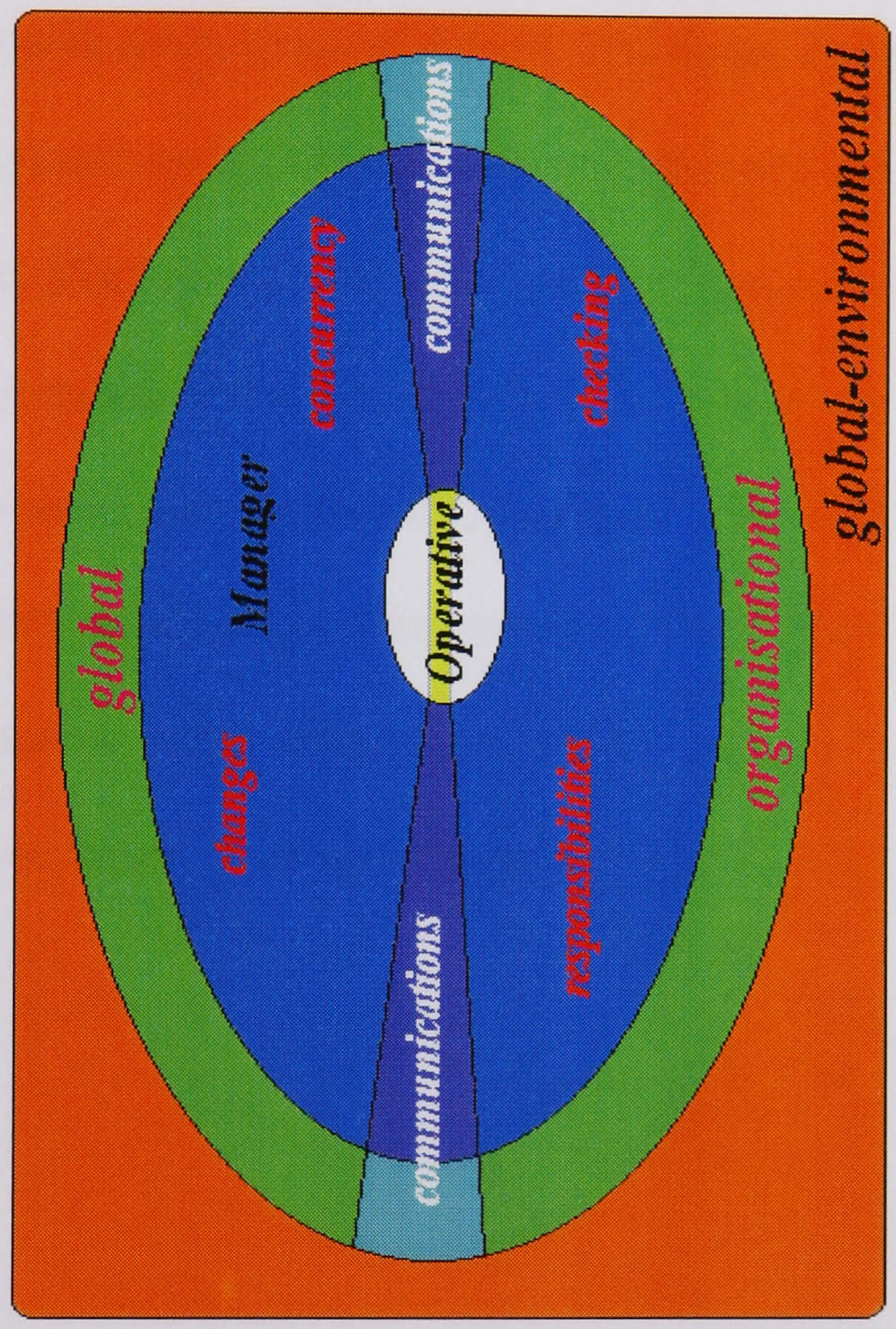
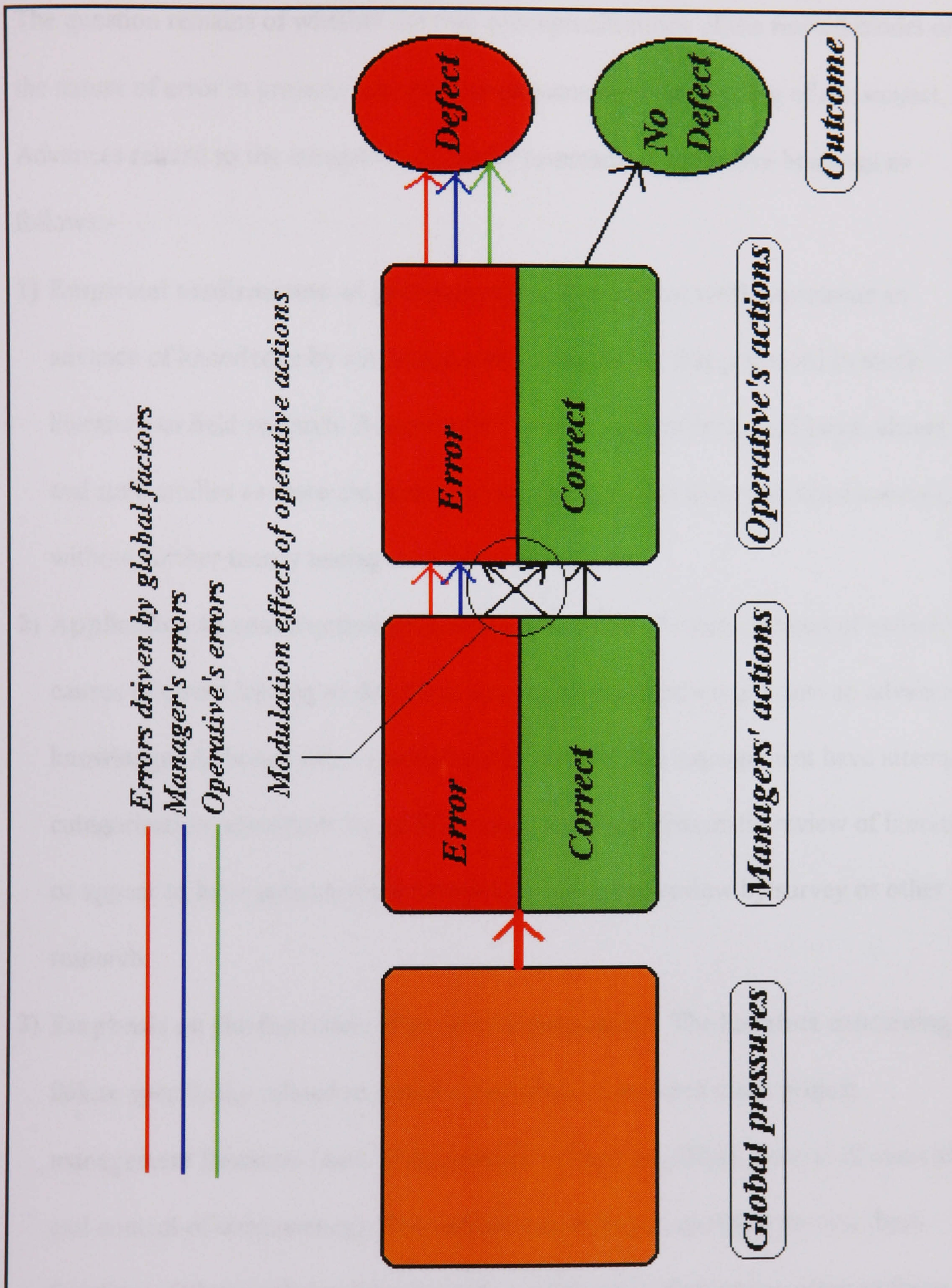


Figure 11.2 cannot easily illustrate the operation of the model. The interview and observational studies illustrated the importance of links between categories of errors and a second conceptualisation of the model, shown in figure 11.3, illustrates how errors have been seen in this research to develop into actual or potential defects. Often driven by global pressures, unrelated to the project, managerial errors either combine with or supplement operative errors to cause defects. The figure shows how errors by managers may be "modulated" by the actions of the operative and the unwanted outcome may be avoided. The figure also shows that errors can arise at all levels of the model. The green line represents simple errors with the operative as the first and final cause. The blue line represents management errors, which could be followed by the operative to cause a defect, or which could be corrected by the operative. The red line represents wider global forces, which drive management errors and thence lead to operative errors. For these forces, there are two modulators, the manager and the operative.

FIGURE 11.3 - THE PATHOLOGY OF ERROR IN PROJECTS



11.5 ADVANCES IN KNOWLEDGE

The question remains of whether the two conceptualisations of the refined model of the nature of error in projects represent an advance in understanding of the subject. Advances related to the current work can be summarised under five headings as follows:-

1) **Empirical confirmation of previous work.** The current work represents an advance of knowledge by subjecting a model similar to that proposed in much literature to field research. Research into models of error is, by and large, absent and such studies as there are primarily involve induction from published sources, without further theory testing.

2) **Application to construction projects**. The method of categorisation of underlying causes of errors leading to defects in construction projects represents an advance of knowledge. Although other researchers in construction management have attempted categorisation, none have based their categories on a systematic review of literature or appear to have presented the detailed categories to review by survey or other research.

3) **Emphasis on the functions of project management**. The literature concerning failure specifically related to construction projects indicted many project management functions (such as the division of responsibilities, control of changes and control of concurrency). The current research systematically models these functions. Other work has been limited to either extracting one or other of these functions in isolation or broadly indicting management as a whole.

4) **Consideration of systems effects.** The model proposed from the current research represents an advance on similar conceptualisations of errors in that the systems effects of the model were expressly addressed. The interview and observational studies expressly considered the linkages between error causes, showing that errors can be modulated by the actions of others.

5) **Methodological advances**. The investigative method used for this research represents a methodology which is supported by recognised social science research (Rose 1982, Gill and Johnson 1997) and can form a pattern for future work in applied social science. The methodology involves six steps:-

- Wide literature review
- Formation of propositions
- Preliminary verification
- Search for corroboration/refutation
- Further studies to support corroboration
- Comparison of studies and triangulation.

11.6 REFLECTION

WITHIN APPLIED RESEARCH

Generally

The argument for an applied research approach, set out in Chapter 6, is based on the need to provide practical solutions to applied problems. The outcome is expected to be in the form of immediately applicable innovations, or in the form of guides to policy, which in turn inform practical decisions. In terms of an applied research approach, therefore, it can be seen that the conclusions from this research represent an intermediate step.

However, the research does provide the basis for guidance. For example, a possible development from the work could be a guide to managing project work, which would concentrate on covering the key conclusions of the current work. Whether the guide produced acceptable and effective improvements in performance in relation to defects would form the basis of further research. The current work serves to give some confidence that the development of such a guide would be based on research rather than conjecture.

On the methods used

The overall approach of all four empirical studies was to develop and test the propositions represented in the model illustrated in figure 5.1 by using an investigative methodology. This involved an iterative pattern of sequential studies, which fed back into the model and led to modifications. An aim of the investigation, in line with a practical applied research methodology was a generalisable model having applicability over as wide a sample as was practically possible in a PhD study. All four studies were subject to limitations which affected the extent of generalisation possible, the internal validity and reliability of the findings. The main reflections associated with each study are summarised as follows:-

1) **Preliminary study**.

The preliminary study sought to survey a fairly wide sample of the construction industry. However, it concentrated on managers and professionals and largely ignored the views of operatives. The method of sampling was not random, but limited geographically and to organisations related to a student population. Generalisation of the results from this study is, therefore, limited. Construct validity was affected by treating categories of the causes of errors as synonymous with categories of error avoidance measures. This could have affected ratings and rankings of causes. The study was not piloted, thus, within itself, the study was not checked for reliability. The questionnaire presented respondents with a pre-decided menu (a closed question questionnaire), which directed them to responses contained within the instrument. This was partially redressed by providing an open question, but the presentation of the questionnaire would nevertheless have restricted the range of responses.

An underlying problem with the preliminary study, as it was carried out, was that it was attempting to achieve two objectives, which partially conflicted. Firstly, an element of theory testing (in the form of a preliminary confirmation of the model) was sought. Thus, the pre-decided format of the questionnaire represented deductively derived theory, which was to be subjected to testing. Secondly, novel causes of errors were being canvassed. This inductive element of the research was under-represented in that only one question was relevant to it. On reflection, it might have been an improvement to defer testing propositions at the preliminary stage and instead to concentrate on inductive methods. A more open-ended investigation of the causes of error (perhaps by using focus groups, open interviews or unstructured questionnaires) could have been used before closing on a fairly defined model.

2) **Statistical study**

The limitations of the statistical study are documented in detail in Chapter 8, but to summarise, difficulties existed in particular in the form of the small sample size, difficulty in operationalising variables and problems of intervening variables with this type of research. The use of speculative house-builders as the focus of the research and the concentration on the larger amongst these limited the generalisability of findings. Much data was relayed by the key manager for the respective projects and collection of data was also carried out by a single researcher. This could have given rise to the problem of "selective induction" reported by Schofield (1993), where the results are influenced by the expectations of the researcher. Problems of selective induction could have been reduced by using more than one researcher, or using external checks. Problems of construct validity in operationalising variables and in ensuring that measures were reliable could have been reduced by piloting the study.

3) **Interview study**

Three broad criticisms can be levelled at the interview study. Firstly, the problem of selective induction mentioned above also applies to this study. Secondly, the data could have been affected by the biases of the interviewee and causes, especially where involving errors by the interviewee, might not be accurately reported. Thirdly, data was very local and generalisation was not possible beyond the experience of the interviewees. However, direct face-to-face questioning did allow the detailed pathology of error occurrence to be followed and this was instrumental in revealing the links between errors at different levels of project organisations.

One criticism of the application of applied propositional research objectives to the interview method was that it under-used the potential of the method. This was apparent when the interviewees expounded on the nature of their occupation and how they handled the occurrence of errors. They were able to give considerable detail of the day-to-day working of their organisations, which was relevant to error research generally, but did not fit the causal objectives of the research. This problem of "throwing information away" because of prior theory construction is recognised by Gill and Johnson (1997 page 131).

On reflection, the interview study was very valuable in revealing the **pathology** of errors in the form of the links between causes. It would also have been an effective form of early inductive research, perhaps in place of the broader preliminary study, where it would have allowed a less constrained collection of causes of errors than the pre-determined questionnaire used. An effective use of interview research would also be at the implementation phase of any practical intervention proposed from the current research. Implementing change in organisations is affected by local considerations and understanding the detailed attitudes of participants are important in ensuring that propositions accurately reflect their needs (Checkland 1981).

4) **Observational study**

The observational study involved the researcher following the construction of a housing site for a short period of time. Three main criticisms can be levelled at this study. Firstly, the period of one week was too short and on reflection a longer period would have been worthwhile. The time-scale chosen was largely dictated by the time available to the researcher and offered by the company concerned. It was sufficient to allow the pathology of a number of instances of errors leading to potential defects to be recorded, but a further period would have allowed the path of the errors to be followed to their outcome. Secondly, the information obtained from the study was local and not generalisable beyond the site studied. A third, more technical criticism was that the recording of data was carried out by a single researcher without checks in the form of using separate assessors.

In common with the interview study, the observational study gave rise to a large amount of descriptive information concerning how the project was being carried out. Some of this information was recorded as background illustrative material in Chapter 10, but, as with the interview study, the objectives of the research did not always coincide with the data offered and there was a feeling that some was wasted.

Summary of reservations

Following Gill and Johnson's (1997) terminology for research evaluation criteria, the reservations of and possible improvements for each study are summarised in table 11.1. Gill and Johnson divide generalisability into two evaluation criteria, population and ecological validity. Population validity considers the extent to which findings can be generalised from the sample of people involved in the research to a wider, but defined population. Ecological validity considers the extent to which it is possible to generalise beyond the wider population, or the extent to which findings are typical of other contexts. The distinction between these two concepts is further discussed under the heading "generalisation" below.

The combination of methods

Whilst table 11.1 shows that all methods used are subject to some criticisms, the combination of methods, where conclusions point in the same direction, mitigates criticisms of individual studies. Returning to the detective analogy, corroboration arising from different sources, using different methodologies should give greater confidence in the reliability of individual conclusions.

Concerning the choice of methods a greater use of observational and interview methods might have allowed a greater understanding of the subject matter of the research, particularly in the earlier stages, where constructs were defined. However, a combination of methods would still have been valuable, as this would allow the methodological triangulation advocated by Winch (1990), Miller and Crabtree (1998) and Robson (1993).

TABLE 11.1 FIELD RESEARCH - RESERVATIONS AND IMPROVEMENTS (Evaluation criteria - Gill and Johnson 1997)

Study	Reservations	Improvements
PRELIMINARY		
Ecological validity	Early closure on pre-decided constructs	More inductivist methods at early stage of study
Population validity	Sampling reservations • Managerial bias • Geographical • Associated with students	More careful sampling or acceptance of limitations.
Internal validity	Causes and avoidance of errors treated as the same	Tests for differences between causes and avoidance measures. Focus on causes only.
Reliability	No pilot or duplication of study	Pilot, replication or triangulation
STATISTICAL		
Ecological validity	Affected by closure on pre-decided constructs in previous study	Open question or more inductivist approach earlier
Population validity	Sampling reservations • Size of sample • Geographical • Size of organisation • Type of organisation	Use larger sample and more careful sampling or acceptance of limitations.
Internal validity	Operationalisation of constructs and some proxies, intervening variables, measures for defects	More detailed review of earlier studies, closer control of variables, use of complementary approaches (triangulation)
Reliability	No pilot, use of single researcher, use of key manager to relay data.	Pilot, replication or triangulation. Multiple raters, direct observation.
INTERVIEW		
Ecological validity	Depends on accounts of interviewees, but relatively good.	Use other external checks on accounts, for example, observation study.
Population validity	Limited to accounts of interviewees - no attempt at sampling.	Accept limitations, use theoretical saturation (Glaser and Strauss 1990) or triangulation.
Internal validity	Pre-closure could lead to selective induction.	Combine with other methods by triangulation.
Reliability	Use of single researcher	Multiple researchers, replication or triangulation.
OBSERVATIONAL		
Ecological validity	Not problematic, but time period too short	Longer study

Population validity	Limited to one situation	Accept limitations, use triangulation.
Internal validity	Pre-closure could lead to selective induction.	Combine with other methods by triangulation.
Reliability	Use of single researcher	Multiple researchers, replication or triangulation.

Generalisation

The distinction made by Gill and Johnson (1997) between ecological and population validity touches on the problem of induction, first identified by Hume in the eighteenth century. Popper (1959) describes the problem of induction as an inability to generalise from a finite population to an infinite. In the observational study, conclusions induced from the study are only applicable to that study and there is no logical basis for assuming that results would be applicable elsewhere. In the interview study, conclusions can only be applied to the population actually interviewed. In the statistical study, conclusions can be applied to the 23 housing projects studied, but the ability to generalise to other projects, even of a similar type, is limited. In the preliminary study, the method of sampling, geographical restrictions and the method of organising returns limited findings to the sample itself with limited possibility of generalisation beyond. It is likely that most research in construction management is faced with such limitations on generalisability and all research faces the problem of induction (Hammersley 1992).

The problem of induction led Popper to propose falsifiability, where no positive finding can be taken to conclusively prove scientific knowledge (Popper 1959). However, Popper did recognise that findings can achieve the status of provisional validity by a process of <u>verisimilitude</u>. Verisimilitude is a concept common to both positivist and interpretivist research (see Chapter 6) and is achieved when results repeatedly confirm expectations. As a relatively novel piece of work, the findings of the current research cannot claim verisimilitude. However, the combination of these findings and further work could start the process of verification leading to a measure of provisional validity. The <u>replication</u> methodology proposed by Yin (1993) for case study research is a form of verification that appears to rely on verisimilitude and, therefore, further studies in a similar area giving similar results are of value. Further studies are suggested below, partly in order to follow the replication methodology suggested by Yin.

<u>ALTERNATIVE METHODOLOGIES</u>

Two alternative methodologies that could have been considered in the current research are a more positivistic approach based on the natural sciences and an interpretivist methodology.

It is submitted that the reductionism implicit in a strictly positivistic methodology is not suitable for complicated problems involving multiple variables and interlinked systems. It may have been possible to isolate one cause of defects and carry out a closely controlled experiment and this approach could be valuable for further detailed research which follows one aspect of the findings. However, the current research has suggested that the <u>links</u> between error causes are important and this fact would have been lost in a reductionist positivisitic piece of research.

The desire to concentrate on <u>cause</u> in the current research means that an interpretivist approach is not likely to be applicable either. This is well recognised in the interpretivist literature (for example see Rooke et al 1997 and Guba and Lincoln 1998). The desire, whether arising from a philosophical or methodological standpoint, to concentrate on situated understanding means that knowledge of a generally applicable nature of value beyond the research setting cannot be generated. However, interpretivist approaches are appropriate complementary methodologies in two areas. Firstly, a greater use could have been made of them in the early inductivist phases of the current research (see above). Secondly, interpretivist approaches would be valuable in implementing changes proposed as a result of further work.

11.7 FURTHER RESEARCH

Three areas of study are suggested by the findings from this research. Firstly, the research concludes by proposing refined models of the nature of errors in projects. This model should be carried forward to some implementable solution (perhaps in the form of a guide to practice). In combination with implementation, further studies should be carried out on the effectiveness of the model as represented by the guide.

Secondly, and notwithstanding the desirability of considering the model as a complete system, **communications** should be separately investigated. It appeared as an important factor in all studies and was also regularly indicted in the literature. Patterns of communications and the reasons for communications failures would repay further study, updating the work by the Tavistock Institute (1966), but in the context of human error. The method of investigation, possibly best suiting this type of study, would be by using more detailed observational studies.

Finally, the importance of primary factors, but at a managerial level, indicated by the statistical study, suggest that the primary characteristics of managers should be further investigated. Of particular interest in this respect would be the interaction of <u>qualifications</u> with <u>experience</u>, two factors linked to project performance, but in a surprising way. Better performance in relation to errors was noted with better qualifications, but also with <u>less</u> experience. A more detailed statistical study could specifically target the education and formal training of the site manager, its affect on both experienced and inexperienced managers and performance within the industry.

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APPENDICES

THE ERROR BASIS OF DEFECTS

ANDREW R ATKINSON

QUESTIONNAIRE

ASSURANCES

The information provided in this questionnaire will be treated in the strictest confidence and not divulged to any other party. Unless you specifically note in the space below, neither your name or the name of your organisation will be used in any report, published or unpublished. If you wish to review any answers at a later date or discuss the completion of the questionnaire, you are invited to contact me, Andy Atkinson at South Bank University, Wandsworth Road, London, SW8 2JZ, telephone 0171 815 7253.

Additionally, general queries concerning this research programme can be directed to Professor Victor Torrence, the London Master Builders Professor of Building at University College, London, Wates House, 22 Gordon Street, London WC1, telephone 0171 387 7050.

ACKNOWLEDGEMENT

CIRCLE AS APPROPRIATE

May I acknowledge your contribution to the research and use your name in a published report?	YES	NO
May I acknowledge your organisation's contribution to the research and use its name in a published report?	YES	NO
Would you like to receive a summary of the findings from the research?	YES	NO

GENERAL INFORMATION ABOUT YOU AND YOUR ORGANISATION

Your name

Your position in the organisation

Name and address of your organisation

Telephone number of your organisation

ROLE OF YOUR ORGANISATION

For example:-

Client
Consultant building surveyor, architect, structural engineer, services engineer, quantity surveyor.
Main , management or design and build contractor, construction manager.
Subcontractor.
Other role (for example valuers, facilities managers, etc)

YOUR EXPERIENCE

In the construction industry generally YEARS

In your current role YEARS

SUPERVISORY EXPERIENCE

Do you supervise staff within your organisation YES NO

ERROR QUESTIONS

The following have been put forward as methods of avoiding errors leading to defects in projects. Using your knowledge and experience drawn from your occupation, rate the effectiveness of these error avoiding measures on a scale of five. Treat (1) as the lowest score (ineffective) and (5) as the highest score (very effective). Intermediate scores indicate that a measure is partially effective.

After you have rated the above factors, rank the five most important factors in ascending order in the space provided (i.e. give rank (1) to the most important factor and the rank (2) to the next most important factor and so on.

	Errors leading to defects can be avoided by:	RANK	
1	Improving the education and training of individuals		1 2 3 4 5
2	Being careful in the selection of individuals		1 2 3 4 5
3	Making individuals sign off work to certify that they have checked their own work		1 2 3 4 5
4	Independently checking all work which might lead to defects		1 2 3 4 5
5	Supervising the work of junior staff		1 2 3 4 5
6	Clearly defining work responsibilities		1 2 3 4 5
7	Controlling changes properly (e.g. variations)		1 2 3 4 5
8	Completing tasks fully before releasing work (e.g. not starting construction until relevant drawings are complete)		1 2 3 4 5
9	Using clear communications (e.g. clear drawings, specifications and bills of quantities).		1 2 3 4 5

10	Having a positive "culture" in the organisation (i.e. partners, directors,managers or colleagues who keep in touch with the details of work and take a keen interest in producing a good job)	☐	1 2 3 4 5
11	Having an economic climate that ensures an adequate return for work	☐	1 2 3 4 5
12	Having adequate time to carry out work	☐	1 2 3 4 5
13	Having a steady political climate within which to operate	☐	1 2 3 4 5
14	Having clients with reasonable expectations with regard to quality of work	☐	1 2 3 4 5
15	Are there any other factors that you feel are important in avoiding errors that can cause defects? If so, list them below and rate them from five.		
	....	☐	1 2 3 4 5
	....	☐	1 2 3 4 5
	....	☐	1 2 3 4 5

Finally, if you are interested in this research and would be prepared to complete a further questionnaire or be interviewed as a follow up please tick the boxes

I am prepared to complete a further questionnaire YES NO

I am prepared to be interviewed YES NO

Thank you for your help in this research. if you have indicated that you would like a summary of the findings, I will contact you when the main study is complete.

Andy Atkinson

PRELIMINARY STUDY QUESTIONNAIRE - OBJECTIVES

ACKNOWLEDGEMENTS

To confirm lack of confidentiality or otherwise. To engender support by offering feedback on the research

GENERAL INFORMATION ABOUT YOU AND YOUR ORGANISATION

General information for possible follow up. Roles are required to see if there are any differences in response between respondents from different sections of the industry. They are also needed to show that the sample is balanced in the industry.

Experience questions are to monitor the "authority" of the replies.

ERROR QUESTIONS

Questions 1 - 14 map on to the preliminary model of the nature of error in a project context.

Question 15 seeks to extend the model to include other factors identified by the respondents

Differences in response between sections of the industry are not expected, but the replies will examine for these. However, it is possible that there will be a difference between the <u>perceived importance</u> of some factors, as expressed in scores to certain measures in this survey and the <u>observed importance</u> of these factors in the house-building study. This difference could give an insight to the reasons for the recurrence of some errors leading to defects and accidents.

30 January 1995

Dear Student,

THE ERROR BASIS OF DEFECTS - A RESEARCH PROJECT BY ANDY ATKINSON

Further to my request for help with my research into the error basis of defects, I enclose four copies of a questionnaire. If you can help, perhaps you could distribute the copies among your work colleagues and supervisors. I am interested in a good spread of responses from <u>senior</u> as well as junior staff and from a variety of specialists (including architecture, building surveying, quantity surveying, engineering, contracts management, tradespeople etc). You can also fill in one if you wish!

I have included a stamped addressed envelope for the return of the questionnaires. Perhaps I could ask you to collate the returns and send them to me (If you wish you can give them to me by hand). To try and avoid confusions in filling in the questionnaires, I have included a sample completed one. This has been filled in "at random" and does not represent any view - correct or otherwise. If anyone has difficulty with filling in the questionnaire they can refer to the sample or phone me on 071 815 7253.

Finally, I would stress that you are under no obligation to help with the survey. I am not keeping records of who returns the questionnaires and I do not need names or addresses of individuals as part of the research. They are, however, useful in showing that the research is bona fide and that I have not cooked the returns! Additionally, I may remind you "as a group" to return questionnaires if you can.

Thank you in advance for your help,

Yours sincerely,

A.R. ATKINSON

encls

APPENDIX 7c
PRELIMINARY STUDY CORRELATION SCATTERGRAMS
ROLES AND SUPERVISORY POSITIONS

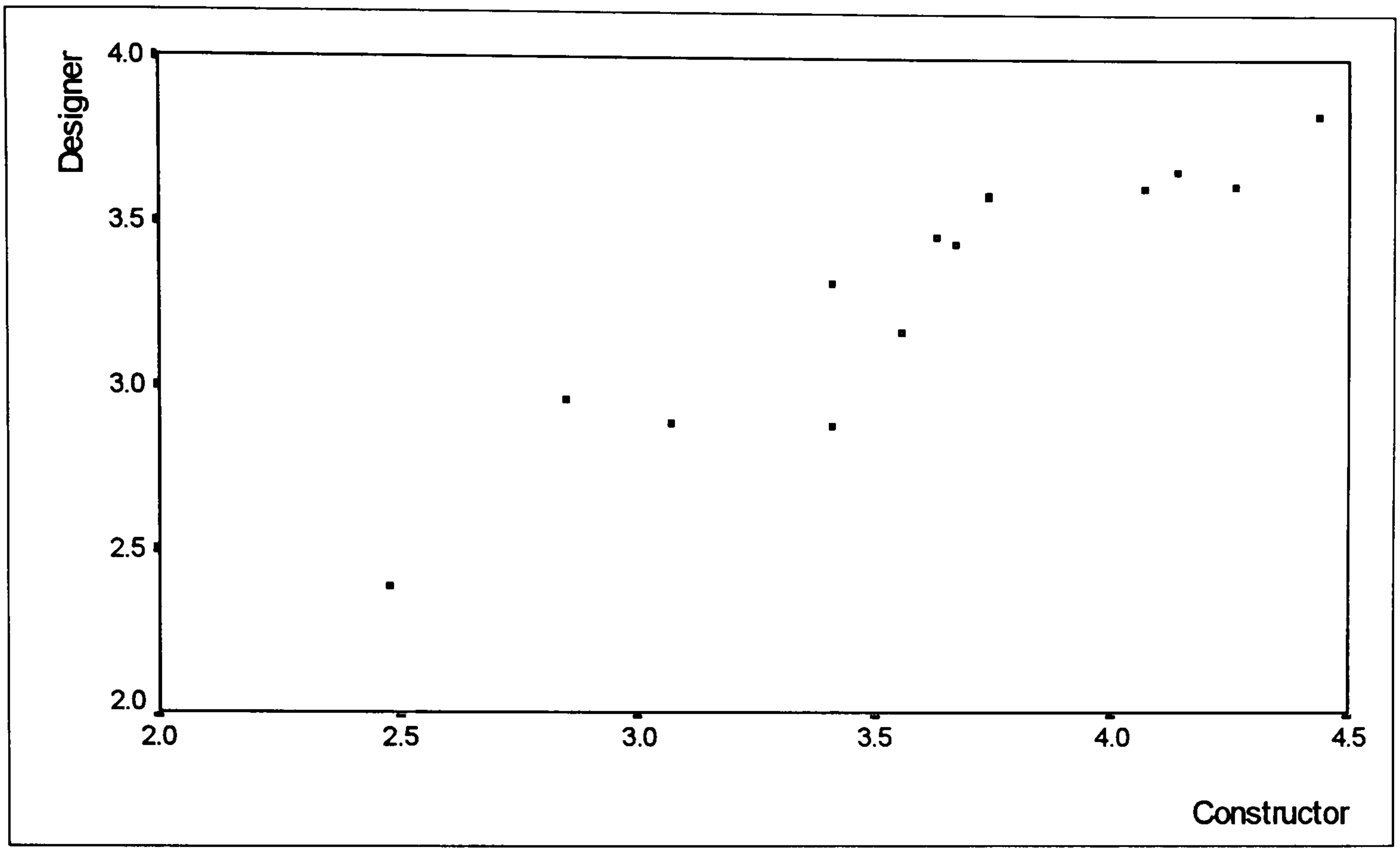


Figure 1 Designer/Constructor correlation

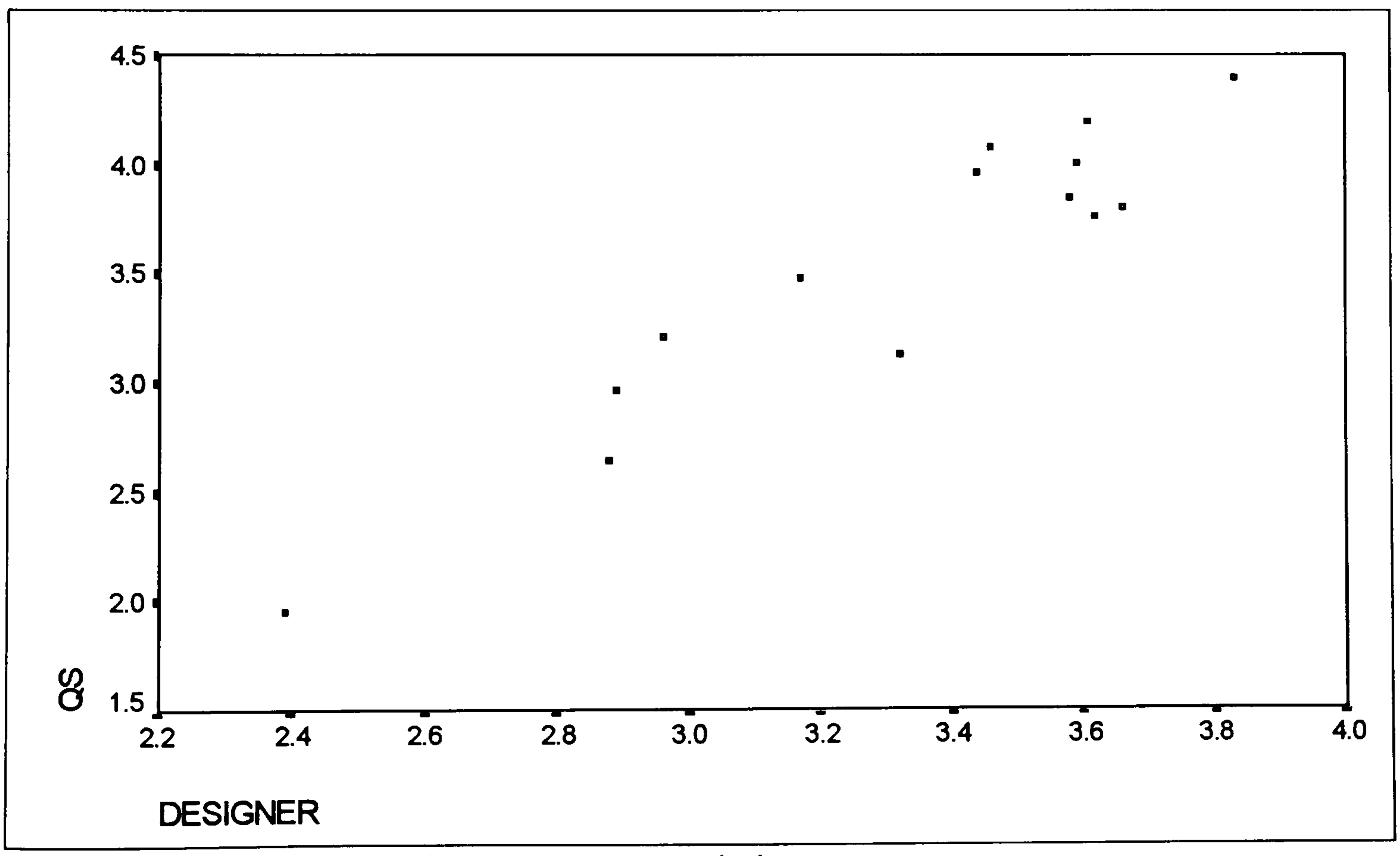


Figure 2 - Designer/Quantity Surveyor correlation

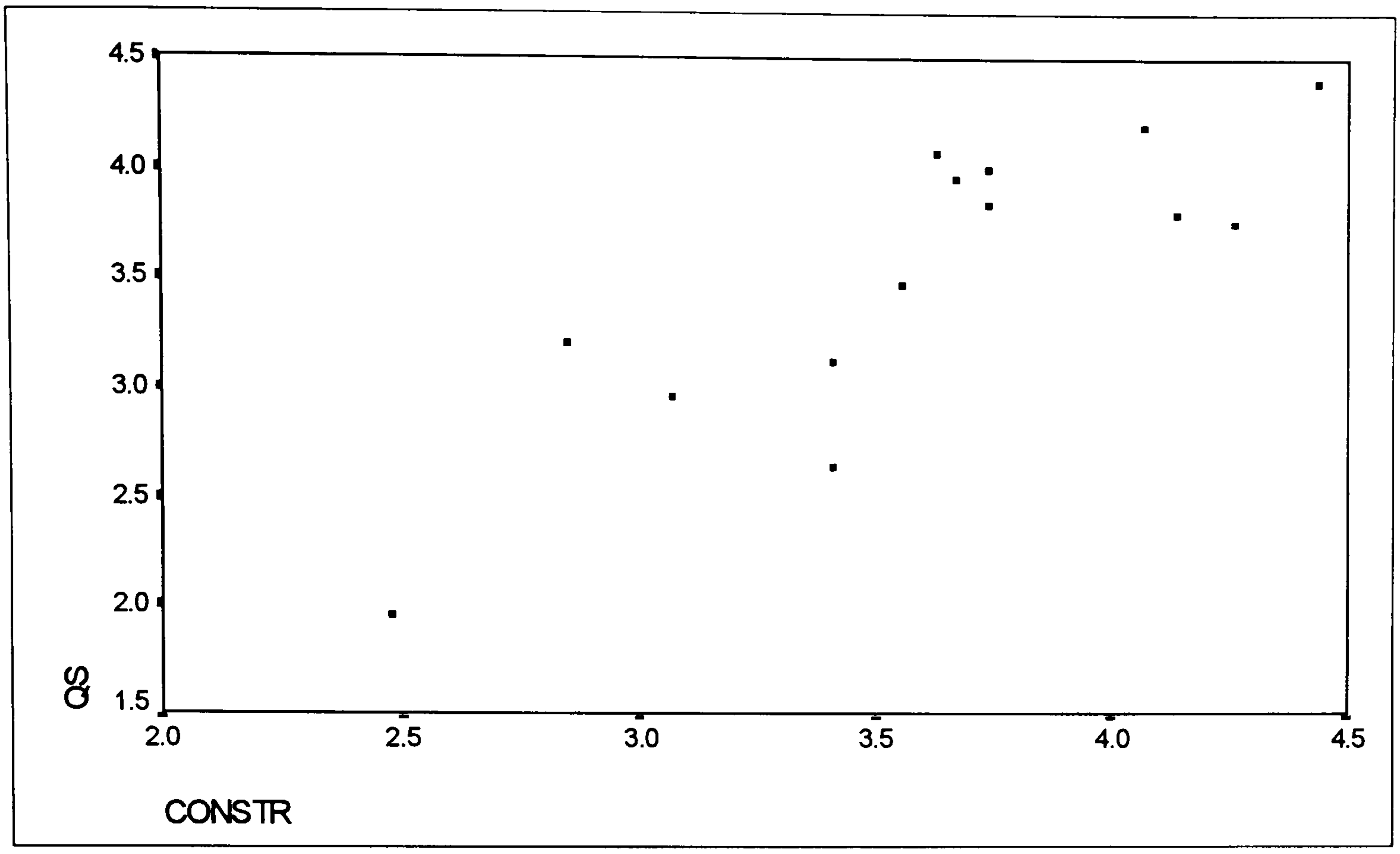


Figure 3 - Constructor/Quantity Surveyor correlation

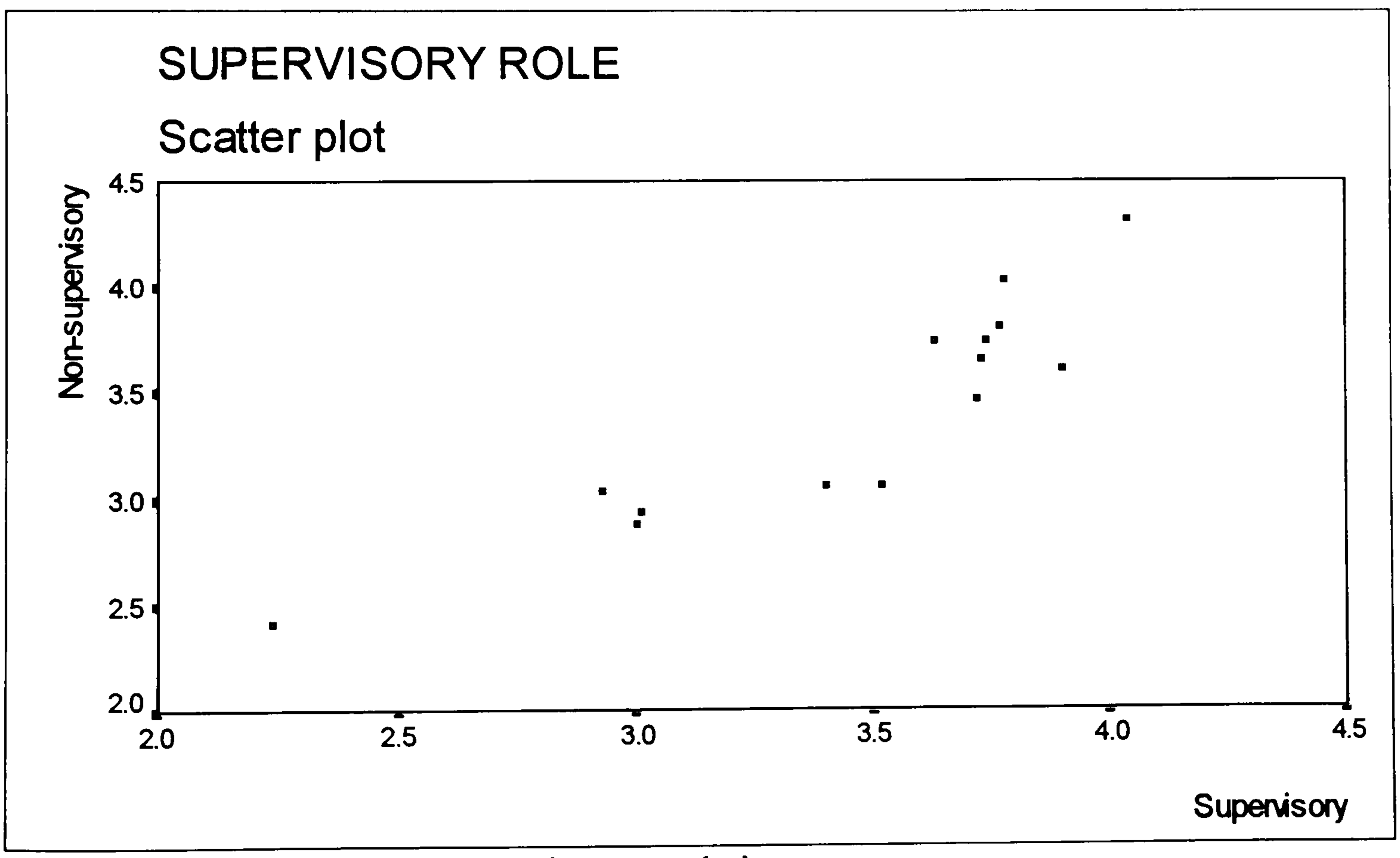
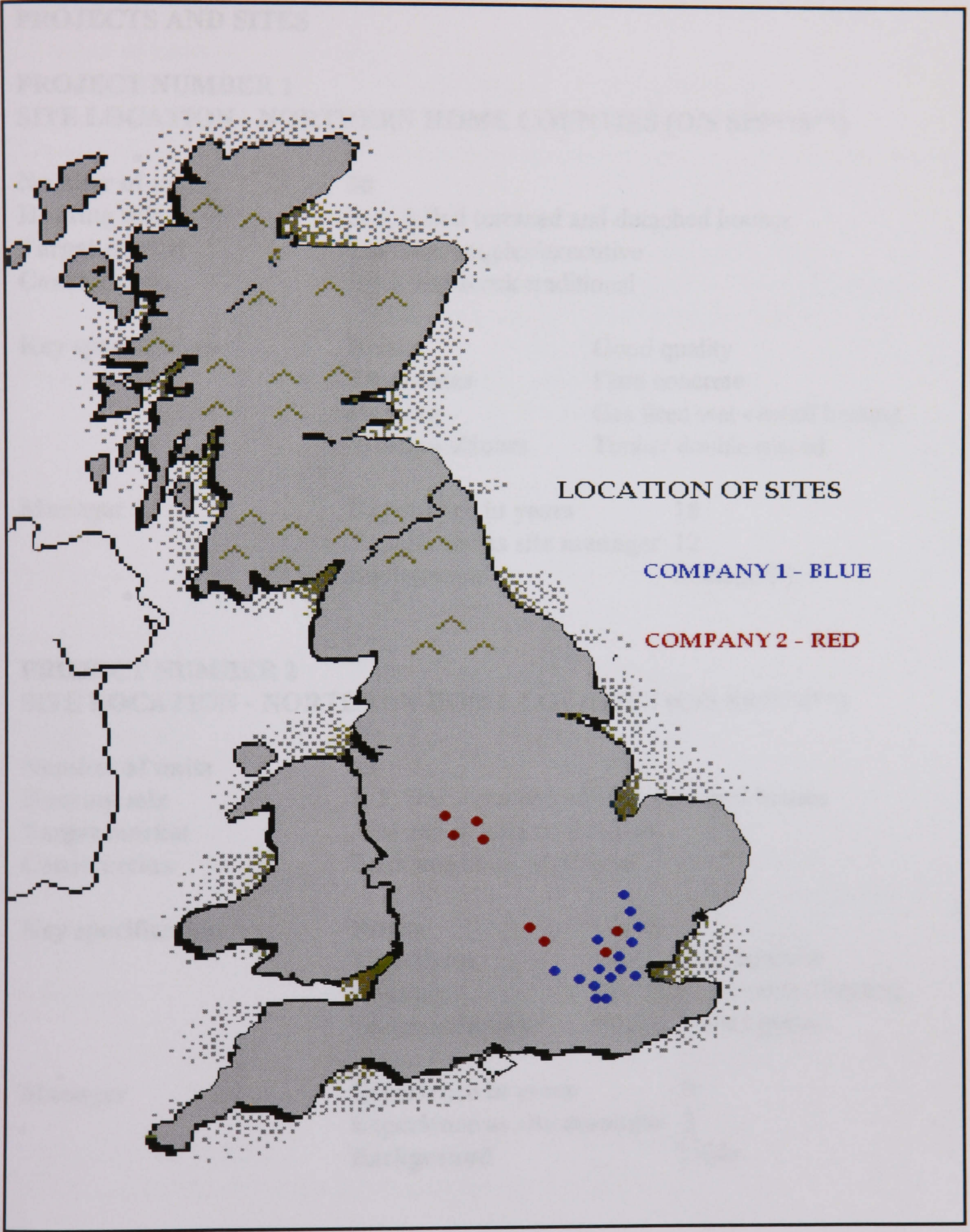


Figure 4 - Supervisor/Non-supervisor correlation

APPENDIX 8a
LOCATION OF SITES



APPENDIX 8b

PROJECTS AND SITES

PROJECT NUMBER 1
SITE LOCATION - NORTHERN HOME COUNTIES (O/S SP93**)**

Number of units	**38**	
Housing mix	2, 3, 4 Bed terraced and detached houses	
Target market	Childless couples/executive	
Construction	Brick and block traditional	
Key specification	**Bricks**	Good quality
	Tiles/slates	Plain concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed
Manager	**Experience in years**	18
	Experience as site manager	12
	Background	Managerial

PROJECT NUMBER 2
SITE LOCATION - NORTHERN HOME COUNTIES (O/S SP94**)**

Number of units	70	
Housing mix	2, 3, Bed terraced and semi-detached houses	
Target market	First and second time buyers	
Construction	Brick and block traditional	
Key specification	**Bricks**	Cheap
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed
Manager	**Experience in years**	9
	Experience as site manager	2
	Background	Trade

PROJECT NUMBER 3
SITE LOCATION - NORTH LONDON (O/S TQ29**)**

Number of units	**26**
Housing mix	25 X 2 Bed flats, 1 x 3 Bed penthouse
Target market	Luxury market
Construction	Block rendered traditional with pre-cast concrete floors

Key specification	**Bricks**	Cheap
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber triple glazed
Manager	**Experience in years**	14
	Experience as site manager	10
	Background	Managerial

PROJECT NUMBER 4
SITE LOCATION - NORTH-EASTERN HOME COUNTIES (O/S TL41**)**

Number of units	**102**
Housing mix	Terraced, semi-detached and detached houses, low rise flats
Target market	Mixed first/second time buyers
Construction	Brick and block traditional

Key specification	**Bricks**	Cheap
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed
Manager	**Experience in years**	18
	Experience as site manager	15
	Background	Managerial

PROJECT NUMBER 5
SITE LOCATION - WEST MIDLANDS (O/S SJ93**)**

Number of units	**42**
Housing mix	3 and 4 bedroom detached houses
Target market	Second/third time buyers
Construction	Brick and block traditional

Key specification	**Bricks**	Medium quality
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed

Manager	**Experience in years**	12
	Experience as site manager	3
	Background	Managerial

PROJECT NUMBER 6
SITE LOCATION - WEST MIDLANDS (O/S SK11**)**

Number of units	**36**
Housing mix	3, 4 and 5 bedroom detached houses
Target market	Second/third time and executive buyers
Construction	Brick and block traditional

Key specification	**Bricks**	Medium quality
	Tiles/slates	Interlocking concrete mainly
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed

Manager	**Experience in years**	26
	Experience as site manager	20
	Background	Managerial

PROJECT NUMBER 7
SITE LOCATION - WEST MIDLANDS (O/S SK11**)**

Number of units	**24**
Housing mix	3 and 4 bedroom detached houses
Target market	Second/third time and executive buyers
Construction	Brick and block traditional

Key specification	**Bricks**	Medium quality
	Tiles/slates	Interlocking concrete mainly
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed

Manager	**Experience in years**	30
	Experience as site manager	15
	Background	Trades

PROJECT NUMBER 8
SITE LOCATION - WEST MIDLANDS (O/S SK21**)**

Number of units	**22**	
Housing mix	2, 3 and 4 bedroom terraced and detached houses	
Target market	Second/third time and executive buyers	
Construction	Brick and block traditional	
Key specification	**Bricks**	Good
	Tiles/slates	Plain concrete
	Heating	Gas fired wet central
heating/electric		
	Windows/doors	Timber double glazed
Manager	**Experience in years**	30
	Experience as site manager	15
	Background	Trades

PROJECT NUMBER 9
SITE LOCATION - NORTHERN HOME COUNTIES (O/S TL52**)**

Number of units	**28**	
Housing mix	4 bedroom detached houses	
Target market	Second/third time buyers	
Construction	Brick and block traditional	
Key specification	**Bricks**	Cheap
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed
Manager	**Experience in years**	14
	Experience as site manager	5
	Background	Trades

PROJECT NUMBER 10
SITE LOCATION - NORTH-EASTERN HOME COUNTIES (O/S TL41**)**

Number of units	**26**
Housing mix	Two and three bedroom terraced houses and flats
Target market	Second time buyers
Construction	Brick and block traditional

Key specification	**Bricks**	Cheap
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed
Manager	**Experience in years**	25
	Experience as site manager	18
	Background	Managerial

PROJECT NUMBER 11
SITE LOCATION - NORTHERN HOME COUNTIES (O/S TL31**)**

Number of units	77	
Housing mix	Three and four bedroom detached houses	
Target market	Second time buyers/executive	
Construction	Brick and block traditional	
Key specification	**Bricks**	Cheap
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed
Manager	**Experience in years**	19
	Experience as site manager	11
	Background	Trades

PROJECT NUMBER 12
SITE LOCATION - EAST ANGLIA (O/S TL46**)**

Number of units	20	
Housing mix	Four and five bedroom detached houses	
Target market	Top of the market	
Construction	Brick and block traditional	
Key specification	**Bricks**	Medium
	Tiles/slates	Interlocking/plain concrete (some slates)
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed
Manager	**Experience in years**	35
	Experience as site manager	15
	Background	Trades

PROJECT NUMBER 13
SITE LOCATION - NORTH-EASTERN HOME COUNTIES (O/S TQ79**)**

Number of units	**82**	
Housing mix	2, 3, 4 bedroom terraced, semi-detached and detached houses	
Target market	Mixed	
Construction	Brick and block traditional	
Key specification	**Bricks**	Cheap
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed
Manager	**Experience in years**	31
	Experience as site manager	15
	Background	Trades

PROJECT NUMBER 14
SITE LOCATION - GREATER LONDON (O/S TQ17**)**

Number of units	**185**	
Housing mix	2, 3, 4 bedroom terraced and semi-detached houses and low-rise flats	
Target market	Housing association and first time buyers	
Construction	Brick and block traditional	
Key specification	**Bricks**	Cheap
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed
Manager	**Experience in years**	28
	Experience as site manager	12
	Background	Managerial

PROJECT NUMBER 15
SITE LOCATION - GREATER LONDON (O/S TQ58**)**

Number of units	**65**
Housing mix	1, 2, 3 bedroom terraced houses and low-rise flats
Target market	Housing association and first time buyers

Construction	Brick and block traditional	
Key specification	**Bricks**	Medium quality
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed
Manager	**Experience in years**	48
	Experience as site manager	27
	Background	Trade

PROJECT NUMBER 16
SITE LOCATION - SOUTH-WESTERN HOME COUNTIES (O/S SU96**)**

Number of units	**69**	
Housing mix	2, 3, 4 and 5 bedroom mixed houses and low-rise flats	
Target market	Mixed	
Construction	Brick and block traditional	
Key specification	**Bricks**	Medium quality
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed
Manager	**Experience in years**	33
	Experience as site manager	20
	Background	Managerial

PROJECT NUMBER 17
SITE LOCATION - WESTERN HOME COUNTIES (O/S SU97**)**

Number of units	**57**	
Housing mix	2, 3, 4 and 5 bedroom mixed houses	
Target market	Mixed	
Construction	Brick and block traditional	
Key specification	**Bricks**	Cheap
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed

Manager	**Experience in years**	23
	Experience as site manager	18
	Background	Managerial

PROJECT NUMBER 18
SITE LOCATION - WESTERN HOME COUNTIES (O/S SU66**)**

Number of units	**42**
Housing mix	1, 2 and 3 bedroom mixed houses and low-rise flats
Target market	First, second time buyer and retirement
Construction	Brick and timber framed

Key specification	**Bricks**	Cheap
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central
heating/electric		
	Windows/doors	Timber double glazed

Manager	**Experience in years**	33
	Experience as site manager	18
	Background	Managerial

PROJECT NUMBER 19
SITE LOCATION - SOUTH-WESTERN HOME COUNTIES (O/S TQ16**)**

Number of units	**22**	
Housing mix	4 and 5 bedroom detached houses	
Target market	Executive	
Construction	Brick and block traditional	
Key specification	**Bricks**	Medium quality
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central
heating/electric		
	Windows/doors	Timber double glazed

Manager	**Experience in years**	36
	Experience as site manager	31
	Background	Trade

PROJECT NUMBER 20
SITE LOCATION - INNER LONDON (O/S TQ48**)**

Number of units	**70**
Housing mix	1 and 2 bedroom flats in medium rise block
Target market	Executive/investment
Construction	Steel framed, brick clad, steel sheet roof

Key specification	**Bricks**	Medium quality
	Tiles/slates	Steel sheeting on purlins
	Heating	Electric
	Windows/doors	UPVC double glazed

Manager	**Experience in years**	18
	Experience as site manager	8
	Background	Managerial

PROJECT NUMBER 21
SITE LOCATION - INNER LONDON (O/S TQ38**)**

Number of units	**25**
Housing mix	1 and 2 bedroom flats with medical centre in low-rise block
Target market	Executive/investment
Construction	Un-framed masonry

Key specification	**Bricks**	Good quality
	Tiles/slates	Interlocking concrete/sheet felt
	Heating	Gas fired wet central heating
	Windows/doors	UPVC double glazed

Manager	**Experience in years**	27
	Experience as site manager	10
	Background	Trade

PROJECT NUMBER 22
SITE LOCATION - INNER LONDON (O/S TQ38**)**

Number of units	**112**
Housing mix	2 bedroom flats in low-rise blocks
Target market	First-time buyers
Construction	Un-framed masonry

Key specification	**Bricks**	Medium quality
	Tiles/slates	Interlocking concrete
	Heating	Electric
	Windows/doors	Timber double glazed

Manager	**Experience in years**	10
	Experience as site manager	4
	Background	Trade

PROJECT NUMBER 23
SITE LOCATION - SOUTH-WESTERN HOME COUNTIES (O/S SU96**)**

Number of units	**61**
Housing mix	2, 4 and 5 bedroom terraced and detached houses
Target market	First-time buyers and executive
Construction	Brick and block traditional

Key specification	**Bricks**	Medium quality
	Tiles/slates	Interlocking concrete
	Heating	Gas fired wet central heating
	Windows/doors	Timber double glazed

Manager	**Experience in years**	26
	Experience as site manager	18
	Background	Trade

APPENDIX 8c

HOUSE-BUILDING STUDY RESEARCH VISITS DIARY

DATE	LOCATION	PERSON VISITED	PURPOSE
13/9/95	On site - site 18	Building manager, Company 1, Region 1	Preliminary meeting to discuss purpose of study.
21/9/95	Company 2, Region 1 Head Office	Production and commercial managers for the Region	Preliminary meeting to discuss the purpose of the research
26/9/95	On site - site 22	Site manager	Interview and site inspection
28/9/95	On site - site 21	Site manager	Interview and site inspection
28/9/95	On site - site 20	Site manager	Interview and site inspection
29/9/95	On site - site 18	Site manager	Interview and site inspection
2/10/95	On site - site 17	Site manager	Interview and site inspection
2/10/95	On site - site 19	Site manager	Interview and site inspection
4/10/95	Site tour, sites 1, 2, 3 from Company 2 Region 1 Head Office	Site managers	Interviews and site inspections
11/10/95	On site - site 16	Site manager	Interview and site inspection
12/10/95	On site - site 4	Building manager (acting site manager)	Interview and site inspection

12/10/95	On site - site 15	Site manager	Interview and site inspection
18/10/95	Company 2, Region 2 Head Office	Production manager	Preliminary meeting to discuss the purpose of the research
19/10/95	On site - site 14	Site manager	Interview and site inspection
30/10/95	Company 1, Region 1 Head Office	Deputy managing director for the Region	Open interview
30/10/95	Company 1, Region 1 Head Office	Building manager	Open interview
6/11/95	Site tour, sites 5, 6, 7, 8 from Company 2, Region 2 Head Office	Site managers	Interviews and site inspections
6/12/95	Company 2, Region 1 Head Office	Commercial manager	Open interview
19/12/95	Head Office, Building Guarantee Company	Technical and Underwriting managers	Preliminary meeting to discuss the purpose of the research
19/12/95	Company 2 Head Office	Company Managing Director, Region 2 Production and Commercial managers	Open interviews
5/2/96	Head Office, Building Guarantee Company	Technical and Underwriting managers and senior surveyor	Open interviews
5/2/96	Head Office, Company 1, Region 2	Two Building managers and Commercial manager	Preliminary meeting to discuss the purpose of the research

14/2/96	Site tour, sites 9, 10, 11 from Company 1, Region 2 Head Office	Site managers	Interviews and site inspections
21/2/96	Head Office, Company 1, Region 2	Building manager	Open interview
21/2/96	Head Office, Company 1, Region 2	Building manager	Open interview
21/2/96	Site tour, sites 12 and 13	Site managers	Interviews and site inspections
21/2/96	Head Office, Company 1, Region 2	Commercial manager	Discuss site costings
1/3/96	Head Office, Company 2, Region 1	Commercial manager	Open interviews and discuss site costings
8/3/96	Head Office, Company 1, Region 1	Customer care manager	Open interview
8/3/96	Head Office, Company 1, Region 1	Two Building managers	Collect drawings and programmes. General discussion of regional problems
8/3/96	On site - site 23	Site manager	Interview and site inspection. Discuss setting up of diary study
3/4/96	Head Office, Building Guarantee Company	Area surveyor and inspector	Open interview
17/4/96	Head Office, Company 1, Region 2	Regional Construction director and customer care manager	Open interviews

22/4/96	On site - site 23	Site personnel	Diary study for the week 22-26/4/96
8/5/96	On site - site 23	Building Guarantee Company inspector	Open interview

NUMBERS SHOWN IN BOXES ADDED LATER FOR CROSS-REFERENCING PURPOSES

APPENDIX 8d - HOUSE-BUILDING STUDY QUESTIONNAIRE

QUALITY ASSURANCE IN HOUSEBUILDING

ANDREW R ATKINSON

QUESTIONNAIRE

Question No.

ASSURANCES

The information provided in this questionnaire will be treated in the strictest confidence and not divulged to any other party. If you wish to review any answers at a later date or discuss the completion of the questionnaire, you are invited to contact me, Andy Atkinson at South Bank University, Wandsworth Road, London, SW8 2JZ, telephone 0171 815 7253.

Additionally, general queries concerning this research programme can be directed to Professor Victor Torrance, the London Master Builders Professor of Building at University College, London, Wates House, 22 Gordon Street, London WC1H 0QB, telephone 0171 387 7050.

GENERAL INFORMATION

1 Your name

2 Your position in your firm

3 Name of firm

4 Name and Address of site

5 Telephone number

YOUR EXPERIENCE

VARIABLE 9* **VARIABLE 10***

6 In the construction industry generally

VARIABLE 8

7 In your current role

1 THE SITE

8 a How many units are there on the site?

____

9 b What is the housing mix (one bed, two bed, three bed, flats, houses etc) and how many of each?

____

10 c What is the target market of the houses?

____

11 c How complex are the houses/flats? Very Normal Simple

____

*** VARIABLE = No specific provision in questionnaire**

12 d What is the construction? (e.g. "Traditional", "Timber frame" etc)

____

13 e Does the site require special foundations. If so, can you give details?

____

14 f Specification details for key materials (Bricks, Tiles, Heating, Windows/ex doors)

Bricks________________________

Tiles/slates____________________

Heating________________________

Windows and doors________________

VARIABLE 3

15 2 SKILLS OF TRADESPEOPLE

How do you rate the skill of subcontractors working on this site?

Trade	Poor	Average	Good	Excellent
Groundworks				
Bricklayer				
Carpenter				
Roofer				
Glazer				
Plasterer or dryliner				
Joiner				
Plumber				
Electrician				
Tiler				
Decorator				
Other?				

16 3 CHECKING

How often, on average, do you check the work of subcontractors

Trade	Before payment	Weekly	Daily	At end of task
Groundworks				
Bricklayer				
Carpenter				
Roofer				
Glazer				
Joiner				
Plasterer/Dry liner				
Plumber				
Electrician				
Tiler				
Decorator				

How to you check work on site?

Visual inspection? Standard form/checklist? Other?

17 4 HOW IS WORK PROGRAMMED?

Informally

Bar chart

Using a CPA program

Do you programme the work, or is it programmed by a central planning department?

Programmed on site

VARIABLE 7

Central planning department

How often is the programme updated ?

VARIABLE 11

Not normally updated

Occasionally

VARIABLE 7

Monthly

Weekly

Other

Who has copies of the programme?____________________

5 COMMUNICATIONS

Roughly speaking, how regularly do you talk to:-

Times/month

18 a) Architects/engineers designing the project? **VARIABLE 4** ____________

19 b) Other managers/accountants etc? **VARIABLE 6** ____________

20 c) Other colleagues in the office(s) (E.g. buyers, support staff) **VARIABLE 4** ____________

VARIABLE 11

Roughly speaking, how regular are site visits ?

21 a) From the design staff? **VARIABLE 4** ____________

22 b) From managers? **VARIABLE 6** ____________

Are there formal company meetings which the site management attends?

23 How regularly? **VARIABLE 6** ____________

Are there formal meetings between subcontractors/trades and the site management?

24 How regularly? **VARIABLE 6** ____________

Who keeps the minutes of the subcontractor meetings? ____________________

25 How good are the project documents for this project ? **VARIABLE 5**

AMOUNT OF INFORMATION	Insufficient	Too much	Just right!
a) Specification			
b) Drawings			

CLARITY	Very clear	Clear	Unclear
a) Specification			
b) Drawings			

PRACTICALITY	Buildable	Possible	Unbuildable*

* If possible, list difficult areas

____

____

26 Were the designers in-house or consultants? In-house Consultants

a) Architects______________________________

b) Engineers______________________________

6 OTHER FACTORS

27 In your opinion, has the current economic climate affected quality relating to the project?

If so, in what way?

____

____

28 In your opinion, was the project on a tight budget?

Very tight Normal Not tight **VARIABLE 12**

____

29 In your opinion was the project pressurised for time?

Very, Normal Slack etc **VARIABLE 13**

____

30 How do you view the overall quality of the houses (i.e. as perceived prior to snagging/handing over to sales):-

Level of construction Poor Below ave Average Good Very good

Foundations______________________________

VARIABLE 2

First floor joists______________________________

Roof plate______________________________

Roof carcase______________________________

Structure complete______________________________

First fix______________________________

Second fix______________________________

Decoration______________________________

External works______________________________

31 <u>In your recollection, were there any particular quality problems relating to the project.</u>

VARIABLE 1

If so, how were they managed?

32 In your view, what are the main factors that influence the quality of houses for this project.

33 Do you have any other comments concerning this research?

34 Would you take part in a further study?

ARA/22 September 1995/Q.4

TEXT BOUND INTO

THE SPINE

PPENDIX 8e - HOUSE-BUILDING STUDY QUESTIONNAIRE PART 2

QUALITY ASSURANCE IN HOUSEBUILDING
ANDREW R ATKINSON

Question No

SITE VISIT CHECKLIST

35

SITE ____________

DINESS OF SITE 36

	TIDY	NORMAL	UNTIDY

OMPLEXITY OF DWELLINGS 37

	COMPLEX	AVERAGE	SIMPLE

ECIFICATION AND QUALITY 38

SPECIFICATION	QUALITY		
	GOOD	AVE	POOR
)OF			
TERNAL WALLS			
IISHINGS			
INERY			

AGE OF CONSTRUCTION 39

)PORTION OF HOUSES COMPLETED ____________

WEATHERTIGHT

TO EAVES ____________

OUT OF GROUND ____________

SALES OFFICE SALES LITERATURE ____________

SALES RATE ____________ 40

TARGET MARKET ____________ 41

TOGRAPH!

APPENDIX 8f -CONSTRUCTION OF VARIABLES

DEPENDENT VARIABLES

1

NAME	**Reported defects and error instances**
SPSS SHORT NAME	**faults**
QUESTION IN QUESTIONNAIRE	**31, 39**

OBJECT
To obtain a categorical division between sites based on error instances related to the site.

REPRESENTING IN THE MODEL
Dependent variable - level of error

CONSTRUCTION
A division of the sites into two categories, those with high as opposed to low levels of defects/errors based on calculating the product of the un-weighted total number of errors reported by the site manager (either leading to defects or detected and corrected beforehand) and the reciprocal of the proportion of the site completed (drawn from direct inspection and recorded on the questionnaire supplement) divided by the estimated construction cost of the site to give an error rate per £ million per site.

Multiplying the number of defects with the reciprocal of the proportion of the site completed controls for differences in the stage of construction reached on each site (the expectation being that more errors would be evidenced on sites nearing completion as opposed to those just starting). Dividing by the construction cost controls for differences in size and complexity between sites (the expectation being that bigger and/or more complex sites, as evidenced by higher construction costs, would have a higher number of errors).

2

NAME	**Perceived quality**
SPSS SHORT NAME	**quality**
QUESTION IN QUESTIONNAIRE	**30**

OBJECT
To obtain a categorical division between sites based on the perceived quality of construction at the current stage.

REPRESENTING IN THE MODEL
Dependent variable - quality of work/freedom from defects

CONSTRUCTION
A division of the sites into two categories, high as opposed to low quality, constructed from the returns of the site manager of the quality of work at each completed stage of construction to date. Each stage is scored on an arithmetical scale, summed and expressed as a mean score for the site. Sites are then divided into two categories, high and low scoring. Scores represent:-

Interviewee rating	**Score**
Poor	1
Below average	2
Average	3
Good	4
Very good	5

Nine stages are supplied in the questionnaire (giving a maximum of 45 points where all stages are or have been active). Taking the mean score allows for the situation where not all stages have started and scores are not yet available

INDEPENDENT VARIABLES

3

NAME	**Skills of tradespeople**
SPSS SHORT NAME	**trades**
QUESTION IN QUESTIONNAIRE	**15 - Skills of tradespeople**

OBJECT
To obtain a categorical division between sites based on the average skill level of the operatives on each site.

REPRESENTING IN THE MODEL
Primary factors generally related to the knowledge of operatives.

CONSTRUCTION
A categorical division constructed from the returns of the site manager of the skills of each trade active on each site to the date of the interview. Each trade is scored on an arithmetical scale, summed and expressed as a mean score for the site. Sites are then divided into two categories, high and low scoring. Scores represent:-

Interviewee rating	**Score**
Poor	1
Average	2
Good	3
Excellent	4

Eleven trades are supplied in the questionnaire (giving a maximum of 44 points where all trades are or have been active). There is a provision for the interviewee to supply other, less usual, trades (for example, lift installers), thus the maximum can increase above this. However, taking the mean score allows for this and for the situation where not all trades are yet active and scores are not yet available.

4

NAME	**Experience of manager**
SPSS SHORT NAME	**manager**
QUESTION IN QUESTIONNAIRE	**7 - Preliminary question**

OBJECT
To obtain a categorical division between sites based on the experience of the site manager in a supervisory position.

REPRESENTING IN THE MODEL
The role of the project manager generally.

CONSTRUCTION
A division of sites into two categories, those staffed by experienced as opposed to inexperienced managers, based on the number of years experience reported by the site manager in that role.

5

NAME	**Background of manager**
SPSS SHORT NAME	**Quals1**
QUESTION IN QUESTIONNAIRE	**6 - Supplementary question**

OBJECT
To obtain a categorical division between sites based on the background of the manager (trades background or managerial background).

REPRESENTING IN THE MODEL
The role of the project manager generally.

CONSTRUCTION
A division of the sites into two categories, those staffed by managers from a trades background as opposed to those staffed from a managerial background.

6

NAME	**Qualifications of manager**
SPSS SHORT NAME	**Quals2**
QUESTION IN QUESTIONNAIRE	**6 - Supplementary question**

OBJECT
To obtain a categorical division between sites based on the formal qualifications of manager (qualified or un-qualified)

REPRESENTING IN THE MODEL
The role of the project manager generally.

CONSTRUCTION
A division of the sites into two categories, those staffed by managers with formal as opposed to those with no formal qualifications.

7

NAME	**Informal communications**
SPSS SHORT NAME	**comms1**
QUESTION IN QUESTIONNAIRE	**18, 20, 21**

OBJECT

To obtain a categorical division between sites based on the level of communications between the site and other parts of the organisation and covering non-line activities (that is activities necessary to perform the task, but not between supervisors and the supervised - for example, to include communication with designers but not with line managers). "Communications" are distinguished from "Culture" (see below), in that the latter were taken as line communications between supervisors and the supervised.

REPRESENTING IN THE MODEL

The managerial factor "communications".

CONSTRUCTION

A division of sites into two categories, high as opposed to low communications levels, based on the un-weighted sum of the number of communication events per month (talk/visit) from non-line staff as reported by the site manager.

8

NAME	**Formal communications**
SPSS SHORT NAME	**comms2**
QUESTION IN QUESTIONNAIRE	**25**

OBJECT

To obtain a categorical division between sites based on the quality of the formal communication tools (specification/drawings) used between the major elements of the construction process (design, specification, buying, surveying and construction).

REPRESENTING IN THE MODEL

The managerial factor "communications".

CONSTRUCTION

A division of the sites into two categories, high as opposed to low quality formal communications, based on the total score of the quality of documents as perceived by the site manager and scored as follows (see also questionnaire):-

Ratings	Amount of information		Clarity of information		Extent of buildability
	Spec	Drawings	Spec	Drawings	
Insufficient/unclear/un-buildable	1	1	1	1	1
Too much/clear/possible	2	2	2	2	2
Just right/very clear/buildable	3	3	3	3	3

Maximum score achievable = 15

9

NAME	**Organisational Culture**
SPSS SHORT NAME	**culture**
QUESTION IN QUESTIONNAIRE	**19, 22, 23, 24**

OBJECT
To obtain a categorical division between sites based on the quality of the organisational culture as represented by the level of contact between line managers, other managers, site managers and sub-contractors.

REPRESENTING IN THE MODEL
The managerial factor of "organisational culture".

CONSTRUCTION
A division of the sites into two categories, positive as opposed to negative organisational culture, based on the sum of the number of communication events per month (talks/visits) from line managers plus the number of meetings between site management and superiors plus the number of meetings between site management and sub-contractors as reported by the site manager.

10

NAME	**Planning/programming**
SPSS SHORT NAME	**planning**
QUESTION IN QUESTIONNAIRE	**17**

OBJECT
To obtain a categorical division between sites based on the intensity of planning and programming of the works.

REPRESENTING IN THE MODEL
Managerial factors or division of responsibilities, change control and control of concurrency.

CONSTRUCTION
A division of the sites into two categories of the method of planning as follows:-

No planning	0
Central planning, not updated	1
Central planning, updated	2
Central plus local planning, not updated	3
Central plus local planning, updated	4

The categories were combined into two groups, "central" (the second and third categories) and "local" (the last two categories). There were no "un-planned" sites.

11

NAME	**Intensity of project management**
SPSS SHORT NAME	**project**
QUESTION IN QUESTIONNAIRE	**17 - 25**

OBJECT
To obtain a categorical division between sites based on the intensity of project management for the site.

REPRESENTING IN THE MODEL
Project management factors generally

CONSTRUCTION
A division of the sites into two categories, high as opposed to low intensity of project management, based on the product of scores for planning, formal and informal communications and organisational culture.

12

NAME	**Cost pressure**
SPSS SHORT NAME	**costp**
QUESTION IN QUESTIONNAIRE	**28**

OBJECT
To obtain a categorical division between sites based on cost pressures

REPRESENTING IN THE MODEL
Global factor of "cost pressure".

CONSTRUCTION
A division of the sites into two categories, tight as opposed to not tight cost pressures, based on data provided by the site manager. Data were initially divided into three categories (tight, normal, not-tight) later reduced to two for analysis purposes.

13

NAME	**Time pressure**
SPSS SHORT NAME	**timep**
QUESTION IN QUESTIONNAIRE	**29**

OBJECT
To obtain a categorical division between sites based on time pressures.

REPRESENTING IN THE MODEL
Global factor of "time pressure".

CONSTRUCTION
A division of the sites into two categories, tight as opposed to not tight time pressures, based on data provided by the site manager. Data were initially divided into three categories (slack, normal, tight).later reduced to two for analysis purposes

APPENDIX 8g SUMMARIES OF VARIABLES SCORES

SITE	RECORDED DEFECTS/ERRORS						QUALITY				TRADE SKILL			
	Report	% site finished	Adj faults	Site cost (£m)	Faults /£m	Level of faults	Score	No of stages	Ave Quality	Perceived quality	Score	No of trades	Average	Skill level
Variable →						*1*				*2*				*3*
1	3	50	6.00	0.92	6.52	2	35	9	3.89	1	28	11	2.55	2
2	4	90	4.50	0.47	9.57	2	33	9	3.67	2	30	11	2.73	2
3	2	60	3.50	0.82	4.26	1	33	9	3.67	2	33	12	2.75	2
4	0	75	.00	0.92	0	1	33	9	3.67	2	31	11	2.82	2
5	3	75	4.00	1.25	3.20	1	34	9	3.78	2	31	12	2.58	1
6	2	85	2.50	1.41	1.77	1	36	9	4.00	1	37	12	3.08	2
7	4	70	5.50	0.94	5.85	2	33	9	3.67	2	33	12	2.75	1
8	4	75	5.50	0.88	6.25	2	36	9	4.00	1	34	12	2.83	1
9	4	50	8.00	1.24	6.45	2	144	9	4.89	1	29	11	2.64	2
10	1	60	2.00	0.56	3.57	1	34	9	3.78	2	27	11	2.45	1
11	2	70	3.00	4.77	0.62	1	33	9	3.67	2	27	11	2.45	1
12	8	80	10.00	1.17	8.54	2	33	9	3.30	2	24	12	2.00	1
13	3	35	8.50	2.1	4.04	1	39	9	4.88	1	33	12	2.75	2
14	0	95	.00	1.9	0	1	39	9	4.88	1	33	11	3.00	2
15	2	15	13.50	1.3	10.38	2	9	3	3.00	2	11	4	2.75	1
16	5	40	12.50	1.84	6.79	2	32	9	3.56	2	28	11	2.55	2
17	1	65	1.50	2.05	0.73	1	32	9	3.56	2	30	11	2.73	1
18	3	50	6.00	0.75	8.00	2	31	9	3.44	2	21	11	1.80	1
19	5	90	5.50	0.86	6.39	2	37	9	4.11	1	30	11	2.73	1
20	0	5	.00	2.07	0	1	3	1	3.00	2	2	1	1.00	1
21	4	50	2.00	1.1	1.81	1	24	6	4.00	1	29	10	2.90	2
22	2	75	2.50	2.23	1.12	1	33	9	3.67	2	29	11	2.64	1
23	1	5	20.00	1.9	10.52	2	16	4	4.00	1	9	4	2.50	1

SITE	Informal comms		Formal comms		Culture		Planning Level	Manager's				Project Management		Cost Pressure	Time Pressure
								Experience		Back-ground	Quals				
	Score	Level	Score	Level	Score	Level		Years	Level			Score	Level		
Variable →		*4*		*5*		*6*	*7*		*8*	*9*	*10*		*11*	*12*	*13*
1	1.00	2	13.00	1	20.00	2	1	12.00	1	2	1	320	1	1	1
2	20.00	2	13.00	1	29.00	1	1	2.00	1	1	1	9280	1	2	1
3	19.00	2	12.00	1	17.00	2	2	10.00	1	2	2	18088	2	2	1
4	17.00	2	13.00	1	13.00	2	2	10.00	1	2	2	10608	2	2	1
5	21.00	2	13.00	1	30.00	1	1	3.00	1	2	2	25200	2	2	1
6	4.00	2	12.00	1	25.00	1	1	20.00	2	2	1	2800	1	1	1
7	5.00	2	15.00	1	34.00	1	1	15.00	2	1	1	3400	1	1	1
8	32.00	1	6.00	2	8.00	2	1	30.00	2	1	1	512	1	1	1
9	22.00	1	12.00	1	26.00	1	2	5.00	1	1	2	32032	2	1	1
10	42.00	1	11.00	1	24.00	1	2	18.00	2	2	2	48384	2	2	1
11	21.00	2	12.00	1	30.00	1	2	11.00	1	1	2	26460	2	1	1
12	21.00	2	7.00	2	29.00	1	1	15.00	2	1	1	4872	1	2	1
13	25.00	1	13.00	1	26.00	1	1	15.00	2	1	1	20800	2	2	1
14	13.00	2	13.00	1	20.00	2	2	12.00	1	2	1	16640	2	2	2
15	52.00	1	9.00	2	18.00	2	1	27.00	2	1	1	14976	2	1	2
16	23.00	1	13.00	1	15.00	2	2	20.00	2	1	1	22080	2	2	2
17	14.00	2	12.00	1	17.00	2	2	18.00	2	2	1	13328	2	2	1
18	8.00	2	8.00	2	19.00	2	1	33.00	2	2	1	1824	1	2	2
19	14.00	2	9.00	2	24.00	1	1	31.00	2	1	1	2688	1	2	2
20	41.00	1	11.00	1	13.00	2	1	8.00	1	2	2	6396	1	1	2
21	29.00	1	8.00	2	28.00	1	1	10.00	1	1	1	11368	2	2	2
22	25.00	1	9.00	2	16.00	2	2	4.00	1	1	1	12800	2	2	2
23	30.00	1	7.00	2	29.00	1	1	18.00	2	1	1	3480	1	2	2

VARIABLE KEY

Variable number	Variable name	Level 1	Level 2
1	Recorded defects/errors	Low	High
2	Perceived quality	High	Low
3	Skill level	Low	High
4	Informal communications	High	Low
5	Formal communications	High	Low
6	Culture	Positive	Negative
7	Planning	Low	High
8	Experience of manager	Inexperienced	Experienced
9	Background of manager	Trades	Managerial
10	Qualifications of manager	Unqualified	Qualified
11	Project management	Less intensive	Intensive
12	Cost pressure	Less intensive	Intensive
13	Time pressure	Less intensive	Intensive

APPENDIX 9a - RECORDS OF ERRORS AND PROBLEMS
9a(i) RECORD OF ERRORS REPORTED BY SITE MANAGERS

SITE	ERROR	FACTOR
1	Brickwork quality poor:- • Missed ties • Leaning piers • No frame ties	P
2	Brickwork defects:- • Small amount of poor work dismantled • Odd dirty cavities	P
	Carpentry defects:- • Odd nail missing • Odd tie-down strap missing	P
3	Poor brickwork (general at first) - firm removed as they could not operate at a distance from their office (60km)	P COMMS CHECK
	Poor roofing - insufficient trades supervision - improved after threats from NHBC	P CHECK
	Plasterwork (unspecified)	P
	Plumbing defects caused by variable performance of alcoholic plumber.	P
	Expansion joints in brickwork did not match RWPs or internal wall layouts.	FORMAL
	Too many expansion joints causing expense of extra stainless steel ties.	FORMAL
	Late changes in drawings:- • Ground details and drainage • Introduction of garages • Detailed requirements of town planning	CHANGE
	Lack of accurate drawn information	FORMAL
	Insufficient pre-planning re drawings	FORMAL PLAN
	Problems with trussed rafters (unspecified)	P
4	Odd "rogue labourer".	P
5	Poor electrician until firm was replaced (not specific) New firm was dearer and there was a battle with the QS over prices.	P COST

	Poor ground caused drainage re-design (drains had to be supported on "needle piles") i.e. lack of pre-planning/late changes caused problem.	CHANGE FORMAL
	Landscaper turfed over the manholes	P
	Floor joists over-spanned and had to be strengthened by steel to halve the span (picked up by NHBC) (possibly also poor communications/checking)	FORMAL
6	Half-timber fronts to houses "a cow to build" "keeps scaffolding up for ever and a day". (possibly also poor communications)	FORMAL
	"Had to move a few drains".	FORMAL
	Boundary fencing not provided initially.	COST
7	Poor time performance of landscapers. Company had no leverage on landscapers as it was winding down.	TIME
	"Tudorbeathan" half-timber fronts have a "buildability/time implication as their exterior has to be almost fully plastered before the scaffolding can be struck.	FORMAL
	Operatives nailed pipes twice and caused two house floods.	P
8	Drawing discrepancies (upstairs windows shown as 1200mm deep on drawings and 1050mm deep on schedules) - windows ordered to the wrong sizes.	FORMAL
	Trusses pitched too steeply to garages, covering windows in the flank walls.	FORMAL
	LPG tanks shown to the wrong properties (all-electric units!)	FORMAL
9	Drawing problems:- • Windows obstructed porch pillars • Garage personal door opened into neighbouring garden (Boundary had to be changed, door removed and opening bricked up!) • Boiler outlet ditto • Rainwater gutters and downpipe also sited in neighbouring garden • Water main shown running through house foundations	FORMAL
10	Poor decorations caused by poor preparation lead to the sacking of two painters.	P
11	Poor quality dry lining caused by untrained labour.	P
12	Window slightly mis-positioned by the bricklayers	P
	Odd wrong joists hangar used.	P
	One lintel under-sized on one unit (material schedule was wrong).	FORMAL

	Staircase layouts did not match floor joist layouts.	FORMAL
	Drains positioned in the wrong place on drawings (Soil and ventilating pipes in the middle of bedrooms).	FORMAL
	External rendering requires that the scaffolding be kept up too long.	FORMAL
	Precast concrete floor beam layouts do not match ground floor architectural layouts (Drawings issued without proper pre-issue checks - "the technical department did not have time").	FORMAL
	Incorrectly quoined jambs on "one-and-only knapped flint faced unit".	P
13	Poor performance and delay caused by glazers (not cutting back putties and a "poor business performance").	P
	Landing window positioned on drawings in a garage roofspace (detected by the bricklayers and site manager).	FORMAL
	Pipe casing sizes incorrect.	FORMAL
14	Nothing reported	
15	Poor bricklaying generally ("partly caused by speed of working").	P TIME
16	Carpentry omissions:- • Sway bracing • Strapping • Nailing (Possibly also poor communications if details were not clear on drawings).	P
	Roof tiling - poor cutting to valleys and "wet work".	P
	Brickwork problems:- • Odd mortar splashes • Ties facing towards inner skin • Dirty cavities	P
17	Drawing problems - tumble dryers and refrigerators do not fit into the kitchen units in one house type.	FORMAL
18	Timber frame assembly problems expressed as "teething problems"	FORMAL
	Some "oversailing" brickwork.	P
	Poor paintwork preparation.	P
19	Poor ground conditions.	FORMAL
	Units too close together inhibiting the use of scaffolding.	FORMAL
	Working hours restrictions - no evening or weekend working.	TIME

	Soil pipes shown on drawings as passing through the windows	FORMAL
	Problems with customer bespoke changes. • Partitions omitted at late stage • Colour scheme changed ditto.	CHANGE
	Late changes to front door sizes.	CHANGE
20	No problems reported.	
21	Poor "U" values and fire protection to basement ceilings.	FORMAL
	Lack of ventilation and poor routing of vents to medical centre (including a disagreement with the gas board on the routing of vents).	FORMAL
	Subsidence of existing building.	FORMAL
22	Change of timber stairs to concrete (needed in 4-storey flats to comply with Building Regulations).	FORMAL
	Bay window dropped during construction (temporary wedges collapsed) and had to be re-propped)	P
23	Window missed out of unit - not noticed as a "deviation" for this site.	COMMS
	Levels of roads do not suit ground conditions.	FORMAL

APPENDIX 9a(ii)
RECORD OF ERRORS REPORTED BY SENIOR MANAGERS

INT NO	ERROR	FACTOR
3	Considerable number of Company built houses were found to have no/trace cement in the wall mortar - exact cause of error has never been determined.	P CHECK
6	Manager 18 failed to construct a rooflight in a unit because "the detail was not there". Reported as a primary site manager failing.	MAN FORMAL
	Reported that manager 19 "couldn't handle the site" (just could not cope) and a replacement was brought in to assist/take over. Reported as a general management failure (encapsulating all the managerial level of the model).	MAN
	Manager 17 reported as a "poor finisher" and was moved to a "starting site" to compensate.	MAN
	Manager 20 similarly reported.	MAN
	Manager 16 reported as failing to carry out sufficiently rigorous site checks in allowing carpenters to cut floor joists to fit joist hangars that were too small - manager was generally accused of being too office bound.	MAN
	Manager 23 reported as allowing groundworkers on a site to lay wrong house drive tarmac, without checking specification or drawings.	MAN
7	Problem on site 9 in that water board were paid approximately £100 000 to divert a main running through the middle of the site. They failed to do so as agreed and this caused re-design of foundations and re-programming of site activities, with a claim of £20 000 being made against the water board.	CHANGE
8	Piling on a site was set out of position. Set out in accordance with engineer's layouts without proper tying up between architect's and engineer's drawings.	FORMAL
	Increased thickness of floor screeds on one site because the standard staircase did not fit the storey heights.	FORMAL
	Garages sited on layout drawings 600mm from boundary with 700mm outward opening door in the side (i.e. either the door will not open, or it will hit the fencing). (Door had to be re-positioned and the opening bricked up).	FORMAL

	On some units the kitchen fittings are "too tight" - the drawers catch cupboard knobs and the cooker will not fit in the blank opening provided.	FORMAL
9	General "materials degradation caused by site manager not planning deliveries properly (a general planning failure covering much of the managerial level of the model).	PLAN
	Customer induced changes cause considerable problems.	CHANGE
	A house settled on a raft and the raft broke its back on a gas holder base below - reported as a design fault.	FORMAL
11	Negative pressure on a chimney stack causing downdraughts in the flue and smoke in the room of a unit - reported as unforeseeable.	FORMAL
12	On one (not case study) site poor quality joists in the finished work (warping, shrinking) reported as caused by poor site supervision.	COST CHECK
	The show houses in site 11 have exhibited "very high maintenance costs" as a result of too much haste in construction "We threw them up too quickly and reaped what we sowed". The interviewee took responsibility for this problem at board level i.e. the board planned for the problems.	TIME

APPENDIX 9a(iii)
RECORD OF ERRORS REPORTED BY INSURERS

INT NO	ERROR	FACTOR
13	Interviewee reported a "disaster site" (not one of the case studies) constructed by a 50-unit/annum mediocre builder in the North of England. Site was situated on a hill with the houses dug into the hill. Each unit was badly built with problems of basement leakage and several other technical defects. Problems were reported as:- • Technical - form of construction, site characteristics • Poor checking and supervision caused by departure of former site manager • Lack of technical quality control (a more general project management failure • Lack of control of sub-contractors	CHECK SYST
	Overall this was seen by the interviewee as managerial failings to be corrected by:- • Employing someone (at site management level) "who is qualified to do the work". • Permit the interviewee's company (a Building Guarantee Company) to place an inspector on the site for the construction duration.	MAN CHECK
	Interviewee reported a second "disaster site" in the North of England where a dispute developed between the company manager and the owner and the company went into liquidation and was re-floated. The new company lacked a supervision structure - reported as a "lack of a system". This can generally be perceived as an overall project management/management failing.	SYST
14	One one (non-case study) site, reported that bin-stores were placed on inadequate foundations. The builder had pressurised the interviewee's company's inspector (a Building Guarantee company) to accept the foundation depths. This later caused a claim against the Guarantee company.	CHECK
	On one (non-case study) site, interviewee reported several problems including:- • Poor sound insulation between units caused by poor workmanship and lack of knowledge • Large number of other, unspecified, errors classed as multiple systemic errors	P SYST

	Interviewee (Building Guarantee Company underwriter) was currently working on claim for re-plastering a unit where the plaster had de-bonded from the wall - use of wrong plaster.	P
15	Interviewee reported technical problem where a detail of a wall incorporating an unusually wide cavity was used. Defects were caused by:- • Poor architectural details around windows and doors • Inadequate wall ties.	FORMAL P
	Solutions were proposed by the interviewee's company (Building Guarantee company):- • Removal of gang of bricklayers and new gang employed, who were to receive training before starting the work • Extremely vigorous supervision of bricklaying. Reported as "eventually, if the site manager walked around the site in the evening and could see the 'yellow of a cavity wall bat', then the bricklayers were off the site".	P CHECK
	A (non-case study) site of a single bungalow with a basement had basement leaks. Reported as being caused by the builders lack of technical ability and experience. This primary failing was considered to be at the managerial/supervision level.	MAN
	A (non-case study) site of 4 units had similar basement problems for similar reasons.	MAN
16	Frost affected ground floor suspended floor slab failed because of poor supervision.	P CHECK
	Reported the case of a unit (on a non-case study site) inadvertently built over a pond and had to be demolished after construction. This was the only instance in the interviewees experience (12 years) of a house which had become a physical danger to the occupants.	FORMAL
	Interviewee reported instance of one site (non-case study) where parapet walls to gables of houses were built without damp-proof courses and poor mechanical fixings of coping bricks. Reported as partly a design fault and partly that the problem was "overlooked by the site manager".	FORMAL CHECK
	Interviewee reported instance of one site (non-case study) where steps in house terraces (i.e. changes in floor levels down the site) were constructed without proper damp proofing. Reported as being caused by:- • No architect's detailing involving "assuming too much knowledge down the line" and the fact that the architect was "not responsible for the details". • Problem not being "picked up by the agent".	FORMAL CHECK

	Interviewee reported site (non-case study) where there was a claim related to floor joist failure caused by:- • Bricklayer putting floor joists into a unit at too high a level (possibly because of poor design detailing?) • Carpenter over-notched the joists to reduce them to the correct floor levels. • Electrician over-notched the same joists to accommodate cabling. • Not picked up by the acting agent (the main agent had been away from the site for some time). • Mistake was repeated in other units because clear instructions were not subsequently given to the carpenters not to notch the floor joists.	P FORMAL P P CHECK COMMS
	Interviewee reported one 10-unit housing site which had an extraordinary number of defects. On one unit 27 defects were recorded by the inspector for the interviewees Building Guarantee company (the average number of defects being 2-3 per unit). The problem was reported as being one of lack of general building knowledge - an individual trades-person had set himself up as a builder, without a site agent.	SYST
17	Interviewee reported instance of subsidence to a unit caused by workers digging foundations in a clay area ignoring a nearby Oak tree (likely to cause clay drying shrinkage). Reported as a problem of a myopic workforce, but could be classed as a design or supervision failing.	0 FORMAL COMMS
	Interviewee reported instance of walls in two units on a (non-case study) site being constructed with mortar containing "a minimal cement content". The technical remedy was to re-point the units. Cause was attributed to a knowledge error by the bricklayers and lack of supervision.	P CHECK
	Interviewee reported instance of one (non-case study) site where the foundations to several units were constructed to a V-shaped cross section and acted as "a knife" cutting into the sub-strata and causing subsidence. This error was attributed to lack of site supervision.	CHECK

APPENDIX 9a(iv)
RECORD OF GENERAL PROBLEMS REPORTED BY SITE MANAGERS

SITE	PROBLEM	FACTOR
3	Some design errors were not formally corrected and left to construction and site managers to correct.	FORMAL
	Circuitous communications routing for design questions:- • Site manager > • building manager > • technical services > • consultant designer > • technical services > • building manager > • site manager.	COMMS
4	Buyers are "not very good"	COMMS COST
6	New house type "teething problems".	CHANGE
7	New house type "teething problems".	CHANGE
8	Poor drawings for this more "ad hoc" site.	FORMAL
	Poor setting up of materials schedules	FORMAL
9	Problems of design/construction liaison "got over on site".	COMMS
	"A lot of detailing left to site interpretation".	FORMAL
	Budget constraints	COSTS
	Time allotted to complete units.	TIME
12	Problems of • concurrency, • time constraints • design left to site to interpret.	CONCUR TIME FORMAL
13	Problems with drawings and communicating drawing revisions in relation to new house types.	FORMAL CHANGE
14	Lack of authority for site manager to select sub-contractors and trades-people.	RESP P
	insufficient time.	TIME
15	"Faster the men work, the more quality suffers".	TIME
	"Buidability a bit of a problem".	FORMAL
	Lack of pre-planning of the site.	PLAN
16	Timescale too fast.	TIME
	Lack of head-office pre-planning - "buying/scheduling all too rushed and buyer is over-worked".	PLAN

	"Building (industry) has been taken over by the QSs" - too much emphasis on cost/time at the expense of quality.	COST
	Quote from painters on the job - "That's the standard you get for my price" and anecdote that painter is not making enough return to want to take on any more units on that site.	COST
	Ordering/buying is all through the head office with no site float.	RESP
	"Time"	TIME
	"Too much paper-work"	FORMAL
	"Too much QA and too many checkers".	FORMAL
	Negative attitudes of senior managers. Tendency to set un-realistic targets and use "the sack" if these are not met. i.e. generally negative attitude. Seen by the site manager as no longer an effective sanction - "they can only sack you and even that is no longer easy. Not meeting un-realistic targets is no longer a good enough excuse. This is also true further down the line - it is not so easy to get rid of poor tradesmen or firms; but it can be done!".	CULT
	"Performance targets always tend to rise".	TIME
18	Lack of money.	COST
	Insufficient time causing site congestion.	TIME
	Lack of management staff on site.	COST
	Too much paper-work.	FORMAL
	Too many meetings.	COMMS
	Too much centralised control of ordering, firing, hiring.	RESP
	"Can't get rid of useless sub-contractors" - i.e. lack of local authority for selection.	P
19	Odd drawing overlay problems	FORMAL
	Lack of time	TIME
	"Can't get rid of poor sub-contract firms".	P
	Use of patronism (bricklaying sub-contractor manager knows the former managing director).	CULT
	Change orders are not always passed on in the bricklaying firm.	COMMS CHANGE
	Negative approach of senior managers (Managing Director).	CULT
	Too much paper-work.	FORMAL
20	Too much time filling in QA forms.	FORMAL

	Lack of money leading to poor selection of trades and lack of qualified managers.	COST
21	Drawings lagging building production and hence too much left for site to decide.	FORMAL
	Specification not concise enough.	FORMAL
	Programming inadequate - does not allow for the complexities of site. More detailed planning, including pre-planning would help.	PLAN
	Over-tight sub-contract tendering.	COST
	Split responsibilities - two architects on a part speculative and part JCT80 contract.	RESP
	Inadequate company culture with "no Laurie Barratt at the helm to direct operations".	CULT
22	Too much time filling in forms for QA.	FORMAL
	Variable standard of work (of sub-contractors). "The trouble is, even with good people, the standard of work is so variable. One day a tradesman will turn out good work, the next, terrible work. Perhaps he just had a bad day! He knows its bad, we know its bad, its just one of those things".	P

APPENDIX 9a(v)
RECORD OF GENERAL PROBLEMS REPORTED BY OPEN INTERVIEWEES

INT	PROBLEM	FACTOR
1	Internal fights over sub-contract selection. QS and production manager have to sit down and "slog it out".	P COST
	"Things go wrong when site manager is- • Spending too much time in the office • Lazy • Too friendly with sub-contractors".	MAN
3	Sub-contractor selection difficult. Previous work checks always cover "good" sites offered by the interviewees.	P
	"Nomadic trades gangs" changing too much within sub-contractor firms.	P
5	Fast pace demanding good organisation of men, mortar etc.	TIME
	Changes introduced late in the construction programme (e.g. "home-maker changes).	CHANGE
6	Main problem is a lack of checking.	CHECK
	Excessive time pressure. e.g. new site is starting on day of purchase of site.	TIME
	Conflict as a problem.	CULT
	Managing director who wants to "build out" all sites in order to have a product to show customers. He is, therefore always wanting to cut lead times, but at the same time has a knack of timing the market and "producing the goods".	TIME CULT
	Site 23 started with too little lead in e.g:- • Show houses built without water services in place • Roads, sewers, water mains, electric mains, gas mains still not installed.	TIME CONCUR
8	Lack of trades apprenticeship.	P
	Lack of site manager training in "man management" and "safety aspects".	MAN
	Customers are demanding more and are more ready to sue.	SOC
	Prices are too tight for workforce and many corners are cut.	COST
	"Pushing for house numbers sometimes causes problems".	TIME

	"I spend quite a lot of time marking up problems on drawings and returning them to (design head office):- • Section cross-referencing absent • Vague details e.g. fixings types and spacings not shown.	FORMAL
	"It is far better that the detail is there than it is got over on site. We're often told to 'do it and tell us what you've done and we'll put it on paper".	FORMAL
9	Time pressure to meet cash flow requirements and sales targets.	TIME
	Cost pressure.	COST
	"When things go wrong it is usually the plumbing and electrical trades and this is caused by the design element present in their work".	P
	"Changes completely throw the whole thing out" - e.g. sales, budgeting.	CHANGE
10	Pressures mean that company is more money oriented leading to tight margins and importance of surveying function (in turn leading to tension and internal power struggles) "QS usually gets his way on selection as it is difficult to argue against taking the lowest price - you can end up being responsible for the performance of the sub-contractor that you have selected"..	COST
	Lack of an apprenticeship system.	P

APPENDIX 9a(vi)
RECORD OF GENERAL PROBLEMS REPORTED BY INSURERS

INT	PROBLEM	FACTOR
13	Smaller builders make bigger mistakes!	SYST
	When things go seriously wrong (about 1/year for organisation) it usually involves a "catalogue of errors" rather than one major mistake - indicative of systemic errors.	SYST
	65% of mistakes are caused by poor workmanship.	P
14	Recession related defects with house-builders having trading difficulties.	COST
	Lack of control caused by companies having no directly employed operatives.	RESP
	Becoming "human nature to screw the other party".	SOC
15	Crux of all defects is poor education and greater awareness, supervision and checking on site..	SYST CHECK
17	Poor performance of a site is indicated by "the sub-contractors running the site" and starting to take short cuts to make money.	CHECK
	Problems caused by conflict in many building companies between head office and site (us and them) and relating to ordering plant, materials etc.	CULT

APPENDIX 9a(vii)
RECORD OF ERRORS AND PROBLEMS - SUMMARY

PRIMARY	MANAGERIAL										GLOBAL		
	Informal Comms	Formal comms	Change	Concurr -ency	Respons division	Planning	Checking	Organis cult	Manager	Systemic	Cost	Time	Society
ERRORS - SITE MANAGERS													
25	2	30	4			1	2				2	3	
ERRORS - SENIOR MANAGERS													
1		7	2			1	2		6		1	1	
ERRORS - INSURERS													
10	2	6					10		3	4			
GENERAL PROBLEMS - SITE MANAGERS													
4	5	16	4	1	4	3		4			8	9	
GENERAL PROBLEMS - SENIOR MANAGERS													
6		2	2	1			1	2	2		4	6	1
GENERAL PROBLEMS - INSURERS													
1					1		2	1		3	1		1
TOTALS													
47	**9**	**61**	**12**	**2**	**5**	**5**	**17**	**7**	**11**	**7**	**16**	**19**	**2**

APPENDIX 9b - OPEN INTERVIEW QUESTIONNAIRE FORM

QUALITY ASSURANCE IN HOUSEBUILDING

ANDREW R ATKINSON

QUESTIONNAIRE

OPEN INTERVIEW

ASSURANCES

The information provided in this questionnaire will be treated in the strictest confidence and not divulged to any other party. If you wish to review any answers at a later date or discuss the completion of the questionnaire, you are invited to contact me, Andy Atkinson at South Bank University, Wandsworth Road, London, SW8 2JZ, telephone 0171 815 7253.

Additionally, general queries concerning this research programme can be directed to Professor Victor Torrance, the London Master Builders Professor of Building at University College, London, Wates House, 22 Gordon Street, London WC1H 0QB, telephone 0171 387 7050.

GENERAL INFORMATION

Your name

Your position in your firm

Name of firm

Name and Address of firm

Telephone number

YOUR EXPERIENCE

In the construction industry generally

In your current role

YOUR BACKGROUND

PhD6/q5

APPENDIX 9c

OPEN INTERVIEWEES

No	ORGANISATION	POSITION	EXPERIENCE	
			INDUST	ROLE
1	Company 2, Region 2.	Production manager	39	10
2	Company 2, Region 2.	Commercial manager	16	3
3	Company 2, Region 1	Commercial manager	20	5
4	Company 2	Company managing director	24	7
5	Sub-contract company	Trade foreman	16	2
6	Company 1, Region 1	Building manager	29	13
7	Company 1, Region 2	Contracts manager (building manager)	22	10
8	Company 1, Region 2	Contracts manager (building manager)	38	13
9	Company 1, Region 2	Regional Construction director	25	9
10	Company 1, Region 1	Regional deputy managing director	50	7
11	Company 1, Region 1	Customer care manager	12	1

No	ORGANISATION	POSITION	EXPERIENCE	
			INDUST	ROLE
12	Company 1, Region 2	Customer care manager	u/k	u/k
13	Building Guarantee Company 1	Technical manager	33	8
14	Building Guarantee Company 1	Senior Development Underwriter	12	5
15	Building Guarantee Company 1	Principal surveyor	17	2
16	Building Guarantee Company 1	Area surveyor	12	7
17	Building Guarantee Company 2	Building inspector	20	10

Indust = Industrial
Role = In current role

APPENDIX 10a - OBSERVATIONAL STUDY TRANSCRIPT INCLUDING CONTEMPORARY AND ADDED COMMENTARY. 28 October 1996

STUDY PERIOD - 22 to 26 April 1996	POTENTIAL OR ACTUAL CAUSE OF PROBLEMS	RESEARCH COMMENTARY ADDED 17 July 1996 AS PART OF THE DIARY ANALYSIS
LOCATION **Company 1, Region 1, Site 23, Surrey.** **Ordnance Survey Reference SU96*58*** **CONTEMPORARY TRANSCRIPT INCLUDING RESEARCHER NOTES AND DAILY SUMMARIES WRITTEN AT TIME OF RESEARCH.** MONDAY 22nd 8.00 Arrive on site. Manager (SM) is on site already. Assistant manager (AM) arrives at same time as me. Site already very busy with a 7.30 start. Window cills have not arrived and SM is on phone to suppliers to expedite. AM has problems with door linings/stops deliveries for first five units (insufficient linings).		
Home-maker[1] problems to deal with on the 4 five-bed detached units - move a chimney, revise SVP position, change load bearing internal walls, upgrade garage to habitable room (110 walls to become cavity walls). Instructions have been given too late without proper drawings. (Possibly also problems with planning permission as off-site parking ratio is altered!).	Change Societal pressure	The problems of "home-maker" changes were to figure large during the week - they illustrated the potential for error caused by making *uncontrolled* changes late in the construction sequence. Many changes were made so late that completed work had to be pulled down (particularly on the more expensive detached houses under construction at the far side of the site - plots 34-37).

[1] Home-makers are bespoke modifications made by prospective purchasers of the company's houses. The facility to make such modifications are promoted as a sales incentive and offered by the site sales staff. A home-maker coordinator (HMC) agrees the modifications with purchasers, but without routine communications with the site or head office construction staff. The coordinator has an estate agency background and is not technically qualified to assess implications of modifications, some of which involve structural changes.

8.35 SM returns call re window cills. AM ditto re door linings.		
9.00 Walk round site with AM (Informal site inspection). Minor finishing problems etc:-		Checking and inspection of work by the site staff (site manager and assistant) was to be exclusively informal during the week - direct observation, exhortation and complaint often delivered in a robust manner, particularly by the (bricklayer trained) site manager (SM). The assistant manager (AM) was more conciliatory and adopted a much more overtly "problem solving" approach.
• Wallpapering - Show house wallpaper to beds 1 and 2 reversed (1 unit only) - should be the other way round and will have to be changed!	Primary Comms (Ambiguity)	
• Point for extractor has been fixed in the wrong position and will have to be moved.	Primary Comms	
10.00 Hard hat campaign. HSE (Health and Safety Executive) is putting pressure on sites generally, pressurising the site management, who, in turn, pressurise the workers. Workers (in this instance, Bricklayers) put hats on when agent/assistant walks round, but need to be continually reminded.		With reference to the hard hat campaign, safety was taken seriously, but no evidence was revealed that safety considerations positively benefited productivity (as reported in some literature - ACSNI (1993 for example).
10.45 Given task to perform - Complete materials received sheets - these reconcile materials delivered with suppliers' delivery notes. Basically, a routine clerical task which SM has to catch up on at home or in spare moments.		My task as a site clerk kept me occupied as I observed the site and helped me integrate with the staff.

10.50 EB (Electricity board) co-ordinator phoned by SM. SM is requesting electricity supply to part of the site, but Electricity board need to check whether:- 1 "They have a right to lay a cable there"[2] 2 They have received payment (The board demand payment in advance)	Changes Costs Systemic	Long lines of *communications* and *conflicting Company objectives* were illustrated by the utility company problems being experienced on the site. Large cheques were deliberately routed through very senior company management in order to give control. Senior management were physically located separately from the Regional office and had objectives, which did not always match those at site level. Hence there was a delay in authorisation.
SM Follows up (2) immediately. He explains that large cheques, such as that involved here, are sent to head office for approval. Delay can occur there and it looks (to him) that the electricity board have yet to be paid.	Comms	
11.30 Ground-works sub-contractor on phone with problem with detached houses.		The site office acted as a "communications hub" with several sub-contractors directly organising their operations through its telephone.
11.40 AM supervising fork lift driver unloading materials.		
11.45 Starts raining heavily and workers start covering up brick stacks and part completed work.	External	

[2] The position of the sub-station has been changed to another part of this 3 firm "consortium" site (on one of the other firm's land!) and a right to site the sub-station in the new position is not automatically available. WC, the Electricity Board "Way-leave Coordinator" has to check the legal details before any work can be carried out.

12.00 SM discussing problems of theft of materials over the week-end. People were, apparently, driving up and loading sand, bricks etc - "Treating the site like B and Q!" (B and Q is a large retail DIY store chain). SM decides to have entrance to the site blocked with heavy pre-cast concrete floor beams to stop cars entering in an attempt to reduce losses - action ordered from tonight.	Societal External	Influences completely external to the Company were limited to one very wet day and some minor materials problems, including theft noted here.
12.30 SM ordering materials for plots 42 et seq. AM on phone to cleaners - need to have show houses cleaned and ready by the week-end.		
12.36 SM on phone to arrange for show cabin and huts to be moved to a new location at the week-end. There is a potential problem here as moving the huts requires a larger crane than available on site, but the head office surveyors do not want to authorise the cost of a larger crane.	Costs	A large element of the activity in the site hut consisted of very short term (1-8 days) planning on the telephone. Here the site manager was arranging for the site office to be moved to a new, more convenient, location on the site. The problem of needing a larger crane than was available on-site illustrated both the influence of cost on performance (and in this case, safety - too small a crane was dangerous) and conflict within the Company. Conflict between cost considerations (as personified by the influence of the Commercial Director and quantity surveyors) and performance/quality (as personified by the site management) featured quite strongly during the week
12.45 Bricklayers all stopped work - poor weather.		
12.45 Awaited cills for windows turn up and are ready for installation (4 units) tomorrow.		
SM reflects on importance of planning. He notes that AM can be forgetful at times with planning - "can't afford to be forgetful with planning".		Planning on the site was <u>not</u> evidenced by any form of written bar chart or CPA programme other than the use of the "white-board" noted below. Rather, it was evidenced as an ability <u>within</u> the site manager. An important element of that ability appeared to be a very good short/medium term memory - referred to here in the site manager's comment about the assistant. The use of memory in planning is shown in the study, particularly at the end of the week.

12.50 Sales meeting with site sales staff and AM in sales cabin at the front of the site.		
Customer/sales liaison problems **Plot 35** • customer querying positioning of doors/partition around WC • customer querying the implementation of home-maker alterations (changing garage into study) - door to garage not put in wall. • customer querying length of wall around utility room (Blockwork taken to end of doorway by mistake). Meeting covered progress over site on reserved and sold units (for feeding back to customers/planning future sales load.	Societal Economic Changes Comms "Systemic"	
Informal discussion ensued covering general home-maker problems - home-maker instructions often received too late in the programme. This causes post-completion maintenance budget to rise (£250.00). Anecdote mentioned of the "extreme home-maker" on Site 16 (an adjacent site being constructed by the Company), where three flats were changed to one extremely large unit, with considerable technical and programming effects.	Concurrency Changes	The influence of purchaser power was felt strongly on this site. The tight economic climate led the Company to "bend over backwards" in pandering to its customers. Informed purchasers, particularly those buying expensive detached units were, in some cases, taking full advantage of this. The illustrations here support findings in the interview study, that external customer influences have become much more prominent. Communications and planning at site level generally, including between sales and construction staff were informal and friendly.
Discussion developed to cover site/head office relationships:-		Some friction, perhaps caused by remoteness and conflicting objectives, was evident between the site staff as a whole (us) and head office staff and management (them). This could be a problem of lack of good communications or participation by the more senior head office management.

Attitudes - head office don't care too much and this tends to be reciprocated by site. Lack of positive feedback - head office "only let you know when there are problems" (Sales and construction personnel on site agree on this!). 14.45 Materials deliveries and positioning by SM 15.00 SM/AM phone "mastic pointers" to arrange their programme for the week/next week. SM general comments and discussion on provision of services for the site:-	Culture	
1 Water main is not connected as connection bill was not paid at the year end in December (in order to improve the Company's cash flow!). Still not paid at beginning of April and consequently water may not be on until June!	Costs > > (Potential) primary error "Systemic"	
2 Work will be finished in several units but water services will not have been tested thus any plumbing leaks will damage finishes etc, when water is supplied. 3 Similar problems are faced with Gas/Electric all caused by too fast a building programme.		

Management of finances are directed from the top in order to suit year end accounts and tax year and not necessarily building programme.		The water main problem illustrated the influence of cost and conflicting orientation/objectives between more senior management and the site. The example of the water main showed that influences can have a hierarchical structure. That is, the failure to pay the connection charges because of wider Company considerations **fed into** or **led to** problems of having to install the main at the same time as completing the dwellings. i.e. wider economic considerations (classed as "Global Influences" in the model) led to problems of concurrency (classed as "Managerial Influences" in the model). Problems of concurrency left no opportunity to correct relatively inevitable "primary factors" such as a poorly trained trades-person not jointing a pipe correctly. However, blame was unlikely to be attributed to economic pressures when finishes were damaged in a particular unit.
15.15 SM/AM on site checking progress/quality. AM driving fork-lift truck.		Both site manager and assistant adopted a very participative approach to managing and evidenced this by driving the fork-lift or carrying out some minor work tasks.
Problem of some window units not fitting tightly in their blank openings.	Comms	
15.30 Wallpaperers requesting lighting in order to work in internal bathrooms (no windows!) - lighting is supposed to be provided in decorator's contract, but programme for show houses is very tight. AM on phone to try and solve problem with Company buyer. Buyer prefers that decorators supply lighting and charge Company for hire if Company eventually accepts responsibility.	Comms Multiple causes	The problems of lack of light to internal bathrooms and no provision for generator supplied lighting appeared to stem from two causes - firstly the failure to connect the main supply caused by late payment of the charges (and stemming from economic pressures on the Company plus a legal connection problem noted below). Secondly, a failure in formal communications, in that the "internal" nature of the bathrooms in question was not drawn to the decorator's attention. Even if it were, it is almost inevitable that the decorators would assume that power was available unless direct reference was made to the need for lighting in specific instances
15.45 Phone call from home-maker co-ordinator (HMC) - changes to plot 36 (currently at slab/first lift stage):-	Economics > Changes Systems	Changes caused by late home-maker requests **not properly controlled** caused some re-working and gave rise to several potential defects in the finished units - see below.

• Move wall to rear garage forward by 750mm and upgrade 110mm wall to cavity walling, provide steel support over to take roof load (See sketch at end) • Provide French doors in lieu of patio doors and place in revised position. • Redesign kitchen layout • Move radiator. • Re-hang some doors to other hand. • Replace rendered feature bay fronts with brickwork (i.e. demolish and re-build fronts) • Provide double in lieu of single doors to bedrooms 2 and 5) • Increase width of shower cubicle to 900mm. • Reduce size of linen cupboard slightly. • Replace wardrobes with better and bigger units. • Increase size of loft access. • Provide brick paviors to the whole driveway. • Replace front door with better quality one. • Provide obscure glass in door to lounge/hall. • Provide loft light. • Provide electrical installation to TV/Satellite installation.		

All of these have to be dealt with on site (starting from 16.20) 16.20 AM checks with CB (Buyer) provision of revised materials for the above.		
16.30 Steel beams on "Fivebed" house type found to be wrong - two at front of garage called off too short (2100mm instead of 3730mm) - AM back on phone to buyer to sort out problem.	Comms	This appears to be a mistake in the steel beam schedule for that house type - a failure in formal communications. It illustrates a "process stream" model of construction and how errors "upstream" can influence performance "downstream". The error in the schedule is probably a "primary" error (but made at a higher managerial level) in transposing details from drawings or specification to schedule.
16.50 Left site.		

<u>COMMENT ON KEY EVENTS AND POINTS OF THE DAY - Written up at 20.30</u>

1 Fire brigade/short term management

- Window cills not delivered
- Incorrect door lining deliveries
- Wallpaper specification in 2-bed houses incorrect and corrected on site.
- Planning for next week's programme (mastic pointers).

2 Problems caused by late changes - mainly customer/sales induced (Home-makers)

- Upgrading garages
- Moving partitions etc as plots 35/36

3 Communications problems (with home-maker scheme)

- Sales to home-maker co-ordinator
- Home-maker co-ordinator to site construction staff.

4 Conflicting objectives (especially quality/specification with time and financial corporate objectives)

- CF payments to water/electricity utilities held up (to miss year end/tax year etc) by Corporate Head Office.

5 Planning methodology.

Tends to be "in the head" and short term. Interesting comment by SM that AM forgets some things and this is a planning failing.

6 Interpersonal and inter-organisational conflicts.

- Between site managers and sales office
- Between sales office and Home-maker co-ordinator
- Between both sales office, construction staff and head office.

CF lack of positive reinforcement:-

"They only let you know when there are problems"

"They don't seem to care too much and this can rub off on us".

Comment by SM that the Company is poor compared to his previous firm.

7 Sundry errors and correction items

- Windows not fitting
- Walls built in the wrong place
- Wallpaperers needing lighting for internal bathrooms
- Steels for "Fivebed" house type wrong.
- Electrical points in the wrong place.

8 Role of externals - Weather problems at 11.00 and subsequently all day.

9 Building programme projected - Jan 1996 to Sept 1996.

TUESDAY 23rd		
7.54 Arrive on site		
7.58 Window installer asks for details of windows - referred to agent out on site.		
8.05 SM looking for bricklayers to continue ground-works (footings) brickwork - stopped yesterday because of rain and failed to turn up this morning.		
8.15 Call off materials plots approx. 50-60		
8.40 SM phone to Water Board to check that main to be installed next week.		
8.45 Walk to meet other agents in site consortium[3] concerning access for the Water Board installing their main - the route of the main must be clear of plant such as scaffolding and materials. Walk back through site with SM.	Checking Comms	Communications with "rival" site managers on adjacent sites were informal and direct.
• Check delivery of PVC windows and complain to installers about vagueness of delivery dates.		Checking and control largely consisted of "walking" round the site with eyes open. The success of this strategy appeared to depend on very regular walks and good technical experience (the manager knew what to look for) rather than any adherence to checklists or organised procedures.
• Ensure adequate concrete for lamp standards - SM uses direct, robust approach with ground-worker (authoritative, gruff, but friendly and cajoling at the same time).		

[3] The site was originally approximately three times bigger than at present and two thirds were sold off to two other major house-builders in order (presumably) to improve the Company's finances in a difficult trading period. In order to deal with common town planning, services and roads issues, the three companies were constituted as a consortium with agreed legal terms.

• Check levels and access to homes on first four plots (show houses). The problem here is that the step down from houses to paths and parking bays is too big. 9.15 Fencers have not arrived yet to install fencing around entrance areas, show houses and show cabin (in its proposed new position) - SM on phone to fencing company to re-plan their schedule. 9.20 AM comments that plasterboard jointers have not arrived after being put back because of non-delivery of window cills (The jointers cannot work inside the units unless the windows are glazed **and** the window installers are out of the way). 9.30 Ground-worker (GW) on phone trying to get hold of a hired laser level or the one on hire repaired - the existing one appears to have moisture in its works after the heavy rain yesterday. 9.35 SM on phone to call off door frames from joinery company. 9.40 PD, the painter boss (Director/owner of the decorating sub-contract firm) comes into site office for a chat. Decorators are currently working on the show houses and are under some pressure to complete - completion of the show houses is required by the end of the week ready for inspection by the Company senior management (including the Regional MD) next week.	Comms	The influence of the construction programme and the need for good planning <u>**and**</u> performance from external agencies (the window suppliers) can be seen in this incipient delay.

10.00 BM (Line building manager - SM's immediate superior) visits the site to generally check progress, support the site staff and discuss problems. Uses a supportive, empathetic style, clearly exhibiting his roots as a tradesman and "site person". Problems discussed:-		The relations between site manager and building manager were good and mutually supporting (both come from a bricklaying background). Physical presence and a "problem solving" approach illustrated a participative culture.
• Electricity Board problems related to the installation of the mains stemming from "consortium arguments" in the positioning of the sub-station. Originally was to be on one of the other members portion of the site, but this was not "cut and dried" in the conveyance agreement between the consortium members. The consortium member concerned no longer wants the sub-station on its portion (presumably for aesthetic/sales reasons), but the third member of the consortium is prepared to have the sub-station on its portion. However, the legal mechanism of the changes of position (Way-leave) remain to be completed and ensuing delays mean that only about 8 weeks remain to install mains and sub-station.	"Systemic effects" Economics > Time > potential error	The sub-station "way-leave" problem, together with late payment of the electricity company, was likely to influence the performance of the site as a whole and magnify the impact of errors by trades-people. Lack of power had already affected decorations (see above) and would delay both sales of houses and testing of electrical installations. Again, a wider Company problem had managerial implications (concurrency), eventually having tactical, primary implications.
• Progress planning - re-positioning of sales unit, finishing "small units" (first phase of the Company's site), finishing footings for the rest of the site. All discussed/planned informally during a walk round the site by Building Manager and Site Manager.		The discussion of progress planning and the problems of disposal of "muck" on the adjacent site illustrated the use of informal communications (upwards and downwards) allowing issues to be dealt with.
• Warning on problems of disposal of "muck" (surplus excavated sub-soil) - not to be dumped on another consortium member's site! - The other member will check site levels against conveyance drawings and legal action may ensue!		

• "Home-maker problems discussed (plot 35-36 especially) - steel beam not to be put in plot 35 garage roof (to support construction where wall below re-positioned to suit purchaser), but construction to be supported on timber (no calculations/drawings provided to support this decision - they may arrive later?). General discussion ensued on whether home-maker changes should be allowed - they are advocated by senior managers in order to achieve sales, but not liked by construction staff. It was felt by BM/SM that if changes were to be allowed, they should be better managed. There is a need for a technically qualified design/construction co-ordinator to deal with home-maker type problems.	Changes	The inevitable nature of many project management problems was illustrated in the discussion of the use of "home-makers". It was generally agreed by all staff encountered during the week, that sales were of primary importance and to achieve these the purchaser needed to be appeased. Hence an apparent conflict between sales and senior managers and the site over the home-maker policy was seen here as really one of how to manage change induced by "home-makers". Accommodating changes was necessary and even desirable, but should be properly controlled through a design/construction co-ordinator. The failure to provide such an individual was probably driven by costs - hence another conflict, which could be eventually reduced to that of sales needs versus their costs!
• General problem of starting sites too quickly pointed out by BM - no firm planning permissions (started "on risk"), no settled run-in (time lead-in) for services provisions etc. 10.50 PD (painting sub-contractor) returns and expounds on quality (he links quality to selection of trades people). Considers that he now has a good set of painters, but he has "had to get through a few". PD gets on well with SM - both have a very direct approach and SM considers PD a good performer, making very good progress. (Note - appears that a good memory, feel for the job is important for this type of construction)	"Systemic" effects - Time > concurrency > error	As far as quality is controllable at the work-face, the painting sub-contractor re-iterates the view that quality depends on selection of the worker and this will involve some shuffling of the pool of workers in order to get "the right selection".

11.10 Interview with BS, bricklaying foreman (see separate sheet) (NB his comments on pace of work). 11.15 SM on phone to landscaper concerning turf laying for this week (around show houses) - more short term/informal planning. 11.50 Visit to "penthouse flat" on other Company site (16) in development[4]. A customer purchased three top floor flats, in a block of 9 on three floors (i.e. the whole of the top floor of a block), and wanted the flats knocked into one and the specification upgraded. Work is currently at "second fix" stage plus paving and landscaping, with scheduled "legal" completion on this Friday[5]. The carpets are due to be laid tomorrow (Wednesday) in advance of some second fixing work! 12.00 Back in site office. SM on phone calling off timber (joinery order for week commencing 6/5/96). (Appears that management of site depends on individual energy of manager, good memory, informal planning - "white-board planning" - delivery dates (materials provision appears to be the key restraint) are written on a large white-board in the site office as they are scheduled on the telephone). (N.B. Work and activity comes in waves - hectic then quiet then hectic then quiet and so on).	Systemic effects - Economics > change > error **and** Societal > Time > Concurrency > error (Multiple systemic causes)	The finishing of the "penthouse flat" illustrated <u>concurrency</u> in action. Carpenters, painters, plumbers and electricians were all frantically working together to complete in an extremely short time. In this case the concurrency was again **driven** by other forces - the desire to accommodate **<u>change</u>** stemming from **<u>global</u>** *customer demands*, ultimately driven by wider **<u>global</u>** economic considerations.

[4] The development consists of a large area of housing in the grounds of a hospital for the mentally ill. The hospital remains in use, but due to changes in hospital treatment, especially the move towards "care in the community" some buildings and most of the grounds are no longer required for hospital use. They have accordingly been sold off for development and the company have two sites in the grounds spaced about 0.8km apart. As mentioned above, one of the sites was further sub-divided into three and two portions sold to other house-builders in a consortium arrangement.

[5] On legal completion, the purchaser owns the property - this cannot take place without works being substantially complete.

12.15 Lunch in the site canteen (Number 1 breakfast - large traditional egg/bacon/chips meal taken with the trades people and other consortium managers) This type of meal is not universally popular with staff and many prefer lighter meals - on this site there is an alternative of eating at the adjacent super-store restaurant. 13.05 AM on phone to check delivery dates for materials. 13.50 AM on phone chasing electrician for progress - wanted on site for Thursday at the latest (to finish show houses).		This site and the adjacent consortium sites were relatively democratic in their eating arrangements in that managers and workers from all three sites shared the same canteen.
14.00 AM on phone - problems with wallpaper to show units - the paper requires a ready-mixed paste and will not stick with traditional paste (pieces are falling off the walls). The decorators have not priced for ready-mixed paste and, as the Company has supplied the paper, they feel that this is an extra. A fear has arisen that there may not be enough paper now to finish show houses for the week-end and the paper has a long order/delivery time for additional rolls.	Comms Costs Multiple independent causes	A conflict on <u>cost</u> was evident in the wallpaper adhesive problem.
AM on phone to home-maker co-ordinator to discuss wallpaper, but no reply - he thinks that all surveyors/staff are still at lunch!		The view that all the head office staff are still at lunch illustrated the gap in communications and attitudes mentioned above between site and head office.
14.30 Cleaners are booked for Friday (to clean show houses), but have not been warned about lack of power, lighting, or hot water. AM on phone to try and warn cleaners but keeps getting answering machine. Internal door suppliers have let site down (show houses) - they cannot supply doors until Thursday because <u>their</u> suppliers cannot supply until Wednesday.	Multiple Systemic	

14.45 Wallpaper paste (ready-mix) cannot be delivered until Thursday as order was not made until PM today - it is needed immediately. SM comments that site staff are not allowed to buy paste directly from adjacent DIY super-store because of head office imposed "cost implications". 14.50 SM on phone to get windows fitted to plots 120-123 so that scaffolding can be dropped. AM Back to home-maker co-ordinator to progress ready-mixed wallpaper paste. Agreed that this is now to be provided by the decorator - the paperhanger is to call at a trade supplier this evening to collect paste for use tomorrow (Wednesday). 15.10 Conversation with GW, ground-works supervisor concerning problems etc. Excavation depths are given by the Company, but contract is taken with depths at the ground-workers risk - thus if deeper dig or soft spots are encountered these have to be handled without extra payment to the ground-workers. However, there is not normally any problem here except the occasional setting out errors by site engineers. 15.55 SM on phone to change order for skips - yet another one is filled up. Now to be 3 exchange skips delivered in the morning in lieu of 2. 16.35 CB (Company buyer) visits to deliver lintel schedule for plot 35. He is asked for beam schedule for pre-cast pre-stressed concrete floor beams.	Costs > Comms > error Causal system	

16.40 SM planning tomorrow ground-works with GW (ground-worker supervisor) - sequence of paving, patios etc. They cannot finish some until power cables are installed. 16.50 Left site.		The discussion between site manager and ground-works supervisor again illustrated the nature of short term planning on the site:- • Informal • Face to face meetings • Very frequent • Short time horizon • Unwritten - relying on memory (except for memo type notes on white-board).

COMMENT ON KEY EVENTS AND POINTS OF THE DAY - Written up at 20.00

1 More short term (1 week hence) planning:-

- calling off materials - door frames, roof timbers etc.
- arranging sub-contractors for fencing, plasterboard jointers, cleaners, landscapers etc.

2 Use of "white-board", rather like a public diary, for short term planning. A diary can get lost, forgotten etc and is less visible!

3 Solving short term problems:-

- getting bricklayers back after yesterday's rain.
- getting fencers to turn up

4 Nipping problems in the bud - short feedback cycle of checking and control.

- adequate concrete to lamp standards.
- steps down from show units to parking bays too steep.
- no muck to be dumped on the adjacent site.

5 Planning bigger operations:-

- installation of water main through adjacent sites.

6 Changes as continuing problems - home-maker changes as yesterday.

7 Wider organisational problems:-

- services problems with electricity and water.
- Home-maker changes not properly co-ordinated by head office.
- No organised run-in for sites.

8 Essential elements of site management:-

a) Good short-term memory

b) Compulsive action:-

  - continual follow-up on phone
  - keep in front of problems, e.g. muck on adjacent site, concrete to lamp standards.

c) Use of visible planning on white-boards.

d) Good feel for where job is:-

  - e.g. knowing that cabins/show suite to be moved at end of week, that fork lift trucks cannot move cabins and that larger cranes are needed.

e) A reliance on "just-in-time" planning:-

  - i.e. an expectation and demand that things will happen now, tomorrow or the next day at the latest.

f) Where appropriate some advance notice, but all planning largely "in the head" or <u>confirmed</u> with Company imposed plans.

(General note - SM is highly regarded by several sub-contractors as well as the senior managers in the Company - Managing Director, Construction Director, Building Manager).

WEDNESDAY 24th		
9.05 Start on site. Task to sort/file timber schedules for house types. SM at top of site (show houses) supervising tarmac laying to parking areas.	Checking (Direct supervision)	Continuous supervision was used during the week, but only directly witnessed here. The building manager related an anecdote of this site manager allowing the incorrect tarmac to be laid on a previous contract and, perhaps, this is why he was giving this operation such attention here!
9.10 Taking photographs of site and entrance for research report.		
9.40 SM talks to forklift driver concerning work required.		
Surveyor on phone concerning changes to a unit		
Sales staff visit site office to request further changes to plot 36.		
SM points out "a sign of a good tradesman - he always brings a sweeping brush with him!".		The link between tidiness and quality was used elsewhere in the research.
9.50 Problem with Company cheque for electricity supply - now written out but has to be signed by Group Chairman because of large amount - yet further delay will ensue.		
(<u>Researcher contemporary notes</u> - Company seems to use pressure from below to activate management system above i.e. when the site start to shout then something happens..		

Long lines of action and communications, delay in action, conflicting objectives (orientation - Turner), profit/cash flow versus production, lack of overall planning (strategic project planning) and concurrent working. Concurrency applies to planning, design, procurement, construction, but probably not as badly as with major "contract" works. It is handled by fire brigade management, short term planning, compulsive/reactive styles)		
10.00 Ready-mix concrete supplier phone to confirm delivery of concrete with ground-works supervisor (GW).		Continual short-term planning and compulsive confirmation as witnessed with the concrete supply appeared to be a feature of day-to-day planning.
10.30 Dry liner on phone (outwards) asking for boards and bonding plaster.		
10.35 SM chases up "hard hats" - "If there's anyone out there without a hat on can you whack them over the head with a f...... shovel!" - to labourer "Patsy, where's your hard hat? Put it on your f...... head then!"		Safety issues treated as a "given" and measures enforced by "direct communication" where the object individual was near enough!
10.45 SM driving fork lift truck. (When work demands it both SM and AM will carry out trades/general tasks - taping, jointing, making good, driving, handling machinery etc).	Culture - participation	Participative management in action
10.55 Joinery sub-contract surveyor on site measuring staircase openings for pre-made staircases - i.e. not happy to work solely from drawings.	Comms	A certain lack of trust for formal communications, or an allowance for design mistakes based on experience, illustrated here. Maps on to exhortations by Norman (1988) among others to "allow for error".
Bricklaying foreman (BS) checks work required against schedules in the site office.		
Delivery of staircase trimmings - put in secure store.		

11.30 SM not in office so bricklayer foreman says he will "make the decision himself".	Responsibility	A failure of the formal communications system resulting in trades-people making their own decisions (for better or worse).
11.40 AM Rang in to remind SM to take paper up on floor of plot 132 for vinyl to be laid tomorrow (This allows the concrete screeded floor to dry sufficiently for the vinyl to stick). (Another example of compulsive planning behaviour - think -> phone in -> do!).		
NB AM is not on site today as he has to take his baby daughter to hospital for some checks on her vision - SM suggested yesterday that he come in if he can manage it, but otherwise take the day off.		
NB errors noted by researcher on site walk round - square foundations to splayed bays over (probably not a serious problem, but stems from alternative designs for bay windows and changes to plot allocations of bay types).	Economics > Societal > Changes and Comms	
12.15 Trip to area being excavated in order to learn how to use the laser level (an offer of tuition was made by GW, the ground-works supervisor). However, the team is still using a "dumpy" level and will not take delivery of the laser until this afternoon (advantage of laser is that it only requires one primary, whereas the dumpy needs three!).		
12.30 Discussion with SM concerning site accidents in his experience:-		
• A dumper over-turned into a basement construction and buried operator in concrete.		

• A labourer was impaled on a reinforcing bar dropped down a lift shaft during careless cleaning operations. Both victims survived their accident. 12.45 GW on phone to chase up laser level - not to be delivered and talk on other end of bill not having been paid! **(Text of site office "white-board"** Intl drs and linings 120-127 del 24/4/96 Int ironmongery 120-127 " 24/4/96 Skt/Arch plots 120-123 del on 26.4.96 W/bds 103-109 del on 26-4-96 Kitchen line Plot 132 25-4-96 2 x 1 quadrant 300m ASAP told Bill to order plots 103-127 trap hatches. 1 load 4.2N blocks w/c 22.4.96 Floor beams 59-67 - 2/3 May Joists 115-119 w/c 29/4/96 Windows 120-127 Fitting w/c 15/4/96 Roof trusses 34-35 w/c 29/4/96 Roof trusses 36-37-38 w/c 6/5/96 " " 110-119 w/c 13-5-96 Roof timbers 110-119 w/c 6-5-96 Front doors 120-127 6.5.96 " " 103-109 2.5.96 " " 110-119 3.6.96 Porch 16.4.96)		The "white-board" was the only evidence of formal planning at the site level. Nevertheless, there was no evidence of tasks and deliveries having been forgotten or incorrectly sequenced. On the contrary, the site management appeared to be on top of the process and failures of progress caused by possible poor planning were rare (and usually limited to failures to "chase up materials" sufficiently rather than failures to plan ab inito). Thus, the planning was there, but contained in the memory of the site manager.

(SM is out on site for approximately 50-60% of time during the day - in and out like a yo-yo, a very restless character:- • Supervising • Checking • Moving materials • Short term planning) 13.45 Take message from window installer's office - the installers do not need to return to the office to pick up goods for the next day. SM off on the site to catch kitchen fitters to get them to finish off in the show units. 14.15 Take message for wall-paperers from the sub-contractor supervisor (PD).	Participation Checking Comms	
14.20 Sales personnel visits site office to discuss dimensions around the WC for plot 35 - purchaser particularly wants 24" between doors and rear of room.	Economics > Society > Changes > Errors	
14.30 Tree surgery work around the show houses has not been carried out - not now a good time as trees are budding. SM comments that it should have been done before all work started on the site and that the trees now make the show houses dark inside. 15.00 Painters/paperers on phone (outwards) trying to contact their boss for payment!		There was some evidence of **poor planning** at the overall project and Company construction programme level. The failure to prune trees at the correct time was one such instance of failure.
SM and GW chat about a good fork lift truck driver working on the adjacent consortium member site. SM had offered him a job, but he did not want it at the time. (NB obtaining workers by word-of-mouth recommendation). 15.30 SM personally taking up paper from floors in show house ready for vinyl laying.		The attempt to "poach" the fork lift truck driver was evidence of the importance site management attach to the **selection** of the individual in achieving performance.

15.45 Chat with GW about his private work in renovating his own houses - he has renovated and subsequently sold about four houses and as a consequence has made enough money to have no mortgage and buy a house in Ireland. Talks about his hobby of ballroom dancing - an incongruous hobby as he personally is a large thick set man[6]. 16.30 Bricklayers pack up and most workers start to leave the site. 16.35 Leave site.		

COMMENT ON KEY EVENTS AND POINTS OF THE DAY - Written up at 18.00

1 Key role of site manager

- Sort out problems as they arise on site - out on site 50-70% of the day supervising, advising, checking, very short term planning and not allowing problems to develop. Planning on the white-board as text above.

2 Planning ahead and then following up to make sure plans are still on target. For example:-

- ready-mix concrete supplier phones GW to confirm concrete deliveries.
- Joinery sub-contractor surveyor checks on site the measurements for stair openings.
- AM reminds SM to take up paper from show house floors.

3 The electricity board cheque saga - conflicting organisational orientation (Turner 1978) - profit/cash flow or production?

4 Participation

- SM/AM Both drive the fork lift when necessary.
- AM Working on show house finishings.
- SM taking up paper floor protection in show house. (NB he also remembered to do this some time after the reminder!).

[6] Apparently this was also considered somewhat incongruous within the foreman's own firm. His boss had a photograph of the foreman in a tuxedo on the wall of the office and took delight in pointing it out as being of his best foreman - "the dancing ground-worker".

5 Tidiness as an indicator of quality - "sign of a good tradesman - he always brings a sweeping brush with him" - SM.

6 Safety issues

- Continual compulsive "hard hats" reminders.

- Problems with ground-workers installing sewers and working in un-sheeted deep trenches. SM mimics the labourers concerned:-

- ""But I'll only be in there for a minute" - you'll be in there for a f...... sight longer than a minute if you don't get out now!"[7]

- Anecdotes on safety issues noted above.

- Attitude to children and customers found "wandering the site" (i.e. they are told to leave immediately)[8].

These points all indicate that safety is treated as a "given" rather than a positive production bonus. Safety does not help productivity (at least in the short term), <u>but</u> is still taken as a very serious "given".

7 Concurrency as a problem (poor head office planning)

- No run-in

- Starting "at risk" etc.

- Tree surgery work still not done.

8 Selection by work of mouth recommendation (fork lift truck driver).

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[7] The ground-works problem arose on this site and was discussed at some time during the day, but only recalled and noted in the evening.

[8] An incident where prospective purchasers appeared round the corner of the site hut occurred during the day, but was not recorded at the time. The manager (SM) politely but firmly asked that they leave for safety reasons.

THURSDAY 25th		
8.00 Arrive on site		
8.05 Problems of performance of electricians - the sub-contractor cannot provide labour over the next two days to second fix the show units and smaller "top units". Poor attendance on previous job (the other Company site on the same development) has lead SM to be wary of the firm's performance on this job. He was persuaded to give them a go by the surveyors in the Company (i.e. on cost grounds - a conflict between price and performance).	Costs > Selection > Error (Systemic effect)	Cost pressures were illustrated here and set against (conflict with) performance (time) requirements.
According to SM the "electricians won't do what I want them to do" - they are required to change the fittings in the show houses from plastic to brass rather than work on second fixing other units where painters are still working. In their turn, the electricians are claiming that the show units are not ready for the second fix change over as they are still being wallpapered on the ground floor. SM asked for upper floors to be done. The upshot of this difference is that SM put the electricians off the site and contacted the sub-contractor's office to inform them. 4 minutes later the firm calls back to say the electricians will do the show units as requested.		The coercive nature of control exercised in this instance by the site manager proved to be counter productive in that it appears a disgruntled electrician may have deliberately broken a WC pan (see below) as a result of this abrasive argument. A more conciliatory, participative approach may have avoided such action at the same time as getting the required performance.
Apparently the underlying problem is the poor price being paid by the sub-contractor to their electricians for second fix electrical work, thus they prefer to work on easy units rather than harder remedial show units.	Cost	
(The method of control/communications adopted by SM is very direct and robust trade-based approach and includes some brinkmanship. Hence the "sparks" are off the site, then back on the site!)	Comms	

8.30 More home-maker problems in Unit 34. Layout to study/garage has been changed to extend study into garage area. This has the effect of either extending the span of some upper floor joists, or requiring an intermediate beam support. The home-maker co-ordinator has indicated layout changes but:- • No technical details are provided. • No consequential problems handled (e.g. planning permissions or building regulations requirements). • No changes to orders for floor joists, steel beams made.	Systemic effect as before Changes	This set of changes illustrated the consequences of uncontrolled change pointed out by such authors as Petroski (1985). In the current small example these extend to wider issues of planning permissions.
9.20 SM has a look at plot 34 and then to top of site to observe tarmac topcoat being laid in show house parking bays. 9.35 Roof truss company phones to confirm delivery of trusses for 1/5/96 (Again, a good short term follow-up, short cycle planning - Just-in-time style planning). 9.50 Ready-mix concrete supplier phone to try and deliver concrete earlier than required - GW has told them to deliver no sooner than 10.30!	Checking - supervision	

9.55 PD (Painter boss) has a problem with the quality of wallpaper - it will not go on (in one show unit) and looks poor. He contacts Company head office on instigation of SM to try and get a decision on changing the paper (Which is a plain yellow "rag roll" effect paper prone to showing imperfections). He has suggested lining the walls, but has been told by the head office to carry on papering at the moment. 10.20 SM on phone to BM (Building manager) - electricians come up in the conversation and SM explains problems with them not complying with programme etc.	External problem	The problem of the appearance of the wallpaper illustrated aesthetics as a "defect" - in prominent positions such as the entrance to show houses, such poor appearance could have severe (economic) effects.
10.35 More home-maker problems on plot 36. Purchaser looked around the site last night and complained that home-maker alterations had not been put into effect. Apparently 1200mm wide rear door to kitchen is required, but 1500mm wide opening has been left. The home-maker co-ordinator had not communicated change in door size. With all home-makers, alterations are made on A4 faxed paper and not "full sized field drawings" (Kaminetzki 1991). They lack precision and detail and are often too late! (Appears to be a lack of construction stage architectural role, when this role can be called for). 11.00 HOS from head office phoned to confirm what information had been provided for plot 36 home-maker - not at all clear from the drawings.	Comms	Illustrated poor formal and informal communications, particularly in relation to <u>changes</u>. This maps on to points made by Kaminetzki (1991).

11.20 BI from the Building Guarantee Company on site for inspection. He was watching the concrete placers pouring concrete when mixer/driver added water to the mix as it was being placed (in order to make the concrete flow better into the trench). This would affect adversely the strength of the poured concrete and BI objected and insisted on obtaining further advice before approving pour. He phoned Guarantee Company head office engineer to see whether this was a real problem and this was confirmed! BI is to write to Company head office to point out issue and will later consider any further tests/measures that may be required. (This is a "classic" violation as Reason (1990) - a short cut to "take the easiest path". Successfully picked up by inspection, but now concern is raised over concreting to the whole site)[9]. SM is "not too concerned" about the problem, He points out that the ground-workers are contracted to take all such construction risks and will have to replace concrete if required. Nevertheless, knock-on problems over the issue could cause delay affecting other trades and the Company.	Simple violation - primary error	This event fitted into the category of "violations" pointed out by Reason (1990).
On BI "condemning other foundations SM points out that the Guarantee Company should be here all the time inspecting, but the "trouble is that you can't inspect everything all the time" (i.e. the recognised QA problem of not being able to inspect quality into the works - Oakland (1993)).	Checking	

[9] In fact, a visual inspection reveals that this appears to be an isolated failing - the foundations to the detached unit with the "watered" concrete are clearly distinguishable the next day as having characteristically "glossy" surfaces, unlike the rest of the foundations.

12.00 Problem of what the correct plate height is on the "Fivebed" house type (plot 35) - no section is shown on the drawings. This is left for the bricklayer and site manager to sort out on site. (Poor communications - the lack of a section - decision left to the site rather than designer - this indicates a role for a "technical co-ordinator" for these communications problems and to deal with "home-makers").	Comms> error	The lack of a section illustrated poor formal communications, which, in this instance, could easily be redeemed by reference to a qualified party such as a designer. The Company designers were located some 200 miles away and there is no locally based skilled design co-ordinator.
12.05 Buyer (CB) phones to inform SM that the opening sizes for French doors in plot 36 (subject to home-maker changes) should be 1267mm and not 1200mm. The latter opening will be too small. SM decides to suspend work on unit until proper drawings and instructions are given - "no point in spending too much time when details keep changing".	Systemic Comms> error	Again, poor communications in relation to changes were evidenced here.
12.20 Bricklaying supervisor (BS) reveals problem with lintels to the "Fivebed" house type (plot 35) not matching up with the lintel schedule. Some changes appear to have been made by the lintel supplier to suit their supply and to suit the "cottage eaves" house details.	Comms Changes	Poor formal communications and changed suppliers were evidenced here.
12.45 SM on phone to fencing sub-contractors - worried that fencers have left site as post holes were not dug in preparation for them. The holes are now dug (10 minutes later) and job is ready to proceed, but fencers have vanished.		
12.50 Lunch/breakfast		
13.15 Counting lintels to plot 35 and checking against drawings and schedules. See "Fivebed" problem above.		
14.15 Pass list of lintels drawn up on site to BS (bricklayer supervisor) for use on plot 35.		

14.35 SM chasing order from head office for timber external boarding for next week - more short term planning. 15.30 SM on phone to electricity company to try and progress electric supply. Electricity company have still not been informed of sub-station position and supply situation. SM comments that "16 houses will be completed at the end of May and they will have no power at all!". Further associated problem is that "the electricity company have put the new sub-station position to the Borough Council and they are not happy with the position because of its prominent position and the lack of screening". I.e. a knock-on effect is the need for alterations to planning approvals. (A good example of concurrency, with a lack of control stops, indicative of poor <u>overall</u> planning viz., introduces:- • Legal problems • Town planning problems) Negotiations with the consortium, the planners, the services supply companies etc is the responsibility of the commercial managers (quantity surveying background). 15.45 Go to the top of the site to learn how to use the laser level. The dig depths at the rear of the site are about 1500mm in clean clay, but the excavations are near to existing trees and thus must be deep to avoid subsidence caused by clay shrinkage.	Systemic	The wider consequences of <u>change</u> were illustrated here.

GW recounts the ground-works efforts to win work from the company as including entertaining senior staff - events such as boxing, racing, rugby etc. (thus awarding contracts may not be related to any recognised restraint - time, cost or quality!). 16.50 Leave site.		

COMMENT ON KEY EVENTS AND POINTS OF THE DAY - Written up at 21.00

1 Direct and sometimes overly abrasive management style of SM (eventually leading to complaints from electrical sub-contractor to building manager). SM uses threat of "removal" as tool to get compliance with programme. Uses some "brinkmanship" (e.g. putting "sparks" off-site for not complying with the programme).

2 Uncontrolled changes (again) - the home-maker to plots 35 and 36 left to be solved on site. Also evidence here of poor communications.

3 Control/supervision method

Stand and watch some work performed - i.e. continuous supervision rather than test/inspect. Example is SM watching the tarmac wearing course to parking bays being laid. Again, evidence here of short-cycle feedback and control methods.

4 Aesthetic quality problems - the unsatisfactory yellow rag-roll effect wallpaper.

5 Checking and inspection - BI catching the ground-workers in the act of watering foundation concrete to make it flow. Classical violation as Reason (1991).

6 Poor communications

- Section details of "Fivebed Cottage" house type not showing height of plate at front of garage - left to site to decide.

- Lintels ordered not matching those delivered because of changes to suppliers etc.

7 Concurrency and lack of planning again - the continuing sub-station problem.

FRIDAY 26th		
8.01 Arrive on site		
AM is collecting new WC pan for one seen to be damaged yesterday afternoon. SM is on site - he suspects that the electrician has deliberately damaged the pan after yesterday's arguments about work schedules.	Sabotage - primary error	
Plumber notes that tank stand is in wrong place in a show unit and SM agrees to get carpenter (Doug) to move it later that day.	Comms (or primary?)	This appeared to be a simple primary trades-person's error, picked up, in this instance, by another following tradesman before it developed into a problem.
SM is not happy with the Company after lack of overall planning and support concerning the sub-station and water main problems. He considers problem to be in control of commercial director and surveyors, but envisages that they will avoid responsibility by attributing blame to others - for example one of the other consortium members. SM reports that the other consortium member most affected had requested meetings concerning the siting of the sub-station, but they had had no response from the company.	Culture	The problem of poor site/head office attitudes was evidenced here, together with, what appeared to be a lack of good overall planning of the site. This in turn <u>may</u> have been driven by other pressures, such as time and cost constraints in the head office. For example, it was known that the surveyors were working under considerable pressure at the time, as the market had just started to recover slightly from recession and a decision had been made at Group level to retain the house-building company. Several new sites were being started and sub-contracts were being let. Conversely, staff had been lost through redundancy, including most of the Regional design staff, as a result of pressures on cost.
(Researcher note - this implicates organisational attitudes, orientation, lack of management-site communications and general remoteness of senior managers (Turner 1978), compounded by lack of overall project level planning (Morris 1994, Meredith and Mantel 1995).		

8.50 GW (Ground-worker) in site office demanding details of ground and finished levels for proposed retaining walls. Robust argument develops concerning "theft" of drawings, where SM claims that the ground-works sub-contractor has two copies of all relevant drawings (Generally this argument is superficial banter). GW borrows SM's spectacles to read the drawings (yet again) - indicative of quality assurance problems caused by short-sightedness!		The importance of good <u>formal communications</u> was illustrated here. The work on retaining walls could not start without proper drawings.
9.05 Carpenter (Doug) in the office for a discussion with SM. As a result of home-maker changes on plot 34 the span of joists are longer. The carpenter has "raided" a pack of joists for another unit, but after he has cut these to length, he realises that the depth of the joists is different. (Researcher note - this is another consequence of uncontrolled change and the socio-technical nature of error in complex technologies. The error in cutting up the wrong depth joists could be treated as a primary, carpenter error, but problem is really due to poorly planned and communicated changes - incidentally this is realised by the site manager (SM) and not inaccurately attributed.	Changes > error	Consequence of uncontrolled changes were illustrated here.
9.20 GW (Ground-worker) complains that gutter outlets on plots 122/123 are wrongly positioned necessitating a longer run of rainwater drains and re-positioning of rainwater eyes. The consequence is likely to be only increased costs, but could result in over-shallow falls and a slight increase in task duration. Thus, this illustrates inter-relatedness of cost, time and quality. Caused in this case by plumber not following detail on drawing, and this not being checked or corrected by agent/foreman.	Comms	This illustrated the inter-relatedness of cost, time and quality. The interaction of these three factors was used elsewhere in the research, where cost and time were used as *proxies* for defects.

Problem again invokes robust discussion between SM and GW. SM did not ask GW to provide extra drain - he simply told him to "f... off". 9.50 SM on phone to fencers about fencing around show houses - they did not stay on site yesterday to fix posts and have not turned up today. They report that their van has broken down. SM "won't have that" and is giving the fencers "some stick". SM is still exhibiting a very abrasive style of management! 10.00 SM on phone to building manager - wants the electricians and fencers removed from the site. He considers that he has given plenty of notice to both sub-contractors. Concerning chasing these firms, SM comments "I know their phone numbers off by heart because I am phoning them all the time!".		
10.05 SM on setting examples - He relates that he is not able to get hold of the surveyors after 2pm on Friday because they are all in the pub - lead by the Commercial Director. SM claims that he has never been drinking during the working day. 10.06 Lack of control - PD (decorator) does not like the quality of the wallpaper, but SM says he has no control whatever over wallpapering standards and this is thus not his problem. 10.20 SM on phone to ground-working sub-contractor's office to discuss the "watering the concrete" incident. The Building Guarantee Company have sent a fax to the building manager (BM) to complain about the problem.	Culture	

(General question - should senior managers have to spend time on site in order to improve attitudes, communications, understanding and culture?) 10.22 Walk around site with SM:- 1 Talk to ground-workers in their site hut about avoiding watering concrete batches in future (core tests may need to be taken for those where BI saw concrete being watered). In the worst scenario concrete may have to be removed on one or two units. 2 Look at foundations/trenches at far end of site. Two units appear to have some laitence on top of concrete and thus may be suspect. One unit remains to be excavated and one unit has open excavations. 3 Look at units 34-37. SM noted first floor joists are very level and commented on the high level of skill of the carpenter. 4 Look at the show unit of an adjoining consortium site and talk with SM's counterpart running this site. Overall - SM again using short feedback cycle feedback and control (keeping on top of the job). 11.25 Further discussions with GW concerning "water in the concrete" incident. 11.31 SM on phone to head office to progress detailing of unit 35 - details of lead trays needed now for the bricklayers. 12.00 Lunch at the nearby super-store. 12.50 SM on phone planning move of cabin units with crane hire firm (to be carried out early next week).		Pro-active approach to avoiding defects was illustrated here. Checking - informal and based on manager's personal skill.

SM checking concerning the replacement of 4 floor joists used on plot 34 (as a consequence of the home-maker there). (i.e. using memory and good short-term planning to pick up problem created earlier by changes).		
13.05 SM Brings white-board plan up to date.		Written plan updating ready for the following week.
Thumb through Building Guarantee Company site file. Items include:-		The site file did not contain all defects as this would "clutter up the file too much" - BI. As defects were attended to, the item was normally removed. Some defects had considerable potential, for example, not providing sufficient weep-holes over lintels could have produced dampness internally. However, the occurrence of the problem was likely to be infrequent. Most defects were commonplace and appeared with stochastic regularity according to BI. This site was considered by him to be "no worse and no better" than any other site run by a large house-building company with a premium rating from the Guarantee Company.
27/2 Cavity fill too high generally	?	
Brickwork in foundations laid on slurry in trenches.	Primary	
Weep-holes over openings not at 450 c/s	?	
6/3 Suspended slabs needed where fill over 600 generally	?	
25/4 Water added to concrete plot 63	Primary	
6/3 Suspended slabs needed because of well-shaft, plots 118, 119.	?	
28/2 Insufficient under-floor vents to rear elevation on plot 130	?	
Incorrect bonding party-external wall blocks on plot 130	Primary	

14.00 BS (Bricklayer supervisor) wants to know what lintel to put over door D7 (a non-load-bearing opening). Choices are a small lintel, or alternatively to leave wall open to ceiling for carpenter to box in later. Detail not shown on drawings or on lintel schedule. 14.15 Given instruction on driving 360 degree tracked excavator. 14.30 Carpenter comes into the office looking for truss clips. GW (Ground-worker) is on phone organising next weeks excavation programme.	Comms	Another failure in formal communications.
14.45 BS (Bricklayer foreman) pays up a bricklaying gang - they are not "up to scratch" and will not be employed for next week! SM/AM on phone sorting out work schedules for next week.		This was an example of the use of hiring and firing to ensure an adequate standard of worker on the site. Again, emphasis was put on selection - other primary based options such as training and education were not used.
16.00 Sales personnel (SP) comes into office and informs SM/AM that the Sales Director does not know about problems on the site:- • Substation • Water supply • Poor wallpaper finish • Poor fencing to show houses AM notes that all these things had been discussed in monthly construction/sales meetings and minuted! (Poor communications, orientation, attitude)	Participation (Culture)	Poor communications.

16.15 Buyer (CB) visits site and AM mentions problems with lintels on block 36 - 2 missing and patterns do not match orders etc. AM/CB generally plan information requirements for next week. 16.35 General discussion of next week's plans with sales (SP/CB/AM) - provision of flagpoles, fencing show houses entrance areas etc. 16.45 Left site		Use of informal planning for the following week's operations.

COMMENT ON KEY EVENTS AND POINTS OF THE DAY - Written up at 9.45 on Saturday

1 Deliberate sabotage - not in Reason (1991) paradigm - the broken WC pan caused by electrician resentment.

2 SM was not happy with poor senior management organisation and is looking for another job.

3 Communications

- ground-workers do not have drawings for retaining walls, even though SM claims that they have two copies.
- details of lintels over D7, plot 34 are not on the drawings.

4 Genuine knowledge based errors masking organisational error! problem of carpenter cutting up **wrong depth joist** for plot 34 really caused by home-maker changes increasing span of joists. (Poorly planned and communicated changes).

5 Interaction of cost, time, and quality - wrongly positioned gutter outlets to plots 122/123 caused increased run of drains (cost), extra time to excavate (time) and reduced falls (quality).

Cause of error:-

- Plumber not following drawing?
- Non-availability of running outlet?
- No checking (very difficult to spot)?

6 Short feedback cycle planning evidenced again - e.g. chasing fencers all the time for performance.

7 Attitudes, orientation, examples feature again (Surveyors all in the pub after 1.00pm on a Friday).

8 The "reverse checking" syndrome - workers picking up errors and communicating these to the checkers - PD and the problems with the wallpaper in the show house - decorator tries to warn managers and interior designers, but in the end they give up!

9 Supervision and checking **as opposed to** proactive control:-

a) SM warns ground-workers in passing not to add water to the concrete mix.

b) SM checks work of carpenters (plots 34-37) on a walk round.

10 Short-term planning again - bringing the "white-board" up to date at the end of the week. Discussions with buyer (CB), about next week's deliveries.

11 Communications top to bottom - sales director not knowing about problems on the site despite meetings.

12 Type of defect uncovered.

Generally a few minor problems with low risk (but high potential!) consequences.

Note - to add to Methods Section - Method of researcher integration:-

- Discussions with bricklaying foreman
- learning to use laser level with ground-worker
- Driving excavator
- Helping with problems (lintels on plot 35)
- Work tasks - completing materials requisition sheets
- Generally achieved participant/observer status.

PUBLICATIONS ARISING FROM THE RESEARCH

ATKINSON A R (1998) Human Error in the Management of Building Projects, Construction Management and Economics, Volume 16 No 3, May, 339-349.

ATKINSON A R (1998) The Role of Human Error in the Management of Construction Defects, Proceedings of the RICS Construction and Building Research Conference, Oxford 2-3 September, Volume 2, 1-11.

ATKINSON A R (1999) Implications for Construction Safety of studies of the Management of Human Error. 2nd International Conference on Implementation of Safety and Health on Construction Sites, Honolulu, March 24-27.