NON-EXCUSABLE DELAYS IN CONSTRUCTION

BY

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ABSTRACT

Existing literature and research findings indicated that delays are common amongst construction projects in many countries across the globe. Delays can be caused by one or more of the following: the client (excusable with compensation); force majeur or third party (excusable delays without compensation); or the contractors (non-excusable delays or contractor responsible delays). Previous studies cited that approximately 50% of these delays can be classified as non-excusable delays. The root-causes (or factors) that cause non-excusable delays identified in these studies however, are given no detailed attention. Improving and constantly monitoring the factors causing non-excusable delays can help to determine and improve contractor's performance.

This research explores issues related to the factors causing non-excusable delays. It includes establishing indicators to identify these factors and appropriate corrective actions. The research also develops an indicator that offers an alternative to intuitive judgement which can provide a consistent and standardised assessment of qualitative factor. The proposed indicator employs both quantitative and qualitative measures to evaluate qualitative factor which caused non-excusable delays.

A correct determination of the root-causes (or factors) of non-excusable delays is vital for deriving an appropriate corrective action. This study offers a method of identifying these root-causes as well as identifying and establishing their corrective actions, a structured approach of deriving corrective actions was also developed. This approach was tested in a survey and proved to be consistent with the opinion of twenty nine contracting organisations. One of the significant contributions in this research was the development of an alternative indicator to assess "communication performance" using the concept of fuzzy logic control. The establishment of the

common indicators that were used to identify the critical factors is another important achievement for this research. Fifteen critical factors were established and the findings indicate that resources schedule was the most effective indicators used to identify majority of the factors under consideration. Apart from the knowledge contribution in the subject of delays, the methodology employed to identify the factors of non-excusable delays using cause-and-effect analysis has helped to generate additional factors that previous studies did not focus on.

DEDICATION

To my parents, wife and all my seven children who inspired me until the completion of this research and, at times, I had to turn down their entertainment schedule just to continue my work.

DECLARATION

No portion of the research referred to in this thesis has been submitted in support of an application for another degree or qualification at this or any other university or other institution of learning.

ACKNOWLEDGEMENT

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Trillion of dollars are spent each year on the construction industry world-wide. An improvement of even a fraction of a per cent in performance would produce billions in saving and one of the main influences on contractors' performance that was identified from the literature review was delays. Delays lead to negative impacts on contractors' performance which include: disputes, low productivity, and increases in cost.

The subject of delays has been addressed by several researchers and they have observed the detrimental effect on contractors' performance particularly on project schedules. Very little evidence is available from previous studies on issues related to the factors or causes of non-excusable delays (NED) which influence contractors' performance. This research attempts to investigate and evaluate issues relating to the factors or causes of NED during the construction stage of projects, with emphasis focusing on the critical factors (top fifteen factors).

The research reported in this thesis focuses on the issues related to critical factors of NED that influence contractors' performance including:

- indicators to identify them;
- their permanent corrective actions;
- a best indicator to measure contractors' performance;
- developing an indicator to assess 'communication performance'; and
- identification of short-term corrective actions for improving delays.

To address and establish the above issues it was decided to obtain the data for this study from the professionals of industry especially site managers. This decision was made in view of their experience on handling and managing the factors or causes of NED and because these factors were mostly due to their action or inaction. Additionally clients' data were collected for this study and these were used to reaffirm or cross check the contractors' view and opinions.

The significance of establishing the issues related to the critical factors of NED was to provide a greater insight and understanding of the factors or causes of NED that persistently influence contractors' performance. Addressing these issues can also help to establish the important information needed by contractors to monitor and control the factors of NED during the construction stage.

1.2 BACKGROUND AND JUSTIFICATION OF RESEARCH

The need to effectively monitor and control the factors or causes of delays during the construction process appears to be appreciated in the literature. Several previous studies cited factors that caused delays including their significant impact on contractors' schedule and cost performance. At least 4000 projects were identified from the literature review which had experienced schedule overruns. This study had gathered the records of construction schedule overruns for the past three decades (refer to Table 2.1) which involved more than 900 contracting construction organisations. Morris et al. (1989) evaluated several records of project delays and concluded that the success rate of projects is generally poor. He further emphasised that there are hardly any records showing underruns. Tah et al. (1993) stated that poor performance of projects in term of time and cost overruns is commonplace in the industry. It was observed from the literature that among parties in contract there is a difference in opinion as to which indicator was best able to measure performance and also that there are several performance indicators including; cost, time, quality, etc. Hence there is a need to establish a best indicator to measure contractors' performance on site. Assaf et al. (1995) studied the causes of delays on large building projects and concluded that materials and labour related factors were amongst the main factors which led to the poor performance of contractors. The literature investigation revealed that several factors were commonly recurring over several decades. Despite their persistent occurrence on site they still recurred and this prompted a need to establish the factors or underlying causes that influence contractors performance. In addition it was considered worthwhile to conduct a study on the factors or underlying causes of delays which could provide a greater insight and understanding are thereby improve monitoring and control of performance.

Abd. Majid and McCaffer (1997b) cited that almost fifty percent of the factors that caused delays were classified under NED and this information has helped to establish the basis to study the issues related to factors of NED under groups of causes (or principal causes). Twelve groups of causes and sixty nine contributing factors of NED were identified (refer to complex fish bone diagram, Figure 3.12) from the literature review. For several decades these factors have led to the poor schedule performance of contractors, this is the reason for establishing the factors of NED that influence contractors' schedule performance. Apart from establishing the sixty nine factors for twelve groups of causes an investigation on indicators that can identify the critical factors of NED including their corrective actions was also carried out. This was extended to including an investigation on corrective actions.

Only a few previous studies adopted a holistic approach of studying the factors of delays that involved the identification of factors (or root-causes) and included the determination of their corrective actions. Most previous studies focused on establishing the factors of delays and their impact on cost and time with the exception of Yates (1993) who conducted a holistic approach of addressing the issues of delays. The significance of adopting a holistic approach was it can highlight several other important issues related to the factors of NED that need to be addressed. Since very little evidence was available from previous studies that focused on the indicators that identify factors of delays and the associate corrective actions the need to establish indicators and corrective actions of the factors under consideration was justified. This study attempts to adopt a similar approach but this has led to widening the scope of study, and the problem of handling a large amount of data that need to be collected. Thus it was decided to focus only on the top fifteen factors (also known as critical factors) selected from twenty five common factors of NED in order to limit the scope of the investigation. Yates (1993) suggested a computerised process of monitoring and controlling the factors of delays but the relationship between factors and indicators including their corrective actions were not established. Moreover, the suggestion for the proposed computerised process did not include indicators that can identify qualitative factors such as 'inefficient communication', 'too many responsibilities', 'low moral and motivation' etc. which are normally assessed by the intuitive judgement of site managers. Apart from establishing the indicators that can be used to identify the critical factors of NED this study also attempts to develop an alternative indicator to intuitive judgement for assessing qualitative factor specifically on contractors 'communication performance'.

The findings identified during the literature stage which included a pilot study have confirmed that several qualitative critical factors were assessed by intuitive judgement of the site managers and this led to the problem of obtaining a consistent and standard assessment among several site managers. To achieve a consistent and standardise assessment a quantitative model has to be developed and as an alternative indicator that can assess a qualitative factor instead of intuitive judgement.

Moreover, the assessment data using a quantitative model can be collected in a data bank which later can be used to benchmark the performance of qualitative factors among several projects. Although the judgement of the site managers is still essential, the creation of an alternative indicator that can quantify an approximate judgement can help to achieve a consistent and standard assessment. The theory of Fuzzy Logic was used to develop this alternative indicator.

Experience has helped the managers to make an appropriate decision in the event of the occurrence of problems on site and this has proved to be an important asset to a manager. Establishing permanent corrective actions for the critical factors considered in this study could be a great asset to the site managers. The permanent corrective actions established could remove or improve the factors of delays where as short-term corrective actions could improve delays but not the underlying factors. Again, very little evidence is available that describes permanent corrective actions, especially for the critical factors of NED. However, Mondy et al. (1995) cited a list of short-term corrective actions (see **section 6.3.3**) and Yates (1993) also cited several short-term corrective actions, very few could be regarded permanent. This research identifies the need to establish the permanent corrective actions for the critical factors of NED and in addition to establishing the corrective actions the study attempts to establish a structured approach of deriving permanent corrective actions. It is vital to establish an approach of deriving corrective actions which can provide a mechanism to assist site managers in deriving their own permanent corrective actions. More importantly, it may be used to derive other factors' corrective actions which were not included in this study.

From an extensive literature review it was revealed that the losses due to delays, for projects reported in the United States, were in the region of US$30 million - US$35 million (Riad et al., 1991) and in an event it was up to US$120 million (Chalabi et al., 1984). While National Economic Development Office (1992) reported that time delays on projects range from two months to thirty five months and the cost increase was in the range of -6% up to +50% correspondingly in term of value was between -£3 million to +£25 million. Thus, improving a contractors schedule performance by several percent could result in a substantial saving in terms of monetary value. Previous studies cited the significant effect on contractors' schedule performance due to the factors of delays and improving schedule performance is regarded as the key measure of success for contractors (Construction Institute of Industry, CII, 1990 p343 and Maloney, 1990 p399-455). Most of the previous literature focused on clients' needs and there are only a few of the studies that aimed at improving the contractors performance due to delays (Rogge et al., 1982). Furthermore, the data on excusable delays were normally recorded by the contractors but information due to NED were seldom being recorded by them. Since a contractor has more control over these type of delays (Chalabi et al., 1984) this justifies the need to investigate and evaluate issues related to critical factors of NED that influence contractors schedule performance. To achieve the aim of this study several objectives have been identified which are presented in the following section.

1.3 AIM AND OBJECTIVES OF THE RESEARCH

The preceding sections discussed the importance of improving and controlling the factors or causes of NED which will eventually help to improve the contractors schedule performance. The aim of this research is to investigate and evaluate the issues related to critical factors of NED that influence contractors schedule performance. To achieve this aim it is necessary to thoroughly review the existing literature and research findings, and also to investigate the professionals' opinion. The review and investigations were carried out with the following objectives:

(a) to identify and establish the best indicator to measure contractors' performance;

(b) to identify and establish the factors of NED;

(c) to identify and establish the critical factors of NED from (b);

(d) to establish the quantifiable indicators that identify the critical factors of NED;

(e) to establish the critical factors that are identified by qualitative judgement;

(f) to develop a means to assess qualitative factors;

(g) to develop and establish an approach of deriving corrective actions for the critical factors; and

(h) to identify corrective actions to improve delays and to establish corrective actions to improve the critical factors of NED.

1.4 RESEARCH METHODOLOGY

This section discusses the research methodology in an attempt to realise the aim of this study in the light of the existing knowledge and investigation evidence. In achieving this aim and objectives, a research methodology is required and Figure 1.1 highlights the essential stages of conducting this research. This figure shows five essential stages of conducting the research which includes the following:

- literature review;
- discussion with the professionals from the industry;
- two stages pilot survey;
- main survey; and
- analysis of data.

A comprehensive literature review was conducted which led to the identification of the following essential information which includes:

- a list of the records compiling more than 4000 projects that experience schedule overruns;

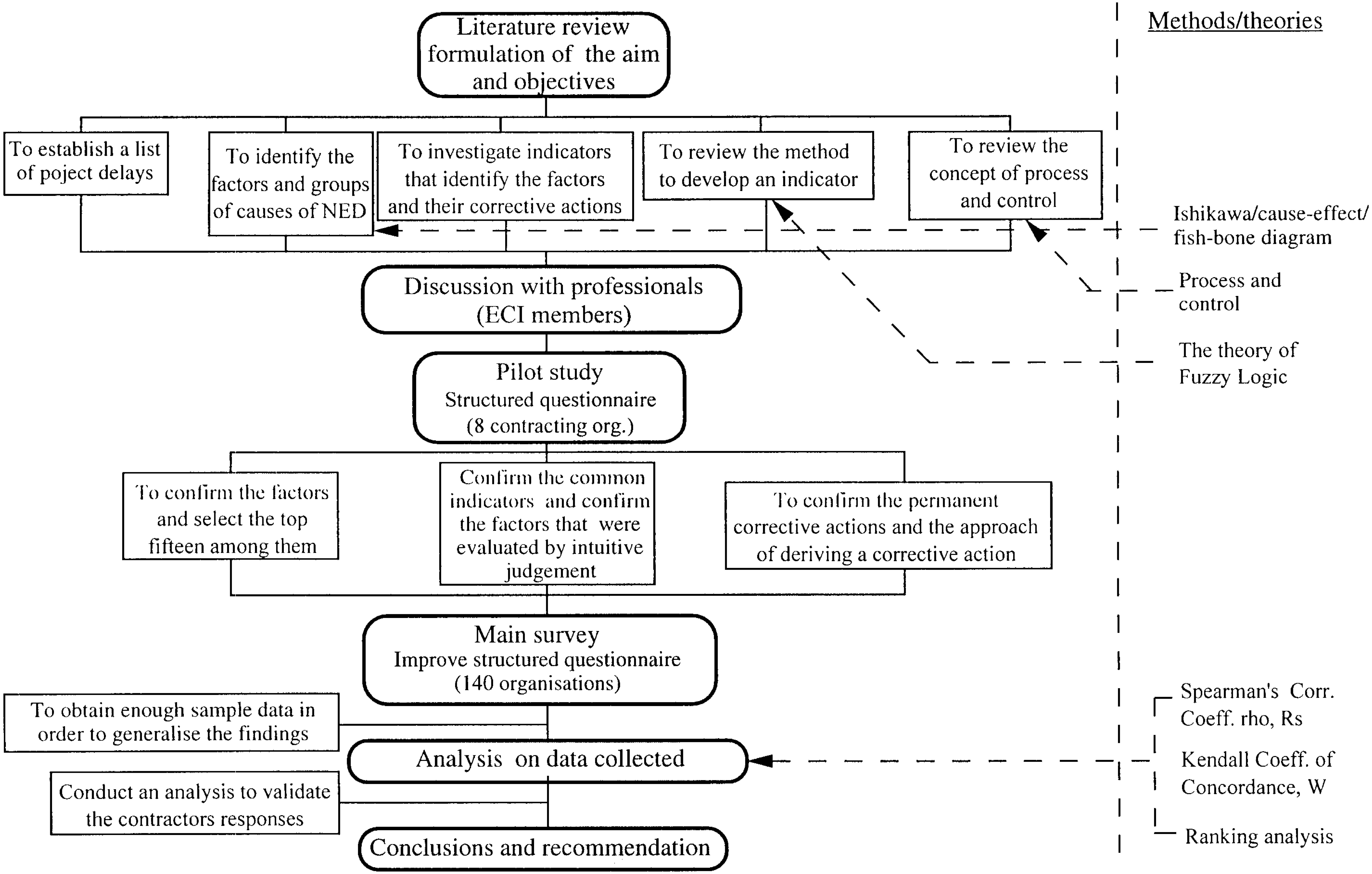


Figure 1.1: Research methodology

- a matrix of the factors of NED which influence contractors' performance and the development of a complex fish bone diagram showing the relationship between factors and groups of causes that lead to non-excusable delays;
- a matrix of indicators that identify the critical factors of NED including the factors that were assessed by the intuitive judgement of site managers; and
- the various methods and theories, such as fish bone diagram, fuzzy logic, used for problem solving.

Following an extensive literature review, along with a series of discussions with the Productivity Task Force Committee of European Construction Institute (ECI) (refer to **Appendix IV**) the problem of this research was identified. A two stages pilot study was then conducted on selected organisations from a list of UK Top 100 for the year 1996 and the European Construction Institute member companies.

Recommendations from the pilot study were included in the preparation of a main survey questionnaire which consisted of 198 questions. The questionnaire was posted to 65 ECI member companies and 75 UK Top 100 Contractors. A 26% response rate was achieved, even though the questionnaire was exceptionally long. The administration of the questionnaire is discussed in **Chapter 7** and after receiving the responses the next stage was to conduct an analysis on the data collected. Findings and conclusions were then derived based on the analysis, and an indicator was developed to assess 'communication performance' using the theory of fuzzy logic. A proposed structured approach of deriving a corrective action was developed and tested in the main survey along with the permanent corrective actions for the critical factors.

1.5 THE MAIN ACHIEVEMENTS

Several findings and suggestions established from this study are significant to the contractors and the construction industry. The methodology of developing an alternative indicator to intuitive judgement has provided a new platform for creating more tools which will be available to the site managers. There are several achievements to the work undertaken and these include:

(1) the establishment of schedule performance as the best indicator to measure contractors performance;

(2) the establishment of sixty nine factors under twelve groups of causes relating to NED that influence contractors schedule performance:

(3) the establishment of the ranking of fifteen critical factors according to their impact on NED;

(4) the establishment of most effective indicators that were used to identify twelve critical factors;

(5) the establishment of three critical qualitative factors that were assessed by intuitive judgement;

(6) the development of an indicator to assess 'communication performance' using the theory of Fuzzy Logic;

(7) the establishment of a structured approach of deriving permanent corrective actions for the critical factors of NED; and

(8) identification of short-term corrective actions for improving delays and establishment of the most appropriate permanent corrective actions to improve critical factors.

The establishment of 'schedule performance' as a best indicator to measure contractors' performance

From the analysis, the contractors ranked 'schedule performance' highest and the clients ranked 'cost performance' highest. Although there was a difference in the respondents opinion which was due to the differences in the priorities of project objectives, this research has concluded that 'schedule performance' was the best indicator to measure contractors' performance.

The establishment of sixty nine factors under twelve groups of causes relating to NED that influence contractors schedule performance

Sixty nine factors under twelve groups of causes were identified from the review and tested in the main survey. The findings of the literature were used to construct a complex fish bone diagram as a mean of identifying twelve groups of causes of delays. The fish bone diagram also assisted in identifying the sixty-nine underlying factors of these twelve groups of causes. A statistical analysis indicated a significant agreement in the ranking between the contractors' and clients' responses for five groups of causes and these include:

- factors for material related delays;
- factors of improper planning;
- factors of sub-contractors related delays;
- factors of inadequate supervision; and
- factors of improper construction methods.

The other seven groups of causes revealed no significant agreement between both groups of respondents. Despite insignificant agreement in the ranking between both respondent groups, the contractors ranking has helped to establish the factors of NED under twelve groups of causes.

The establishment on the ranking of fifteen critical factors according to their impact on NED

Among twenty five common factors identified and tested in the pilot study, only the top fifteen critical factors that were selected for further evaluation in the main survey. From the analysis this study has established a new ranking of critical factor in ascending order as follows:

- slow mobilisation/late delivery;
- unreliable supplier/sub contractor;
- poor planning;
- unavailability of proper resources;
- poor monitoring and control;
- shortages of personnel;
- inefficient communication;
- lack of experience;
- low morale/motivation;
- too many responsibilities;
- inappropriate practices/procedures;
- wrong method statement;
- poor contract;
- interference with other trades; and
- inadequate fund allocation.

The above ranking was agreed by both groups of respondents with a confidence level of 95% and the ranking was based on their influence toward contractors' schedule performance.

The establishment of the most effective indicators that were used to identify twelve critical factors

A list of twenty five indicators were identified from the literature review and only twenty were selected for further evaluation in the main survey. An analysis of the respondents' opinion has established the most effective indicators that were used to identify twelve critical factors and are tabulated in Table 8.15.

The establishment of three critical factor that were assessed by intuitive judgement

The analysis had established that the remaining three of the fifteen critical factors including: 'inefficient communication'; 'too many responsibilities'; and 'low moral and motivation' were assessed using intuitive judgement of site managers. Statistical tests confirmed that these factor were identified by the intuitive judgement site managers at a 95% confidence level, especially on the contractors' responses. The clients' responses supported the contractors' opinion on one of the factors i.e. 'too many responsibilities'.

The development of an indicator to assess 'communication performance' using the theory of Fuzzy Logic

The development of an alternative indicator to assess 'communication performance' using the theory of Fuzzy Logic has provided another significant achievement of the work. The illustration in **sub-section 8.6.3** has shown the ability of the model to assist the professionals in evaluating 'communication performance' instead of using site managers' intuitive judgement. This illustration was based on assessing two linguistic input values that influence contractors communication performance. From the linguistic inputs, the model can help to derive a conclusion on communication performance and this concludes the achievement of developing an alternative indicator using the theory of Fuzzy Logic.

The establishment of a structured approach of deriving permanent corrective actions for the critical factors of NED

The model of the proposed structured approach of deriving permanent corrective actions was based on the theory of inventive problem solving and the model was tested in the main survey. The analysis of the respondents' data helped to validate the approach and this study concluded that the structured approach provides consistency in deriving permanent corrective actions for the critical factors.

Identification of short-term corrective actions for improving delays and the establishment of the most appropriate permanent corrective actions to improve the critical factors of NED

Permanent corrective actions for the critical factors of NED have been successfully identified and were selected among several suggestions for each factor which represents the most appropriate corrective actions. The list of corrective actions to each individual factors are tabulated in Table 8.37 and can be used as one of the preventive measures. In addition to the establishment of the permanent corrective actions, several short-term (or immediate) corrective actions were identified which are listed in **Section 6.3.3**.

1.6 ORGANISATION OF THE THESIS

This thesis comprises three major components which can be summarised as follows:

(1) General investigation on the background of the problems.

(2) Reviewing the issues related to non-excusable delays which include the following:

  (a) factors and groups of causes relating to NED;

  (b) indicators that were used to identify the critical factors of NED; and

  (c) identify the critical factors that were assessed by intuitive judgement.

(3) Investigate and validate the above issues including the establishment of a structured approach of deriving permanent corrective actions using the respondents from the pilot and main surveys. Developing an indicator to assess 'communication performance' and finally deriving the findings and making conclusions based on the findings.

A diagrammatic guide to the structure of the thesis is shown in Figure 1.2 and the three main components of the research are presented in nine chapters and are briefly described as follows.

Chapter 1: Presents a general introduction to the subject and the specific problem under investigation. It also specifies the aim and objectives, research justification, the methodology of conducting this research and a brief summary on the structure of the thesis.

Chapter 2: From the available literature this chapter investigates the issues related to delays which include the following:

- definition and types of delays;
- delay damages;
- method of quantifying delays;
- researches related to construction delays; and
- matter arising from the review.

The review on the above issues established the problems that need to be investigated and helped to identify the scope of study that warrant further investigation.

Chapter 3: This chapter reviews the available management literature and establishes the groups of causes (or principal causes) and factors of NED. A fish bone diagram constructed used to assist in identifying the factors of NED that were not cited in the literature and it also helped to establish the relationship between factors and group of causes.

Chapter 4: Investigates the literature available on definition of indicator and indicators to identify the critical factors including their permanent corrective actions. The chapter also reviews an approach of decision making which then helped to model a structured approach of deriving a corrective action.

Chapter 5: Investigates the theoretical basis of developing an alternative indicator to assess 'inefficient communication' instead of using intuitive judgement of site managers. The review focuses on the theory of fuzzy logic which was used to develop this indicator for its ability to model uncertain or approximate reasoning involving human descriptive or intuitive thinking. Several methods of analysis which were used to validate the findings are also discussed.

Chapter 6: This chapter presents the review on the concept of process and control with the purpose of proposing the framework for monitoring and controlling the factors of NED. The proposed framework is also reflecting the main stages of investigating the issues addressed for this research. In addition, this chapter identifies the short-term corrective actions that are usually considered by site managers.

Chapter 7: This chapter discusses the design of the research questionnaire, research population, questionnaire administration and responses. Explanation of the pilot and main surveys as the strategy to collect necessary information to validate the findings. The analysis conducted on the general information from the respondents and project data obtained from the main survey was conducted and its finding summarised.

Chapter 8: Presents the analysis and statistical tests to establish the findings from the literature review and pilot study. The results of the analysis are discussed and conclusions drawn from these and used to validate the issues identified earlier. The chapter also illustrates on the use of the proposed alternative indicator to assess 'inefficient communication' which was designed using the theory Fuzzy logic. In addition, statistical tests were also used where appropriate to reaffirm the contractors' responses using the clients' data and an analysis was also conducted to establish the approach of deriving a corrective actions. Finally, validating the permanent corrective actions for the critical factors is discussed.

Chapter 9: Presents the findings of the research, conclusions drawn from the findings and the recommendations for further research on the subject matter. This chapter highlights the contribution of the research work to the body of knowledge.

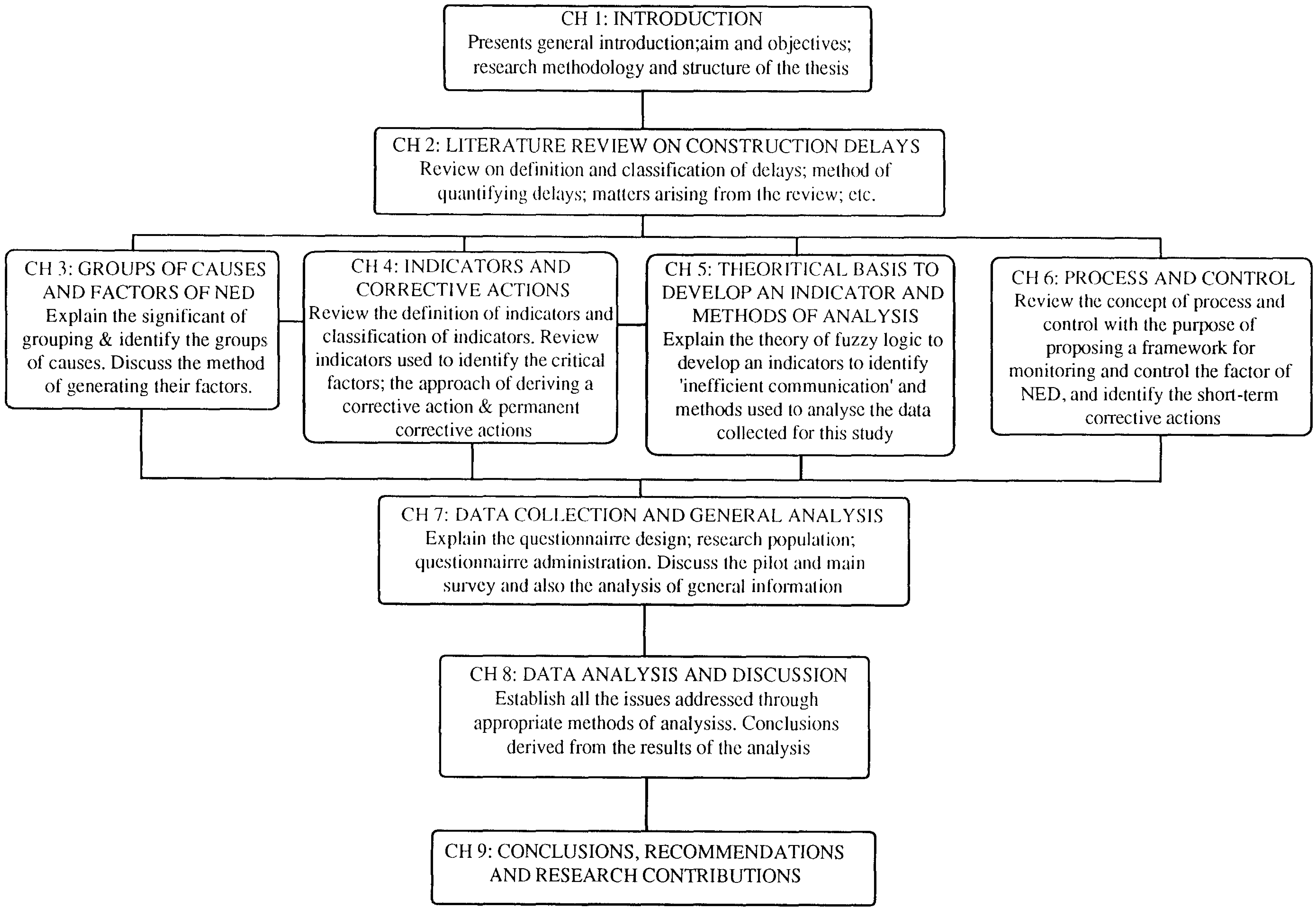


Figure 1.2: Guide to the thesis

CHAPTER 2

LITERATURE REVIEW OF CONSTRUCTION DELAYS

2.1 INTRODUCTION

The literature review forms part of an important process of conducting research in which it serves to propagate the formulation of the research problems as well as identify the boundary of knowledge. It also helps to create a sound foundation and provides a platform for expanding the knowledge within the subject. The subject of delays has been discussed by several authors in the past three decades. Delays were still being reported among the construction projects despite several research project being conducted to address these issues. The persistent occurrence of delays in the construction project has prompted the researcher to investigate further the issues related to delays. The extensive literature review has uncovered some issues that need to be addressed in the light of continually enhancing knowledge on construction delays.

This chapter explores the results of the literature search, since it is important to identify an appropriate process research methodology. Before focusing on a specific issue all types of delays were explored including an examination of the issues of definition of delays, types of delays, methods of quantifying the delays and delays damages. A close examination on previous work has helped the researcher to formulate the research topic and identify the scope of the study.

The specific focus of the study is to investigate the critical factors of non-excusable delays, determine indicators to identify them and the corrective actions required. The review of these issues was conducted and are described in the next two chapters.

Whilst considering these issues several research methodologies were identified and the research program was formulated to assist in achieving the objectives of the study.

2.2 METHODOLOGY OF LITERATURE SEARCH

The methodology of conducting the literature review was highlighted to emphasise the important of this process in identifying and formulating the problem of the study. Figure 2.1 indicates the conduct of the study during the literature review stage of this research. An earlier stage, the subject of the study was identified in a broad spectrum. Based on the literature and researcher's own experience the problem of the study was identified. Key words such as project delays, construction delays, performance and control system related to the subject, help to locate the available reports, articles and serials through the available on-line database systems and indices at Loughborough University, United Kingdom.

The second stage was to cross examine the cited articles, periodicals, books, reports and serials amongst the database systems and indices. Initially, almost all the articles cited came from the following database system which includes:

- CD-ROM (CITIS which cited 75 articles relating to construction delays and 43 articles relating to project delays, performance and control system);
- BIDS (COMPENDEX which cited 39 articles relating to project delays and 20 articles relating to construction delays);
- OCLC (First Search which cited 21 articles relating to delays);
- DIALOG (On line data base to identify American theses, two theses which are related to the subject);

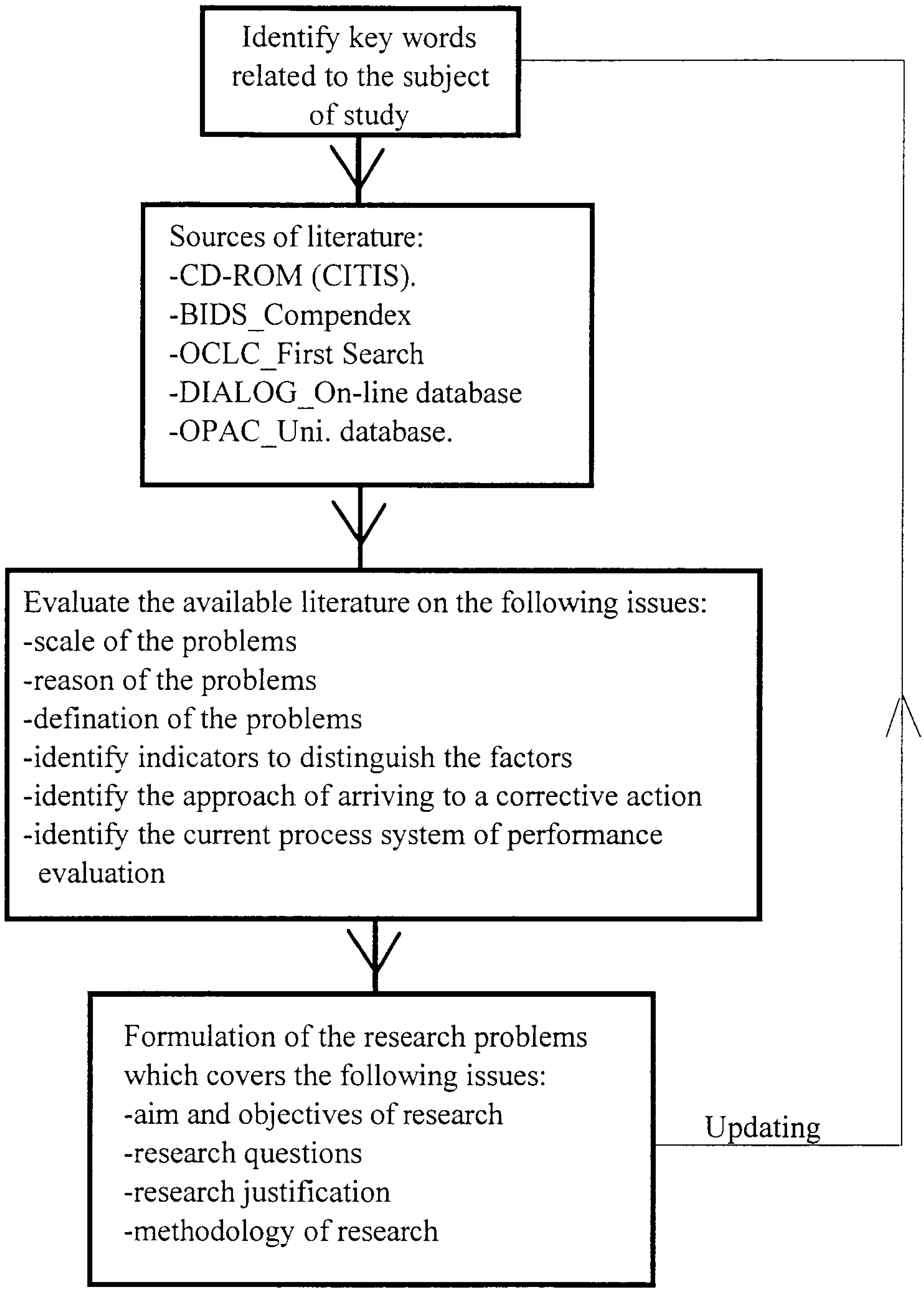


Figure 2.1: Flow chart of conducting the literature search

- CD-ROM database to identify local theses for universities in the United Kingdom;
- OPAC (University's Library data base system on books, journals, periodicals and articles which cited few articles related to the subject);
- conference index and other engineering indices; and

- a study on non-excusable delays (Abd. Majid, 1992).

The search for the above was not only limited to the construction industry but also included manufacturing sector, transportation sector and engineering services.

The next stage was to examine the articles obtained from the university's library or through the inter library loan system, if it was not available within the university's collection. The evaluation on the articles obtained generally cover the following issues:

- scale of the problems;
- reasons of why delay occurred;
- definitions of delays;
- methodology of identifying root-causes;
- identification of the various indicators to the factors or factors causing delays;
- identification of the approach of determining a corrective solution; and
- identification of the process system for monitoring non-excusable delays.

A critical evaluation on the above issues was conducted from the available research reports in order to formulate the research problems. The aim, objectives, research questions and justification were eventually developed based on this review. Once the problem was identified, a search was conducted for articles related to achieving the objectives. Such articles include subjects related to the indicators of delays; including fuzzy logic; decision making; etc., and updating, by seeking the latest articles about the subject was carried out as the need arose. **Section 1.3** presents the aim and objectives of the research. An appropriate research methodology was identified to seek answers to the research questions which was briefly explained in **Section 1.4** .

Most of the materials obtained from the literature are cited in the references and the others are listed as a bibliography. The uncited bibliography provides additional resources in understanding the subject of delays. Most of the earlier research on delays generally focused on causes and types of delays, but before embarking on further discussion on delays the researcher would like to explore the definition of delays. It was observed that several authors have classified delays into different types which then helped to focus the scope of the study.

2.3 DEFINITION OF DELAYS

Generally, most authors defined delays of a project as the late completion of work from the planned schedule or contract schedule. The literature has revealed two versions towards this definition in which one group prefer to advocate a more general definition such as "time overrun from the planned or contract schedule". The other group prefers to relate delays to the critical activities of a network schedule. It is likely that each group has their own reason for preferring to use either version of the definition. The first group who subscribed to a more general definition includes Arditi et al. (1985 and 1989); Harris et al. (1991); Royer (1986); National Economic Development Office (1970); Ibbs (1984); Yates (1992 and 1993); Mendelson (1994); Riad et al. (1991); Chalabi et al. (1984); Bartholomew (1987); Morris et al. (1987); and Abd. Majid and McCaffer (1997b). The second group prefers to define delays in relation to critical activities and these include Kraeim et al. (1987); Trauner (1990); Rad (1979); Querns (1986); and Householder et al. (1990). This group defined delays as "the time overrun beyond the date that critical activities have been delayed".

For the first group, the definition suits when a planned schedule or the contract schedule does not identify its critical activities. While the later group prefers to relate delays to critical activities and some of them have demonstrated the effectiveness of evaluating delays using a network schedule.

From the review the researcher prefers to subscribe the following definition:

Delays mean "*The time overrun either beyond the contract date or beyond the date that the critical activities have been delayed*"

The preceding definition encompass both situations where sometimes a contract schedule or the planned schedule identifies critical activities and in another case the contract schedule is just a bar schedule. After a closer examination of the definition of delays, the next issue frequently discussed by previous researchers was the classification of types of delays.

2.4 TYPES OF DELAYS

There are three basic ways to classify delays:

(1) excusable delays with compensation;
(2) excusable delays without compensation; and
(3) non-excusable delays.

Figure 2.2 is an overview of the types of delays and exhibits some examples of causes for each types, however, the causes of delays are not limited to those in this Figure. Nevertheless most delays occurred can either be classified under excusable or non-excusable. It is important to note that some causes may need careful evaluation since they can either be classified under third party or contractor's fault. For example the national shortages on materials can be classified either way, but for the purpose of evaluating the literature reports, unless the document explained otherwise it was classified under third party. The next sub-section further discussed the types of delays generally defined by various researchers.

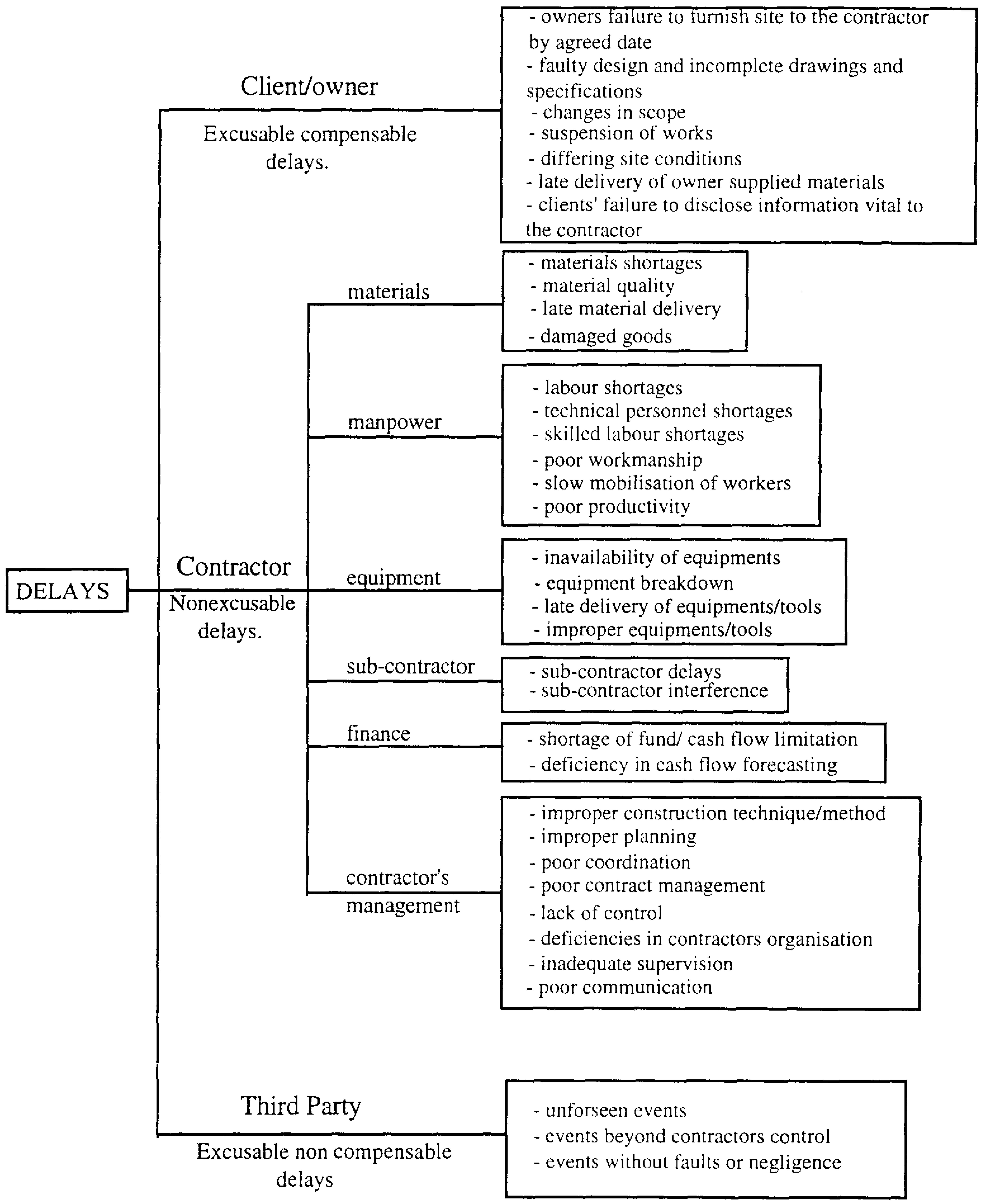


Figure 2.2: Classification of types of delays

2.4.1 Excusable delays without compensation

In general , this type of delay is caused by an unforseeable event beyond the control of either the client or contractor. Normally delays resulting from these events are classified under excusable delays without compensation. From the literature cited by various authors which include: Ibbs (1984); Arditi et al. (1985); and Kraiem et al. (1987) delays that were classified under this type were not compensated interm of cost. In most cases, a contract specifically notes the kind of delays which are not compensable, for which the contractor does not received any additional money, but may be allowed an extension of time. Both parties can incur loses in term of cost due to the causes classified under this category. These causes of delays include events such as force majeur; act of public enemy; war, acts of another contractor; strike etc.

2.4.2 Excusable delays with compensation

If the delay is compensable, the contractor is entitled to additional monetary compensation (Trauner, 1990). This type of delay is the result of clients action or inaction that affected the contract schedule date. Whether or not a delay is compensable depends primarily on the term of the contract. The decision concerning delays must be made within the context of specific contract. The contract should clearly define the factors that justify an extension of time and damage compensation for extra cost associated with delays. There are many factors in which a contractor could be delayed by the client such as changes in scope of work; failure to provide access; failure to make progress payment etc.

2.4.3 Non-excusable delays

Non-excusable delays (NED) are events that occur which are within the contractor's control, or are foreseeable (Trauner, 1990). In this instance the client is entitled to claim damages and the amount of damages is usually stipulated in the contract. Normally, the amount of damages depends on the contract value of the project but the amount is sometimes very high, depending on the length of delay and the rate of damages per day. Again the contract documents usually stipulate the events that classified the factors under this type of delay. Examples of these causes of delays include: material related delays; labour related delays; equipment related delays; improper planning; financial related delays etc.

From the preceding classification and definition of delays, non-excusable delays were perceived to create a lot of problems to the contractor. From the other types of delays a contractor could at least recover the loses in term of time or both time and cost. Many studies focus on the identification of the causes of non-excusable delays but little evidence is highlighted on issues such as indicators to distinguish the factors of delays and their common corrective actions. Having established both the definition and classification of delays the next question asked was 'how to quantify the delays'.

2.5 METHODS OF QUANTIFYING DELAYS

The process of analysing construction delays requires some documents to be made available before the actual quantification start. The necessary documents should include the followings:

(1) as-planned schedule; and

(2) as-built schedule

As-planned schedule

The as-planned schedule is the schedule submitted before the construction begins. Most projects have some form of as-planned schedule and this schedule is usually submitted in accordance with the contract requirements. The schedule can be in the form of network like the Critical Path Method (CPM), Programme Evaluation and Review Technique (PERT) or a simple bar chart.

As-built schedule

The as-built schedule is the schedule that reflects the actual work or event carried out during the construction. The site staff use the actual data to record the actual duration and sequence to carried out the activities. If the work schedule was developed using computer software then the as-planned schedule becomes the as-built schedule through updating. If the updating using a computer is not possible then the site personnel have to develop their own as-built schedule by reviewing several pieces of information which include the followings (Trauner, 1990):

- project daily reports
- project diaries
- minutes of meeting
- pay request/estimates
- inspection report by the designer, clients, consultant etc.
- correspondence
- memos

Based on the above information, it is possible to construct an as-built schedule. The process of analysing the as-planned and as-built schedule is not as easy as it appears. The normal indication is to compare the as-planned and as-built schedules and draw conclusions although comparison often lead to errors in the analysis (Trauner, 1990).

Several authors including Kraeim et al. (1987); Trauner (1990); Royer (1986), and others deliberated on the use of network schedule such as Critical Path Methods (CPM), Programme Evaluation and Review Technique (PERT) as the means to quantify construction delays. It can be concluded, from various explanations obtained from the literature that the comparison must be made on each individual activity. The comparison should not be made by comparing a number of activities of as-planned and as-built schedule as in Figure 2.3. From this Figure the delay was 22 calendar days i.e. by comparing activity D where as-planned was due to be completed on the 50th day and the actual completion was on the 72nd day. Total comparison approach may lead to inaccurate conclusions but instead one must make an analysis on each individual activity to obtain more appropriate results.

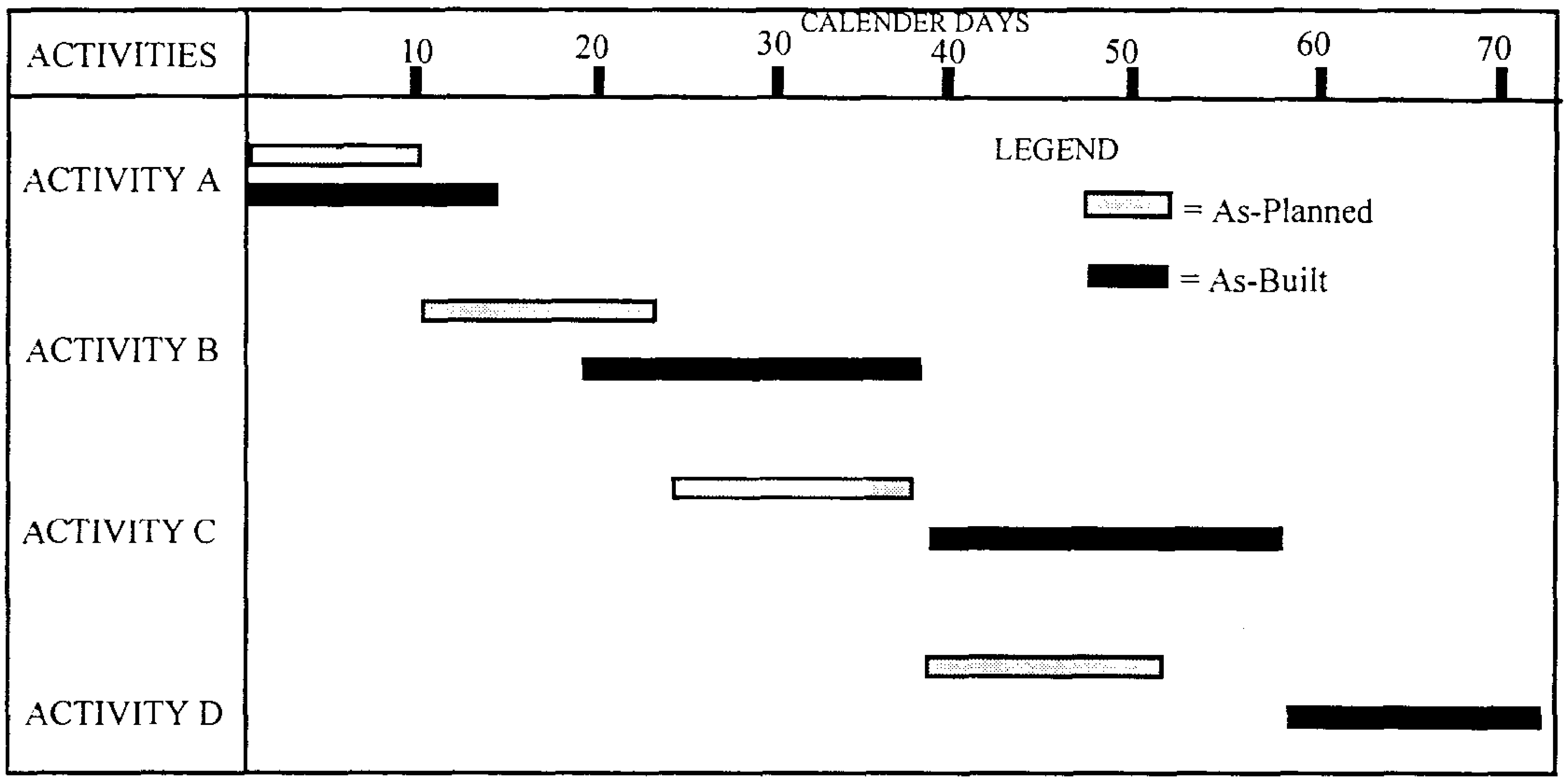


Figure 2.3: As-planned vs as-built schedules

From the above figure, one can make the assumption that activity D was delayed by 22 days but if carefully analysed activity D was delayed due to the preceding activities A, B and C. The actual duration taken to execute activity D was the same as planned and this concludes that activity D itself was not delayed. Thus instead activity A was delayed by six days also delaying the start of activity B by six days. The completion of activity B was extended by another four days and so activity C required an additional six days beyond the allocated duration. It is important to note that analysis conducted after several delayed activities is not an appropriate monitoring analogy. It is useless to implement a corrective action when the delayed activities have become history. The monitoring and control were inefficient due to the following reasons:

- impossible to rectify the earlier activities when they have been completed; and
- only short-term measures could be implemented to rectify or improve the situation.

Several delays analyses systems have been suggested by a few authors including: Kriem et al. (1987), Riad et al. (1991), which analysed delays for a certain number of days. As highlighted earlier this suggestion was not suitable for implementing a permanent corrective action. It is recommended that delays are continuously monitored which focus on critical activities, hence the problem of historical delays analysis, as suggested by Kraeim et al. (1987), Trauner (1990), and Royer (1986) can be avoided. Instant recognition of delays will provide an opportunity for the managers to implement permanent corrective action.

An effective delay analysis on critical activities should be conducted daily if one is to consider implementing the permanent corrective actions. The permanent corrective actions have to be implemented immediately once the delay is observed otherwise it will become irrelevant when the activity has been completed. The concept of permanent corrective action is to remove or improve the factors that cause the delay (Mondy et al., 1995) and they can then become a preventive measure for the future projects. Further explanation on permanent corrective action and short-term corrective actions is discussed in **Section 6.3**. Efficiency of monitoring could be improved further if the proposed model of evaluating performance due to the factors of delays is modelled in a computer that linked to the planning software.

2.6 DELAY DAMAGES

Delay damages can be in the form of monetary and/or time depending on the type of delays. For excusable delays without compensation the contractor is only entitled to time extension without any monetary compensation. With excusable delays with compensation the contractors are usually entitled to both monetary and time compensation. However, non-excusable delays entitled the client to claim damages from the contractor and it is commonly known as liquidated damages. Liquidated damages are usually predetermined prior to the execution of the contract and the exact amount is specified in a contract. The following is the typical contract clause that incorporates liquidated damages (Trauner, 1990):

"Should the contractor fail to complete the contract within the time allowed by the contract to include time extension allowed by executed change orders, then for each calendar day of delays, the client has the right to withhold the amount of US$500 per calendar day as liquidated damages.

These liquidated damages are compensation to the owner for costs the owner may experience due to the contractor's delays, and are not construed as penalties."

Several authors have reported the impact of delays on both the contractors and the client. Some of these delays run into several millions pounds sterling in terms of cost (National Economic Development Office, 1970) and others ended in dispute. Dallaire (1974), reported that schedule delays can cost $2 million a month while Riad et al. (1991), reported that the losses due to delays was in the order of US$30 million - US$35 million thus improving a few percent on schedule delays can lead to substantial savings. Abd. Majid and McCaffer (1997b), concluded that almost fifty percent of the causes were classified under non-excusable factors, and this justifies the focus of the study on issues related to non-excusable delays. To further identify the specific issues and scope to be covered researches related to construction delays were examined.

2.7 RESEARCHES RELATED TO CONSTRUCTION DELAYS

During the past three decades, records show that schedule and cost overruns were common amongst construction projects. Tah et al. (1993) cited that poor performance of projects in terms of time and cost overruns were common place in the construction industry. These common phenomena still exist within the construction industry in most countries across the globe. It was cited that the success rate of projects was generally poor (Morris et al., 1989). Despite much attention being given to construction management and analysis over the past three decades the literature indicates that delays and cost overruns were the norm, particularly for the larger and more complex projects.

Kraiem et al. (1987) states that long inefficiency delays would result in high cost due to liquidated ascertained damages. Arditi et. al. (1985) reported that some 18% of the total numbers of project in Turkey were delayed for as long as four years and some as much as 233% overruns as compared to the original schedule. About 50% of top ten causes reported by Arditi et al. (1985) were classified under non-excusable delays. The increase in cost for the Nuclear power plant projects in USA is high as reported by Rad (1979). National Economic Development Office (1992) claims that 66% of the time wasted during the construction stage was due to improper site supervision. National Economic Development Office (1992) also revealed that the time delays ranged from two (2) months to thirty five (35) months and the cost increase was in the range of -6% up to +50% correspondingly. In term of value this is between -£3 million to +£25 million. The Building Research Advisory Board of National Academy of Sciences (1978) quoted that cost may overrun by US$10 million for contracts between US$20 - US$50 million on projects involving tunnels. Householder et al. (1990) cited in a study that cost overruns due to delays were experienced by both contractors and client while Royer (1986) reported that a project was delayed as long as one year. The second major reason discussed in the study is cost overruns due to delays. Okpala et al. (1988) concluded that the principal cause of high cost of construction was due to delays. Dallaire (1974) reported that schedule delays can cost over US$2 million per month on power projects. Rogge et al. (1982) reported delays of between 0-20% occurred in the working week. Yates (1992) reported an extensive project delays generated by 21 separate contractors on site. Morris et al. (1987) cited over 4000 projects which have experienced schedule and cost overruns. Riad et al. (1991) conducted a study on delays related to a nuclear power plant in which losses due to delays on a US$112.5 million contract were in the order of US$30 million- US$35 million. A delay reported on a dam project by Chalabi et al. (1984) was 40% longer than scheduled and required an additional US$120 million. Elinwa et al. (1993), conducted studies on building projects and revealed that time overruns was between 50% - 420% which corresponds to a cost increase between 8% to 142%. The recent report by Assaf et al. (1995), identified the causes of project delays. Yates (1993), states that the industry is well aware of the problems of delays and conducted a research funded by National Science Foundation of Research supported by Business Round Table, the US Corp. of Engineers and Stony construction. Abd. Majid and McCaffer (1997b) reviewed the problems of delays in various parts of the world. A comprehensive review covering the available literature from 1964 until 1995, revealed a list of projects which had encountered schedule/cost overruns (refer to Table 2.1). A study conducted by Assaf et al. (1995) has concluded that these problem still persist within the construction industry. A very recent work by Yates (1997), examined the differences between types of delays encountered for different types of projects, different contracting methods, different project values, and different types of firms.

TABLE 2.1: Project overrun record.
(Partly adapted from Morris et al., 1989)
Year 1964 until 1995

References	Projects	Overrun		Comment
		% of time	*% of cost*	
Healey, 1964	13 Indian Irrigation and Power Projects.	-	12 - 230	Design changes, changes in scope.
Wilson, 1969	36 CEBG power plants.	almost half of the units have 12 months schedule	-	Labour problem, manufacturing difficulties.
Allen and Moris, 1970	84, UK Laboratory Research Projects.	206	0 - 50	No obvious reasons.
National Economic Dev. Office (NEDO), London, UK. 1970	13 UK Power Projects. 16 UK Oil and Chemical Plants.	Average 35	0 - 50	Design changes, insufficient training.
National Economic Dev. Office (NEDO), London, UK. 1970	7 UK Oil Gasification Projects.	0 - 27	-	Poor industrial relations.
Ministry of Programme Implementation, New Delhi, India.	187 Indian Public Projects.	0 - 19	19 - 45	Slow performance, problem on equipment supply.
Hufschmidt and Gerni, 1970.	8 CORPS of Engineers Projects. 79 Bureau of Reclamation Projects. 61 TVA Projects.	- - -	-35 to +55 -35 to +85 -18 to +16	Changes in design, schedule change etc.
Merewitz, 1973.	49 US Highway Projects. 49 US Water Projects. 59 US Building Projects. 15 US Other Projects.	- - - -	-40 to +80 -30 to +110 -30 to +110 -20 to +250	No obvious reason.
Gene Dallaire, 1974.	29 Nuclear Plants (US).	-	350	Late delivery, shortages of labour, poor productivity, strike.
Blake et al., 1976.	Various US Power Plant Projects.	-	58 - 258	No obvious reason.
National Economic Dev. Office (NEDO), London, UK. 1976.	3 Ethylene Units, 3 Distillation Units, 3 Refineries	0 - 68	-	Site management represent heart of the problems.
Department of Energy, London, UK. 1976	Various North Sea Projects.	-	44 - 100	Underestimation.

continued Table 2.1

Project overrun record

Year 1964 until 1995

References	*Projects*	*Overrun*		*Comment*
		% of time	*% of cost*	
Mason et al., 1977	199 UK Nuclear Power Plants.	88	26	Inflation and interest charges.
Cochran, 1978.	Trans-Alaskian Pipelines.	-	26 - 200	Resources shortages.
Enno Koehn et al., 1978.	Residential.	6 months average delays	1.1% increase per month delay	Environmental Protection Agency.
Building Research Advisory Board of Nat. Academy of Sc., ASCE, 1978.	Tunnelling.	-	25 - 50	Delay payment, unavailability of labour, sub contractor delays.
General Accounting Office, Washington DC, 1979.	940 US Civil and Military.	-	75	Increase quantity, schedule changes.
Marrow et al., 1979.	10 US Energy Prototype Projects.	-	100 - 200	Uncertainty.
Institute of Industrial Economics, Bergen, Norway, 1979.	20 Oil Projects.	-	10 - 780	No obvious reason.
Parvis F. Rad, 1979.	Nuclear Power Plants.	no figure quoted	no figure quoted	Unavailability of manpower, unavailability of materials, late delivery, sub standard material quality.
General Accounting Office, Washington DC, 1981.	2 US Coal Liquifaction Plants.	-	43	Poorly defined and administered project.
Richard L. Tucker et all, 1982.	8 Building Projects.	0 - 20	-	Reworks, waiting for materials and tools, equipment breakdown, waiting for crew.
General Accounting Office, 1982.	444 US Civil and Military Projects.	-	140	Schedule changes.
David F Rogge et al., 1982.	2 Construction Sites.	no figure quoted	no figure quoted	Equipment, material related delays.
Myers and Dwey, 1984.	55 UK Process Plants.	0 - 30 months	140 - 210	Poor project definition.
General Accounting Office, Washington DC, 1984.	3 US Nuclear Power Plants.	-	362 - 548	No obvious reason.
David F Rogge, 1984.	not defined	> 50	-	Inadequate expenditure on equipment, tools, materials, and waiting for materials, tools.
A. Fattah Chalabi et al., 1984.	Dam Project.	24 months delay	$US120 million	Equipment breakdown, poor communication, inadequate machinery, material shortages.

continued Table 2.1

Project overrun record

Year 1964 until 1995

References	*Projects*	*Overrun*		*Comment*
		% of time	*% of cost*	
Utilities Data Institute, Washington DC, 1885.	42 US Nuclear Plants.	-	190 - 3,900	No obvious reason.
Baum et al., 1985.	World Bank Projects, 1945-85.	-	30 - 40	No obvious reasons.
World Bank, Washington DC, 1985.	1,014 World Bank Projects, 1945 - 1985.	-	30 - 40	Delays due to increased innovation and complexity.
Arditi et al., 1985.	384 Turkish Projects.	34 - 44	40 - 110	Contractor's financial difficulty, shortage of material, shortage of qualified workers/personnel, deficiency in planning.
Segelod, 1986.	35 Swedish Projects.	10	-30 to +40	Technical innovation.
Okapala et al., 1988.	192 Projects in Nigeria.	no figure quoted	no figure quoted	Shortages of materials, poor contract managements, labour related delays.
Arditi et al., 1989.	1 Federal Project.	109 days delay	-	Shortage of qualified workers, poor co-ordination, deficient planning and supervision, sub contractor delay and slow mobilisation.
Jerry et al., 1990.	Project not well documented.	no figure quoted	no figure quoted	Failure to co-ordinate and approve shop drawing.
Riad N. et al., 1991.	Nuclear Power Plant.	-	50 - 90	Slow to mobilise, failure to provide sufficient equipment and failure to co-ordinate.
Abd. Majid, M.Z., 1992.	2 Office Blocks, UK.	> 8 weeks	4 - 8	Shortages of plants, general workers, materials, finance, Equipment breakdown, delay by sub contractor, slow mobilisation, deficiency in control and supervision.
National Economic Dev. Office (NEDO), London, UK. 1992.	Project not specified.	66	-	Supervisor not qualified.
Yates, 1993.	50 US army CORPS 35 district office.	no figure quoted	no figure quoted	Equipment, labour and material shortages.
Elinwa et al., 1993.	10 Building Contracts	50 - 420	8 - 142	Sub contractor delays and material shortages.
Sadi A. Assaf et al., 1995.	48 organisations (project not specified).	no figure quoted	no figure quoted	Material related delays, labour related delays, equipment delays.

Table 2.1 summarises the available record of project delays and cost overruns. The records shown in the table indicate that it is hardly showing underruns and there were various reasons reported for the delays. The list also indicates the seriousness of the problem of delays experienced by previous projects. More than 40 studies on project delays, which comprised of more than 4000 projects, have been compiled to substantiate the significance of this study. This compilation runs from 1964 until 1995. However, the record of delays was not only limited to this period. There are studies on delays conducted before 1964 and there are also recent studies on the subject of delays conducted by various researchers in the United Kingdom. Various types of projects have been included in the list such as infrastructure works, nuclear plants, process plants, transportation projects, tunnelling, oil projects, building projects, etc. Where possible the causes of delays for each study were established but few did not establish the causes of the delays. Most of these studies cited the impact of delays in term of time and or cost. Usually, the overrun were recorded in the percentage of time and/or cost. Excluding the projects that were completed earlier than scheduled some 4000 projects identified from the list experienced delays. The record revealed that a project was delayed by 420% of the planned schedule and some experienced delays up to 35 months (almost three years). The scale of overrun in monetary value can reach of up to US$120 million as reported by Chalabi et al. (1984). The observed figure has prompted the researcher to conduct further study of the subject of delays.

Generally, all studies on the subject of delays focus on identification of factors causing delays, groups of causes and establish the damage in terms of time and cost. Apart from studies that focus on factors and identify the effect of delays, a study by Rogge et al (1982) has to some extent suggested a methodology of obtaining delay information known as a `Foreman-Delays Survey (FDS)'.

Foreman-Delays Survey (FDS) were used by the construction foremen to make a qualitative and quantitative determination of the job factors resulting in loss of time. Subsequent use of this information as a management tool for the reduction of the magnitude of these factors and the improvement of worker morale was investigated. Rogge et al. (1982) concluded that the use Foreman-delays surveys were useful in information gathering but it does not provide information on the efficiency of the work method used, or assessing the factor that caused the problem. The method introduced was to measure performance and productivity improvement, although it was used to predict the trend of delays but it did not suggest the corrective measures.

Yates (1993) conducted a study that not only looked into the factors and consequences of delays but adopted a holistic approach in resolving the issue of delays. The work focused on designing a program that promoted schedule performance into the process of evaluating delays. The Delay Analysis System (DAS) was designed for determining possible causes for project delays and suggested an alternative course of action to prevent them. The proposed DAS program simulates the process of delay determinations by comparing technical parameters and accessing knowledge bases. In this system, the potential causes of delays are determined and the program generates suggestions for possible alternative courses of corrective action to reduce delays. The objective of DAS program was to presents information that could assist the managers to make decisions but some common factors of delays were not included. The logical reason for excluding these factors was the unavailability of indicators to distinguish them except using the intuitive judgement of managers. The pilot study for this research revealed a number of common factors such as inefficient communication, low moral and motivation, and too many responsibilities which persistently arise on site and were normally being assessed by intuitive judgement. Besides these factors the program does not established the relationship between the indicators and factors. A list of indicators was established but it is user's judgement to decide which indicator was used to identify the factor considered. The capability of the program is much reduced when the factors of delays were qualitative in nature. These factors require an intuitive judgement as their indicators and there is no evidence available from the literature which proposes an indicator that is able to identify the factors quantitatively. Furthermore, an indicator like intuitive judgement cannot easily be modelled in a computer unless it is designed with the capability of quantifying them. Usually information accumulated during the course of a construction related to project delays was normally lost due to inability to quantify it. Another issue, beside providing a list of corrective actions, is to establish a methodology of determining a corrective action. In the situation where corrective action is not identified this could provide an avenue to assist the managers in drawing the corrective action.

This study will augment and provide additional information for the DAS system. Nevertheless the study on DAS system has lead the writer to adopt a holistic approach of investigating issues related to delays, specifically the issue of non-excusable delays. The review revealed very little information on studies that focused on the issue of non-excusable delays. The following paragraph discusses on the findings from the literature that justifies the focus of the work.

Based on the classification and definition of delays (see **Section 2.3 and Section 2.4**), the factors causing delays for each individual study identified in Table 2.1 could therefore be classified. From the information gathered it was revealed that approximately fifty percent of the factors cited were classified under non-excusable delays (NED). Thus, this study focuses on the issues related to non-excusable delays. Moreover, addressing the issue can benefit the contracting organisations and the construction industry involved in projects. Since the factors of NED were due to the contractors inefficiencies, improving and controlling these inefficiencies would certainly give an impact towards contractors' performance and the industry as a whole. Alfeld (1988) states in his book, Construction Productivity: On-Site Measurement and Management, that:

"Perhaps no other industry in the world promises as large a pay back for performance improvement as does construction. Hundreds of billion, even trillion of dollars are spent each year on construction. An improvement of even a fraction of a percent in performance would produce billions in savings. Yet perhaps no other industry in the world has so steadily resisted abandoning traditional, reactive management methods for performance based management system."

The findings from the literature helps to narrow down the subject of the study and the foregoing discussion sets the framework for the research. It was anticipated that the findings on the issues related to critical factors of non-excusable delays are of great value to the contractors.

2.8 MATTER ARISING FROM THE REVIEW

There are several issues cited earlier that require further investigation and these help to develop the problems of the study. An extensive literature review revealed the factors (root-causes) of NED, cited by various researchers - including: Yates (1993); Arditi et al. (1985); Ibbs (1984); Dallaire (1974); Ling (1991); and others. According to Ibbs (1984) and Arditi et al. (1985), one of the causes of delay was due to sub-contractors, but they do not elaborate on the factors (root-causes) that contributed to sub-contractors delays such as poor planning, poor co-ordination, shortage of resources etc. There are several possible factors of NED that can contribute to a group of causes. Abu Bakar (1992) argued that to evaluate and understand a problem one has to assess the root-cause so that appropriate action can be decided based on the root-cause. Fey et al. (1994) concluded that to better evaluate a problem one must identify the cause at micro level. Root-causes, in this study, will be referred to as factors of NED where it can be distinguished into groups of causes by using the Ishikawa or Fish Bone also known as Cause-and-Effect diagram. Abd. Majid and McCaffer (1997b) demonstrated that using the above mechanism root-causes could easily be classified into groups of causes. This technique was further elaborated by Harris and McCaffer (1995), Hensey (1993), Oakland (1993), and Pall (1987). Figure 2.4, shows a simple example of how the tool is being used to distinguish and classify the factors into a group of causes. Apart from distinguishing the factors, it indicated and established the relationship between them (Pike et al., 1994 p232-235). Although cited records revealed the various factors and groups of causes, the study attempts to determine the common factors at micro level and this could further help to understand them in the process of searching for an appropriate corrective action.

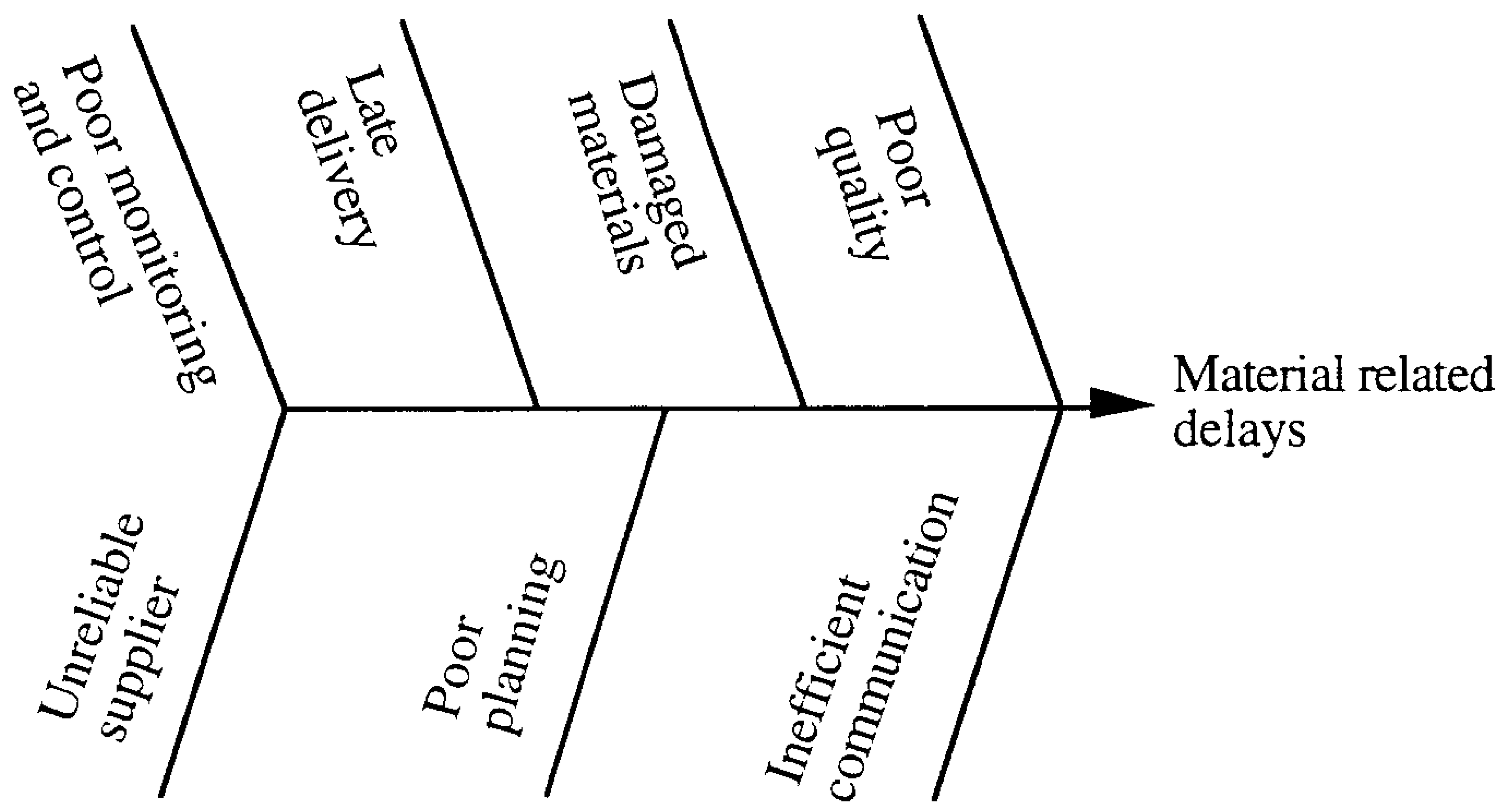


Figure 2.4: Simple cause-and-effect diagram.
(Identification of factors for a group of causes)

Following the process of identification of factors, the next essential step was to determine indicators that were able to distinguish these factors on site. These indicators should be able to show the status of the performance due to these factor(s). As mentioned earlier Yates (1992) developed a computerised Delay Analysis System (DAS) in which the study was to determine the possible causes for project delays and suggest an alternative course of action to prevent further delays. In the study several indicators were identified, but the system did not distinguish which indicators were used to identify the factors of delays and their relationship was not established. Consequently, the study attempted to identify the indicators that could distinguish the factors of NED while establishing the relative importance amongst several indicators for a particular factor. There is very little evidence from the literature to support the existing indicators such as schedule, daily record, progress curve and others which could be used to distinguish qualitative factors such as inefficient communication, low motivation etc. Most of the quantitative tools used cannot identify root-causes of the problems (Abubakar, 1992). Yates (1992) cited the technical causes of delays (factors) most of which were classified as a quantitative factor. Qualitative factors were excluded, thus problems of evaluation were not encountered for this type of factors.

To create an efficient and consistent assessment on qualitative factors an alternative indicator that can replace an intuitive judgement should be developed. Consistency in the assessment can be achieved if the proposed indicators have the capability of quantifying the factor. Developing a quantitative indicator can overcome the problem of modelling it in the computer and it will certainly increase the efficiency of processing the data during monitoring. Therefore, it was necessary to develop an indicator that covers wider types of factors, in which such tool can be made available to the site managers as an alternative mechanism. Currently, experienced construction managers will use their intuitive judgement to evaluate the qualitative factors (Barrie et al., 1992 p187-188) and this supports the argument for the need to develop alternative indicators. Several types of indicators available were explained in Chapter 4. When the factors have been identified and indicators shows that the schedule performance is affected, a search for corrective action or measures to reduce the effect would, hopefully, put the performance back on the right track. Various studies, including Yates (1992), have identified measures to reduce delays but there is little evidence to indicate how the corrective action was deduced. Most of the reports such as Suckarieh (1987), Abubakar (1992) and Mondy et al. (1995) revealed that the decisions on the corrective action were usually the responsibility of the site managers, based on their experience. Hence, the study also attempts to propose a methodology to derive permanent corrective actions for the critical factors and hopefully to confirm the approach with the expert opinion.

2.9 SUMMARY

(1) One of the essential stages of the research process is the literature review. The importance of the literature stage is to identify and formulate the problem of the study. Emphasis was also given to establish a structured process for the literature survey.

(2) The literature review examined issues related to delays which includes: the scale of the problems; reasons of why delay occurred; definitions of delays; methodology of identifying root-causes; indicators to the factors; identification on the approach of deriving permanent corrective actions; and identify the current process system for performance evaluation.

(3) The definition of delays encompasses two groups of thought, one prefers a more general definition and the other associates delays to critical activities. Thus, the definition has considered both views which is summarised as follows:
"*The time overrun either beyond the contract date or beyond the date that the critical activities have been delayed*"

(4) Delays were classified into three types: excusable delays with compensation; excusable delays without compensation; and non-excusable delays.

(5) The quantification of delays is not as simple as one could imagine and several authors have commented on the evaluation by comparing the as-planned and as-built schedules. However, many of these authors have proposed simulation as a means of analysis but this was viewed as ineffective in implementing a permanent corrective action. The researcher has suggested that monitoring delays on daily basis, focused on critical activities, will create an opportunity to implement a permanent corrective action.

(6) The permanent corrective actions should be implemented as soon as the delay on critical activities has been observed. If not, it will become irrelevant if the activities have completed and the only measure is to implement short-term corrective action.

(7) The literature revealed damages due to delays which can sometimes reach several million pounds sterling. Addressing and improving the problem of delays can lead to substantial savings and this highlights the significance of this study.

(8) Table 2.1 reveals that there were projects being delayed by as long as 35 months (almost three year) and the scale in monetary value can reach up to US$120 millions.

(9) Research work conducted by Yates (1993) does not include factors that were evaluated by intuitive judgement such as inefficient communication, low morale and motivation, lack of experience, and too many responsibilities. Thus, the proposed system is limited to the technical causes considered and from the review only quantitative indicators were discussed.

(10) Based on the classification and definition of delays previously reported, factors of delays (or root-causes) could be grouped under appropriate types of delay. It was revealed from the review that almost fifty percent of these factors could be classed under non-excusable delays.

(11) Several authors concluded that to evaluate and understand a problem one has to asses the root-causes so that the appropriate action can be taken. It was highlighted that root-causes (factors) could be identified using a cause-and-effect diagram.

(12) There is little evidence available from previous studies which focus on indicators to identify factors of delays especially factors of NED. To date only Yates (1993) has conducted a study on delays that includes indicators of the causes of delays. However, she does not established the relationship between factors and indicators.

(13) Intuitive judgement is currently being used to evaluate qualitative factors thus there is a need to propose alternative indicators that can quantify them. Hopefully these indicators can provide a consistent and standard assessment.

(14) Very little evidence is available from the literature showing how managers arrived at the corrective actions. Although Yates (1993) has proposed several corrective actions nothing is mentioned on the approach of determining them. Hence, this study also attempts to establish an approach of deriving permanent corrective action for the critical factors.

CHAPTER 3

GROUPS OF CAUSES AND FACTORS OF NON-EXCUSABLE DELAYS

3.1 INTRODUCTION

An extensive literature search was carried out to identify factors of non-excusable delays however some of them were not cited from the review. To identify as many factors as possible a strategy was formulated which can assist to determine the factors that were not revealed by the literature. In this study the strategy employed was to use the principal causes or groups of causes to generate the factors. Several previous studies have classified factors of delays under several groups of causes and this offered the basis of establishing the principal causes. Using Ishikawa analysis the factors of non-excusable delays were generated from these groups of causes.

From the review, some reports revealed the principal causes or groups of causes but not their root-causes. For these reasons the factors were generated from the principal causes using Ishikawa diagram or known as cause-and-effect analysis. Once the factors have been identified then they were confirmed by the managers (The Productivity Task Force Committee of European Construction Institute - refer to the list in **Appendix IV**) assigned to this project. This chapter presents the review of the groups of causes and the factors identified for each group of causes. Twelve groups of causes were identified from the literature and as well as those factors identified from the literature review, some were determined using the cause-and-effect analysis. The use of this mechanism had also helped to establish the relationship between the factors and groups of causes. The common factors were then identified and tested to establish the top ranked factors.

3.2 GROUPS OF CAUSES OF NON-EXCUSABLE DELAYS (NED)

3.2.1 Significant of grouping

Several authors conducted studies on the factors or causes of delays and classified them under various groups of causes. The advantage of grouping was to determine the factors which are related through a common characteristic. For example, the factors of delays related to 'materials' which include late delivery, poor quality, poor material planning, damage materials, etc. can be collected under the group of 'materials related delays'. Another significance of using groupings was that it helps to highlight the factors which appear in several groups of causes. A good example was 'poor planning', it appeared under several groups such as materials, equipment, labour, finance etc. Factors that commonly appear in several groupings can be considered as a common factor. The advantage of grouping factors was not only that it revealed the common factors but also it helped to focus our attention when generating the possible factors for a particular group. Some studies only identified a principal cause of delays for example 'shortages of materials' in which it can be due to a single or several attributable factors (root-causes). The attributable factors for 'shortages of materials' can be late delivery; and or unreliable supplier; and/or poor material planning; and/or poor monitoring and control; and/or due to inefficient communication. Thus, there are several factors that can influence these shortages and it is important to determine the correct factors that cause the problem. The correct identification of the factors helps to determine appropriate permanent corrective actions. Abu Bakar (1992) reported that the existing systems of evaluating performance did not appear to be capable of clearly isolating the actual root-causes of schedule overruns, let alone explain such causes in a way that would direct the corrective efforts of management. Hence, it is essential to identify the root-causes (factors) of delays which then allows a correct choice of permanent corrective action.

Arditi et al. (1985) discussed the findings on the factors of delays by highlighting them into groups of causes. The initial findings from Arditi's study were to identify the causes for construction delays. One of these causes, classified as a principal cause or group of causes, was 'difficulties in obtaining construction materials' which was ranked highest in the initial study. However, it required further investigation to identify the contributing factors that lead to 'difficulties in obtaining construction materials'. It was revealed that the contributing factors for this group of causes were due to shortage of cement and steel products; inadequate supply of sand, gravel and stone; low quality of available materials; and difficulty in obtaining imported materials. The indication from previous studies had shown the importance of grouping factors which not only indicated the principal cause but it also helped to identify the correct factor(s).

Previous studies have also cited a strategy of distinguishing the factors of delays from a principal cause or group of causes. Yates (1993) used the groups of causes to classify the factors of delays and further tabulated them into a delay matrix. Abd. Majid and McCaffer (1997b) have demonstrated the use of groups of causes to generate the contributing factors using cause-and-effect diagram. The finding from the review formed the basis for the researcher to employ a strategy to generate the factors using the principal cause or group of causes for this study.

3.2.2 Definition of group of causes

Several of the previous studies classified factors of delays into groups of causes but none cited defined a group of causes. Mainly the classifications was used to discuss the findings by highlighting the factors in the groups of causes. Assaf et al. (1995) classified the factors of delays into nine major groups and then elaborated the findings based on these groupings. Arditi et al. (1985) has also discussed the findings of his study by highlighting the top groups of causes of delays. Yates (1993) used the groups of causes to classify factors of delays but the definition of group of causes was not addressed. The review cited no definition of group of causes however it was necessary to classify and define the groups of causes for this study.

A group of causes was defined as a principal cause that comprises of several factors (root-causes). In this study, a group of causes is referring to the groups of causes of NED. Factors of non-excusable delays will be generated and identified under various groups. The identification of the various groups of causes is discussed in the next section.

3.2.3 Classification of groups of causes of non-excusable delays

The groups of causes were reported by several authors and as discussed earlier these groupings provided a basis for this study to establish the groups of causes of non-excusable delays. Assaf et al. (1995) classified the factors of delays into the following groups:

- materials;
- manpower;
- equipment;
- financing;
- changes;
- government relations;
- planning and controlling;
- environment; and
- contractual relationship.

Some of the above groupings such as environment, government relations and changes are classified under excusable delays. For example, the factors that were identified to influence environment were hot weather, rain, social and cultural elements. The factors for government relations and changes such as obtaining permits, excessive bureaucracy, mistakes in soil investigation, etc. were also classified under excusable delays. Since most of the factors were classified under excusable delays, these type of groupings were not adopted for this study. While contractual relationships have a mixture of factors which do not clearly represent the non-excusable group. Thus, it was also excluded for consideration in establishing the groups of causes. Another author Yates (1993) has classified the groups of causes as follows:

- engineering;
- equipment;
- external delays;
- labour;
- management;
- materials;
- owner;
- sub-contractor; and
- weather.

From the above list weather, engineering, owner, external delays were the groups of causes that were mainly comprised of factors classified under excusable delays. Meanwhile 'management group' was comprised of a mixture of factors that can be classified both under excusable delays and non-excusable delays, which makes it difficult to classify the type of delays it belongs to. However, this group of causes can further be brokendown into several principal causes such as 'technical personnel shortages', 'inadequate supervision', etc. From the above study, several groups of causes could be adopted to establish the principal causes for this research. Apart from the earlier mentioned works there were also others like Arditi et al. (1985); Ibbs (1984); Rad (1979); and Chalabi et al. (1984) that have contributed in the identification and classification of groups of causes for this study. Abd. Majid and McCaffer (1997b) further classify the groups of causes of non-excusable delays into twelve categories which was based on the above mentioned sources. From the review the groups of causes of non-excusable delays that were identified for this study were as follows:

- material related delays;
- labour related delays;
- equipment related delays;
- financial related delays;
- improper planning;
- lack of control;
- sub-contractor related delays;
- poor co-ordination;
- inadequate supervision;
- improper construction methods;
- technical personnel shortages; and
- poor communication.

The classification of the above groups of causes may not be limited to those mentioned but for the purpose of this study they can adequately cover various factors (root-causes) of non-excusable delays. Nevertheless, the above classification has also been confirmed by the respondents of the pilot study for this research. After the classification of groups of causes, the next step was to identify the contributing factors for each groups of causes. The identification of factors (root-causes) of NED has helps to better understand the factors at operational level. The following section discusses and identifies the factors of non-excusable delays for each of the groups of causes established earlier.

3.3 FACTORS OF NON-EXCUSABLE DELAYS

A factor of non-excusable delays is one of the elements that made up of a group of causes. A set of factors that belong to a group of causes could be cited from the literature review. However, uncited factors have been identified through discussion with the professionals from the industry along with the help of cause-and-effect diagram for each groups of causes. The cause-and-effect diagram also helped to establish the relationship between groups of causes and factors. The next sub-section explains how this mechanism helped to establish their relationship and encouraged the focus of thought in revealing the possible factors for the groups of causes. Further explanation on the mechanism or technique is essential before demonstrating the technique to identify the factors for each groups of causes.

3.3.1 Cause-and-effect diagram

The difficulty in citing some of the non-excusable factors from the literature has led to the search for a mechanism that can assist in distinguishing the possible factors. Cause-and-effect analysis was adopted to assist in distinguishing the factors of a principal cause. It is only when a root-cause of a problem was correctly diagnosed that any solution subsequently applied have a chance of lasting success in eradicating the problem (Hensey, 1993). Cause-and-effect analysis uses structured brainstorming, where it breaks down the complex problems and generate all possible causes of an observed 'effect'. Apart from this feature, the diagram sorts an idea generated and pointing to the root-causes.

Prior to constructing the diagram, the problem or effect to be investigated must be defined, together with the classification of the groups of causes. These groups of causes which were recognised as the main branch of the root-causes. A main branch would comprised of several root-causes (factors) and can simply be generated through brainstorming. It is important to note that the effectiveness of employing this mechanism becomes more apparent if the user had some practical experience of handling a project delays. To generate an idea using cause-and-effect diagram, it is best to resolve one group at a time that help to focus on the individual principal causes. Most importantly, the mechanism has helped to promote an open mind that encouraged the focus of thought in revealing the factors. To generate the flow of idea hard thinking was required that focus on what factors could possibly contribute to the group of causes. The overall fish bone diagram can help to generate ideas to identify the groups of causes i.e. main branches of the fish bone diagram and to focus on one group of causes at a time to generate the possible factors. Finally, the complex fish bone diagram helps to reveal the relationship of the factors to the groups of causes and finally on the 'effect' i.e. non-excusable delays. Pall (1987), cited that one of the characteristics of fish bone diagram is that it established the relationship of the root-causes to the 'effect'. Abd. Majid and McCaffer (1997b) have developed the complex fish bone diagram on factors of non-excusable delays. It provides as the main source of identifying the factors of non-excusable delays for this study. The following sub-section explains the review of the factors based on individual groups of causes.

Factors for materials related delays

'Materials related delays' was identified as one of the groups of causes of non-excusable delays. Any factor that is related to materials was categorised under this group of causes. One of the sources used to identify the factors under materials group of causes was the literature review. Not all the possible factors could be cited from the literature hence cause-and-effect diagram was employed to assist in identifying additional factors. To comprehend the literature review this study used cause-and-effect diagram or fish bone diagram to generate additional factors which were not cited. The combination of both methods and validated by the Productivity Task Force Committee of the European Construction Institute (please refer to the list in **Appendix IV**), has established the factors to be considered for this study. The same approach was applied to all the groups of causes that were identified earlier in **sub-section 3.2.3**

From the review, only non-excusable factors cited for this group of causes were considered through a careful selection and evaluation. This was necessary because some studies did not classify the factors for the group of causes under specific types of delays. As well as the task of identifying the factors, the researcher has had to evaluate and classify the type of factors based on the definition mentioned earlier.

Several studies identified that 'material quality' was one of the factors that influence delays. Yates (1993); Rad (1979); and National Economic Development Office (1970), discussed about 'low quality materials' that had been rejected from site which delayed the related works. 'Low quality materials' which did not comply to the specification was classified under non-excusable delays because it was viewed as the fault of the contractor. Another non-excusable factor cited by Yates (1993) was 'damaged goods' in which most of the times was due to improper handling and storage. The most common cited factor for this group of causes was 'late material delivery'. This factor was identified by several authors includes Yates (1992); Rad (1979); Okpala et al. (1988); Assaf et al. (1995); and Abd. Majid and McCaffer (1997b). But from the discussion, before conducting the pilot test, one of the assigned managers for this study argued to exclude this factor. The argument put forward by the manager was that 'late delivery' most of the time was due to 'unreliable supplier' or 'inefficient communication with the supplier' or 'poor planning' thus this factor was excluded from the study. Besides those factors cited from the review, the cause-and-effect diagram has helped to generate an additional factor for the group of causes.

The mechanism employed to generate additional factors was cause-and-effect diagram following the approach explained earlier. Figure 3.1 shows an additional factors identified besides that cited from the literature. These factors were then confirmed by managers (please refer to the list of Productivity Task Force Committee, **Appendix IV**) before conducting the pilot test.

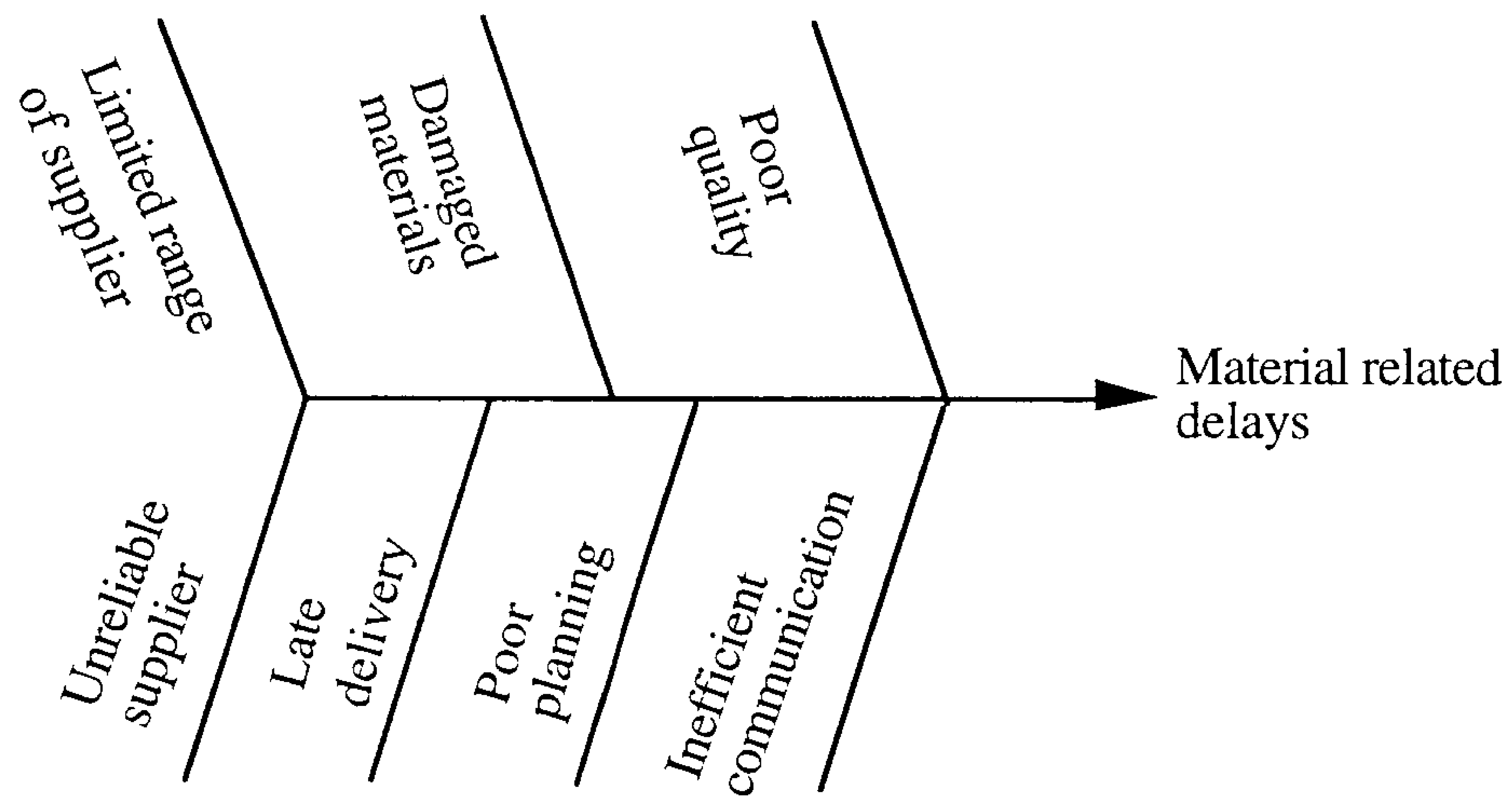


Figure 3.1: Breakdown of factors for materials group of causes using cause-and-effect analysis

The above diagram also helps to show the relationship of factors to a group of causes while it clearly indicates the breakdown of the factors (root-causes). It was also important to note that the generated factors were not limited to those identified above.

Factors for labour related delays

Labour related delays, one of the groups of causes identified earlier, was commonly cited in the literature that caused delays. Several factors that related to labour can be distinguished and categorised under this principal cause. The methodology of establishing the factors for this group of causes was similar to that of the materials' group. Rogge (1984); Tucker et al. (1982); Rogge et al. (1982); Arditi et al. (1989);

Riad et al. (1984); Ibbs (1984); and Abd. Majid and McCaffer, (1997b) cited 'slow mobilisation' as one of the factor that cause delays. This factor was classified under non-excusable delays as it was normally within the responsibilities and control of contractor. Meanwhile, 'poor quality' or 'poor workmanship' was cited in several studies include Rogge (1984); Rogge et al. (1982); Ibbs (1984); National Economic Development Office (1970); and Rad (1979). Another non-excusable factor cited from the literature was 'labour strike' and highlighted by various authors include Chalabi et al. (1984); Yates (1993); and National Economic Development Office (1970). The 'labour strike' usually occurred due to disputes between the main contractors and labour force that causes by various possible factors such as late payment, poor facilities, poor welfare service, etc. However, if it was due to a 'national strike' it may require a careful interpretation to which type of delays it can be classified. 'Inefficient communication' or 'poor communication' was another non-excusable factor cited from the studies conducted by Chalabi et al. (1984); Tucker et al. (1982) and others. The 'poor communication' was due to inefficient communication practised by the contractors on site whether between their own site organisation, consultant and client. 'Low morale/motivation' was cited by Tucker et al. (1982) in detecting problem of labour on site using the Foreman-Delay Survey.

Besides the factors revealed by the literature an additional factor could also be generated from the cause-and-effect diagram as shown in Figure 3.2.

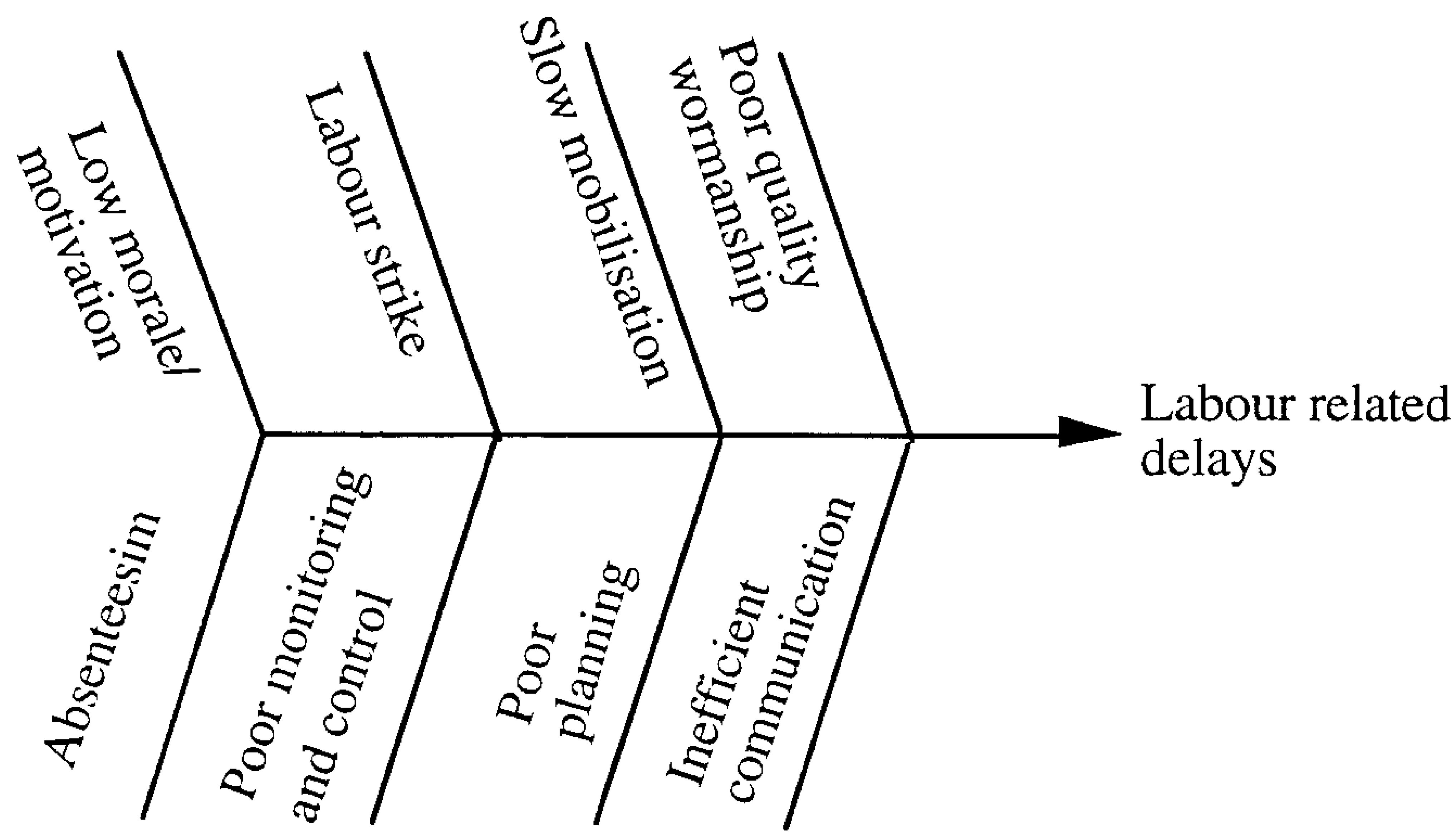


Figure 3.2: Breakdown of factors for labour group of causes using cause-and-effect analysis

Additional factors generated apart from the review were 'poor planning'; poor monitoring and 'absenteeism' in which both factors were included in this group of causes. 'Poor planning' can be due to inaccurate projection of labour requirement to execute the planned activities.

Factors for equipment related delays.

Some of the factors that were categorised under equipment related delays was revealed from the review include 'equipment breakdown', 'improper equipment' and 'poor communication with the supplier'. 'Equipment breakdown' was reported in several studies which include Vorster et al. (1990); Rogge et al. (1984); Tucker et al. (1982); Rogge et al. (1982); Yates (1993); Chalabi et al. (1984); Dallaire (1974); and Abd. Majid and McCaffer (1997b). The significant reason reported for 'equipment breakdown' was due to the lack of proper maintenance by the contractor or the supplier, Chalabi et al. (1984). Some of the earlier authors also identified 'improper equipment' as one of the causes of delays. Yates (1993); and Vorster et al. (1990) cited 'improper equipment' used by the contractor has contributed to delays. Tucker et al. (1982) emphasised the importance of communication not only between various parties which also includes the suppliers. Clear and effective communication between contractors and supplier, who supply the machinery, helps the smooth running of the project. Poor communication was the roadblock to effective execution of project which then cause delays.

Apart from the above factors, an additional possible factors identified were 'unreliable supplier' and 'poor equipment planning'. Both of these factors were categorised under this group of causes and Figure 3.3 shows the representation of the factors identified.

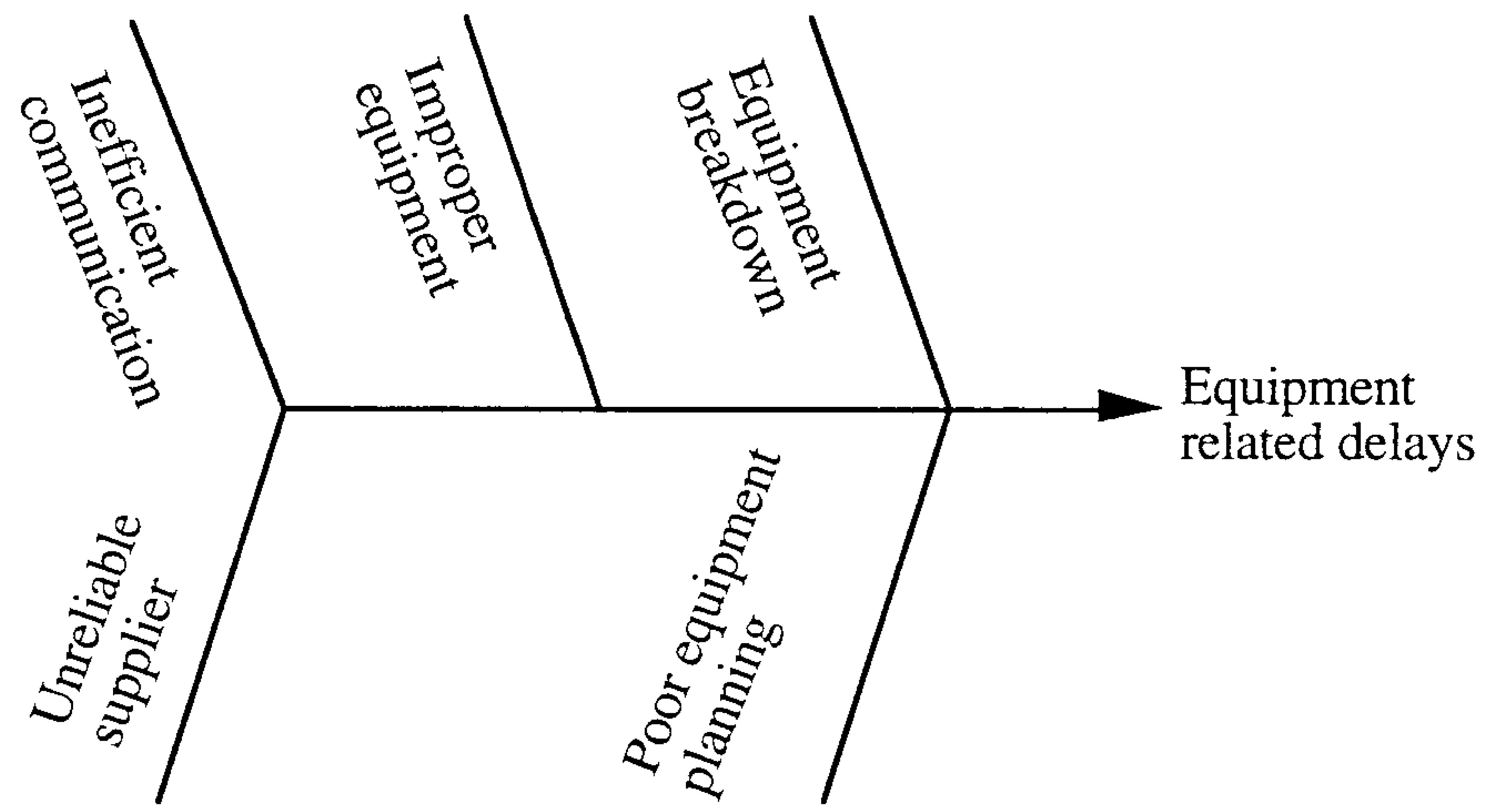


Figure 3.3: Breakdown of factors for equipment group of causes using cause-and-effect analysis

The above figure shows the additional factors generated were 'unreliable supplier' and 'poor equipment planning'.

Factors for sub-contractor related delays

As mentioned earlier the review (refer to labour related delays) cited 'slow mobilisation' was not only for the contractors own labour force but it also include the sub-contractor's labour force. Several studies have cited this factors under labour related delays. 'Poor quality workmanship' by the sub-contractor's labour force was another factor mentioned by the previous authors (refer to labour related delays) and classified it under labour related delays. This was one of an example where 'poor quality workmanship' can be classified under several groups of causes. Obviously if the factor was due to non compliance of workmanship by the sub-contractor it has to be classified under non-excusable delays. Yates (1993), and Tucker et al. (1982) cited 'interference between trades' has to some extend hinder the progress of the works and Yates (1993) added that 'sub-contractor's bankruptcy' was also identified as a factor that contributed to delays. While Riad et al. (1991) cited failure to man the project i.e. to 'monitor and control' the project was classified as non-excusable delays. Figure 3.4 includes has also distinguished other factors that were not cited from the review.

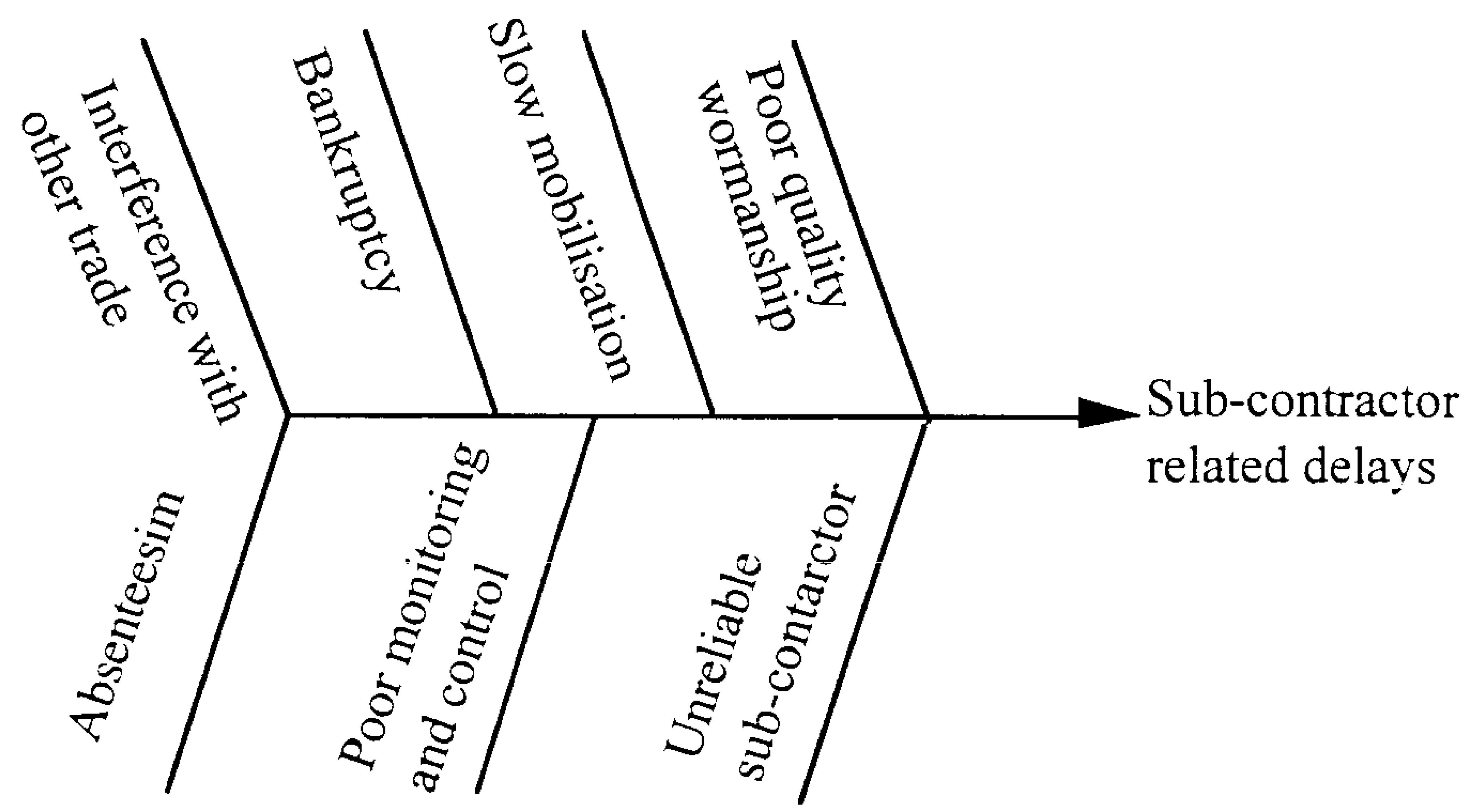


Figure 3.4: Breakdown of factors for sub-contractor group of causes using cause-and-effect analysis

An additional factor identified from the cause-and-effect analysis was 'unreliable sub-contractor'.

Factors for improper planning

Several studies observed that this was one of the principal cause of delays but strictly it can be due to several number of contributing factors. Studies conducted by Yates (1993); O'connor et al. (1987); Arditi et al. (1985 and 1989); Ibbs 1984; Chalabi et. al. (1984); and Elinwa et al. (1993) have highlighted this principal cause. However, Abd. Majid and McCaffer (1997b) have identified the root-causes that contribute to this group of causes. Using the cause-and-effect analysis it was possible to generate an additional factors. Figure 3.5 shows the breakdown of the factors that relate to improper planning.

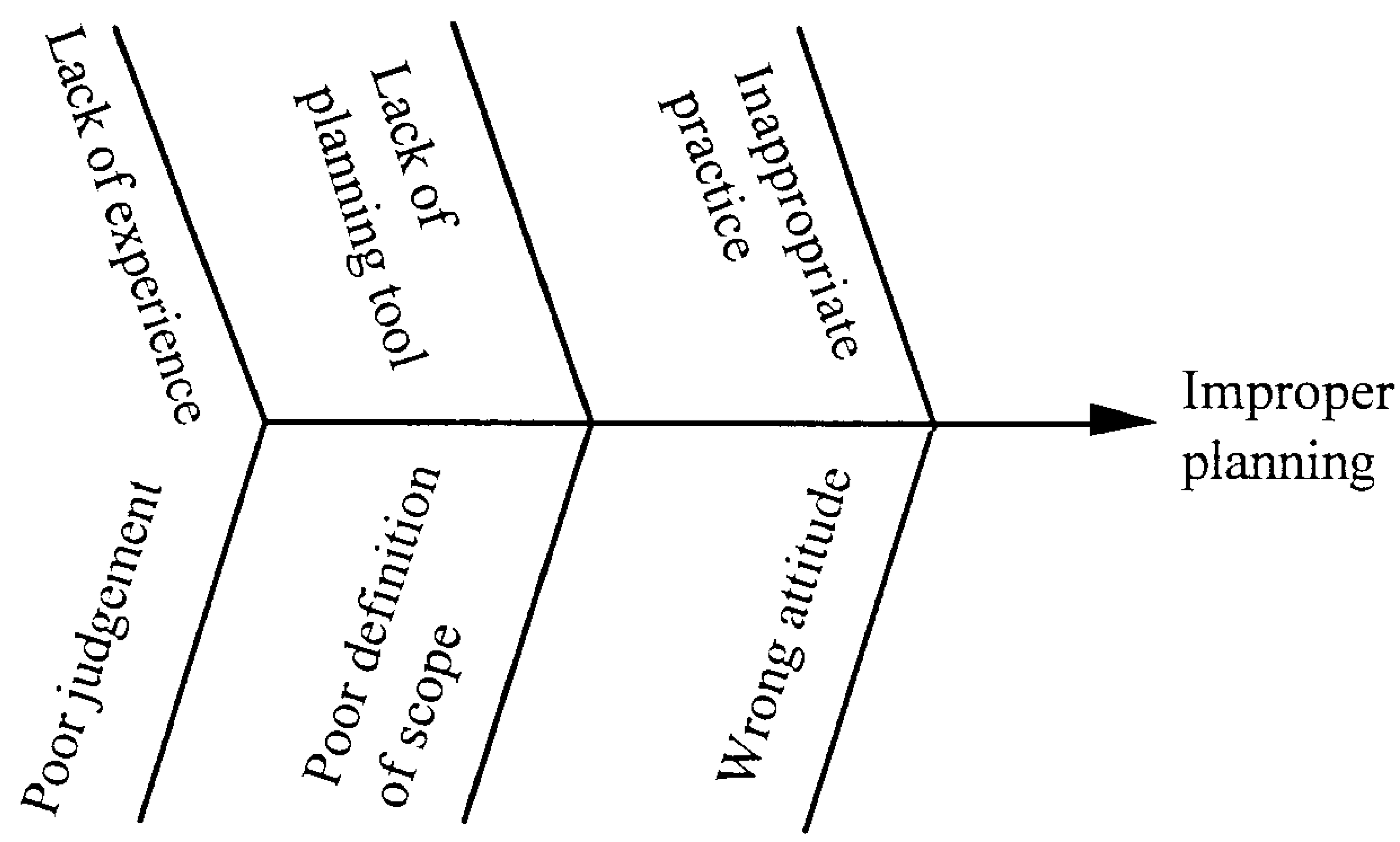


Figure 3.5: Breakdown of factors for improper planning group of causes using cause-and-effect analysis

The above factors were identified and this figure clearly indicates further breakdown of the cause was possible.

Factors for financial related delays

Arditi et al. (1985); Riad et al. (1991); Ibbs (1984); Rad (1979); and Abd. Majid and McCaffer (1997b), mentioned that 'inadequate fund' was one of the non-excusable factor that led to delays. Chalabi et al. (1984) cited 'poor financial planning' has contributed to construction delays. While Elinwa et al. (1993), identified that 'poor monitoring and control' was one of the factors that influence the smooth running of a project. Figure 3.6 shows other possible factors that were identified as contributing factor towards delays.

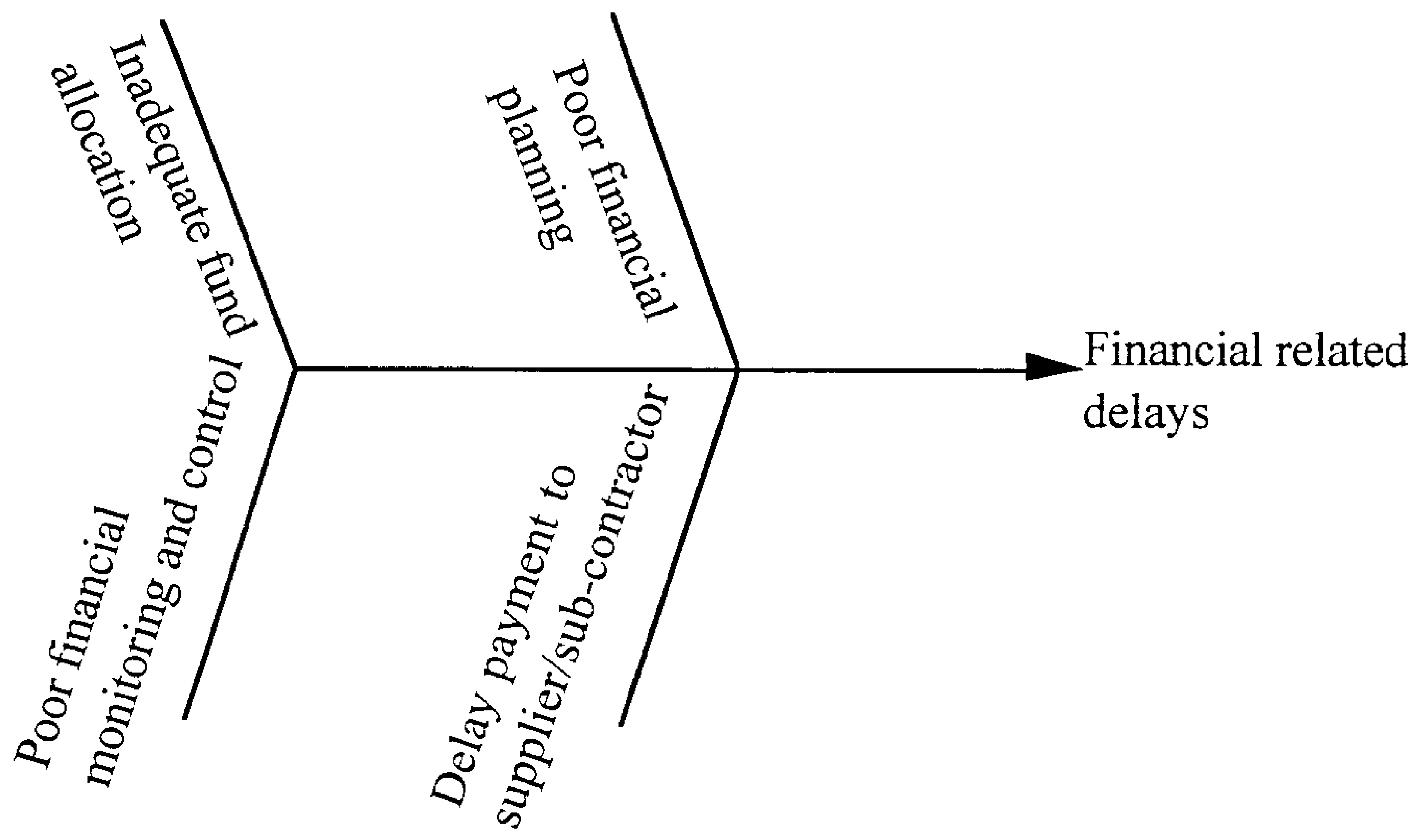


Figure 3.6: Breakdown of factors for financial group of causes using cause-and-effect analysis

Factors for lack of control

Arditi et al. (1985 and 1989) reported that 'shortages of site personnel' has lead to delays. 'Shortage of personnel' has led to failure to man the job or to control the job and Ibbs (1984) cited that failure to mobilise and man the job was one of the non-excusable factors. Several authors reported that 'lack of control' as one of the principal cause which result in delays. However, this principal cause could be attributed from several factors and once again the cause-and-effect was use to generate the possible factors that contributed to the lack of control. Figure 3.7 shows the possible factors generated under this group of causes.

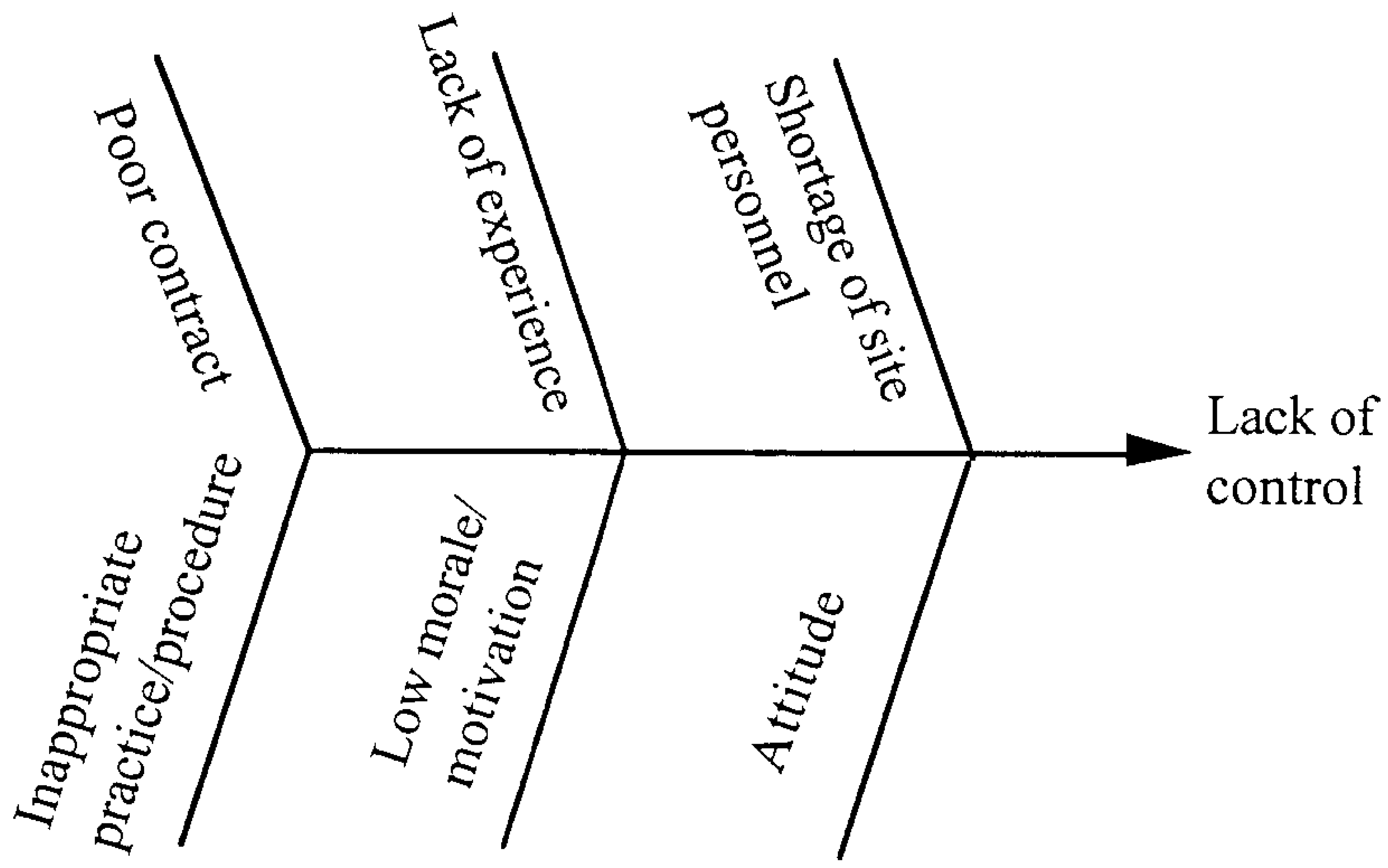


Figure 3.7: Breakdown of factors for lack of control group of causes using cause-and-effect analysis

Factors for poor co-ordination

Royer (1986); Riad et al. (1991), Rad (1979), Elinwa et al. (1993) cited 'poor co-ordination' as one of the principal cause that lead to delays. However, they did not distinguish the root-causes that contributed to this principal cause. Abd. Majid and McCaffer (1997b) used the cause-and-effect diagram to generate the following factors as shown in Figure 3.8. The factors identified were among the possible factors to be considered for this study.

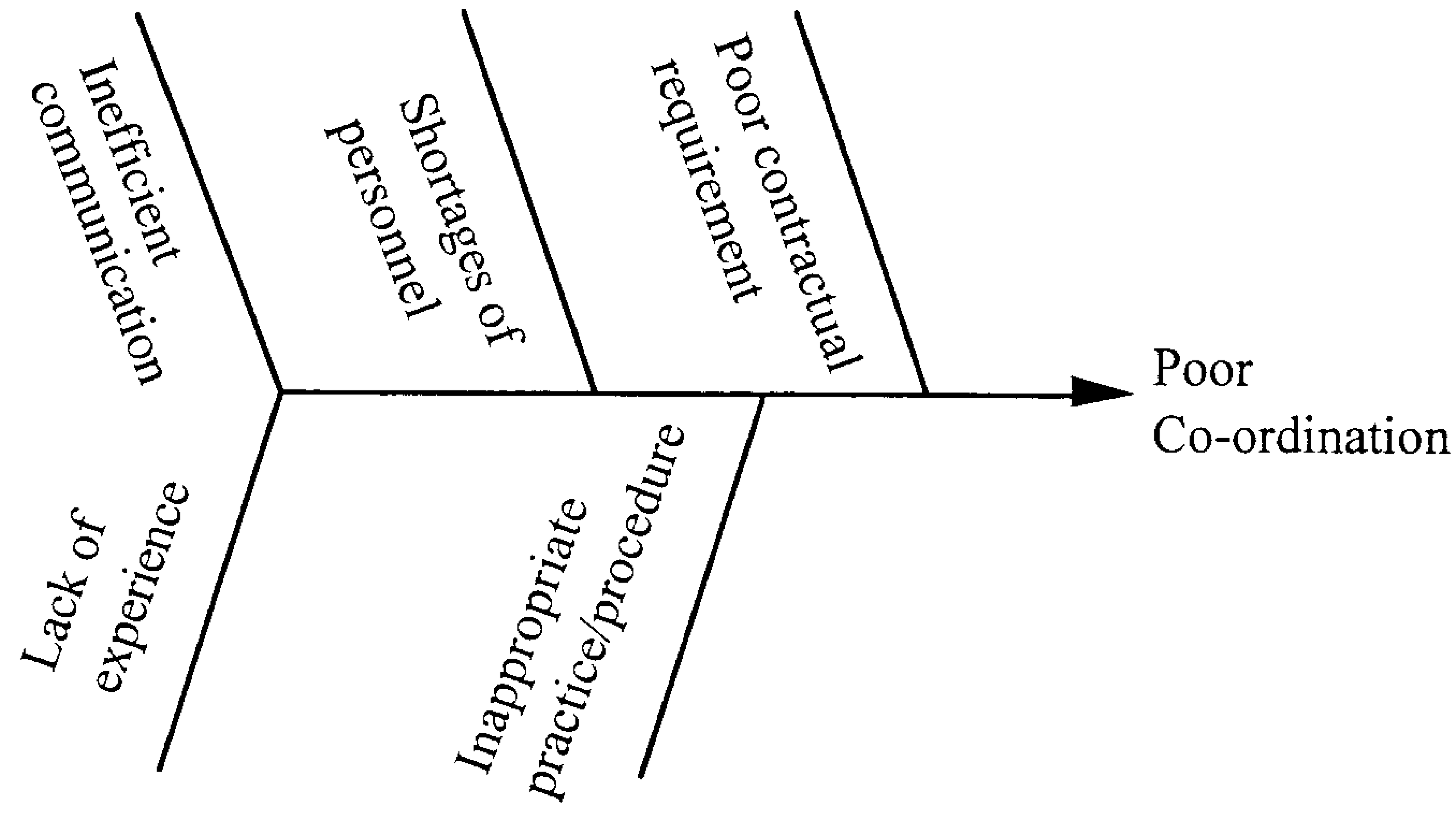


Figure 3.8: Breakdown of factors for poor co-ordination group of causes using cause-and-effect analysis

Factors for inadequate supervision

Inadequate supervision was cited by several authors include Arditi et al. (1985) and (1989); Riad et al. (1984); Ibbs (1984); and Rad (1979). However Abd. Majid and McCaffer (1997b) highlighted the need to identify its attributes which were the factors that contributed to this group of causes. Figure 3.9 below shows the possible factors that were categorised under 'inadequate supervision'.

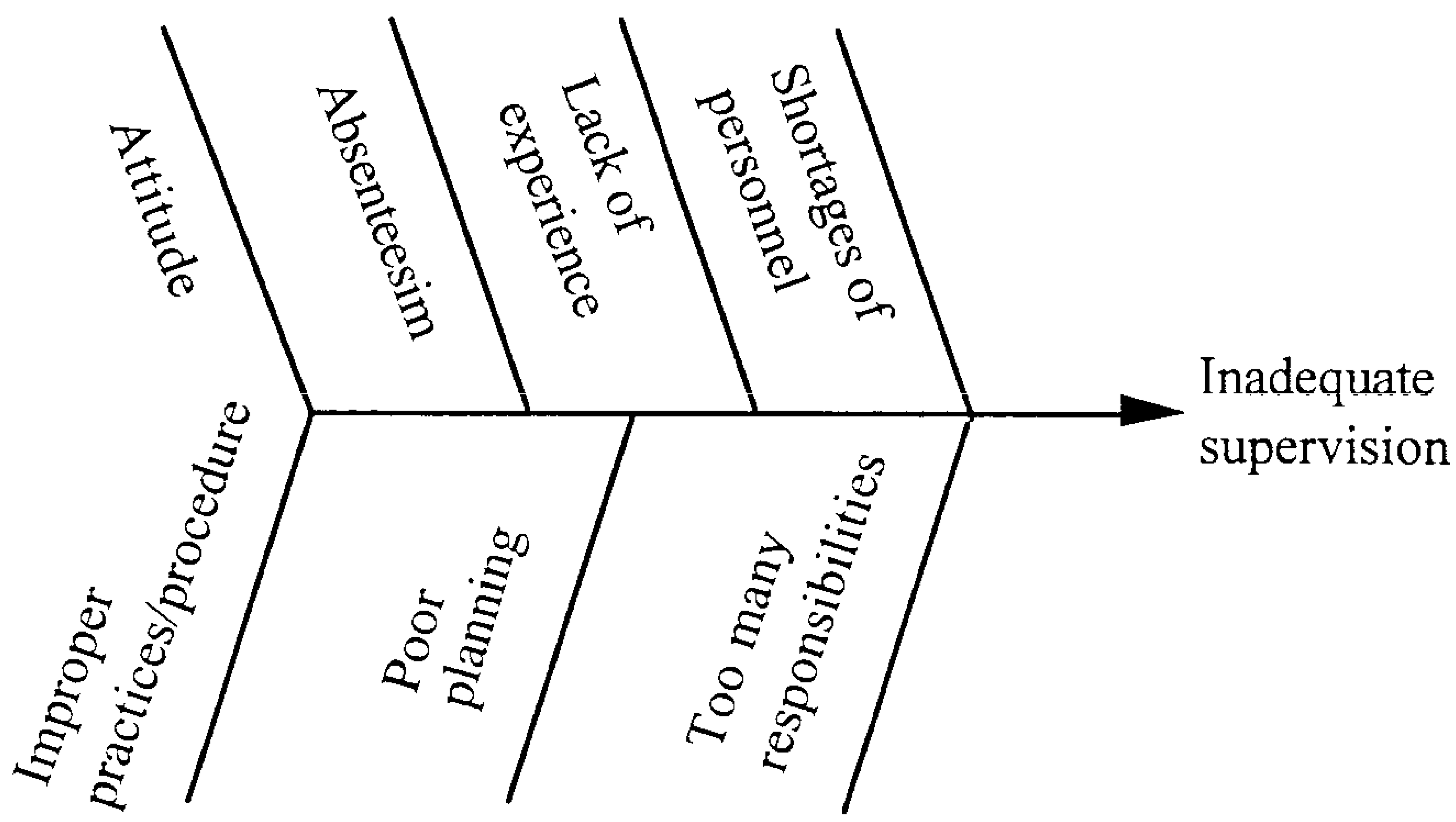


Figure 3.9: Breakdown of factors for inadequate supervision group of causes using cause-and-effect analysis

Factors for improper construction method

'Improper construction methods' was cited by a couple of authors which include Yates (1993) and Rad (1979). However, this group of causes can comprised of several attributable factors and it was identified as one of the principal cause. Figure 3.10 has revealed the factors that were categorised under this group of causes.

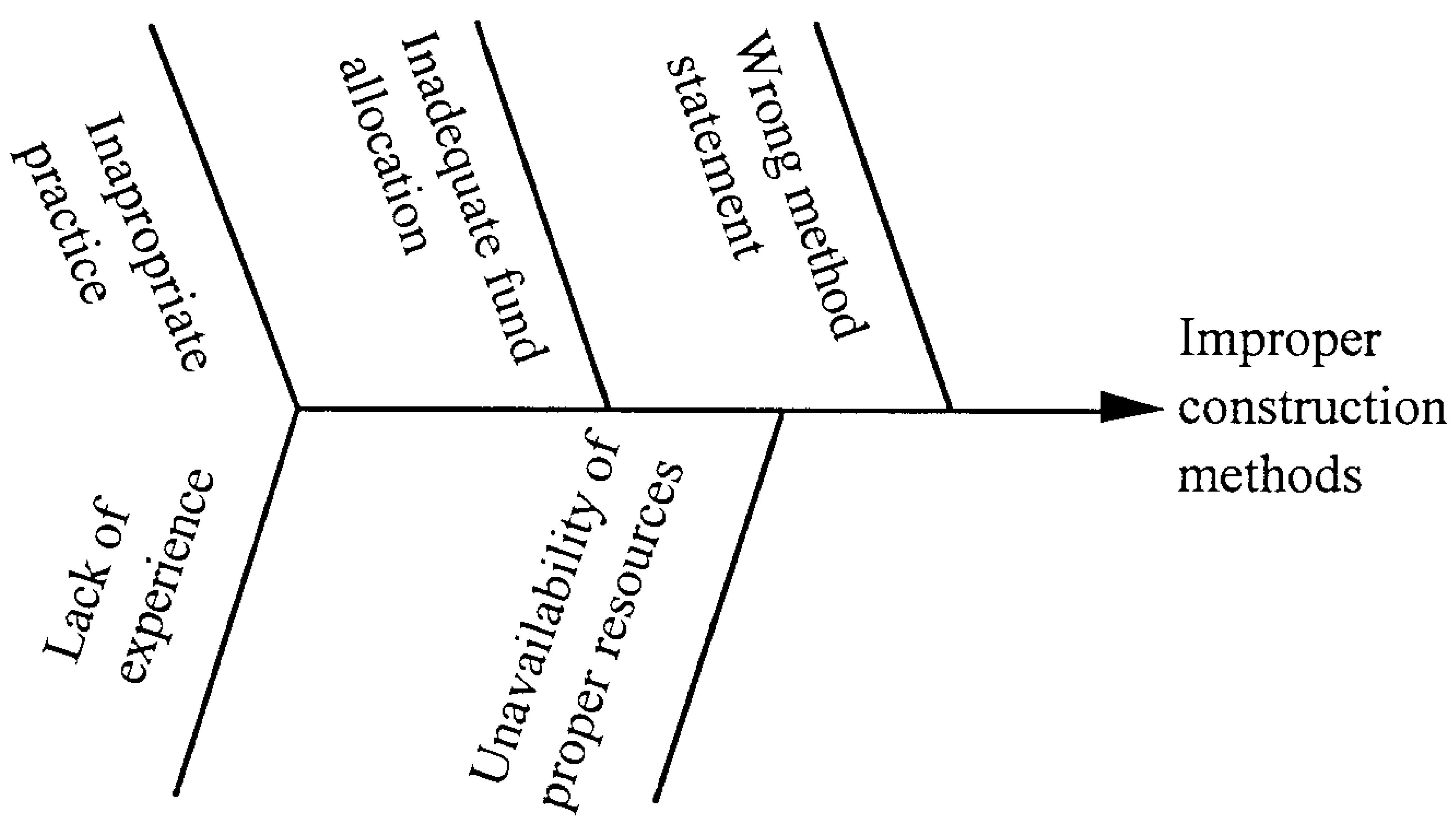


Figure 3.10: Breakdown of factors for improper construction methods group of causes using cause-and-effect analysis

Factors for technical personnel shortages

Arditi et al. (1985 and 1989) cited technical personnel shortages as one of the group of causes that lead to delays but the study only highlighted the factors that were categorised under an excusable delays. However, non-excusable factors were carefully distinguish and cause-and-effect analysis has facilitated the process. Figure 3.11 shows the non-excusable factors identified that were categorised under this group of causes.

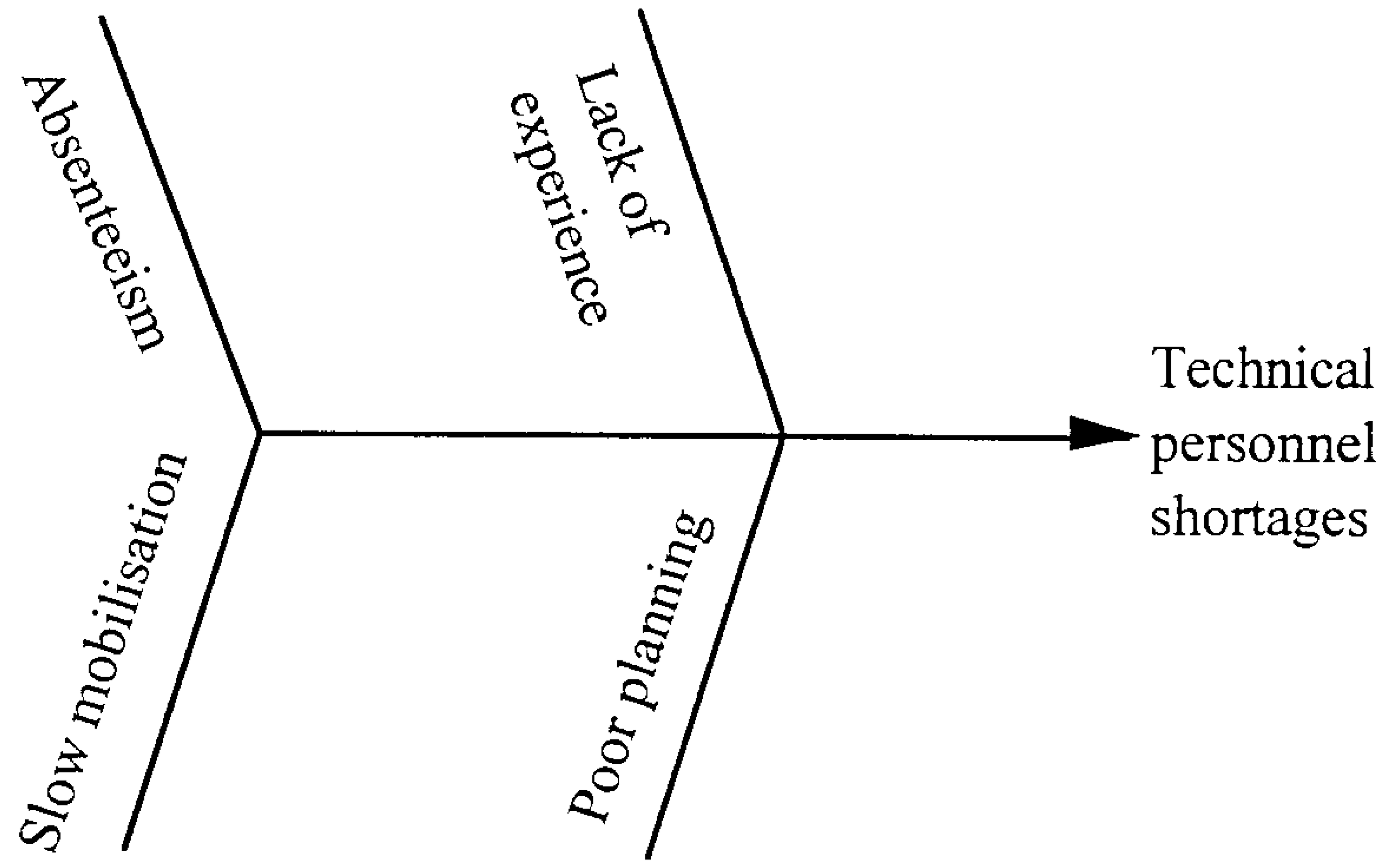


Figure 3.11: Breakdown of factors for technical personnel shortages group of causes using cause-and-effect analysis

Factors for poor communication

Several studies concluded that one of the principal cause of delays was due to 'poor communication'. O'Connors et al. (1987); Tucker et al. (1982); Rogge et al. (1982); Rad (1979); and Chalabi et al. (1984) reported the significant impact of this cause toward delays. However, further appraisal was necessary to identify the root-causes that contributed to 'poor communication'. Figure 3.12 shows the possible factors that can be categorised under this group of causes.

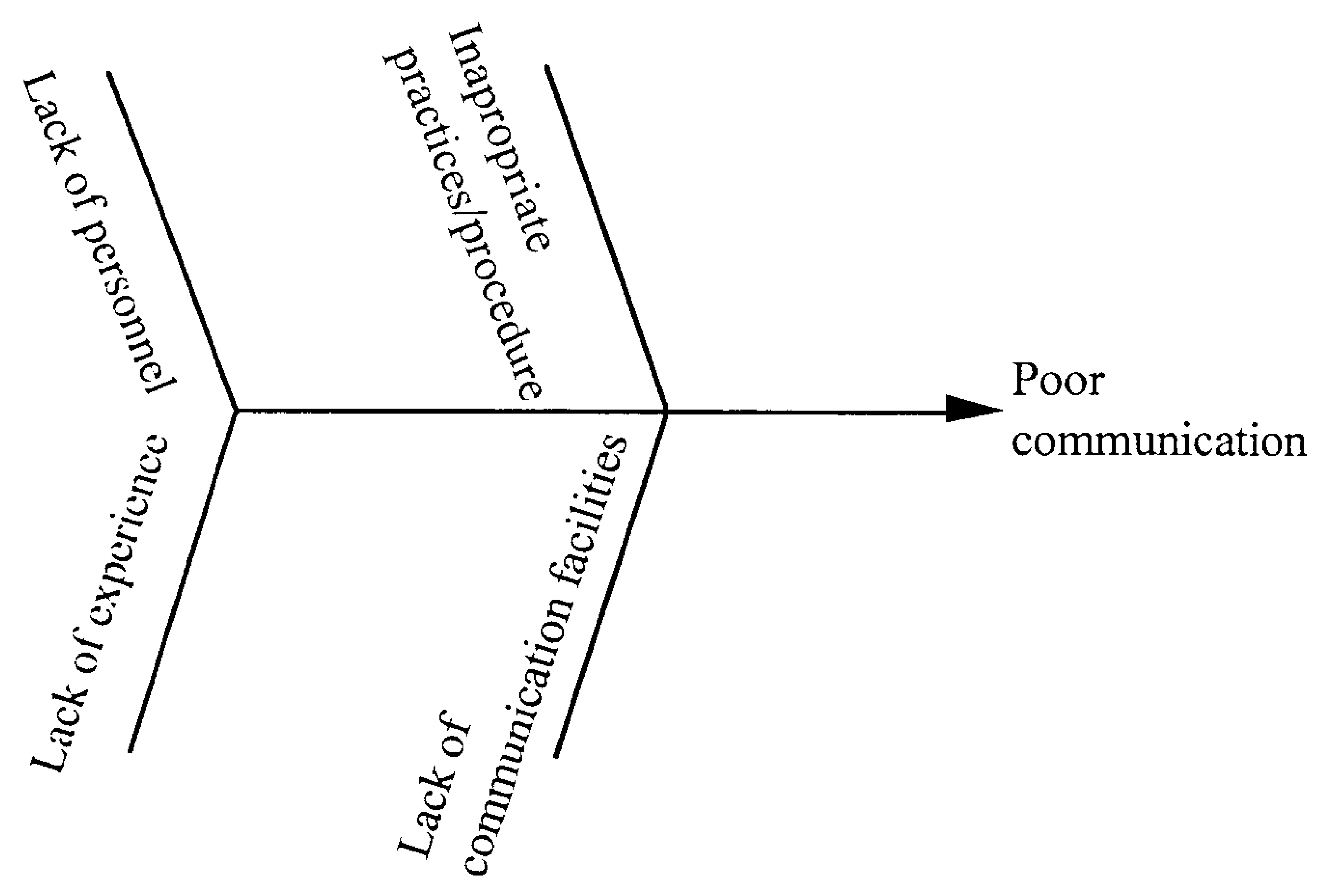


Figure 3.12: Breakdown of factors for poor communication group of causes using cause-and-effect analysis

The above figure highlighted the possible factors that were categorised under 'poor communication' nevertheless there may be other possible factors which can be the attributes to this group of causes.

3.4 RELATIONSHIP BETWEEN FACTORS, GROUPS OF CAUSES AND NON-EXCUSABLE DELAYS

The complex nature of the relationship between factors, groups of causes and non-excusable delays has to be established in order to highlight the significant number of factors that can influence the contractor's schedule performance. Sixty nine root-causes (factors) were highlighted in Figure 3.13 indicates that there is a high probability of one occurring on site is inevitable. Presenting this complex relationship in graphical form can assist managers to quickly identify the factors that will occur on site.

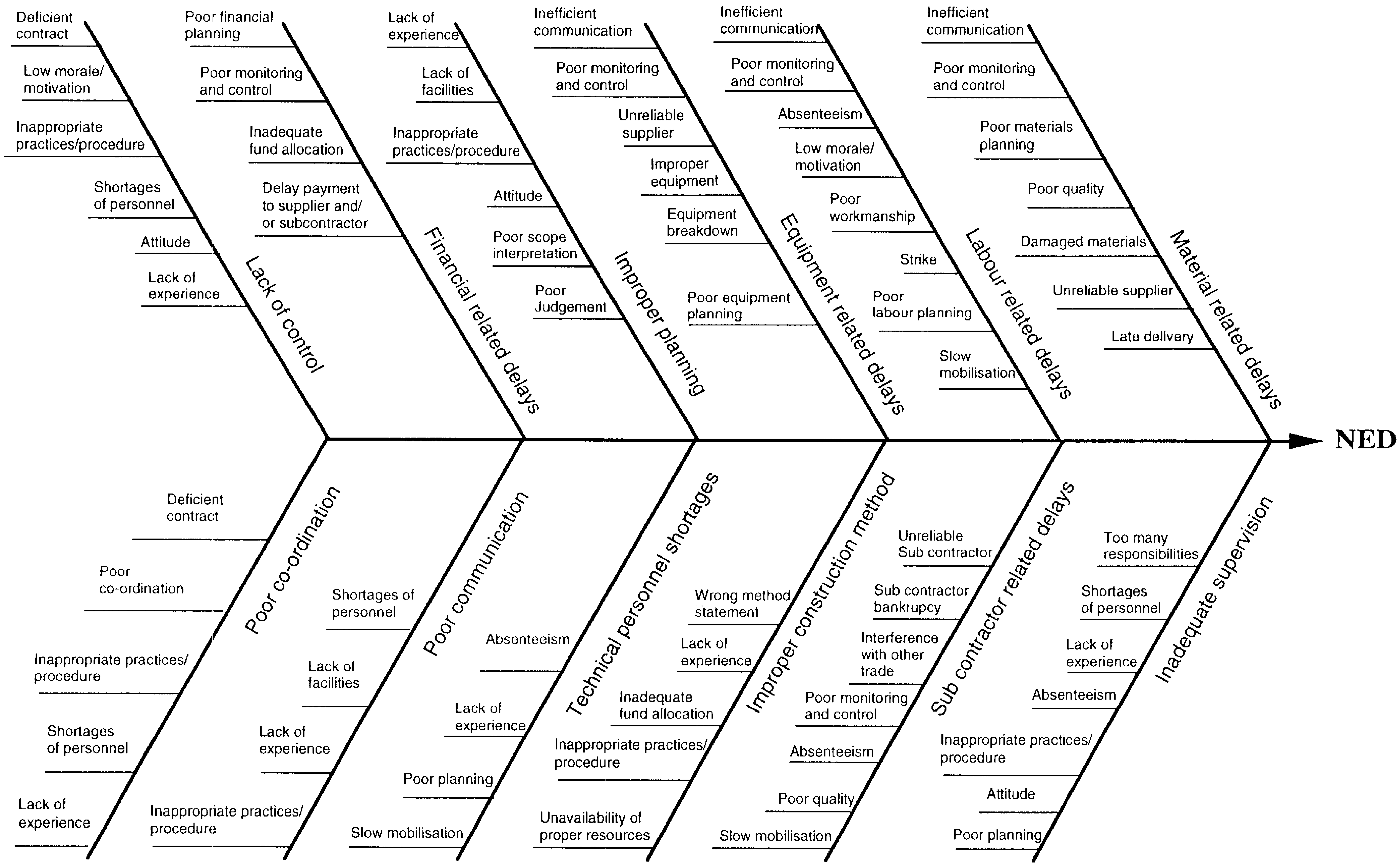


Figure 3.13: Fish bone diagram of factors of NED

Some of these factors feature in more than one group of causes so it require a special attention during monitoring and control of these factors on site. The factors that feature in more than one groups of causes were likely to increase their chance of influencing delays if it was not closely monitored and control. The cause-and-effect diagram helps to establish the complex nature of these relationship and indicate their effect. The group of causes formed the main branch of a cause-and-effect diagram and the factors identified subscribe to these main branches. Figure 3.13 shows the relationship between the factors and the 'effect' i.e. non-excusable delays. Sixty nine factors were identified in which some of them are quite similar in nature for example 'poor planning' which feature in several groups of causes. The factors that feature in several groups of causes eventually established themselves as a common factor. These common factors were then tested to establish their relative ranking. Initially only twenty five factors were considered for the first stage of the pilot test (refer to the first stage pilot questionnaire section B (iii) - **Appendix I**) in trying to establish the top fifteen factors. The next section reveals the common factors that possess similar characteristics and this helps to reduce the number of factors to be tested for their ranking. However all sixty nine factors identified earlier were tested through their respective groups of causes in the pilot test as well as in the main survey in order to establish the factors for each group of causes. A matrix table was employed in the next section that can clearly distinguish the common factors which feature in more than a group of causes.

3.5 FACTORS OF NON-EXCUSABLE DELAYS MATRIX

Table 3.1 displays a matrix of twenty seven factors initially identified from the literature stage. These factors were arranged in the first column of the table and the groups of causes across individual column horizontally. An asterisk sign was used to indicate factors that were related to groups of causes. The number of asterisks

Table: 3.1: Factors of NED matrix

Factors of non-excusable delays	Groups of causes of NED											
	Mat. related delays	*Labour related delays*	*Equip. related delays*	*Improper planning*	*Financial related delays*	*Lack of control*	*Sub-contractor related delays*	*Poor co-ordination*	*Inadequate supervision*	*Improper construction method*	*Techn. personnel shortages*	*Poor communication*
1.Slow mob./late delivery		*					*				*	
2.Unreliable supplier/ sub-contractor	*		*				*					
3. Damaged materials	*											
4. Poor planning	*	*	*		*				*		*	
5. Poor quality	*	*					*					
6. Strike		*										
7. Absenteeism		*					*		*		*	
8. Equipment breakdown			*									
9. Improper equipment			*									
10 Lack of experience				*		*		*	*	*	*	*
11 Lack of facilities				*								*
12 Inappropriate practices/proc.				*		*		*	*	*		*
13 Attitude				*		*			*			
14 Poor monitoring and control	*	*	*		*		*					
15 Inadequate fund allocation					*					*		
16 Delay payment to supplier/sub contarctors					*							
17 Shortages of personnel						*		*	*			*
18 Low morale/ motivation		*				*						
19 Deficient contract/scope				*		*		*				
20 Interference between trades							*					
21 Too many responsibilities									*			
22 Unavailability of resources										*		
23 Wrong method statement										*		
24 Inefficient communication	*	*	*					*				
25 Sub-contractor bankruptcy							*					
26 Poor judgement				*								
27 Limited range of suppliers	*											

Note: * Factors related to categories

along horizontal line represent the number of appearances of each factors in the groups of causes. This matrix table displays the common factors that have appeared under several groups of causes. Once the common factors were established the next step was to identify the top fifteen factors. Only top fifteen factors were considered to limit the number of questions for the main survey questionnaire. These top fifteen factors were then classified as the critical factors of non-excusable delays in this study.

3.6 CRITICAL FACTORS OF NON-EXCUSABLE DELAYS

Critical factors for this study were those in the top fifteen among all the factors identified from the stage of the pilot study. Although twenty seven common factors were identified through the literature and cause-and-effect analysis, only twenty five factors were considered for the ranking test with the exception of the last two factors (see Table 3.1). The main reason for excluding them was to limit the number of questions for the main survey and moreover these can adequately cover the issues of concerned for this study. Even with only fifteen factors the total number of questions developed was 198, and the questionnaire was unusually extensive for a respondent to response. The limit was set to fifteen in anticipating a reasonable number of respondents will participate in this study. If the number of respondents were not encouraging it can influence the power of the statistical test. To establish the top fifteen factors the researcher has to conduct a pilot test using twenty five factors identified earlier. The initial selection of the fifteen factors were then presented to the Productivity Task Force Committee of European Construction Institute (refer to the list in **Appendix IV**) for this project. The results established were based on the ranking of eight respondents on the twenty five factors and the Committee had agreed on most of the factors except one i.e. 'low moral and motivation' which was ranked lower but included it in the second stage of the pilot test.

The survey's response shows that the independent sample group i.e. Top 100 UK contractors was only 10% while the response from the ECI's member companies was 43% which was a significant contribution toward this study. The reason for the low response from the Top 100 UK contractors, even after a follow up, was due to the length of the questionnaire that discouraged them. Even before the pilot test the Task Force Committee was concerned over the total number of questions in which they feared that too much time spent on responding to unusually long questionnaire. Instead of reducing the number of questions the researcher employed a two stage pilot test strategy and reducing the factors to twenty five (refer section B(iii) for first stage pilot questionnaire). From this twenty five only fifteen were selected for the second stage of pilot test (refer section D of second stage pilot questionnaire, **Appendix II)** to establish their corrective actions.

3.7 SUMMARY

(1) The review has highlighted that the existing system of evaluating performance did not appear to be capable of clearly isolating the actual root-causes (factors) of schedule overruns, let alone explained such causes in a way that would direct the corrective efforts of management.

(2) The significance of using groupings of causes is that highlights some factors which appear in several groups of causes and these factors are later known as the common factors. Apart from drawing the attention on the common factors, the groupings also help to focus the generation of the possible factors under the principal causes.

(3) This chapter dentified a strategy to generate non-excusable factors by first establishing the principal causes each was known as a group of causes. Twelve groups of causes were identified from the literature which included: materials related delays; labour related delays; equipment related delays; financial related delays; improper planning; lack of control; sub-contractor related delays; poor co-ordination; inadequate supervision; improper construction methods; technical personnel shortages; and poor communication.

(4) A group of causes was defined as a main cause that comprised of several factors. Cause-and-effect diagrams were use to generate an additional factors besides those cited from the literature. This mechanism helped to promote an open mind that encouraged the user to focus thoughts in identifying factors from groups of causes. Brainstorming was employed to generate the factors and it was effective if the user had some practical experience on construction delays.

(5) Most importantly the cause-and-effect diagrams can establish the relationship between factors (root-causes) and groups of causes. The review has also established the use of the technique in determining the factors of a principal cause. As well as those factors identified from the literature review for all the twelve groups of causes an additional factors were generated using this technique.

(6) Sixty nine factors were established from the literature review along with those generated by the cause-and-effect diagram. Due to the high number of factors the probability of one occurring on site was high and the graphical presentation as shown in Figure 3.13 would give an appreciation on the risk of these factors to appear on construction site.

(7) The delay matrix table (see Figure 3.1) has provided a basis to highlight the common factors and these factors were then considered for further evaluation to determine the rank among them. Finally, only the top fifteen factors, known as the critical factors, were investigated to further establish their common indicators and corrective actions in the main survey.

CHAPTER 4

INDICATORS AND CORRECTIVE ACTIONS

4.1 INTRODUCTION

The aim of this chapter is to review the indicators that were used to identify the fifteen critical factors including an approach in deriving permanent corrective actions. Since very little evidence available from the literature that cited permanent corrective actions for the critical factors of NED there was a need to design a mechanism to derive permanent corrective actions for these factors. Amongst the critical factors, three of them were identified to be assessed by intuitive judgement of site managers, while twelve of them used quantitative indicators such as resource schedule, daily report, work schedule, etc. which are readily available to the site managers. This chapter also briefly discusses both the short-term and permanent corrective actions cited from the literature review. The development of a structured approach of deriving corrective actions for the critical factors was based on the theory of inventive problem solving. The significance of designing this tool is it can be used to derive permanent corrective actions for the critical factors and later be validated in the main survey.

4.2 MONITORING AND CONTROL FOR CONSTRUCTION SITE

The site manager and staff are the key to the successful performance of a contractor. Procedure, guidelines, rules, handbooks and other aids are very useful to the construction professionals in helping to anticipate and avoid problems, and in reacting to minimise the effects of unexpected developments.

Other aids that are useful to the professionals are indicators that are used to identify factors of delays which include: daily records; work schedules; materials schedules; equipment schedules; manpower schedules; etc. These indicators are often used by the professionals to alert them on the status of project performance. If potential delays become apparent, all the resources at the manager's disposal can be brought to bear before delays become significant. As defined in Chapter 2, delays occur when the expected completion date is extended and it becomes significant when critical activities are involved. An effective indicator that could alert the site managers to their attention is the 'work schedule' but this indicator cannot highlight the 'reasons' for such delays. Other indicators such as 'labour schedule' was used to highlight the factors of delays such as 'slow mobilisation' and at the same time it could also be highlighted by 'daily construction record'. Sometimes two or more indicators were required to identify delay factors but very little was known to establish the most appropriate indicators used to identify the critical factors of delays. One of the objectives of this study was to identify the most appropriate indicators that were used to identify critical factors of NED. Before exploring further it is appropriate to define the term 'indicator' used in this study.

4.3 DEFINITION OF INDICATOR

The term **indicator** is defined as a 'tool' used to identify the critical factors of NED, and was adopted from Yates (1993). In her study the term was used to refer to the 'tools' that were often used by the site managers to assist them in monitoring and controlling the progress of works. O'Brien (1991 p10.1), used the term 'tool' referring to the 'progress schedule' while Barrie et al. (1992 p252), also qualify 'work schedule' as a control 'tool'. Other 'tools' such as daily report, procurement record, manpower report, correspondence, etc. were known as 'indicators'. The term 'indicators' in this study refers to 'tools' that were used to identify any non-conformance of standard either in term of time, quality, safety, cost, rule of thumb or against the contract specification. Thus, most indicators have the characteristics of identifying the factors by comparing them against any of the specified standard for example 'slow mobilisation' can be identified by comparing the actual against planned schedule. Therefor the indicators that can be used to identify the critical factors were classified as 'quantitative indicators'. However, there are factors which cannot be identified by quantitative indicators. These factors are usually evaluated by the 'intuitive judgement' of site managers and the assessment depends upon the site managers experience. It could also depend very much on experience of the managers and furthermore they may consider different elements to assess a factor that influence delays. For example, the elements cited that influence 'inefficient communication' were 'communication channel', and/or 'distribution of information', and/or 'interpersonal skills' which were assessed differently among the managers. Apart from inconsistency among managers in evaluating these elements, there was no rule or standard to compare their judgement . Inconsistency and non-standard evaluation prompted the researcher to develop an alternative indicator using the theory of fuzzy logic which is discussed in Chapter 5. The foregoing discussion explains the classification of types of indicators used in this study. It was observed that indicators can be classified into two different categories, 'qualitative indicators' which refer to those using the 'intuitive judgement' of site managers, and the other under 'quantitative indicators'.

4.4 QUANTITATIVE INDICATORS

Quantitative indicators are 'tools' that can identify non-performance of factors in terms of either time, quantity, cost, quality or against any standard specified in the contract, and all these are performance variables. From the findings of pilot study, twelve out of fifteen critical factors selected were confirmed using quantitative indicators where they can be evaluated against any of the performance variables mentioned earlier. The twelve critical factors identified using quantitative indicators include:

- late delivery of materials or equipment;
- slow mobilisation of labour;
- unreliable supplier;
- unreliable sub-contractor;
- inadequate fund allocation;
- poor planning;
- inappropriate practices/procedures;
- lack of experience;
- inappropriate method statement;
- shortages of personnel;
- unavailability of proper resources; and
- interference with other trade.

The methodology of identifying these indicators was to review the available literature, and seek clarification from the professionals of the Task Force Committee and then confirmed by respondents of the pilot study. To validate the findings from the literature they were tested in a main survey using samples selected from a list of the Top 100 UK contractors for the year 1996 and the European Construction Institute member companies.

4.5 THE REVIEW OF QUANTITATIVE INDICATORS

Investigation into various literature materials has helped to identify the indicators for the twelve critical factors mentioned earlier and, where possible, more than one indicators need to be identified. The reason for identifying more than one indicator was to establish the most appropriate indicator that was used to identify these factors. The quantitative indicators cited from the literature were then verified by the Productivity Task Force Committee of the ECI (refer to list in **Appendix IV**) before they were confirmed by the respondents of the pilot study.

4.5.1 Indicators for late delivery of materials or equipment

The delivery of equipment was usually based on the 'equipment planning schedule' and the materials delivery using the 'materials planning schedule'. Harris and McCaffer (1995 p36) discussed the issue of resource planning requirement for an activity when preparing a work schedule. These resource schedules which include materials, and equipment were normally used to provide a record on the resources requirement for the whole duration of the project period. The current planning software for the 'resource schedules' provided a feature for tracking when monitoring these resources. 'Resource schedule' was usually used to detect late delivery by comparing the actual arrival date against the planned arrival. Thus 'resources schedule' is one of the 'tools' or indicators that were used to identify the factor that led to delays. Apart from this indicator, daily report can also provide the record on the resources arrival on site but the difference is it can only highlight the event and is unable to provide quantification of non-conformance. Although it cannot provide the feature of tracking, it is useful in providing additional information in the event of identifying the factors that cause delays.

'Correspondence' between the supplier and the purchaser provides another source of indication for tracking the materials or equipment requirements on site. Normally, when these resources are required on site, purchase or rent requisition will be communicated to the supplier where both require prior arrangements. Hence 'correspondence documents' can track the late delivery of materials or equipment which are supposed to arrive on site. In addition to the three indicators cited from the review, the option of citing more indicators was through the pilot study. It is important to note that before the pilot study, indicators for each factor was deliberated with the professionals from Brown and Root UK Ltd, and Stone and Webster UK Ltd. Yates (1993) also cited a list of indicators which some of them are similar to those cited in this study.

4.5.2 Indicators for slow mobilisation of labour

'Slow mobilisation of labour' can be highlighted by a 'manpower schedule' which was normally used to track the requirements of labour during the construction duration. Most current planning software was able to provide the report on tracking the resources requirement when required for executing the activities of projects. It can be used to track non-conformance such as 'late mobilisation of labour' by comparing the actual arrival and planned schedule and was also useful in identifying the factors of NED. Yates (1993), in a study, cited 'manpower schedule' as one of the indicators used to identify the factors of NED such as 'late arrival' and/or 'slow mobilisation'. However the relationship of indicators and factors of delays was not established. Harris and McCaffer (1995 p37) recommended that in order to check the resource usage on materials or equipment comparison should be made between the actual and planned such as to identify 'slow mobilisation'. Another indicator that was used to identify 'slow mobilisation' was 'manpower report' and the review on current practice cited that this can be generated from the scheduling software instead of using a conventional 'labour report form'. Hence another indicator that was used to identify 'slow mobilisation of labour' was identified, although it may not be as effective as 'labour schedule'. 'Daily report' records the total manpower requirement that provides the breakdown of the manpower utilisation according to the work activities. This 'daily record' could also be used as an indicator to the 'slow mobilisation of labour' on site.

4.5.3 Indicators for unreliable suppliers

Procurement activities by a contractor usually include the purchasing of materials and equipment. The procurement process includes tracking and expediting, routing and shipment, materials and equipment handling, accountability and warehousing, and final acceptance documentation (Barrie et al., 1992). The 'procurement records' used during the process, provide an indication on the performance of the supplier. According to Barrie et al. (1992) the non-performance supplier can be identified using the 'procurement records' and thus it is one of the indicators used to identify the reliability suppliers. Another indicator cited was 'material supply schedule' and it was the usual practice where a supplier in contract with a contractor will be supplied with the material schedule requirement for the project. If suppliers fail to adhere to this schedule, it can effect their credibility and this phenomena can be translated as 'unreliable supplier'. The 'material schedule' that was cited was one of the indicators used to identify 'unreliable supplier'. Another avenue for detecting non-performance of suppliers cited was 'daily records' and the information recorded here includes the materials late arrival on site. Hence, it was cited that the 'daily record' can be a supplementary document to check the reliability of suppliers during the construction process.

4.5.4 Indicators for unreliable sub-contractors

The progress of sub-contractors is usually monitored using a work schedule and this schedule forms part of the contract document which is agreed earlier by the two parties to the contract. It provides the basis for monitoring sub-contractors activities and will be incorporated in the main contractor's work schedule. The main work schedule is usually used to co-ordinate the work of various trades on construction sites. If the sub-contractor's work progress does not conform to the agreed schedule and no effort is made to improve the situation then it is an indication that these sub-contractors were not reliable. Monitoring the progress by comparing the actual against planned schedule, provides an early indication of sub-contractors' performance. The 'work schedule' was cited as one of indicators used to identify an 'unreliable sub-contractor'. Another indicator used to identify this factor was 'productivity measurement' and there are a few methods of measuring the productivity of sub-contractor's work. Productivity measurement, as suggested by Construction Industry Institute (1986) and Price (1986), was the measure of a unit work rate and an example of a productivity rate for concreting work which can be measured either by metre cubic per hour or metre square per hour. A low production rate is an early indication of non-performance of sub-contractors. In addition to 'productivity measurement', 'daily record' was used to record sub-contractors activities on site. Normally it was used to record the sub-contractors labour force and it provides an information for detecting non-conformance. This indicator was used to identify sub-contractors performance in executing their work. All three indicators cited earlier were tested in the pilot study before being validated by the respondents from the main survey.

4.5.5 Indicators for inadequate funds

The 'planned budget' is the basic reference standard for monitoring and controlling expenditure of projects. A project cash flow will provide a basis for comparing the planned expenditure and income for a project, and it can also be used as a guide for providing the amount of cash required. Normally this cash flow is prepared based on the work schedule (Harris and McCaffer, 1995) and if the progress of work is on track the amount of cash that has to be made available should ideally be made available according to the cash flow forecast. The overall cost performance of a contractor is usually based on this forecast budget and any variance in the expenditure can effect the progress of the work. When 'inadequate cash' was allocated, as compared to the forecast cash requirements, the smooth running of the project can be jeopardised. Any shortages in the allocation of cash, as compared to the overall planned budget, will increase the risk of delaying the work according to the schedule. Hence 'inadequate fund' allocation can be identified by using an indicator of 'budget performance' i.e. the differences in the cash allocated against forecast. Another indicator used to identify this factor was 'variance' in the actual allocated cost with that of the planned budget. In this situation if there is a negative difference between actual and budgeted expenditure then the cash was not allocated accordingly to meet the actual requirement. If there is any 'variance' in the cash requirement it certainly will effect the smooth running of projects and can result in delays. The 'variance analysis' for the cash requirement is one of the indicator cited that can be used to identify this factor.

4.5.6 Indicators for poor planning

Scheduling experience is important for determining good construction planning and it is an advantage to those responsible in determining a construction schedule. A comparatively inexperienced schedule planner will require a lot of guidance which is not as efficient as compared to the experienced schedule planner. The judgement of an experienced schedule planner, on the timing of construction activities and the sequence of activities, was more sensible. The quality of the work schedules depends on the experience of the planner, thus poor planning can be the result of 'lack of experience'. This argument concluded that 'lack of experience' was an indicator to identify 'poor planning'. Another indicator cited from the professionals was the timing of the critical activities which certainly determined the final completion date of a project. If the timings of critical activities were not correctly judged then it can influence the completion date of projects. This suggested that a bad judgement on the timing of critical activities can lead to 'poor planning'. Apart from the timing of critical activities, the correct 'sequence of critical activities' ensures the smooth running of construction work and an incorrect sequence has direct consequences, especially on the allocation resources. The prior arrangement of the resources required to execute the critical activities will be disrupted if the sequence of the activities is not right. This indicates that 'poor work planning' could be due to the 'incorrect sequence of the critical activities' and it can also influence the non-critical activities. Comparatively its impact on non-critical activities is less significant than that of critical activities. Thus the 'sequence of the critical activities' was used to identify 'poor planning'.

4.5.7 Indicators for inappropriate practices and procedures

Most construction work requires an appropriate procedure to successfully produce a product that complies to contract specifications. The working procedure should be clearly written in the contract document but in few instances it is not. Those documents which did not stipulate work statement would need to be determined before executing the work and this work statement is sometimes called 'method statement'. A correct 'method statement' can lead to the proper installation or execution of work which eventually helps to produce good quality work. However a wrong method of executing an activity can lead to rework and, if involved critical activities, it can significantly influence the completion date. In addition to 'method statement', 'working experience' also had some influence on the practice and procedure of executing an activity. Previous experience can help to determine an appropriate procedure otherwise 'inappropriate procedure' will be formulated. Working experience on a different locality of the project will exposed a manager to many kinds of procedures and practices in executing a project (Barrie et al., 1992 p88), and this exposure certainly had an advantage. Work experience was used to identify this factor along with the policies of an organisation which also plays a important role in influencing the smooth running of projects. For example 'procurement policy' where it depends on the magnitudes of orders, this administrative policy sometimes can effect not only cost but also the timing of the material's arrival if it is not clearly documented (Barrie et al., 1992 p348). Hence the 'work policies' can be used as an indicator to identify inappropriate practice and procedure.

4.5.8 Indicators for lack of experience

An indicator that was used to identify 'lack of experience' during the construction stage is cited by Barrie et al. (1992). The following requirements has provided some suggestions toward identifying the indicator. Barrie et al. (1992 p162) cited some of the essential requirements when selecting an experienced site manager as:

- experience as a site a manager (preferably several years of experience as a site manager);
- qualification of the person who manages the project; and
- related experience which is comparable in term of type, scope and complexity.

The requirements were not only limited to those listed above but an appropriate personality and the ability to work independently were also considered. This information can be established through the references acquired from previous employers or previous projects. In addition to references, basic qualifications can also influence the ability to resolve technical problems including structural and civil design, familiar with contract administration, acquired basic knowledge on other engineering disciplines etc. An appropriate 'basic qualification' and experience can overcome the issue of 'lack of experience' thus it is an important method used to select site manager besides their experience. These two indicators were used to identify 'lack of experience'.

4.5.9 Indicators for inappropriate method statement

Harris and McCaffer (1995, p215) briefly discussed the method statement and information required to be detailed in a method statement. Details such as type of labour and plant required to execute the works, when it is not carefully identified, can lead to the use of a wrong technique. Inappropriate equipment usage, which is the cause of inaccurate or wrong description of method statement, can result in delays due to inappropriate method or resources. Inaccurate 'work descriptions' was identified as one of the indicators to identify 'inappropriate method statement'. Without 'consulting the site personnel', whom presumably has the appropriate knowledge of work method, can lead to formulating an inappropriate method statement. A proposed work method will not be suitable without 'consultation of site personnel' and this can be used to identify 'inappropriate method statement'.

4.5.10 Indicators for unavailability of proper resources

There were instances when a contractor was forced to employ an inappropriate technique or equipment for carrying out a work, in the situation when an appropriate machine fails to operate. Rather than waiting for an alternative machine to arrive, which probably takes few days, the operation will use a less superior or less-than-optimum method and this can lead to additional cost and delays Voster et al. (1990). One of the indicators used to indicate the execution of work which does not accord to the planned schedule, is 'productivity measurement'. For example the productivity rate of actual concreting work is 40 cubic metre per hour using a crane and skips as compared to the planned method which was supposed to use a pump at 100 cubic metre per hour. Since the pump fails to operate the method was changed to a less productive method thus 'productivity measurement' was used to identify 'unavailability of the proper resources'. Another indicator 'progress measurement' was also used to identify this factor, and the indication is non-conformance of schedule. 'Resource planning' was another indicator used to identify this factor, where the equipment used was not according to planned resources schedule. These three indicators cited earlier were then tested in the pilot and main survey.

4.5.11 Indicators for shortages of personnel

One of the indicators that was used to identify this factor was 'site personnel planning', where it provided a basis to detect non-conformance by comparing the actual and planned requirements. If the actual number was less then planned than there was a shortage of site staff, but in a few instances it may be due to 'poor resources planning' and in this situation the schedule requirement itself does not correctly forecast the actual need on site. The 'manpower planning' for site staff was used to identify 'shortages of personnel' on site.

4.5.12 Indicators for interference with other trades

Interference amongst various trades in a construction site can certainly disrupt the smooth running of the work in progress and there are few indicators that help to identify this factor. One of them is the 'site team meeting' where representatives from various trades will raise an issue of interference from other trades in their work. Thus, 'site team meeting' amongst various trades can provide an indication of a problem and another indicator that can highlight the problem of interference is the 'daily site report'. This report was used to identify the problem of interference if the progress of the trades or sub-contractors were not in accordance to the main work schedule. Another indicator used to identify this factor is 'contractor's complaint' which is normally reported as soon the problem occurs. Thus, it was used to identify the factor and these three indicators cited were then tested in the survey to establish the most effective indicators used.

4.6 QUALITATIVE INDICATORS

A qualitative indicator is a tool that helps to identify a qualitative factor and an indicator like 'intuitive judgement' of site managers was classified under this category. Barrie et al., (1992) p188, observed that site managers judgement itself reflect a qualitative evaluation and it was normally used to identify a qualitative factor such as 'inefficient communication'. In this study, three out of fifteen critical factors i.e. 'inefficient communication'; 'low moral/motivation'; and 'too many responsibilities' were assessed using intuitive judgement of site managers. These three factors were usually assessed by site managers' judgement which reflected the nature of the factors that were not evident in the quantities themselves.

Since the available literature does not reveal an appropriate indicator for these factors an alternative option was to seek the opinion of the managers from the Productivity Task Force Committee of the European Construction Institute. Initially, nine factors were identified which presumably were assessed by intuitive judgement and these were identified before conducting the first stage of the pilot study. Amongst the factors that were tested under intuitive judgement during the pilot survey were as follows:

- poor planning;
- lack of experience;
- inappropriate practices;
- inappropriate procedure;
- poor monitoring and control;
- inefficient communication;
- too many responsibilities;
- inappropriate method statement; and
- low morale/motivation.

From the above nine factors only three critical factors were selected for further validation in the main survey. The selection of these three factors was based on a two thirds majority from eight respondents involved in the pilot study that confirms the use of intuitive judgement of site managers in assessing these factors. Although there were a few factors that had an equal number of respondent responses which said they used intuitive judgement these were excluded. The three critical factors selected for further validation in the main survey were as follows:

- inefficient communication;
- too many responsibilities; and
- low morale/motivation.

Apart from identifying the factors that were identified by intuitive judgement, a question was asked as to whether there is a need to develop an alternative indicator. The next sub-section discusses the justification of developing an alternative indicator for qualitative critical factors.

From the review indicators that were cited are tabulated in Table 4.1 and Table 4.2 provides the indicators for the fifteen critical factors that were confirmed using the pilot respondents. The matrix table shows the common indicators, indicated by the asterisks, for each factor along vertical columns. Indicators for the twenty five factors were established from the review and discussion with the managers from the Productivity Task Force Committee of the European Construction Institute (see **Appendix IV**). Initially nine factors (refer to Table 4.1 under column x) were tested under the 'intuitive judgement' indicator whilst the remaining were tested under quantitative indicator during the first stage of the pilot survey. From this survey only the top fifteen factors (see Table 4.2) were considered which need to be validated in a main survey. From this table only three critical factors were confirmed using

Table 4.1: Matrix of indicators (before the pilot test)

Factors of Non excusable delays	Types of Indicators																								
	a	b	c	d	e	f	g	h	j	k	l	n	m	o	p	q	r	s	t	u	v	w	x	y	z
1.Slow mobilisation/Late delivery	*	*	*	*																					
2.Unreliable supplier/ sub-contractor	*		*					*																	
3. Damaged materials					*																				
4. Poor planning																							*		
5. Poor quality					*						*														
6. Strike			*										*											*	
7. Absenteeism		*	*										*												
8. Equipment breakdown			*			*																			
9. Improper equipment	*		*			*	*																		
10 Lack of experience																	*	*							
11 Lack of facilities																									*
12 Inappropriate practices/ procedure.																							*		
13 Attitude																							*		
14 Poor monitoring and control																							*		
15 Inadequate fund allocation									*	*															
16 Delay payment to supplier/ sub-contractor	*											*													
17 Shortages of personnel	*																								
18 Low morale/ motivation																							*		
19 Deficient contract																							*		
20 Interference with other trades			*											*									*		
21 Too many res-possibilities																									*
22 Unavailability of proper resources	*		*				*																		
23 Wrong method statement																							*		
24 Inefficient communication																							*		
25 Sub-contractor bankruptcy																						*			

Note:

Types of indicators:

a - Schedule b - Manpower record

Continued Table 4.1

c - Daily record or superintendent diary	d - Correspondence
e - Inventory report and/or quality control report	f - Construction equipment usage report
g - Productivity measurement	h - Procurement record
j - Budget performance	k - Variance analysis
l - Test report	m - Time sheet
n - Payment record against schedule	o - Site team meeting
p - Experience (scheduling or work)	q - Timing and sequence of critcal activities
r - Reference from previous record	s - Basic qualification
t - Method statement	u - Working policy
v - Contractor's complaint	w - Financial ratios
x - Intuitive judgement	y - Strike notification
z - Lack of planning and communication deliverables	

* Indicate the relationship between indicators and factors.

Table 4.2: Matrix of indicators for the citical factors
(established after the pilot test)

Factors of Non excusable delays	Types of Indicators																			
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
1 Late delivery	*		*	*																
2 Slow mobilisati-on	*	*	*																	
3 Unreliable supplier	*		*				*													
4 Unreliable sub-contractor	*		*			*														
5 Inadequate fund allocation								*	*											
6 Poor planning											*	*								
7 Inappropriate practices/ procedure											*				*	*				
8 Lack of experience													*	*						
9 Wrong method statement					*													*	*	
10 Unavailability of proper resources	*			*		*														
11 Shortages of personnel	*																			
12 Interference with other trades			*							*							*			
13 Inefficient communication																				*
14 Low morale/ motivation																				*
15 Too many res-possibilities																				*

Note:

Types of indicators:

a - Schedule
b - Manpower record
c - Daily record
d - Correspondence
e - Alternatif method
f - Productivity measurement
g - Procurement record
h - Budget performance
i - Variance analysis
j - Site team meeting
k - Work experience
l - Timing and sequence of critcal activities
m - Reference from previous record
n - Basic qualification
o - Method statement
p - Working policy
q - Contractor's complaint
r - Work descriptions
s - Consultation
t - Intuitive judgement

* Indicate the relationship between indicators and factors.

intuitive judgement of site managers. One of these factors was selected to assist in developing an alternative indicator to that of intuitive judgement.

4.6.1 Justification of developing an alternative indicator

Barrie et al. (1992 p161) and Kavanagh et al. (1978) outlined the General Service Administration (GSA) on the selection of construction managers and suggested some criteria in evaluating the selection. Many of these criteria such as competency of technical knowledge; good professional and business reputation; experience in constructing building; etc. required subjective judgement and was difficult to evaluate without a quantitative yardstick. To effectively measure the qualitative critical factors, some form of quantitative measures has to be established and furthermore quantitative measures can provide a standard evaluation among managers. In addition to establishing a standard assessment, quantitative measures can also assist in providing a consistent evaluation. Eventually, a consistent and standard assessment data can be accumulated into a data bank that can be used for benchmarking in improving qualitative critical factors. It was difficult to attain a standard and consistent evaluation through an intuitive judgement thus providing an alternative indicator can offer another mean for detecting non-performance of the qualitative factors.

4.6.2 Method of developing an indicator

Fellows et al. (1983 p255) cited that many construction problems were evaluated using intuitive knowledge or trial and error. Literature has also noted that some construction problems are qualitative in nature and were evaluated by the intuitive judgement of the managers. Therefore to assist the managers in evaluating qualitative factors, qualitative indicators which offer quantifiable algorithms had to be developed. This indicator can be developed based on the quantifiable arbitrary values obtained from the experts of the construction industry.

There were few options available from the review which were identified to develop a quantitative indicator. The first is a conventional method which sometimes does not provide an accurate situation. The conventional method or mathematical modelling had a few disadvantages, especially when involved with uncertain elements or approximate values. If uncertain elements or approximate values were involved then it is difficult to derive a mathematical model. Approximate values such as 'ineffective communication channel', which was probably due to 'slow distribution of information', indicates that this element itself does not have any quantifiable value and is difficult to measure in a mathematical model. For difficult problems a conventional method like mathematical model, will give an approximate representation of the situation (Daley et al., 1989).

An alternative to the mathematical model is fuzzy algorithm and is worth considering in light of the success of fuzzy application on several numbers of industrial and commercial applications world-wide especially in the manufacturing and electronic sector. In general, fuzzy system is more suitable for uncertain or approximate reasoning, especially for the system where a mathematical model was difficult to establish. For example, the input and parameter values of a system may involve fuzziness, inaccuracy, or incompleteness. Furthermore, fuzzy logic allows decision making with estimated values under incomplete information, and if the decision made is not correct due to incomplete information it can be changed later if an additional information was available. Hence, fuzzy system was employed to develop an indicator for a qualitative factor and the detailed theory is discussed in Chapter 5.

4.7 PERFORMANCE INDICATORS

4.7.1 Definition

A performance indicator is an indicator for measuring the efficiency of a construction work as compared to planned which includes using schedule, cost, quality, etc. In this context it was used to measure the performance of contractors during the execution of a project. The following section helps to explain this definition which was used in this study. The most commonly used performance indicator in construction industry to compare the actual and planned schedule, and if it is less than an index of one it indicate non-conformance in terms of time (Yates, 1993). The Construction Industry Institute, CII, (1986) also defined performance in relation to measuring productivity i.e. earned man-hour divided by actual man-hour but this study attempted to review the available performance indicators used to measure contractors performance.

4.7.2 Review on performance indicators

Schedule performance

Several performance indicators were reviewed with the aim of identifying several common ones and to establish a best indicator for measuring contractor performance on site. Yates (1993) in a study, suggested an indicator to measure contractors performance using work schedule and cited the following method of measuring the contractors performance:

$$\text{Performance Indicator (PI) index} = \frac{\text{actual quantities to date}}{\text{planned quantities to date}}$$

One of the elementary forms of schedule evaluation is achieved by comparing what has been accomplished to the amount of work that planned to be accomplished. The data used to compute performance index is by determining the ratio and if the ratio is less than one it shows a deviation from planned. Yates (1993) suggested that the schedule performance indicator can be used to measure performance on site. Several authors including Barrie et al. (1992), Harris and McCaffer (1995) have discussed the use of planning tools to monitor and measure the current progress of construction work. These conclude that measuring time performance can be used to determine the contractors performance on site.

Cost performance

In addition to time performance, cost evaluation was cited by several authors as an indicator to measure the contractor performance including Barrie et al. (1992) and Harris and McCaffer (1995). The measure of cost performance, as explain by several authors is comparing the 'actual' and 'budgeted' cost and also the earlier method of computing can be used. In actual practice this is not as easily computed since a lot of data is needed before it can finally be established. Any deviation from the budgeted cost can influence the contractor performance but this must be carefully computed where actual expenditure was more than budget. The result from this computation needs careful examination before arriving at a conclusion. Nevertheless, from the review, cost performance was often used to measure contractors performance on site. Apart from the above, quality and safety performance were also cited from the discussion with the professionals of industry and they believed that these indicators can be used to measure contractors performance.

Quality and safety performance

From the discussion with the professionals quality and safety performance were also used to measure the contractors performance. The method used for determining quality performance was to compare the actual work with that specified in the contract. If non-conformance was found in relation to the specification then quality performance has not been achieved by the contractors, however the professionals from industry acknowledge the difficulty to quantify them since they are subjective in nature. The safety performance was also difficult to quantify and to measure safety performance is to compare what has been implemented on site to that of safety requirements which were stipulated in the contract documents or other legal requirements.

From the above discussion the literature did not cite a best indicator for measuring contractors performance. One of the objectives of this study is to establish a best performance indicator to measure contractors performance.

4.8 CORRECTIVE ACTIONS

4.8.1 Introduction

Mondy et al. (1995) classified corrective actions into two categories which were either short-term or permanent. The short-term corrective actions is normally aimed at correcting the problem for example reducing or improving delays. An example of a short-term corrective action which is usually employed by the managers to recover delays is 'work overtime'. This type of corrective action does not remove or improve the factors and it was not effective and economical as compared to permanent measures (Mondy et al., 1995). A permanent corrective action is to correct or to improve the cause of the problem such as the critical factors of NED. According to Mondy et al. (1995) this type of corrective action is more economical and effective, and this study attempts to establish the permanent corrective actions for the critical factors. The review revealed very little evidence on permanent corrective actions especially for non-excusable factors.

The permanent corrective actions, where possible, will be source from the literature materials. If the permanent corrective actions cannot be cited from the review the corrective actions will be formulated using a proposed structured approach and then verified by the professionals from the Productivity Task Force Committee of the ECI (see **Appendix IV**). The development of proposed structured approach is discussed in the following sections. The list of the permanent corrective actions for the critical factors of NED which were derived from the structured approach is shown in section D (see **Appendix III**). Three corrective actions were identified for each critical factor that were derived using the proposed structured approach and this is explained in section 4.8.2. Apart from the review the Productivity Task Committee of the ECI (see **Appendix IV**) assisted in verifying the suggestions which were not cited from the review and these were tested in the second stage of the pilot study. An example of formulating the three corrective suggestions for each factors is explained in section 4.8.5.

4.8.2 A structured approach of deriving solutions

Site managers are taught various techniques for solving routine problems encountered in everyday practice. Delays due to non-excusable factors which require site managers to use their own personal experience or heuristic knowledge to identify a permanent corrective action are no exception. Several methods are used to enhance the problem solving process, such as brainstorming (Osborn, 1963); decision tree and problem solving process (Cookes, 1991); analytical decision analysis and cognitive process (Parkin, 1996); Total quality (Task Force, 1993) and several others which have been used with some success. However, the need for an alternative approach in addition to the conventional methods mentioned earlier would enrich the methodology available for site managers. The proposed structured approach in deriving permanent corrective actions for the critical factors of NED is known as 'Structured Approach for Deriving Solutions (SADS). This approach is a simplified model which was designed based on the 'Theory of Inventive Problem Solving'. It is not a tool that creates a solution to a problem but focuses on the approach of deriving permanent corrective actions.

4.8.3 Background theory

SADS is based on the theory of inventive problem solving (known as TRIZ in Russian abbreviation). It has been developed in the former Soviet Union by Altshuller (1984). The main postulate of SADS is as follows: Evolution of the engineering systems is not a random process but is governed by certain objective laws (Fey et al., 1994). Altshuller (1984) formulated a few laws of Evolution of Engineering Systems whereby these laws can be utilised for problem solving in place of intuitive judgement and a few of these laws are being incorporated in the proposed approach

Fey et al. (1994) quoted that Altshuller analysed approximately 400,000 invention descriptions from different fields of engineering. The most effective solutions were selected and examined to reveal the objective laws (trends) of problem solving. The evaluation of the solution's effectiveness was based on the concept of Engineering Contradiction. A problem becomes a creative one when an attempt to improve the system's parameters by conventional means leads to the deterioration of the other parameters, i.e. generates a 'Contradiction'. In order to solving a problem one has to overcome this contradiction or satisfy the conflicting requirements (Fey et al., 1994). The laws used in the SADS are briefly described in the following paragraph.

The law of ideality states that engineering systems evolve in the direction towards increasing Ideality. Any system is not a goal in itself, it is only a fee for realisation of the desired function. The lower the fee the more ideal the system is. An ideal system is the system that needs no energy to operate, costs nothing to produce, occupies no space, cannot be broken etc. In other words, an ideal system is a system that does not exist as a material body but does perform the specified functions. In the real system, the "degree of Ideality" can be characterised by costs (both monetary and by other measures) associated with the system in relation to the sum of its useful functions.

The law of Transition from macro to micro level reflects the evolution of engineering systems in the direction of increased dispersion of their components.

The law of increasing controllability states that evolution of engineering systems moves towards increasing use of the controllable fields.

These laws are very helpful for professionals, since they give a general direction for creative thinking. The proposed approach SADS is similar to one of the three principal subsystems of TRIZ i.e. algorithm for inventive problem solving (known as ARIZ in its Russian abbreviation). Although it is mostly the ARIZ application that exists in the manufacturing sector, the algorithm seems to be practical and may be utilised in the construction sector (Rivin, Public lecture, 1995). ARIZ were previously applied in the manufacturing and aerospace industry hence the application of the technique in this research will be known in short as SADS. It is a set of sequential structured procedures aimed at eliminating the contradiction within the proposed corrective actions that may create a viable option.

4.8.4 Model of the approach

Laws explained earlier indicate the direction of the most effective transformation of the system, and SADS structured procedure was designed to incorporate these laws whilst maintaining the logical sequence of approach to derive the most appropriate permanent corrective actions. Figure 4.1 shows the model of the approach and indicates the stages of refining the corrective actions.

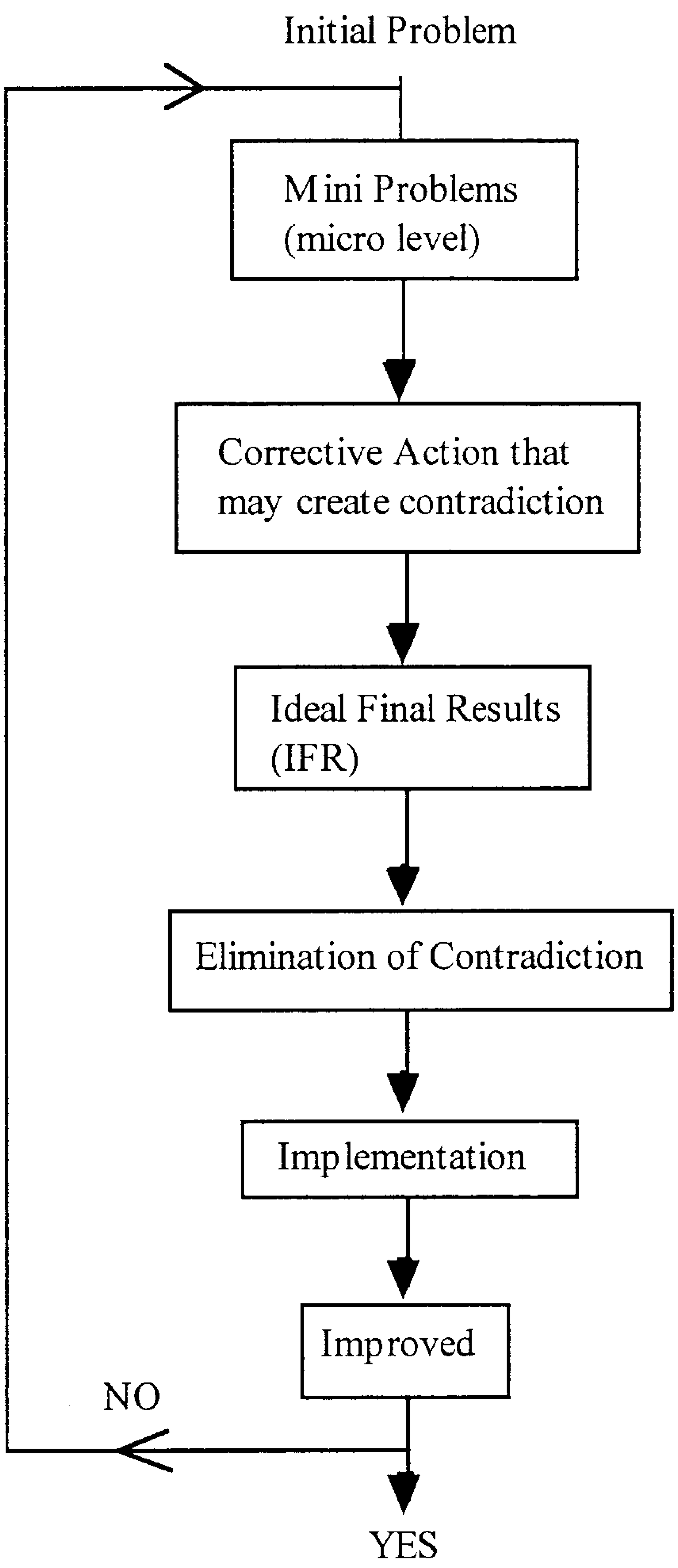


Figure 4.1: Structured approach of deriving permanent corrective actions

The above flow chart begins with the determination of problems at micro level. Once a problem has been identified, finding the root-cause (or factors) to the problem is essential. This process will eliminate the inaccuracy of identifying the actual factor(s) that lead to the consequences. Moreover, the determination of the factor will subsequently instigate the analysis of the problem at micro level. When the factor has been determined then a corrective action can be derived. The derivation of a permanent corrective option may incorporate contradiction within the proposal. One should not discard the corrective action with contradiction. An innovation could be developed in trying to remove or transform this contradiction. The next step is to assess the availability of the resources within the system to be incorporated in the proposed corrective action. This is to create an ideal corrective action based on the principal of ideality. If the option is seeking the resources beyond the boundary of the system then the degree of Ideality may be reduced and an increase in cost and/or time is inevitable. To realise Ideal Final Result (IFR), the critical component of the system in the conflict zone must possess contradictory elements.

The next step of the approach offers three basic groups of methods for overcoming the contradictory elements:

- separation of the contradictory elements in time, or in space;
- system transformations (combination of systems, combination of system and anti-system, separation of contradictory properties between system and sub-systems); and
- phase transformation of the resources involved in the system.

If the problem has not improved, SADS recommends to reformulate the mini problem. As a rule, an absence of a solution after thoroughly performed analysis is an indication that a wrong problem was initially formulated. The flow chart of the above steps is shown in Figure 4.1 and the illustration of the approach is given in the following section.

4.8.5 Identification of permanent corrective actions

The process of identifying the corrective action was through the literature review and if they were not cited then they were derived from the structured approach and verified by the professionals from the Productivity Task Force Committee (see **Appendix IV**). Several suggestions were made for each factors and the strategy was to establish the pattern of respondents opinion for selecting the permanent corrective actions. Using these suggestions this study attempted to establish a structured approach of deriving permanent corrective actions for the critical factors of NED. The following example explained the process of deriving a permanent corrective action for a critical factor.

Factor: Late delivery

The following are the possible options:

(1) loss claim from the supplier using a penalty clause; and

(2) change supplier

Using the above suggestions the model approach helped in identifying the most appropriate suggestions that follow the proposed structured approach:

(1) identify the suggestion with contradiction i.e. additional cost or time required;

(2) identify an ideal suggestion - if possible the corrective action has no cost implemented;

(3) using an ideal element to remove the contradiction, or the ideal suggestion can be improved to become a practical suggestion.

Finally the suggestions for the 'late delivery' take the following key proposition:

(1) seeking for an alternative supplier but may influence the materials or equipment cost;

(2) ideally, the contract clause for delivery may influence the delivery programme; and

(3) the general perception is that a penalty clause stipulated by the contractor for late delivery would minimise the occurrence of late delivery.

This process was employed to identify corrective actions for all the factors before conducting the second pilot study. Only a few so called permanent corrective actions were cited from the review but no clear suggestions were made especially for the critical factors of NED. However, the following permanent corrective actions were cited from review:

(a) Inefficient monitoring and control

Barrie et al. (1992, p187-189) highlighted that good monitoring was based on effective feedback time, short regular intervals and an efficient process of data. This suggestion provided a good basis for determining a possible suggestion using the structured approach.

(b) Inefficient communication

Cullen et al. (1990) discussed the distribution of information and highlighted how clear communication channel helped to improve inefficient communication. This idea was adopted in deriving the permanent corrective actions for this factor which were listed in D(xiii) of section D of the main questionnaire (see **Appendix III**).

(c) Low moral/motivation

Harris and McCaffer (1995, p192) cited job satisfaction as essential in boosting the workers moral/motivation and this has provided an idea to derive an appropriate suggestion using the approach and this was later validated in the main survey.

(d) Inappropriate method statement

Harris and McCaffer (1995, p215) cited that it was necessary to consult and discuss this issue with the site personnel before establishing the method statement. The idea was then tested and validated by the respondents from the main survey.

In addition the above, Yates (1993) highlighted several suggestions, although mostly are classified as short-term measures such as removing the supervisor for 'inadequate supervision' and increase the number of labour for 'shortages of labour', etc. Other corrective actions identified were as shown in section D of the main questionnaire (see **Appendix III**).

4.8.6 An illustration on the structured approach of deriving permanent corrective actions for critical factors of NED

Referring to the model of the structured approach (refer to Figure 4.1) the following sequence of deriving the most appropriate permanent corrective action is undertaken.

Mini problem

Late delivery of critical materials or equipment should be manageable without effecting the contractor's performance.

Problem contradiction

To change to an alternative supplier can influence the budgeted cost and probably require an additional time.

Ideal Final Result (IFR)

Ideally the contract clause for delivery will control the arrival of materials or equipment.

Elimination of contradiction

The general perception is that a penalty clause stipulated by the contractor for late delivery can minimise the occurrence of late delivery.

Permanent corrective action

The most appropriate permanent corrective action that can be considered among the above is after the **elimination of contradiction** where the final suggestion includes an ideal element. Thus, it offers an economical suggestion which is attractive and likely to be considered.

4.9 SUMMARY

(1) The term indicator refers to the 'tool' that is often used by managers to assist them in monitoring and controlling the activities in progress. These 'tools' include items such as daily report, procurement record, manpower report, correspondence, etc.

(2) Indicators were classified into two categories:

(a) Quantitative indicators such as work schedule, daily report, etc.

(b) Qualitative indicators refer to 'intuitive judgement' that was used to assess the critical factors NED.

(3) The critical factors that were identified by the quantitative indicators include: late delivery of materials or equipment; slow mobilisation of labour; unreliable supplier; unreliable sub-contractors; inadequate fund allocation; poor planning; inappropriate practices and procedures; lack of experience; inappropriate method statement; unavailability of proper resources; shortages of personnel; and interference with other trades.

(4) The critical factors that were assessed by 'intuitive judgement' include: inefficient communication; low moral/motivation; and too many responsibilities.

(5) Several indicators were cited from the review that were used to identify the twelve critical factor. Apart from the review the managers from the Task Force Committee had suggested some additional indicators which were also tested in the pilot study.

(6) Intuitive judgement cannot provide a consistent and standardised assessment among the mangers. Thus, developing an alternative indicator can hopefully, provide a consistent and standard assessment on qualitative critical factors.

(7) A mathematical model had a few disadvantages, especially when involving uncertain elements or approximate values. Fuzzy logic was identified as a suitable method to develop an alternative indicator using uncertain or approximate reasoning.

(8) Corrective actions were categorised into two namely:

(a) short-term corrective actions ; and

(b) permanent corrective actions.

The short-term corrective actions do not remove or improve the factors of non-excusable delays but is aimed at correcting the problem i.e. to recover or improve delays. Permanent corrective actions aim is to correct or improve the non-excusable critical factors and this type of corrective action is more economical and effective compared to the earlier type.

(9) Structured approach of deriving permanent corrective actions is a methodology to reach a solution based on certain established rules. The model helps to derive several choices of corrective action for each critical factor. The proposed approach was developed based on the theory of inventive problem solving suggested by Altshuller (1984) from Russia. This theory was formulated based on the studies of 400,000 inventions.

CHAPTER 5

THEORETICAL BASIS TO DEVELOP AN INDICATOR AND METHODS OF ANALYSIS

5.1 INTRODUCTION

This chapter outlines the development of an alternative indicator that can assess a qualitative factor using the theory of Fuzzy Logic and including a brief explanation on several statistical methods of analysing the data. The most important issue discussed in this chapter is the concept of Fuzzy Logic Controller (FLC) used in developing an indicator which provide a new technique of developing tools available for the site managers. The application of fuzzy set theory in construction management is not been fully explored although research has been conducted in project scheduling (Ayyub et al., 1984), tender evaluation (Nguyen 1985) and project risk allocation (Tah et al., 1993). In general, most of the application employed in construction management research focus on other subject area which include: pattern recognition; quantitative analysis; inferences; and information retrieval. However, the most successful domain has been the application of FLC in electronic, manufacturing, and especially the house hold appliances.

5.2 OVERVIEW OF FUZZY LOGIC APPLICATION

The uncertainties and imprecision involved in assessing the problem related to construction works has provided the impetus for the use of fuzzy set theory (Russell et al., 1994, p20.). Fuzzy set theory has grown to become a major scientific domain which may be referred to as fuzzy system which include fuzzy sets, logic, algorithms, and control (Munakata et al., 1994, p69-76). Furthermore, fuzzy systems are suitable for uncertain or approximate reasoning that involved human descriptive or intuitive thinking. The basic idea behind fuzzy logic control was to incorporate the 'experience' of a human process operator in the design of controller. From a set of linguistic rules which describe the operators control strategy, a control algorithm is constructed where the words are defined as fuzzy sets (Kickert et al., 1978, p29-44). However, the application of the fuzzy system were applied in various categories. The most common categories reported by Munakata et al. (1994, p71) as follows:

- control;
- pattern recognition;
- quantitative analysis;
- inference; and
- information retrieval.

The most widely applied categories is fuzzy control in which the majority are industrial applications especially the electrical home appliances. Munakata et al., (1994 p71) highlighted the application of fuzzy control on various fields which include: transportation; automobiles; consumer electronics; robotics; computers; telecommunication; steel; chemical; nuclear; mechanical; civil; environmental; geophysics engineering; safety/maintenance; agriculture; medicine; management; and education.

Specifically, areas of application on management involved scheduling, decision-support system, credit evaluation, damage/risk assessment, market analysis, etc. However, research has been conducted in project scheduling (Ayyub et al., 1984), tender evaluation (Nguyen, 1985), general construction risk management (Kangari, 1988) and construction monitoring and control (Russell et al., 1994). Basically the use of fuzzy logic control is more suitable in the situation to evaluate the qualitative factors and act as a sensor (or indicator). In this study, fuzzy logic control was adopted to develop an alternative indicator and this concept has been successfully applied on various process system. One of the successful application was to simulate the process control of an experienced cement kiln operator. In a study by Umbers et al. (1980) where they modelled the skills of the cement kiln operators using Fuzzy Control System and suggested that many aspects of the operators' control behaviour could be modelled by using fuzzy algorithm. The next section explores the basic concept of fuzzy set theory and the main ideas underlying the Fuzzy Logic Control.

5.3 FUZZY SETS AND FUZZY LOGIC

A brief explanation on some of the basic concept of fuzzy set theory and fuzzy logic is important before discussing the application of fuzzy logic control. This section highlights the terminology used in this study for the convenient of the reader. The terminology used hereafter was cited by Zadeh (1973).

Terminology and Notation

1) Fuzzy set

A fuzzy set G in a universe of discourse U is characterised by a membership μ_G which takes value in the interval [0,1] namely $\mu_G : U \rightarrow [0,1]$. Ordinary set (non fuzzy) membership function would only take two values. That is an element of the universe either belongs to or does not belong to the set. This indicates that the membership of an element is crisp - it is either yes or no, right or wrong. A membership degree is a real number on [0,1]. In extreme cases, if the degree is 0 the element does not belong to the set and if 1 the element belong 100% to the set.

A fuzzy set G in U may be represented as a set of ordered pairs of a generic element μ and its grade membership function. A fuzzy singleton is a fuzzy set whose support is a single point in U, if G is a fuzzy singleton whose support in the point y, thus

$$G = \mu/y \qquad (1)$$

where μ is the grade of membership of y in G. A non fuzzy singleton will be denoted by $1/y$. A fuzzy set G may be viewed as the union of its constituent singletons. On this basis, G may be represented in the following form,

$$G = \int_{\mu} \mu_G(y)/y \qquad (2)$$

where the integral sign stands for the union of the fuzzy singletons $\mu_G(y)/y$ if G has a finite support $\{y_1, y_2, \dots\dots\dots, y_n\}$ then (2) may be replaced by the summation,

$$G = \mu_1/y_2 + \dots\dots\dots + \mu_n/y_n \quad (3)$$

or $$G = \sum_{i=1}^{n} \mu_i/y_i \qquad (4)$$

in which μ_i where $i = 1, 2, \dots\dots\dots n$ is the grade of membership of y_i in G. It should be noted that + sign in (3) denotes the union rather than arithmetic sum.

2) Support, crossover point and fuzzy singleton

The support of a fuzzy set G is the crisp set of all points μ in U such that $\mu_G(\mu) > 0$. The grade of membership μ in U at $\mu_G = 0.5$ is called the crossover point and a fuzzy set whose support is a single point in μ with $\mu_G = 1.0$ is referred to a fuzzy singleton.

3) Arithmetic operation

Let A and B be two fuzzy sets in U with a membership function μ_A and μ_B, respectively. The arithmetic operation of union and intersection for fuzzy sets are defined via their membership functions. The representation are as follows;

Union: The membership function $\mu_{A \cup B}$ of the union $A \cup B$ is pointwise defined for all $u \in U$ by

$$\mu_{A \cup B}(u) = max\{\mu_A(u), \mu_B(u)\}$$

Intersection: The membership function $\mu_{A \cap B}$ of the intersection $A \cap B$ is pointwise defined for all $u \in U$ by

$$\mu_{A \cap B}(u) = min\{\mu_A(u), \mu_B(u)\}$$

5.3.1 Fuzzy logic and approximate reasoning

In a fuzzy logic and approximate reasoning, there are two important fuzzy implication inference rules named the generalised modus ponens (GMP) and the generalised modus tollens (GMT):

premise 1: x is A',
premise 2: if x is A' then y is B,
consequence: y is B' (GMP)

premise 1: y is B',
premise 2: if x is A then y is B,
consequence: x is A' (GMT)

The fuzzy implication inference is based on the compositional rule of inference for approximate reasoning suggested by Zadeh (1973). The above fuzzy set A, A', B, B' via linguistic variables x, y instead of crisp sets in traditional logic. The GMP, which reduces to modes ponens when A=A' and B'= B, is closely related to the forward data-driven inference which is particularly useful in the FLC. The GMT, which reduces to modus tollens when B'= not B and A'= not A, is closely related to the backward goal-driven inference which is commonly used in expert system.

Sup-star compositional rule of inference

If R is a fuzzy relation in $U \times V$, and x is a fuzzy set in U, then the sup-star compositional rule of inference asserts that the fuzzy set y in V induced by x is given by

$$y = x \circ R$$

where $x \circ R$ is the sup-star composition of x and R. If the star represents the minimum operator, then this definition reduces to compositional rule of inference defined by Zadeh (1973).

5.4 THE CONCEPTS OF THE FUZZY LOGIC CONTROL (FLC)

Lee (1990) described the main principal of developing a fuzzy logic controller (FLC) along with the application of FLC from laboratory level to industrial process control. The basic steps involved in developing this sensor (or indicator) are described as follows:

- identify the fuzzy input, output and their ranges;
- define the membership function for each input and output parameter;
- construct a rule base; and
- defuzzification.

In this study, 'inefficient communication' was the factor selected and confirmed during the pilot test to be amongst the factors that were assessed using intuitive judgement. This factor was identified as one of the critical factors that has a significant impact towards contractor's schedule performance. Although there are three factors identified that used intuitive judgement but only one was selected to develop its indicator. The justification to develop only one alternative indicator was to restrict the number of questions required for the main survey. For this study, 'inefficient communication' was chosen to be the key factor that influence contractor's schedule performance and Le Bright (1995) highlighted that the number one deterrent to the good project execution is 'inefficient communication'. Thus, the review has justified the selection for developing an alternative indicator which, hopefully, help to improve the consistency and efficiency of monitoring this factor on site. The elements that contributed to 'inefficient communication' had to be established before carrying out the assessment on 'communication performance'. From the review two elements were identified that contributed to 'inefficient communication'. The elements cited were 'communication channel' and 'distribution of information' in which both of these elements had a significant effect towards 'communication' (Cullen et al., 1986). These elements were employed to explain on the steps of developing the indicator using the Fuzzy logic concepts.

The first step is to identify the fuzzy input and their ranges or linguistic ratings. The input variables identified for 'inefficient communication' were 'communication channel' and 'distribution of information'. Besides these input variables, other variables can also be added or replaced depending on the elements known to have contributed to 'inefficient communication'. To determine the range for the fuzzy input variables, the questionnaire was specifically designed with pre-determined linguistic rating which was tested in the pilot study and has been confirmed by the expert from the Productivity Task Force Committee (refer to the list **Appendix IV**).

The linguistic rating used for 'communication channel' which were tested in the main survey are as follows:

- Inefficient Communication Channel (ICC);
- Slightly Inefficient Communication Channel (SICC);
- Slightly Efficient Communication Channel (SECC);
- Efficient Communication Channel (SECC); and
- Very Efficient Communication Channel (VECC).

While the linguistic rating identified for 'distribution of information' and tested in the main survey were as follows:

- Inadequate Briefing (IB);
- Slightly Inadequate Briefing (SIB);
- Slightly Adequate Briefing (SAB);
- Adequate Briefing (AB); and
- Very Adequate Briefing (VAB).

One important point to note that the linguistic rating or label was classified into five levels of rating and for a finer fuzzy control more levels of ratings were needed. From Figure 5.1a and Figure 5.1b illustrate the differences in fuzzy level between one fuzzy input which represent three levels of rating and the other had seven levels of rating. Comparing between them, Figure 5.1a has a coarser fuzzy input with three rating levels: N, negative; ZE, zero; and P, Positive. While Figure 5.1b represents a much finer fuzzy input with seven levels of rating: NB, negative big; NM, negative medium; NS, negative small; ZE, zero; PS, positive small; PM, positive medium; and PB positive big. For this study, it was decided to use five levels of rating which can adequately serve the purpose of evaluating the factor of 'inefficient communication'.

Coarse

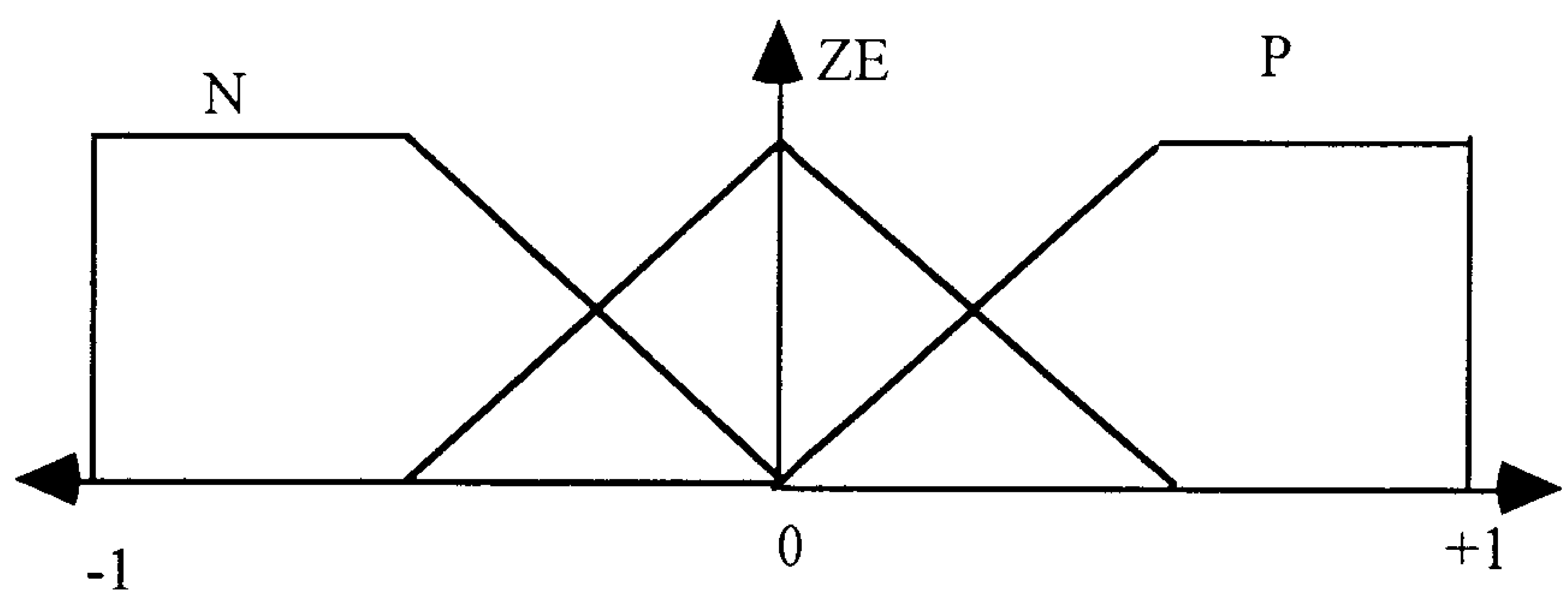


Figure 5.1a: Coarse fuzzy partition with three terms (Adapted from Lee, 1990)

Finer

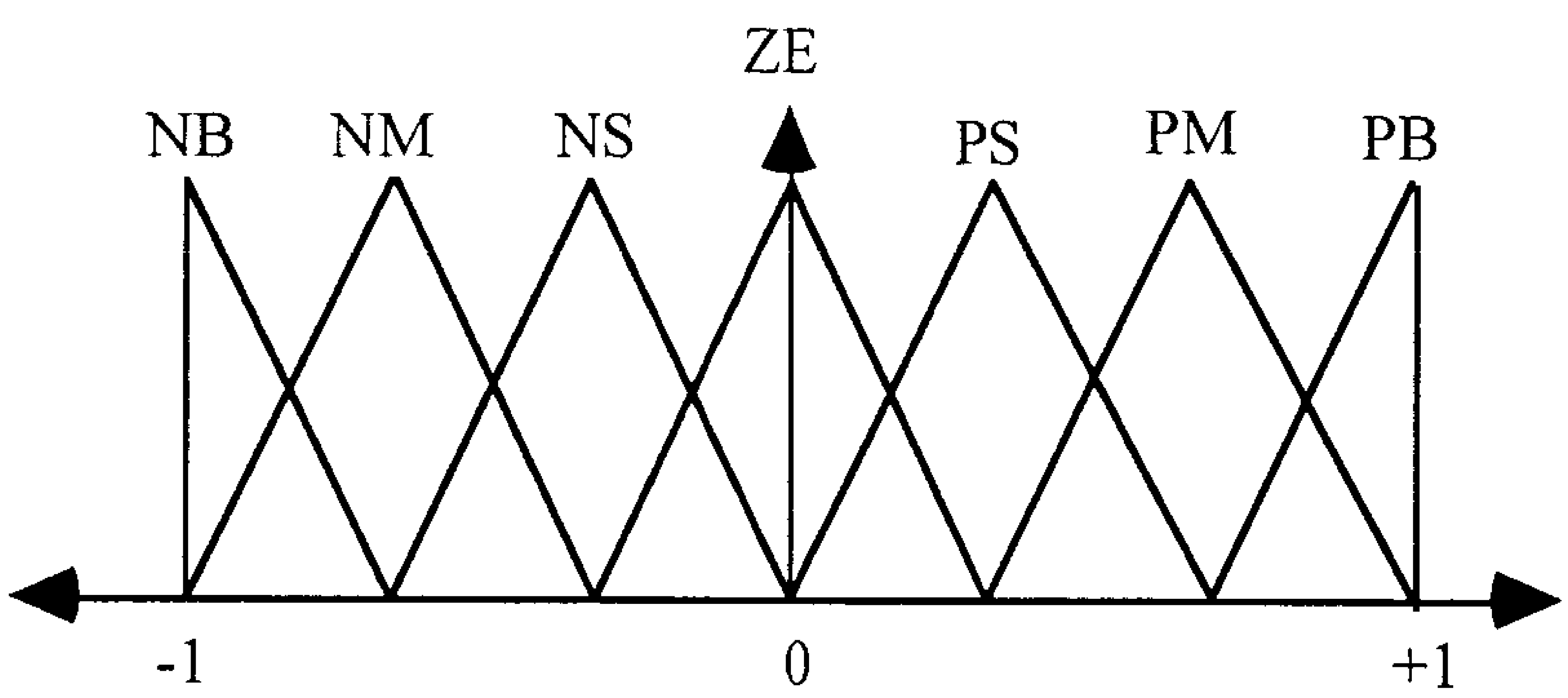


Figure 5.1b: Finer fuzzy partition with seven terms

(Adapted from Lee, 1990)

Apart from establishing the linguistic rating, these ratings can also be represented by linguistic values which may take a range of values from 0 to 1 or 0 to 10. This arbitrary values which take a certain range of values were provided by the expert from the industry. For example, in this research 'ICC' for 'communication channel' takes a range of values from 0 to 3 and 'SICC' takes a range of values from 1 to 5. These range of values was determined during the main survey by averaging the values, furnished by the expert, to the nearest whole number. While the apex of the triangle represented the mean of the range of values which was converted to the nearest whole number. The logical reason for considering the exact whole number was it is unlikely for managers to rate 'efficient communication channel' on the scale of 0 to 10 with a figure of 6.45. Once the linguistic rating have been established, the fuzzification membership function can easily be developed. There are several shapes available to develop this membership function, one can use trapezoidal shape as shown in Figure 5.2a or triangular shape as in Figure 5.2b or bell shaped or some other complicated shape. The fuzzy function of a fuzzy set could take a bell-shaped function, triangle-shaped function, trapezoidal-shaped function, etc. (Lee, 1990). He further emphasised that using triangular shape function can reduce the complexity in manipulation and thus make it slightly more practical to the user. Whatever shape of fuzzy function used it will only differ slightly in the smoothness of change at a different set level.

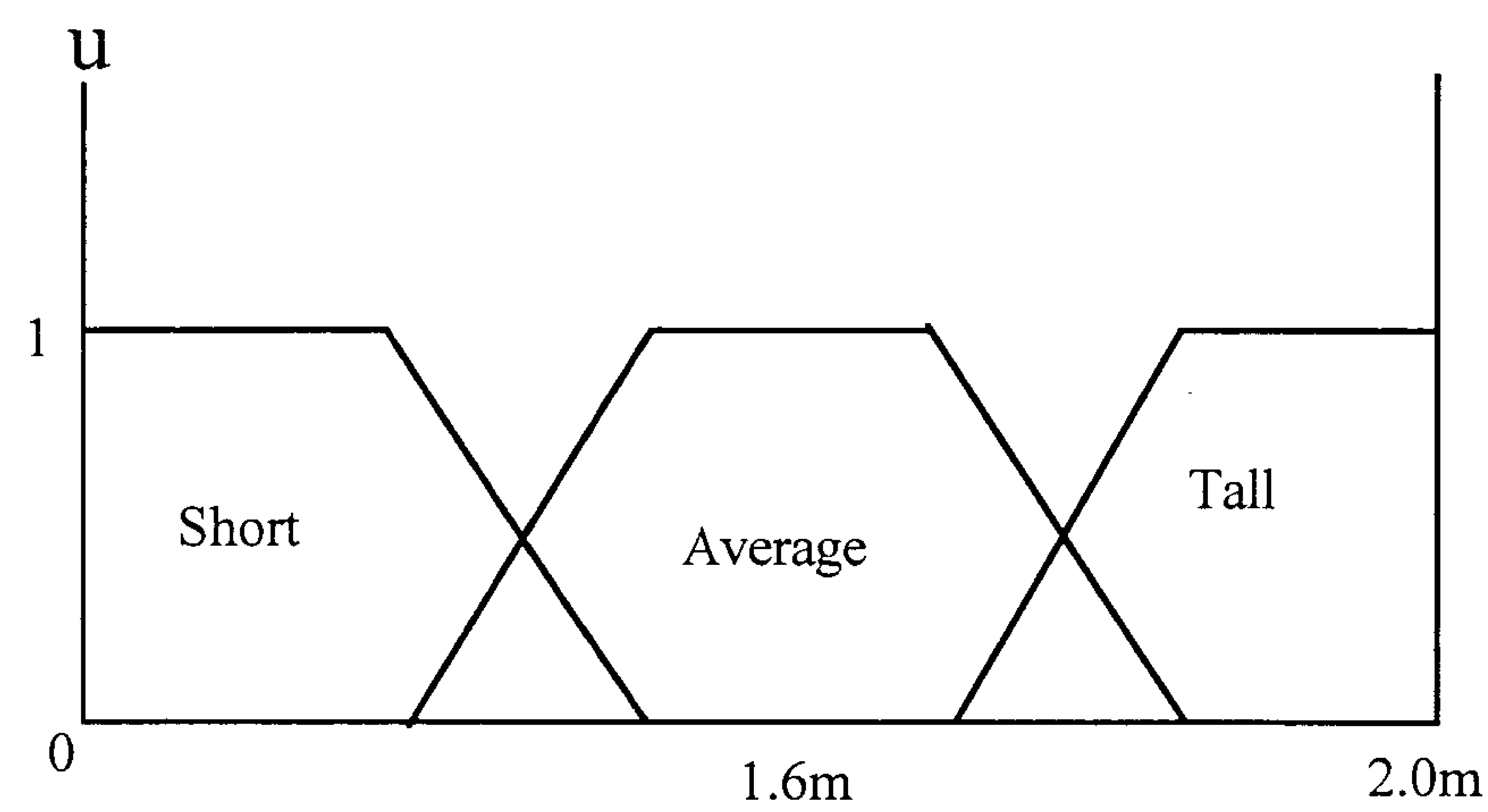


Figure 5.2a: Trapezoidal membership function

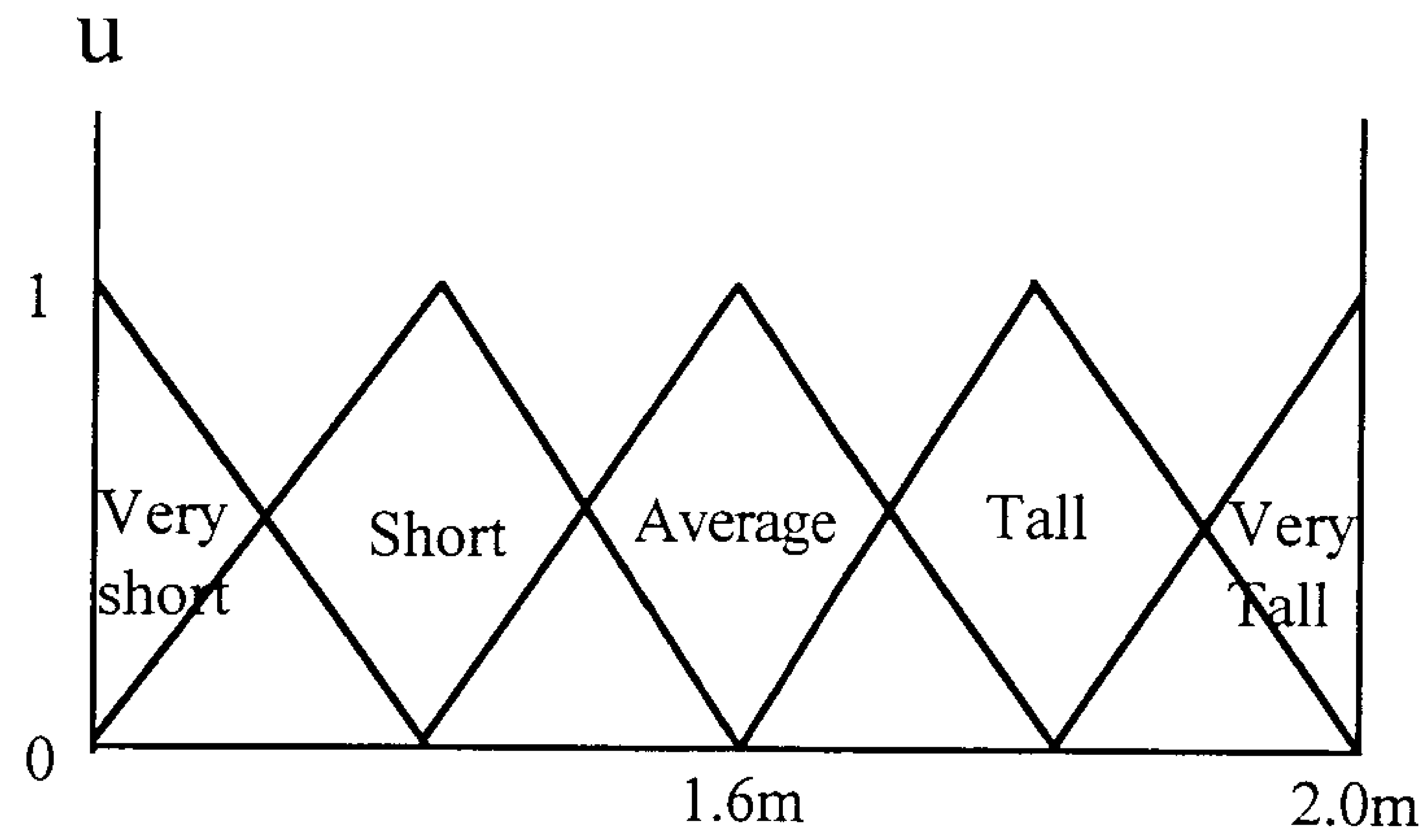


Figure 5.2b: Triangle membership function

The triangular shape was chosen to represent each linguistic rating since this shape helps to simplify the application process. Furthermore, the selected simple shape can simplify the defuzzification process and a process which is simple can encourage the managers to adopt the proposed approach. However, both ends of the membership function do not exactly take the triangular shape. The reason is that both ends belong hundred percent to the fuzzy set. For example 'inefficient communication channel' (ICC) where its zero value belongs hundred percent to the linguistic rating i.e. majority of the experts will judged that zero rating belongs to the worst linguistic rating. In another words, the fuzzy grade of the membership function of zero is one (where one represent 100% of the grade or is referred to as fuzzy singleton). For the triangular shape fuzzy sets the singleton value is at the apex of the triangle. The output variables considered for this indicator was 'communication performance', and correspondingly the linguistic variables identified were as follows:

- Inefficient communication (I);
- Slightly Inefficient communication (SI);

- Slightly Efficient communication (SE);
- Efficient communication (E); and
- Very Efficient communication (VE).

The above linguistic rating represents five levels of rating performance and it could be represented by ranges of values as in the case of the input variables. The range of the linguistic values were established similar to that of the input variables. Using the expert opinion the range of the values for each linguistic rating was established as in Figure 8.3.

The second step is to define the membership function for the input and output sets. The earlier step has briefly explained the linguistic rating together with the range of the input and output sets, and the shape employed to represent these ratings. Figure 5.3 shows an example of membership function, in which speed was represented by the linguistic rating: 'slow', 'medium' and 'high'.

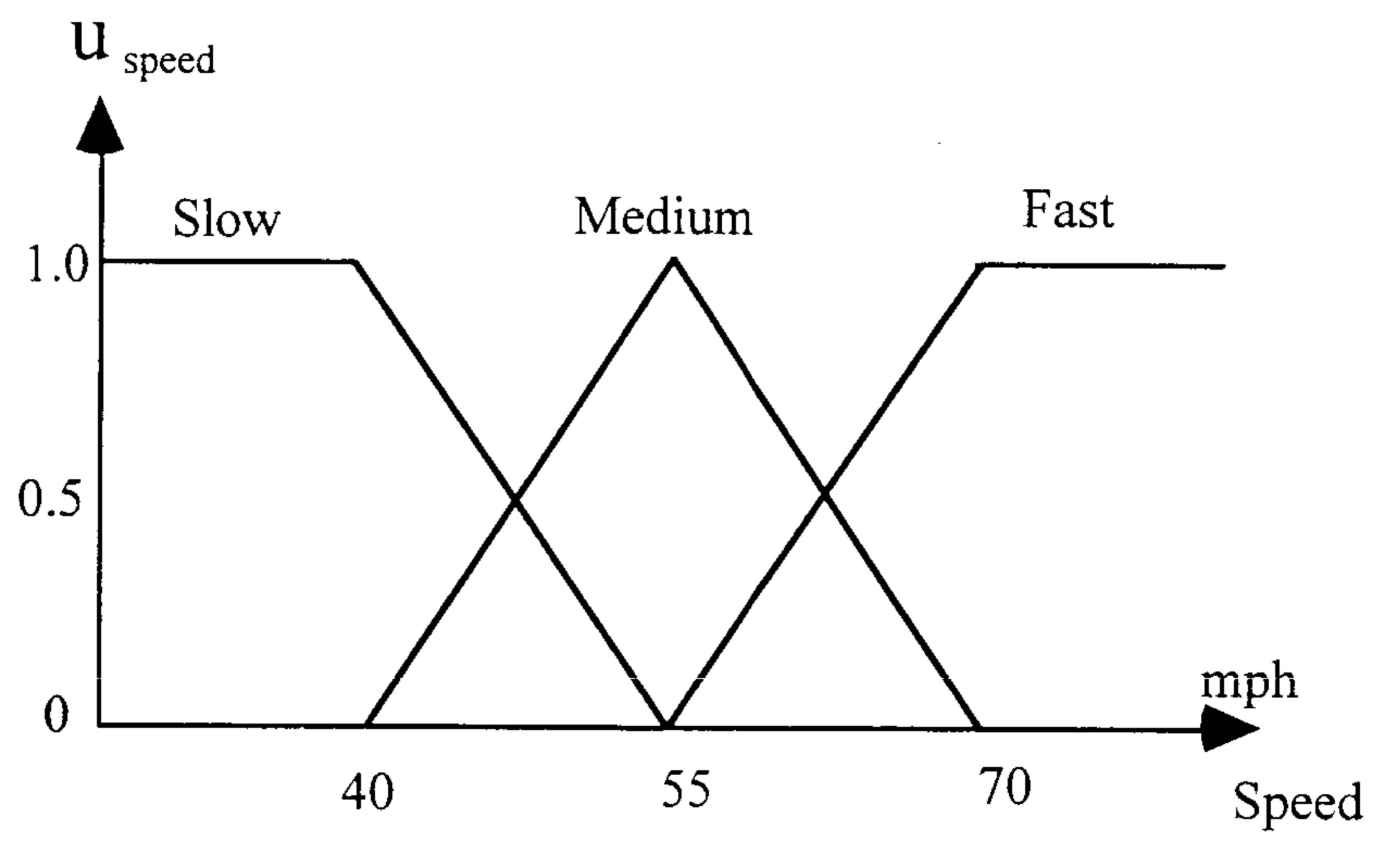


Figure 5.3: Diagrammatic representation of fuzzy speed

(Adapted from Lee, 1990)

From the above figure, if speed is interpreted as a linguistic variable, then its term set T(speed) could be:

T(speed) = {slow, moderate, fast, very slow, more or less fast,............}

where each term in T(speed) is characterised by a fuzzy set in a universe of discourse U = [0,100]. Then one can interpret 'slow' as 'a speed below 40 mph', 'moderate' as 'a speed close to 55 mph', and 'fast' as 'a speed above about 70 mph'. These terms can be characterised as fuzzy sets whose membership function are shown in Figure 5.3. Using the range of values and the linguistic rating one can establish the membership function for both the input and output variables. Employing the triangular shape to represent the linguistic variables, the membership function figure can be established as shown in Figure 8.1, Figure 8.2 and Figure 8.3.

The third step is to establish the rules that characterised the control goals and the control policy by means of a set of linguistic control rules. In fuzzy logic control, the dynamic behaviour of a fuzzy system is characterised by a set of linguistic description rules based on expert knowledge.

A fuzzy logic with a fuzzy if-then rules has been mainly applied to control problems. These rules are developed based on the expert knowledge or more specifically the human expert. It generally formulated in the form of:

IF (a set of conditions are satisfied); and
THEN (a set of consequences can be inferred)

Since the antecedents and the consequences of if-then rules are associated with fuzzy concepts, they are often called fuzzy conditional statements. A fuzzy control rule is a fuzzy conditional statement in which the antecedent is a condition in the application domain and the consequent is an inference. Fuzzy control rules have provided a convenient way for expressing the control policy. It may involve several linguistic variables of the antecedent and several inferences. When this is the case, the system is referred to as a multi-input-multi-output (MIMO) fuzzy system. But in this example the case of two-input-single output (MISO) fuzzy system, thus, the fuzzy control rules have the form:

R_1: if x is A_1 and y is B_1 then z is C_1

R_2: if x is A_2 and y is B_2 then z is C_2

....

....

R_n: if x is A_n and y is B_n then z is C_n

where x, y and z are the linguistic variables representing 2 variables and one output variable. A_i, B_i and C_i are linguistic values of linguistic variables x, y, z in the universe of discourse u, v and w respectively with i = 1,2,......n. In this study, one of the rules formulated was as follows:

if distribution of information is inadequate
and communication channel is inefficient,
then communication performance is inefficient.

Several checks have to be carried out to ensure that the if-then rule covers all the possible permutations. This is known as the completeness of the rules and there is no specific number of rules (Lee, 1990). The output fuzzy rules will depend on the number of fuzzy rating and the fuzzy variables. Two variables with five fuzzy rating each can result in 5x5 number of possible control rules and with an additional fuzzy input can result in 5x5x5 number of permutations.

Fuzzy control rules are more conveniently formulated in linguistic rather than numerical terms. The selection of the linguistic variables has a substantial effect on the performance of an FLC. The experience and engineering knowledge play an important role over the choice of linguistic variables and their membership function have a strong influence on the linguistic structure used to develop the fuzzy control rules. The derivation of the control rules can be of several mode and to name a few it includes the following sources:

- expert experience and engineering knowledge;
- based on operator's control actions;
- based on the fuzzy model of a process; and
- based on learning.

The formulation of the fuzzy control rules using the expert experience can be achieved by means of heuristic knowledge. Discussion with the expert, which known as introspective verbalisation of human expertise. A common example cited in fuzzy articles of such verbalisation is the operating manual for a cement kiln. There are two principal approach to derivation of fuzzy control rules. The first is a heuristic method in which a collection of fuzzy rules is formed by analysing the behaviour of a controlled process. The second approach which was adopted for this study is basically a deterministic method which can systematically determine the linguistic structure and/or parameters of the fuzzy control rules that satisfy the control objectives and constraints (Mamdani, 1978). The method of determining and converting the process of input-output data into a set of fuzzy control rules. But using a logical examination would encounter difficulties in the identification of multi-variables fuzzy inputs.

Mamdani (1981) proposed a prescriptive algorithm for deriving the best control rules by restricting system responses to a 'prescriptive fuzzy band' which is specified by fuzzy control rules. However, this method requires a careful analysis on determining the fuzzy band.

A fuzzy control algorithm should always be able to infer a proper control action for every state or process. This property is called 'completeness' and the completeness of an FLC relates to its rule base, data base, or both. In this case, the rule base strategy was adopted. The rule base was developed through the expert and logical examination and the property of completeness is incorporated into the fuzzy control rules. An additional rule is added whenever a fuzzy condition is not included in the rule base. However, there is no general procedure for deciding on the optimal number of fuzzy control rules (Lee 1990) and the most important is to check the consistency of the fuzzy rules in order to minimise the possibility of contradiction. The consistency of the rules may be improved through the use of the concept of fuzzy clustering of fuzzy control rules.

The last step in developing an indicator is defuzzification and there were three methods cited in the literature. Defuzzification is the process of transforming a fuzzy output values into a crisp value. It is employed because in many instances professional can only appreciate the crisp value or the normal linguistic rating. In this situation the defuzzification strategy is aimed at producing a non fuzzy linguistic rating. Three commonly used strategies may be described as max criterion, the mean of maximum and the centre of area.

1) The max criterion method (MAX)

   The max criterion produces the point at which the possibility distribution of the control action reaches maximum value.

2) The mean of Maximum Method (MOM)

   The MOM strategy generates a control action which represents the mean value of all local control actions whose membership functions reach the maximum.

3) The Centre of Area Method (COA)

The widely used COA strategy generates the centre of gravity of the possibility distribution of the control action.

Figure 5.4 shows a graphical interpretation of various defuzzification strategies. Amongst these three COA yields superior results, however MOM strategy yields a better steady-state performance. An FLC based on COA generally yields a lower mean square error than that based on MOM but the latter yield better performance than Max Criterion strategy. In this research COA method was selected and used to defuzzify the fuzzy output value into crisp value.

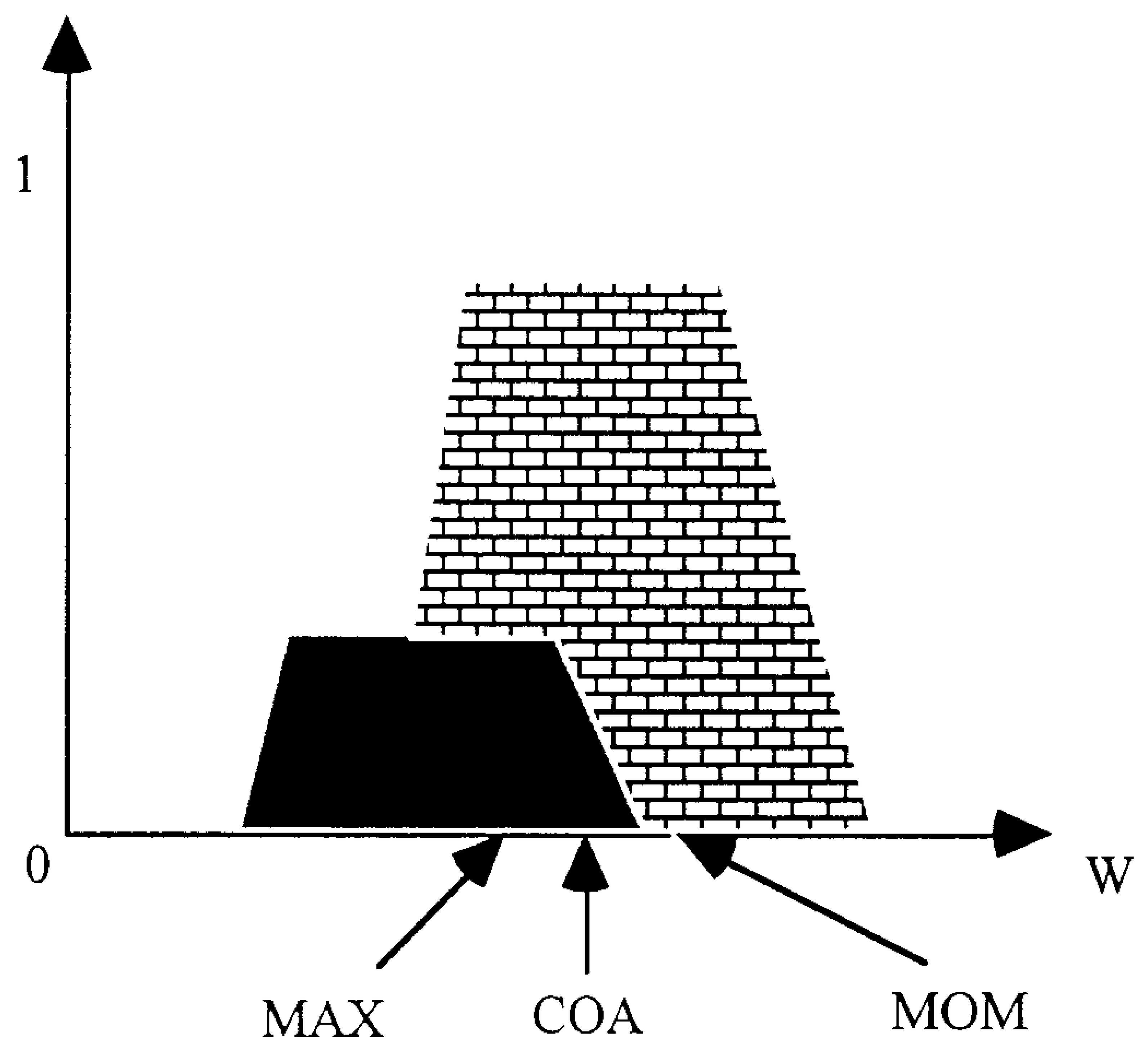


Figure 5.4: Diagramatic representation of various defuzzification strategies

(Adapted from Lee, 1990)

5.5 METHODS OF ANALYSIS

5.5.1 Statistical tests

One of the scientific methods of testing the hypothesis in a research is using a statistical test. The hypothesis could be rejected or accepted by using an appropriate method and procedure. Before developing a questionnaire, the methods of statistical test to analyse the data collected has to be determined. This is necessary because it normally determine the type of data to be collected and it influence the structure of the questions. The type of data collected appropriately follow the measurement or scaling used to define a variable quantitatively. In management sciences non-parametric techniques of testing hypothesis and data is identified as a suitable technique to be employed. Few reasons that made this technique suitable for this study, in which most of the data collected is in 'Likert scale' or ranking. Likert scale, for example 1 = very low and 7 = very high, or something similar are normally employed in collecting data to prove a predetermine hypothesis. Many of the non-parametric tests are identified as 'ranking tests' and the techniques were used with scores which are not exact in numerical sense (Siegel et al., 1988). The primary merits being it does assume that the scores or data were drawn from a population distributed in a certain way, example, from a normally distributed population but it is essential to collect enough data to represent a population. The reason is to increase the power of the test and inferences could be made appropriately. A central function of modern statistics is statistical inference and it is concerned with two type of problems: estimation of population parameter and test of hypothesis. It is the latter, test of hypothesis, that will be briefly discussed in this section.

Before further discussion on the methods chosen for the data analysis, the writer will briefly explain on the scaling or measurement used to collect the data. The scaling or measurement of data collected helps to determine the methods of test employed.

5.5.2 Scaling or Measurement

Scaling or scoring of data in non-parametric statistic normally were classified into four types which includes the followings:

- nominal or categorical scale;
- ordinal or ranking scale;
- interval scale; and
- ratio scale.

The measurement used to collect most of the variables relevant for this study was ordinal or ranking scale. Specifically, as mentioned earlier, Likert scale was used to measure most of the variables. For example, in this study, the measurement used to measure the level was seven and five Likert Scale for all four section of the questionnaire (refer to main questionnaire sample in **Appendix III**). However, there is also a 'yes' or 'no' measurement being used in section C(ii) and this is a dichotomous scale which is also classified under ordinal scale. For details explanation on different types of scaling please consult Siegel et al., (1988).

Besides the scale used to measure the variables, the objective of the analysis will finally determine the statistical method used. For section B(i), and B(ii), of the questionnaire the objective was to establish the impact of individual factors for each groups of causes in term of their relative ranking and is there any association between the contractor's response and the client's response. The ranking was based on the average index which will be discussed in the **section 5.6**. To measure if there is any association between the contractors' group and the client's group Spearman's rank correlation analysis was used. Fellows et al. (1997) highlighted that Likert scale is not suitable to analyse by regression due to the nature of the scale employed. Mean and standard deviations are not appropriate and rank correlation were suggested as the only mean of comparing the ranks between different groups. A brief theory on Spearman's rank correlation coefficient is discussed in the next sub-section.

5.5.3 The Spearman's rank correlation coefficient test

Spearman's rank correlation coefficient is a measure of association, in this case, between two groups of respondents and the variables were measured in an ordinal scale. The variables under study may be ranked by both groups i.e. the variables identified for each group of causes was ranked according to Likert scale or ordinal scale. There are N variables as an object ranked by the respondents using the ordinal scale and the average ordinal scale were computed using the formula explained in **Section 5.6**. The ranking was based on the calculated average ordinal scale or known as average index and it was used as a measure of rank-order correlation to determine the correlation between contractors and client. The expression for calculating the Spearman's rank correlation coefficient is as follows:

$$R_S = 1 - \frac{6\sum_{i=1}^{N} d_i}{N^3 - N} \qquad (1)$$

where d_i the different in ranks between two groups and N is the total number of variables. But if there is a tie in the ranks within a group then use either of the following equations:

$$R = \frac{\sum xy}{\sqrt{\sum x^2 \sum y^2}} \qquad (2)$$

or

$$R_S = \frac{\sum x^2 + \sum y^2 - \sum d^2}{2\sqrt{\sum x^2 \sum y^2}} \qquad (3)$$

where $x = X - \overline{X}$, and $\overline{X}$ is the mean scores of the contractor's group while $y = Y - \overline{Y}$, and $\overline{Y}$ is the mean scores for the client's group. While d is the different between the ranking of the contractor and the client.

The null hypotheses were tested for N=4 and above while N=3 or less no significant test was carried out. If test were to be carried out for groups of causes with N=3 even if there is a perfect match in ranks for the three factors between both groups the probability achieved is 16% or 1/6. Hence, the probability is not significant if a confident level of 5% is to be observed. For this study, a significance value of 0.05 was adopted and if the calculated value exceed 0.05 or 5% then the null hypothesis is accepted. If the calculated value is less than 0.05 then the alternative hypothesis is accepted.

The values of Spearman's rank correlation coefficient can be in the range of $+1 > R_S >$ -1 and when the value is zero implies an absence of any correlation. If the value is nearly positive one it indicate a strong correlation and a negative correlation indicates an opposite rank in between two respondent groups. While the significant value can be interpreted from the Spearman's table of critical values. In this study, a one tail test was used to observed it's significant value. For more detailed explanation consult Siegel et al. (1988) and Meddis (1984). For data of **section C(ii)** a Binomial probability test was employed and its brief theory is discussed in the next sub-section.

5.5.4 The Binomial probability test

Section C(ii) of the main survey questionnaire was designed to validate three qualitative factors that were identified during the pilot test. The questions were designed to confirm that the factors were evaluated by an intuitive judgement. Hence, to investigate these phenomena, Yes - No questions was chosen as an appropriate strategy. To validate the data obtained using a Yes - No structure, the appropriate test employed was Binomial probability test. This test can also be conducted on a small sample population even below ten. Since the client's respondents for this section is only six the method was employed. A brief discussion on the theory of the test is important to appreciate the appropriateness of the method applied.

If a coin is tossed, the outcome on the first toss has no effect on the second toss, and this outcome is independent. When there is only two possible outcomes either Yes or No and in this case the population is called dichotomous population. Taking a sample from a dichotomous population the successive selections or trials are independent of each other, and if the number of trial is fixed, it is an example of binomial experiment. The binomial experiment is an experiment with a fixed number of trials and has the following characteristics:

- exactly two outcomes for each trial, usually denoted by S (success) and F (failure) and for this study Y (yes) and N (no);
- the probability for success, denoted p, remain constant from trial to trial; and
- outcomes of successive trials are independent.

The probability of failure for each trial is $(1-p)$ and it is usually denoted by q. A binomial random variable is the number of success in a fixed number of trials. A binomial random variable is defined by two parameters (constant): the probability of success, p on each trial and the number of trials , n. If the binomial random variables is x then its values will be an integers from zero through n.

If there is a total of n trials and there are x successes, then n choices for the first success , $n-1$ for the second, $n-2$ for the third and so on, down to $(n-x+1)$ for the xth success. If a binomial experiment has n trials and the probability of success on one trial is p, then the probability of exactly x successes in n trials is given by

$$P(x)=\left(\frac{n}{x}\right)p^{x}(1-p)^{n-x}$$

where

$$\left(\frac{n}{x}\right)=\frac{n(n-1)(n-2)(n-3)....(n-x+1)}{x(x-1)(x-2)(x-3)....3.2.1}$$

For more detailed discussion please consult Byrkit (1987), and Siegel et al. (1988). The above equations were used to calculate the probability of saying No for the data of section C(ii) collected from the main survey. The Binomial probability test was used to calculate the situation when there is two possible outcomes. The assumption used for the test was the expected outcome is equal i.e. the numbers of respondent saying yes, p= 0.5 and $(1-p)$ = 0.5. The probability or significant values obtained from the calculation are then compared to the significance limit of 5%. That is the level of confident for it does occur by chance was 95%. The final statistical method employed for this study is Kendall's coefficient of concordance, W which is briefly explained in the following sub-section.

5.5.5 The Kendall's coefficient of concordance, W

Section D of the questionnaire was to test if there is any agreement in the pattern for the three suggestion of each factors. Apart from identifying the common corrective actions the objective was to establish the structured approach of deriving permanent corrective actions for the critical factors. The structured approach proposed in the previous chapter is to establish the most appropriate corrective actions among the three suggestions proposed and it was designed to derive the last option as the most appropriate one. To test this pattern Kendall's coefficient of concordance, W was selected as the most appropriate method. Spearman's rho express the degree of association between two sets of ranking by the different groups, while Kendall's coefficient of concordance, W expresses the degree of association amongst k variables which in this case are the fifteen factors. The test measures the consistency in the ranking amongst these variables and if there is a perfect agreement in the ranking between the variables then Kendall's coefficient of concordance, W is +1. If there is a disagreement amongst the ranking then Kendall's coefficient of concordance, W is 0. Hence, W, the coefficient of concordance, may take values only between 0 and +1. To compute W the following equations were used:

$$W = \frac{s}{\frac{1}{12}k^2\left(N^3 - N\right)}$$

Where s is represented by the following equation,

$$s = \sum\left(R_i - \frac{\sum R_i}{N}\right)$$

where k = number of variables or judges

N = number of ranks

$\frac{1}{12}k^2\left(N^3 - N\right)$ = maximum possible sum of squared deviations, i.e. the sum s which would occur with perfect agreement amongst k rankings.

At first the sum of ranks, R_i, in each column of $k \times N$ table was computed (refer to Table 8.21). Then the sum of R_i and divide that sum by N to obtain the mean value of R_i. Each value of R_i may then be expressed as a deviation from the mean value. Finally, s, the sum of squares of these deviations, is found.and to compute, W:

The above equation was used to validate whether there exist a pattern according to the proposed structured approach and the data collected for section D of the main questionnaire were then analysed using this method. For a more detailed theory of the above method please refer to Siegel et al. (1988), and Siegel (1956). The next important calculation which involved data analysis for section B and C, is determination of an average index which were used to ascertain the ranking.

5.6 AVERAGE INDEX

To establish the ranks for all the factors in section B, the indicators of section C and the corrective actions of section D, an average severity index was calculated which then reflect the rating of five or seven Likert scale categories. For example for section B(ii) the rating used were as follows:

1 = very low,	2 = low,	3 = slightly low,	4 = average,
5 = slightly high,	6 = high,	7 = very high.	

The above rating were mainly used to determine the severity of influence on contractor's schedule performance. The average index was calculated as follows (Al-Hammad et al., 1996):

$$\text{Average Index} = \left(\frac{\sum_{i=0}^{6} a_i x_i}{6 \sum_{i=0}^{6} X_i} \right) \text{ for seven scale rating}$$

or

$$\text{Average index} = \left(\frac{\sum_{i=0}^{4} a_i x_i}{4\sum_{i=0}^{4} X_i} \right) \text{ for five scale rating.}$$

where a_i = constant expressing the weight given to i; X_i= variable expressing the frequency of the response for; i = 0,1,2,3,4,5,6 and illustrated as follows: X_0 = frequency of the 'very low' response and corresponding to $a_0 = 0$; X_1 = frequency of the 'low' response and corresponding to $a_1 = 1$; X_2 =frequency of the 'slightly low' response and corresponding to $a_2 = 2$; X_3 = frequency of the 'average' response and corresponding to $a_3 = 3$; X_4 = frequency of the 'slightly high' response and corresponding to $a_4 = 4$; X_5 = frequency of the 'high' response and corresponding to $a_5 = 5$; X_6 = frequency of the 'very high' response and corresponding to $a_6 = 6$. The above computation was applied to the data collected for section B(i), B(ii) C(i), and section D. Except section C(iii) where the rating were classified as follows:

0 = very low, 1 = low,
2 = Average, 3 = high,
4 = very high.

The same method of computation was applied to the five scale rating for section C(iii). But for the five rating scale, the classification of the rating is similar to that of seven scale except that there is no 'slightly low' and 'slightly high' categories. Hence the representation of the linguistic rating for the previous equation follow the rating used in section C(iii) (refer to the main questionnaire in **Appendix III**).

The results of each values of the average index or mean score were shown under the column of the contractor's mean and client's mean shown in the Table 8.1 to Table 8.13, and Table 8.18 to Table 8.32. These average index could be further interpreted back to reflect the respondents rating. Initially the researcher used a discrete scale converted to a continuos index (average index) which then can be split into a discrete categories (Abd. Majid and McCaffer 1997a). In this case the discrete categories were classified as follows:

(1) Very high	$5.50 \leq$ Mean score ≤ 6.00
(2) High	$4.50 \leq$ Mean score < 5.50
(3) Slightly High	$3.50 \leq$ Mean score < 4.50
(4) Average	$2.50 \leq$ Mean score < 3.50
(5) Slightly Low	$1.50 \leq$ Mean score < 2.50
(6) Low	$0.50 \leq$ Mean score < 1.50
(7) Very Low	$0.00 \leq$ Mean score < 0.50

The same classification can be establish for the other rating scale and the computed average index from the analysis can then be reflected to the above categories. The calculated mean score can also be converted to a percentage index as suggested by Abd. Majid and McCaffer (1997a).

5.7 SUMMARY

(1) Fuzzy systems are suitable for uncertain or approximate reasoning that involved a human descriptive or intuitive thinking. One of the fuzzy domain used to design a sensor (or indicator) that incorporate the 'experience' of human process operator is fuzzy logic control (FLC). It is the most successful domain and its application majority are industrial application especially in electrical home appliances.

(2) Basically, the use of fuzzy logic control is more suitable in the situation to evaluate the qualitative factors and act as a sensor (or indicator). The fuzzy logic

control algorithm was employed to develop an indicator for 'Communication Performance' and assessment on communication can be made using this model (see **Section 8.6.3**).

(3) There are basically four essential steps identified to develop an indicator which uses the principal of fuzzy logic control (FLC). The four basic steps involved are as follows:

- identify the fuzzy input, output and their ranges;
- define the membership function for each input and output parameter;
- construct a rule base; and
- defuzzification.

(3) The first steps is to identify the fuzzy input and linguistic ratings. Two input sets identified were 'communication channel' and 'distribution of information'. The linguistic ratings used for 'communication channel' are as follows:

- Inefficient Communication Channel (ICC);
- Slightly Inefficient Communication Channel (SICC);
- Slightly Efficient Communication Channel (SECC);
- Efficient Communication Channel (SECC); and
- Very Efficient Communication Channel (VECC).

While the linguistic ratings identified for 'distribution of information' and tested in the main survey were as follows:

- Inadequate Briefing (IB);
- Slightly Inadequate Briefing (SIB);
- Slightly Adequate Briefing (SAB);
- Adequate Briefing (AB); and
- Very Adequate Briefing (VAB).

(4) Triangle-shaped function was employed which can reduce the complexity of manipulation and make it slightly more practical to the user. The fuzzy control becomes finer if more levels of ratings used and the number of levels depend on the controlling requirement either fine or coarse.

(5) The second step of developing the indicator is to defined the membership function for the input and the output sets for example slow speed is a 'speed below 40 mph'; moderate can take the range between 40 to 70 mph. While in this research, the range of values for the membership function were obtained from the main survey.

(6) The third step is to establish the rules that characterised the control goals and the control policy by means of a set of linguistic rules. These rules are developed base on the expert knowledge or more specifically the human expert and this rule can be formulated in the form of:

IF (a set of conditions are satisfied)
THEN (a set of consequences can be inferred)

(7) A fuzzy control algorithm should always be able to infer a proper control action for every state or process. This property is called 'completeness' and completeness and its rule base, data base, or both. In this study, a rule base was adopted and the property of completeness is incorporated into fuzzy control rules.

(8) The last step in developing an indicator is defuzzification and there were three methods identified. Defuzzification is the process of transforming a fuzzy output values into a crisp value. The three strategies commonly used include:

(a) The max criterion method (MAX);

(b) The mean of maximum method (MOM); and

(c) The centre of area method (COA).

In this study, COA was adopted for its superior results meanwhile it is the most practical method.

(9) Three methods of statistical test employed for this study which include: Spearman's rank correlation coefficient; Binomial probability test; and Kendall's coefficient of concordance. The ranking of the variables (factors) was based on the average index and these values can then reflected the discrete categories.

CHAPTER 6

PROCESS AND CONTROL

6.1 INTRODUCTION

This chapter presents the review on the process and control in order to relate the various issues addressed in this research. Reviewing the concept of process and control can help to draw a framework that is required to highlight the various issues addressed in this research. This framework can later be used for designing the process of monitoring and control the factors of NED. The proposed framework can be represented by identifying the main stages of addressing the issues of this research. The main stages that were involved are as follows:

- identification of the factors of NED;
- indicators to identify or assess; and
- identification of permanent corrective actions.

In addition this chapter identifies the short-term corrective actions for improving delays. This identification can help to offer an alternative corrective actions which is also required as an immediate measures.

6.2 PROCESS

Process is defined in the Oxford Dictionary as 'a series of actions ...'. Pall (1987), defined 'process' as the logical organisation of people, materials, energy, equipment and procedures into work activities designed to produce a specified end result. This definition is similar to that of a system which was used in the system theory. From the system theory described by Harold Koontz (1980):

"The system approach requires that the physical, human and capital resources be interrelated and co-ordinated within the internal and external environment of an organisation."

System is defined in the Oxford Dictionary as 'a combination of interrelated elements or a methodical'. The general systems represents an organisation as an open system, one that interacts with environmental forces and factors, much like physical systems such as the human body, a microscopic organism, or a cell. The key organisational components that change inputs into outputs are transformation process. The transformation process in an organisation that continually receiving new energy in the form of resources (people, materials and money) or information (concerning strategy, environment and history). This new energy, called inputs, is then transformed into new outputs. Koontz (1980) shared a similar view on the definition of 'system approach' that can also represent a process.

A manageable process must have measurable inputs and outputs and be adaptable to change. The end product must have a value greater than that of the inputs to the process. Certainly to improve the efficiency of a process, it requires a technology that could help to expedite the information process. Computer technology can helps to improve the efficiency of processing and also to model the process. The effectiveness of the process can be enhanced by establishing the sub-process within the system. Each stage of a process requires a sub-process and the sub-process identified aids the approach of deriving permanent corrective actions. The success of managing the process and controlling its output will depend on the management's ability to define and separate the components of the process. Every process technological or administrative, complex or simple must be designed around three fundamental concepts and Pall (1987) described these as follows:

(1) The basic feedback loop, also known as the 'command and control' concept. This means that to achieve satisfactory results (that is conformance to requirements) those responsible for managing the process must always be in the position to (a) know what is to be done and (b) know what is being done and take corrective action if necessary (control).
Without the basic feedback loop, no set of components, however well chosen and ordered, and no sophisticated management system will ensure effective operation and conformance to requirements.

(2) Independence of purpose where it should possess the following basic characteristics:

- the process must be in control and capable of producing the expected results, which means it must be effective.
- the process must be efficient: It has to operate at an optimum cost as well as providing a fast examination on the data or information.
- the process is adaptable: There has to be an effective and economical way of changing it over time as a result of corrections necessitated by variations in input or by changing requirements. This means that changes to the process should be applicable without adverse impact on its effectiveness or efficiency.

(3) Clear and complete definition of components - people, procedures, information, equipment, materials and energy. Procedures include the description of the interrelationships of these components and of activities they are expected to perform.

Several authors including Mohamed Zairi (1994), Mondy et al, (1995), and Pall (1987) have stressed the importance to emphasis on process rather than to manage and control an activity. Mohamed Zairi (1994), suggested to focus on process first, for which the results became an outcome and compared the differences on the approach between process-based and results-based (refer **Table 6.1**)

Table 6.1: A comparison between process-driven and results-driven approaches
(Adapted from Zairi, 1994)

Process-based approach	***Results-based approach***
Improvement defined in long-term	*Measurable short-term improvement goals*
Action taken by managers because it is the right things to do	*Action by managers because opportunity for improving business results*
Focus on learning and improving quality	*Management insist on seeing results*
Everyone is educated and trained to improve quality for end customer	*Experts are recruited to help managers achieve results*
Managers and employee are encouraged to believe in quality and to support implementation programmes	*Managers and employees are encouraged to quantify everything they do and to measure impact on business results*
Investment 'up front' before results are achieved	*Building conviction through obtaining results*

Result-based approach

This represents the traditional culture of focusing on short term goals, particularly financial results, and a remoteness from the process where all the action takes place. A result-based approach reflects a culture of short-termism and incremental achievements rather than a real desire to strengthen business activities and become more competitive.

Process-based approach

This approach means that continuous improvement is a long-term activity, that the ultimate focus is on the customer and that quality is measured by its direct impact on customer. It also means there is a culture of learning and recognition on the creative contributions. Focusing on the process means that a manager and employees alike are working in harmony for solving problems and developing competitive strengths.

Upon reviewing the strategic management of quality, there was a need to propose a process model that represents a series of activities or components that illustrate the issues involved in this research and also highlight the relationship of the key tasks identified.

Mondy et al. (1995) highlighted the issue of the controlling process which is vital to keep things from going wrong. Michael Hammer the guru of re-engineering, which is the fundamental re-thinking and radical re-design of business processes to achieve dramatic improvements in critical, contemporary measures of performance such as cost, speed, quality and service. Hence, both authors have discussed the importance of focusing on processes that help to achieve the objectives

Barrie et al. (1992) outlined the general objectives for an information system to aid the management in the planning and control of engineering and construction projects as follows:

(1) To provide an organised and efficient means of measuring, collecting, verifying, and quantifying data reflecting the progress and status of operations on the project with respect to schedule, cost, resources, procurement, and quality.

(2) To provide a standard against which to measure or compare progress and status. Examples of standards include Critical Path Method schedule, control budgets, procurement schedules, quality control specifications and construction working drawings.

(3) To provide an organised, accurate and efficient means of converting the data from the operations into information. The information system should be realistic and should recognise:

- the means of processing the information (e.g., manual versus computer);
- the skills available; and
- the value of information compared with the cost of obtaining it.

(4) To report the correct and necessary information in a form which can best be interpreted by construction managers and at a level of detail most appropriate for the individual managers or supervisors who will be using it.

(5) To identify and isolate the most important and critical information for a given situation, and get it to the correct construction managers and supervisor (that is those in the position to make best use of it).

(6) To deliver the information to them in time for consideration and decision making so that, if necessary, corrective action may be taken on the operations that generated the data in the first place.

Pall (1987) suggested that a process should show a relationship between problems and their system, defects and defect causes. Figure 6.1 shows the relationship among symptoms, problems, defects, and defect causes. A cause is an established reason for the existence of defect and if there is are multiple causes establish the critical factors that dominate the rest. In this study, the causes were known as the factors for delays, specifically non-excusable delays.

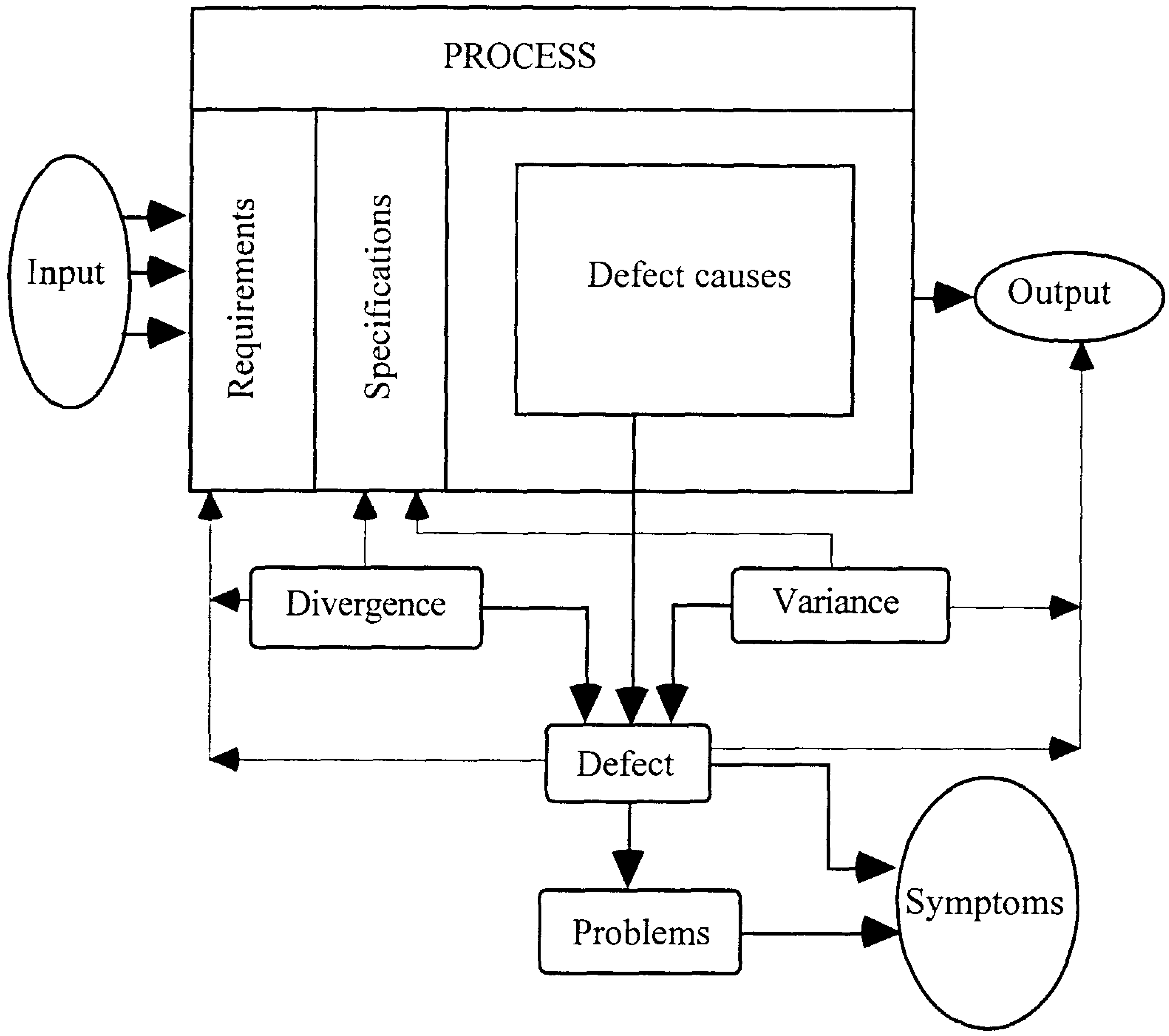


Figure 6.1: Relationship among symptoms, problems, defects, and defect causes (Adapted from Pall, 1987)

In the management of quality, the initial phase of the quality improvement is focused more on the outcome than on intent, as effective prevention can be only based on comprehensive understanding of the problem and establish defect identification and removal. Within quality control it is detection that is being actively pursued during the initial stage - specifically, defect identification and defect-cause analysis. A properly designed control system will ensure the process is efficient and effective Strategic control points will be identified to provide an effective control over the process. Therefore controlling the components in the system will become the strategic control point for the proposed model of the process which can be viewed as a process model for monitoring and controlling the factors of NED. Planning and control will enable the project to be completed on schedule , within budget and in accordance with the client's objectives. For this to occur, it is important to understand the control process and establish all the practical tools within the system.

6.3 CONTROL

The definition of control according to the Shorter Oxford English Dictionary is 'to check or verify, and hence to regulate....' it is described as '......to make situations behave according to certain desired performance criteria'.

Pall (1987) distinguished control as the component of detection and correction; the latter includes action on the work product and action on the process itself.

Detection comprises of an activity such as inspection, measurements and test and its purpose is to identify if there is any non-conformance. Detection of non-conformance such as inefficiency that lead to delays and include the causes identification. An identification of the root-causes (or factors) can be carried out with the assistance of the Fish bone analysis (also known as Cause-and-effect analysis or Ishikawa diagram).

Correction is the action taken to improve the situation by first identifying the root-causes (factors) that led to non-conformance, specifically factors of non-excusable delays. Pall (1987) suggested that correction should also include improving the process itself and corrective actions taken to improve performance can be permanently embedded in the process. For example, a penalty clause stipulated by the contractor for late delivery should minimise the occurrence of "late delivery". This corrective action can then becomes a preventive measure for "late delivery".

Pall (1987) described control as a process universally observed in nature and the functioning of most biological mechanisms; it essentially represents a feedback loop and involves a well-established and accepted sequence of steps:

- choosing the measurement system (unit measure, instruments and so on);
- establishing the actual performance through measurement;
- comparing actual performance against a previously established specification;
- interpretation of the variation between actual performance and objective;
- action to minimise or remove the variation (remedy); and
- action to remove the causes of variation.

Other authors such as Mondy et al. (1995) described controlling as the process of comparing actual performance with standards and taking necessary corrective action. A good control system is designed to keep things from going wrong, and not just to correct them after they have occurred. The controlling process suggested by Mondy et al. (1995) consists of the following three steps:

- establish standard;
- evaluate performance; and
- take corrective action.

Wearn (1989) highlighted that all systems of control on projects are similar in principle and consist of the following decisions:

- state the project objectives;
- plan and review the effect of changes;
- establish a monitoring system to check and verify progress; and
- decide on any actions required to alter the remaining work.

Harris and McCaffer (1995) discussed several methods of cost control on projects used by the management on construction projects. They stated that the elements of any control system should comprise of the followings:

- observation;
- comparison of observation with some desired standard; and
- corrective action to take if necessary.

Several authors have highlighted similar steps and the essential components for the process of control on projects. These steps could also be applied at any level be it at project level, organisational level, departmental level or the task level as elaborated by Pall (1987). The following paragraphs discuss issues related to the elements which form the component of control process.

6.3.1 Observation

Observation described by Pall (1987) is to determine a problem due to non-conformance and this includes defect identification. When the problem has been defined, the next logical step proposed by Pall (1987) is to determine the possible root-causes (or factors). At this stage the technique employed to identify the factors is the cause-and-effect diagram.

Barrie et al. (1992), listed the general objectives for an information system to aid the management in planning and control, and the first point is to provide an organised and efficient means of measuring, collecting, verifying and quantifying data reflecting the status of operation on the project with respect to schedule, cost, resources, procurement and quality. Often more than one tool is required to perform the monitoring since 'work schedule' alone cannot provide enough information to detect the factors. Usually 'work schedule' will only indicate time performance and other tools such as daily reports, resource schedules, etc. can help to identify the factors.

The types of tools used will depend on the factors to be identified. Apart from observing that there is a variance or problem on an activity the most important agenda is to detect the root-causes that lead to the variance or problem. Hence, one of the important control strategies is to establish which indicators were used to identify the factors which led to this deterioration. The next important stage is to determine the status of the ongoing work.

6.3.2 Comparison of observations with some standard

From the observation if there is any variance or deviation from the desired planning then the factors that cause the variance must be identified. According to Harris and McCaffer (1995), in a control system a manager should be able to observe the current performance indicators and compare them with a standard plan or norm and if necessary institute a corrective action to keep the performance at an acceptable level. To formulate an appropriate permanent corrective action the managers have to identify the correct root-causes, then only the performance can be brought back to the right track.

Wearn (1989) described checking and verifying the actions and the results with the predictions and intentions as a process of monitoring that observed what changes were required to overcome problems and achieve objectives. Monitoring has to be based upon measuring interim results during the progress of activities, and inferring from interim results during the progress of activities, and inferring from these measurements whether the final results will be satisfactory. Due to the short nature of the project cycle, monitoring at short regular intervals is vital in order to react instantly when a deviation occurs.

Mondy et al. (1995) expressed that evaluating performance consists of checking for deviations from the standards and determining if the deviations exceed the control limits. Evaluation process involves observing and measuring performance.

Evaluation requires accurate measurement of what is taking place and effective means of comparison with standards. The measurement and comparison becomes more complicated when the factor involved is qualitative in nature, as compared to a quantitative factor. One of the important points highlighted by Mondy was that evaluation needs an accurate measurement and the lesson drawn was that it is vital to include and report the right information in all the tools used.

Preceding authors have discussed the elements of identifying non-conformance using several tools that could translate the deviation or variance of the actual from the standard or planned. Once deviation has occurred a corrective action is required to improve the situation and the next important strategic control point, in a process, is to identify the corrective actions.

6.3.3 Corrective action to take if necessary.

The most important step for a manager to consider is what action needs to be taken to correct performance when deviation occur. The cause of the variation must be identified before corrective action can be taken. The decision as to whether corrective action is required will depend on the event that influences the final outcome. Chapter Two explains an event that necessitates the corrective action to be instituted for example when the final completion date was delayed.

Barrie et al. (1992) discussed a situation where corrective action is not necessary when there was a 'float', in an activity involved, that could be spared and the final completion date was not affected. Float of an activity is spare time that can be utilised without effecting the final completion date. Thus, managers will always look for the critical activities and if any factors are jeopardising them then corrective action should be taken to improve the problem.

Mondy et al. (1995) highlighted that corrective action may either be immediate and/or permanent. An immediate corrective action is often aimed at correcting the symptoms. An example of a symptom is delays and the following suggestions identified by Mondy et al. (1995) are some of the short term (or immediate) corrective actions which can be considered:

(a) overtime work;
(b) additional workers and equipment may be assigned;
(c) a full-time director may be assigned to push the project through;
(d) extra effort asked from the employees; or
(e) if all these fail, the schedule may have to be readjusted, requiring changes along the critical path.

The short term corrective action would usually require some additional cost of implementation and it is not as effective as the permanent corrective action. According to Mondy et al. (1995) the permanent corrective action is more economical and effective in which it correct the cause of the symptoms or problems. Therefore, one of the objectives of this research is to establish the permanent corrective actions for the critical factors identified. Almost no evident was found from the review that suggested permanent corrective actions for non-excusable factors. In addition, Yates (1993) cited several short-term corrective actions which are similar to that listed above.

The review has revealed the importance of designing a process that represent a series of related activities that resulted in the work product. Thus, the following section will discuss the proposed process for monitoring and control the factors of non-excusable delays. This proposal was designed based on the concept of process and control discussed earlier and highlights the strategic control point along the process.

6.4 PROPOSED PROCESS FOR MONITORING AND CONTROLLING THE FACTORS OF NED

The proposed process that involves the stages of the task to monitor and control the non-excusable factors is discussed. This proposed process can later be modelled in a computer which can be linked to the 'planning software', thus it can provide efficient data processing. It is not the scope of this research to computerised the process identified but it can be use as a basis for further development. The review has identified the basic components for the proposed process which include the following:

- identification of non-excusable delay factors;
- indicators to distinguish and detect the factors and perhaps indicate their occurrence which led to the problems; and
- corrective actions for the critical factors.

From the above list the basic components identified can be represented in a flow chart as shown in Figure 6.2. From this figure shows the necessary components for proposing the process to monitor the factors non-excusable delays. Figure 6.3. shows the proposed process of monitoring and control the factors of non-excusable delays.

Referring to Figure 6.3 the first essential component is the observation phase and, as highlighted from the literature review, it identifies the root-causes or specifically the factors of non-excusable delays. Factors identification is the first control point of the process and in addition to the tools available to identify these factors, the methodology discussed in Chapter Three can assist the site managers to identify them.

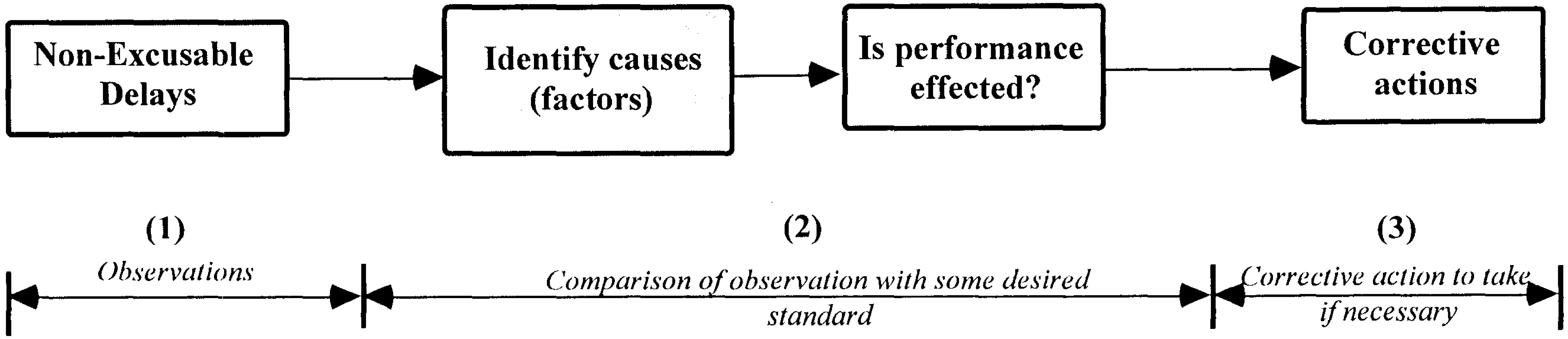


Figure 6.2: Framework for monitoring and control

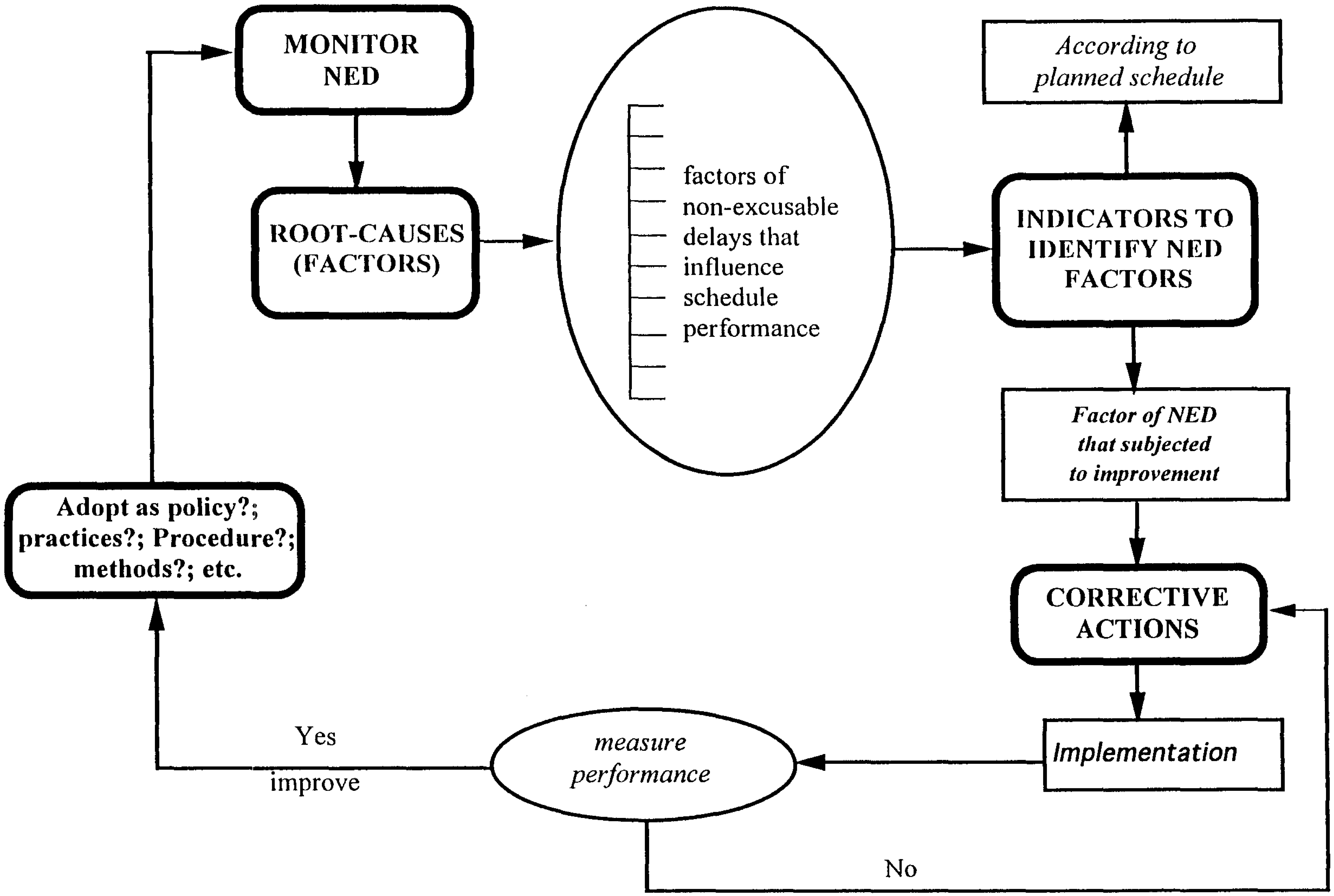


Figure 6.3: Process system for monitoring NED

The second control point in the process is to evaluate whether schedule performance was affected. The existing quantitative tools used to assess schedule performance like Critical Path Method (CPM), Programme Evaluation and Review Technique (PERT), Gantt Chart and others were proven to be adequate for the purpose. However these tools are normally used to highlight delays and they cannot always identify the factors that caused the delays. Thus, others tools (or indicators) such as daily reports, resource schedules, etc. were used to identify the factors.

It was revealed that some factors which use the intuitive judgement of site managers were difficult to evaluate so an alternative indicator was developed. This indicator was developed to assist site managers in providing a consistent and standardised assessment. Once delays have been established and correct factors have been identified the next step is to identify their corrective actions.

The third important control point is to identify the corrective actions for the factors which need improvement. In this stage the factors subjected to improvement will be analysed and several improvement options can be formulated based on the factors identified. Although suggestions for permanent corrective actions of critical factors have been identified a sub-process (refer to the structured approach of deriving permanent corrective actions) was required to determine other corrective actions beside those factors considered for this study. This sub-process is the structured approach of deriving permanent corrective actions. The approach of deriving permanent corrective actions can be the sub-process which was designed for this stage. The short-term measures were also identified from the review in a previous section.

The final step identified in the process is adopting the corrective actions that can result to the formulation of policy, procedures, methods, technique, etc. Once corrective actions have successfully improved the factors and delays then they can become preventive measures for future projects. However, it is not the objective of this study to establish or formulate the policy, procedures, etc.

In conclusion the three important stages identified formed the strategic control points of the proposed process of monitoring and control the factors of non-excusable delays shown in Figure 6.3. This figure represents a process that addresses the issues discussed in Chapters Two, Three, and Four.

6.5 SUMMARY

(1) From the review several authors cited the definition of 'process' as similar to that of a 'system'. According to the definitions from the Oxford Dictionary both words subscribed to a similar definition in which a process is defined as '*a series of actions*' and a system is '*combination of interrelated elements*'.

(2) A manageable process must have measurable inputs and outputs and be adaptable to change. To improve the efficiency of a process high speed processing technology is required which could assist the site managers to make decisions.

(3) Every process must be designed around three fundamental concepts which Pall (1987) described as follows:

(a) The basic feedback loop, also known as the 'command and control' concept in which the user: knows what to do; and knows what is being done and is able to control it. Without this feedback loop it is ineffective and may not conform to the requirements.

(b) Possess the following basic characteristic: it must be in control and produce the expected results; it must be efficient; and must be adaptable.

(c) Clear definition of process components.

(4) From the review several authors stressed the importance of emphasising on process rather than managing and controlling individual components. Thus a need to propose a process model that represents a series of activities or components can help to illustrate the issues investigated for this study.

(5) Several authors have suggested the essential basic components in a control process. Generally it comprised of the following important steps:

(a) observe or monitor;

(b) identify or evaluate (comparison with some desired standard); and

(c) take corrective action if necessary.

(6) The review has help the researcher to develop a proposed process required for monitoring and controlling non-excusable delays. The proposed process for monitoring the factors of non-excusable delays is shown in Figure 6.3, can later be modelled in a computer that augments the planning software.

CHAPTER 7

DATA COLLECTION AND GENERAL ANALYSIS

7.1 INTRODUCTION

In pursuance of the aim and objectives of this research and in accordance with the methodology defined in chapter one, a survey was carried out on critical factors of non-excusable delays that influence contractors' performance. The aim of the investigation was to establish the following issues on:

- the best contractors' performance indicator;
- the factors for each groups of causes of NED;
- the critical factors of NED;
- the common indicators to identify the critical factors;
- the critical factors that are identified by qualitative judgement;
- an alternative indicator to assess communication performance; and
- the approach of deriving permanent corrective actions and to identify appropriate corrective actions for the critical factors.

The findings from the survey provided an essential and useful basis for monitoring and controlling the critical factors that contributed to NED (see Chapters 8 and 9). The extensive scope of the research has lead to the development of a substantial number of questions. A two stage pilot test was carried out in order to control the total number of questions for the main questionnaire. To conduct a one stage pilot test was not desirable as the respondent had to reply to a long questionnaire. The first stage of the pilot test determined the number of questions required to be designed for the second stage of pilot the survey. Apart from controlling the number of questions and improving the format, clarity on the questions was also investigated. The pilot survey was used as an opportunity to clarify important information that could be included in the main survey. The approach of mailed survey was considered to be a suitable means of obtaining information for this research.

7.2 DESIGN OF QUESTIONNAIRE

7.2.1 General information

Section A of the main questionnaire begins with general information questions used to identify the source which provided a useful contact point for clarifying queries about any answers given. This section includes the identification of types of organisations. Contractors were specifically the targeted key sample population for this study and the client's group was used to validate their claim. The objective of the instrument was to ensure there was a wide coverage of information gathered within the scope of this study. In addition to the general information, questions on duration of project delays were asked according to the project types. During the pilot test, it was discovered that asking the respondent to quantify non-excusable delays was not possible, and none of the respondents from the pilot test were able to provide such information. There are various reasons for the respondents not providing them:

- did not have the knowledge of the data; and
- data was not retrievable.

Thus, in the main survey the respondents were requested to quantify the duration of delays which included the various types. However, only 23 out of 36 (64%) respondents were able to quantify the delays, although all except one reported delays on their projects.

7.2.2 Performance indicators

The questions in Section B(i) of the main questionnaire asked for the respondents opinion on contractors' performance indicators. Four performance indicators identified from the literature were tested these were: schedule; cost; quality; and safety. Before conducting the pilot study these indicators were discussed with the professionals from the Productivity Task Force Committee of the European Construction Institute (see **Appendix IV**). The questions were designed to establish the best contractors' performance indicator.

7.2.3 Factors for each group of causes

The questionnaire included questions to establish factors for the twelve groups of causes identified from the literature and confirmed by the pilot study. Apart from identifying the factors for each group of causes, it was essential to establish their ranking for each group in order to reflect the severity of influence towards contractor's schedule performance. Questions asked in section B(ii) used the Likert scale to investigate the severity of influence towards schedule performance. The method of analysing the data is explained in Section 5.5. These data helped to cross-check the information given by the respondents in section B(iii) of the main questionnaire.

7.2.4 Ranking of critical factors

The questions for Section B(iii) of the main survey were designed to investigate the relative impact of the factors towards schedule performance. During the pilot study it was confirmed that the top fifteen factors (critical factors) would be considered for further validation in the main survey. The objective of the questions was to establish the ranking of fifteen critical factors based on the order of significant impact towards

NED. The data obtained helped to establish the ranking of fifteen critical factors and they were further cross-checked by the data gathered for section B(ii) of the main questionnaire. The clients' responses were used to confirm the ranking determined by the contractors.

7.2.5 Indicators to identify the critical factors.

Questions for Section C(i) of the main questionnaire were designed to gather the data for establishing indicators to identify the fifteen critical factors established earlier. These data also help to determine the common indicators among several indicators which can identify each factor. Indicators such as resources schedule, daily report, variance analysis, procurement record etc. were tested in the main survey. They were then classified into two categories i.e. quantitative indicators and qualitative indicators. Only twelve factors identified during the pilot study could be identified by the quantitative indicators and the remaining three factors were identified by qualitative indicator i.e. intuitive judgement of the site managers. The classification, as explained in Chapter Four, was based on the available indicators used to identify the factors. For the qualitative factors the normal indicator used to identify them was the intuitive judgement of the site managers which was confirmed by more than two thirds of the respondents during the pilot survey. Although there were other factors, mentioned by half of the pilot respondents, an intuitive judgement was required to assess them. After deliberations it was decided that these factors were not significant enough to be pursued for the main survey. Questions for Section C(i) of the main questionnaire (see **Appendix III**) were to establish the most appropriate quantitative indicators for each factor which had more than one indicator.

The questions in Section C(ii) of the main questionnaire (see **Appendix III**) were designed to validate the three qualitative factors identified during the pilot survey which use the intuitive judgement of site managers. While Section C(iii) was designed to acquire the arbitrary values for developing an alternative indicator to that of intuitive judgement. It was decided from the pilot study to develop only one alternative indicator i.e. for factor of 'inefficient communication'. This factor was selected based on the literature review and confirmed by the pilot study. The other two factors were excluded in order to control the number of questions required for the main survey questionnaire. The rating amongst the contributing elements that influenced the qualitative factors were determined in order to establish whether there was a significant difference in their influence. Respectively the questionnaire designed for section C(ii) and C(iii) is to validate the factors that used an 'intuitive judgement' and to collect data to develop an alternative indicator.

7.2.6 Permanent corrective actions

The questions for section D of the main questionnaire were designed to establish the approach of deriving permanent corrective actions and at the same time establishing the most appropriate permanent corrective actions for the critical factors. The critical factors were again used to establish the approach and their permanent corrective actions. The methodology of the approach and corrective actions were both identified during the literature stage and tested in the pilot survey. Hence, the questionnaire designed for section D follows the pattern of the approach and was validated in the main survey

7.3 RESEARCH POPULATION

The majority of the samples selected for this study come from contracting organisations within the United Kingdom. Two main sources of list of companies were used to gather the information required for this study. A list of all the European Construction Institute (ECI) member companies was included for the study which comprised of approximately sixty five organisations representing clients, contractors and consultants. The majority of these organisations were involved in process engineering and power supply projects. Initially most of the data collected for the main survey came from the ECI member companies in which most of them concentrate on process engineering and power supply projects and only a few of them were involved in the civil and building projects. Thus, it was later decided to include another 75 contractors selected from the list of Top 100 UK contractors for the year 1996. The reason for selecting companies from this list was due to their experience, established business practices, specialisation on specific projects and expertise acquired from developing many major projects.

7.4 QUESTIONNAIRE ADMINISTRATION AND RESPONSE

The issues raised from the literature review and pilot study clearly identified project personnel who are principally site-based, as an appropriate target for the research enquiries. Consequently, the questionnaires were directed to the project managers or site managers of contracting organisations. This request was highlighted in the introduction page of the main survey questionnaire which explained that they were amongst the most appropriate professionals to respond. Due to the substantial amount of information to be collected the pilot survey was conducted in two stages. The first stage of the pilot survey was to determine the number of questions which needed to be developed for the second stage. The strategy of adopting two stages pilot survey helped to reduce the number of questionnaire and this process is shown in Figure 7.1. A brief explanation on the pilot survey is discussed in the next sub-section.

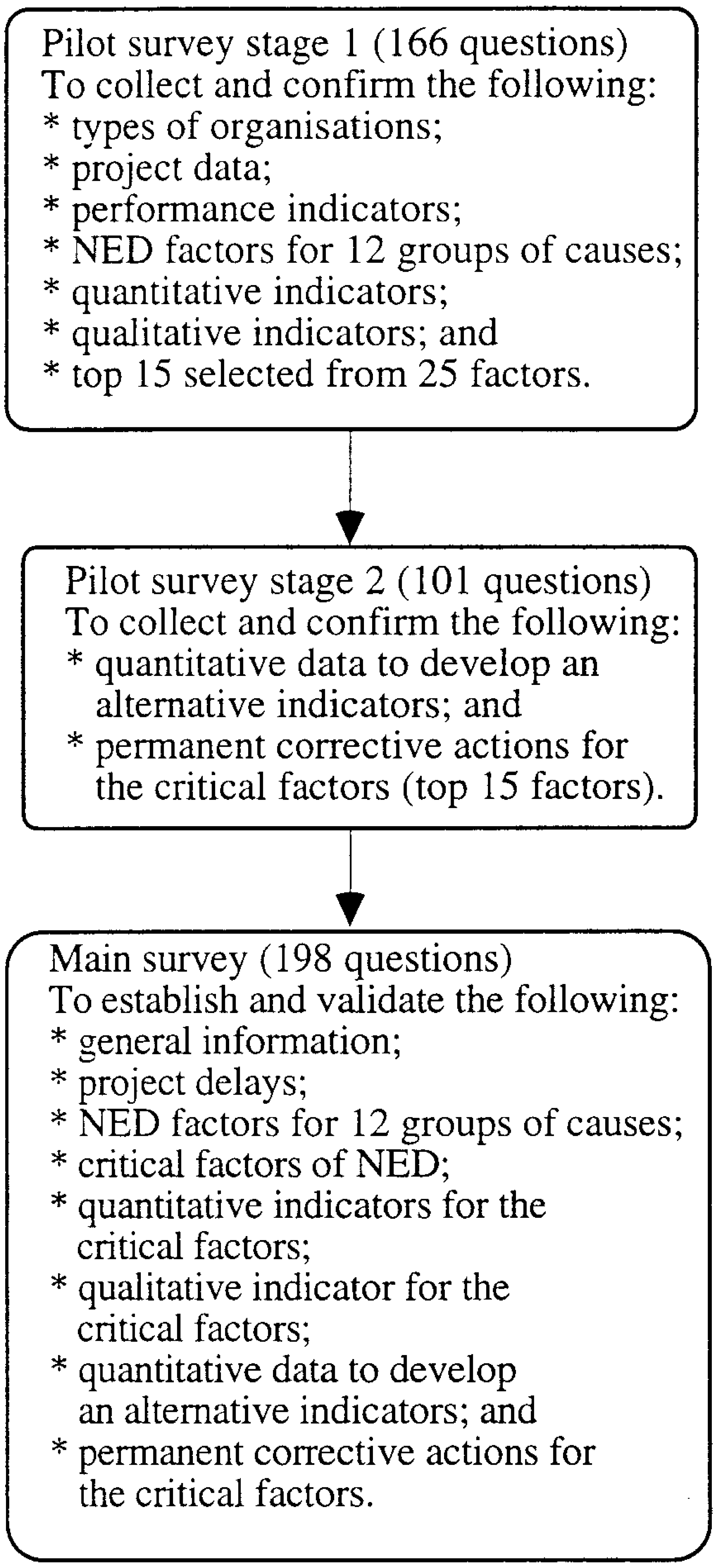


Figure 7.1: Process of data collection

Nearly 45 percent (twenty seven respondent out of sixty five) of the ECI member companies submitted their response during the main survey. The information concerning factors of NED, indicators to these factors and the related corrective actions were analysed and proved beneficial to this research. Even though there was a tremendous response from the European Construction Institute member companies the initial analysis indicated that majority of the respondents' experience was on the process engineering and power supply projects. These comprised of 12 process engineering and 7 power supply projects while only two were gathered from civil engineering projects and one from building projects. It was deemed necessary to extend the coverage of the questionnaire so that the results could represent the various types of projects. Therefore, to increase the coverage on civil and building projects, an additional seventy five respondents with these experiences were selected from the UK Top 100 contractors.

The questionnaire developed for this study was completed after an extensive input and review by the Productivity Task Force Committee of European Construction Institute (see **Appendix IV**). Apart from the Task Force Committee, one additional project manager (Stone and Webster UK Limited) were selected to extensively review the questionnaire before conducting the pilot survey.

7.4.1 Pilot survey

A pilot survey was performed with eight selected ECI member companies, including two from the Task Force members. Due to the huge amount of information to be gathered it was deemed appropriate to conduct the pilot survey in two stages. The rational for conducting a two stage pilot survey were as follows:

- to reduce the number of questions for the main survey questionnaire from approximately 267 to 198;
- to identify the top fifteen factors then proceed further in identifying the related corrective actions;
- to improve the format, and the presentation which can further reduce the number of pages ; and
- to improve the clarity of the questions developed.

The first stage of the pilot survey attempted to collect general information such as types of organisations; project data for the study; performance indicators; identify the factors to each group of causes and their ranking; and identify qualitative and quantitative indicators. At this stage the information gathered provided a useful indication in classifying the top fifteen factors out of twenty five identified from the literature review. On average each factor excluded will eliminate a further six questions for the main survey questionnaire. To achieve the objectives of the study it was decided to concentrate on the top fifteen factors which had a significant influence towards schedule performance during the construction stage. The permanent corrective actions, along with the indicators to the critical factors, were again reviewed after the identification of the top fifteen factors during the first stage of the pilot survey. At this stage the common indicators to the factors were confirmed and they were then validated in the main survey. The information was also gathered to confirm the factors that used the intuitive judgement of the site managers. Thirteen pages of questionnaire comprising of 166 questions (refer to the first stage of the pilot questionnaire in **Appendix I**)were reviewed to determine the easiest and most straight forward method to request the research data. The data collected from this stage has in fact provided a strong basis to carry out further investigation.

The second stage of the pilot survey attempted to collect the quantitative data to develop alternative indicators for qualitative factors in which were identified in the first stage of pilot study. The selection of these factors was based on the response of two thirds of the respondents from the first stage of the pilot survey. Also at this stage permanent corrective actions were identified and tested for the critical factors identified earlier. The questionnaire developed follows the method for developing an alternative indicators. From the review, the method employed to develop alternative indicator was fuzzy system. This indicator will be known as the logic indicator and the theory is briefly explained in Chapter Five. The task to identify the permanent corrective actions was difficult since very little information was obtained from the literature. Hence, gathering the experience of the manager's from the Productivity Task Force Committee of the European Construction Institute and assisted by the structured approach of deriving permanent corrective actions was confirmed at this stage.

The majority of the quantitative data needed for the second stage of pilot survey is organised on the nine pages of the questionnaire comprising of 101 questions (refer to second stage pilot questionnaire in **Appendix II**). As explained earlier the number of questions is critical while designing the right format which helped to reduce the number of pages in addition to considering only fifteen factors. It is important to determine the easiest and most straightforward method for the respondent to respond.

The questionnaire was also designed to be completed by site managers or project managers who posses the knowledge of construction delays. The data needed to complete the questionnaire required someone with a good understanding of managing delays - especially non-excusable delays.

7.4.2 Main survey

The main questionnaire was completed and mailed, a follow up by the Productivity Force Committee of the European Construction Institute (see **Appendix IV**)to those who had not responded provided additional response. A copy of the questionnaire's final version is printed in **Appendix III**

The Committee from the Productivity Task Force (see **Appendix IV**) was helpful in ensuring the total number of responses (from the ECI member companies) and directing the respondent in completing the questionnaire. The follow-ups also provided qualitative information on the ease or difficulty of completing the questionnaire. Completed questionnaires were sent back to the European Construction Institute (ECI) who are located at Loughborough University, United Kingdom.

The closing date for data collection was 29th November 1996. After the discussion with the Chairman of the Productivity Task Force, it was decided to extend the deadline until the end of January 1997. This gave member companies more time to participate in the study and increase the number of respondents. Initial analysis from the data collected showed that most delays were reported on process engineering and power supply projects. Thus there was a need to cover other project types such as civil and building projects so the findings from this research could represent a wider coverage. To achieve this a decision was made to include a sample population from the UK Top 100 contractors in which 75 companies were selected. The closing date for this sample survey was 21st March 1997. Only eight responses were received from the selected UK Top 100 contractors. The main reason for the low response was due to the amount of questions to be answered which was beyond the norm.

7.5 PROJECT GENERAL INFORMATION

From the main survey the largest percentage of questionnaires were returned by contractor organisations (80%) then client organisations (17%), and the remainder were submitted by consultants (3%). Two contractor organisations claimed that their role included consultant services. Figure 7.1 shows the percentage breakdown of the respondents according to the type of organisations.

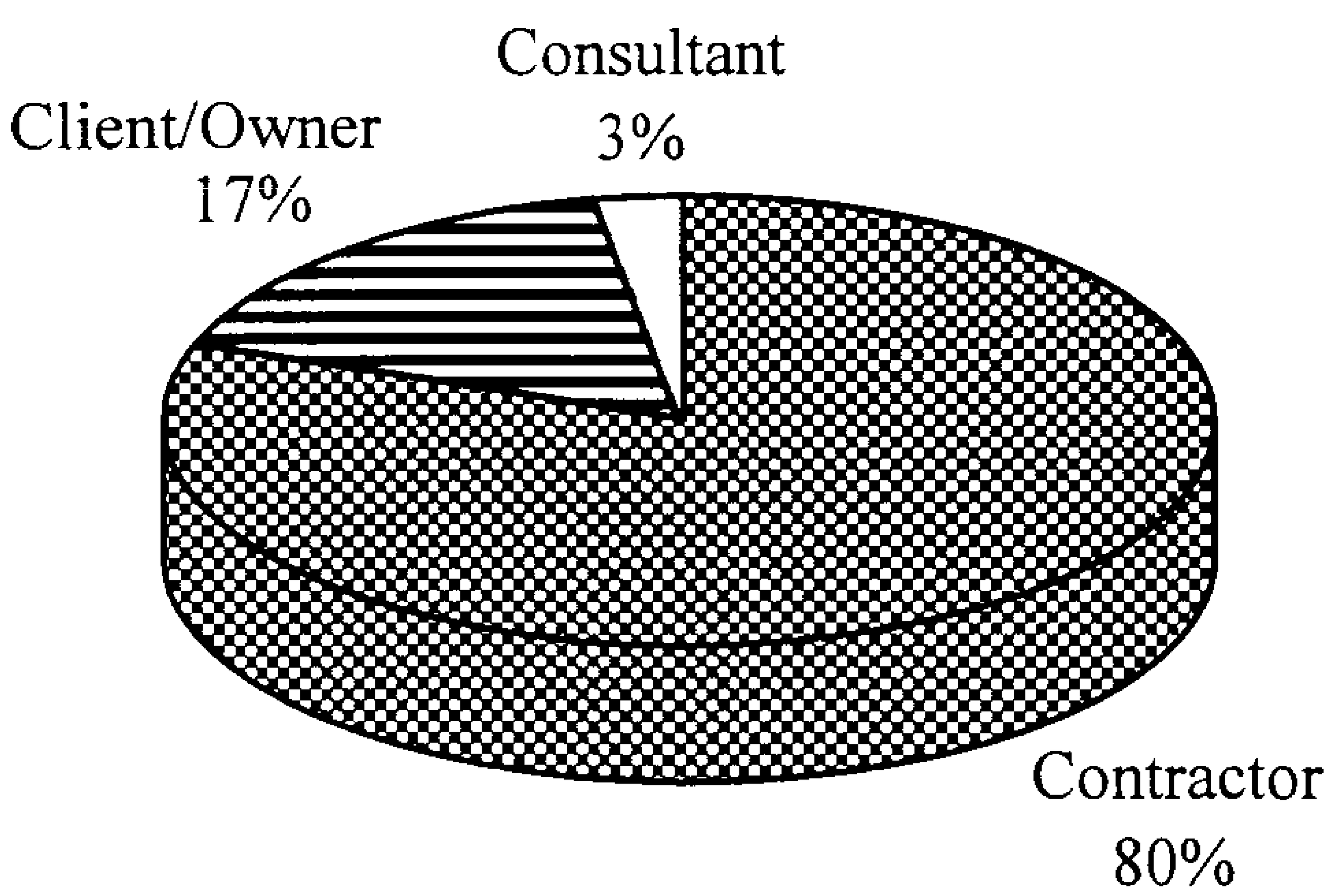


Figure 7.2: Types of organisations represented

The above figure represents 29 responses from contractors, 6 from the clients and 1 from a consultant organisation. The rational to include the clients and the consultant organisations is to confirm the contractor's information. Since only one response was received from a consultant organisation the information was ignored in the final analysis. For the purpose of confirming the contractors' information the client's data was adequate and furthermore, the follow-up to get more respondents from consultant organisations did not materialise.

The hardest information to be gathered from respondents was to quantify the duration of non-excusable delays. Most information that was retrievable was on general delays which include excusable delays with and without compensation. Obtaining the data on general delays was adequate since the review had indicated that many of the factors which caused delays were non-excusable. Abd. Majid and McCaffer (1997b) observed that 50 percent of the factors which causes many of the previous project delays were classified under non-excusable delays.

Most respondents indicated schedule delays on their projects ranging from a minimum of 6 to a maximum of 50 weeks, which is approximately more than 11 months delays (assuming 4.5 weeks = 1 month). The data for project delays are tabulated according to the project types and are shown in Table 7.1.

Table 7.1: Project delays

Project types	Total no projects delayed	Total no. of projects quantifying delays	Total schedule delays (weeks)	Average delays per project (weeks)
Power Supply	8	4	56	14
Process Engineering	15	11	181	16.5
Building Constructions	6	5	84	16.8
Civil Engineering	5	3	137	44
Others	1	-	-	-

Based on the above information gathered for this study, a total number of eight power supply projects were delayed. Four respondents had quantified the amount of delays for each project. Process engineering reported fifteen project delays and eleven respondents had quantified the delays. Building and civil had six and five reported delays and these were quantified as five and three respectively. The average delays for civil engineering projects was forty-four weeks which was the highest amongst the four types of projects while process engineering was the lowest with an average of fourteen weeks. The risk of delays for civil engineering projects is much higher compared to the other types of projects. The high risk of delays may be due to the nature of work which were exposed to longer unpredictable weather and an unfavourable physical environment which was often beyond the control of the parties involved. Table 7.2 indicates a good basis for comparing the delays amongst the project types. This information highlights the amount of risk that can be considered in forecasting the total duration for the construction stage according to the project types.

Table 7.2: Average project delays

Project types	Average delays per project (%)
Power Supply	25.0
Process Engineering	9.1
Building Constructions	20.0
Civil Engineering	32.1
Others	-

The average percentage delays according to project types is shown in **Table 7.2** and indicates that the civil engineering projects were the highest reported average project delays with 32.1 percent overruns per project and power supply at around 25 percent overruns per project. Usually these projects are more susceptible to unfavourable weather conditions and unpredictable ground conditions. Amongst the lowest average percentage delays was process engineering plants which had 9.1 percent overruns per project and was much lower than that of building construction which had 20.0 percent overruns per project. The reason may be due to their repetitive components which allows off-site fabrication before installation under a better control environment. These indications should instigate further study on the approaches and strategies undertaken by process engineering projects in comparison with other project types.

7.6 SUMMARY

(1) The instrument used to collect the data required for this research was a postal survey questionnaire. The questionnaire was designed into various distinct sections to serve the purpose of achieving the objectives of this study.

(2) Two lists of companies were used to gather the information required for this study. One from the list of the European Construction Institute (ECI) member companies and the others from the Top 100 UK contractors for the year 1996.

(3) At the initial stage it was discovered that a substantial amount of information had to be collected to achieve the objectives of this research. For this reason, a two stage pilot survey was conducted avoiding the design of a long questionnaire for the respondents to answer.

(4) From the main survey the largest percentage of questionnaires were returned by contractors' organisations (80 percent - representing 29 respondents), the clients' organisations (17 percent - representing 6 respondents) and the remainder were submitted by the consultant (3 percent representing only one respondent). Since only one response was received from the consultant organisation the information

was ignored in the final analysis as the clients responses were adequate to validate the contractor's information.

(5) The average project delays were established according to the project types. Process engineering projects were the lowest with 9.1 percent overruns per project and building construction recorded an average delay of 20 percent overruns per project. Meanwhile, the highest recorded delays were civil engineering projects with 32.1 percent overruns per project, followed by the power supply projects which recorded an average of 25 percent overruns in schedule. It can be concluded that the highest risk of schedule overruns was civil engineering projects followed by power supply projects.

CHAPTER 8

DATA ANALYSIS AND DISCUSSIONS

8.1 INTRODUCTION

The data analysis for this chapter is organised according to the sequence of the sections identified in the main questionnaire. There are four main sections which includes:

(1) the analysis on general information (see section A of main questionnaire in **Appendix III**) which refers to Chapter 7;

(2) the analysis to establish the following issues:

   (a) the best indicator to measure contractors performance;

   (b) the factors for each group of causes; and

   (c) the critical factors of non-excusable delays.

(3) the analysis to establish the most effective indicators for critical factors and to develop an alternative indicator to assess 'communication performance' using the Theory Fuzzy Logic; and

(4) the analysis to establish and validate the critical factors' corrective actions, and the structured approach of deriving permanent corrective actions.

The data obtained from the main survey were analysed and where appropriate, a statistical test was conducted to confirm and support the contractors responses using the clients data. Nevertheless, for all the sections the contractors responses were adequate to validate and establish the issues under investigation.

8.2 GENERAL ANALYSIS

A total of 35 respondents comprising 29 contractors and 6 clients returned a completed questionnaire. A 26 percent response rate was achieved even though the length of the questionnaire was beyond the norm. These included eight respondents from the Top 100 contractors for the year 1996 which increase the sample size and their data were included in this analysis. However, only a few of the questionnaires, specifically the questions on the ranges of quantitative values of section C(iii) (refer to the main questionnaire in **Appendix** III) contained partial or incomplete data which reduced the sample size to be analysed. Fourteen out of twenty nine contractors has successfully completed and provided the ranges of quantitative values for developing the an alternative indicator to asses 'communication performance'. The follow up to clarify the situation and request did not help much to improve it.

8.3 CONTRACTORS' PERFORMANCE INDICATORS

The objective of conducting the analysis for this section is to establish the best indicator to measure contractors performance during the project execution. To achieve this objective a ranking method was used and this ranking is determined by computing the mean values of the respondents response (for further explanation please refer to **Section 5.6**). The significant of using ranking method is it shows the top choice which then can be used to establish the best indicator among several choices. Where appropriate a statistical test was conducted to reaffirm and support the contractors' ranking by using the clients data. If a null hypothesis is rejected it indicates that there is a significant agreement in the ranking which was determined at 95% confidence level. This shows that there is an agreement in the ranking between both groups of respondents and the clients response reaffirm the contractors opinion. But if there is no significant agreement the contractors ranking can still validate and establish the findings of this research.

Information gathered for section B(i) was used to determine the best indicator to measure contractors' performance during the project execution. It aimed to establish the best indicator which was used to measure contractors' performance among several identified during the pilot study. Four common types of indicators were tested in the main survey using the selected sample groups. Details for completing this section were briefly explained in section two of the main questionnaire. The survey invited the respondents to rank four performance indicators, and the results are summarised in Table 8.1.

Table 8.1: Contractors' performance indicators - survey results

Contractors' performance is best measured by	contractors' mean	Clients' mean	Ranking by contractors	Ranking by clients	Spearman's coeff., rho	NOTES
Schedule performance	4.89	4.67	1	2		Significance
Cost performance	4.32	4.83	3	1	0.2110	0.7890
Quality performance	4.50	4.50	2	3		thus
Safety performance	4.18	4.50	4	3		accept, Ho

Table 8.1 shows the ranking of the performance indicators determined using the mean values which were computed from the respondents data. The highest ranked indicator was the best indicator to measure the contractors' performance confirmed by the respondents data. The mean values offer more insight into the classification of the ranking (refer to the ranges of ordinal scale in the next section) and indicates the relative ranking among these indicators. The above table also highlights the comparison between contractors and clients responses. The contractors' group ranked 'schedule performance' as the best indicator to measure their performance followed by quality, cost and safety. Meanwhile, the clients' group ranked cost as the best indicator to measure contractors' performance. The different in the top

ranked indicators between both groups may be due to the differences in the priority of the project objectives. The correlation test conducted on both groups of respondents gives the Spearman's coefficient, rho, (R_S) of 0.2110 and a significance value of 0.789 > 0.05 (see Table 8.1) which implies insignificant agreement in the ranking. The null hypothesis H_0 that there is no significant agreement in the ranking between contractors and clients groups is thus accepted. From the analysis it can be concluded that there is a differences in ranking between the contractors and clients responses however the objective to determine the best indicator to measure the contractors performance has been achieved. The contractors responses has established and validated the objective of establishing the best indicator to measure the contractors performance.

8.4 FACTORS AND GROUPS OF CAUSES OF NON-EXCUSABLE DELAY (NED)

The objective of conducting the analysis for this section is to establish the factors under the groups of causes identified from the literature review and the ranking according to their significant influence towards contractors' performance. A ranking method was used to achieve this objective and the significant of using this method is it can reveal the most influential factors within each group of causes. Where applicable a statistical test was conducted to reaffirm these rankings using the clients' data. If the null hypothesis is accepted it shows that there is disagreement in the ranking between both groups of respondents and if there is a significant agreement in the ranking the alternative hypothesis is accepted at 95% confidence level.

The information identified from the literature, Abd. Majid and McCaffer (1997b) that focuses on the factors and groups of causes of delays provided the essential framework in which to conduct a study on issues related to NED. Section B(ii) of the main questionnaire aimed to establish and classify the factors under each groups of causes. These groups of causes were identified and confirmed during the pilot study. The main questionnaire was designed in such a way that the respondents could rate the severity of the factors influence on contractors' schedule performance. The mean values obtained as shown in Tables 8.2 until 8.13 can be interpreted according to seven categories (refer to the ranges of ordinal scale below) which reflected the overall respondents opinion. These categories range from 'very low influence' to 'very high influence' towards each group of causes.

Table 8.2 to 8.13 summarise the mean values for each group of causes as well as verifying whether there is a significant agreement in the ranking between the groups of respondents using the Spearman's rank coefficient, rho (R_S) and compares them with the critical values of rho. In addition to analysing the agreement in ranking between both groups, analysis was also carried out on each factor to identify the most influential factor within each group that influenced contractors' schedule performance. The mean ranking score could also reflect the ordinal rank such as 'high influence', 'slightly high influence', 'average influence', etc. The ranges of ordinal scale indicating the strength of influence towards contractors' schedule performance is shown below:

* Very high influence	$5.5 \leq$ Mean score $\leq$ 6.00
* High influence	$4.5 \leq$ Mean score < 5.5
* Slightly High influence	$3.5 \leq$ Mean score < 4.5
* Average influence	$2.5 \leq$ Mean score < 3.5
* Slightly Low influence	$1.5 \leq$ Mean score < 2.5
* Low influence	$0.5 \leq$ Mean score < 1.5
* Very Low influence	$0.0 \leq$ Mean score < 0.5

Hence, using the above scale, the respondents mean values can be interpreted to reflect these ordinal scale categories. The method of classifying the range of scales was discussed by Abd. Majid and McCaffer (1997a) and also in Chapter Five.

8.4.1 Factors of materials related delays

The null hypothesis H_0, tested for this group of causes, is that there is no significant agreement in the ranking between the contractors and clients groups. The alternative hypothesis H_1: is that there is a significant agreement in the ranking between both groups. The null hypothesis will be accepted if the significance level observed is more than 5%. This indicates that a probability of 95% is required to conclude that there is a significant agreement in the ranking between both groups of respondents. Referring to Table 8.2, the Spearman's coefficient, rho (R_s) value is 0.8410 and a significance level of 0.036 was observed which is less than 0.05 hence H_0 is rejected. From the test one can deduce that there is a significant agreement in the ranking at a confidence level of 95%. This concludes that there is a significant agreement in ranking between both groups of respondents on the factors for this group of causes. The rating on the mean values is unlikely to occur by chance with 'unreliable suppliers' ranked highest by the contractors having a mean value of 4.41(see Table 8.2).

Table 8.2: Factors of material related NED - survey results

Factors of material related delays	contractors' mean	clients' mean	Ranking by contractors	Ranking by clients	Spearman's coeff., rho	NOTES
Unreliable supplier	4.41	3.33	1	2		Significance
Damaged materials	2.07	2.40	5	6		0.036
Poor quality materials	2.62	3.00	4	4	0.8410	thus
Poor material planning	3.86	5.50	2	1		reject, Ho
Inefficient communication with supplier	3.34	3.33	3	2		
Limited range of supplier	1.72	2.80	6	5		

Using the ranges of ordinal scale, a mean score of 4.41 is classified as a 'slightly high influence' factor towards materials related NED. 'Poor material planning' is also classified under the 'slightly high influence' contributor by the contractors group. The clients group ranked this factor as a 'very high influence' towards materials related NED. The results of this analysis have established the factors for this group of causes and their ranking according to their influence towards contractors schedule performance. The statistical test shows that clients ranking has significantly reaffirmed the contractors' ranking and the objective of establishing the factors for this group of causes has been achieved.

8.4.2 Factors of labour related delays

As shown in Table 8.3, the null hypothesis H_0 is accepted and this shows that there is no significant agreement in the ranking amongst the groups of respondents. The Spearman's correlation coefficient rho, (R_s) is 0.4140 and has a significance value of 0.355. This value is much higher than 0.05 which rejected the alternative hypothesis, H_1 at a confidence level of 95%. It was revealed that 'poor labour planning' was ranked highest by both contractor and client groups with a mean score of 3.86 and 4.67 respectively. The contractors' group classified this factor as a 'slightly high influence' whilst the client classified this as a 'high influence' factor towards labour related NED.

Table 8.3: Factors of labour related NED - survey results

Factors of labour related delays	contractors' mean	clients' mean	Ranking by contractors	Ranking by clients	Spearman's coeff., rho	NOTES
Slow mobilisation of labour	3.04	4.00	5	2		Significance
Poor quality workmanship	3.32	3.83	4	3		0.355
Poor labour planning	3.86	4.67	1	1	0.4140	thus
Strike results from contractors' fault	0.85	2.83	7	4		accept, Ho
Absenteeism	1.68	1.50	6	7		
Low morale and motivation	3.36	2.67	3	6		
Inefficient communication	3.57	2.83	2	4		

The results of the above analysis have established the factors for this group of causes and their ranking according to their influence towards contractors schedule performance. Although the statistical test shows that there is a disagreement in the ranking between both respondents' groups but the objective of establishing the factors for this group of causes has been achieved using the contractors ranking.

8.4.3 Factors of equipment related delays.

Table 8.4 shows the calculated value for the Spearman's correlation coefficient, where rho (R_S) is 0.8720. This indicates that there is almost an agreement in the ranking between the respondents groups. The significance value computed is 0.054 which is very close to the significance level of 0.05. If the significance value of 0.05 is to be strictly observed than the null hypothesis H_0: that there is no significant agreement in the ranking is accepted. Nevertheless 94.6% confidence level was achieved even though the alternative hypothesis H_1: that there is a significant agreement in the ranking between both groups is rejected.

Table 8.4: Factors of equipment related NED - survey results

Factors of equipment related delays	contractors' mean	clients' mean	Ranking by contractors	Ranking by clients	Spearman's coeff., rho	NOTES
Unreliable supplier	3.52	3.00	2	3		Significance
Poor equipment planning	3.55	4.83	1	1		0.054
Equipment breakdown	2.55	2.17	4	4	0.8720	thus
Improper equipment	2.34	2.17	5	4		accept, Ho
Inefficient communication.	3.17	3.20	3	2		

Among the factors identified, 'poor equipment planning' was ranked highest by both respondent groups. It was observed that the contractors' group had classified all the factors for this group between 'average' and 'slightly high' influencing towards equipment related NED.

The results of the analysis have established the factors for this group of causes and their ranking according to the influence towards contractors schedule performance. Although the statistical test shows that there is a disagreement in the ranking between both respondents groups but the objective of establishing the factors for this group of causes has been achieved using the contractors ranking.

8.4.4 Factors of improper planning

As shown in Table 8.5, both groups almost agreed on the rankings of the factors. The Spearman's correlation coefficient, rho (R_S) is 0.9000 and a significance value of 0.037 < 0.05, which indicates a significant agreement in the ranking hence the null hypothesis H_0, is rejected. The alternative hypothesis H_1: that there is a significant agreement in the ranking between both groups with 95% confidence level was achieved. 'Lack of experience' was ranked highest by both groups of respondents. This factor is classified under 'slightly high influence' towards this group of causes.

Table 8.5: Factors of improper planning - survey results

Factors of improper planning	contractors' mean	clients' mean	Ranking by contractors	Ranking by clients	Spearman's coeff., rho	NOTES
Lack of experience	3.66	4.00	1	1		Significance
Lack of planning tool	2.32	2.80	5	5		0.037
Inappropriate practices	2.79	3.17	4	3	0.9000	thus
Wrong attitude i.e. find an easy way out	2.96	3.00	3	4		reject, Ho
Poor judgement	3.52	3.50	2	2		

The results of the above analysis have established the factors for this group of causes and their ranking according to their influence towards contractors' schedule performance. The statistical test shows that clients' ranking has significantly reaffirmed the contractors' ranking and the objective of establishing the factors for this group of causes has been achieved.

8.4.5 Factors of financial related delays

From Table 8.6, the statistical test indicates that the null hypothesis H_0 is accepted and this proves that there is no significant agreement in ranking between the groups of respondents. However, 'poor financial monitoring and control' was ranked highest by both groups followed by 'poor financial planning'. Both these factors were categorised as 'slightly high influence' toward financial related NED.

Table 8.6: Factors of financial related NED - survey results

Factors of financial related delays	contractors' mean	clients' mean	Ranking by contractors	Ranking by clients	Spearman's coeff., rho	**NOTES**
Poor financial monitoring and control	3.21	4.20	1	1		Significance
Poor financial planning	2.97	3.20	2	2	0.8000	0.200
Inadequate fund allocation	2.52	2.60	4	3		thus
Delay payment to the supplier/ sub contractor	2.76	2.20	3	4		accept, Ho

The results of the above analysis have established the factors for this group of causes and their ranking according to the influence towards contractors schedule performance. Although the statistical test indicates that there is a disagreement in the ranking between both respondents' groups but the objective of establishing the factors for this group of causes has been achieved using the contractors ranking.

8.4.6 Factors of lack of control

The statistical test conducted on this group of causes confirmed that there is no significant agreement in ranking between the two groups of respondents and thus the null hypothesis H_0 is accepted. The contractors' group claimed that 'shortages of site personnel' was ranked highest with a mean value of 3.45. The clients' group responded that the 'lack of experience' was the major factor that influenced 'lack of control' (see **Table 8.7**).

Table 8.7: Factors of lack of control - survey results

Factors of lack of control	contractors' mean	clients' mean	Ranking by contractors	Ranking by clients	Spearman's coeff., rho	NOTES
Lack of experience	3.31	4.17	4	1		Significance
Inappropriate practices and procedures	3.41	3.83	2	2		0.239
Attitude - Could not care less attitude	2.75	1.83	6	6	0.4857	thus
Shortages of site personnel	3.45	2.50	1	4		accept, Ho
Low morale/motivation	2.97	2.00	5	5		
Poor contract	3.38	3.00	3	3		

The results of the above analysis have established the factors for this group of causes and their ranking according to the influence towards contractors schedule performance. Although the statistical test indicates that there is a disagreement in the ranking between both respondents' groups but the objective of establishing the factors for this group of causes has been achieved using the contractors' ranking.

8.4.7 Factors of sub-contractors related delays

The statistical test conducted on this group of causes has rejected the null hypothesis, H_0 (see Table 8.8). Thus an alternative hypothesis H_1: that there is a significant agreement in the ranking between both groups of respondents, is accepted. The Spearman's correlation coefficient rho, (R_s) is 0.8929 with a significance value of 0.7% and is much lower than the 5% limit. This indicates that there is a significant agreement in the ranking between both groups of respondents at a confidence level of 99%. Once again 'poor monitoring and control' was ranked highest by both groups of respondents. The mean values of this factor are 3.93 and 4.50 (see Table 8.8) for both the contractors and clients groups respectively, and was classified under 'slightly high influence' factor towards this group of causes.

Table 8.8: Factors of sub-contractors related NED - survey results

Factors of sub contractor related delays	contractors' mean	clients' mean	Ranking by contractors	Ranking by clients	Spearman's coeff., rho	NOTES
Slow mobilisation	3.48	3.33	4	3		Significance
Unreliable sub contractor	3.79	2.83	2	4		0.007
Poor quality workmanship	3.55	3.83	3	2	0.8929	thus
Absenteeism	2.21	1.50	6	6		reject, Ho
Poor monitoring and control	3.93	4.50	1	1		
Bankruptcy	2.07	1.40	7	7		
Interference with other trade	3.07	2.50	5	5		

The results of the above analysis have established the factors for this group of causes and their ranking according to their influence towards contractors schedule performance. The statistical test shows that clients' ranking has significantly reaffirmed the contractors' ranking and the objective of establishing the factors for this group of causes has been achieved.

8.4.8 Factors of poor co-ordination

Table 8.9 shows that the statistical test on the null hypothesis, H_0 is accepted for this group of causes. Hence, there is no significant agreement in the ranking between both groups of respondents. It is interesting to note that the order of ranking for the factors by both groups was completely opposite which is indicated by - 0.0510. The contractors' group ranked 'poor communication skills' highest whilst clients' group viewed 'inappropriate practices and procedure' as the highest influential factor towards this group of causes.

Table 8.9: Factors of poor co-ordination - survey results

Factors of poor co-ordination	contractors' mean	clients' mean	Ranking by contractors	Ranking by clients	Spearman's coeff., rho	NOTES
Lack of experience	3.21	3.00	5	3		Significance
Inappropriate practices and procedures	3.38	3.67	3	1	- 0.0510	0.935
Shortages of personnel	3.45	3.50	2	2		thus
Poor communication skills	3.86	2.83	1	4		accept, Ho
Poor contractual requirements	3.34	2.83	4	4		

The results of the above analysis have established the factors for this group of causes and their ranking according to the influence towards contractors' schedule performance. Although the statistical test indicates that there is a disagreement in the ranking between both respondents' groups but the objective of establishing the factors for this group of causes has been achieved using the contractors' ranking.

8.4.9 Factors of inadequate supervision

From Table 8.10, both the contractors and clients' groups agreed on the ranking of the factors for this group of causes. The Spearman's correlation coefficient, rho (R_S) is 0.8929 with a significance value of 0.7% which is less than 5%. The coefficient value of 0.8929 indicates that there is a significant agreement in the ranking between both groups of respondents at a confidence level of 95%. Thus, the alternative hypothesis H_1: that there is a significant agreement in the ranking between both groups of respondents was accepted and the null hypothesis H_0 was rejected. Clients' group ranked 'too many responsibilities' highest and contractors' group ranked 'poor planning' highest for this group of causes.

Table 8.10: Factors of inadequate supervision - survey results

Factors of inadequate supervision	contractors' mean	clients' mean	Ranking by contractors	Ranking by clients	Spearman's coeff., rho	NOTES
Lack of experience	3.89	3.33	2	3		Significance
Absenteeism	1.78	1.50	7	7		0.007
Shortages of personnel	3.54	3.00	4	4	0.8929	thus
Too many responsibilities	3.68	4.17	3	1		reject, Ho
Improper practices or procedures	2.93	2.67	5	5		
Attitude - could not care less	2.71	1.67	6	6		
Poor planning	4.04	3.50	1	2		

The results of the above analysis have established the factors for this group of causes and their ranking according to their influence towards contractors schedule performance. The statistical test shows that clients ranking has significantly reaffirmed the contractors' ranking and the objective of establishing the factors for this group of causes has been achieved.

8.4.10 Factors of improper construction method

For this group of causes, the statistical test shows that there is a significant agreement in the ranking between both groups of respondents with a confidence level of 95% being achieved. From the analysis the coefficient, rho (R_S) is 0.900 with a significance value of 3.7% less than 5% (see Table 8.11). The contractors' group ranked 'lack of experience' highest and the clients' group ranked 'unavailability of proper resources' as the major factor that influence "improper construction method".

Table 8.11: Factors of improper construction methods -survey results

Factors of improper construction methods	contractors' mean	clients' mean	Ranking by contractors	Ranking by clients	Spearman's coeff., rho	NOTES
Lack of experience	3.86	2.67	1	2		Significance
Inappropriate practices	3.10	2.33	4	4	0.9000	0.037
Inadequate fund allocation	2.93	2.00	5	5		thus
Unavailability of proper resources	3.41	3.83	2	1		reject, Ho
Wrong method statement	3.21	2.50	3	3		

The results of the above analysis have established the factors for this group of causes and their ranking according to their influence towards contractors' schedule performance. The statistical test shows that clients ranking has significantly reaffirmed the contractors' ranking and the objective of establishing the factors for this group of causes has been achieved.

8.4.11 Factors of technical personnel shortages

The statistical test revealed that there is no significant agreement in the ranking for both groups of respondents (see Table 8.12) hence the null hypothesis H_0 is accepted. The contractors' group ranked 'Lack of experience' highest among the contributing factors. Meanwhile, clients' group ranked 'poor site personnel planning' highest for this group of causes.

Table 8.12: Factors of technical personnel shortages - survey results

Factors of technical personnel shortages	contractors mean	clients mean	Ranking by contractors	Ranking by clients	Spearman's coeff., rho	NOTES
Slow mobilisation	3.10	3.83	3	2		Significance
Poor site personnel planning	3.14	4.00	2	1	0.4000	0.600
Absenteeism	1.39	1.33	4	4		thus
Lack of experience	3.28	2.67	1	3		accept, Ho

The results of the above analysis have established the factors for this group of causes and their ranking according to the influence towards contractors' schedule performance. Although the statistical test indicates that there is a disagreement in the ranking between both respondents' groups but the objective of establishing the factors for this group of causes has been achieved using the contractors' ranking.

8.4.12 Factors of poor communication

From Table 8.13 the statistical test conducted on the null hypothesis H_0: that there is no significant agreement in the ranking between both groups of respondents, is accepted. Both the contractors and clients' groups ranked 'inappropriate practice or procedure' highest among the factors within the group of causes. The contractors' group mean value for this factor can be classified under 'slightly high influence'.

The results of this analysis have established the factors for this group of causes and their ranking according to the influence towards contractors' schedule performance. Although the statistical test indicates that there is a disagreement in the ranking between both respondents' groups but the objective of establishing the factors for this group of causes has been achieved using the contractors' ranking.

Table 8.13: Factors of poor communication - survey results

Factors of poor communication	contractors' mean	clients' mean	Ranking by contractors	Ranking by clients	Spearman's coeff., rho	NOTES
Lack of experience	3.48	2.83	2	3		Significance
Lack of communication facilities	3.28	2.50	3	4	0.4000	0.600
Inappropriate practices or procedures	3.69	3.33	1	1		thus
Shortages of personnel	3.25	3.00	4	2		accept, Ho

The Spearman's correlation test conducted on the twelve groups of causes (shown in Tables 8.2 to 8.13) highlight that five groups of causes were proved to have a significant agreement in ranking between both groups of respondents. Seven groups of causes have shown no significant agreement in ranking. Nevertheless, the objective of establishing the factors under each group of causes has been established using the contractors' ranking and for some groups of causes clients' data helped to reaffirm the contractors' response. The contractors' opinion were considered as they had a direct experience of handling the issues and the clients data was only used to reaffirm the contractors' responses.

8.5 THE CRITICAL FACTORS OF NON-EXCUSABLE DELAYS

The objective of conducting the analysis for this section is to establish the ranking of critical factors (top fifteen factors identified from the pilot study) according to their order of impact on non-excusable delays. A ranking method was used to achieve this objective and the significant of using this method is it can highlight the order of fifteen most influential factors that caused non-excusable delays. A statistical test was conducted to reaffirm the ranking of the contractors using the clients responses. If the null hypothesis is accepted it shows that there is disagreement in the ranking between both groups of respondents and if there is a significant agreement in the ranking the alternative hypothesis is accepted at 95% confidence level. This test was conducted to reaffirm the contractors' opinion using the clients' responses.

The data collected for section B(iii) of the main questionnaire (refer to **Appendix** III) has helped to establish the ranking of the critical factors of NED which was determined by the contractors responses. The ranking of critical factors was computed for both the respondents groups using the ranking determined by them and these ranking were then allocated with scores according to their rank. Ranking number one takes a score of sixteen, rank number two take a score fifteen and rank number fifteen takes a score of one. The scores for each factors were aggregated according to the respondents groups which then give a total ranking score. The total ranking score for each factor is then aggregated to all the fifteen factors which give the overall total ranking scores. To determine their final ranking the total ranking score for each factor is divided by overall ranking scores then multiply by 100 to give a relative index (RI) in percentage and the higher the percentage the higher the rank. The highest RI was ranked top in an ascending order and the result was summarised in Table 8.14. In addition to establishing the factors' ranking the clients' responses were used to prove the contractors' ranking. Amongst the top ranked factors established by the contractors respondents are as follows:

(a) slow mobilisation of resources;

(b) unreliable supplier/sub-contractors;

(c) poor resources planning; and

(d) unavailability of proper resources.

The Spearman's correlation test was used to verify whether there is an agreement in ranking between both groups of respondents. The null hypothesis H_0, that there is no significant agreement in the ranking between the respondents groups, is tested. It was observed that the Spearman's correlation coefficient, rho (R_s) is 0.7359 and a significance value of 0.59% which is much less than 5% hence the null hypothesis is rejected. The alternative hypothesis H_1, that there is a significant agreement in the ranking between both groups, is accepted at a confidence level of 95%. From the test it can be observed that there is a significant agreement in the ranking for both groups and thus it reaffirmed the contractors ranking. Column 4 of Table 8.14 shows the calculated contractors' mean values using the data collected for Section B(ii) of the main questionnaire and these were used to cross check the contractors' own response for Section B(iii) of the main questionnaire. Using the Spearman's correlation test the contractors ranking (column 2) can once again be validated by these data and the test shows that there is a significant agreement between both sections. Table 8.14 shows the Spearman's correlation coefficient value of 0.6969 and correspondingly its significance value is 0.91%, which is less than 5% limit. This also indicates that there is a significant agreement in the ranking using the mean values of section B(ii) and section B(iii) of the contractors response with a 99% confidence level being achieved.

Initially, twenty five factors were identified in the pilot study and fifteen of these were selected to be tested in the main survey. The factors which were not considered in the main survey had mean values of less than 3.0 with exception of 'poor workmanship' and 'poor judgement'. It is interesting to note that the mean values for all the critical factors obtained for section B(ii) were above 3.0 (see column 4 of Table 8.14) except ranked number fifteen which had a mean value of 2.52. Using the ordinal ranges of scale the mean values for all the factors are classified under 'slightly high influence' and 'average influence' factors toward contractors' schedule performance.

Table 8.14: Ranking of fifteen critical factors by the contractors and clients

1	2		3		4	5
Factors of NED	contractors		clients		contractors' mean	contractors' ranking
	RI(%)	ranking	RI(%)	ranking	section B(ii)	section B(ii)
Slow mobilisation/late delivery	8.66	1	7.4	6	3.42	6
Unreliable supplier/sub contractor	8.35	2	7.6	5	3.90	1
Poor planning	8.28	3	10.6	1	3.57	3
Unavailability of proper resources	8.28	3	10.2	2	3.41	9
Poor monitoring and control	8.17	5	8.7	4	3.57	3
Shortages of personnel	7.41	6	6.6	7	3.42	6
Inefficient communication	7.27	7	6.3	8	3.42	6
Lack of experience	6.75	8	9.4	3	3.52	5
Low morale/motivation	5.91	9	4.2	13	3.17	13
Too many responsibilities	5.81	10	6.0	10	3.68	2
Inappropriate practices/procedures	5.46	11	4.7	12	3.21	11
Wrong method statement	5.46	11	2.9	15	3.21	11
Poor contract	5.39	13	3.8	14	3.36	10
Interference with other trades	4.90	14	6.3	8	3.07	14
Inadequate fund allocation	3.90	15	4.8	11	2.52	15

Note:

Spearman's correlation coefficient between contractors and clients is 0.7359 with a significance of 0.59%.

Correlation coefficient between contractors' ranking and ranking on the average mean score of Section B(ii) is 0.6969 with a significance value of 0.91% (contractors' group only).

$$\text{Relative Index (RI \%)} = \frac{\text{Total aggregated ranking scores of each factor}}{\text{Total aggregated ranking scores of all factors}} \times 100$$

From the above analysis the null hypothesis of no significant agreement in the ranking between section B(ii) and section B(iii), for the contractors groups, is rejected. The alternative hypothesis, that there is a significant agreement in the ranking between the factors in section B(ii) and section B(iii), is accepted with a confidence level of 99%. From the results of the analysis the objective to establish the critical factors according to the order of impact on non-excusable delays has been achieved. The statistical test has confirmed the contractors ranking using the clients responses and also the contractors response for section B(ii) where the result shows a significant agreement in the ranking at 95% confidence level.

8.6 INDICATORS TO IDENTIFY THE CRITICAL FACTORS

The objectives of conducting the analysis for this section is to establish the following:

(1) the most effective quantitative indicators that were used to identify twelve of fifteen critical factors; and

(2) the qualitative indicator that was used to assess the remaining three critical factors.

The above indicators which were classified into two types: quantitative and qualitative indicators were confirmed by the respondents of the pilot study. Quantitative indicators that were identified includes work schedule, material schedule, labour schedule, daily report, etc. and qualitative indicator identified was an intuitive judgement of site managers.

The analysis for this section is divided into two sub-sections according to the types of indicators and the objectives of analysis.

8.6.1 Quantitative indicators

The data collected for section C(i) of the main questionnaire (refer to Appendix III) were analysed with the objective to establish the most effective indicators that were used to identify the twelve critical factors of NED. A ranking method was used to achieve this objective and the significant of using this method was it highlights the order of ranking based its effectiveness to identify the critical factors. The ranking of these indicators were determined by computing the mean values for each indicator using both the respondents data.

Table 8.15 shows the ranking of indicators for the twelve critical factors which were selected during the pilot study. The objective of this section is to establish the most effective indicators used by the majority of respondents in identifying the critical factors.

Table 8.15: Indicators to identify the critical factors - survey results

Factors of NED	Indicators of delays	contractors' mean	clients' mean	contractors' ranking	clients' ranking
1) Late delivery of materials or equipment	a) Materials or equipment schedule	4.69	4.67	1	1
	b) Daily construction record	3.86	2.80	2	2
	c) Correspondence	3.34	2.20	3	3
2) Slow mobilisation of labour	a) Manpower schedule	3.79	4.50	1	1
	b) Manpower report	3.72	3.75	2	2
	c) Daily construction record	3.64	3.75	3	2
3) Unreliable supplier	a) Procurement record	3.76	3.00	2	2
	b) Material supply schedule	3.90	4.50	1	1
	c) Daily record	3.29	2.80	3	3
4) Unreliable sub-contractors	a) Schedule/progress measurement	4.79	4.17	1	1
	b) Daily report	3.76	4.00	2	2
	c) Productivity measurement	4.00	3.60	3	3
5) Inadequate fund allocation	a) Budget performance	3.68	4.20	2	2
	b) Variance analysis	3.61	4.40	1	1
6) Poor planning	a) Scheduling experience	4.09	4.40	3	2
	b) Timing of critical activities	4.43	4.40	1	2
	c) Sequence of critical activities	4.17	4.60	2	1
7) Inappropriate practices and procedures	a) Method statement	3.91	4.00	2	2
	b) Work experience	3.91	4.20	1	1
	c) Working policy	3.17	3.75	3	3
8) Lack of experience	a) Reference from previous track records	3.87	3.25	1	2
	b) Basic qualification	3.26	4.20	2	1
9) Inappropriate method statement	a) Work descriptions	3.22	4.00	2	1
	b) Consultation with site personnel	3.83	4.00	1	1
	c) Alternative work method	2.96	3.50	3	3
10) Unavailability of proper resources	a) Daily reports/progress measurement	3.69	4.60	2	1
	b) Productivity measurement	3.90	3.80	2	3
	c) Resource planning	4.14	4.00	1	2
11) Shortage of personnel	a) manpower planning	4.07	3.83	1	1
12) Interference with other trades	a) Site team meeting	4.64	3.00	1	1
	b) Daily report	3.57	2.00	2	2
	c) Contractor's complaint	3.29	1.00	3	3

In this section the respondents were asked to rank each indicator using a similar rating frequency as explained in the previous section. The average rating frequencies (or mean values) were computed using the respondents data and tabulated as shown in Table 8.15. The mean values for the top ranked indicators are within the range of 3.00 to 4.79 (for both groups) which fall under the categories of 'slightly high' and 'high'. These values were then used to rank the indicators for each factor. It was confirmed by the respondents of the main survey that the highest ranked indicators are the most effective in detecting or identifying these factors. However, its effectiveness will also depend on the right and accurate reporting of information by the site personnel.

Table 8.15 shows 'resources and work schedules' as the common indicators, ranked highest by the majority of respondents, and used to identify 'late delivery', 'slow mobilisation of labour', 'unreliable supplier', 'unreliable sub-contractors', 'unavailability of proper resources', and 'shortages of site personnel'. Many respondents from the contractors' group indicated their preference to use 'resources schedules' such as materials schedule, labour schedule, equipment schedule, etc. and the clients group had a similar opinion. This finding indicates that 'resources schedules' are the preferred tools used to identify these factors by both groups and it may be due to the effectiveness of these tools that are able to highlight the factors of delays. The 'resources schedules' can quantify and effectively highlight the non-conformance by comparing the 'actual' against 'planned' thus making these tools the best available to monitor the critical factors. Apart from this finding, the table also shows similarities in the ranking for most of the factors under investigation by both groups. However, statistical tests on these data did not provide any significant results and the reason is explained in the following paragraph.

The statistical test to confirm whether there is a significant agreement between both the respondent groups is not possible. It is not possible to achieve a significance value of less than 5% with N=3 or less. The Spearman's correlation test for three variables (N=3) can only produce a correlation index of 0.5 with a significance value of 0.33 or 33% and if the correlation index obtained is 1.0 (a perfect match) its significance value achieved is only 0.16 or 16%. Thus, both the probabilities are not significant if a confidence level of 5% is to be observed. More importantly, the objective of establishing the most common indicators for each factor by way of ranking has already been achieved.

8.6.2 Qualitative indicators

The objective of conducting the analysis for this sub-section is to establish the critical factors that were identified by intuitive judgement of the site managers. Three out of fifteen critical factors identified during the pilot study which includes: 'inefficient communication'; 'too many responsibilities'; and 'low moral and motivation' cannot be assessed by the available quantitative indicators.

The respondents data collected for section C(ii) of the main questionnaire (refer to **Appendix** III) were analysed to establish the finding of the pilot study. The questions designed for this sub-section comprised of **Yes No** questions, and its objective is to establish whether the critical factors identified during the pilot study were evaluated using intuitive judgement of site managers. The method of analysis used to validate the finding is Binomial probability test and it can establish the opinion of respondents in a YES NO situation. The test conducted for this section is to validate whether the three critical factors that were assessed by qualitative indicator and the NO response means the factor was assessed by intuitive judgement.

Table 8.16 and Table 8.17 show the respondents frequencies on the availability of indicators where No responses indicate 'intuitive judgement of site managers' being employed to assess these factors. Twenty-eight respondents from the contractors group responded to the questionnaire.

Table 8.16: Contractors responses on the availability of quantitative indicators

Factors of NED delays	Respondents frequency	
	Yes	**No**
1) Inefficient communication	8	20
2) Too many responsibilities	9	19
3) Low morale/motivation	9	19

Table 8.17: Clients responses on the availability of quantitative indicators

Factors of NED delays	Respondents frequency	
	Yes	**No**
1) Inefficient communication	1	5
2) Too many responsibilities	-	6
3) Low morale/motivation	2	4

Note: The **No** response indicates the use of intuitive judgement

The statistical test used to prove and validate the outcome on whether these factors were assessed by intuitive judgement is the Binomial probability significance test. The Binomial probability test is applied when there are only two possible outcomes which is either Yes or No and the response ratio for each factor has to be identified. The assumption made for the response ratio is equal and it is represented by p (probability of saying No) = 0.5 and (1-p) (probability of saying Yes) = 0.5. The significance test was carried out on each factor for both the respondents groups using the following binomial probability formula:

$$P(x) = \binom{n}{x} p^x (1-p)^{n-x}$$

where $\binom{n}{x} = \frac{n(n-1)(n-1)(n-2)(n-3)........(n-x+1)}{x(x-1)(x-2(x-3)........3\times2\times1}$

P is the probability, p is the probability of No respondents on one trial, n is the number of trials or samples, x is the number of No frequencies in n samples.

From the above formula, we can calculate the Probability (20 out of 28 or worse) for the 'inefficient communication' of the contractors response. In this situation x = 20, 21, 22,....28. n = 28 and p = 0.5.

Hence, the Probability (20 out of 28 or worse)

= Probability(20) + Probability(21) + Probability(22)

+ Probability(23) + ... + Probability(28)

= 0.0116 + 0.0044 + 0.0014 + 0.0004 +..........+ 0.0001

= 0.0179

Thus, the significant test indicates that the probability of 20 saying No out of 28 (see Table 8.16) for 'inefficient communication' is 1.79% < 5% which is significant at a confidence level of 95%. This shows that the contractors' response has confirmed, with a confidence level of 95%, 'inefficient communication' factor was assessed by the intuitive judgement of site managers. Meanwhile, five out of six respondents in the client group answered 'No' (see Table 8.17) giving the Binomial probability value of 0.109 or 10.9% which is not significant at a 5% confidence limit but is almost significant at 90% confidence level.

The second and third factors investigated revealed that the significant test for the binomial probability gives a value of Probability (19 out of 28 or worse) = 0.0179+ 0.0257 = 0.0436 or 4.36% < 5% which is significant. It revealed that intuitive judgement was used to asses these factors which was confirmed by the majority of contractors respondents. The clients' group also confirmed that the factor of 'too many responsibilities' which gives a binomial probability value of 0.016, is significant compared to a confidence limit of 0.05. This shows that the test on the clients' data provide a significance value of 1.6% has verified the contractors' responses. However, the clients response on the factor of 'low moral and motivation' gives a binomial probability value of 0.344 or 34.4% which was much greater than 5% and therefore it does not support the contractors response. Nevertheless, the contractors' responses had significantly confirmed that all the three critical factors identified were assessed by intuitive judgement of site managers. Furthermore, the objective to establish the critical factors that were assessed by intuitive judgement has been achieved using Binomial Probability significant test. Hence, this justifies the need to develop an alternative indicator to intuitive judgement which can provide a consistent and standard assessment.

8.6.3 Development of an indicator to assess 'communication performance' using the theory of Fuzzy Logic

This section uses the data collected for section C(iii) of the main questionnaire (refer to Appendix III) and the objective is to develop an indicator to assess 'communication performance' using the theory of Fuzzy Logic. The contractors' response in the main survey validated that three out of fifteen critical factors could only be assessed by the intuitive judgement of site managers. Le Bright, (1995) acknowledged that out of these three factors 'inefficient communication' was the number one obstacle to good project execution. Developing a qualitative sensor to assess 'communication performance', as an alternative evaluation to human 'sensor' (or intuitive judgement) is an appropriate decision. In addition it can also initiate the development of more sensor tools for project monitoring and controlling using the theory of Fuzzy Logic. The decision to develop only one sensor was to limit the number of questions for the main survey questionnaire. The exclusion of developing the sensor for 'too many responsibilities' and 'low morale/motivation' has reduced the number of questions by approximately 16% to a total of 198 questions. Moreover, these sensors can be developed based on similar information collected for the 'inefficient communication'.

An alternative indicator to human 'sensor' was developed based on the theory of fuzzy logic controller (FLC). The overview of the concept is briefly explained in Chapter Five. Table 8.18 and Table 8.19 indicate the ranges and means of each fuzzy set that belong to the elements under investigation. The ranges for both the elements were determined using the respondents ranges of data. However, there are few ranges of data which were not within the expected range which were excluded in the analysis and the overall average range which was adopted is 4.0 for the intermediate membership functions and 3.0 for the extreme ends. The actual overall average range value for intermediate function is 4.167 taken as 4.0 (to the nearest whole number) calculated based on the average values of all the ranges (SIB, SAB, AB, SICC, SECC, and ECC) in column five (see Table 8.18 and 8.19). The overall average range value for extreme ends was 3.0 calculated based on the ranges for IB, VAB, ICC, and VECC.

Table 8.18: Ranges and mean values of communication channel

1	2	3	4	5	6
ICC	ICC Mid-pt.	Frequencies	Col. 2x3	Range of ICC	Mean value
0-1	0.5	4	2		
0-2	1	4	4	0-3	1.0
0-3	1.5	3	4.5		
1-2	1.5	1	1.5		
1-3	2	2	4		
	Total	14	16.0		
		Mean	1.14		
SICC	SICC Mid-pt.	Frequencies	Col. 2x3	Range of SICC	Mean value
1-2	1.5	1	1.5		
2-4	3	5	15	1-5	3.0
2-5	3.5	3	10.5		
3-4	3.5	1	3.5		
3-5	4	2	8		
4-5	4.5	2	9		
	Total	14	47.5		
		Mean	3.39		
SECC	SECC Mid-pt.	Frequencies	Col. 2x3	Range of SECC	Mean value
3-4	3.5	1	3.5		
4-5	4.5	2	9	3-7	5.0
4-6	5	3	15		
4-7	5.5	2	11		
5-6	5.5	4	22		
6-7	6.5	2	13		
	Total	14	73.5		
		Mean	5.25		
ECC	ECC Mid-pt.	Frequencies	Col. 2x3	Range of ECC	Mean value
5-6	5.5	3	16.5		
6-7	6.5	2	13	5-9	7.0
6-8	7	2	14		
6-9	7.5	1	7.5		
7-8	7.5	4	30		
8-9	8.5	2	17		
	Total	14	98.0		
		Mean	7.0		
VECC	VECC Mid-pt.	Frequencies	Col. 2x3	Range of VECC	Mean value
7-9	8	2	16		
7-10	8.5	1	8.5	7-10	9.0
8-10	9	3	27		
9-10	9.5	8	76		
	Total	14	127.5		
		Mean	9.11		

Table 8.19: Ranges and mean values of distribution of information

1	2	3	4	5	6
IB	NB Mid-pt.	Frequencies	Col. 2x3	Range of IB	Mean value
0-0	0	1	0		
0-1	0.5	2	1	0-3	1.0
0-2	1	5	5		
0-3	1.5	4	6		
1-3	2	2	4		
		14	16		
		Mean	1.14		
SIB	SIB Mid-pt.	Frequencies	Col. 2x3	Range of SIB	Mean value
1-2	1.5	1	1.5		
1-3	2	1	2	1-5	3.0
2-4	3	2	6		
3-4	3.5	4	14		
3-5	4	5	20		
4-5	4.5	1	4.5		
		14	48		
		Mean	3.43		
SAB	SAB Mid-pt.	Frequencies	Col. 2x3	Range of SAB	Mean value
2-4	3	1	3		
3-5	4	1	4	2-7	5.0
3-6	4.5	1	4.5		
4-6	5	3	15		
4-7	5.5	1	5.5		
5-6	5.5	4	22		
5-7	6	1	6		
6-7	6.5	2	13		
		14	73		
		Mean	5.21		
AB	AB Mid-pt.	Frequencies	Col. 2x3	Range of AB	Mean value
5-7	6	2	12		
5-8	6.5	1	6.5	5-9	7.0
6-7	6.5	2	13		
6-8	7	1	7		
6-9	7.5	1	7.5		
7-8	7.5	5	37.5		
7-9	8	1	8		
8-9	8.5	1	8.5		
		14	100		
		Mean	7.14		
VAB	VAB Mid-pt.	Frequencies	Col. 2x3	Range of VAB	Mean value
7-9	8	2	16		
6-10	8	1	8	7-10	9.0
7-10	8.5	1	8.5		
8-10	9	2	18		
9-10	9.5	8	76		
		14	126.5		
		Mean	9.04		

A triangular shape was chosen to determine the fuzzification function. This shape was selected in order to simplify the process of analysis and to make its application more practical to the project personnel. To introduce a more complicated shape would discourage the use of this tool. The vertex of the triangles correspond to the mean values of the data set (see column six of Tables 8.18 and 8.19). The mean values were determined using the data from individual members and taken to the nearest whole number. Using these data, the membership functions for both the elements can be drawn (as shown in Figure 8.1 and Figure 8.2). These figures represent the membership function for the input set and Figure 8.3 displays the membership function for the output set.

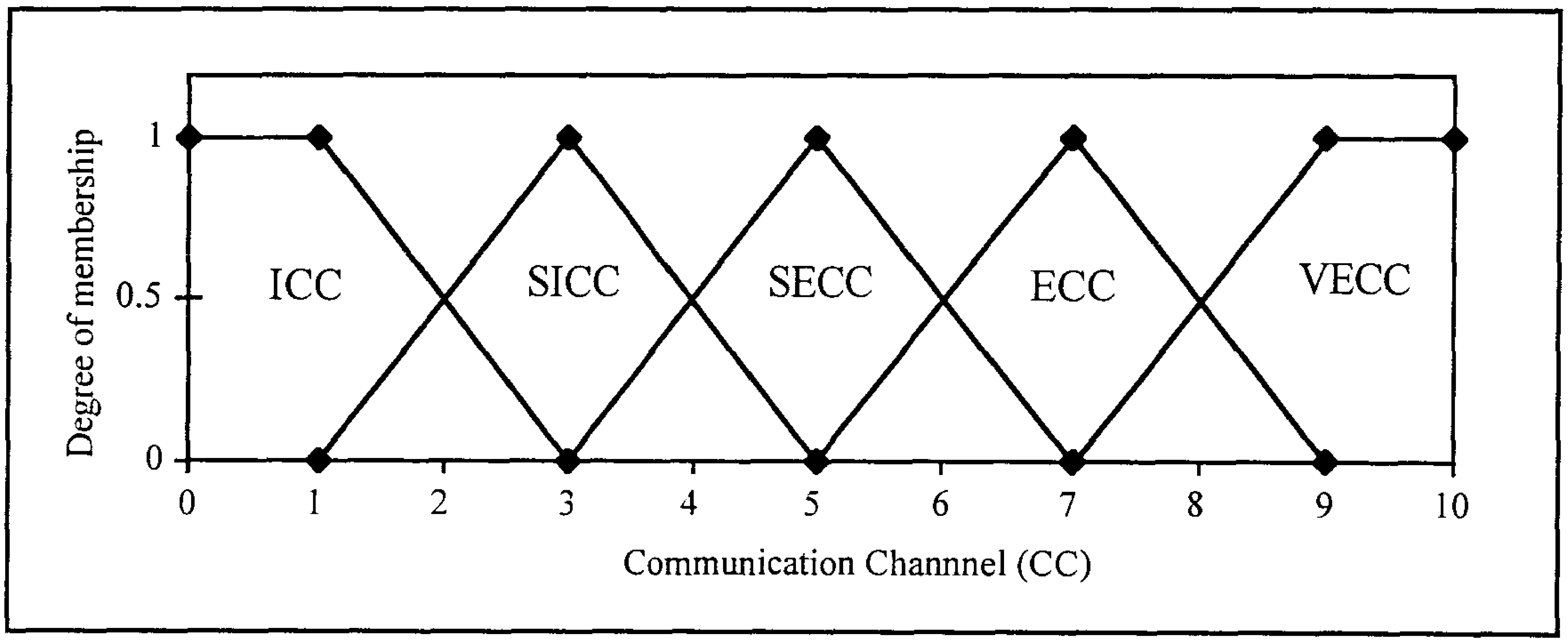


Figure 8.1: Membership function for communication channel

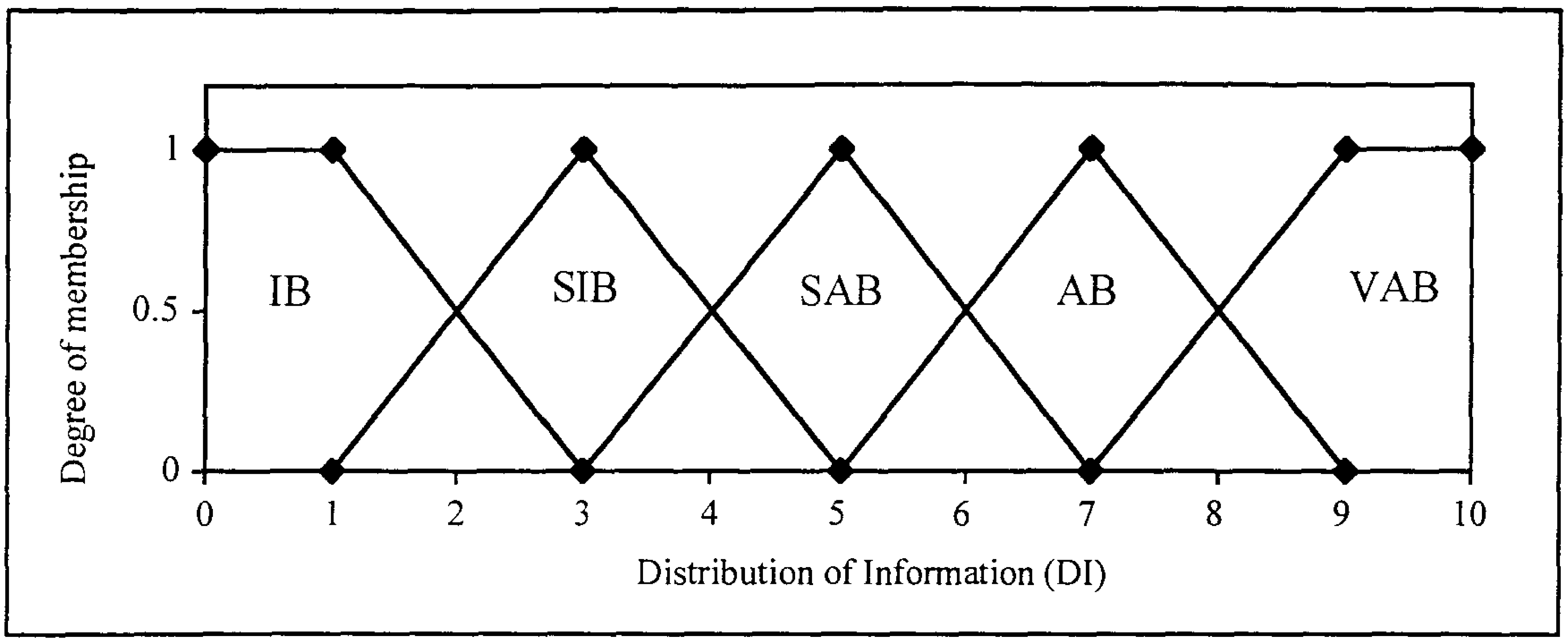


Figure 8.2: Membership function for distribution of information

The input data can either be linguistic labels, index of scales or both. An index of scales from 0-10 was used to represent the various linguistic labels for both the input elements. In this case the linguistic labels used varies from 'inefficient communication channel (ICC)' to 'very efficient communication channel (VECC)' and index of scales which may represent the score or rating of the 'communication channel'. The fuzzy grades of membership for the linguistic label of 'communication channel' used are as follows:

(1) ICC (Inefficient Communication Channel) = 1|0 + 1|1 + 0|3

(2) SICC (Slightly Inefficient Communication Channel) = 0|1 + 1|3 + 0|5

(3) SECC (Slightly Efficient Communication Channel) = 0|3 + 1|5 + 0|7

(4) ECC (Efficient Communication Channel) = 0|5 + 1|7 + 0|9

(5) VECC (Very Efficient Communication Channel) = 0|7 + 1|9 + 1|10

Similar fuzzy grades of membership were used for 'Distribution of Information' where the following notation represents:

(1) IB - Inadequate Briefing;

(2) SIB - Slightly Inadequate Briefing;

(3) SAB - Slightly Adequate Briefing;

(4) AB - Adequate Briefing; and

(5) VAB - Very Adequate Briefing.

Both ends of the fuzzy grades belongs 100% to the linguistic label which takes a membership value of one. The same fuzzy grades of membership were considered for 'Distribution of Information'. The fuzzy set of the second, third and fourth take the triangular shape. As mentioned earlier, the vertex of the triangle corresponds to the mean values of the data collected from the survey. The membership function for all the input set is clearly indicated in Figure 8.1 and Figure 8.2. The output fuzzy rules were developed using 5x5 matrices along with the consideration of expert opinion toward the inferences. The 'if-then' rules are then tabulated in the 'IF-THEN' Table. For simplicity, the construction of the 'if-then' rules does not take into account the weighting differences between the variables, since it was revealed from the analysis that the differences are insignificant. This is indicated where 'Distribution of information' has a weighted average of 52% while 'communication channel' is 47%.

Table 19a: 'IF-THEN' Table

		Communication Channel				
		ICC	SICC	SECC	ECC	VECC
	IB	IC	SIC_1	SIC_2	SEC_1	SEC_2
Distribution	SIB	SIC_3	SIC_4	SEC_3	SEC_4	EC_1
of	SAB	SIC_5	SEC_5	SEC_6	EC_2	EC_3
information	AB	SEC_7	SEC_8	EC_4	EC_5	VEC_1
	VAB	SEC_9	EC_6	EC_7	VEC_2	VEC_3

where,

IC represents 'Inefficient Communication',

SIC represents 'Slightly Inefficient Communication',

SEC represents 'Slightly Efficient Communication',
EC represents 'Efficient Communication', and
VEC represents 'Very Efficient Communication'.

The rules that define the notation in the 'if-then' table are given below.

IC If Distribution of Information (DI) is inadequate and Communication Channel (CC) is inefficient, then Communication Performance (CP) is inefficient.

SIC_1 If DI is slightly inadequate and CC is slightly inefficient, then CP is slightly inefficient.

SIC_2 If DI is inadequate and CC is slightly efficient, then CP is slightly inefficient.

SIC_3 If DI is slightly inadequate and CC is inefficient, then CP is slightly inefficient.

SIC_4 If DI is slightly inadequate and CC is slightly inefficient, then CP is slightly inefficient.

SIC_5 If DI is slightly adequate and CC is inefficient, then CP is slightly inefficient.

SEC_1 If DI is inadequate and CC is efficient, then CP is slightly efficient.

SEC_2 If DI is inadequate and CC is very efficient, then CP is slightly efficient.

SEC_3 If DI is slightly inadequate and CC is slightly efficient, then CP is slightly efficient.

SEC_4 If DI is slightly inadequate and CC is efficient, then CP is slightly efficient.

SEC_5 If DI is slightly adequate and CC is slightly inefficient, then CP is slightly efficient.

SEC_6 If DI is slightly adequate
and CC is slightly efficient,
then CP is slightly efficient.

SEC_7 If DI is adequate
and CC is inefficient,
then CP is slightly efficient.

SEC_8 If DI is adequate
and CC is slightly inefficient,
then CP is slightly efficient.

SEC_9 If DI is very adequate
and CC is inefficient,
then CP is slightly efficient.

EC_1 If DI is slightly inadequate
and CC is very efficient,
then CP is efficient.

EC_2 If DI is slightly adequate
and CC is efficient,
then CP is efficient.

EC_3 If DI is slightly adequate
and CC is very efficient,
then CP is efficient.

EC_4 If DI is adequate
and CC is slightly efficient,
then CP is efficient.

EC_5 If DI is adequate
and CC is efficient,
then CP is efficient.

EC_6 If DI is very adequate
and CC is slightly inefficient,
then CP is efficient.

EC_7 If DI is very adequate
and CC is slightly efficient,
then CP is efficient.

VEC_1 If DI is adequate
and CC is very efficient,
then CP is very efficient.

VEC_2 If DI is very adequate
and CC is efficient,
then CP is very efficient.

VEC_3 If DI is very adequate
and CC is very efficient,
then CP is very efficient.

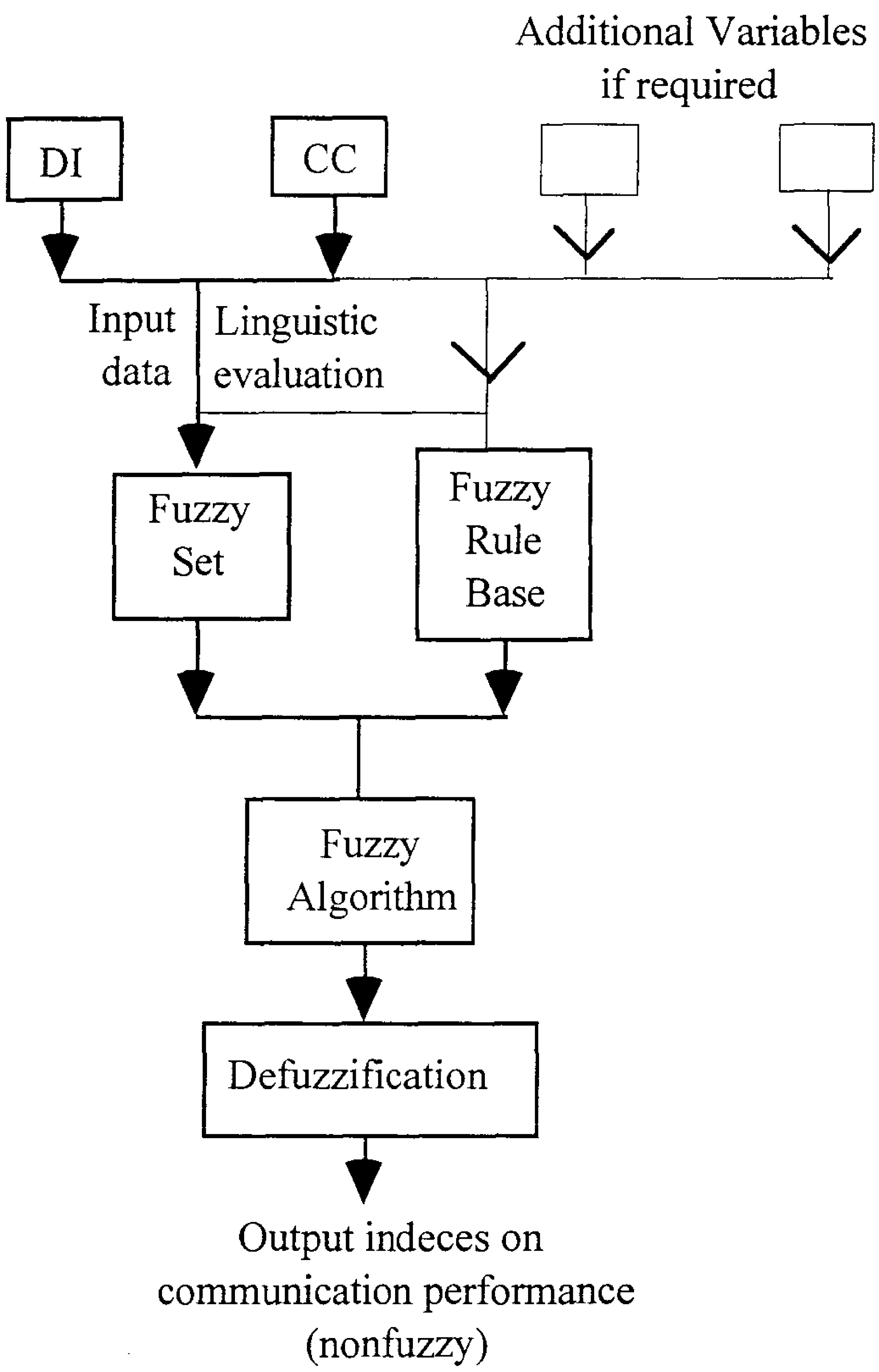


Figure 8.3: Assessment model for communication performance

Figure 8.3 represents the model flow chart to assess 'Communication Performance' (CP) developed using the concept of fuzzy logic controller (FLC). In this study two variables - DI and CC were confirmed by the respondents as the influencing elements on 'Communication Performance' (CP). Figure 8.4 shows that the model can accommodate other elements and it is not necessarily limited to those determined by the respondents but one could add or replace these elements. The crisp values, or linguistic assessment, on the variables are then fuzzified into a fuzzy set. The fuzzy input are then evaluated using the rules of inferences and fuzzy algorithm which results in fuzzy output. The output of the fuzzy value is transformed into an output indices and this process is known as defuzzification. The single crisp value is obtained to determine the status of 'Communication Performance'.

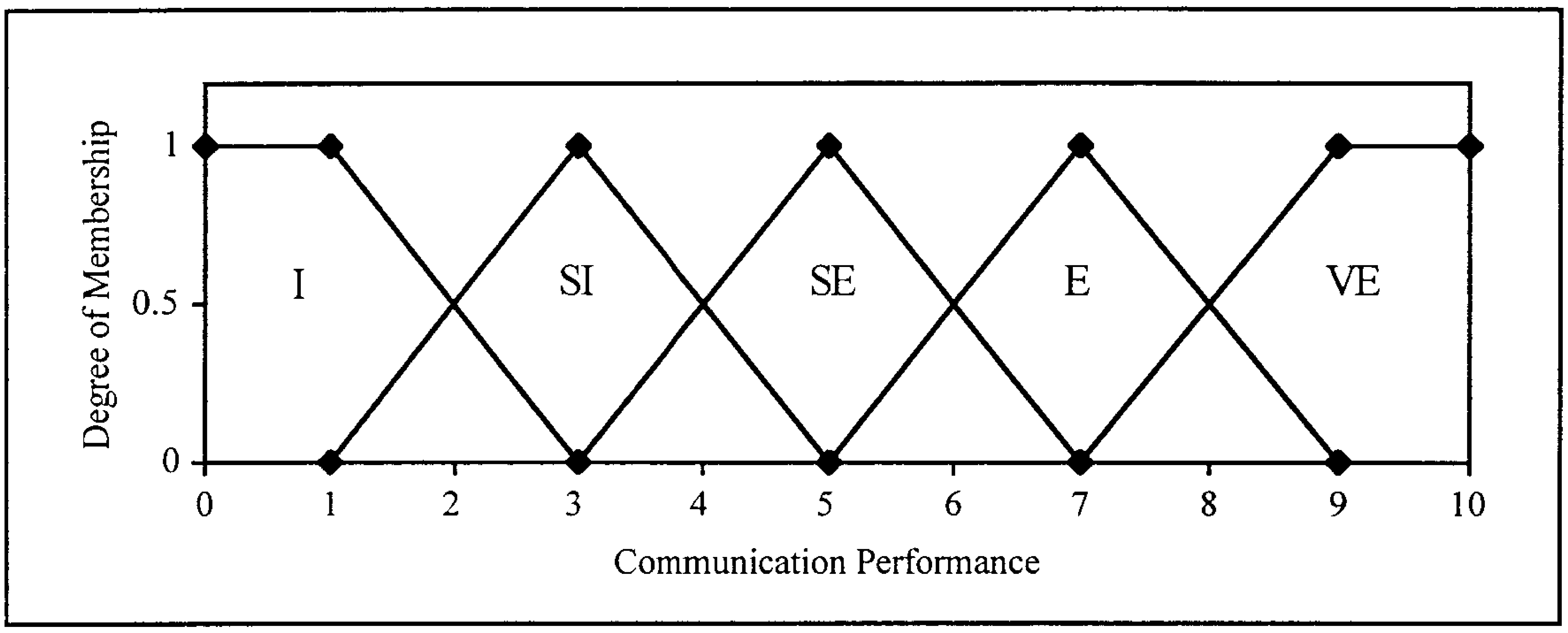


Figure 8.4: Membership function for communication performance

Figure 8.4 shows the output membership function for 'Communication Performance' which is represented by five linguistic sets. The output linguistic sets are determined using the 'If-Then' rules and the input membership functions. The membership function values for the output sets are as follows:

I = 1|0 + 1|1 + 0|3

SI = 0|1 + 1|3 + 0|5

SE = 0|3 + 1|5 + 0|7

E = 0|5 + 1|7 + 0|9

VE = 0|7 + 1|9 + 1|10

The degree of membership for both ends belong 100% to the linguistic set which is represented by singleton value. The defuzzification process utilises the output function (see Figure 8.4) and the 'if-then' rules to transform the fuzzy value.

The output indices were determined using the 'if-then' rules and the output function (Figure 8.4). Several calculations had to be carried out to ensure that the rules represented appropriate inferences especially at the cross over point. Using the rules it was necessary to check a number of possible permutations, especially when two output rules were involved in determining the crisp values. The ranges of crisp output indices for interpreting the inferences of communication performance are as follows:

$0 \leq I \leq 2$	where	I is inefficient communication,
$2 < SI \leq 4$		SI is slightly inefficient communication,
$4 < SE \leq 6$		SE is slightly efficient communication,
$6 < E \leq 8$		E is efficient communication,
$8 < VE \leq 10$		and VE is very efficient communication.

Example:

The following example illustrates the assessment of 'Communication Performance' using two input variables. A simple example if, 'Communication Channel (CC)' is = SECC and 'Distribution of Information (DI)' = AB then 'Communication Performance' is = Efficient (EC_4) - refer to the 'If-Then' Table. The evaluation could also take a crisp index of values between 0-10 which represent 'ineffective' to 'very effective' scales for 'Communication Channel' and 'inadequate' to 'very adequate' for 'Distribution of Information'.

With the predetermined information we can now compute 'Communication Performance' (CP) for a given numerical value of CC and DI. From Figure 8.4, say CC is 5|1.0 i.e. CC is slightly efficient communication channel (SECC) with a degree = 1.0, and DI is 6|0.5 i.e. DI is adequately brief (AB) with a degree = 0.5. Hence from the 'if-then' table, two rules are applicable, Rule SEC_6 and EC_4. Using each of these two rules we can compute a membership function of 'Communication

Performance' (CP) as follows, where $\wedge$ takes the minimum of the operand membership functions. The weight of each rule is determined as:

$$SEC_6 = m_{SAB}(DI) \wedge m_{SE}(CC) = 0.5 \wedge 1.0 = 0.5$$

$$EC_4 = m_{AB}(DI) \wedge m_{SE}(CC) = 0.5 \wedge 1.0 = 0.5$$

The membership function for CP, m(CP), is thus the maximum of the preceding two intermediate membership function m_{SE6} and m_{E4}. This is a fuzzy value for CP, thus we need to convert this fuzzy value to crisp value, using the centre of area method (COA). By computing the centre of gravity of m(CP), CPo can be established and this is known as defuzzification.

Using Figure 8.5 and the centre of gravity, CPo under the area efgh is computed as follows:

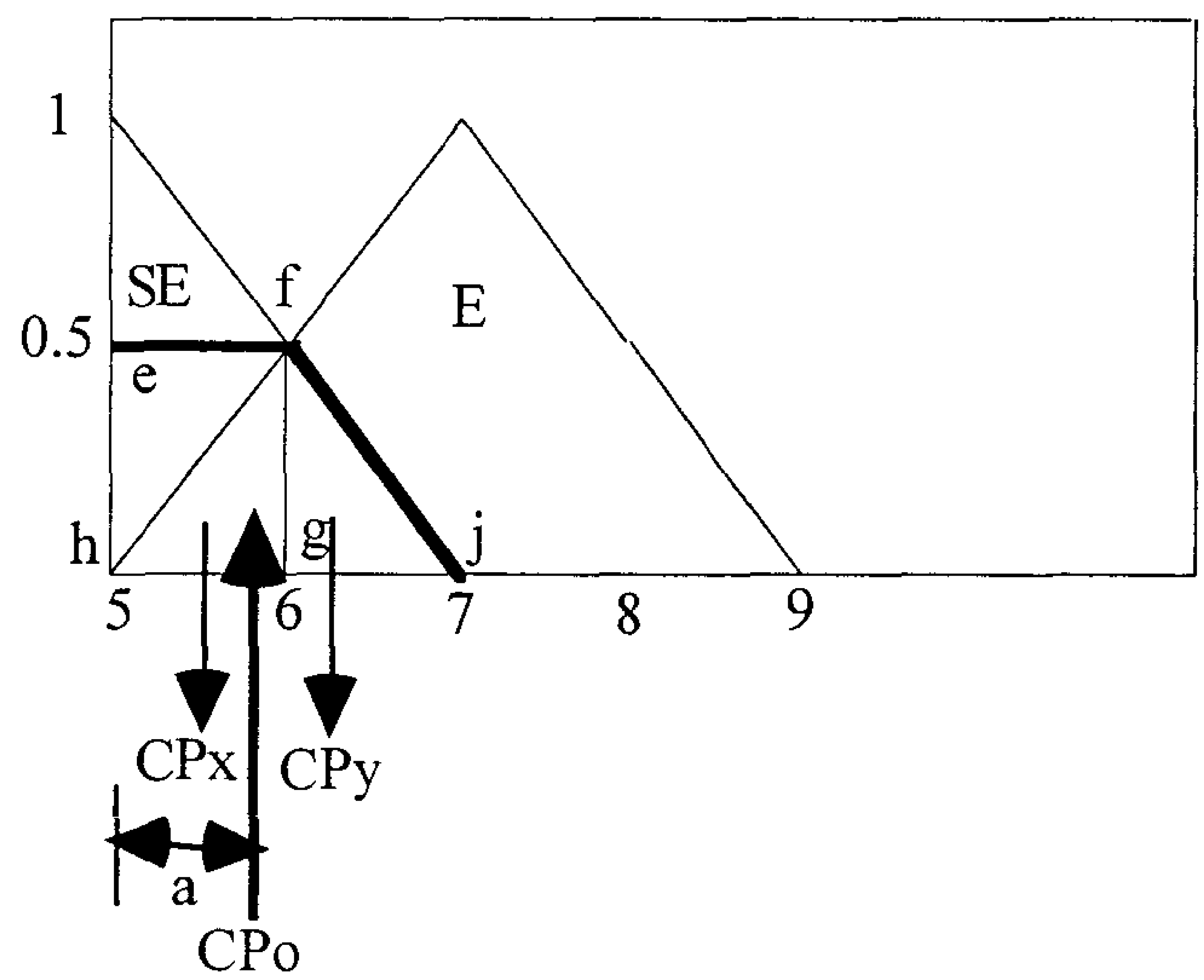


Figure 8.5: Defuzzification

Taking moment at point 5,

Total area CPo x a = Area CPx (0.5) + Area CPy (1.33)

Area efjh x a = Area efgh x 0.5 + Area fgj x 1.33

$$0.75a = 0.5 \times 1 \times 0.5 + 0.5 \times 0.5 \times 1 \times 1.33$$

$$a = 0.78$$

Therefore CPo = 5 + 0.78 = 5.78

Hence, from the above calculation the Communication Performance index (CP) is 5.78 which can be interpreted as 'slightly efficient communication'.

8.7 CORRECTIVE ACTIONS

8.7.1 Introduction

The analysis conducted for this section is to establish and validate the following issues:

- the structured approach of deriving permanent corrective actions; and
- the permanent corrective actions for the critical factors.

8.7.2 Analysis on structured approach

The proposed structured approach, identified during the pilot study, modelled the method of deriving permanent corrective actions. Chapter Four discusses the proposed approach that was formulated with the objective of establishing the method of deriving permanent corrective actions among several identified and to be validated in the main survey. To achieve this objective the questionnaire was designed according to the flow of the approach (see Figure 4.1) where individual NED factors are represented by three choices of corrective action. Initially the factors that lead to delays were identified, which are known as a 'mini problem' and then their corrective actions were formulated based on the sequence of the approach as shown in the example of Section 4.6.2.4. Following this sequence, three choices of corrective actions were generated and confirmed in the pilot study and they were then validated in the main survey. A graphical method was used to show whether the pattern is in accordance to the sequence of the approach. The data collected for section D of the main questionnaire (refer to Appendix III) were analysed to establish the proposed approach by observing the pattern of selection. This pattern was determined using the ranking of three suggestions for each critical factor in which lightest shade was ranked lowest and darkest shade was ranked highest by the respondents and Figure 8.6 displays a clear pattern among all the critical factors analysed.

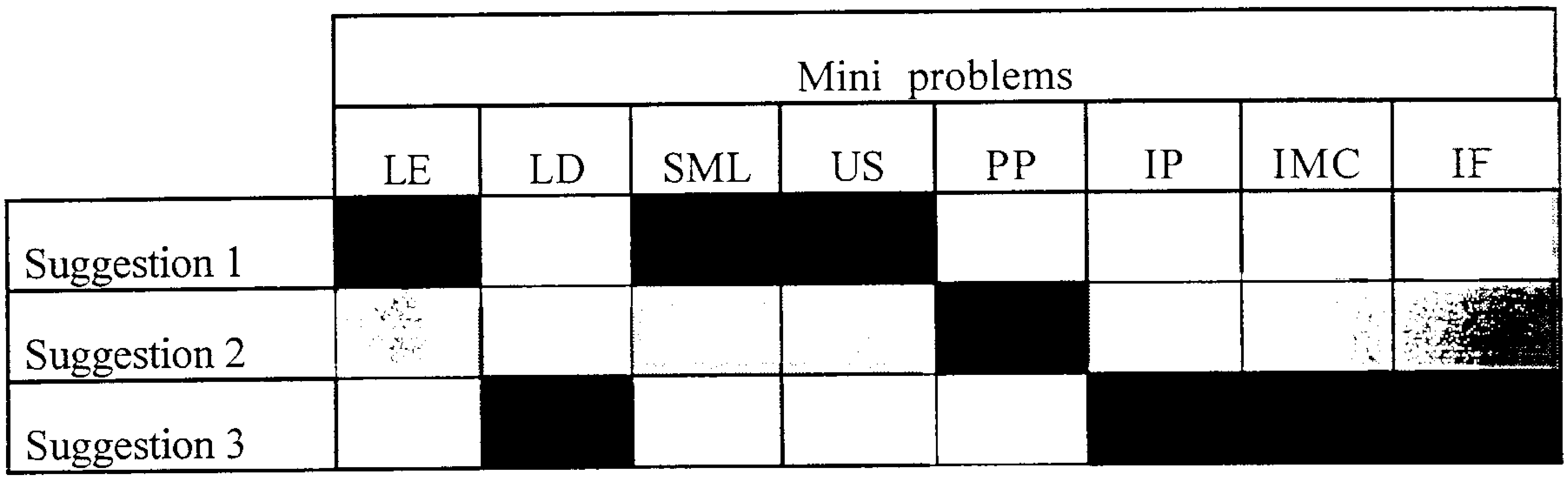
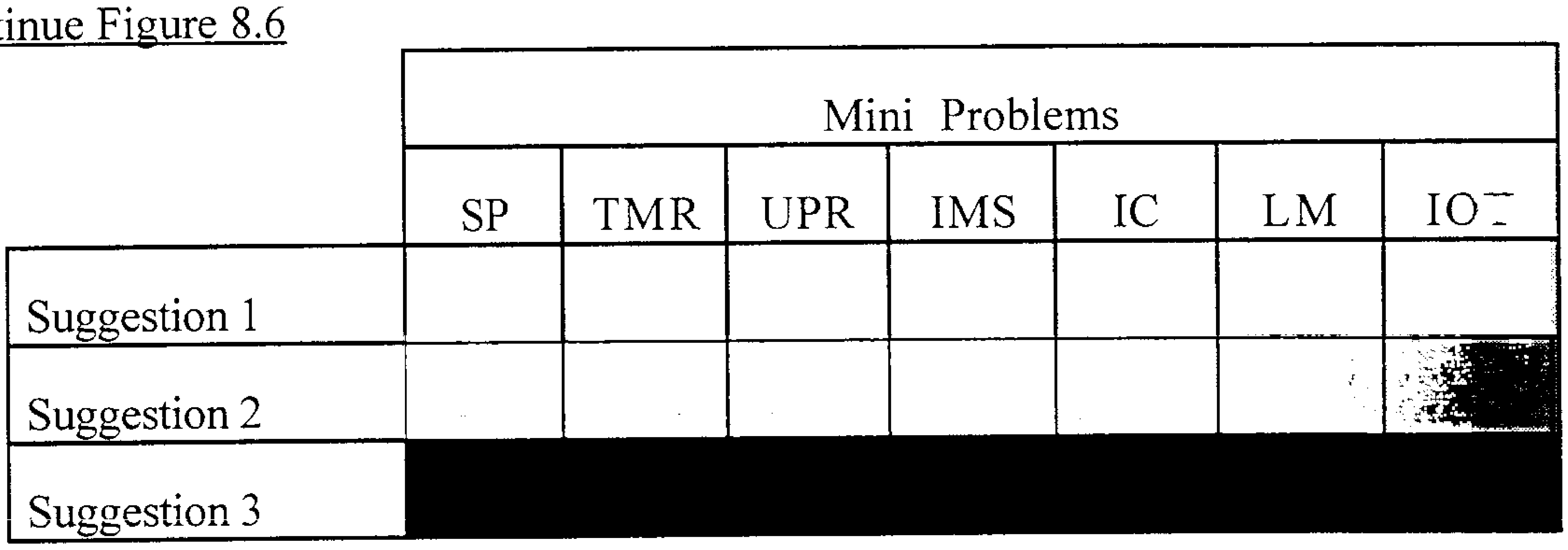


Figure 8.6: Pattern of the contractors ranking on permanent corrective actions for the critical factors

<u>Continue Figure 8.6</u>



Notation;

(1) Lack of Experience LE

(2) Late Delivery (materials and equipment) LD

(3) Slow Mobilisation of Labour SML

(4) Unreliable Supplier/sub-contractor US

(5) Poor Planning	PP
(6) Inappropriate practice/procedure	IP
(7) Inefficient Monitoring and Control	IMC
(8) Inadequate Fund	IF
(9) Shortage of Personnel	SP
(10) Too Many Responsibilities	TMR
(11) Unavailability of Proper Resources	UPR
(12) Inappropriate Method Statement	IMS
(13) Inefficient Communication	IC
(14) Low Morale/Motivation	LM
(15) Interference with Other Trade	IOT

Ideally, the sequence of deriving a corrective action for the critical factors should be from the lightest shades to the darkest shades. The lightest shades indicate the lowest ranking, which is interpreted as the 'least appropriate' corrective action while the darkest shades indicate the 'most appropriate' corrective actions. The reason why suggestion number one is the least appropriate corrective action is due to the existence of contradiction in the corrective actions. These contradictions which exist within the proposed corrective actions can be in the form of:

- cost increased and/or
- time increased.

The second suggestion is one which ideally no additional cost and/or extra time are incurred to implement them. The elements that exist in these suggestions should ideally control or improve the critical factors. Elements such as 'penalty clause' that can prevent late delivery; 'availability of very experience site personnel' that help to reduced the impact of lack of experience; 'proper resources planning' that can prevent shortages of resources; etc. The third suggestion is presumably the most appropriate corrective action among the three. This suggestion was derived by eliminating the contradiction using an ideal corrective action or formulated using the combination of suggestions one and two.

Figure 8.6 shows that 11 out of 15 critical factors display a similar sequence, which is in accordance to the proposed structured approach. This strongly indicates that there is a common sequential approach of deriving permanent corrective actions by site managers among contractors responses. However, the client group responded with 8 out of 15 (see Figure 8.7) that follow a common pattern to the approach. From the analysis only a few of the factors do not follow the pattern of the approach and several observations were made to explain this deviation. For the 'lack of experience', the first suggestion (engaging an additional experience personnel would minimise the impact but can increase the operating cost) which consists of an element of contradiction was viewed as the most appropriate solution to improve this factor. The third suggestion, (sharing and discussing within the site personnel would reduced the impact on the lack of experience), which probably cost less, was not selected as the most appropriate measure. Despite an additional cost to be incurred, the criteria of minimalist approach (no additional cost to implement) has become less important as compared to the additional cost required for the first suggestion. Another factor (poor planning) which was the second suggestion (i.e. "sharing the knowledge and experience among quantity surveyor, planning engineer, temporary work designer and site personnel within the organisation can minimised poor planning") was selected as the most appropriate suggestion by the contractors group and it comprehends the minimalist approach. Both observations discussed on the issues of selection criteria which was not investigated and beyond the scope of this research. However, the objective to establish the structured approach of deriving a corrective action has been achieved using the graphical method.

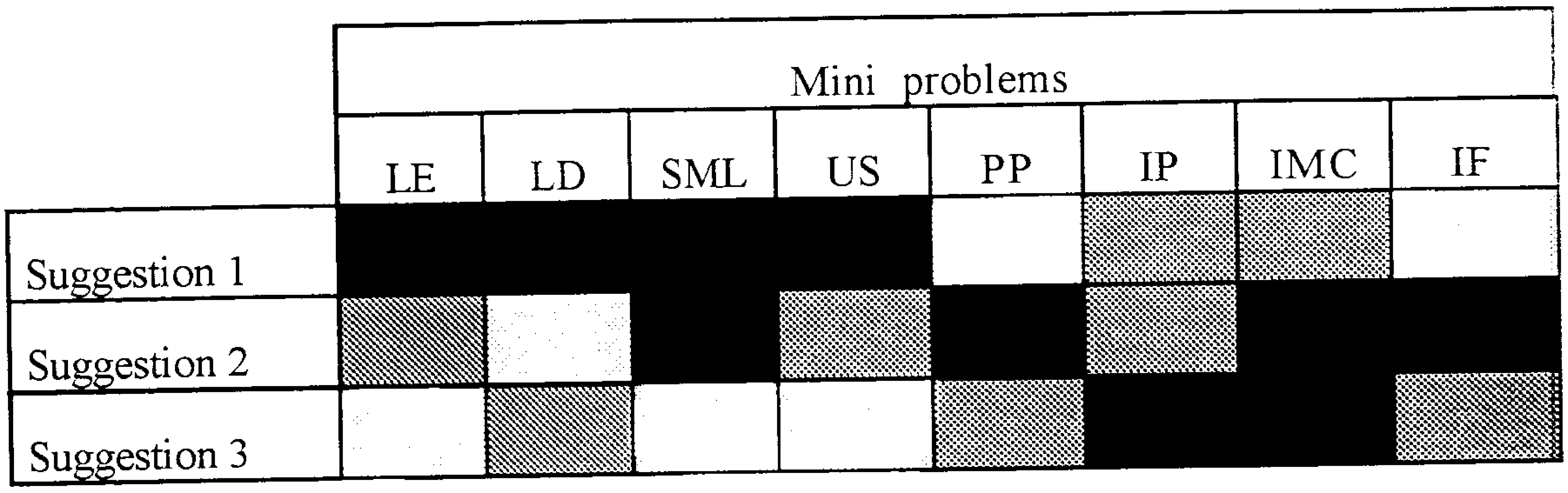
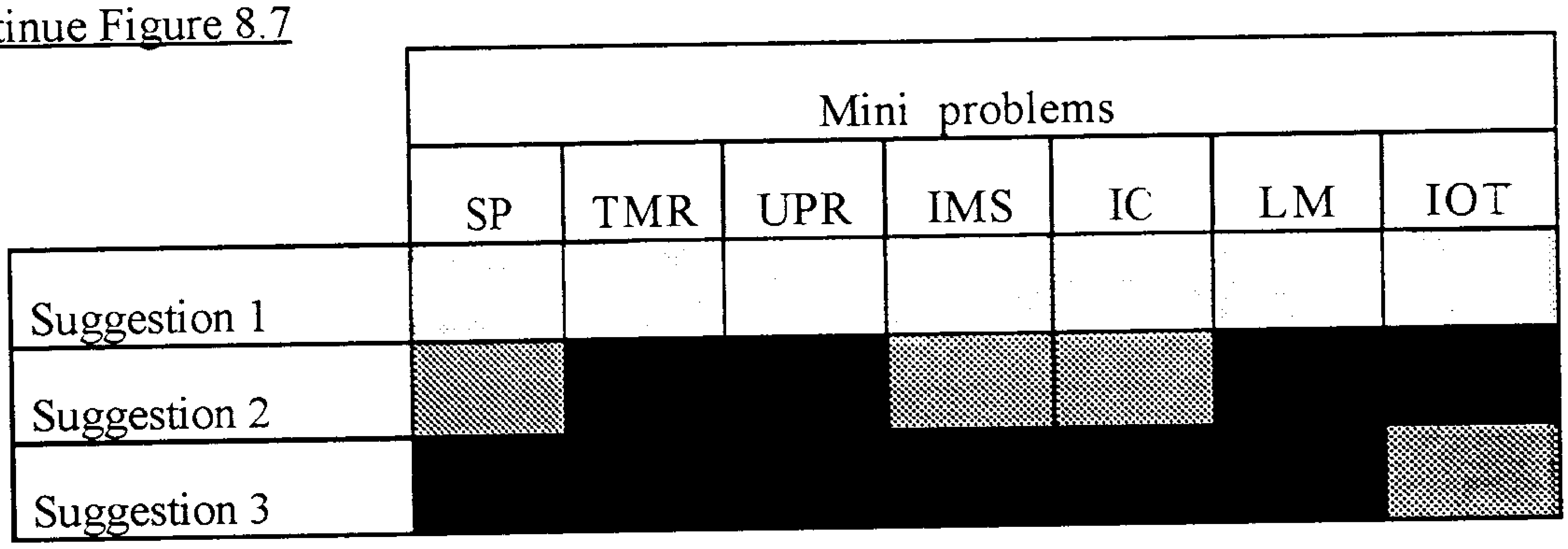


Figure 8.7: Pattern of the clients ranking on permanent corrective actions for the critical factors

Continue Figure 8.7



The second method of validating the sequence of the approach was by using the overall mean value determined by averaging the mean values of all the factors for both groups of respondents. The overall mean values for the first, second and third are 3.44, 4.28 and 4.56 respectively (see Table 8.20 for the contractors' group). Using the ordinal range of categories (see range of scale below) the calculated mean values for both the respondents groups can be classified and the first suggestion falls under the category of 'average'; the second suggestion is categorised under 'slightly appropriate'; and the third falls under an 'appropriate' category. Both indications, once again, verified that there is a common sequence in deriving the corrective actions for the critical factors. The determination on the overall mean values has validated the sequence of the structured approach thus the objective of establishing this approach has been achieved.

Table 8.20: Overall mean values of respondent groups

	Contractors	Clients
Overall mean value for suggestion 1	3.44	3.28
Overall mean value for suggestion 2	4.28	3.94
Overall mean value for suggestion 3	4.56	3.94

The ordinal range of values for classifying the respondents views are as follows:

$5.50 \leq$ very appropriate ≤ 6.00

$4.50 \leq$ appropriate < 5.50

$3.50 \leq$ slightly appropriate < 4.50

$2.50 \leq$ average < 3.50

$1.50 \leq$ slightly inappropriate < 2.50

$0.50 \leq$ inappropriate < 1.50

$0.00 \leq$ very inappropriate < 0.50

The third and final method used to validate that there is a similar sequence to derive a corrective action, is Kendall's coefficient of concordance, W. This test is carried out in order to check whether there is a significant agreement in the ranking amongst individual factors that verify the agreement in the sequence of deriving the corrective actions. The Kendall's coefficient of concordance, W measures the agreement amongst the NED factors based on the mean values of the respondents. This method has a special application in providing the standard method of ordering entities according to the consensus. Initially, the s value has to be determined using the following formula:

$$s = (R_i - \sum R_i / N)^2$$

where s is the sum of squares of observed deviation from the mean ranking, R_i is the individual ranking while N is the number of entities or judges. The number of entities refer to the number of factors. Table 8.21 shows that the computed value for s is 128 as compared to the critical value of s = 89.8 with a significance value of 0.05. When the s value is less than s critical it proved that there is a significant agreement in the ranking amongst individual factors at a confidence level of 95% and the value of W obtained is 0.28. Hence, this test has proved that the pattern of ranking is in accordance to the sequence of the approach. The pattern of ranking 3, 2 and 1 verified the respondents' approach in deriving a corrective action and the objective of establishing this approach has been achieved.

Table 8.21: Kendall's coefficient of concordance, W

	Respondents average ranking on each factor (contractors)		
	Suggestion 1	Suggestion 2	Suggestion 3
LE	1	2	3
LD	2	3	1
SML	1	2	3
US	1	2	3
PP	3	1	2
IP	3	2	1
IMC	3	2	1
IF	3	2	1
SP	3	2	1
TMR	3	2	1
UPR	3	2	1
IMS	3	2	1
IC	3	2	1
LM	3	2	1
IOT	3	2	1
Ri =	38	30	22
$R_i - \frac{\sum R_i}{N}$,	+8	0	-8
$(R_i - \frac{\sum R_i}{N})^2$	64	0	64

from $S = (R_i - \frac{\sum R_i}{N})^2 = 128$

Hence from $W = \frac{S}{\frac{1}{12}(k)^2\left[N^2 - N\right]}$ =0.28

where k= 15 and N=3.

8.7.3 The permanent corrective actions for critical factors of NED

The objective of conducting the analysis for this sub-section was to determine the most appropriate permanent corrective actions for the critical factors. To achieve this objective ranking method was used and this ranking was determined by the mean values of the suggestions for each critical factors. These mean values were determined (see Table 8.22 to Table 8.36) by averaging the respondents responses on individual suggestion. Using these mean values, the ranking of corrective actions for each factors can be deduced. If the corrective action is ranked number 1 then it indicates that it is the least appropriate, and number 3 indicates the most appropriate corrective actions. Table 8.22 to Table 8.36 show the mean values and ranking of corrective actions for both respondent groups. The results are then summarised in Table 8.37 which shows the list of appropriate corrective actions for the critical factors based on the contractors response. The contractors' response was considered on the basis of their direct experience in handling these issues and the clients data was used to verify their response. The objective of establishing the permanent corrective actions for the critical factors has been achieved and Table 8.37 shows the permanent corrective actions which can be considered by the site managers. The statement of suggestions for Tables 8.22 to 8.36 please refer to section D of the main questionnaire (see Appendix III).

Table 8.22: The ranking of corrective actions for 'lack of experience'

Lack of Experience	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	4.44	5.20	1	1
2) Suggestion number two	4.33	5.00	2	2
3) Suggestion number three	4.30	3.60	3	3

Table 8.23: The ranking of corrective actions for 'late delivery'

Late Delivery (materials and equipment)	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	3.96	4.40	2	1
2) Suggestion number two	3.81	3.00	3	3
3) Suggestion number three	4.11	3.40	1	2

Table 8.24: The ranking of corrective actions for 'slow mobilisation of labour'

Slow mobilisation of labour	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	3.74	2.20	1	1
2) Suggestion number two	2.89	2.20	2	1
3) Suggestion number three	2.78	2.00	3	3

Table 8.25: The ranking of corrective actions for 'unreliable supplier/sub-contractors'

Unreliable supplier/sub contractor	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	4.44	5.20	1	1
2) Suggestion number two	4.33	5.00	2	2
3) Suggestion number three	4.30	3.60	3	3

Table 8.26: The ranking of corrective actions for poor planning

Poor planning	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	3.89	3.60	3	3
2) Suggestion number two	4.63	4.75	1	1
3) Suggestion number three	4.44	4.25	2	2

Table 8.27: The ranking of corrective actions for inappropriate practice/procedure

Inappropriate practice/procedure	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
a) Suggestion number one	3.19	3.75	3	2
b) Suggestion number two	4.07	3.75	2	2
c) Suggestion number three	4.85	4.50	1	1

Table 8.28: The ranking of corrective actions for inefficient monitoring and control

Inefficient monitoring and control	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	3.93	3.40	3	2
2) Suggestion number two	4.78	3.60	2	1
3) Suggestion number three	4.96	3.60	1	1

Table 8.29: The ranking of corrective actions for inadequate allocation

Inadequate allocation	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	3.04	2.20	3	3
2) Suggestion number two	3.59	3.20	2	1
3) Suggestion number three	4.07	3.00	1	2

Table 8.30: The ranking of corrective actions for shortage of personnel

Shortage of personnel	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	3.30	3.80	3	3
2) Suggestion number two	4.37	4.40	2	2
3) Suggestion number three	5.04	4.80	1	1

Table 8.31: The ranking of corrective actions for too many responsibilities

Too many responsibilities	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	3.74	4.00	3	3
2) Suggestion number two	4.69	4.80	2	1
3) Suggestion number three	4.73	4.80	1	1

Table 8.32: The ranking of corrective actions for unavailability of proper resources

Unavailability of proper resources	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	3.52	3.00	3	3
2) Suggestion number two	4.26	3.80	2	1
3) Suggestion number three	4.48	3.80	1	1

Table 8.33: The ranking of corrective actions for inappropriate method statement

Inappropriate method statement	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	3.15	3.25	3	3
2) Suggestion number two	4.56	4.00	2	2
3) Suggestion number three	5.11	5.00	1	1

Table 8.34: The ranking of corrective actions for inefficient communication

Inefficient communication	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	2.67	2.60	3	3
2) Suggestion number two	4.56	4.00	2	2
3) Suggestion number three	5.19	4.80	1	1

Table 8.35: The ranking of corrective actions for low morale/motivation

Low morale/motivation	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	2.26	1.60	3	3
2) Suggestion number two	4.74	4.40	2	1
3) Suggestion number three	5.37	4.40	1	1

Table 8.36: The ranking of corrective actions for interference with other trades

Interference with other trades	Contractors' mean	Clients' mean	Contractors' mean	Clients' mean
1) Suggestion number one	2.59	2.20	3	3
2) Suggestion number two	5.11	4.60	2	1
3) Suggestion number three	5.41	4.40	1	2

Table 8.37: List of permanent corrective actions

Critical factors of NED	Permanent corrective actions
1) Lack of experience	Engaging additional experienced personnel would minimise the impact but may influence the budgeted cost.
2) Late delivery (materials and equipment)	The general perception is that a penalty clause stipulated by the contractor for late delivery would minimise the occurrence of late delivery
3) Slow mobilisation of labour	Engaging additional resources to ensure workers arrive on time would minimise the impact but may influence the budgeted cost
4) Unreliable supplier/sub-contractor	Replacing with an alternative supplier/sub contractor but may influence the budgeted cost and time
5) Poor planning	Ideally sharing the knowledge and experience of QS, planning engineer, temporary work designer and site personnel within the organisation would minimise poor planning
6) Inappropriate practice/procedure	The general perception is that benchmarking and constantly improving the practice/procedure will minimise the impact of inappropriate practice/ procedure
7) Inefficient monitoring and control	The general perception is systematic monitoring and control taking into consideration the accuracy, short regular interval, effective feedback and standard procedure will minimise inefficient monitoring and control
8) Inadequate fund	The general perception is to carry out a rigorous cash flow analysis and provide the fund accordingly which will minimise shortage of fund
9) Shortage of personnel	The general perception is to use proper personnel planning and provide accordingly will minimise the shortages
10) Too many responsibilities	The general perception is to identify individual capability and carefully plan personnel job function benchmarks with another similar project will avoid assigning too many responsibilities

Continue Table 8.37

11) Unavailability of proper resources	The general perception is to conduct an appropriate training session which will enrich the pool of resources
12) Inappropriate method statement	The general perception is to plan, discuss and audit the method statement before implementation hence avoiding an inappropriate method statement
13) Inefficient communication	The general perception is to provide a clear and concise communication channel within the organisation which will minimise the communication inefficiencies
14) Low morale/ motivation	The general perception is to improve the job satisfaction along with incentive scheme; safety and health; psychological need; and status which will improve morale/motivation
15) Interference with other trades	The general perception is to conduct a regular co-ordination meeting which will minimise the interference

8.8 SUMMARY

(1) A 26 percent response rate was achieved even though the length of the questionnaire was beyond the norm. This comprised of eight respondents from the UK Top 100 contractors and twenty seven from the European Construction Institute (ECI) member companies. A total number of 35 returned questionnaire were used to validate the findings of this research.

(2) The contractors group selected 'schedule performance' while the clients group selected 'cost performance' as the best indicator to measure contractors performance. These differences may be due to the difference in priority of project objectives for both groups. Although there is no significant agreement in

the ranking the analysis to establish the best indicator to measure contractors performance has been achieved using the ranking analysis on contractors data.

(3) The Spearman's correlation test conducted on twelve groups of causes (as shown in Tables 8.2 to 8.13) highlight that five groups of causes have significant agreement in ranking between both groups of respondents. These include the following groups of causes:

(a) material related delays;

(b) improper planning;

(c) sub-contractor related delays;

(d) inadequate supervision; and

(e) improper construction methods.

The other groups of causes accepted the null hypothesis at a confidence level of 95%. However the ranking analysis has established the factors for each group of causes according to their influence towards contractors schedule performance, even though there is a disagreement in the ranking between both groups of respondents.

(4) The top ranked factors established by the contractors' group include the following:

(a) slow mobilisation of resources;

(b) unreliable supplier/sub-contractors;

(c) poor resources planning; and

(d) unavailability of proper resources.

The statistical test conducted, rejected the null hypothesis and so there is a significant agreement in the ranking between both groups of respondents. A further test was conducted to cross check the contractors own responses using the data of section B(ii) and confirms the ranking for section B(iii). The test conducted shows there is a significant agreement in the ranking between these sections at 95 % confidence level and the objective of establishing the critical factors according to their influence on NED has been achieved using ranking analysis which further confirmed by the Spearman's correlation test.

(5) The most effective quantitative indicators used to identify the twelve critical factors were established using ranking analysis. The mean values for the top ranked indicators are within the range of 3.00 to 4.90 which fall under the categories of 'slightly high' and 'high' for its effectiveness to identify the critical factors. The most effective indicators used to identify the critical factors were 'resources and work schedules' and they were ranked highest by the respondents. These indicators (or tools) can effectively highlight the non-conformance by comparing the actual against planned. The objective to establish the most effective quantitative indicators used to identify the critical factors has been achieved using the ranking analysis.

(6) Three of the fifteen critical factors confirmed by the respondents of the pilot study cannot be identified by the available quantitative indicators. Using the Binomial Probability Test which aim is to prove and validate the outcome of contractor response on whether these factors were assessed by intuitive judgement, has validated that all three factors were assessed intuitively by the contractors group with 95% confidence level. The client group has validated the contractors response on 'too many responsibilities', but 'inefficient communication' and 'low moral/motivation' were not significant to reaffirm the contractor response. Nevertheless the objectives of establishing the critical factors that were assessed by intuitive judgement has been achieved using the Binomial Probability test on contractors data.

(7) An alternative indicator was developed to assess 'communication performance' using the theory of fuzzy logic. The steps of analysis that has been modelled can

be used to asses 'communication performance' of contractors instead of using intuitive judgement of site managers (see Figure 8.4). The example in sub-section 8.6.3 illustrates the assessment of 'communication performance' using two input elements and this illustration shows the ability of this indicator to asses 'communication performance' of contractors that can also assess 'inefficient communication'. The objective was to develop an alternative indicators has been achieved using the theory of Fuzzy Logic and this has been achieved.

(8) Three methods were used to confirm and establish the approach of deriving a corrective action. The methods for validating the approach are as follows:

(a) graphical method;

(b) overall mean values; and

(c) Kendall's coefficient of concordance, W.

All the above methods have successfully proved and validated the approach of deriving permanent corrective actions by site managers.

(9) Table 8.22 to Table 8.36 show the ranking of corrective actions for the critical factors. Each of these Tables indicates the most common permanent corrective actions for these factors and are summarised in Table 8.37 for consideration of site managers. The ranking analysis on contractors data has helped to achieve the objective of establishing the permanent corrective actions for the critical factors.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

9.1 INTRODUCTION

This chapter presents the conclusions on the findings including the contributions of the work to the body of knowledge and lastly the recommendations for further work.

The aim of this research was to investigate and evaluate issues related to the critical factors of non-excusable delays (NED) that influence contractors schedule performance. A holistic approach of investigating issues related to factors of NED led to the establishment of several objectives that helped to achieve the aim of this study and these objectives are presented in Section 1.3.

In an attempt to realise the aim and objectives of this research, a research methodology identified in Section 1.5 which helped to accomplish the issues was investigated. Several essential tasks identified in this methodology which includes:

- literature review;
- discussion with the professionals from the industry;
- pilot survey;
- main survey;
- data analysis; and
- the theory of Fuzzy Logic to develop an indicator to assess 'communication performance'.

Literature review

A comprehensive literature review was conducted that led to the identification and establishment of the following essential information:

(a) a list of records compiling more than 4000 projects that experienced schedule delays (see Table 2.1);

(b) a complex fish bone diagram that shows all the possible factors (or root-causes) under twelve groups of causes that caused NED (see Figure 3.12);

(c) matrix of common NED factors which influence contractors schedule performance (see Table 3.1);

(d) matrix of indicators that were used to identify the common NED factors (see Table 4.1);

(e) several factors amongst common NED factors that were assessed by intuitive judgement (see Table 4.1);

(f) the methods of analysis to validate the findings of the literature and pilot study (see Sections 5.5 and 5.6); and

(g) the short-term corrective actions that usually used by the site managers to improve or recover delays (see section 6.3.3).

Discussion with the Professionals from the industry

Following an extensive literature review a series of discussion were held with the professionals from the Productivity Task Force Committee for the European Construction Institute (see **Appendix IV**) and verifying the issues that need further investigation. The issues related to the factors of NED were discussed amongst the Task Force Committee and further deliberated by two construction managers that were assigned to this project.

Pilot survey

The pilot study was conducted after the completion of designing the pilot questionnaire which had extensive comments from the members of the Task Force

Committee of the European Construction Institute (ECI). Due to the large amount of information to be gathered using a questionnaire that consisted of approximately 266 questions was required, thus led to engaging a two stages pilot study in order to reduce the number of questions to be designed. Also the selection of top fifteen common factors (or known as critical factors of NED) during the first stage helped to reduce the number of questions to be designed for the second stage of pilot study. Eight respondents were involved in the two stages of pilot study which were recommended by the Task Force Committee of ECI. Data collected has confirmed most of the findings from the literature review and for a more detail discussion on pilot study please refer to Section 7.4.1.

Main survey

A main questionnaire (see **Appendix III**) was designed using the findings obtained from the pilot study including the comments from the members of Task Force Committee of ECI. The respondents opinion from the pilot study was also considered and included in the preparation of the main questionnaire. The main questionnaire was mailed to the contracting organisations selected from a list of the ECI member companies (65 companies) and Top 100 UK contractors (75 companies). Data collected from the main survey had validated the findings from the pilot study and a brief explanation on the main survey is discussed in Section 7.4.2.

Data analysis

Data collected from the main survey were used to validate the issues investigated and appropriate analysis methods were used to achieve these objectives. Chapter 8 discuss on the results obtained from the analysis which was organised according to the scheme of the main questionnaire. Conclusions were drawn from these analysis that help to establish the objectives of this research.

The theory of Fuzzy Logic to develop an indicator to assess 'communication performance'

The theory of Fuzzy Logic was used to develop an alternative indicator to assess 'communication performance' and data collected for Section C(iii) of the main questionnaire determined the ranges for the fuzzy input. A more detailed explanation on this development is discussed in sub-section 8.6.3 and the illustration of using the model indicator has shown its ability to assist site managers to assess 'communication performance'.

9.2 CONCLUSIONS

This research reviewed the findings of previous work related to non-excusable delays and identified the issues that warrant further investigation. Section 1.2 briefly discusses the background of the issues involved in this study and Sections 1.3 justifies the need for further investigation. The investigation on issues related to the critical factors of NED using the research methodology explained earlier helped in the establishment of the objectives of this research. From the analysis presented in Chapter 8 using the data collected from 29 contractors and 6 clients, conclusions can be drawn to establish the issues investigated for this research which includes:

(a) the establishment of schedule performance as a best indicator to measure contractors' performance;

(b) the establishment of sixty nine factors for twelve groups of causes relating to NED that influence contractors schedule performance;

(c) the establishment on the ranking of fifteen critical factors according to their impact on NED;

(d) the establishment of the most effective indicators that were used to identify twelve critical factors;

(e) the establishment of three critical factors that were assessed by intuitive judgement;

(f) the development of an indicator to assess 'communication performance' using the Theory of Fuzzy Logic;

(g) the establishment of a structured approach of deriving permanent corrective actions for the critical factors of NED; and

(h) identification of short-term corrective actions for improving delays and establishment of the most appropriate permanent corrective actions to improve the critical factors.

A brief explanation on the conclusions drawn from the above are summarised as follows:

(A) The establishment of schedule performance a best indicator to measure contractors' performance

Several indicators identified from the literature that were used to measure the contractors' performance on site. These indicators which were cited includes:

- schedule performance;
- cost performance;
- quality performance; and
- safety performance.

From the ranking analysis on the contractors' responses (refer to Table 8.1) 'schedule performance' was ranked highest and the clients ranked 'cost performance' highest. Although there was a differences in the respondents opinion which was due to the differences in the priorities of project objectives, the ranking analysis concluded that a best indicator to measure contractors performance was 'schedule performance'. The objective of establishing a best indicator was achieved using the contractors' ranking although the statistical test conducted on both respondents' groups had shown no significant agreement in the ranking. This concludes that a best indicator to measure contractors' performance determined by this study is '**schedule performance**'

(B) the establishment of sixty nine factors for twelve groups of causes relating to NED that influence contractors schedule performance

Twelve groups of causes and sixty nine factors which were identified from the literature review (refer to Section 3.2.3), were tested in the main survey. The results are tabulated in Table 8.2 to Table 8.13 which summarises the mean values and using these values the ranking of the factors within each group of causes were determined. The establishment of sixty nine factors for the twelve groups of causes has led to the validation of the complex fish bone diagram of Figure 3.12 and also the matrix Table 3.1. The ranking of factors for five groups of causes had been reaffirmed by the clients data where there was a significant agreement in the ranking at 95% confidence level and the others had no significant agreement in the ranking between both groups of respondents. Nevertheless, in conclusion the ranking analysis on contractors responses had established sixty nine factors for the twelve groups of causes relating to NED and validated the findings from the literature.

(C) the establishment on the ranking of fifteen critical factors according to their impact on NED

Among twenty five common factors identified and tested in the pilot study only the top fifteen factors (or known as critical factors) were selected based on the pilot respondents ranking. The rational to select fifteen factors was to control the number of questions to be designed for the main survey questionnaire. The main survey respondents ranking on the critical factors which were confirmed during the pilot study were analysed and the results are tabulated in Table 8.14. The results of the ranking analysis had validated the pilot finding and the new ranking was obtained using the contractors data (see Table 8.14) and this new ranking was reaffirmed by the clients response using a statistical test (refer to Section 8.5). The statistical test had proved that there was a significant agreement in the ranking between both groups of respondents at 95% confidence level. In conclusion, both analyses had validated the new ranking of fifteen critical factors according to their impact on NED.

(D) The establishment of the most effective indicators that were used to identify the critical factors

The matrix of indicators (refer to Table 4.1) that were used to identify the common factors was produced from the literature review. Since the investigation was restricted to the critical factors only indicators (refer to Table 4.2) that identify these factors were tested in the main survey. The results of the analysis are tabulated in Table 8.15 and the ranking analysis had established the most effective indicators that were used to identify the critical factors. It was concluded that the 'resources and work schedules' were among the most effective indicators which was confirmed by the contractors' ranking and many factors had the same ranking when compared to the clients' ranking. This conclude that the objective of establishing the most effective indicators that were used to identify the critical factors was achieved by way of ranking (see Table 8.15).

(E) The establishment of three critical factors that were assessed by intuitive judgement

Three of the fifteen critical factors (refer to Table 4.2) identified were assessed by intuitive judgement and these include: 'inefficient communication'; 'too many responsibilities'; and 'low morale/motivation'. The findings from the pilot study was then tested in the main survey and the frequency of responses for both respondents groups are shown in Table 8.16 and Table 8.17. A statistical test was conducted using the Binomial probability method in order to validate that these factors were assessed by intuitive judgement. The analysis (refer to Section 8.6.2) using the contractors' data had proved and validated that all the three factors were assessed by intuitive judgement of site managers at 95% confidence level and the clients responses had reaffirmed on one of them i.e. 'too many responsibilities'. Nevertheless, it can be concluded that all the three critical factors were assessed by intuitive judgement using the contractors frequencies and the objective of establishing them had been achieved.

(F) The development of an indicator to assess 'communication performance' using the theory Fuzzy Logic

Developing an alternative indicator for 'communication performance' which can be used to assess 'inefficient communication' was selected among the three of the critical factors that were evaluated by intuitive judgement and the rationale to develop only one indicator was discussed in sub-section 8.6.3. The theory of fuzzy logic was selected to develop this indicator as it is more suitable to model uncertain or approximate reasoning involving human descriptive or intuitive thinking. A mathematical model would not be suitable when involving approximation and furthermore it can become a complicated representation. An illustration of assessing 'communication performance', using the proposed model indicator (refer to Figure 8.4), is highlighted by an example in sub-section 8.2.4.3. Using two linguistic input values, in which the "communication channel" was 'slightly effective' and "distribution of information" within the organisation was 'effective' had produced a result of 'slightly effective' Communication Performance with a crisp value of 5.78 out of ten scale. The model had illustrated its ability to assess communication performance instead of using the site managers intuitive judgement and this concludes the achievement in developing an indicator to assess 'communication performance' using the theory of Fuzzy Logic.

(G) The establishment of a structured approach of deriving permanent corrective actions for the critical factors of NED

One of the objectives determined for this research was to establish the proposed structured approach of deriving permanent corrective actions (see Figure 4.1). The basis to develop the approach follows three essential steps and is briefly explained in Section 4.8.4. An example of using the approach of deriving a corrective action is shown in sub-section 4.8.6 and the list of corrective actions is highlighted in Section D of the main survey questionnaire.

From the analysis all the three methods (refer to Section 8.7.2) used had validated the structured approach of deriving permanent corrective actions and from this analysis it can be concluded that the proposed structured approach provides a consistency in deriving permanent correctives actions for the critical factors. Hence the objective of establishing a structured approach of deriving correctives actions for the critical factors of NED had been achieved.

(H) Identification of short-term corrective actions for improving delays and establishment of the most appropriate permanent corrective actions to improve the critical factors of NED

The review of the literature had identified the short-term corrective actions that were normally considered by the site managers when the need arises. The short-term measures were not aimed at improving or removing the factors of delays but undertaken to reduce or improve delays. The short-term measures for improving delays identified from the literature review were as follows:

- overtime work;
- additional workers and equipment may be assigned;
- a full-time director may be assigned to push the project through;
- extra effort asked from the employees; and
- if all these fail, the schedule may have to be readjusted, requiring changes along the critical path.

The list of permanent correctives actions for each critical factors is highlighted in Section D of the main questionnaire (see Appendix III) and the results of the analysis are shown in Tables 8.22 to 8.36. A ranking analysis was used to establish the most appropriate permanent corrective actions for the critical factors. The top ranked corrective actions amongst three suggestions for each factors were concluded to be the most appropriate corrective actions. The ranking analysis helped to establish the most appropriate corrective actions and they are tabulated in Table 8.37. These corrective actions which were established from the survey data, provide guidelines for site managers to consider when encountering these factors and also they can be considered as preventive measures for the future projects. The objective of establishing the most appropriate permanent corrective actions for improving the critical factors had been achieved.

From the above mentioned achievements it can be concluded that the aim of this research has been achieved.

9.2.1 Other conclusions

The establishment of an average schedule overruns according to the project types

To establish an average schedule overruns according to the project types is not an objective of this research but the analysis on the respondents data has revealed an essential finding. The results of the finding was tabulated in Table 7.2 which shows the average percentage of schedule overruns according to different projects types. Civil engineering and power supply projects were the highest recorded schedule overruns per project which registered on average 32.1% and 25% respectively. Building works recorded an average of 20% schedule overruns per project and the lowest is Process engineering plants with an average of 9.1% schedule overruns per project. This is an interesting finding obtained from this study and the information may be very useful in estimating the risk of schedule overruns according to types of project. Although only 63% (twenty two out of thirty five) of the respondents that quantify delays it can be considered a good achievement despite the sensitivity of the data requested.

9.3 CONTRIBUTIONS TO THE RESEARCH

More is now known, as the result of this research, about the factors of NED that influence contractors' performance and in particular this research has developed an alternative indicator to intuitive judgement for assessing 'communication performance'. In addition to develop an indicator this work has successfully identified critical factors that can influence contractors' performance during the construction stage and established the contributing factors for each group of causes.

Not only were the critical factors established but also indicators to identify them were determined. Finally, the approach of deriving permanent corrective actions for improving the critical factors and their most appropriate permanent corrective measures were established. Several findings have been established in this research and contractors may used these information which were highlighted in the conclusion section as guidelines for them to monitor and control NED. The proposed process of monitoring and controlling the factors of NED is shown in Figure 6.3.

The significant of this research can, therefore, be viewed in the following areas.

(i) The establishment of a best indicator to measure contractors' performance. The review revealed several performance indicators that were used to measure the contractors performance on site. The contractors' group themselves responded that schedule performance was the best indicator to measure their performance on site and logically to keep the schedule on track can helps to influence other elements especially cost. Hence, it is recommended that the contractors use 'schedule performance indicator' as their top priority over other indicators. This does not enunciate that other indicators are not important to measure the contractor performance on site.

(ii) Development of the complex fish bone diagram (refer to Figure 3.12) using twelve groups of causes along with the establishment of their contributing factors is very significant to the body of knowledge. Highlighting these factors within their groups can reveal the factors that are commonly cited in various groups of causes (refer to Table 3.1). The ranking analysis on the main survey data helped to confirm the relationship between the factors and groups of causes, and thus validated the complex fish bone diagram. More importantly, the identification and establishment of factors within their groups, which indicates significant influence on contractors schedule performance prove to be an essential knowledge to the contractors.

(iii) The establishment of critical factors which had a significant influence on NED had led to greater awareness towards the occurrence of these factors during the construction stage. Establishing their ranking of impact towards non-excusable delays brings an important new knowledge and gives fresh insight into understanding the factors of NED. Perhaps the top fifteen factors (or critical factors) had a significant role in affecting performance and presents a useful information to the knowledge and the professional of the industry.

(iv) The research has established indicators that were used to identify the critical factors thus establishing their relationship. Yates (1993) in a study does not provide the relationship between indicators and factors of delays. Even though the establishment of indicators were limited to the critical factors of NED but this study has also confirmed that a few among these factors were assessed by intuitive judgement of site managers Establishing the indicators to identify the critical factors bring another important new knowledge to the area.

(vi) Apart from establishing quantitative indicators, the most important contribution to the body of knowledge was the development of an alternative indicator to intuitive judgement using the concept of Fuzzy Logic Controller (FLC). The decision to use FLC was based on its appropriateness to model uncertain or approximate reasoning that involved human descriptive or intuitive thinking. Furthermore this domain has been widely applied in adding features for home appliances such as logic washing machine, logic video player, logic hi-fi and many others and it also has been successfully applied to robotics, telecommunication, aerospace, etc. The significance of developing this indicator can provide a standard and consistent assessment on qualitative factor which is difficult to achieve using the intuitive judgement of several site managers who give several different opinions. It is not only consistency that can be achieved but it can also be modelled into a computer which can improve the efficiency of evaluation process. The research has facilitated a new approach in designing indicators that use quantitative and qualitative measures to determine the performance of a factor. The versatility of the approach could encourage others to develop more tools using this concept which can be made available to the site managers.

(vii) The simple structured approach of deriving permanent corrective actions provides a basis that can assist the site managers to refine a selected appropriate permanent corrective action. The structured approach was designed using the theory of inventive problem solving and the significant of this approach was it helps the user to improvise a proposed permanent corrective action. The approach by itself does not derive or formulate a corrective action but merely to assist the site managers in deriving an appropriate permanent corrective action. Not only the establishment of the most appropriate permanent corrective actions for the critical factors but also the structured approach of deriving permanent corrective actions has added to the knowledge in the subject.

(viii) A list of the most appropriate permanent corrective actions (see Table 8.37) for the critical factors was established and it was aimed at improving or removing the critical factors of NED. The most appropriate corrective actions for the critical factors identified added to the knowledge in the subject. In addition to improving or removing the inefficient factors the corrective actions can be adopted as preventive measures for future projects. This information is useful and importance to the site managers for monitoring and controlling the critical factors of NED.

9.4 FURTHER RESEARCH

As a result of the work undertaken the following areas are recommended:

i) The efficiency of processing information using computer technology will significantly improve monitoring and control factors of delays. Information gathered for this study could be used as a database to design a delay analysis programme which can augment the existing planning software. It is recommended that the programme is designed following the approach of monitoring and controlling the factors of delays as discuss in Chapter 6.

ii) Developing a more comprehensive database will increase the versatility of the proposed computerised evaluation model. To achieve this it is recommended that future work includes factors of other types of delays. Also, work can be extended beyond the critical factors considered in this study.

iii) Developing alternative indicators for evaluating qualitative factors using the concept of Fuzzy Logic Controller (FLC) can provide a consistent and standardised assessment as compared to the intuitive judgement of site managers. In addition it can be validated to seek the opinion of the professionals from industry. It is recommended that for future study, more indicators are developed that can help to assess other qualitative factors and this will enrich the tools available for the site manager. The design of indicators using the concept of FLC can be modelled in a computer and thus the efficiency of processing is improved.

iv) The right and accurate information being recorded in any indicator is very vital during the monitoring process. Emphasis on essential information being recorded for a specific indicator can reduce the problem of missing information. Thus correct and accurate information recording helps to improve the effectiveness of monitoring and control during the construction process. It is recommended that a study is conducted to establish the types of information that need to be recorded in a particular indicator. This will help to improve the monitoring and control process.

v) As mentioned earlier, a comprehensive database should include as many factors as possible. It is feasible to establish the corrective actions for other factors which were excluded from this study. The fifth recommendation is to establish a long term strategy or policy which may have been derived from these corrective actions that has been successfully implemented. Many strategies and policies which may have been derived from this process can be used as a benchmark to improve the performance of contractors.

vi) It is recommended to develop indicators which consist of multiple input elements that influence a qualitative factor. A possible method identified to develop such an indicator is to use **genetic algorithm** specifically to help formulate the 'If Then Rules' which become more complicated as the number of elements increase.

vii) It is recommended to determine the essential feature such as selection criteria, for the proposed structured approach and by establishing the criteria that influence the choice of final corrective action may improve the adaptability of the structured approach. The criteria can be established according to their significant influence towards the final corrective actions. In addition the formulation of the practices, procedures, policy, or work methods can be developed based on these corrective actions once they have been successfully implemented.

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APPENDIX I

PILOT SURVEY (First Stage)

ECI

EUROPEAN CONSTRUCTION INSTITUTE

FACTORS OF NON EXCUSABLE DELAYS THAT INFLUENCE CONTRACTORS PERFORMANCE

THE PRODUCTIVITY ON-SITE SUB-GROUP QUESTIONNAIRE
MAY 1996
(First Phase)

Loughborough University

Introduction.

The European Construction Institute (ECI) was established in 1990 and it's main objective is to improve performance of the construction industry. Currently the on-site sub group of Productivity Task Force is investigating the critical factors of non excusable delays (NED) that influence contractors schedule performance. Non excusable delays may be defined as delays that are due to the contractors action or inaction. Examples of some of the factors of NED identified from the literature are slow mobilisation of workers, equipment; poor resources planning; late delivery; poor monitoring and control; and etc.

This questionnaire is part of the research **to investigate and evaluate the factors that influence contractors performance**. The objectives of the research is focused on the **construction phase**. The pilot study will be conducted in **two stages** and the questionnaire is divided into four (4) main sections. The objective is to identify the critical factors at the earlier stage and thus may restrict to between 12 to 14 factors for further evaluation.

For the first stage of the pilot study the questionnaire will consist of section A, B and part of section C. Section A asks for general information, organisation and project data. Section B asks for performance indicators; identification of factors for each of the main categories of NED (a main category of NED is defined as a main cause of NED which comprises several factors); and finally to identify the relative ranking. Section C (i) and C (ii) seeks to identify quantitative and qualitative indicators that identify a potential problem.

The questionnaire for second stage (which is not included in this pilot and will be sent later) will consist of section C (iii) and D. Section C (iii) seeks to develop indicators which may not be available as identified during the first stage of the pilot study. Finally section D seeks to identify the common corrective actions and/ or preventive measures.

The data collected in the survey will be treated as **confidential.**
Please return the completed survey questionnaire using the self addressed enveloped enclosed to:

Department of Civil and Building Engineering,
Loughborough University of Technology,
Loughborough, Leics.,
LE11 3TU, UK.
(Attn: Mr. **Abd. Majid**, M.Zaimi.)

Specific questions regarding the questionnaire should be addressed to Mr. **Abd. Majid**, M.Zaimi. at 01509 263171 Ext. 4133.

Your assistance in completing the questionnaire is very much appreciated. To maintain the consistency in data collection the **same respondent** preferably **site manager or project manager** is required to be involved in both stages of the pilot study.
Do you want a summary of the research finding.

Please circle **Yes 1** **No 2**

Section A.

This section is to obtain project general information; types of organisations; and project data for the study.

(i) General Information.

Company Name			
Company Address			
Contact Name			
Contact Position and Experience (years)			
Contact Phone		Contact Fax	

(ii) Type of Organisation.(Please tick one where appropriate)

Contractor	
Client/Owner	
Consultant	
Supplier	
Others (Please state)	

(iii) Project Data.

Note: Please choose project experiencing schedule delays

Project Type	Budgeted Project Value (£)	Final Project Value (£).	Project Title
Road Works			
Residential			
Services Works			
Commercial Building			
Industrial Building			
Power Plant			
Others (Please state)			

Section B (i).

This sub section is to investigate the contractors performance indicator.

Rate the response that best describes your opinion of the contractor's performance indicators.

Contractor's performance are best measured by	Rating.
1) Schedule performance	
2) Cost performance	
3) Quality performance	
4) Safety performance	
Others (Please state)	

Rating. Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Section B (ii).

This sub section is to identify and establish the relationship of the factors to each categories of the main causes.

Material related delays.

Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Rate the response that best describe your opinion the severity of the following material related delays factors that influence performance.

Factors of material related delays	Rating
1) Unreliable supplier	
2) Damaged materials	
3) Poor quality materials	
4) Poor material planning	
5) Inefficient communication with the supplier	
6) Limited range of supplier	
Other factors (Please state)	

Labour related delays.

Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Rate the response that best describe your opinion of the following labour related delays' factors that influence performance.

Factors of labour related delays	Rating
1) Slow mobilisation of labour	
2) Poor quality workmanship	
3) Poor labour planning	
4) Strike results from contractors' fault/ negligence	
5) Absenteeism	
6) Low morale and motivation	
7) Inefficient communication	
Other factors (Please state)	

Equipment Related Delays.

Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Rate the response that best describe your opinion of the following equipment related delays factors that influence performance.

Factors of equipment related delays	Rating
1) Unreliable supplier	
2) Poor equipment planning	
3) Equipment breakdown	
4) Improper equipment	
5) Inefficient communication	
Other factors (Please state)	

Improper planning.

Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Rate the response that best describe your opinion of the following improper planning factors that influence performance.

Factors of improper planning	Rating
1) Lack of experience	
2) Lack of planning tool to assist the planner	
3) Inappropriate practices i.e. inappropriate planning method	
4) Wrong attitude i.e. find an easy way out	
5) Poor definition of scope	
6) Poor judgement	
Other factors (Please state)	

Financial related delays.

Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Rate the response that best describe your opinion of the following financial related delays' factors that influence performance.

Factors of financial related delays	Rating
1) Poor financial monitoring and control	
2) Poor financial planning	
3) Inadequate fund allocation even with good forecast	
4) Delay payment to the supplier/sub contractor which then subjected to interrupt supply/work	
Other factors (Please state)	

Lack of control.

Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Rate the response that best describe your opinion of the following lack of controls' factors that influence performance.

Factors of lack of control	**Rating**
1) Lack of experience	
2) Inappropriate practices and procedure such as site management practice, quality management procedure and etc.	
3) Attitude - Could not care less attitude	
4) Shortages of site personnel	
5) Low morale/motivation	
6) Poor contract with own sub contractor or supplier	
Other factors (Please state)	

Sub contractor related delays.

Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Rate the response that best describe your opinion of the following sub contractor related delays' factors that influence performance.

Factors of sub contractor related delays	**Rating**
1) Slow mobilisation	
2) Unreliable sub contractor	
3) Poor quality which lead to remedial works	
4) Absenteeism	
5) Poor monitoring and control	
6) Bankruptcy	
7) Interference with other trade	
Other factors (Please state)	

Poor co-ordination.

Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Rate the response that best describe your opinion of the following sub contractor related delays' factors that influence performance.

Factors of poor co-ordination	Rating
1) Lack of experience	
2) Inappropriate practices and procedure	
3) Shortages of personnel	
4) Poor communication skills	
5) Poor contractual requirement	
Other factors (Please state)	

Inadequate supervision.

Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Rate the response that best describe your opinion of the following sub contractor related delays' factors that influence performance.

Factors of inadequate supervision	Rating
1) Lack of experience	
2) Absenteeism	
3) Shortages of personnel	
4) Too many responsibilities	
5) Improper practices or procedure	
6) Attitude - could not care less	
7) Poor planning	
Other factors (Please state)	

Improper construction method.

Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Rate the response that best describe your opinion of the following improper construction methods' factors that influence performance.

Factors of improper construction methods	Rating
1) Lack of experience	
2) Inappropriate practice such as old technology	
3) Inadequate fund allocation (force to use inappropriate method)	
4) Unavailability of proper resources	
5) Wrong method statement	
Other factors (Please state)	

Technical personnel shortages.

Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Rate the response that best describe your opinion of the following technical personnel shortages' factors that influence performance.

Factors of technical personnel shortages	Rating
1) Slow mobilisation	
2) Poor site personnel planning	
3) Absenteeism	
4) Lack of experience	
Other factors (Please state)	

Poor communication.

Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Rate the response that best describe your opinion of the following poor communication's factors that influence performance.

Factors of poor communication	Rating
1) Lack of experience	
2) Lack of communication facilities	
3) Inappropriate practices or procedure	
4) Lack of personnel	
Other factors (Please state)	

Section B (iii)

The objective of this sub section is to investigate the relative impact of the factors under consideration towards schedule performance.

From the below listed, please list in order of significant the impact on NED

Factors of NED	Order of significant	Factors of NED	Order of significant
1 Late delivery/ slow mobilisation		16 Shortages of personnel	
2 Damaged materials		17 Delay payment to supplier/sub contractor	
3 Poor planning		18 Inefficient communication	
4 Equipment break-down		19 Wrong method statement	
5 Improper equipment		20 Unavailability of proper resources	
6 Unreliable supplier/ sub contractor		21 Poor contract	
7 Inadequate fund allocation		22 Interference with other trades	
8 Poor quality		23 Too many responsibilities	
9 Absenteeism		24 Sub contractor bankruptcy	
10 Lack of facilities		25 Low morale/ motivation	
11 Inappropriate practices/procedure.		Others (Please state)	
12 Lack of experience			
13 Attitude			
14 Poor monitoring and control			
15 Strike			

Where **1** is the most significant and **25** is the least significant.

Section C

Indicators such as work schedule, daily report, charts, instruction and others are means to indicate if there is problem arises. Thus the factors identified earlier in section B would require an indicator to distinguish them and act as a sensor. Indicators may be classified into two:
(i) Quantitative indicators - These are indicators which are available such as charts, schedule, daily report and others which are used for monitoring and measuring quantitative factors.
(ii) Qualitative indicators - These type of indicators may not be available but previously managers would used their intuitive judgement and experience to assess qualitative factors.

Section C (i)

Quantitative Indicators.
These are reports/documents/instructions/charts and others that are available for monitoring and measuring.

Rate the response that best describe your opinion of the effectiveness of quantitative indicators used to indicate delays on these projects.

Where 1 = very low, 2 = low, 3 = slightly low, 4 = average.
5 = slightly high, 6 = high, 7 = very high.

Factors of NED delays	Indicators of delays	Rating	Comment
1) Late delivery of materials or equipment.	a) Materials or equipment schedule		
	b) Daily construction record		
	c) Correspondence		
	Others (Please state) 1)		
	2)		
2) Slow mobilisation of labour	a) Manpower schedule		
	b) Manpower report		
	c) Daily construction record		
	Others (Please state) 1)		
	2)		
3) Damaged materials	a) Quality control report		
	b) Inventory report		
	Others (Please state) 1)		
	2)		

4) Equipment breakdown	a) Construction equip-usage report		
	b) Daily construction report		
	Others (Please state) 1)		
	2)		
5) Improper equipment	a).Construction equipment usage record		
	b) Productivity measurement		
	c) Equipment planning		
	d) Daily record		
	Others (Please state) 1)		
	2)		
6) Unreliable supplier	a) Procurement record		
	b) Material supply schedule		
	c) Daily record		
	Others (Please state) 1)		
	2)		
7)Unreliable subcontractors	a) Schedule/progress measurement		
	b) Daily report		
	c) Productivity measurement		
	Others (Please state) 1)		
	2)		
8)Inadequate fund allocation	a) Budget performance		
	b) Variance analysis		
	Others (Please state) 1)		
	2)		
9) Poor quality materials or workmanship	a) Test report		
	b) Quality control report		
	Others (Please state) 1)		
	2)		

10) Absenteeism	a) Daily records		
	b) Time sheet		
	c) Field labour log		
	Others (Please state) 1)		
	2)		
11) Lack of planning facilities	a) Lack planning deliverables		
	Others (Please state) 1)		
	2)		
12)Lack of communication facilities.	a) Lack of communication deliverables		
	Others (Please state) 1)		
	2)		
13) Strike	a) Daily reports		
	b) Time sheet		
	c) Superintendent dairy		
	a) Strike notification		
	Others (Please state) 1)		
	2)		
14) Shortages of personnel	a) manpower planning		
	Others (Please state) 1)		
	2)		
15) Delay payment to supplier or sub contractor.	a) Payment reminder		
	b) Cash flow schedule		
	Others (Please state) 1)		
	2)		
16) Unavailability of proper resources	a) Daily reports/progress measurement		
	b)Productivity measurement		
	c) Resource planning		
	Others (Please state) 1)		
	2)		

17) Interference with other trade	a) Site team meeting		
	b)Daily report		
	c) Contractor's complaint		
	Others (Please state) 1)		
	2)		

Section C (ii).

Qualitative Indicators.
Qualitative factors such as poor planning, lack of experience, poor monitoring and others may need intuitive judgement and manager personnel experience to evaluate them. These type of indicators may not be available as in the form of quantitative indicators. Please indicate whether the following factors could be distinguished by any form of indicators similar to that discuss in **Section C (i)**.

Are delays indicators available for the following factors? *If the assessment on the factors are based on personnel experience or intuitive judgement the indicators are considered NOT available.*

(Please thick the relevant box).

Factors of NED delays	Indicator's availability		If Yes please state
	Yes	No	
1) Poor planning			
2) Inappropriate practices			
3) Inappropriate procedure			
4) Lack of experience			
5) Poor monitoring and control			
6) Inefficient communication			
7) Wrong method statement			
8) Too many responsibilities			
9) Low morale/motivation			
Others (Please state)			

APPENDIX II

PILOT SURVEY (Second Stage)

ECI

EUROPEAN CONSTRUCTION INSTITUTE

FACTORS OF NON EXCUSABLE DELAYS THAT INFLUENCE CONTRACTORS PERFORMANCE

THE PRODUCTIVITY ON-SITE SUB-GROUP QUESTIONNAIRE
AUGUST 1996
(Second Phase)

Loughborough University

SECTION C (iii)

This sub section is to develop qualitative indicator model which may measure the factors quantitatively. In developing the indicators some form of quantitative assessment will be asked from the respondent.

C(iii)-a. Poor Planning

Rate the response that best describe your opinion the criteria that influence poor planning.

Where **rating** **0 = very low,** **1 = low,** **2 = average,** **3 = high,** **4 = very high.**

	Rating
(i) Scheduling experience	
(ii) Timing of critical activities	
(iii) Sequence of critical activities	

Others (*Please state and rate)*

(iv) ________________________________	
(v) ________________________________	

What are the range of quantitative values that best describe your opinion on the followings:

(i) Scheduling experience (Referring to the personnel who prepared the work schedule)

(a) No experience (NE)= _____ year to _____ year.
(b) Less experience (LE)= _____ years to _____ years.
(c) Average experience (AE)= _____ years to _____ years.
(d) Above average experience (AAE)= _____ yr. to _____ yr.
(e) Very experience (VE)= _____ years to _____ years.

(ii)Timing of critical activities

(a) Bad timing (BT)= -_____ % to -_____ %.
(b) Slightly bad timing (SBT)= -_____ % to -_____ %.
(c) Average timing (AT)= -_____ % to -_____ %.
(d) Slightly good timing (SGT)= +_____ % to +_____ %.
(e) Good timing (GT)= +_____ % to +_____ %.
Note: (-,+ *% out of normal timing*).
e.g. Good timing (GT)= +10 % to +15 %. (**positive %** indicate the buffer timing of normal duration and **negative %** is otherwise)

(iii)Sequence of critical activities.

(a) Bad sequence (BS)= _____ % to _____ %.
(b) Slightly bad sequence (SBS)= _____ % to _____ %.
(c) Average sequence (AS)= _____ % to _____ %.
(d) Slightly good sequence (SGS)= _____ % to _____ %.
(e) Good sequence (GS)= _____ % to _____ %.
Note: (*% number of activities out of sequence*).
e.g. Good sequence (GS)= 0 % to 5 %

C(iii)-b. Inappropriate practices/procedure

Rate the response that best describe your opinion the criteria that influence inappropriate practice in working system (specifically to the type of project).

Where **rating** **0 = very low, 1 = low, 2 = average, 3 = high, 4 = very high.**

	Rating
(i) Job specification	
(ii) Work experience	
(iii) Working policies	
Others (*Please state and rate*)	
(iv)________________________	
(v)________________________	

What are the range of quantitative values that best describe your opinion on the followings:

(i) Job specification. *(Where **values** from **0-10** may represent **poor** to **very good**)*

(a) Poor job specification (PJS)=_____to_____
(b) Slightly poor specification (SPS)=______to______
(c) Slightly good specification (SGS)=______to______
(d) Good specification (GS)=______to______
(e) Very good specification (VGS)=______to______

(ii) Work experience (*Where **values** from **0-10** may represent **inappropriate** to very **appropriate***)

(a) Inappropriate experience (IE)=______to______
(b) Slightly inappropriate experience (SIE)=______to______
(c) Slightly appropriate experience (SAP)=______to______
(d) Appropriate experience (AE)=______to______
(e) Very appropriate experience (VAE)=______to______

(iii) Working policies (*Where **values** from **0-10** may represent **rigid** to **very flexible***)

(a) Rigid policies (RP)=______to______
(b) Slightly rigid policies (SRP)=_______to_______
(c) Slightly flexible policies (SLP)=______to_______
(d) Flexible policies (FP)=______to_______
(e) Very flexible (VF)=_______to_______

C(iii)-c. Lack of experience

Rate the response that best describe your opinion the criteria that influence lack of experience (related to site manager).

Where **rating** **0 = very low, 1 = low, 2 = average, 3 = high, 4 = very high.**

	Rating
(i) Project work experience	
(ii) Site manager's experience	
(iii) Site manager's basic qualification	

Others (*Please state and rate*)

(iv) ______________________________ [ ]

C(iii)-d. Poor monitoring

Rate the response that best describe your opinion the criteria that influence poor monitoring and control.

Where **rating** **0 = very low, 1 = low, 2 = average, 3 = high, 4 = very high.**

	Rating
(i) Feedback timing	
(ii) Monitoring interval	
(iii) Processing efficiency	
(iv) Control on resources	

Others (*Please state and rate*)

(v) ______________________________ [ ]

C(iii)-e. Inefficient communication

Rate the response that best describe your opinion the criteria that influence inefficient communication.

Where **rating** **0 = very low, 1 = low, 2 = average, 3 = high, 4 = very high.**

	Rating
(i) Distribution of information to personnel	
(ii) Interpersonal skill	
(iii) Communication channel	

Others (*Please state and rate*)

(iv)______________________________ [ ]

C(iii)-f. Inappropriate method statement

Rate the response that best describe your opinion the criteria that inappropriate method statement.

Where **rating** **0 = very low,** **1 = low,** **2 = average,** **3 = high,** **4 = very high.**

	Rating
(i) Work description	
(ii) Alternative work method	
(iii) Consultation with site personnel	

Others (*Please state and rate*)

(iv)____________________________________ [ ]

C(iii)-g. Too many responsibilities

Rate the response that best describe your opinion the criteria that influence too many responsibilities.

Where **rating** **0 = very low,** **1 = low,** **2 = average,** **3 = high,** **4 = very high.**

	Rating
(i) Comparison with similar project/organisation	
(ii) Ability of individual personnel	
(iii) Assigned work completed on time	

Others (*Please state and state*)

(iv)____________________________________ [ ]

C(iii)-h. Low morale/motivation

Rate the response that best describe your opinion the criteria that influence low morale/motivation.

Where **rating** **0 = very low,** **1 = low,** **2 = average,** **3 = high,** **4 = very high.**

	Rating
(i) Incentive scheme	
(ii) Earning enough to satisfy psychological need, security and status	
(iii) Job satisfaction	

Others (*Please state and rate*)

(iv)____________________________________ [ ]

SECTION D

This section is to investigate the common corrective actions and/or preventive measures to the factors under consideration.

Where **rating** **1 = very inappropriate,** **2 = inappropriate,** **3 = slightly inappropriate,** **4 = average,** **5 = slightly appropriate,** **6 = appropriate,** **7 = very appropriate.**

D(i) Lack of Experience.

Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of lack of experience on delays.

	Rating
Engaging an additional experience personnel would minimise the impact but may influence the budgeted cost.	
Ideally seeking the idea and experience of personnel within the organisation would minimised the impact of lack of experience.	
The general perception is that sharing and discussing within the site team on a particular problems/ issue would reduce the impact of lack of experience.	
Others *(Please state and rate your view in comparison with the above).*	

____

____

D(ii) Late Delivery (materials and equipment).

Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of late delivery on delays.

	Rating
Seeking for an alternative supplier but may influence the materials or equipment cost.	
Ideally the contract clause for delivery may influence the delivery programme.	
The general perception is that a penalty clause stipulated by the contractor for late delivery would minimise the occurrence of late delivery.	
Others (*Please state and rate your view in comparison with the above*).	

____

____

D(iii) Slow mobilisation of labour.

Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of slow mobilisation of labour on delays.

	Rating
Engaging additional resource to ensure workers arrive on time would minimise the impact but may influence the budgeted cost.	
Ideally morning row call and banning late arrival would reduce the occurrence of late arrival.	
The general perception is that barring late workers and morning inspection would minimised the late arrival.	
Others (*Please state and rate your view in comparison with the above*).	

____

____

Where **rating** 1 = **very inappropriate,** 2 = **inappropriate,** 3 = **slightly inappropriate,** 4 = **average,** 5 = **slightly appropriate,** 6 = **appropriate,** 7 = **very appropriate.**

D(iv) Unreliable supplier/sub contractor

Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of unreliable supplier/sub contractor on delays.

	Rating
Replacing with an alternative supplier/sub contractor but may influence the budgeted cost and time.	
Ideally the performance clause would influence the reliability of the supplier.	
The general perception is that a penalty clause stipulated in the contract would govern the reliability and performance of supplier/sub contractor.	
Others (*Please state and rate your view in comparison with the above*). ______________________________ ______________________________	

D(v) Poor planning

Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of poor planning on delays.

	Rating
Engaging an experience planning engineer would influence the budgeted cost.	
Ideally sharing the knowledge and experience of QS, planning engineer, temporary work designer and site personnel within the organisation would minimise poor planning.	
The general perception is that knowledge and experience of QS, planning engineer, temporary work designer to check on activities' timing and sequence would minimise the occurrence of poor planning.	
Others (*Please state and rate your view in comparison with the above*). ______________________________ ______________________________	

D(vi) Inappropriate practice/procedure.

Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of inappropriate practice/procedure on delays.

	Rating
Changing the existing practice/procedure may influence the budgeted cost.	
Ideally improving the existing practice/procedure would mitigate inappropriate practice/procedure.	
The general perception is that benchmarking and constantly improving the practice/procedure will minimise the impact of inappropriate practice/procedure.	
Others (*Please state and rate your view in comparison with the above*). ______________________________ ______________________________	

Where **rating** **1 = very inappropriate,** **2 = inappropriate,**
3 = slightly inappropriate, **4 = average,**
5 = slightly appropriate, **6 = appropriate,**
7 = very appropriate.

D(vii) Inefficient monitoring and control.
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of inefficient monitoring and control on delays.

	Rating
Computerisation would influence the efficiencies in monitoring and control but may influence cost if not taken into consideration.	
Ideally fix and regular interval of monitoring and control will reduce inefficient monitoring and control.	
The general perception is a systematic monitoring and control taking into consideration the accuracy, short regular interval, effective feedback and standard procedure will minimise inefficient monitoring and control.	
Others (*Please state and rate your view in comparison with the above*).	

____

____

D(viii) Inadequate fund allocation.
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of inadequate fund allocation on delays.

	Rating
Increase the fund allocation would influence the cost performance.	
Ideally planned cash flow analysis will influence the fund allocation.	
The general perception is carry out a rigorous cash flow analysis and provide the fund accordingly which will minimise shortage of fund.	
Others (*Please state and rate your view in comparison with the above*).	

____

____

D(ix) Shortage of personnel
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of shortage of personnel on delays.

	Rating
Employing additional personnel would influence the budgeted cost.	
Ideally a proper personnel schedule requirement and engage accordingly would influence the shortage.	
The general perception is a proper personnel planning and provide accordingly will minimise the shortages.	
Others (*Please state and rate your view in comparison with the above*).	

____

____

Where **rating** **1 = very inappropriate,** **2 = inappropriate,**
3 = slightly inappropriate, **4 = average,**
5 = slightly appropriate, **6 = appropriate,**
7 = very appropriate.

D(x) Too many responsibilities
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of too many responsibilities on delays.

	Rating
Engaging an additional personnel will influence the budgeted cost .	
Ideally a proper personnel evaluation and assigned responsibilities accordingly would avoid assigning too many responsibilities.	
The general perception is to identify individual capability and carefully plan personnel job function benchmark with the other similar project will avoid assigning too many responsibilities.	
Others (*Please state and rate your view in comparison with the above*).	

____

____

D(xi) Unavailability of proper resources
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of unavailability of proper resources on delays.

	Rating
Engaging an appropriate resources will influence the budgeted time and cost.	
Ideally conducting a training would increased the pool of resources.	
The general perception is to conduct an appropriate training session which will enrich the pool of resources.	
Others (*Please state and rate your view in comparison with the above*).	

____

____

D(xii) Inappropriate method statement.
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of inappropriate method statement on delays.

	Rating
Engaging an expert advice would influence the budgeted cost.	
Ideally discussing and sharing the experience within the organisation would influence inappropriate method statement.	
The general perception is to plan, discuss and audit the method statement before implementation hence will avoid inappropriate method statement.	
Others (*Please state and rate your view in comparison with the above*).	

____

____

Where **rating** **1 = very inappropriate,** **2 = inappropriate,** **3 = slightly inappropriate,** **4 = average,** **5 = slightly appropriate,** **6 = appropriate,** **7 = very appropriate.**

D(xiii) Inefficient communication
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of inefficient communication on delays.

	Rating
Engaging a communication personnel will influence the budgeted cost.	
Ideally provide a simple communication channel would influence the communication inefficiencies.	
The general perception is to provide a clear and concise communication channel within the organisation will minimised the communication inefficiencies.	
Others (Please state and rate your view in comparison with the above). ______ ______	

D(xiv) Low morale/motivation
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of low morale/motivation on delays.

	Rating
Replacing with the new manpower would influence the rhythm of the existing working system.	
Ideally improve job satisfaction would influence morale/motivation.	
The general perception is to improve the job satisfaction along with incentive scheme; safety and health; psychological need; and status will improve morale/motivation.	
Others (*Please state and rate your view in comparison with the above*). ______ ______	

D(xv) Interference with other trade
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of interference with other trade on delays.

	Rating
Stopping one of the trade would influence the time performance.	
Ideally with a proper planning and co-ordination will reduce the interference.	
The general perception is to conduct a regular co-ordination meeting which will minimise the interference.	
Others (*Please state and rate your view in comparison with the above*). ______ ______	

APPENDIX III

MAIN SURVEY

ECI

EUROPEAN CONSTRUCTION INSTITUTE

FACTORS OF NON EXCUSABLE DELAYS THAT INFLUENCE CONTRACTORS PERFORMANCE

THE PRODUCTIVITY ON-SITE SUB-GROUP QUESTIONNAIRE
OCTEBER 1996

Loughborough University

Introduction.

The European Construction Institute (ECI) was established in 1990 and it's main objective is to improve performance of the construction industry. Currently the on-site sub group of Productivity Task Force is investigating the critical factors of non excusable delays (NED) that influence contractors schedule performance. Non excusable delays may be defined as delays that are due to the contractors action or inaction. Examples of some of the factors of NED identified from the literature are slow mobilisation of workers and equipments; poor resources planning; late delivery; poor monitoring and control; and etc.

This questionnaire is part of the research **to investigate and evaluate the factors that influence contractors performance**. The objectives of the research is focused on the **construction phase**. The questionnaire is divided into four (4) main sections. Section A asks for general information, organisation and project data. Section B asks for performance indicators; identification of factors for each of the main categories of NED (a main category of NED is defined as a main cause of NED which comprises several factors); and finally to identify the relative ranking. Section C (i) and C (ii) seeks to identify quantitative and qualitative indicators that identify a potential problem. While section C (iii) seeks to develop indicators which may not be available as identified during the pilot study. Finally section D seeks to identify the common corrective actions and/ or preventive measures.

The data collected in the survey will be treated as **confidential.**
Please return the completed survey questionnaire using the self addressed enveloped enclosed to:

Department of Civil and Building Engineering,
Loughborough University of Technology,
Loughborough, Leics.,
LE11 3TU, UK.
(Attn: Mr. **Abd. Majid**, M.Zaimi.)

Specific questions regarding the questionnaire should be addressed to Mr. **Abd. Majid**, M.Zaimi. at 01509 263171 Ext. 4133.

Your assistance in completing the questionnaire is very much appreciated. Preferably the **site manager or project manager** is deem appropriate to respond to this questionnaire.

Do you want a summary of the research finding.

Please circle **Yes 1** **No 2**

SECTION A

This section of the questionnaire is to obtain general information; type of organisation; and project data for the study

(i) General information.

Company name and address:____

____

____.

Type of organisation:

(*Please circle the appropriate description*)

Client/owner	1
Contractor	2
Consultant	3
Others	4

If others please specify ____________________

Contact name:____

Contact Position: ____

Contact Phone: ______________________ Contact Fax: ______________________

Number of years you have been in the industry:____________ years.

(ii) Project data

Please choose project that experienced schedule delays.

PROJECT TYPE	**Planned Project Duration (weeks)**	**Final Project Duration (weeks)**
Power Supply		
Process Engineering		
Building Construction		
Civil Engineering		
Others (*Please specify*) ____________________		

SECTION B (i).

This sub section is to investigate the contractors performance indicator.

Rate the response that best describes your opinion of the contractor's performance indicators.

Contractor's performance are best measured by	**Rating**
a) Schedule performance	
b) Cost performance	
c) Quality performance	
d) Safety performance	
Others (*Please state and rate*)	
e) ________________________________	

Where **rating** **1 = very low, 2 = low, 3 = slightly low, 4 = average, 5 = slightly high, 6 = high, 7 = very high.**

SECTION B (ii).

This sub section is to identify and establish the relationship of the factors to each categories of the main causes.

Where **rating** **1 = very low, 2 = low, 3 = slightly low, 4 = average. 5 = slightly high, 6 = high, 7 = very high.**

(a) Material related delays.
Rate the response that best describe your opinion the severity of the following material related delays factors that influence performance.

Factors of material related delays:	**Rating**
a) Late delivery	
b) Unreliable supplier	
c) Damaged materials	
d) Poor quality materials	
e) Poor material planning	
f) Inefficient communication with the supplier	
Other factors (*Please state and rate*)	
g)________________________________	

Where **rating** 1 = very low, 2 = low, 3 = slightly low, 4 = average. 5 = slightly high, 6 = high, 7 = very high.

(b) Labour related delays.
Rate the response that best describe your opinion of the following labour related delays' factors that influence performance.

Factors of labour related delays	**Rating**
a) Slow mobilisation of labour	
b) Poor quality workmanship	
c) Poor labour planning	
d) Strike results from contractors' fault/ negligence	
e) Absenteeism	
f) Low morale and motivation	
g) Inefficient communication	
Other factors (*Please state and rate*)	
h)____________________________________	

(c) Equipment Related Delays.
Rate the response that best describe your opinion of the following equipment related delays factors that influence performance.

Factors of equipment related delays	**Rating**
a) Unreliable supplier	
b) Poor equipment planning	
c) Equipment breakdown	
d) Improper equipment	
e) Inefficient communication	
Other factors (*Please state and rate*)	
f)____________________________________	

(d) Financial related delays.
Rate the response that best describe your opinion of the following financial related delays' factors that influence performance.

Factors of financial related delays	**Rating**
a) Poor financial monitoring and control	
b) Poor financial planning	
c) Inadequate fund allocation even with good forecast	
d) Delay payment to the supplier/sub contractor which then subjected to interrupt supply/work	
Other factors (*Please state and rate*)	
e)____________________________________	

Where **rating** **1 = very low, 2 = low, 3 = slightly low, 4 = average. 5 = slightly high, 6 = high, 7 = very high.**

(e) Improper planning.
Rate the response that best describe your opinion of the following improper planning factors that influence performance.

Factors of improper planning	**Rating**
a) Lack of experience	
b) Lack of planning tool to assist the planner	
c) Inappropriate practices i.e. inappropriate planning method	
d) Wrong attitude i.e. find an easy way out	
e) Poor definition of scope	
f) Poor judgement	
Other factors (*Please state and rate*)	
g)____	

(f) Lack of control.
Rate the response that best describe your opinion of the following lack of controls' factors that influence performance.

Factors of lack of control	**Rating**
a) Lack of experience	
b) Inappropriate practices and procedure such as site management practice, quality management procedure and etc.	
c) Attitude - Could not care less attitude	
d) Shortages of site personnel	
e) Low morale/motivation	
f) Poor contract with own sub contractor or supplier	
Other factors (*Please state and rate*)	
g)____	

(g) Technical personnel shortages.
Rate the response that best describe your opinion of the following technical personnel shortages' factors that influence performance.

Factors of technical personnel shortages	**Rating**
a) Slow mobilisation	
b) Poor site personnel planning	
c) Absenteeism	
d) Lack of experience	
Other factors (*Please state and rate*)	
e)____	

Where **rating** **1 = very low, 2 = low, 3 = slightly low, 4 = average. 5 = slightly high, 6 = high, 7 = very high.**

(h) Sub contractor related delays.
Rate the response that best describe your opinion of the following sub contractor related delays' factors that influence performance.

Factors of sub contractor related delays	**Rating**
a) Slow mobilisation	
b) Unreliable sub contractor	
c) Poor quality which lead to remedial works	
d) Absenteeism	
e) Poor monitoring and control	
f) Bankruptcy	
g) Interference with other trade	
Other factors (*Please state and rate*)	
h)______________________________	

(i) Poor co-ordination.
Rate the response that best describe your opinion of the following sub contractor related delays' factors that influence performance.

Factors of poor co-ordination	**Rating**
a) Lack of experience	
b) Inappropriate practices and procedure	
c) Shortages of personnel	
d) Poor communication skills	
e) Poor contractual requirement	
Other factors (*Please state and rate*)	
f)______________________________	

(j) Poor communication.
Rate the response that best describe your opinion of the following poor communication's factors that influence performance.

Factors of poor communication	**Rating**
a) Lack of experience	
b) Lack of communication facilities	
c) Inappropriate practices or procedure	
d) Lack of personnel	
Other factors (*Please state and rate*)	
e)______________________________	

Where **rating** **1 = very low, 2 = low, 3 = slightly low,**
4 = average. 5 = slightly high, 6 = high,
7 = very high.

(k) Inadequate supervision.

Rate the response that best describe your opinion of the following sub contractor related delays' factors that influence performance.

Factors of inadequate supervision	**Rating**
a) Lack of experience	
b) Absenteeism	
c) Shortages of personnel	
d) Too many responsibilities	
e) Improper practices or procedure	
f) Attitude - could not care less	
g) Poor planning	
Other factors (Please state and rate)	
h)____	

(l) Improper construction method.
Rate the response that best describe your opinion of the following improper construction methods' factors that influence performance.

Factors of improper construction methods	**Rating**
a) Lack of experience	
b) Inappropriate practice such as old technology	
c) Inadequate fund allocation (force to use inappropriate method)	
d) Unavailability of proper resources	
e) Wrong method statement	
Other factors (Please state and rate)	
f)____	

SECTION B (iii)

The objective of this sub section is to investigate the relative impact of the factors under consideration towards schedule performance.

Investigation by the Task Force during the Pilot Stage the following factors were rated in the top fifteen.

From the below listed, please list in order of significant the impact on NED

Where **1** is the **most significant**
15 is the **least significant**.

Factors of Non Excusable Delays	Order of significant
a) Late delivery/slow mobilisation	
b) Poor planning	
c) Poor monitoring and control	
d) Poor contract	
e) Inefficient communication	
f) Unreliable supplier/ sub contractor	
g) Shortages of personnel	
h) Inadequate fund allocation	
i) Unavailability of proper resources	
j) Lack of experience	
k) Inappropriate practices/procedure	
k) Too many responsibilities	
l) Wrong method statement	
m) Low morale/motivation	
n) Interference with other trades	
Others *(Please state and rate)*	

SECTION C

Indicators such as work schedule, daily report, charts, instruction and others are mean to indicate if there is problem arises. Fifteen factors identified earlier in section B(iii) would require an indicator to distinguish them and act as a sensor. Indicators may be classified into two:
(i) Quantitative indicators - These are indicators which are available such as charts, schedule, daily report and others which are used for monitoring and measuring quantitative factors.
(ii) Qualitative indicators - These type of indicators may not be available but previously managers would used their intuitive judgement and experience to assess qualitative factors.

Section C (i)

Quantitative Indicators.
These are reports/documents/instructions/charts and others that are available for monitoring and measuring.

Rate the response that best describe your opinion of the effectiveness of quantitative indicators used to indicate delays on these projects.

Where **rating** **1 = very low, 2 = low, 3 = slightly low, 4 = average 5 = slightly high, 6 = high, 7 = very high.**

Factors of NED delays	Indicators of delays	Rating	Comment
1) Late delivery of materials or equipment.	a) Materials or equipment schedule		
	b) Daily construction record		
	c) Correspondence		
	Others (Please state) 1)		
	2)		
2) Slow mobilisation of labour	a) Manpower schedule		
	b) Manpower report		
	c) Daily construction record		
	Others (Please state) 1)		
	2)		
3) Unreliable supplier	a) Procurement record		
	b) Material supply schedule		
	c) Daily record		
	Others (Please state) 1)		
	2)		
4) Unreliable subcontractors	a) Schedule/progress measurement		
	b) Daily report		
	c) Productivity measurement		
	Others (Please state) 1)		
	2)		
5) Inadequate fund allocation	a) Budget performance		
	b) Variance analysis		

Continue

	Others (Please state) 1)		
	2)		
6) Poor planning	a) Scheduling experience		
	b) Timing of critical activities		
	c) Sequence of critical activities		
	Others (Please state) 1)		
	2)		
7) Inappropriate practice/ procedure	a) Method statement		
	b) Work experience		
	c) Working policy		
	Others (Please state) 1)		
	2)		
8) Lack of experience	a) Reference from previous track records		
	b) Basic qualification		
	Others (Please state) 1)		
	2)		
9) Inappropriate method statement	a) Work descriptions		
	b) Consultation with site personnel		
	c) Alternative work method		
	Others (Please state) 1)		
	2)		
10) Unavailability of proper resources	a) Daily reports/progress measurement		
	b)Productivity measurement		
	c) Resource planning		
	Others (Please state) 1)		
	2)		
11) Shortages of personnel	a) Manpower planning		
	Others (Please state) 1)		
	2)		
12) Interference with other trade	a) Site team meeting		
	b) Daily report		
	c) Contractor's complaint		
	Others (Please state) 1)		
	2)		

SECTION C (ii).

Qualitative Indicators.
It was established that only 3 factors (confirmed during the pilot study) from the top fifteen are classified under qualitative factors where it needs intuitive judgement and manager's own personnel experience to evaluate them. These types of indicators may not be available as in the form of quantitative indicators. Please indicate whether the following factors could be distinguished by any form of indicators similar to that discussed in **Section C (i)**.

Are delays indicators available for the following factors? *If the assessment on the factors are based on personnel experience or intuitive judgement the indicators are considered **NOT** available.*

(Please thick the relevant box).

Factors of NED delays	Indicator's availability		If Yes please state
	Yes	No	
1) Inefficient communication			
2) Too many responsibilities			
3) Low morale/motivation			
Others (Please state)			

SECTION C (iii)

This sub section is to develop qualitative indicator model which may measure the factors quantitatively. In developing the indicators some form of quantitative assessment will be asked from the respondent.

C(iii)-a. Inefficient communication

Rate the response that best describe your opinion the criteria that influence inefficient communication.

Where **rating** **0 = very low,** **1 = low,** **2 = average,**
3 = high, **4 = very high.**

	Rating
(i) Distribution of information to personnel	
(ii) Communication channel	
(iii) Interpersonal skill	

Others (*Please state and rate*)

(iv)________________________________ ☐

*What are the **range of quantitative values** that best describe your opinion on the followings:*

(i) Distribution of information (Where values from **0-10** may represent **inadequate briefing to very adequate briefing**) eg. 0 to 2 may take the range of IB.

(a) Inadequate briefing (IB) = ______ to ______
(b) Slightly inadequate briefing (SIB) = ______ to ______
(c) Slightly adequate briefing (SAB) = ______ to ______
(d) Adequate briefing (AB) = ______ to ______
(e) Very adequate briefing (VAB) = ______ to ______

Continue ques. **C(iii)-a.**

*What are the **range of quantitative values** that best describe your opinion on the followings:*

(ii) Communication channel	(a) Ineffective communication channel (ICC) = ______ to ______
(Where values from	(b) Slightly ineffective communication channel (SICC) = ______ to ______
0-10may represent	(c) Slightly effective communication channel (SECC) = ______ to ______
ineffective to	(d) Effective communication channel (ECC) = ______ to ______
very effective)	(e) Very effective communication channel (VECC) = ______ to ______

(iii) Interpersonal skill	(a) Poor interpersonal skill (PIS) = ______ to ______
(Where values from **0-10** may	(b) Slightly poor interpersonal skill (SPIS) = ______ to ______
represent **poor** to **very good**)	(c) Slightly good interpersonal skill (SGIS) = ______ to ______
	(d) Good interpersonal skill (GIS) = ______ to ______
	(e) Very good interpersonal skill (VGIS) = ______ to ______

C(iii)-b. Too many responsibilities

Rate the response that best describe your opinion the criteria that influence too many responsibilities.

Where **rating** **0 = very low, 1 = low, 2 = average,**
3 = high, 4 = very high.

	Rating
(i) Comparison with similar project/organisation	
(ii) Ability of individual personnel	
(iii) Assigned work completed on time	

Others (*Please state and state*)

(iv)____ [ ]

C(iii)-h. Low morale/motivation

Rate the response that best describe your opinion the criteria that influence low morale/motivation.

Where **rating** **0 = very low, 1 = low, 2 = average,**
3 = high, 4 = very high.

	Rating
(i) Incentive scheme	
(ii) Earning enough to satisfy psychological need, security and status	
(iii) Job satisfaction	

Others (*Please state and rate*)

(iv)____ [ ]

SECTION D

This section is to investigate the common corrective actions and/or preventive measures to the factors under consideration.

Where **rating** 1 = very inappropriate, 2 = inappropriate, 3 = slightly inappropriate, 4 = average, 5 = slightly appropriate, 6 = appropriate, 7 = very appropriate.

D(i) Lack of Experience.
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of lack of experience on delays.

Suggestions	Rating
1) Engaging an additional experience personnel would minimise the impact but may influence the budgeted cost.	
2) Ideally seeking the idea and experience of personnel within the organisation would minimised the impact of lack of experience.	
3) The general perception is that sharing and discussing within the site team on a particular problems/ issue would reduce the impact of lack of experience.	
Others *(Please state and rate your view in comparison with the above).* ______ ______	

D(ii) Late Delivery (materials and equipment).
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of late delivery on delays.

Suggestions	Rating
1) Seeking for an alternative supplier but may influence the materials or equipment cost.	
2) Ideally the contract clause for delivery may influence the delivery programme.	
3) The general perception is that a penalty clause stipulated by the contractor for late delivery would minimise the occurrence of late delivery.	
Others (*Please state and rate your view in comparison with the above*). ______ ______	

D(iii) Slow mobilisation of labour.
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of slow mobilisation of labour on delays.

Suggestions	Rating
1) Engaging additional resource to ensure workers arrive on time would minimise the impact but may influence the budgeted cost.	
2) Ideally morning row call and banning late arrival would reduce the occurrence of late arrival.	
3) The general perception is that barring late workers and morning inspection would minimised the late arrival.	
Others (*Please state and rate your view in comparison with the above*). ______ ______	

Where **rating**	**1 = very inappropriate,**	**2 = inappropriate,**
	3 = slightly inappropriate,	**4 = average,**
	5 = slightly appropriate,	**6 = appropriate,**
	7 = very appropriate.	

D(iv) Unreliable supplier/sub contractor
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of unreliable supplier/sub contractor on delays.

Suggestions **Rating**

1) Replacing with an alternative supplier/sub contractor but may influence the budgeted cost and time. [ ]

2) Ideally the performance clause would influence the reliability of the supplier. [ ]

3) The general perception is that a penalty clause stipulated in the contract would govern the reliability and performance of supplier/sub contractor. [ ]

Others (*Please state and rate your view in comparison with the above*). [ ]

____

____

D(v) Poor planning
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of poor planning on delays.

Suggestions **Rating**

1) Engaging an experience planning engineer would influence the budgeted cost. [ ]

2) Ideally sharing the knowledge and experience of QS, planning engineer, temporary work designer and site personnel within the organisation would minimise poor planning. [ ]

3) The general perception is that knowledge and experience of QS, planning engineer, temporary work designer to check on activities' timing and sequence would minimise the occurrence of poor planning. [ ]

Others (*Please state and rate your view in comparison with the above*). [ ]

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D(vi) Inappropriate practice/procedure.
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of inappropriate practice/procedure on delays.

Suggestions **Rating**

1) Changing the existing practice/procedure may influence the budgeted cost. [ ]

2) Ideally improving the existing practice/procedure would mitigate inappropriate practice/ procedure. [ ]

3) The general perception is that benchmarking and constantly improving the practice/procedure will minimise the impact of inappropriate practice/procedure. [ ]

Others (*Please state and rate your view in comparison with the above*). [ ]

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Where **rating** **1 = very inappropriate,** **2 = inappropriate,** **3 = slightly inappropriate,** **4 = average,** **5 = slightly appropriate,** **6 = appropriate,** **7 = very appropriate.**

D(vii) Inefficient monitoring and control.
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of inefficient monitoring and control on delays.

Suggestions — **Rating**

1) Computerisation would influence the efficiencies in monitoring and control but may influence cost if not taken into consideration. [ ]

2) Ideally fix and regular interval of monitoring and control will reduce inefficient monitoring and control. [ ]

3) The general perception is a systematic monitoring and control taking into consideration the accuracy, short regular interval, effective feedback and standard procedure will minimise inefficient monitoring and control. [ ]

Others (*Please state and rate your view in comparison with the above*). [ ]

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D(viii) Inadequate fund allocation.
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of inadequate fund allocation on delays.

Suggestions — **Rating**

1) Increase the fund allocation would influence the cost performance. [ ]

2) Ideally planned cash flow analysis will influence the fund allocation. [ ]

3) The general perception is carry out a rigorous cash flow analysis and provide the fund accordingly which will minimise shortage of fund. [ ]

Others (*Please state and rate your view in comparison with the above*). [ ]

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D(ix) Shortage of personnel
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of shortage of personnel on delays.

Suggestions — **Rating**

1) Employing additional personnel would influence the budgeted cost. [ ]

2) Ideally a proper personnel schedule requirement and engage accordingly would influence the shortages. [ ]

3) The general perception is a proper personnel planning and provide accordingly will minimise the shortages. [ ]

Others (*Please state and rate your view in comparison with the above*). [ ]

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Where **rating** **1** = **very inappropriate,** 2 = **inappropriate,**
3 = **slightly inappropriate,** 4 = **average,**
5 = **slightly appropriate,** 6 = **appropriate,**
7 = **very appropriate.**

D(x) Too many responsibilities
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of too many responsibilities on delays.

Suggestions	**Rating**
1) Engaging an additional personnel will influence the budgeted cost.	
2) Ideally a proper personnel evaluation and assigned responsibilities accordingly would avoid assigning too many responsibilities.	
3) The general perception is to identify individual capability and carefully plan personnel job function benchmark with the other similar project will avoid assigning too many responsibilities.	
Others (*Please state and rate your view in comparison with the above*).	

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D(xi) Unavailability of proper resources
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of unavailability of proper resources on delays.

Suggestions	**Rating**
1) Engaging an appropriate resources will influence the budgeted time and cost.	
2) Ideally conducting a training would increased the pool of resources.	
3) The general perception is to conduct an appropriate training session which will enrich the pool of resources.	
Others (*Please state and rate your view in comparison with the above*).	

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D(xii) Inappropriate method statement.
Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of inappropriate method statement on delays.

Suggestions	**Rating**
1) Engaging an expert advice would influence the budgeted cost.	
2) Ideally discussing and sharing the experience within the organisation would influence inappropriate method statement.	
3) The general perception is to plan, discuss and audit the method statement before implementation hence will avoid inappropriate method statement.	
Others (*Please state and rate your view in comparison with the above*).	

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Where rating 1 = very inappropriate, 2 = inappropriate,
3 = slightly inappropriate, 4 = average,
5 = slightly appropriate, 6 = appropriate,
7 = very appropriate.

D(xiii) Inefficient communication

Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of inefficient communication on delays.

Suggestions **Rating**

1) Engaging a communication personnel will influence the budgeted cost. [ ]

2) Ideally provide a simple communication channel would influence the communication inefficiencies. [ ]

3) The general perception is to provide a clear and concise communication channel within the organisation will minimised the communication inefficiencies. [ ]

Others (Please state and rate your view in comparison with the above). [ ]

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D(xiv) Low morale/motivation

Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of low morale/motivation on delays.

Suggestions **Rating**

1) Replacing with the new manpower would influence the rhythm of the existing working system. [ ]

2) Ideally improve job satisfaction would influence morale/motivation. [ ]

3) The general perception is to improve the job satisfaction along with incentive scheme; safety and health; psychological need; and status will improve morale/motivation. [ ]

Others (*Please state and rate your view in comparison with the above*). [ ]

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D(xv) Interference with other trade

Please rate the response that best describe an appropriate corrective actions and/or preventive measures that could minimise the impact of interference with other trade on delays.

Suggestions **Rating**

1) Stopping one of the trade would influence the time performance. [ ]

2) Ideally with a proper planning and co-ordination will reduce the interference. [ ]

3) The general perception is to conduct a regular co-ordination meeting which will minimise the interference. [ ]

Others (*Please state and rate your view in comparison with the above*). [ ]

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Thank you for responding.

APPENDIX IV

THE PRODUCTIVITY TASK FORCE OF THE EUROPEAN CONSTRUCTION INSTITUTE

(1) Christopher Brown (Chairman)	-PMMS Consultancy Groups
(2) David Fisher	- Stone and Webster, UK
(3) Barry Dunn	- Brown and Root, UK
(4) Ian Knight	- Stone and Webster, UK
(5) Steve Tarr	- Balfour Beaty, UK
(6) JH Garven	- Stone and Webster, UK
(7) Peter Rimmer	- HVCA
(8) JP De Bock	- CFE
(9) Ivor William	- European Construction Institute, ECI
(10) ADF Price	- Loughborough University, UK
(11) Paul Olomoloiyie	- University of Wolverhampton, UK
(12) MZ Abd. Majid	- Loughborough University, UK