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An Investigation Into the Impact Of Quality Management Systems Upon Construction Productivity At The Site Level

By

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Dedication

This thesis is dedicated to the memory of my honourable late brother:

Elfatih Eltigani

who died on March 17th 1995

With the utmost love and everlasting gratitute.

May he rest in the perpetual peace and tranquility of Paradise

Author's Publications:

The following publications, some of which are presented in international forums as well as included in their proceedings, are derived from this research work. They indicate different stages of the research progress and disseminate the various results achieved.

(1) **Eltigani, H., Cornick, T. and Mcabe, S., (1993).** *"Quality and Productivity Change and Improvement Through Quality Management Systems in Construction": American Society for Quality Control.* First International Conference, October 6-9 (1993), Sandiego, California.

(2) **Eltigani, H. and Langford, D., (1994).** *"An Investigation Into The Impact of Quality Management Systems Based Upon BS 5750 Upon Site Productivity".* Proceedings Of The Eureka Conference In Norway, June (1994).

(3) **Eltigani, H. and Langford, D.** *"Formal Quality Management Systems and Site Productivity of House-Building Contractors".* Summary of Ph.D. Work to be Published in the Journal of the Scottish Federation of Building Employers; August (1995).

(4) **Djebrani, R. and Eltigani, H.** *"Achieving Quality and Productivity in Building Sites".* To be Published in Property Management Journal, Dec. (1995).

(5) **Eltigani, H. and Langford, D.** *"An Assessment Of The Impact Of Quality Management Systems Upon The Managerially Controllable Factors That Are Found To Influence Site Productivity".* To Be Published At CIB Conference In Glasgow, Sept. (1996).

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Abstract

This study is concerned with an investigation into the impact of Quality Management systems upon construction productivity. The main aim of the study was to establish a relationship between the implementation of formal quality systems and improvement in productivity at the site level.

The main objectives of the study are: to compare the construction productivity at the site level of organisations with formal quality systems as well as those without, to identify and categorise the key factors influencing productivity and to assess the impact, if any, of formal quality systems upon postive control of these factors.

The surrogate measure used in the assessment of productivity is Total Factor Productivity (TFP) and the methodology used in comparing the productivity level of different projects was the construction of the isoquant diagram and hence identifying the productive frontier. Assessment of the impact of formal quality management systems upon productivity variables was carried out through questionnaires followed by interviews with practitioners at the forefront of the quality management movement.

Results of the analysis of data of the first phase of the study pointed towards accepting the hypothesis that there is relationship between the implementation of formal quality systems and improvement in the productivity level achieved by different organisations.

The percentage of projects present on the productive frontier were 71% completed with formal systems, compared to 29% with non-formal ones.

The second phase of the investigation showed that productivity improvement is a function of a set of managerially controllable variables (MCVs) and that the improvement in productivity is dependent on the nature of management of these variables. Moreover, it was also revealed that the implementation of formal quality systems lead to better management of those MCVs that determine productivity.

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Chapter ❶

Introduction to the Research Problem and Historical Background

This thesis investigates the impact of the implementation of formal quality management systems upon construction productivity at the production (site) level. To understand the subject a fundamental view of quality management is briefly discussed.

This ***chapter*** introduces the main issues in general terms and also sets out the research problem, aim and objectives and the organisation of the thesis. A brief historical background is also given.

❶.1 *BACKGROUND*

Attainment of acceptable levels of quality in the construction industry has long been a problem and great expenditures of time, money and resources, both human and material are wasted because of nonexistent quality management procedures (Rounds & Chi, 1985).

The effective management of quality and productivity, defined within the Japanese concept of quality management, is largely credited as the catalyst behind the Japanese industry's extraordinary improvements in quality and simultaneous reductions in costs since 1950 (Aubrey & Felkins, 1988).

The foundation of the Japanese concept of quality management (known as Total Quality Control) is rooted in the teachings of two American experts Drs. Deming and Juran (Burati *et al.*, 1991). Deming (1986) stressed that 85% of the problems encountered in manufacturing are within the process and that statistics can be used to control that process.

The focus of his philosophy is that quality cannot be inspected into a the project, whether it is an automobile or a building, and that management must concentrate on improving the process.

Juran stressed the importance of training and hands-on leadership by top management in order for quality improvements to be achieved (Juran, 1988).

❶.2 *THE LINK BETWEEN QUALITY AND PRODUCTIVITY*

The link between quality and productivity has been strongly emphasised by notable quality experts such as Dr. Deming. He states in his famous book **"Out of Crisis"** (Deming, 1986): "*..Improve quality, you automatically improve productivity, you capture market with lower price and better quality. You stay in business, and you provide jobs. So simple".*

This message has been taken to heart by industrial leaders in Japan in their effort to improve their quality and productivity simultaneously despite the traditional beliefs surrounding the two concepts.

However, the traditional view that there exists a trade off between quality and productivity is strongly rejected by quality management experts who argue that the strategic aim of any successful quality management system is to raise standards and the same time reduce the production cost (Crosby, 1979).

The traditional belief can only hold if the quality improvement effort is by hiring more inspectors and thus hold the production line (which is exactly the opposite to what is actually advocated by quality management theorists). Obviously in such a way productivity will suffer. But, in line with the quality management philosophy, it may be suggested that the correlation between quality and productivity makes strong sense and especially so when slogans such as doing things "right first time" are taken into account. Because if things are done **right first time,** this can only mean less scrap and waste level and less machine utilisation, less labour time and this has to contribute to productivity improvement in one way or another.

❶.3 *THE RESEARCH PROBLEM*

The principles of quality management have been the subject of wide debate and received a great deal of attention in the UK construction industry. As opposed to the Japanese experience which started voluntarily by their industries and first and foremost taught the **people** about the advantages of implementing such strategic a tool of management, the UK experience was somewhat different and was **procedures** driven. After a government white paper in 1982, the government as well as most clients required construction companies to adopt quality management systems based upon the quality standard of BS 5750. In response to such forcible implementation of quality management, people were forced down a certification route (Ashford, 1989). Moreover, under the pressure of getting the right certificate (to qualify for jobs or please their clients) most companies did not reap the fruits of the quality systems in the same way as their Japanese counterparts (Duncan *et al.*, 1990).

Furthermore, the contributions to the quality management debate lacked the empirical evidence as to its efficacy. Moreover, most practitioners in the industry perceive of the quality management systems as **office procedures** with little relevance to actual production or site work (perception established from preliminary interviews carried out by the author). These two factors instigated this study and predisposed the author towards seeking empirical evidence as to the efficacy of formal quality management systems in the UK construction industry and also seek to investigate the impact, if any, of formal quality management systems upon productivity of construction organisations at the production or site level.

Therefore, the study has the following as its main aim and objectives:

❶.4 *AIM AND OBJECTIVES OF THE STUDY*

The aim of this research is to assess the impact of the implementation of quality management systems upon construction productivity at the site level.

❶.4.1 OBJECTIVES OF THE STUDY

1. To critically review the philosophy as well as the practice of Quality Management Systems (QMS) with the intention of developing a working definition for what is meant by quality in a construction management sense.
2. To compare and contrast the productivity of construction projects completed by quality management organisations and those by non-quality management ones with the intention of creating a model in which a productivity frontier may be defined.
3. To identify the key variables influencing construction productivity and categorise them under those which could be positively controlled by management action (internal factors) and those which lie beyond the realm of management control (external factors).
4. Assess the impact of the quality management system, as a management system, upon the factors identified in (3) to see whether or not the implementation of QMS can positively control the managerially controllable productivity variables (MCVs).
5. Draw conclusions as to whether or not the implementation of QMS can lead to better productivity at the site level.

❶.5 *RESEARCH QUESTIONS AND WORKING HYPOTHESES*

The central question raised by this study: does the implementation of formal quality management systems lead to improvement in construction productivity?

This question leads to the formulation of the first working hypothesis as follows:

❶.5.1 HYPOTHESIS ①

There is a relationship between the implementation of formal quality management systems based upon BS 5750 and improvement in productivity at the site level.

The second main hypothesis is also related to the impact of quality management upon productivity. It is centred around the fact that if productivity improvement were to be determined through a set of improvement factors, then the impact of quality management upon these improvement factors determines productivity improvement. In other words, the nature of management of these improvement factors can determine whether or not productivity is likely to improve.

The second hypothesis reads as follows:

❶.5.2 HYPOTHESIS ②

The implementation of formal quality management systems leads to improvement in construction productivity through better management of a set of improvement factors (productivity factors).

Hypothesis ② has been sub-divided into more sub-hypotheses which will contribute to the support or rejection of the main hypothesis. The sub-hypotheses also define in turn, the productivity factors referred to in hypothesis ②.

Sub-hypothesis ②.1

Productivity improvement is a function of a set of variables that influence it and may be controlled by management.

Sub-hypothesis ②.2

The implementation of a formal Quality Management System (QMS) *leads to better management of resources at construction sites.*

This sub-hypothesis is further subdivided into three more sub-hypotheses as follows:

***Sub-hypothesis* ②.2.1**
The implementation of formal QMS *leads to better management of labour.*

***Sub-hypothesis* ②.2.2**
The implementation of formal QMS *leads to better management of materials.*

***Sub-hypothesis* ②.2.3**
The implementation of formal QMS *leads to better management of plant.*

***Sub-hypothesis* ②.3**
The implementation of formal QMS *leads to better management of information of the project.*

***Sub-hypothesis* ②.4**
The implementation of QMS *leads to better design and management of the projects organisation structure.*

***Sub-hypothesis* ②.5**
The implementation of formal QMS *leads to better management of training of personnel and operatives.*

***Sub-hypothesis* ②.6**
The implementation of QMS *leads to better management of motivation of workers.*

❶.6 *OUTLINE OF THE THESIS*

The *Chapters* of the study are organised in the following manner:

Chapter* ❷** This ***chapter of the study is intended to give an overview of quality management in general, reviewing the experts' opinions on its management as well as developing a working definition of what is actually meant by quality in a construction setting. The ***chapter***

concludes with advancing an argument about the efficacy of formal quality management systems in the construction industry.

***Chapter* ❸** Is concerned with the issue of productivity, highlighting its concepts, methods of measurement and ending with the development of a working definition of productivity and a surrogate measure to be used by the study.

***Chapter* ❹** This part of the thesis deals with the factors influencing construction productivity as defined in the literature. These productivity factors, after having been identified, have been categorised into two main categories: **external factors** and **internal factors.** The external factors are those productivity factors which do influence productivity but lie beyond the realm of site management control; for example, the economic environment and the physical environment. On the other hand, the internal factors are those influencing productivity and are under the control of site management action. These internal factors have been divided into five main variables defined as **"Managerially Controllable Variables"** or MCVs for short. It should be emphasised that the management level referred to in this thesis is the management at the site level and not the management issue as a whole. Therefore, the external factors are assumed to lie beyond the realm of site management control. However, it is fully accepted that these factors can be managed by management actions at higher levels such as the company, the industry or the national level (see **section ❹.3.5** for fuller discussion on how management can influence the external factors, i.e. both the physical and economic environment).

***Chapter* ❺** In this *chapter* the link between quality and productivity is investigated philosophically. An argument is presented for the existence of such a link and why it should be strengthened to bring together the two themes.

Chapter ❻ This *chapter* describes the research model and methodology. An attempt was made to clearly mark the research territory and describe in detail how the study was designed and carried out.

Chapter ❼ This *chapter* is concerned with the results of the analysis of data, discussion of results, testing of hypotheses and the main findings of the study.

Chapter ❽ Finally, the main conclusions and implications of the study are presented along with the practical implications of the findings. Suggestions for future studies as well as how a replication work should be carried out are also included in the *chapter.*

The following *section* (❶.7) is devoted to giving a historical background highlighting the evolution of quality control, quality definition, measurement, and other major facets related to quality.

❶.7 *HISTORICAL BACKGROUND*

The development of Quality Control (QC) methods in most industries owes its existence to the development of craft skills and knowledge. The craftsmanship was passed on from father to son over generations. Subsequently, the quality of work was always under the direct control of the craftsman. This meant that the definition of good quality products had to fit the master's criteria or definition.

The small production units prior to the Industrial Revolution had progressed to grew during the industrial revolution into larger production units. Thus bigger factories were needed and subsequently bigger buildings to house the ever-increasing work-force.

Production methods changed dramatically during the industrial revolution, and subsequently the old quality control procedures soon became out of date. Therefore, larger tasks needed to be broken down into smaller ones, with each craftsman supervising only part of the entire production process (Feigenbaum, 1986). This led to the development of the formal structuring of the organisation which gave rise to the new coordination techniques. Thus the craftsmen became inspectors, merely involved in the supervising and inspecting of a larger domain of the production process. This escalated the quality problem and caused it to multiply.

The new methods of mass production gave rise to the formal quality control method by inspection. This stage was described by Feigenbaum (1986) as the **Foreman Quality Control (FQC)** which was developed between the end of the nineteenth century and the beginning of the twentieth century. In this method a large unit of workers performed similar tasks and worked under the supervision of a single foreman who assumed responsibility for the quality of their work.

As organisations grew larger and larger, more and more managers, inspectors and accountants were needed to control and coordinate the work-force. However, this did not ease the quality problems which were found to cause loss of profit due to rejects, re-work and scraps.

❶.8 *POST INDUSTRIAL REVOLUTION*

Many theories appeared at the beginning of the twentieth century to improve productivity (not quality). Some worked on the psychology at work and work motivation, while others worked on perfecting techniques on the production aspect at work such as statistical, optimisation and operational research techniques.

One of the early pioneers of management practice in the beginning of the century was **Frederick W Taylor,** often referred to as 'the father of scientific management' whose work separated the planning of work activities from the actual job it self. This was justified at the time due to shortages in an educated labour force.

The planning was done by specialised engineers and planners leaving the site foremen and workmen to meet the standards of the day's work. Controlling techniques of hiring and firing foremen if work was unsatisfactory were in place. Taylor's approach resulted in substantial increase in productivity. Following Taylor's success, production methods based on his approach became and remained the normal standard in the West (Juran *et al.*, 1974).

During WWI, the demand for increased production processes was amplified and subsequently the job of full-time inspector first appeared on the scene. This led to the origination of inspection quality control, (Dale & Oakland, 1991).

Inspection quality control advanced during WW II to promote yet another phase in quality improvements, through the use of **Statistical Quality Control (SQC).** SQC provided an objective assessment of the quality of a product by examining a sample from a batch rather than a 100% inspection. However, the disadvantage brought about by SQC to organisations was that, quality became a specialised responsibility of a small department within each organisation run by technocrats described as **quality control managers.** Although by using SQC, the quality of output was improved and cost of warranty was reduced, the quality of the production process itself often caused much scrap, re-work and waste (Feigenbaum, 1986). To remedy this condition, emphasis was placed on the quality of the production process. Thus organisations (particularly in Japan in the 1960s) began to introduce the concept of Total Quality Control (TQC). This shifted the responsibility of quality control, from its current position with the technical staff in the organisation, to the responsibility of the strategic managers.

With the success of the Japanese in using TQC and other emphases on the management of quality, quality began to emerge as the single strategic issue of the 1980's. From then onwards, quality was no longer taken as a separate entity but as an all embracing management system. This led to the development of TQC organisations, which later became Total Quality Management, (TQM) and strategic quality management (see later).

❶.9 *DEFINING QUALITY*

What is quality?

It is difficult to find a single all-embracing definition for quality, simply because it means different things to different people. This difficulty in defining quality may be the main reason behind the ignorance which surrounded the subject for many years in the past. Pirsig (1979) points out this difficulty in defining quality by admitting that there is such a thing as quality, but as he puts it *"as soon as any one tries to define it, something goes haywire"*. He also asserted that even though quality cannot be defined, any one knows what is it.

On the other hand, Garvin (1988) gives a contrasting view in his description of the difficulties associated with defining quality. He argued that quality is an unusually slippery concept, easy to visualise and yet exasperatingly difficult to define. As put by Garvin you *"know quality when you see it"*.

Moreover, Garvin (1988) also expresses the difficulty associated with defining quality by comparing it with constructs such as politics, sex or religion. He explains that it is something that everyone understands, and is convinced that he does correctly but few would attempt to define it. Furthermore, Biggar (1990) put his view to this effect by asserting that defining quality is like catching a ghost, every time you think you have caught it, it slips through your very fingers.

Some of the most common definitions given to quality are listed in the following section:

Juran & Gryna (1980) defines quality as *"quality means fitness for use"*. Peters & Austin (1985): *"quality, above all, is about care, people, passion, eyeball and gut reaction. Quality is not a technique, no matter how good"*.

Crosby (1986): *"quality has to be defined as conformance to requirements, not goodness"*.

Feigenbaum (1986): *"quality is... the total composite product and service characteristics of marketing, engineering, manufacture and maintenance through which the product and service in use will meet the expectations of the customer".* Garvin (1988): *"quality consists of the capacity to satisfy wants...".*

BS 4778: part I: 1987): *"quality,... The Totality of Features and characteristics of a product or service that bear on its ability to satisfy a given need".* Sinha & Willborn (1985): *"quality is understood as the characteristics of a product or service that are designed to meet certain needs under specified conditions. Customers perceive quality as satisfactory or unsatisfactory. Quality is associated with all product or service stages, that is with design production and performance. Quality has value not only in terms of 'fitness for intended use', but also in the market, where quality is expressed as price".*

In view of this thesis, the working definition adopted for quality is not philosophical, but one that is practical from management point of view. In other words, a definition that could be managed and measured. The definition will read as follows:

quality is to achieve clients agreed requirements.

When quality is expressed in terms of requirements that can either be achieved or not, it can then be managed. The word **"agreed"** is of key importance as far as the above definition is concerned. So long as the clients requirements are well communicated and agreed upon then we can be sure to manage quality. All available resources should be used to arrive at such an agreement including photos, samples, etc..

❶.10 *MEASURING QUALITY*

Defining quality does not make its understanding any easier. For quality has many characteristics, spread over many phases of the production or servicing process. In order to be able to evaluate quality, BS 4778, 1979, clauses **4.1** to **4.1.1** call for the identification of these characteristics and features bearing upon the fitness for purpose of the product or service. They also explain that the ability to satisfy a given need includes economics as well as availability, maintainability, reliability, design, and other characteristics that the need of product or service involves. The following is an overview of the best cited approaches on the area of quality measurement:

Many attempts were made to quantify the quality characteristics.

Juran & Gryna (1980), classified them as follows:

- Structural, eg hardness, inductance, acidity
- Sensory, eg taste, beauty, status
- Time-oriented, eg, reliability and maintainability.
- Commercial, e.g warranty
- Ethical, e.g., Courtesy and honesty

Juran associated the sensory and ethical characteristics largely to the service industry. In addition, he draws a sharp distinction by giving the following example:-

The service industry generally regards the promptness of service as a quality characteristic; whereas similar characteristics such as timely delivery of products to customers on a promised date, is very different from quality, because it is intrinsic to the production control and delivery scheduling process, (Juran *et al.*, 1974).

Juran also draws a clear distinction between the quality of design and the quality of conformance, for they have different characteristics, and are responsible for the confusion that surrounds quality. The former usually costs money, basically in R&D form; whereas the latter saves money by cutting scrap, rework and warranty.

Furthermore, Juran & Gryna (1980) gave an explanatory example of two different automobiles which differ in size, comfort, appearance, performance, economy and status. These two different automobiles may differ in their grade because they are designed to fulfil the needs and expectations of two distinct types of customers. Despite these apparent differences, they may not differ in quality unless they differ in their abilities to fulfil the function of fitness for their intended purpose. This goes on to suggest that comparisons of products and services based on their quality characteristics such as the ones laid out by Juran & Gryna (1980) may only be drawn on comparable items, for example, the Volkswagen Beetle versus British Leyland's Mini. It is misleading to make comparisons between the Rolls Royce Cornice, and the Volkswagen Beetle other than to show that both are quality cars.

❶.11 *MEASURABLE AND UNMEASURABLE CHARACTERISTICS*

Sinha & Willborn (1985) introduced new classifications for quality characteristics defined earlier by Juran *et al.* (1974). They were grouped in terms of measurable and unmeasurable characteristics such that:-

A) the measurable characteristics can be either: **product oriented** such as length, weight, tensile strength and acidity, **time oriented,** such as reliability and maintainability or **commercial oriented,** such as warranty, time taken in providing a service.

B) Non-measurable characteristics can be either:-

- **Sensory,** such as beauty, taste, look and comfort.
- **Ethical,** such as, courtesy, honesty and trustworthiness.

Sinha & Willborn (1985) stated that, from the technical point of view, a given number of the quality characteristics can be either functional or nonfunctional. Arguing that on many occasions this forms the basis of whether or not they are critical to the product's safety, marketability, or user-affordability.

In order to measure the level of quality, Sinha & Willborn postulated that the concept of defects must also be understood within the context of quality characteristics. Defects must be controlled in order to control quality, which would become an important prerequisite for quality assurance. Not only that, but they also point out that some defects are created by consumers, and not only the producers of products and services.

❶.12 *DIMENSIONS OF QUALITY*

Garvin (1988) introduced the concept of multiple dimensions. He has identified eight different dimensions of quality, which may contain the quality characteristics. They are namely: **performance, features, reliability, conformance, durability, serviceability, aesthetics and perceived quality.** The boundaries between these dimensions is sometimes fuzzy, which makes it difficult to assign definite attributions of its share of quality characteristics one way or the other. These dimensions are described as follows:-

Performance: A car's performance is its cruising speed, acceleration, comfort and handling. A television performance is clarity of picture, sound and colour, ability to receive distant stations. For the service industry such as Fast food outlets, airlines and banks the speed of service or absence of waiting time is crucial to determine its performance.

The connection between performance and quality is dependent on circumstances, because not all performance differences are perceived as quality differences, as governed by the fitness for intended purpose definition given earlier in this ***chapter.***

Features: For a car, a feature can be in the form of free stereo-cassette, anti-lock breaking system and power steering. For a television set, it can be an automatic tuner. For airlines it can be free meals or drinks on board. In a bank it can be in the form of a free credit card facilities. Sometimes it is difficult to distinguish between performance and features. However, features involve measurable attributes. When features, are translated into quality differences, they can be subject to individual preferences, and again to their fitness for intended purposes.

Reliability is measured by the probability of a product not to malfunction or fail within a specified period of time. The commonest measurement of reliability of a product involves comparing three types of measures which include failures; they are: Mean Time of the First Failure (MTFF), the Mean Time Between Failures (MTBF). Obviously these measures are irrelevant in a product such as a house, a building or a bridge as safety against failure is a basic criterion. Instead the reliability of a smaller element or component is more significant, such as air conditioning units, concrete, steel, bricks, tiles, paint or carpets.

Conformance This dimension is of special importance to the construction industry (see *chapter* ❸) especially when it comes to assessing quality. There are two approaches to measuring conformance. The first is by setting a predetermined target in the form of specification or standard of conformance. This method is much favoured in the Western world.

The second approach to measuring conformance is much favoured by the Japanese, particularly in the manufacturing industry, which is closely associated with the work of **Taguchi**, a prize winning Japanese statistician. Taguchi introduced the idea of "loss function" which measures all the losses (to society) in a product, encountered from the moment the product is shipped. Such losses are warranty costs, dissatisfied customers and other problems due to performance failures. This method requires the construction of an elaborate statistical quality model and requires quite a large number of data related to the product concerned.

Durability is the amount of use of a product before it is scrapped. Thus the measurement of durability is made over the whole span of the product's life cycle. However, if repair was possible on a product, the task of accurately assessing durability becomes more difficult. For example, it would be easy to determine the durability of a light bulb because its life span can be measured. Whereas the durability of a machine such as a concrete mixer, a lorry or a bulldozer is measured over its useful life span. The useful life span is determined when it becomes more economical to replace the item than to suffer the additional expenditure on operating costs due to increased maintenance and repair.

Again from the construction industry point of view, it would be difficult to use this definition on a complete project such as a building as they tend to undergo major renovations every number of years. When a building becomes too old it may become listed and its demolition would not be permitted. On the other hand, while the life of a motorway surface may be assessed, yet its durability is not comparable unless the amount of usage is measured. It follows that while the durability of the construction project is difficult to assess as a whole, the durability of single items is not. However, despite the importance of this dimension of quality, it would be difficult to assess it in the service industry in general and the construction industry in particular.

Serviceability: This dimension of quality is applicable to products and services alike, because every product requires a back-up service. Serviceability is not only a measure of the ease of repair, but it is also about its speed, promptness, courtesy and competence. In certain industries where the down-time cost is relatively high, such as manufacturing, farming and construction (particularly contracting), the serviceability dimension is of special importance.

Serviceability is best measured through customer satisfaction, because it is difficult to ensure that employees are providing it to customers by simply monitoring the individual's behaviour. The courtesy of an employee may not be appreciated the same way by every customer. Therefore, satisfying this complex issue of serviceability as a quality dimension can be achieved in two ways; first by minimising discomfort to the customer, and second, by facilitating resumption of the customer's operations without incurring significant material loss. Garvin (1988) noted that the latter causes most dissatisfaction to customers, often causing them not to purchase or call on the service again. As far as the construction industry is concerned, delay in responding to complaints causes severe dissatisfaction to customers.

Aesthetics is purely a subjective quality dimension. It is totally user-oriented and can range from appearance, sound, smell, taste and feel: (in other words the user appreciation of a product or service subject to their interpretations, using any or a combination of their five senses). Its measurement can be costly and sometimes difficult to assess even if market research or opinion poll surveys are employed, particularly if no clear or outstanding pattern emerges.

Perceived quality: this final dimension, which is the customer reflection on the overall reputation of the product or service, even though customers do not always have full information to support their interpretations. Customers perception of good quality is (similar to personal respect) harder to gain than to lose.

Management of Quality Through: Quality Control, Quality Assurance and Total Quality Management

Chapter ❷

❷.1 *INTRODUCTION*

This ***chapter*** describes in detail the evolution, philosophies and concepts of the processes of management of quality at work. The intention is to highlight the key issues involved under the organisation for quality theme and to gain deep insight into its evolution, development and implementation in practice.

❷.2 *QUALITY CONTROL*

What is it?

One definition offered reads as follows: *"The operational techniques and activities that are used to fulfil requirements for quality"*, (BS 4778, part 1: 1987).

Juran & Gryna (1980) defined quality control as the process through which the actual quality performance could be measured and compared with a standard, so that some action may be taken on the difference. Another definition for quality control offered by Dale & Oakland (1991), *"is that quality control is the regulatory process through which a product and service quality performance is measured"*.

It can be seen from the above definitions for quality control that the process of quality control is product-oriented as opposed to process-oriented (see later). In other words, organisation for quality takes the form of checking the finished product against specifications. This contrasts with the views of quality management as will be seen later in the ***chapter***.

❷.3 *THE EVOLUTION OF QUALITY CONTROL*

During the early days of manufacturing and before the industrial revolution, firms existed as small units employing perhaps a dozen or more operatives. Presiding over these people was the master of the firm who had overall responsibilities for both commercial and production functions. This includes the job of inspecting an operative's work and making a decision to either accept or reject it. As firms expanded, the master's job grew more complex and time consuming. Consequently, he had to delegate some of his responsibilities, one of which was inspection. This initially fell on the shoulder of the inspection foreman, whose work, in turn, very soon outgrew him. This created, then, a need for Full-time inspection posts.

Accompanying the creation of the inspection function were numerous changes: More technical problems arose which required specialized skills often not possessed by the production supervisor. More attention was given to the shop floor operatives by the production supervisor instead of the inspectors, and the latter lacked training (Juran & Gryna, 1980).

In the early 20th century, these changes led to the birth of the separate inspection department and the position of the chief inspector was created. The chief inspector was responsible to the person in charge of manufacturing. However, in a multi plant or a multi divisional company, the chief inspector may report directly to the works manager. With the creation of the new department came new services such as standard training, recording of data and the accuracy of measuring instruments. Evidently, it was becoming apparent that the responsibilities of the chief inspector were more than accepting products. Therefore, an addition to product inspection was required and the quality control department evolved with the quality control manager in charge.

❷.4 *EXPERTS OPINIONS ON QUALITY CONTROL*

❷.4.1 JURAN IDEAS ON QUALITY CONTROL

For years the writings and teachings of Joseph Juran have represented the Frontiers of the literature on the management of quality. Juran has also made significant contributions outside the quality area, particularly his book **"Managerial Breakthrough,1964"** in which he presented his ideas and experiences in the management of quality and its application in Japan. Juran's central management theme is the distinction between control and what he calls "breakthrough". In this context control means maintaining the status quo and preventing adverse change, and breakthrough refers to changes to a new and more desirable situations.

A second feature of Juran's ideas relates to the nature and extent of management responsibilities. He derived this from his empirical observations in quality control. In the first edition of his quality control handbook, Juran (1951) states: *"There is widespread feeling that the principal cause of defects is operator carelessness or indifference. This is dead wrong. Over 80% of failures to meet specifications are, in the author experience, for reasons not related to the operators at all"*.

In relation to Juran's observations, control and responsibilities must be explicit. He pointed out that operatives can be said to be responsible if three criteria are met:

- they have the means of knowing what they are supposed to do,
- they have the means of knowing what they are actually doing,
- they have available to them means of regulating their performance.

Juran argues that when all of these criteria are met, operatives can be said to be in a state of self control and can therefore be held responsible for the quality of their output. If any of the above criteria are not met, then no state of self control exists.

A third idea outlined by Juran is that the control of quality can only be exercised at the point of production or operation (compare the scientific management approach advanced by Taylor and vigorously applied in the west). This is a recurring theme in the recent literature on Total Quality Management (TQM) . It is often expressed in terms of slogans such **"quality cannot be inspected into a product"** and **"get it right first time".**

Juran's ideas on the management of quality seemed to be focused on production personnel. Further developments occurred from Juran's ideas:

❷.4.2 FEIGNBAUM IDEAS ON QUALITY CONTROL

Feignbaum (1983) identified three trends of distinct product-quality:

- Customers had increased their quality requirements sharply,
- As a result of this increased customer demand for higher quality products, the in-company quality practices were soon to be outdated,
- Quality costs became very high for many companies,
- Considerable improvement in the quality of many products and quality products and practices was required,
- At the same time, substantial reductions in the overall cost of maintaining quality were needed.

From these necessities, the concept of **"Total Quality Control (TQC)"** did evolve. TQC, as defined by Feigenbaum (1983) is: *"An effective system for integrating the quality maintenance and quality improvements efforts of the various groups in an organization, so as to enable production and operation at the most economic levels which allow for full-customer satisfaction".*

The underlying principles of Feignbaum's ideas and the basic difference between "Total Quality Control and the other ideas was the provision of genuine effectiveness". He further pointed out that control must start at the design of the product or service and end only when the product or service has been placed in the hands of the customer, who remains satisfied. The reason for this breadth of scope, as argued by Feigenbaum (1983) is that the quality of any product or service is affected at many stages of the production cycles.

However, TQC is thought of as an aid, not a substitute, for good engineering designs, good manufacturing methods and conscientious inspection activity that have always been required for the production of defect-free products. The main benefits which are claimed for total quality control are (Dale & Oakland , 1991):

- Improvement in product or service quality,
- Reduction in operating costs or losses,
- Improvement in the employee morale,
- Reduction in production line bottle necks.

Side benefits include improved inspection methods, sounder setting of time standards for labour and the furnishing of a factual basis for cost accounting standards for scrap, rework and inspection.

By 1960, Quality Control had become a national preoccupation in Japan. In 1969, the Japanese union of scientists and Engineers, in cooperation with the American society for Quality Control and the European organization for QC, sponsored the first International conference on QC to be held in Tokyo.

In the first session of this conference, which covered company wide quality control, Feignbaum gave a paper entitled **"Total Quality Control"** which, consistent with his book, urged that managers should work intimately with quality control professionals (Feignbaum, 1969). Another paper in the same session entitled "company-wide quality control activities in Japan" (Ishikawa, 1969) explained that the term TQC is used as a synonym for company-wide quality control. Ishikawa went on to explain how TQC in Japan was different from that defined by Feignbaum. He pointed out that in Japan when a company wishes to implement TQC all the employees from top management to the foremen and workers must study **"Statistical Quality Control"** (SQC).

After WW II, the Japanese industrial system was left in ruin. In addition, Japan in general, had a reputation for cheap imitation products. The Japanese recognized their problems and set about solving them. They had the good fortune to gain the service not only of Joseph Juran, but also of another stalwart in the field of quality management, **Dr. Deming.**

❷.4.3 E W DEMING

As early as the 1950s Deming recognized the lack of awareness of product quality at all levels of the Japanese management and began promoting the introduction of quality control procedures in particular and approved quality awareness in general (Deming, 1986).

In his famous Book **"Out of the Crisis"**, Deming itemized 14-management obligations to improve quality:

1. Create constancy of purpose towards improvement of product and service, with the aim to become competitive, stay in business and provide jobs.
2. Adopt the new philosophy-we are in a new economic age. Western management must awaken to the challenge, learn their responsibilities and take on leadership for further change.
3. Cease dependence on inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product/service in the first place.
4. End the practice of awarding business on the basis of price tag. Instead, minimize total cost. Move towards a single supplier for any one item on a long-term relationship of loyalty and trust.

5. Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs.
6. Institute training on the job.
7. Institute leadership (see point 12): the aim of supervision should be to help people, machines and gadgets to do better job. Supervision of management, as well as supervision of production workers, is need of overhaul.
8. Drive out fear, so that everyone may work effectively for the company,
9. Breakdown barriers between departments. People in research design, sales and production must work as a team, to foresee problems of production and problems in use that may be encountered with the product or service.
10. Eliminate slogans, exhortations and targets for the workforce that asks for zero defects and new level of productivity. Such exhortations can only create adversarial relationships, as the bulk of causes of low quality and low productivity belong to the system and thus lie beyond the power of the workforce.

11a. Eliminate work standards (quotas) on the factory floor; substitute leadership instead.

11b. Eliminate management by objectives, the numbers and numerical goals; substitute leadership instead.

12. Remove barriers that rob people in management and in engineering of their right to pride of workmanship. This means, inter alia, abolishment of the manual or merit rating and of M.B.O
13. Institute a vigorous program of Education and self improvement.
14. Put everybody in the company to work to accomplish the transformation. The transformation is everybody's job.

It is clear from the above points that the Deming's philosophy is based on the replacement of the traditional method of detection-inspecting the finished product for defects with a strategy of prevention. In a system based on prevention the emphasis is placed on product and process design and process control and, by concentrating on source activities, it stops non-conforming products being produced and non-conforming services being delivered. The end result is improved product and/or service quality and increased productivity. This is clearly a more creative approach than a system based on detection, and with it there is a change of emphasis from downstream to upstream processes.

The prevention approach to quality recognizes the importance of the process. Deming's contributions are celebrated in the Deming's Prize the most prestigious industrial award in Japan. The appreciation of the efforts of Juran was represented in the award of the "sacred treasure" in 1981 by the late Emperor Hirohito. During the 1950s quality experts Deming and Juran assisted the Japanese in improving the quality of their products and boosting their exports. Deming made several trips to Japan, at the request of the Japanese Union of Scientists and Engineers (JUSE), to conduct seminars on Statistical Process Control (SPC). Deming stressed that **85% of the problems encountered in manufacturing are within the process, and that statistics can be used to control the process.** The focus of Deming philosophy is that quality cannot be inspected into a project, whether it is a car or a building, and that the management must concentrate on improving the processes. Management is not expected to solve all the system problems, but it has the responsibility of providing the tools to workers to effectively address the problems of the system.

Striving to further improvements, JUSE invited Juran to conduct a seminar on quality Control management. Juran's lectures outlined a managerial approach to quality Control and focused on achieving customer satisfaction through a project-team approach, with project-by-project improvement. Juran stressed the importance of training and hands-on leadership by top management in order for quality improvements to be achieved. The Japanese continued to adapt the teachings of those experts to meet the specific needs of their industries. As stated by Deming (1986):"*...now new* *concepts, systems and tools have been subsequently developed in Japan and this represents qualitative improvements upon the statistical quality control and total quality Control of the 1960s".*

❷.4.4 Recent Advancements Of Crosby

In 1979 Philip Crosby produced his book **"Quality is Free"** (Crosby, 1979). One of the things which Crosby did was to set up a method for measuring the status of a company's quality improvement process and to show what positive steps should be taken to evaluate and improve it.

Crosby also sets down his four absolutes of quality along with 14 steps for their implementation.

The four absolutes of quality are as follow:

- a. **Quality means conformance, not elegance,**
- b. **It is always cheaper to do the job right first time,**
- c. **The only performance indicator is the cost of quality,**
- d. **Performance standard is zero defects.**

Crosby's 14-steps quality improvement program is as follows:

1. Management commitment to quality,
2. Quality improvement team,
3. Quality measurement,
4. The cost of quality Evaluation,
5. Quality Awareness,
6. Correction action,
7. Establish an ad-hoc committee for Z.D program,
8. Supervisory Training,
9. Z.D day (Zero Defects Day),
10. Goal setting,
11. Error cause removal,
12. Recognition,
13. Quality councils,
14. Do it over again.

From the above key points outlined by both of the quality experts Deming and Crosby, it could be asserted that quality management is a company wide process and it should involve every one in the organisation for the performance to be improved. The effective management of quality and productivity, defined within the Japanese concept of TQC, is largely credited as the catalyst behind the Japanese industry's extraordinary improvement in quality and simultaneous reductions in costs. The Japanese concept of TQC has come to be known as the foundation of modern Japanese TQC concept rooted in the teachings of Dr. Deming and Joe Juran.

Crosby has joined Deming and Juran in increasing quality awareness in the US. Crosby's philosophy is focused on the transforming the management culture to being receptive to quality improvement. His approach (Crosby, 1979) begins with discrediting the assumption that there is a correlation between quality and cost. He maintains that doing a job **'right first time'** is more cost effective than making mistakes, tracking them and correcting them. Crosby added that *"companies without this wisdom probably spend more time doing inferior work than if they adopted a clear uncompromising, and high quality standard of zero defects (ZD)"*. With his 14-steps quality improvement process listed above, (Crosby, 1979), he provides management with a structured methodology for implementing a cost-quality approach that involves everyone in the organisation. By tracking the cost of quality (prevention, appraisal and rework), improvement opportunity can be identified with the ultimate goal of achieving Zero Defects.

❷.5 *QUALITY ASSURANCE*

The range of concepts available to date, describing quality, has been influenced and shaped by the work of the several notable "quality gurus" outlined above (Deming, Juran, Crosby, Feigengaum, Ishikawa & Taguchi).

The concept of Quality Assurance postulates that quality cannot be inspected into a product (or incorporated into services), rather it must be built into the design and production process and must also be measured through conforming to design specification and performance throughout its life cycle.

A definition of Quality Assurance (QA) offered by the DTI is that: *"An inspection-based system for detecting faults, and tracing them to their origins, so as to prevent their recurrence". DTI-2 (1983).*

BS 4778, part 1: 1987: *"All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy a given requirements for quality".*

It should be emphasised at this point that providing **Quality Assurance** through obtaining third party certification to BS 5750, is no more than providing a record which gives confidence in the quality system of the organisation. This represents mainly an assurance that a supplier's quality system is capable of producing a product that will conform to specification. However, it does not guarantee that the product and/or the specification will conform fully to its intended use.

Genuine QA is built on the aspiration of suppliers to assure purchasers of the quality of product or service such that it meets the requirements of clients. As defined by Ishikawa (1985) Quality Assurance means to *assure quality in a product so that a customer can buy it with confidence and use it for a long period of time with confidence and satisfaction.*

QA grew as a natural progression particularly after certain development techniques for quality control were put to practice.

❷.6 *TOTAL QUALITY MANAGEMENT*

What is it?

As defined by Koller (1991) TQM is an approach to managing based upon:

- the analytical evaluation of work processes,
- the development of a quality culture,

- the empowerment of employees-all for the purpose of continuous improvement of your product or service. The goal of TQM, as explained by Koller (1991), is continuous improvement of your product or service. The Goal of TQM is not to produce the best possible output today, but rather to provide the capability to produce the best possible output each day. Implicit is the acknowledgement that change is inevitable and that the system of work must accommodate change continuously.

Stripped to its fundamentals, Koller (1991) argues that TQM is:

- Understanding the work processes and management systems analytically,
- Developing methods to foster individual and team efforts to support process improvements and "ownership" of the Job.
- Building "customer" orientation and renewed relationships to meet product and service requirements.
- Obtaining top management commitment to a long-term philosophy of organisational development, improvement and success.

The ability to meet customer's requirements is vital, not only between two separate organisations, but within the same organization. For example, the word processor operator is a supplier to a boss. Is the operator meeting the specified requirements? Does the boss receive error-free work set out as he or she wants it and on time? If so, then what we have is a **quality word processing service.** If everyone is satisfying their own impending customers' needs then there is a much greater chance that the final product and/or service will meet customer's expectations. Quality has to be managed-in, it will not just happen. Clearly, it must involve everyone in the process and be applied through the organization. Failure to meet the requirements in any part of a quality chain have a way of multiplying and failure in one part of the system creates problems elsewhere, leading to a cycle of yet more failure and more problems.

TQM is a way of managing to improve the effectiveness, flexibility and competitiveness of a business as a whole. It involves whole companies getting organized, in every department, in every activity, with every single person, at every level. For an organization to be truly effective, every single part of it must work properly together, because every person and every activity affects and in turn is affected by others. It is in this way that Japanese companies have become so competitive and successful (Oakland, 1989). If a product or service are to meet customer requirements, then this has wide implications (the requirements may include availability and cost effectiveness).

The first item on things to do is to find out what the requirements are, and if we are dealing with a supplier-customer relationship, crossing two organisations, then the supplier must establish a marketing activity charged with this task.

The marketing personnel must, of course, understand not only the needs of the customer, but also the ability of their own organisations to meet the demands. **TQM must apply to, and interact with, all activities pertinent to the quality of the product or service.** It involves all the phases from initial identification to the final satisfaction of requirements and the customer expectations.

❷.7 *AN ANALYSIS OF THE JAPANESE NATIONAL QUALITY INITIATIVE*

As discussed earlier, the Japanese economy after WW II was in ruins. All available resources of capital and manpower had been directed to armaments manufacture, while their civilian economy gained an unenviable reputation for producing poor quality copies of products designed and developed elsewhere.

To learn how to regenerate their industries, they sent teams abroad to study the management practices of other countries and they invited foreign experts such as Dr. Deming and Juran.

The message brought by these two quality gurus is summarised here as follows:

1. The management of quality is crucial to company survival and merits the personal attention and commitment of top management.
2. The primary responsibility for quality lie with those doing the work. Control by inspection is of limited value.
3. To enable production departments to accept responsibility for quality, management must establish systems for the control and verification of work, and must educate and indoctrinate the work force in their application.
4. The cost of education and training for quality, and any other costs which might be incurred, will be repaid many times over by greater output, less waste, a better quality product and higher profits.

These are the basic principles of the management concepts which have since become identified under the generic term of **quality management.**

The Japanese developed and refined what they learnt, adapting it to their environment and to the circumstances of individual companies. They made the management of quality an integral part of the manufacturing process and proved that by reducing the incidence of defective products, the costs of production can decrease substantially. Armed with the techniques of quality management, the Japanese proceeded to achieve virtual world domination in a series of key industries.

Nevertheless, some experts consider that the Japanese economical success is largely due to its dedicated work-force, shaped to its present form by the Japanese culture. This is partly true. At the time when Japan was experimenting with statistical quality control in the 1950's the USA was well ahead in terms of their applications. Indeed the Americans invented statistical quality control methods and were first to apply them. When Japan introduced statistical quality control, it created a number of problems, some of which were due to opposition by the experienced workers who always relied on their common sense in collecting statistical data.

❷.7.1 AN ANALYSIS OF THE BRITISH NATIONAL QUALITY INITIATIVE

The quality management concepts were introduced in defence contracts promoted by the British Standard Institution. In 1971 they published BS 4778: Glossary of terms used in quality assurance and followed this in 1972 with BS 4891: A guide to quality assurance. The process was completed in 1979 with the publication of the first version of BS 5750: Quality Systems. This served as a definitive standard in the UK until 1987 and was used as a basis of the International Organisation for Standardization (ISO 9000) series of standards. BS 5750 was re-issued in 1987 in a form identical with the corresponding ISO standards. These standards introduced the word **"Quality Systems"** into the language of management.

Many companies in the UK (see ***chapter*** ❻) made their first acquaintance with the subject of quality management when obliged to provide evidence of compliance with a quality system standard before or while tendering for a contract. Such an obligation was made by the government and the public clients as explained earlier. In such cases, the standards are used to define actions to be imposed by one party on another. It is interesting to contrast this approach to the management of quality with that preached by Juran and Deming and practised to such good effect by the Japanese. The philosophy they pronounced required that management should devote its attention to the improvement and maintenance of quality not because someone else might oblige them to do so, but because it was a desirable end in it self.

There is significant difference between an organisation which truly believes in the need to manage quality and one which merely prepares itself to comply with a standard. The latter will have the systems, procedures, manuals and so on which are required by the standard, but unless the people who have the task of operating the systems have the right attitudes and inner motivation, the results will not be wholly successful.

❷.8 *REVOLUTION OF BS5750*

In a UK Government white paper it was stated that the UK's world trade share was declining (Department of Trade and Industry, 1982). This was having a dramatic effect on the standard of living in the country, amply demonstrated by rising unemployment and bankrupcies. There was intense global competition, and it was obvious that any country's economic performance and its reputation for quality was made up of the reputation and performance of its individual companies, products and services.

The British Standard BS 5750 for quality had been published three years earlier in 1979. A campaign to bring to the attention of the industry the importance of product and/or service quality in order to remain competitive and survive in the world market place was needed. Hence, the Government launched the national quality campaign in 1983 and used BS 5750 as its core. BS 5750, now revised and made equivalent to ISO 9000 series, is the UK's national standard for quality systems. The series is a set of six standards, three giving the requirements for quality assurance and the other three giving guidance on how to manage and achieve quality.

BS 5750 is a practical standard for quality systems which can be used by all UK industry, including the public sector commerce and service, and it lays emphasis on the prevention philosophy. It also provides for continuous improvement through audit and review procedures. The standards provided a very broad set of requirements, and were seen as a positive step towards improving the UK's reputation for quality. By issuing a register for quality assessed UK manufacturers and PSA insistence on all services industries to be certified, hence all Governments purchasing should be from companies on the register. Therefore, the Government was able to persuade many companies to follow the standards to recommendations.

The quality assessment carried out is essentially an independent third-party audit. One of the accredited organisations for carrying this out and providing subsequent certification is **BSI** which assesses companies' compliance with the requirements set out in BS 5750 parts 1, 2 and 3.

The campaign in the UK matured through the 1980s to promote a company-wide commitment to quality, involving everyone from chief executive officer to the newest recruit. The aim is to make every individual aware of the importance of their own particular role and where it fits into the drive for total quality.

In 1989 the DTI made the initiative to launch the 'managing into the 1990s program' to promote a strategic approach to the 4-key areas of design, quality, purchasing and supply and manufacturing management (Dale & Oakland, 1991). A complete program was put together to help companies to improve performance and competitiveness through the TQM approach. As explained by Dale & Oakland (1991) the DTI initiative provided counsellors, experienced business people, to review with firms their needs, and offered to find the right consultants to meet the requirements. Links with Training Agencies and higher education were encouraged through **Schemes for Teaching Companies (TCS)** and the integrated graduated development.

Lascelles & Dale (1989) reporting on a study carried out to assess the impact of the campaign on the industry said: "*the campaign material had been relatively successful in reaching its prime target of senior management, the majority of respondents have found the material to be useful and believe that the campaign has benefitted their organisations in terms of increased awareness of the importance of Total Quality Management*".

❷.8.1 THE ISSUE OF CERTIFICATION

Third party certification to BS 5750 or ISO 9000 give organisations a marketing advantage, as purchasers are currently demanding it. However, the actual level of competitiveness does not come from the system itself but it would be a function of the perceived value of the product or service relative to other similar products or services in the market. If all competitors acquire third-party certification, then the embodied advantage in having it would subsequently disappear. Undoubtly, the overall advantage would be purchasers who would then, at least, have confidence in what they buy.

❷.9 *AN EVALUATION OF THE JAPANESE & BRITISH APPROACHES TO QUALITY MANAGEMENT BASED ON THE ABOVE DISCUSSION*

If the differences between the British and Japanese industries were to be regrouped in terms of **systems, technologies and people,** the contrast between the Japanese and Western styles becomes more vivid. The western industrial countries particularly the US, had superior systems and higher standard of technology. However, the Japanese had better dedicated workers. The Japanese were first to recognise the shortcomings of scientific management as depicted by the theories of FW Taylor. It is possible that Taylorism conflicted accidently with the Japanese social and cultural norm. In contrast, the western nations in general and the British approach in particular, were over emphasising the value of specialisation such that the workers needed to know as little as possible about the production process and as much as possible about the operations in hand. In other words, Taylor's remedy separated the planning work operations from its execution. Thus, they assigned technocrats (engineers or specialists) to do the planning and left the job to be executed by the relatively unskilled workers and their supervisors. The Japanese avoided this approach and concentrated on the human element. As stated by Ishikawa (1985), the Japanese have insisted on participation by all, from the chief executive officer down to line workers for quality control whereas in the US quality control has always been delegated to QC specialists.

Dr. Ishikawa rejected the theories of scientific management and replaced them in the 1950s by slogans such as: "the next process is your customer", which is the essence of todays TQM. Indeed Japan was promoting such slogans as **"the customer is king"**, while some organisations in the West were thriving on the **"take it or leave it"** concept, largely due to heavy demand.

In conclusion, it fairly can be suggested that it is not only the Japanese culture that gave the advantage in promoting quality in the manufacturing industry, but also the failure of Western style of management, (which at the least, over-emphasised on **productivity** rather than **quality**). The movement, which placed the job of quality control from the specialist to the worker, created an organisation culture which combined with the quality assurance techniques, and gave what is known as the **management of quality**. Later when it grew to engulf everyone in the process as both customer and supplier in the production process, (whether external or internal to the organisational structure). This was a milestone in the progress of quality management and thus was termed as **"TQM"** explained above.

❷.9.1 COMMITMENT TO QUALITY:-

Commitment to quality must be truly company wide and start at the very top (senior executives) if it were to be successful in promoting business efficiency and effectiveness.

The middle management have a particularly important role to play; they must not only grasp the principles of quality but also go on to explain them to the people for whom they are responsible, and ensure that their own commitment is not only communicated, but practised. Only then will the quality culture spread effectively throughout the organisations. This level of management must also ensure that the efforts and achievement of their subordinates obtain the resources, recognition, attention and reward that they deserve. It cannot be said too often that to be successful, the quality program must involve every individual in every department. If the chief executive of an organization accepts the responsibility for, and commitment to, a quality policy, this action alone will offer a broad approach extending well beyond the accepted formalities of the disciplines required in the quality function. It creates in turn, through a process of quality policy deployment, responsibilities for interaction between the marketing, design, producing, purchasing, distribution and service functions, along with improvement objectives.

Management's commitment must be obsessional, not mere lip service. Going into an organization sporting posters and slogans campaigning for quality, instead of belief in quality, one is quickly able to detect falseness. Personnel are told not to worry if quality problems arise: "just do the best you can" or "the customer may not notice". This contrasts with a company where quality means something and can be seen, heard and felt. The quality program should be "user-driven"; it cannot be imposed from the outside of the organization, as perhaps a quality system standard or statistical process control. This means that the ideas for improvements must come from those with knowledge and experience of the methods and techniques and this has massive implications for training and follow-up.

Finally, a quality management programme is not a cost cutting or productivity exercise and it must not be used as such. Although the effects of a continuous and never ending process will certainly produce these benefits, quality management is concerned chiefly with changing behaviour, attitudes and skills so that the culture of the organization becomes one of preventing failure and the norm is operating correctly first time.

❷.10 *APPLICATION OF QUALITY MANAGEMENT PHILOSOPHIES IN THE CONSTRUCTION INDUSTRY*

It can be seen from the first part of this ***chapter***, that the early development work on quality management took place in manufacturing environment and so it is hardly surprising that most literature on the subject is written in the vernacular of the factory. This is unfortunate as it creates a mistaken impression in the minds of those engaged in activities other than manufacturing that the tenets of quality management hold benefits for them. Given the working definition adopted by this study for quality (***achieving agreed clients requirements***), it may be suggested that only monopolies can afford to ignore the customer's demand for value for money and the satisfaction of needs. According to this definition, it may be construed that any person or organisation whose livelihood depends on successful performance in the market place can benefit from quality management and this includes the construction industry.

The differences between a factory and a construction site cannot be ignored. There are special factors which have to be taken into account - the susceptibility to weather, the mobility of labour, the fact that almost every job is a prototype, and so on. These realities undoubtedly make the introduction of quality management more difficult than in other industries. But if it is true that the management of construction sites is a uniquely formidable task, then the question put to the industry is that quality management is the most significant advance in management technique to have arrived on the scene in recent years, but does it need it?

All too many buildings and structures in recent years have failed to satisfy legitimate requirements of their purchasers, and the reasonable expectations of the community at large (Griffith, 1987). Research showed (Building Research Establishment, 1982) that only a minority of construction defects are technical in origin. It is suggested in the same report that far more arise from inadequacies in the management structure of the industry, from lack of training and from the commercial pressures which stem from the almost universal custom of awarding work only to the lowest bidder.

But why should someone expect that quality management will be the panacea for the industry's illnesses?

One of the best answers to this question is given by Duncan *et al.* (1990) who suggested that a deeper look at why all these ills occur is necessary to answer this question. They pointed out that the art of communication is vital to each and every individual within the industry. *"The analysis of error in construction very quickly yields one pertinent fact: our inability to communicate effectively is our biggest enemy"* (Duncan *et al.*, 1990).

When dealing with a complex and varied industry, within which numerous professionals and artisans operate, whose background training and professional development are entirely different from each other, the most effective way to achieve good communication is to formalize it. The advantages of formalization, as explained by Duncan *et al.* (1990) can be seen in many aspects. For example, it is observed that in contractual disputes, the architect blaming the engineer blaming the contractor for errors which have occurred simply because drawings were incompatible or an instruction was misinterpreted. Therefore, formalized systems adopted by all parties for the checking and recording of communications would eradicate many of these problems.

With regard to training, it has been neglected at most levels in the industry. Again formal management systems would require that training policies for all staff are developed and implemented.

In addition to the importance of good communication and training, a study of contract disputes (Duncan *et al.*, 1990) very often yields a surprising lack of understanding as to exactly who is responsible for the principal decisions in the construction process. Very often decisions are made by individuals who are entirely unqualified to make them, and in most cases those individuals believe that the ultimate responsibility will be carried by an immediate superior. Formal quality systems demands that all levels of staff associated with the construction process have a clear definition and understanding of their own limits of responsibility. In addition, all individuals must understand how they fit into the overall management of the parent organisation and relate to their fellow team members.

A further process where formal quality management systems' importance is highlighted by Duncan *et al.* (1990) is that of litigation within construction. Most people in the industry will be aware of the difficulty of processing a claim, or indeed the defence of a claim without proper and accurate records. Clear and accurate records for construction and design are essential. Formal quality management systems require records be kept throughout the period of design and construction as well as being archived following completion. It is argued by many that the very process of identifying and preparing these records and maintaining them from start of the project acts as a stimulant to the professional and construction teams to ensure that the above stated requirements of good communication, training and definition are carried out.

However, one of the most common criticisms levied at formal quality systems is that of the quantity of paperwork generated as a result. It was made clear by Griffith (1987) that the documentation required by the formal system is essential to basic good management provided that the system has been designed only to accommodate the essential requirements of the particular company or group. This view is also shared by Duncan *et al.* (1990) who argued that sensibly applied and streamlined quality management systems are not only beneficial but essential to the construction industry.

Finally, a common criticism put against formal quality systems is that it stifles creativity of architectural and engineering design. However, Cornick (1991a) who is an architect and a leading expert on quality management, points out that a formal quality management system applied to any aspect of architectural or engineering design will neither address nor affect the synthesis or conjecture function of the thought process that contains any creative element. Instead, a quality management system can only affect the analysis-evaluation or reasons for the refutation functions of the process by requiring that they be made more explicit. Recent studies (Cornick, 1991b) suggest that explicit analysis and evaluation is not the normal situation in current architectural practice, but formal quality management would require this situation to change.

Before concluding this chapter, it may be worth noting that the mechanisms of the quality system and its interpretation in the construction industry have been intentionally omitted. The main concern of the thesis is the efficacy of the implementation of quality management systems and in particular its impact on productivity and not the issue of how such systems should be implemented. Moreover, the inclusion of an overly descriptive section such as the description of the mechanisms of the quality standards will serve to enlarge the volume of the chapter without necessarily contributing towards achieving the main objectives of the thesis.

Productivity: Concept, Definition, and Measurement

Chapter ❸

❸.1 *INTRODUCTION*

In general, Productivity is the relationship between the output generated by a production or service system and the input provided to create that output (Prokopenko, 1987). In this context productivity is defined as *the efficient or optimum use of resources - Labour, capital, materials, land, information - in production processes.* As far as this study is concerned, the definition for Productivity would be taken as indicated above (optimum utilisation of resources). Higher productivity would mean accomplishing more with the same amount of resources.

Regardless of the type of the production process, the definition of productivity remains the same. Although Productivity may mean different things to different people, the concept is always the relationship between the quantity and quality of services provided and the quantity of resources used to produce them.

Prokopenko (1987) pointed out that the International Labour Organisation (ILO) has for many years promoted an advanced view of Productivity which refers to the effective and efficient utilisation of all resources labour, plant and materials.

❸.2 *TOWARDS A DEFINITION OF PRODUCTIVITY*

One of the major requirements in dealing with the subject of Productivity is to define precisely what the term means. In view of the importance of the concept of productivity, it is not surprising that a considerable body of literature has developed reflecting a variety of approaches to deal with different aspects of this complex domain. However, one of the principal reasons for much of the confusion is the numerous definitions currently in use.

According to Larousse dictionary (cited in Talhouni,1990) the term appeared for the first time in 1766. For a long time its meaning remained somewhat vague. Recent publications yield a substantial number of definitions. Fenske (1965) divided most of the contemporary definitions into four basic classes. Shaddad (1983), basing it on Fenske's classification, suggested five basic classes of definition:

Productivity as a ratio, as a form of efficiency, as a rate of return, as a utilisation of resources and as having to do with the production process.

❸.2.1 PRODUCTIVITY AS A RATIO

Defining productivity as output per unit input is one of the most widely used definitions. In the Business Round Table (Talhouni, 1990) this definition was the only agreed upon definition. However, when partial measures are taken, this can give a misleading picture of the whole concept of productivity. As criticised by Gold (1976) such a measure as labour productivity for example, does not give an adequate measure of productivity as a whole, or even the productive efficiency of labour. This because increases in output per manhour may or may not reduce unit labour costs.

Easterfield (1953) describes productivity as: "*... any ratio of the output of a worker, machine, plant or industry to the amount of one of the factors of production used*".

Such a broader definition was also offered by the British Productivity Council 1970 (cited in Shaddad, 1983) which defined productivity as: "*... a ratio of output to input of materials, labour, energy and capital equipment*".

❸.2.2 Productivity as a Form of Efficiency

Support for Productivity as a form of efficiency comes from Fabricant (1962), Farrell (1957) and Ranftl (1976).

Efficiency and Productivity are often used as synonymous terms. Although the two may be related, they are not necessarily synonymous. Ranftl (1976) stated that productivity is the efficiency and effectiveness with which resources are used to produce a valuable output. Efficiency may be perceived as the capacity or the adequacy of a production process. It is a relative measure of the actual output to the potential output and is usually measured as a percentage. Efficiency therefore would be limited to the utilisation of equipment, materials and tools whereas productivity may not be producing efficiency but rather utilising the resources which attempt to encompass the totality of production.

❸.2.3 Productivity as a Rate of Return

Horngren (1965) and Risk (1965) interpret productivity as a rate of return. Risk (1965) takes return on investment as a starting point and suggests that by dividing assets between producing divisions or units, the respective ratio of output to assets can be used to measure and compare the productivity of an individual unit.

❸.2.4 Productivity as a Utilisation of Resources

Productivity as the utilisation of resources is a concept that attempts to encompass the totality of the Production factors. For example, the OEEC (1955) interprets productivity in this fashion. It expresses Productivity as: "... *Utilisation of resources in relation to some standard*".

Two writers Feiner (1968) and Roger (1970) have attempted to produce the utilisation of all resources in their definitions. Feiner expresses Productivity as a function of utilisation, performance and method. Roger follows this theme, though substituting effort for performance. To maximise productivity in both cases, each of the three factors included in both definitions should be increased to its largest possible extent.

In its broadest sense productivity is concerned with efficiency in the use of the various resources or factors of production. Efficiency in this context is described by Hillebrandt (1985a) as "the best possible utilisation of resources under given conditions".

❸.3 *THE CASE OF THE CONSTRUCTION INDUSTRY*

An absolute definition of the concept of productivity, especially related to construction, does not seem to exist. However, the Construction Industry Training Board (1968), and Culvert (1970) expressed productivity as a ratio. The CITB in the UK in one of its manuals accepts that Productivity is the relationship between inputs and outputs and can be expressed in terms of a ratio in the form of productivity equals output/inputs. Culvert (1970) expressed productivity as the quantity of output of a given process to the quantity of input for a given level of quality output.

Bishop (1975), Whitmore (1968) and the OEEC (1955) linked Productivity to the utilisation of resources; Bishop writes: "*.... Productivity is taken as the optimum use of resources to obtain an acceptable goal*".

This definition offered by Bishop would have described the theme of productivity sufficiently for the purposes of this study without having to refer to any acceptable goals. The working definition adopted by this study was centred around the resource utilisation of the theme and therefore, optimum utilisation of resources may be considered as a goal in itself to be achieved if productivity is to improve.

The Ministry of Housing and Local Government in the UK offered a much wider view of Productivity and relied on the rate of investment as an interpretation of Productivity similar to that of Risk (1965) and Horngren (1965): "*... for practical purposes we regard it (productivity) as the relationship between the amount of money and effort put into a task and the benefits obtained*".

This study is concerned with the assessment of the impact of quality management systems upon construction productivity at the site level. A great deal of progress can be made towards achieving this objective if productivity is looked at from the utilisation of resources point of view. Such an approach will help the investigation of the impact of Quality Assurance upon the utilisation of resources at the site level as it can compare different projects by measuring the resources used in them against a fixed output. The definition to be adopted by this study is centred around the utilisation of a resources theme. From the definition given by the British Productivity Council that it is *"a ratio of output to input of materials, labour, energy and capital equipment"* and the OEEC definition of utilisation of resources in relation to some standard, and the definition given by Bishop (1975).. *"Productivity is taken as the optimum use of resources to obtain an acceptable goal"*.

The following definition which is a combination of the above three will be taken as the working definition of productivity to be adopted by this study:

Productivity is the optimum utilisation of resources inputs labour, materials and capital in achieving an output acceptable in relation to some standard.

With reference to the above definition, it should be pointed out that the standard referred to need not be achieved. The standard referred to in this definition is that of continuous improvement that any quality management system should be working to achieve. Improvement is a journey not a destination and that is why the standard referred to in this working definition need not be achieved.

Comparing this philosophy of the definition with the concept of benchmarking (which is a tool for performance improvement through comparison with competitors), it should be emphasised that the standard for improvement should be set by the organisation itself as a self imposed measure of performance and not necessarily that of their competitors. If, for example, an organisation's improvement plan included the objective of improving resource utilisation, then this could be a comparable end product despite the heterogeneity of construction output. A reduction in material waste or the amount of rework can be a comparable end product as opposed to having to compare the amount of building work achieved.

Benchmarking, on the other hand, could be used to quantify the performance gap between a required standard and the actual standard; this should give management, as well as staff, the motivation to embark on a vigorous improvement programme to work towards the required standard.

❸.4 *ON PRODUCTIVITY MEASUREMENT*

This section discusses the major approaches to the problem of how to measure productivity as found in recent literature, with an emphasis on plant or site level.
Eilon *et al.* (1976), in dealing with industrial production in general, emphasise that guidelines on how to measure productivity may be gained from an analysis of why its measurement is required. Managers of companies and projects in the construction industry are aware that they need to measure productivity for the following reasons:

a) as a step towards productivity improvement;
b) as a means of comparing a company's and project's performance with that of competitors;
c) as an aid in the establishment of the relative performance of industrial sites;
d) as a means of facilitating a comparison of relative benefits accruing from the use of different methods or processes or inputs;
e) as an aid towards rationalisation in collective bargaining with trade unions.
f) to provide a basis for effective planning and forecasting.

The diversity of methods proposed for the measurement of Productivity is wide. Recent literature on this topic reveals that the basic concern about measurement problems can be seen to be directed at five major levels: **International, national, industry, company and plant or site level.**

This study is primarily concerned with productivity at the site (production) level. This next section will mainly be dealing with the site level.

❸.5 *PRODUCTIVITY MEASUREMENT AT THE SITE LEVEL*

Most of the measurements at this level have been concentrated on partial measures of productivity such as labour (normally measured as output per manhour). This, however, tends to give a distorted image and may lead to confusion and misunderstanding of the basic goals of Productivity measurement.

Eilon *et al.* (1976) listed the major problems in seeking to employ such an overall measure of Productivity:

1. Measuring and combining inputs which are heterogeneous and often difficult to measure,
2. Measuring qualitative changes in outputs, especially in the face of change with time;
3. Determining which particular input-output comparisons are most relevant in evaluating the performance of various operations;
4. Interpreting the findings, that is, the differentiation between the influence of internally controllable and externally imposed factors.

The index approach is the most widely used concept of productivity measurement in all industries, including construction. The other approach is the Production Function approach, which basically the development of some general function of output expressed as a function of input factors by combining observations, economic theory and mathematics. Three types of functions have been proposed in the literature the most important of which is the Cobb-Douglas (Farrell, 1957). This approach is output orientated as opposed to input orientated. A third approach focuses entirely on the costs and revenues and ignores the physical measures which are useful to management.

Tolkowsky (1964) highlights the importance of the concept to the costing of goods, to the significance of the degree of utilisation of capacity and to the impact of idle time on the cost of production.

The so called "system method of productivity measurement" advocated by Smith (1973) is a useful step forward as it integrates the marginal costs with some of the available physical measurements. It does not however, take into account separately, for example, the material volume or the quality of output.

The utility approach was also introduced to measure productivity at the plant or site level. The essence of the Stewart's utility approach is to combine the various surrogate measures to produce a single measure. A surrogate measure is the one which is used in place of another and is often used when the desired measure is unobtainable. Although Stewart's approach is unique, it can be argued that the amount of subjectivity involved in selecting and quantifying the measurement is so high that the technique may have errors inherent in it.

The integrated Productivity approach developed by Norman & Bahiri (1972) embraces the various productivity concepts with both outputs and inputs in financial units. Norman & Bahiri (1972) starting from an accountant's total expense or global factors, claim that their model offers the facility of *"...converting the data from productivity research based on one particular concept into any of the other conceptual models"*. This facilitates comparison of results obtained form different conceptual models.

The most significant contribution to the literature on the use of Productivity as a managerial tool has been made by Gold with his work relating various physical and financial Productivity ratios. Gold (1971;1976) argued for productivity analysis to cover a wide range of inputs of varying proportions, utilisation and relationships and offers an interaction network model. There is little doubt that Gold's model is the most comprehensive and it focuses attention on all major causal factors which must be calculated before a decision on any total productivity measure can be made.

❸.5.1 PRODUCTIVITY MEASUREMENT IN THE CONSTRUCTION INDUSTRY

Productivity is usually measured in terms of a ratio of some measure of output to some measure of resource inputs.

The most well known measure used in the construction industry is **Total Factor Productivity (TFP)**. Lowe (1987a) concludes that: *"total factor productivity is the ideal against which other approaches should be judged"*. Other measures include **average labour productivity** and average **capital productivity,** but as pointed out by Lowe (1987b), both of these measures suffer from serious problems in assessing the efficiency of construction operations. However, under certain circumstances either can provide an adequate alternative measure.

Of the two main single factor productivity measures used, Capital productivity appears to be superior in most construction firms. Notwithstanding the problems associated with construction operations and also the difficulties inherent in obtaining suitable data, capital productivity is recommended for most circumstances when total productivity measures cannot be used (Lowe, 1987a).

❸.6 *PRODUCTIVITY INDICES COMPONENTS*

Ideally, components of Productivity indices are denominated in physical units of measurement, but with a lack of such data, use can be made of quantity indices that are obtained by deflating, their constant monetary (£) equivalent, the current (£) values corresponding to their physical quantities, in order to correct for price changes.

❸.6.1 MEASUREMENT CONSIDERATIONS FOR INDIVIDUAL INPUTS

a) Labour inputs

In a competitive labour market, in which any category of labour is paid a wage equal to its marginal contribution to output, we can weight labour by the corresponding average earnings.

A measure of labour input can be obtained by deflating total labour compensation with an index of average earnings.

b) Materials input

Materials input basically refers to all inputs not classified as labour and capital.

c) Capital input

It is by far the most difficult component of Productivity indices to Quantify. Unlike materials, measurable quantities which are completely consumed during the current time period, capital provides a flow of services that extends beyond the current period.

❸.6.2 OUTPUT

It is seen by this study that an appropriate value of output is receipts (no inventory changes arise when payment is based on completed work-the usual case in construction).

Categorisation of construction output into homogenous units obviously poses some problems but the breakdown of data into certain categories of construction activities (derived from the BQs) does impose a considerable degree of uniformity.

❸.7 *THE MEASURE OF PRODUCTIVITY USED BY THE STUDY*

The working definition adopted for productivity by this study is centred around the **optimum utilisation of resources** theme; the approach to measure the productivity of a construction project adopted is to assess the quantity of resources used in achieving a given output. Obviously, the difficulty in obtaining a homogenous output in construction is an obstacle, but has been overcome by the fact that the output is measured in monetary terms (£). For example, for a given work output, the method to be adopted will seek to assess the amount of resources used in achieving that level of output. If, for instance, we have two firms engaged in doing housing projects, and it was found that the first firm completed their project for a given value of **£M.** For this value of building work, the price of the resource inputs were established as labour **L1,** materials **M1** and plant **P1**. On the other hand, the other company achieved the same amount of building work (**£M**) for labour costing **L2**, material costing **M2** and plant costing **P2** where **(L1 < L2 ; M1 < M2 and P1 < P2)**. Therefore, it may be concluded that the first company has been more productive than the second company in this instance as it used less resources to achieve the same output.

Ideally, components of productivity indices are denominated in the physical units of measurement, but with the lack of such data, the monetary value of the physical quantities was taken as a surrogate measure of the physical quantities. As far as construction output is concerned, categorisation into homogeneous units is almost impossible due to the heterogeneity of construction output. However, the choice of sample for this study was exclusively confined to housing projects in one geographical area (Scotland) in an effort to apply a certain measure of homogeneity. Moreover, the monetary value (£) of output was taken as it is common to both inputs and outputs. As pointed out by Ruddock (1994), an appropriate value measure for output in construction in receipts. "... No inventory changes arise when payment is based on completed work-the usual case in construction".

The theory which is going to be used in comparing the resource utilisation of different companies is the **theory of isoquants.** Before elaborating further about the methodology to be used in assessing the productivity of different projects, it is worthwhile at this stage to briefly highlight this theory, but it will be dealt with in *chapter* ❻ in greater detail.

❸.7.1 THEORY OF ISOQUANTS

The methodology to be adopted in measuring productivity of different construction projects and compare them is using the theory of Isoquants. An Isoquant is a curve connecting points representing different combinations of inputs and producing the same amount of output. In a construction project the inputs are labour, plant, materials and capital. The essence of the methodology is to measure the quantity of resources used in achieving a certain level of output, bearing in mind the difficulty in being able to quantify the construction output in a homogenous manner (for more details on this method see *chapter*❻). This study attempts to develop an analytical framework for Productivity analysis of construction projects. There are two types of productivity ratios used in assessment of productivity at both macro and micro levels:

Total Productivity = Total output / Total input,

Partial Productivity = Total output / Partial input.

As the partial productivity ratio can only give a partial measure of Productivity, the approach to be taken is to assess the whole (Total factor productivity) which seeks to assess all the inputs involved in the production process.

The original concept of total factor productivity can be traced to the work of Stigler (Ruddock, 1994). The concept was later developed by researchers such as Kendrick (1961) and Solow (1958). This measure of productivity will reflect change in output resulting from changes in resource inputs employed.

The actual methodology adopted in assessing the productivities of construction projects is dealt with in the next *chapter*❻.

❸.7.2 EMPIRICAL RESEARCH INTO TOTAL FACTOR PRODUCTIVITY

Empirical research into Total Factor Productivity in construction is rather lacking. In the US, Dacy (1965) estimated total factor productivity of the construction industry with indices of building price, hourly wages, output per man-hour and material prices. Stokes (1981) noted a decline in labour productivity and attempted to explain such a decline by error in measurement of output, change in output mix, change in capita per worker, demographic change in construction labour, economies of scale, change in regulations and regional shifts.

Walker & Chau (1988) estimated Total Factor Productivity for the Hong Kong (HK) construction industry but aggregation of inputs and outputs renders the results to be rather limited. Chau & Walker (1988) presented a method for indirectly measuring the TFP of the Hong Kong construction industry using various construction costs and price indices and other statistics.

The output used includes all building works in the private and public sectors. The inputs include four major categories of input; namely: labour, material, plant & equipment and overheads.

Once again the availability of data on physical measurement of inputs and output stood as an obstacle for this study. Therefore, the analytical framework suggested by Chau & Walker (1988) estimated the productivity trend of the Hong Kong building industry using available statistical data on costs and prices.

For multiple outputs and multiple input systems, some means of aggregating inputs and outputs is required to produce a productivity index. The method of aggregation used in this case is the geometric mean. With the geometric mean, the underlying production function is assumed to be linearly homogenous and the weights are assumed to be constant.

The major limitations of this study are:

- the underlying assumption used for aggregation,
- the validity and reliability of data.

The input and output price indices are compiled by a government department in Hong Kong and as pointed out by Chau & Walker (1988), the weighting patterns used by this department are not based on empirical data and therefore may not be reliable.

Lowe (1987a and 1987b) considered the problems of TFP measurement for the UK construction industry as a whole and , pointing out the difficulties inherent in obtaining suitable data concentrated on the relative merits of labour and capital productivity.

Therefore, the method to be adopted for estimating construction productivity as far as this study is concerned would be **T**otal **F**actor **P**roductivity (TFP) as it is more oriented towards assessment of resources mixture which best describe construction productivity.

Factors Affecting Construction Productivity

Chapter ❹

❹.1 *INTRODUCTION*

This ***chapter*** reviews the literature concerned with the factors influencing construction productivity with the aim of categorising them under different categories that may render them manageable. The number of factors influencing productivity is enormous and enough to discourage some of the most persistent researchers. However, an effort is made to differentiate between those factors which are manageable, ie controlled by management action and those which lie beyond the realm of management control. In such a way it may be possible to model those factors and to study them under different categories as shown later in the ***chapter.***

❹.2 *A REVIEW OF MAIN FACTORS AFFECTING PRODUCTIVITY*

Productivity of a construction project is a function of interrelated variables that individually and collectively influence the outcome of the project. They may be psychological, technical, structural and environmental.

Causey (1970) noted Eight major factors which affected construction productivity either directly or indirectly on large industrial sites under his control. They were as follows:

a. the project design and incidence of design change,
b. supply of materials on site,
c. site planning,
d. efficiency of site management,
e. efficiency of the workforce,
f. the system of timing of rewards adopted for the site,
g. the difficulties with subcontractors,
h. the relationship between contractors and clients.

McNally & Havers (1967) identified the primary factors affecting Productivity on construction projects under the following headings:

- Environmental factors
- Labour availability factors,
- Job Factors,
- Factors such as work rules, size of the company and types of contract.

Bishop (1968) categorised the measures to be taken to improve productivity into the following categories:

(i) measures to be taken to improve management control and utilisation of resources and the control of timing by way of mechanisation, training and motivation.

(ii) The second comprises those factors intended to improve the efficiency of tasks(work methods)

Clapp (1978), after analyzing data from 300 contracts to estimate the effects of the various factors of construction productivity, found the following factors to be important:

1. scale of work available,
2. complexity of the project,
3. employment rate in the region,
4. time of the year,
5. type of contract.

Gottleib (1969) covers 38 factors and classifies them into the following Seven major categories:

1. Technical
2. Managerial
3. Financial
4. Labour
5. Government
6. Economical
7. National

Woods (1976) in his analysis identified 8-specific factors affecting productivity on construction projects:

a. Percentage of unemployment at the local and national levels

b. Supervision (system of supervision)

c. Job Location

d. the size of the project

e. the identification of the project objectives by the workforce,

f. the quality of the workforce

❹.3 *PRODUCTIVITY IMPROVEMENT*

Bishop (1966) and Woods (1966) among other construction writers, have suggested means of improving construction productivity.

Measures suggested by the above writers included technological innovations, introduction of mechanisation, development of industrialised buildings, economies of scale and subcontracting.

Little (1976) suggested ways of improving productivity in the construction industry should include: avoidance of changes in the design phase, and creating closer client-Architect and Engineer-contractor.

Zweigh (1951) describes some conducive variables in the achievement of high productivity in a construction project including:

- a well laid out site,
- steady flow of materials and equipment,
- proper planning and assignment of operations,
- good construction methods.

Judson (1976) echoed Zweigh's points, concluding that:

"No individual or small work group can achieve expected performance standards if they lack the required tools or equipment, or if they run out of materials of if their equipment breaks down".

Nightingale (1972) lists six main factors that influence construction productivity; they are as follows:

a. the nature and quality of raw materials,
b. the basic nature of the process employed,
c. the amount of plant and equipment employed,
d. the efficiency of the plant and equipment used,
e. the volume, continuity and uniformity of production,
f. the utilisation of manpower.

❹.3.1 IMPACT OF INFORMATION

Reinshmidt (1976) states that: "...*one of the most important factors affecting productivity is Information or lack of it. Information which does not flow promptly from one group to another, will cause rework and decreased productivity*".

Moreover, Higgins & Jessop (1974) emphasised the role of information in achieving smooth flow of site work, minimising disruption and hence improving system productivity.

❹.3.2 THE IMPACT OF ORGANISATION OF THE PROJECT STRUCTURE

A growing body of literature notes that organisation of project structure can markedly influence construction productivity. Borcherding (1976) expresses the idea that the span of control and the amount of delegated authority are key factors in construction productivity.

Davis & Warrington (1980) noted that productivity standards in construction depend upon the autonomy of the project and the type of contract. This was also substantiated by Porter (1981).

❹.3.3 THE IMPACT OF TRAINING

Riddle (1976) states that: 'Every one Knows that Productivity is closely related to skill, and without skills there is no way a worker can be productive'. Boydell (1971) on the other hand, expressed his view that if productivity is low, training specialists should look for a possible cause; it may well be the lack of skill and hence training is a contributory factor.

❹.3.4 THE IMPACT OF MOTIVATION

The general literature on motivation and its effect on productivity is extensive, but it thins out when one looks specifically at the construction industry. However, a rich body of literature on productivity suggests that Productivity is a function of intensity of Motivation of the workers. Talbot (1976) and Mason (1978), after extensive review of the different Motivational variables in construction claimed that construction operatives can also be motivated to perform better. Among the motivational variables which found support in construction projects are operatives needs, attitudes, interests, degree of autonomy, degree of variety of tasks, style of management and satisfaction. Herbsman & Ellis (1990) have also pointed out that one of the most important factors for increasing productivity is labour Motivation.

The above factors influencing productivity may be classified into Seven main categories as follows:

1. External (Environmental) factors,
2. Internal factors including:
   - 2.1 Resources
   - 2.2 Information
   - 2.3 Organisation Structure
   - 2.4 Training
   - 2.5 Motivation

The external factors are those factors which lie beyond the control of site management such as the physical environment (weather), and the economic environment. Whereas the internal factors are those which lie within the realm of management control.

Since the main concern of the study is the Analysis of the impact of quality management systems upon construction productivity and that the QMS is a management system, then it can only influence the managerially controllable factors of productivity which are the **internal** factors. The classification suggested here is based on a paper by Mukharejee and Singh (see Prokopenko,1987). Examples of those external factors that are considered to be uncontrollable by management action at the site level include Government policies and institutional mechanisms political, social and economic.

❹.3.5 DISCUSSION OF THE EXTERNAL FACTORS

The external factors influencing construction productivity include the physical environment and the economic environment. Although these factors were considered to be beyond the direct influence of site mangement, they are however fully controllable by management at higher levels. Management at the construction company or the industrial level can minimize the effect of environmental factors upon construction projects. The following discussion is meant to indicate how management can address the external environment influencing construction productivity.

A construction project does not, of course, exist in a vacuum; rather it is dependent on its external environment. It is a subsystem of larger systems such as the company and the industry.

The relevant environment for a construction project is the physical environment and the general economic enivronment.

Management of the physical environment

Construction work is performed mainly in the outdoors and hence is prone to weather conditions, terrain, topograghy and other physical evironmental factors. For example, prolonged rainfall, snowfall, high and low tempratures are the factors contributing to the seasonal and cyclical nature of construction work. Moreover, prolonged rainfall may mean that workers have to be transferred from outdoor to indoor work; high wind may make steel erection, roofing and similar operations dangerous.

Clearly, the productivity of construction projects is influenced by forces from the physical environment. Construction managers have a wealth of available means for reducing the effects of these environmental forces. For example, project management at the company or industry level can reduce or minimise the environmental factors by adquate managerial perception and by obtaining accurate information on physical environmental factors.

Construction management at the company level also has considerable influence on reducing the effects of the physical environmental variables by having accurate weather information for the project. This can be used to level allocations for manpower requirements and equipment may be made available with regard to weather conditions to provide better utilisation of these resources. Project managers can use readily available weather information services to markedly improve their operations. Deliberate actions to offset the effects of adverse physical environmental factors can frequently improve the project performance.

Managing the economic environment

In addition to the physical environment, construction projects are also influenced by the wider economic environment. The economic environment includes government policies and institutional mechanisms, including political, social and economic conditons. Such macro-economic factors do affect the individual projects concerned, but project management cannot actively control them. However, the effect of such factors can be reduced or minimized by management at the company, industry and national levels. However, design of good policies, plans or programmes for productivity improvement by project managers and others requires understanding and consideration of the economic environment in its broader sense.

Bearing in mind all social, political and economic links between clients, managers, workers and government, Prokopenko (1987) defines the so called macro-productivity factors which include structural analysis of the society, natural resources and government role.

Structural changes in the society can often influence national and project productivity independently of project management. As pointed out by Prokopenko (1987) structural changes can cause economic and social development. Therefore, understanding of these changes helps improve government policy, makes project planning more realistic and helps develop the economic and social infrastructures. The most important structural changes in a society are the economic changes. These economic changes can be manifested in the employment patterns and composition of capital, technology and scale.

Employment shifts from one industrial sector to another can often affect economy-wide productivity. For example, employment shifts from agricultural to manufacturing industry have caused an economic wide increase in productivity that has surpassed productivity growth within any one sector in developed countries (Prokopenko, 1987).

However, economic changes can only happen by governments' intervention and therefore, project management or indeed industrial or company management have a limited role to play in addressing wider economic changes.

As for Capital and its composition, its relative intensity and its kind each affect productivity. The growth of capital depends on investment supported by the industry. Moreover, the management of R & D and technology and implementation of new methods, techniques and processes can significantly influence productivity at the industry level as well as the company and project levels.

Concluding Remark

The above discussion was meant to highlight the importance of the wider economic environment and its impact upon productivity. It is by coordinated efforts of management at all levels of the society that such factors can be controlled and used for positive contribution towards the objective of productivity improvement.

As this study concerned itself with the assessment of the impact of quality management systems upon construction productivity at the site level, further analysis of the external environment is believed to be beyond the scope of the study.

❹.3.6 MANAGEMENT OF RISK

Another factor which may arguably be considered here as being of relevance to construction project productivity and management is that of **risk.** In general, risk manifests itself in construction projects with particular reference to the inherent uncertainty of the costs, duration of individual activities or elements within a project when assessing the anticipated final cost or duration of a project. The future is largely unknown and most business decision making takes place on the basis of expectations about the future.

Risk is inherent in all construction work no matter what size the projects are. The construction industry has had a poor reputation for managing risk. Targets are sometimes missed because of unforeseen events that even an experienced project manager cannot anticipate. More often it happens because of events that are predictable in nature. For example, industrial disputes, delayed decisions or unexpeced ground conditions may all be anticipated, but their likelihood and impact are hard to predict with any precision, and no two projects are the same. This makes it very difficult to identify the sources of risk for each project.

However, risk management requires management responses and policies to reduce and control the main risk identified in the analysis.

What can project management do to manage risk?

Perry (1992) points out that project management has a vital role to play in risk management. From the feasibility stage to the initiation of the project, project managers can contribute to economic decisions by producing realistic estimates of cost and time which are based on clear specification of operational and quality requirements.

After the start of the project, the risk element should be studied by the project manager stage by stage. When using estimates of cost and time it should include contingency allowances and show ranges representing the major risks and uncertainties. Moreover, managers should adopt methods for allocating the remaining risks to various parties in a way which will optimise the results of the project. As explained by Perry (1992) the allocation of a risk to a party should be accompanied by motivation for good management.

Nevertheless, in the context of this study priced bills of quantities were used as the primary source of data for house building projects completed in the area of Scotland. Therefore, it is assumed that the **element of risk that a contractor is subjected to is reflected in the bill of quantity** of the project concerned. Consequently, the issue of risk management is discussed here purely to highlight its importance from the project management point of view, but was not included among the MCVs due to the assumption that it was taken care of in the priced bills of quantities as analysed for each project.

❹.3.7 MANAGEMENT OF THE INTERNAL FACTORS

As for the productivity factors that are within the control of management, they will be dealt with in the above order:

I. Management of Resources (Labour, Plant, Equipment, Materials, Technology),
II. Management of Information,
III. Management of the organisation structure,
IV. Management of Training,
V. Management of Motivation.

❹.4 *MANAGEMENT OF RESOURCES*

a) Plant and Equipment

These play a central role in productivity improvement. In order that they become very beneficial to the construction process, the following should be observed (Prokopenko, 1987):

1. Good maintenance,
2. Operating the plant and equipment in optimum process conditions,
3. Increasing plant capacity by eliminating bottle-necks and by corrective measures,
4. Reducing idle time and making more effective use of available machines and plant capacities.

It is also pointed out by Prokopenko that Plant and Equipment efficiency can be improved by attention to utilisation, age, modernisation, cost, inventory control, production planning and control and so on.

b) Materials

Even small efforts to reduce materials consumption can bring remarkable results. The materials optimum use is a vital source of productivity improvement. Prokopenko (1987) spells out the important aspects of materials productivity as follows:

* Control and Control of rejects,
* Use and control of wastage and scraping,
* Upgrading of materials by initial processing to improve utilisation in the main process,
* Improving inventory turnover ratio to release funds tied up in inventories for more productive uses,
* Improving Inventory management to avoid holding excessive stock,
* Developing sources of supply.

The concern for the organisation of the capital resources (plant, equipment and materials) dates back to the early days of the construction industry. It was the subject of much research and application in the early twentieth century.

Taylor (1911) was a pioneer in developing industrial and production engineering techniques.

❹.5 *THE INFORMATION MANAGEMENT*

Drucker (1980) states that: "The manager has a specific tool: information. He does not handle people; he motivates, guides, and organises people to do their work. His tool, his only tool, to do all this is the spoken or written words or the language of numbers". These words of Peter Drucker, while referring to the broad spectrum of management, are specially appropriate in construction project management. As pointed out by Shaddad (1983), analysis of production activities in the construction industry show that a substantial proportion of the resources applied to them relate to handling information, both as input or output.

According to Forrester (1962), management is the process of converting information into action. This conversion process is called decision making. Kast & Rosensweig (1979) also stated that *"managerial decisions are necessary to integrate activity towards objectives and to maintain a viable organisation in a dynamic equilibrium"*.

Information is a key ingredient in any decision making process and it is vital that each organisation devotes attention to designing appropriate information systems.

Project management Information System

Green (1970) asserts that managers have decisions to meet objectives and information is necessary for the process. Therefore,"it is the function of a management information System to contribute towards these needs". Furthermore, Schwartz (1969) described MIS as 'a system of people, equipment, procedures, documents and communications that collects, validates, operates on, transforms, stores retrieves and presents data for use in planning, budgeting, accounting, controlling and other management processes for various management purposes'.

Also Ein-Dor & Eli Segev (1978) stated: "A management Information System is a system for collecting, sorting, retrieving and processing information which is used, or desired, by one or more managers, in the performance of their duties".

❹.6 *ORGANISATION OF PROJECT MANAGEMENT INFORMATION SYSTEM (PMIS) AND PRODUCTIVITY*

The basis of any rational decision, as management theorists would agree, is the availability of relevant sufficient information. As CIB (1970) asserts, there are three closely related processes in construction: the information process, the decision making process and the construction process. If Productivity is to be improved, this relationship should be defined in terms of designing the Information system to suit the particular construction activities in question.

Such an information system should facilitate the information flow and hence the decision process such that people are able to obtain the relevant information wherever and whenever needed.

❹.6.1 Information Flow in The Construction Industry

Many construction writers (Shaddad, 1983) believe that many information flow faults would not exist if the current participant relationships, contractual patterns and organisational structures were changed. Improvements in information flow are likely only to happen when management know how to organise information and have the ability, skills and understanding to do so, while improvement in the management of information may well result in changes in organisation structure and contractual patterns.

The information needed by a construction project manager can be classified as follows:

1. Project Information,
2. General Information,
3. Company or management Information.

The three categories of information above are closely related and if project management is to organise the information system, it should work to bring them together.

Poole (Shaddad,1983) identified Three dimensions that determine the effectiveness of a PMIS. They are:

- **information availability,**
- **information uniformity,**
- **information independence.**

The basis of any rationale decision is the availability of uniform, relevant and sufficient information. There is strong relationship between the organisation of Project Management Information System (PMIS) and Productivity Improvement (Shaddad,1983). The relationship, however, is a rather complex one.

Information which is less available or uniform will cause delays and idle time. It will also affect machine utilisation, continuity of production and hence productivity.

❹.7 *MANAGEMENT OF ORGANISATIONAL STRUCTURE*

Drucker (1974) stated that: *"Structure is a means for achieving the objective and goals of an institution"*.

The organisation of a project's structure is one of the most important managerial activities. It entails the creation of a Structural system suitable for the needs of a particular project, achieving consistency between the various aspects of the structure, and adapting it over time to changing circumstances. As Drucker (1974) pointed out, it is to assist the achievement of objectives.

The well known principles of good organisation such as **Unity of Command, Delegation, and Span of control,** are intended to provide for specialisation and division of work and coordination within a particular project. A project organisation needs to be dynamically operated and led towards objectives and must be maintained, serviced and reorganised from time to time to meet new objectives.

It was pointed out by Prokopenko (1987) that one main reason for the low productivity of many organisation is their rigidity. They fail to anticipate and respond to, for example, market changes, ignore new capacities in the labour force , new developments in technology and other external (environmental) factors. Rigid organisations lack good horizontal communication. This slows down decision making and inhibits delegation of authority close to the point of action, encouraging inefficiency and bureaucracy. Prokopenko (1987) further asserted that, compartmentalisation , according to professional groups of functions also inhibits change. For example, the decision making steps may have been designed for a particular existing technology, for a particular service. Things have to now changed, but procedures have survived because managers want to minimise change. No system, however well designed, is efficient in all situations. Dynamism and flexibility should be incorporated into the system designed in order to maximise productivity.

④.7.1 *VARIABLES AFFECTING THE DESIGN OF ORGANISATION STRUCTURES OF CONSTRUCTION PROJECTS*

For purposes of proper investigation of factors influencing the design of the structure of an organisation, management theorists have focused primarily on the relationship between certain contextual variables and the structural system.

A Study conducted by Djebarni (1993) provided convincing evidence for the influence of ***size***. Construction projects are interesting to consider from this point of view. As far as construction projects are concerned, the size of the project is not determined merely by the number of employees, instead, by the amount of work to be undertaken, and the scale of operations (Shaddad, 1983). Shaddad referred to the size factor as **"the volume of work'**. With large projects there is an opportunity to obtain a well-integrated structural system. With small projects there has to be some reliance on informal systems.

Technology was first introduced as a determinant of organisation structure by Woodward (1958) who presented theoretical formulations supporting the technology influence. The Technology of a construction project can be classified in terms of the dominant technology of the implementation and construction stage.

A closely related concept to that of technology is the **method of construction** with its sub concepts of Traditional vs. Industrialised and Labour intensive vs. Capital intensive. This concept has been regarded by Culvert (1970) as important in deciding the organisation of the project structure.

The Autonomy of an organisation refers to the relationship between a focal organisation and its parent organisation.

With regard to construction projects it is the measure of the extent to which decisions concerning suppliers, subcontractors, designers, information, etc.. can be automatically made at the project level.

❹.8 *TRAINING AND MOTIVATION MANAGEMENT (PEOPLE)*

People, as the principal resource and the central factor in a productivity improvement programme have an essential role to play. As workers, engineers, managers and entrepreneurs and construction project managers.

As pointed out by Prokopenko (1987), each person's role has two aspects: ***Application*** and ***Affectiveness.***

Application is the degree to which people apply themselves to their work. People differ not only in their ability but also in their will to work. This is explained by a law of behaviour: motivation decreases if it is either satisfied or blocked from satisfaction. For example, people may do their job without working hard (no motivation).

Motivation is basic to all human behaviour and thus to efforts of productivity improvement. Apart from incentive schemes, Motivation can be enhanced by encouraging cooperation and participation from workers. Labour participation in goal setting for example, has been quite successful.

Standards of performance play an important role in productivity improvement. It should be set at a high but realisable target. i.e standards should be achievable to maintain confidence and the 'will to do'.

The second factor in the role played by people is *effectiveness*. *Effectiveness* is the extent to which the application of human efforts brings the desired results in output and quality. *Effectiveness* is a function of method, technique, personal skill, knowledge, attitude and aptitude- the "ability to do".

❹.8.1 *MANAGEMENT OF TRAINING*

Training in the Construction Industry

The importance of Training to the construction industry in the UK was asserted by the White paper of the Industrial Training Act of 1964. The significance of the act was the establishment of resources devoted to the improvement of performance, productivity and profitability. The Construction Industry Training board was amongst the first of boards to be formed under the act in July 1964.

Hall (1959) has identified two basic ways or channels by which knowledge and culture are transmitted;

a) Formal methods of learning and knowledge transfer,

b) Informal methods of learning and knowledge transfer.

As explained by Hall (1959), Formal training is broadly confined to off-the-job training of apprentices and trainees at technical colleges. Apprenticeships in the UK for example, provide the construction industry with most of the major craft skills, such as those of carpenters and joiners, plumbers , plasterers and painters.

Informal training generally requires the passage of considerable time. With foremen, for example, this time is measured in decades.

The major variables influencing training have been identified as follows (Shaddad,1983 and Jucius 1975):

1. **Skills,**
2. **Knowledge,**
3. **Attitudes.**

The demands for skills in the modern construction industry are somewhat different from those of earlier days. The problem of the industry, as Jucius (1975) states is: "how to reconcile the need for a supply of manpower capable of high productivity in carrying out simplified sequential operations and, at the same time, retain a substantial number of craftsmen capable of highly-skilled work".

The possession of appropriate skills and knowledge does not always guarantee appropriate action. It is the operative's attitudes, which have been moulded mainly through emotional experiences, that direct and energise the actions. Out of an almost endless list, the following types of attitudes are particularly significant:

a. attitudes towards the project and its members,

b. attitudes towards the individual's role,

c. attitudes towards action.

Changes in attitude or the acquisition of new values cannot be measured directly; it has to be inferred from any resulting behaviour.

It has been pointed out by Shaddad (1983) that training for better quality ought to be provided because:

a. Quality on construction sites is largely determined by the ability and resourcefulness of operatives.

b. Research in the UK has revealed that direct waste of material on site is twice that actually assumed to occur by contractors (Skoyles,1976). Training can reduce waste, increase output, reduce equipment maintenance and improve quality (Glueck, 1974).

c. The construction industry in the US, for example, experienced injuries at twice the rate of other industries and a death rate of three times that in other industries (Parker & Oglesby, 1972). Studies conducted by Levitt and Parker (1976) and Surrey (1969) indicate that proper training in safe work methods reduces accidents significantly.

d. Pigors & Meyers (1969) state that "dissatisfaction, complaints, absenteeism and turnover can be greatly reduced when employees are well trained that they can experience direct satisfaction associated with a sense of achievement and the knowledge that will develop their inherent capabilities at work".

e. Improving the ability of an operator to work can affect machine utilisation by:
   - machine or plant breakdown as a result of mishandling,
   - anticipating machine or plant breakdown early enough for corrective action to take place.
   - fixing machine or plant breakdown speedily.

❹.8.2 *THE ROLE OF PROJECT MANAGEMENT IN THE ORGANISATION OF TRAINING, RECRUITMENT AND SELECTION OF CONSTRUCTION WORKERS*

The personnel department of any construction organisation has traditionally been responsible for meeting the training requirements, the procedures, functional skills and for the development of selected craft training materials to be used on the site. However, project management can contribute to the training programme as follow (Pigors & Meyers, 1969):

1. Reviewing the performance and progress of foremen, craftsmen and operatives on their present jobs and providing pointers to their need for further training, as well as providing pointers to continuing personnel deficiencies which may call for correction.
2. Facilitating on-the-job training schemes;
3. Obtaining some indication of the benefit and effectiveness of past and current training given to the individuals;
4. Specifying, in advance, the job requirements for recruitment and promotion purposes.

Management activities can organise the training and selection of workers. However, the following constraints will apply (Parker & Oglesby, 1972)

a. the availability of construction skill in the area,

b. the availability of training resources in the area,

c. the geographical location of the project,

d. the general and environmental forces.

The organisation of training will cause changes, at the individual level in individual's skills, individual's knowledge, and individual's attitudes. Changes in these three variables will affect the ability level which in turn will affect the following variables:

i. Scrap or waste level,

ii. machine utilisation,

iii. continuity of production,

iv. quality level,

v. labour turnover,

vi. absenteeism.

It is obvious that changes in the above variables will ultimately affect the level of output per material used and output per manhour as well as the output per capital invested and hence **the Productivity of the construction project.**

Ideally, these productivity indices should be measured in terms of their physical measurement, but with the difficulty in being able to find such data as output per manhour, output per material used and output per capital invested in physical terms the study had to rely upon a surrogate measure of these indices. This surrogate measure was taken as the monetary values of these outputs and inputs as £ are common to both. Therefore, a major limitation of this study lies in the reliability of data used to estimate these indices, although any unreliability of data is constant across the sample.

❹.9 *MANAGEMENT OF MOTIVATION*

Different managerial approaches to motivation

Each organisation can be said to have its own distinct managerial approach to work. Miles (1975) found that the approaches and theories of most managers fall into three categories:

1. the traditional approach,
2. the human relations approach,
3. the human resources approach.

The traditional approach is best characterised by Taylor (1911) and his associated scientific management school. The traditional managers saw the inefficient production as a problem primarily of management, not workers. Their underlying motivational assumption was that financial incentives are the primary motive for the work effort. Although Likert (1961), Herzberg *et al.* (1959) and McGregor (1960) emphasise the point that money is not everything. However, it is fair to say that many of the traditional beliefs and assumptions are presented in the way in which construction industry management views and directs its affairs. Financial incentives have been operated in the UK for more than thirty years (Shaddad,1983).

The Human Relations approach emerged out of the realisation by some managers that the traditional approach was not entirely successful in their situations.

Talbot (1976), Mason (1978) and Schrader (1972) proposed motivating the construction workers by the human relations model and suggested such means as improving communication, developing healthy worker attitudes, introducing social activities and encouraging widespread participation and involvement in the decision making. Recent approaches have been proposed under different titles such as: McGregor's theory Y, Likert (1961) System 4 and Miles (1975) Human Relation approach. Essentially the Human Resources models view human behaviour as being motivated by a complex set of inter-related variables such as money, needs and desire for meaningful work.

Maslow's (1954) hierarchical need model is the most prominent in work motivation. It consists mainly of two fundamental premises. The first states that the individuals are wanting animals motivated by a desire to satisfy certain specific types of needs. The second argues that the needs which an individual pursues are universal and are arranged sequentially in five hierarchal levels:

1. **Physiological,**
2. **Safety,**
3. **Belongingness,**
4. **Esteem,**
5. **Self actualization needs.**

❹.9.1 Construction Related Motivational Studies

Construction Related Motivational studies have been limited mostly to the content category of motivational models, namely need and Two factor models.

Nave (1968) and Scharder (1972) analyzed and redefined Maslow's hierarchy of needs in the construction-related terms.

Nave (1968) after reconstructing Maslow's hierarchy of needs in construction related terms, offered some general principles for motivation improvement by such means as expressing concern for employee morale, job security, non-monetary rewards.

Schrader (1972) analyzed Maslow's hierarchy needs and proposed motivating a construction worker by such means as improving communication, involvement of the workers with management, introducing social activities and recognising good performers.

❹.9.2 THE MAIN VARIABLES THAT MAY AFFECT THE CONTEXT OF MOTIVATION IN THE CONSTRUCTION INDUSTRY

A definition of Motivation adopted by Shaddad (1983) has described Motivation as being concerned with those factors which energise, direct and sustain human behaviour, it would appear that several important variables must be taken into account when dealing with the motivational processes of the construction worker.

If motivation stands for the factors which energise, direct, and sustain behaviour, it would appear that several important variables must be taken into account when explaining the motivational processes in construction projects. Porter & Miles (1974) identified three categories of variables:

- **i.** Individual Characteristics,
- **ii.** Job characteristics,
- **iii.** Work environment characteristics.

If motivation is to be affected, one or more of these variables must be changed or affected.

Several theorists of motivation, in industrial research, have encompassed the notion of attitudes relating to performance behaviour at work (Korman, 1970). Three attitudes are found to be of great effect. These are:

- **a.** Attitudes towards self;
- **b.** Attitudes towards job;
- **c.** Attitudes towards the work situation.

❹.9.3 APPLICATION OF MOTIVATIONAL TECHNIQUES IN THE CONSTRUCTION INDUSTRY

Most construction organisations employ one or more methods to manifest role compliance and goal-oriented behaviour. A review carried out by Shaddad (1983) indicated that most research has been focused on four basic motivational methods. These are:

1. Financial incentives,
2. Goal Setting,
3. Participation,
4. Job design.

❹.9.4 FINANCIAL INCENTIVES

A number of studies have recently been conducted in the UK to examine the feasibility of applying financial incentives programmes to construction (Blain & Paterson, 1981). The main argument against financial incentives programmes is the fear that the it would inhibit other strong and pleasurable motives for working, such as the pleasure of work for its own sake, and the solidarity and good fellowship of the work group.

❹.9.5 GOAL SETTING

Goal Setting essentially involves establishing observable standards for employee performance and offering feedback to the employee regarding the extent to which the standards have been achieved. Goal setting techniques, like performance targets and work standards, have been widely used in construction.

❹.9.6 JOB DESIGN

Job design involves the structuring of various aspects of the job content. For example, job design might involve increasing job responsibilities, the variety of tasks of employee autonomy.

Evaluation and effectiveness of job design is more difficult than evaluating the effectiveness of other motivational techniques because it is usually implemented in conjunction with feedback and other structural changes.

It was pointed out by Shaddad (1983) that Construction Management has generally failed to motivate its workers effectively through these techniques. While project managers expect headquarters to delegate almost all responsibility, they, in turn, often desire to regulate closely their foremen and expect responsibility to be withheld from workers. Many foremen, however, realise that workers cannot be motivated through such strict direction and control.

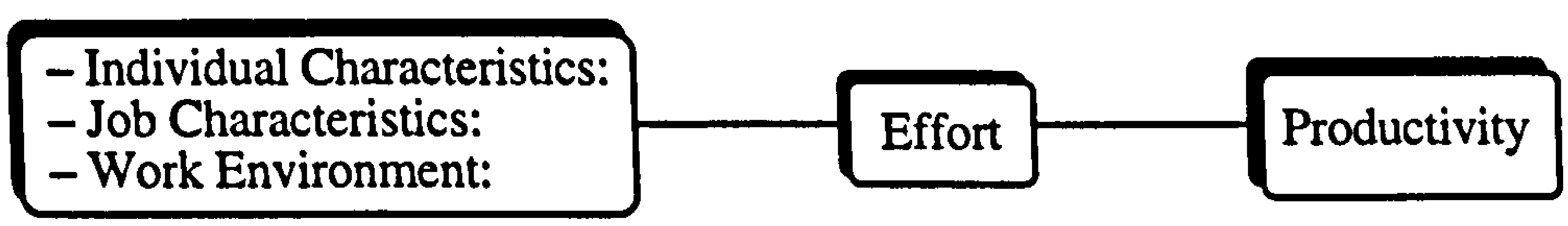
A general model linking motivational variables, effort and productivity was developed by Shaddad (1983) as follows:

- **Individual Characteristics Variables**
- **Job Characteristics**
- **Work Environment Characteristics**

The above variables affect the **Effort** of the worker and hence the Productivity of the job.

Changes in **individual characteristics, job characteristics and work environment** will result in changes in **satisfaction and effort.**

A general model linking motivational variables, Effort and Productivity was developed by Shaddad (1983):



As shown by Shaddad, there is considerable evidence to support the view that the introduction of the various motivational techniques, the intrinsic and extrinsic, such as **job design, financial incentives, goal setting and participation** influence the different Motivational variables. As far as management is concerned, productivity determinants such as *effort, labour turnover, absenteeism, strikes and disputes* should attempt to influence these variables.

❹.10 *CONCLUDING REMARKS*

Having defined the managerially controllable factors that are found to influence construction productivity at the site level, the investigation will now seek to assess the impact of the implementation of Quality Management Systems (QMS) as management systems upon these factors. But before this is done, the relationship between quality management and productivity has to be shown beyond the philosophical context. ***chapter*❻** (methodology) of the study will be concerned with the description of the way in which this relationship was established. In ***chapter*❼** (analysis and results) will further show the impact of the implementation of quality management systems upon the control of the **internal** factors (managerially controllable factors) and hence its impact upon construction productivity. In ***chapter*❽** the overall conclusions of this investigation will be cautiously drawn.

Chapter ❺

Quality and Productivity: The Linkage

❺.1 *INTRODUCTION*

It has been widely believed that improving quality and productivity represents conflicting objectives, each of which could be advanced only at the expense of the other. The argument presented in this ***chapter*** suggests that there is a linkage between quality and productivity and that the strategic aims of any quality management system is to increase productivity as well as quality simultaneously. The ***chapter*** also describe how, from a philosophical point of view, such a link exists.

❺.2 *CAN QUALITY AND PRODUCTIVITY BE LINKED?*

The traditional view is that there exists a trade off between quality and productivity, and that efforts to achieve ever-higher levels of both are likely to be uneconomic. From a quality management point of view, the strategic aim of any quality system is to **raise standards, reduce costs** and **win more business.** If these three objectives were to be achieved, then productivity can only improve. Mefford (1991) argues that quality and productivity are complementary, and programmes that exploit this insight and attempt to improve both of these simultaneously are the most successful. After examining programmes used by successful firms to achieve simultaneous improvements in both, Mefford pointed out that constant improvements in quality and productivity are possible and economic and there need be no trade off between them.

The traditional view in the US and in Europe was that if a firm wants to improve quality it is likely to pay a productivity price as production lines are slowed down and more products are rejected and reworked. Obviously, if a firm's approach to improving quality is to hire more inspectors and repairmen, then productivity will suffer.

Quality experts such as Deming (1986) and Crosby (1979) have long realized the complementary relationship between quality and productivity. As already stated, Deming (1986) said it all: *"Improve quality, you automatically improve productivity, you capture market with lower price and better quality. you stay in business and win more jobs. So simple".*

Mefford (1991) explains that the experience of firms experimenting with new methods of achieving improvement is demonstrating that there is a positive relationship between quality and productivity. In other words, by simultaneously trying to achieve higher levels of quality and productivity, firms are finding that there are synergistic effects. Mefford (1991) added that there are three main reasons for the positive correlation between quality and productivity: direct and indirect linkages and the morale effects. These linkages may be described as follows:

❺.2.1 THE DIRECT LINKAGES

The direct productivity relationship results from how productivity is defined and measured. Productivity is generally defined as a measure of **output/inputs** required to produce it. Obviously, it does not make sense to include in the numerator defective output that cannot or should not be sold. So for every unit of defective output produced that must be scrapped or reworked inputs are wasted. As far as manufacturing of products is concerned, inputs may be labour hours, machine time, and material inputs are wasted when poor quality output is produced. A firm with a lower percentage of defective output with the same amount of resources inputs will necessarily have higher productivity. This according to Mefford (1991) is the direct productivity consequence of programmes to improve quality. ***Therefore, making things right first time can yield substantial direct productivity benefits.*** However, there are also some indirect productivity benefits of quality improvement programmes.

❺.2.2 INDIRECT LINKAGES

One such indirect benefit for productivity of quality enhancement efforts is improvement in the design and operation of the production process. As explained by Mefford (1991) an effective quality improvement programme requires a complete examination of the production process to identify all possible sources of defects. Product/service design, equipment selection and maintenance, worker selection and training, client requirements and inspection procedures will need to be looked at. In doing so it is very likely that problems and potential improvements will be identified in all of these areas. If these changes are implemented, productivity will almost certainly improve. Reduction in the inefficiency of the process is considered as an improvement in productivity.

❺.2.3 MORALE EFFECTS

A third mechanism by which firms are able simultaneously and cost-effectively to improve productivity and quality is through the morale effects. Mefford points out that there is increasing evidence that improvements in quality and productivity have a salutary effect on employee morale. There are several reasons why this occurs. Effective quality and productivity improvement programmes or systems utilize employee involvement. By getting employees in quality circles, quality of work life groups, and work teams employees receive more satisfaction from their jobs and may feel more committed to the firm. As he further explains, this is likely to lead to reduced absenteeism and turnover and a greater commitment on the part of the employee to do a better job.

Therefore, Mefford (1991) concludes that via the three mechanisms discussed synergy and momentum can build between quality and productivity improvement efforts leading to beneficial results in both areas that overwhelm any negative trade-offs, if these do exist. He further added that although the indirect and motivational aspects of **quality/productivity** are intangible, they nevertheless seem to be quite potent and firms able to tap them are believers in the results.

❺.3 *TOTAL QUALITY MANAGEMENT (TQM) AS AN IMPROVEMENT TOOL FOR QUALITY AND PRODUCTIVITY*

How much similarity is there between TQM and productivity? What are the common elements and how does each differ? A clearer understanding of how the two inter-relate might affect our future thinking. If we were to examine the similarities between TQM and productivity an appropriate starting point might be the definition of both terms: Richard Thorpe (management services handbook, 1985) defines productivity as: *"A ratio of a measure of output to a measure of some or all of the resources used to produce this output"*. Over time this definition passed from the academic, to have a practical and different meaning running along the lines. *"More output for the same or less cost"*.

It is interesting to note at this juncture that the Oxford English Dictionary definition of productivity is: "the capacity to produce quality or state of being".

The emphasis in the industry has constantly been, as expressed by Scurr (1991), on *more bang for less bucks* where the real need is to produce quality. TQM embraces this broader concept. There are many well documented definitions of quality improvement.

The above definitions cited for productivity should serve to reinforce the line adopted by the working definition of productivity in the study, which was centred around the resource utilisation theme as well as further demonstrating yet again that the quality and productivity themes can be brought together in a meaningful way.

The strategic aims of any quality management system outlined earlier were:

- **Raise the standards,**
- **Reduce costs,**
- **Win more business.**

The quality management approach, as discussed in *chapters* ❷ and ❸, is a long term approach; it is about cultural change, creating vision, mission and values.

The message given by Scurr (1991) is clear and simple: quality management is rapidly becoming the driving vehicle for productivity, setting the direction of the organisation and establishing the values by which the organisation conducts itself in its day to day work.

Moreover, with regard to the integration of quality and productivity, Gold (1990) points out that two important lessons absorbed by the Japanese and still to be recognised in the West are:

1) That achieving advances in productivity and quality can be mutually supportive rather than mutually antagonistic; and

2) That continuing efforts to develop improvements in quality can help to reveal and to overcome various limitations of existing products and production processes, and thereby to improve productivity and costs as well as sales further.

Many types of programmes are used in the manufacturing industry to improve quality and productivity and few of these have proved to be successful in improving both simultaneously (Mefford, 1991). According to Mefford these systems, although developed by manufacturing firms, appear to have the potential to produce similar benefits in service industries such as the construction industry.

Among the quality-productivity improvement programmes discussed by Mefford, total quality management was the most central method of improving quality and productivity. As he pointed out, although in a TQM programme the focus is on quality improvement, to accomplish this goal a firm is likely to find that the methods employed also lead to significant productivity enhancement. As discussed earlier in any quality management programme, everyone should be made responsible for quality, a stress on constant improvement, Zero Defects and tracking back defects to their source. These methods are likely to yield productivity improvements as well as quality improvements. For example, tracing back defects to their cause can reveal a host of problems. Perhaps workers are not properly trained, equipment is old or poorly maintained, or the production schedule is poorly coordinated. In identifying and correcting the quality problems, productivity will almost certainly increase by the direct and indirect mechanisms discussed above. Another potent mechanism of productivity improvement for TQM programmes is the effect on worker attitudes and morale. By stressing every employee's responsibility for quality, a commitment to performing work properly and constantly looking for ways to improve performance is instilled. Such morale effects can be very effective in improving quality and productivity, and successful TQM programmes are heavily dependent on workers involvement. Therefore, it should not be come as a surprise that firms using TQM are demonstrating productivity growth (Mefford, 1991).

❺.4 *THE IMPACT OF QUALITY MANAGEMENT ON PRODUCTIVITY*

The Deming (1986) doctrine has always been: 'improve quality and you automatically improve productivity'. This message has been taken to heart by the leaders of many organisations desiring to improve their overall performance and competitive positions of their organisations. It is pointed out by Fisher (1991) that in Australia companies have been encouraged by industry-based organisations such as the Total Quality

Management Institute (TQMI) which was established to assist companies to implement the ideas of quality gurus such as Deming, Juran, Ishikawa, Crosby, etc. TQMI summarizes the basic ideas of TQM as follows: *"Total Quality Management is the management philosophy that seeks continuous improvement in the quality of performance of all the processes, products, and services of an organisation"*. It emphasizes the understanding of variation, the importance of measurement, the role of the customer and the involvement of employees at all levels of an organisation in pursuit of such improvement. A feature of the new philosophy is that management must play a key role. TQM lays the burden of responsibility for the bulk of the waste, error and defects on management's shoulders. On the other hand, it is through management's actions that the bulk of the gains for quality improvement must come (Fisher, 1991).

❺.5 *REVIEW OF QUALITY-PRODUCTIVITY STUDIES*

The objective of the first study, carried out by Fisher (1991), was to determine whether companies deliberately progressing down the route of quality management were, in fact, achieving improvements in the quality of their processes and products or services, and whether these improvements in quality were being matched by improvements in the overall organisational productivity or performance, as implied by Deming in the above statement. In this particular study, Fisher's sample was composed of **Four Sydney based companies** which were embarking on quality management programmes. Historical information was obtained from them on the implementation of their TQM processes, and productivity indicators were calculated from before implementation of the TQM to the present time. The Four companies were quite diverse in their activities, as well as in the nature of their quality approaches. It was pointed out that no attempt had been made to characterize the nature of the quality management system implemented by these organisations or judge the success or otherwise of the different processes used. Instead, reliance was made on the fact that the companies themselves considered that they had successfully implemented quality management processes. These companies were taken as truly representing companies implementing TQM. As far as the **quality and productivity indicators** are concerned, no attempt was made by Fisher (1991) to develop measures of quality and productivity for each company, or to obtain the same measures for all companies. Only the information collected by each company was used. Productivity measurement is a more complex matter. Deciding just what productivity means, and how to measure it, is subject to a broad range of opinions and approaches (see ***chapter*** **❸**). Perhaps a more fundamental question is whether an improvement in productivity corresponds to an improvement in company performance. In this study a number of different productivity and performance indicators have been used, both physical and financial. Once again, the information is based solely on the historical information supplied by the companies concerned.

The results of this study are consistent with the conclusions reached in an earlier study by Fisher. In this study Fisher concluded that the TQM processes implemented in these organisations can be said to have generally resulted in improvements in internal and external quality factors, and in some cases improvements in labour productivity.

The quality improvements achieved by the four companies, together with the conviction of all the company managers concerned that the quality processes have made substantial contributions to their company's viabilities are convincing arguments in favour of TQM. However, if we are to gain broad acceptance of this approach, we must find convincing financial arguments to demonstrate that the TQM approach does indeed deliver superior results.

❺.6 *QUALITY-PRODUCTIVITY STUDIES IN THE CONSTRUCTION INDUSTRY*

Similar to other industries, high productivity and quality output have traditionally been seen as mutually exclusive in the UK construction industry and elsewhere. Achieving either Productivity or quality has been a sufficient goal for most firms working in the construction industry.

In a study aimed at assessing the effectiveness of quality management activities in one of the major Japanese construction organisations Takenaka (Hirao, 1994), it revealed that after 17 years of quality management implementation, the productivity of the company grew 3.27 times since 1975. There are many different ways to calculate the productivity of the construction industry; in this case sales per employee was taken as a measure of productivity and was found to have grown by the amount shown above.

In another independent study in the US by Burati *et al.* (1991) 19 US organisations embarking on quality management programmes were reviewed and analyzed. In-depth interviews were conducted with 142 representatives of these organisations. Burati *et al.* (1991) concluded that companies which had been implementing TQM for more than five years made considerable savings which could be credited to the overall quality effort. Some of the representatives interviewed by Burati *et al.* (1991) pointed out that as far as benefits of TQM are concerned: *"..they are firmly convinced that there are many known and unknown benefits that cannot be documented"*.

The above studies served to emphasise the link between quality and productivity. They also gave an indication that the impact of quality management systems can be favourable from the productivity improvement point of view.

Bearing in mind that the strategic objectives of having a quality system in the first place is to raise standards, reduce costs and hence win more business, if a quality management system is to be more successful it must achieve all of these objectives collectively. There would be no point in achieving a higher quality product if this was not going to influence the productivity or indeed the production cost. The degree of success achieved by a quality system should be assessed against these three objectives being achieved collectively without any trade offs. Therefore, producing high quality products at high production costs would trade off the raising of standards objectives for reducing production costs. Indeed by increased production cost, a producer may not be in business for long. Instead, doing things "right first time", as advocated by quality experts, would mean less waste, less rework and hence low production costs and eventually better productivity.

By doing things "right first time", as advocated by quality management systems, it would mean less waste of resource inputs, thus lower production costs and hence better productivity. Therefore, the traditional trade off between quality and productivity has to be rejected on the philosophical grounds of what a quality management system is trying to achieve.

Methodology, Research Model and Hypotheses

Chapter ❻

❻.1 *INTRODUCTION*

This ***chapter*** is concerned with the methodology, the research model and hypotheses of the study. It attempts to clearly mark the territory of the research study.

The objective of the ***chapter*** is to describe the overall research strategy and the techniques adopted for data collection and analysis, development and testing of the research model.

The results of the detailed analysis of data are the subject of the next ***chapter*** ❼.

❻.2 *AIMS AND OBJECTIVES OF THE STUDY*

The aim of this research is to assess the impact of the implementation of quality management systems upon construction productivity at the site level.

Objectives of the study

1. To critically review the philosophy as well as the practice of quality management systems with the intention of developing a working definition for what is meant by quality in a construction management sense.
2. To compare and contrast productivity of construction projects completed by quality management organisations and those by non-quality management ones with the intention of creating a model in which a productivity frontier may be defined.

3. To identify the key variables influencing construction productivity and categorise them under those which could be positively controlled by management action (internal factors) and those which rely beyond the realm of management control (external factors).
4. Assess the impact of the quality management system, as a management system, upon the factors identified in (3) to see whether or not the implementation of QMS can positively control the managerially controllable productivity variables (MCVs).
5. Draw conclusions as to whether or not the implementation of QMS can lead to better productivity at the site level.

⓫.3 *STATEMENT OF THE PROBLEM*

Initial facts-finding mission

At the outset of the study a series of fact-finding visits were made by the author to selected groups of organisations embarking on quality management programmes. The target organisations were chosen in such a way as to represent all the parties involved in the implementation of quality management systems in the UK construction industry.

The nature of the organisations visited was as follows:

- Two consultant organisations (one QS and one Architect).
- Three contracting organisations.
- One Client organisation.
- One quality management consultant.
- One certifying body.

The questions raised in the preliminary interviews with those practitioners were aimed at revealing as much as possible regarding the implementation of the quality management systems and what sort of experience they had with it to date.

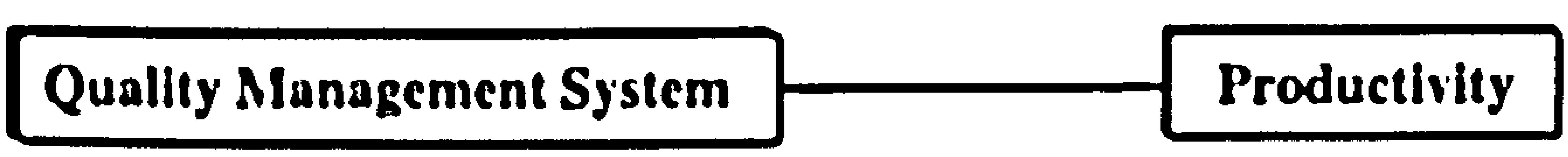
Another category of questions were aimed at assessing the impact of the implementation of quality management systems upon the performance of construction organisations and to find out whether the introduction of quality systems brought about any changes.

An area of particular concern was the impact of quality management systems upon productivity - a link strongly emphasised in the literature (Deming, 1986).

As a result of these initial visits which took place in Oct. 1992, one key finding was that people are yet to establish the impact of quality management systems upon their organisations in an objective way. Moreover, as the quality-productivity link was highlighted in the literature (see *chapter* ❺), again no effort was made to either confirm or negate this theoretical link. Therefore, the author thought it is an area worthy of some attention by researchers and the study was decided to start with an assessment of the impact of quality management systems upon construction productivity.

❻.4 *PHASE I OF THE INVESTIGATION*

The Impact of quality management systems upon site productivity:-



This first phase of the study was aimed at investigating the relationship between the implementation of quality management systems (QMS) and productivity (P) at the site level.

The approach taken in this phase of the study was to assess the productivity of construction organisations with formal quality management systems with those without.

❻.5 *DEFINITION OF THE VARIABLES INVOLVED AT THIS PHASE AND THEIR MEASUREMENT*

❻.5.1 QUALITY MANAGEMENT CRITERIA

The criteria used for classifying construction companies into quality management organisations and non-quality management organisations was based on whether or not an organisation is certified to **BS 5750**; ie if an organisation was certified as having a quality assurance system based upon the guidelines of **BS 5750** it will be classified as a quality management organisation otherwise it would be non-quality management or (traditional organisation). **Despite the author's reservation about the whole issue of certification in the UK and his belief that it did a lot of damage to the whole quality movement, this criteria is seen as the only objective way in which to classify these organisations.** Moreover, it would be almost impossible to find any organisation that would happily admit to not having a quality system of one sort or another.

It was decided that the investigation should be confined to contracting organisations involved in **house building** in Scotland in an effort to standardise the output and minimise the variables involved as much as possible.

❻.5.2 CONSTRUCTION PRODUCTIVITY AT THE SITE LEVEL

From the working definition accorded to the term productivity which was centred around the **optimum utilisation of resources theme** (see ***chapter* ❸**), the approach taken would be based on the notion that productivity may vary among organisations due to their ability to produce different levels of output from the same levels of inputs. In other words, if a particular project organisation were to be productive, it must be using minimum amounts of inputs to produce a given level of output.

This particular approach was taken because productivity measurement at the site level has traditionally been focused upon the partial measure of output per labour input.

This tends to give a distorted image of productivity because labour is only one input in the construction process and according to a Building Research Establishment analysis in 1982, its contribution to productivity only represents 14% while other inputs such as capital represents 27%. For example, if a concreting gang has a high level of output per manhour but an equally high level of material wastage and a low level of plant utilisation, it will not be considered as productive. Therefore, a broader productivity measure is supported by this study, one that includes the most significant inputs in a construction activity. Moreover, the output of construction projects obviously represents the integrated contributions of numerous categories of materials, labour and plant. Labour input is but one player in this output.

Therefore, productivity improvement does not come entirely, or even primarily, from labour improvement. Furthermore, research carried out by the BRE revealed that waste of materials on building sites is very high and is frequently twice that assumed by contractors.

In the light of the above argument, a broader measure of productivity is supported by this study and that other significant inputs such as material and plant should be included in the measurement.

Therefore, Total Factor Productivity (TFP) was chosen as an appropriate measure for the following reasons:

i. It is consistent with the working definition accorded by the study to the term productivity,

ii. Total Factor Productivity (TFP) reflects the methodology chosen for the study which draws in the mixture of resources and which best describes construction productivity.

iii. TFP integrates the contribution of all resources used in a construction project: materials, plant and labour.

Moreover, it reflects a total performance measure which is in accordance with the main objectives of this study.

❻.6 *MEASUREMENT OF TOTAL FACTOR PRODUCTIVITY*

The components measured by total factor productivity should ideally be:

- Output per manhour (labour input).
- Output per materials used (material input).
- Output per plant and equipment utilised (plant input).

Unfortunately, in a construction setting, data for measuring such components directly is not available. None of the information and statistics required for the above components, even output per manhour, will be readily available at site level. Therefore, resort had to be made to surrogate measures in an effort to estimate the values of these resources.

❻.6.1 SURROGATE MEASURE TO ESTIMATE TFP

Due to the practical difficulties in finding physical measures of outputs and inputs to a construction activity, the study opted for estimating these components by using their monetary values; ie using the monetary values of output and inputs. Such a surrogate measure is helpful in estimating the TFP of a particular construction project as it refers to comparisons of all inputs with outputs.

Dacy (1965) estimated TFP of the construction industry with indices of building prices, hourly wages, output per manhour and material prices.

Adopting a similar procedure Thomas *et al.* (1990) defined a model for estimating TFP. Thomas *et al.'s* (1990) model took the monetary value of output and inputs as it is common to both inputs and outputs.

Therefore,

$$\textbf{TFP} = \$\ \textbf{total output} / \$\ \textbf{total inputs}$$

Applying this to a construction project, the value of TFP will be estimated through evaluating the total value of output (in monetary terms) and the value of inputs (labour, plant and materials).

❻.7 *DATA REQUIRED AND ITS SOURCES*

The information required from construction organisations was the priced bills of Quantities (**B of Qs**) of previous projects completed within the period of **1988** to **1992**.

Size of the sample obtained

Out of **numerous contacts made** about **30** organisations replied positively (see *Appendix C* for a copy of the letter sent to organisations). The information requested was for access to priced bills of Quantities and this was considered as sensitive information; this factor depressed the number of participating organisations. From the 30 bills of quantities obtained only **24** were in the specified period required ie housing projects completed between 1988 and 1992. Out of these **24** projects **12** were completed by construction organisations with formal quality systems **BS 5750** and **12** completed by organisations without formal quality management systems based on **BS 5750.**

Method of the analysis of the bills

Having obtained the priced bills of quantities, the task was to assess the productivity of the organisations in every project by way of measuring the resources used in each. The Thomas *et al.* (1990) model for estimating the resources used was taking the monetary value of output and the monetary value of input. Therefore, the task to be carried out here is to estimate the monetary value of the resources used in every project through the analysis of the priced bills of quantities.

Analysis of the bills of quantities was carried out in the following manner:

i) The first step in the analysis is to identify the cost significant items in the bill. These are identified according to Horner's model (Horner, 1986) in which 20% of the items in the bill carry 80% of the total cost.

ii) These items are then broken into their constituent resources using the Wessex building price data book. In this index book, the **unit price** for an item is broken into its constituent resources plant, labour and materials. When this step is complete, the exact division of each cost significant item of labour, plant and material is evaluated.

iii) The total values of Labour plant and materials are computed and hence the productive isoquant is drawn.

As seen in the above procedure, the first step in the analysis is to identify the cost significant items in the bill. These are defined by Horner (1986) as the **20%** items which carry **80%** of the total cost. Horner (1986) have developed this process by drawing on the work of the nineteenth century Italian economist **Vilfred Pareto** who suggested that 80% of the nation's wealth was held by 20% of its population. Using this concept Horner hypothesised that 80% of the value of the bill of Quantities was contained in 20% of the bill items. The question was which 20%? By testing the theory over a range of actual priced bills Horner stated that the cost significant items are those which are greater than the mean value of each bill item. So the 20% of the cost significant bill items may be found by identifying all those items priced at greater than the average price.

As expressed by Horner (1986):

$$A = V1 / N$$

where A is the value of the cost significant item, and $V1$ is 80% of the total bill value. N is the total number of items in the bill of quantities. Then using the 80/20 rule to get the final bill value:

$$V2 = 100/80\ V21 = 1.25\ V1$$

In the above procedure, the cost significant items taken were those whose values were higher than the mean value ($V2/N$).

These cost significant items are then broken into their constituent resource composition using the **Wessex building price data book.** In this index book, the **unit price** for an item is broken into its constituent resources: ***plant, labour and***

materials. When this step is complete, the exact division of each cost significant item of labour, plant and material is evaluated. Finally, the values of labour, plant and materials obtained are plotted and hence the isoquant is drawn (see ***chapter* ❼**).

An isoquant, as explained in ***section* ❻.8**, is a curve connecting the most productive projects as well as enveloping the unproductive projects.

To further substantiate the results obtained from the isoquant diagram, the statistical technique of cluster analysis (see ***section* ❻.12**) was used to show whether or not there is distinction between QMS and non-QMS projects.

❻.7.1 ASSUMPTIONS MADE

As the actual work on site is generally completed by subcontractors, it is assumed that the Quality Management System (QMS) of the main contractors concerned covers all the projects' participants including the subcontractors. It is one of **BS5750** requirements that a contractor should produce a Quality Plan which is basically a project control plan specifying who does what and how and gives a full description to the client as to how the whole job is to be carried out and how its requirements will be met. The contractor is also obliged to ask subcontractors to produce similar **Quality Plans** for their part of the project. In preliminary interviews carried out by the author with contractors who have QMS systems in place, it was revealed that the practice of requiring subcontractors to produce Quality Plans as well as abide by the general requirements of the QMS system of the main contractor is commonplace. Most of those contractors interviewed asserted that they perceive of their QMS as a comprehensive management system which regulates all matters related to project as well as corporate management. Therefore, what is really assumed here is that **all parts of the work completed are carried out according to BS 5750 guidelines.**

The second assumption made here is that the values given in the priced bills of quantities are the actual prices paid by contractors. Again the basis for this assumption is coming from the philosophy of the quality management systems. The strategic aim of those contractors embarking on a quality management programme is to raise the standards of their output and at the same time reduce the cost of production. If a contractor raised the standard of his output at higher production cost, then it has failed to meet the "quality criteria" in the first place. Moreover, it is accepted that in the UK the lowest bid is usually the accepted one. Therefore, the basis of the assumption made here suggests that the values entered in the bill of quantities are the most optimum values and that a contractor with a quality system should be working at the most optimum production cost.

A further assumption made here is regarding the possibility of Front End Loading (FEL). Although cost significant bill items such as excavation may be FEL'd, it is assumed that the behaviour is uniform across projects; ie it is assumed that all contractors are pricing their items in such a way as to include the cost of the item plus the cost of the relevant share of overheads and profit (and any other) additions; thus using FEL in a similar manner. Therefore, if FEL took place, it is uniformly done across the sample.

Comment

Before concluding this section related to the assumptions made, it may be worth noting that the last two assumptions would have been made redundant if priced bills of quantities were used from one contractor before and after the quality system. Many of the intervening variables regarding the way in which different contractors price their bill would be eliminated. The practice of pricing bills of quantities provides a contractor with a mechanism for financial management of projects. The list of items given in the bill of quantities is a matter of fact, but the prices attached to these items is a matter of expert opinion. Therefore, the expert opinion available to one contractor will serve to unify the method of pricing used to estimate items in the bill. Moreover, from a quality management point of view, the expert opinion available to the contractor is supposed to be shaped by a quality culture centred around the key objectives of any quality system identified earlier as raising standards, reducing waste and rework by doing things right first time and hence winning more business. Therefore, taking priced bills from a contractor before and after quality management would also reveal the extent to which the pattern of pricing adopted by the contractor has been influenced by the implementation of the quality management system.

❻.8 *THE ANALYTICAL FRAMEWORK (THEORY OF ISOQUANTS)*

The question posed at this point is how to compare the productivity of projects completed by contractors possessing QMS systems with those who do not. To achieve this objective, the theory of Isoquants was used. **An Isoquant is a curve connecting points representing different combinations of inputs and producing the same amount of output.**

From a theoretical point of view, any production function can be represented graphically through the use of **isoquants.** It is pointed out by Davis *et al.* (1989) that there is an isoquant for every level of output. This graphical representation can be used to measure the efficiency of the utilisation of resources which is the approach taken for the measurement of productivity as defined by this study. As pointed out by Davis *et al.* (1989) that traditional economic analysis relied on the production function to describe the hypothetical relationship between inputs and output. The measure of the efficiency of the utilisation of resources in this case is output oriented based on product per unit input such as labour or some other input.

However, an alternative to this output oriented approach is an input-oriented approach suggested first by Farrell (1957). This approach is based on the notion that, if a production unit utilises its resources efficiently, it must be using minimum amounts of inputs required to produce a given level of output. This approach is consistent with the definition accorded to productivity by this study and can thus be used to define the productive isoquant on the basis of which productivity of construction projects may be compared and analyzed.

This approach was illustrated by Ruddock (1994) as follows:

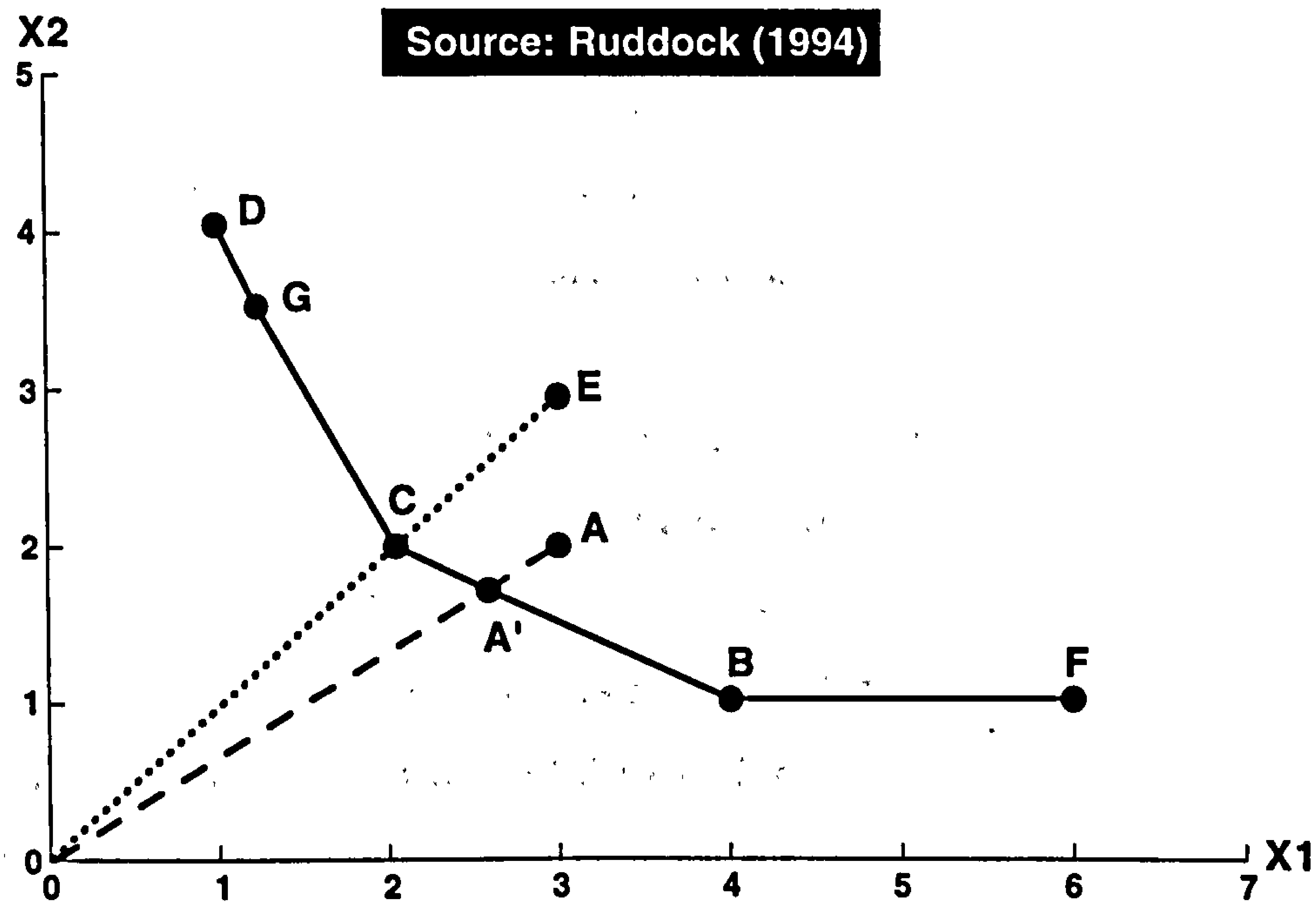


Fig. (❻.1): *A Productive Isoquant Frontier*

The above ***Figure*** (❻.1) (Ruddock, 1994) shows seven organisation (**A** to **G**), all producing a single output (**Y**) with inputs (**X1** and **X2**). It is assumed that all seven organisations produce one unit of output. In the absence of information on the exact location of the unit isoquant, there are no grounds for supposing that **B**, **C** or **D** are utilising resources inefficiently (unproductive). Organisation **B** uses more of the input **X1** than organisation **C** but less of the resource **X2**. Similarly, organisation **D** uses more **X2** than organisation **C** but less **X1**. There are grounds however, for believing that organisation **E** is unproductive as it uses more of both inputs **X1** and **X2** than C and yet produces no more output.

Therefore, for a fixed output, the productivity of projects could be compared from the point of view of resource utilisation. A key assumption made by Farrell (1957) for the productive unit isoquant is that **the productive isoquant is never upward sloping and is always convex to the origin.** Convexity means that if two input bundles can each produce one unit output, then so can any weighted average of them. In terms of the above diagram it means that an organisation could, for example, operate at **C** or **D** or anywhere along the line segment **CD.** These two assumptions allow productive bundles to be separated from non-productive bundles.

Productive bundles are found by picking adjacent pairs of bundles and joining them with a line segment. As shown in the above diagram (from Ruddock, 1994) if the line segment has a non-positive slope and none of the other bundles on the isoquant map lie between it and the origin then the chosen bundle may be considered as efficient in the utilisation of resources or (productive) from this study's point of view. Therefore, bundles **B** and **C,** for instance, would be declared productive as line **BC** has a negative slope and there are no bundles between it and the origin.

The line segments linking all the (productive) input bundles traces out the productive isoquant. This isoquant envelopes all the non-productive organisations.

As a result of the analysis of the priced bills of quantities of projects the isoquant was drawn and productive projects were separated from un-productive ones.

The essence of the above methodology used in this phase of research is to measure the quantity of resources used in achieving the measured value of output. For a given project the value of the resources used in completing cost significant items in the bill are calculated and added up for the whole project. For example, if the total value of a housing project were to be **T** and the number of cost significant items is **N.** For these items the value of labour is **L** and the value of materials is **M** and the value of plant is **P.**

Given that the total value of this project is **T,** then these resource values may be normalised by dividing each resource by the total value of output and hence the relative weight of each resource is obtained as follows:

The relative value of labour = L/T = Lr

The relative value of plant = P/T = Pr

The relative value of material = M/R = Mr

For a value of work say **£V,** the amount of labour, plant and materials used is found by multiplying the relative weights above by the given value above to obtain the resources valued used to obtain a value of output of **£V.**

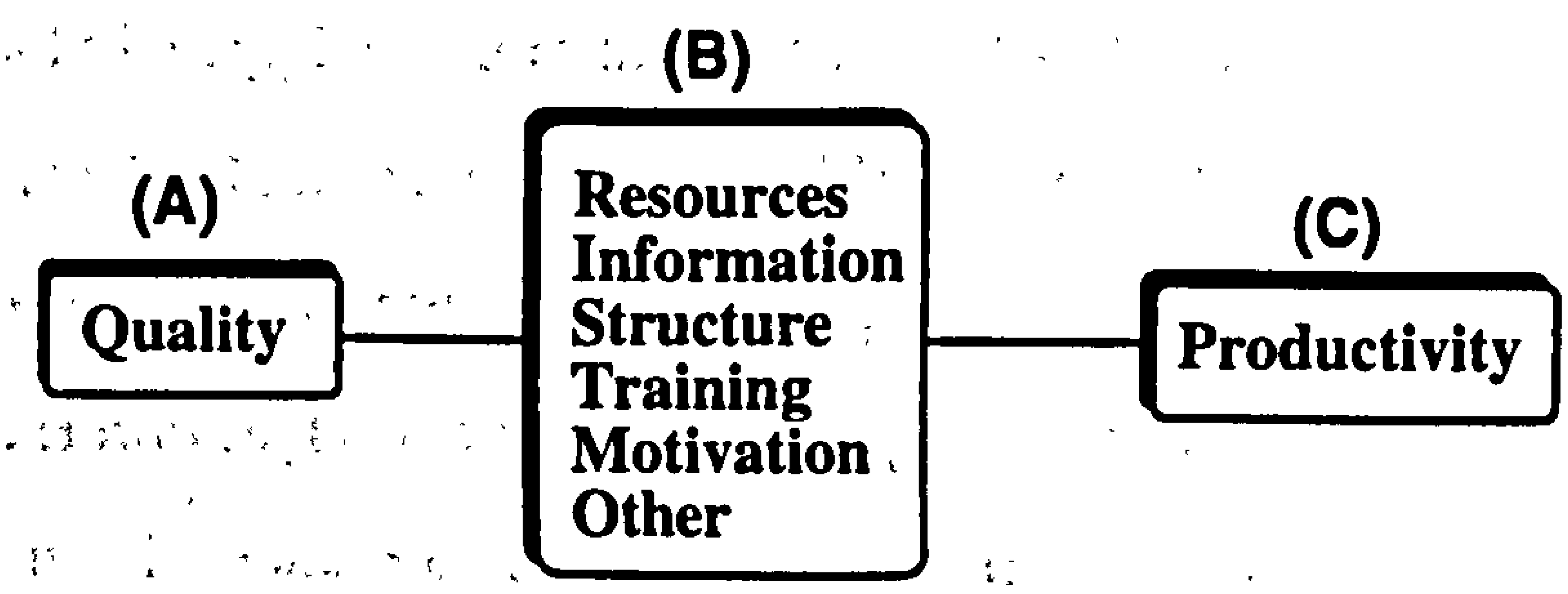
These values are used to determine the position of the project in the Isoquant diagram. Each project in the sample chosen for this study is represented by a single point in the **Isoquant** diagram shown in ***Figure*** (**❼.1**) (see ***chapter*** **❼**). The position of each project is determined according to the value of the resources used in that project **(labour and plant).** The diagram for materials is not included as the price and quantity of material is a function of design specifications and not purely a discretionary matter for the project management team. If it were possible to find data regarding materials waste on site, it would have been possible to consider material as a third variable to compare projects. But in the absence of such data it will be misleading to draw conclusions from material usage purely on the basis of quantity used as that may have been due to design specifications.

❻.9 *SECOND PHASE OF THE INVESTIGATION*

Phase II: MCVs ⟶ Productivity

Identification of the managerially controllable variables (MCVs) that influence construction productivity.

Phase II



The managerially controllable variables (MCVs) have been identified as a result of a wide search of literature concerned with factors influencing productivity in general as well as in the construction industry. As explained in ***chapter*** **❹**, the number of variables influencing productivity is vast and could not be managed as it stands in most writings.

Therefore, it was necessary to classify these factors into two main categories. The classification suggested here is based on a paper by Mukharejee & Singh (see Prokopenko, 1987).

A. ***External factors***

These are factors which influence productivity but lie beyond the realm of site management control. These factors include the physical and the economical environment (see **section ❹.3.5**).

B. ***Internal factors***

These are the factors which again influence construction productivity but lie within management control. They have been defined as the managerially controllable variables (MCVs).

The above model hypothesises that quality management systems can improve productivity through better control of these MCVs. Another sub-hypothesis is that better control over these MCVs can lead to better productivity, ie. productivity is a function of these MCVs combined.

It should be emphasised at this stage that the indication of the nature of the causal relationship between any two variables, whether for example, linear or non-linear, is proved by the fact that a substantial number of researchers in the field believe that it exists. However, it is not claimed that empirically based knowledge is available to explain the precise nature of that relationship. Unspecified intervening variables between the managerially controllable variables (MCVs) defined above and construction productivity suggest that direct linear causal links are not expected and that the true relationships are far more complex than depicted in the above model.

❻.10 *DEFINITION OF THE MANAGERIALLY CONTROLLABLE VARIABLES (MCVS)*

The theme of the study is to assess the impact of quality management systems upon construction productivity. Since QMS are nothing but management systems, they can only influence the managerially controllable factors or variables (MCVs). External factors such as Government policies, physical environment or the financial environment are considered to be external to the system and that QMS can have no impact on it in any way.

As explained above, based on a thorough review of literature related to the factors affecting construction productivity and its subsequent classification into those within management control and those without, this study suggests that the implementation of quality management systems of construction organisations can lead to improvement in construction productivity at the site level through better control of the following Managerially Controllable Variables (MCVs):

1. **Management of Resources.**
2. **Management of Information.**
3. **Management of Organisation structure.**
4. **Management of Training.**
5. **Management of Motivation.**

These factors will be tested on practitioners as well as prioritised by them in phase II of this research. A further statistical test (Kendall coefficient) will be used to name the most powerful factors from the productivity improvement point of view.

The research model as hypothesised above states that construction productivity is a function of all five variables and that changes in any one of them can cause changes in construction productivity.

❻.11 *MEASUREMENT OF THE MANAGERIALLY CONTROLLABLE VARIABLES*

❻.11.1 MANAGEMENT OF RESOURCES

Management of resources was identified (see ***chapter*** ❹) as one of the most important variables influencing construction productivity at the site level. A growing body of literature noted that effective management of resources at site level can markedly influence construction productivity.

The resources defined here are the actual resources used on a construction site; namely, labour, plant & equipment and materials. As the main theme of this phase of research is to assess the impact of quality management systems upon the control of these variables, the investigation will seek to assess to what extent the implementation of these systems will help in achieving the objectives sought after by effective management of each of the resources involved. Management of Labour, plant & equipment and materials have been operationalised in the questionnaire (see ***Appendix. B***), and practitioners (quality and/or site managers were asked to express their satisfaction with their existing quality systems in terms of addressing all of the important issues related to the management of Labour, plant & equipment and materials, i.e. to find out to what extent the implementation of QMS helps in effectively managing resources on site.

❻.11.2 MANAGEMENT OF INFORMATION

The basis of any rationale decision, as management theorists would agree (see ***chapter*** ❹) is the availability of relevant and sufficient information wherever and whenever needed. A CIB (1970) report states that there are three closely related processes in construction; the information flow process, the decision making process and the construction process. If Productivity is to be improved, this relationship should be defined in terms of designing the Information system to suit the particular construction activities in question. Moreover, Poole (Shaddad, 1983) identified Three dimensions that determine the effectiveness of a PMIS. They are:

- Information availability,
- Information uniformity,
- Information independence.

Information which is less available or uniform will cause delays and idle time. It will also affect machine utilisation and continuity of production and this is bound to reflect negatively on construction productivity as perceived by this study as optimum utilisation of resources.

The practitioners (quality/site managers) were asked to express their satisfaction with their present management system and whether it helps in creating an effective PMIS (Project Management Information System) that provides sufficient and relevant information whenever and wherever needed and hence facilitating and enhancing the process of decision making.

❻.11.3 DESIGN AND MANAGEMENT OF ORGANISATION STRUCTURE

The proper design and management of a project organisation structure is one of the key managerial activities, it entails the creation of a project organisation structure that is suitable for the needs of the particular project and that is flexible, dynamic and responsive to the internal as well as external environment. Prokopenko (1987) pointed out that one main reason for low productivity in organisations is their rigidity and failure to anticipate and respond to environmental (both internal & external) changes.

Quality/site managers were asked to assess their existing management system and express their opinion as to the extent to which it helps in designing and managing an organisation structure which clearly specifies who does what, being flexible and dynamic as well as facilitating vertical and horizontal communication within a project team.

❻.11.4 MANAGEMENT OF TRAINING

People, as the principal resource and the central factor in a productivity improvement programme, have an essential role to play as workers, engineers, managers and entrepreneurs and construction project managers.

The possession of appropriate skills and knowledge does not always guarantee appropriate action. It is the operative's attitudes, which have been moulded mainly through emotional experiences, that direct and energise the actions. Therefore, an effective training programme should prepare people in the skills required and provide them with the adequate knowledge, but at the same time develop the right attitudes. As pointed out by Prokopenko (1987), training people in the right skills, knowledge and attitudes will affect the following productivity determinant factors:

- Scrap or waste level,
- machine utilisation,
- continuity of production.

Practitioners (quality/site managers) were asked to express their opinion as to whether or not their existing management system helps in the following areas:

- Providing the training required through formal and informal methods.
- Providing a training programme that influences the skills, knowledge and attitudes of personnel
- Reviewing the performance and progress of foremen, craftsmen, on their present jobs and provide pointers to their needs for further training, and specifying in advance job requirements for future recruitment and promotion purposes.

❻.11.5 MANAGEMENT OF MOTIVATION

Motivation is basic to all human behaviour and thus to efforts of productivity improvement. Apart from incentive schemes, Motivation can be enhanced by encouraging cooperation and participation from workers. Labour participation in goal setting for example, has been quite successful (Deming, 1986).

Practitioners were asked to express their opinions as to whether or not their existing management system helps in:

- encouraging cooperation (not competition) and inviting personnel to take part in decision making and their own job planning,
- adopting motivational techniques aimed at enhancing the motivation of personnel to achieve more,
- structuring the various aspects of job content; for example, by increasing the job responsibilities, achieving variety of tasks and employee autonomy.

❻.12 *CHOICE OF THE METHODOLOGY*

a) Questionnaire

A questionnaire is an effective instrument for observing data beyond the physical reach of a researcher. It also serves to sample the opinion of individuals in spatially diverse locations. It can be economic and expeditious if designed along certain guidelines. These include using unmistakably clear and courteous language, designing the questionnaire to fulfil a specific research objective, simple expressions, brevity and checks for consistency.

The main objectives of the survey carried out in this study were firstly, to sample the opinions of the practitioners as to whether or not they consider the MCVs identified in the literature will improve construction productivity if properly managed and controlled. The survey will also seek to prioritise these variables in the order of their importance from the productivity improvement point of view.

The second objective was to assess the impact of quality management systems upon the control of these variables.

b) Pilot or pre-test

A pilot or pretest often helps to ensure that the instrument meets the essential guidelines discussed earlier. For instance, a pretest helps to verify whether the questionnaire expresses clearly what the researcher expects from the respondents. A pretest was done on construction personnel (3 organisations) and staff at Strathclyde university (2 researchers). Feedback from the questionnaire helped in modifying the questionnaire in search of more clarity.

c) The Survey Population

Building is a complex industry involving participants in a wide range of characteristics in terms of roles, organisation and size, among others. Of these participants, the quality managers or site managers are generally involved in the overall implementation of the quality management system (whether be it formal or informal), consequently, they should be more acquainted with the factors that influence construction productivity and whether or not a quality management system can help in controlling them. Therefore, the quality and site managers are the target population for the data.

d) Bias

It is hardly possible to eliminate bias completely in a study of this nature. Bias operates at two levels in a descriptive survey: the level of selection of the sample from the population, and the level of response from the sample. As for the first level equal opportunity was offered to all house-building contractors to take part in the survey; the second level was the actual responses of the participants who were encouraged to be as objective and fair as possible. However, no deliberate attempt was made to introduce bias in the sample.

Limitation

Despite the persistent effort made by the author to address the questions, related to this survey, to those people at the "sharp end" ie those actually doing the work on site, the sample included quality managers whose opinions may be biased in favour of quality management systems. The practitioners (including quality managers) were encouraged by the author to describe things as they are and not as they would like them to be.

Nevertheless, unconscious bias may have affected the responses of quality management professionals.

❻.13 *QUESTIONNAIRE CONTENT*

The questions asked were mainly "closed" type questions, that is, typical factors/activities are listed for respondents to evaluate. "Open" type questions would require respondents to generate the factors/activities themselves in addition to evaluating them as requested. The closed format provides an ideal advantage in this case. First, it is easier to respond to, consequently is expected to draw a higher response. Second, it delineates the terminologies used to describe the issues raised. This greatly assisted in the subsequent analysis of the responses.

The possible disadvantage of this format of questioning is a lack of evidence that the respondent has really thought through the questions before answering, and the problem of bias. Also it is difficult to ascertain that all the needed questions have been asked. However, these shortcomings can be mitigated by an appropriate choice of survey population comprising, expectedly well motivated and competent respondents. A further improvement is made by the provision for the respondents to include additional factors or comments.

❻.13.1 INTERVIEWS WITH PRACTITIONERS

Following the questionnaires in which the practitioners were given an opportunity to give their opinion on various issues related to the managerially controllable variables influencing construction productivity, it was necessary to take the issues raised in the questionnaires a little further with the **practitioners** and to see how they actually managed to deal with these variables within their systems if at all.

Seven organisations took part in these interviews.

Format of the interview

The structure of the interviews followed the same order as the questionnaire (***Appendix. B***). Practitioners were effectively asked to elaborate on why they are satisfied or dissatisfied with the way their management system dealt with the MCVs. For example, if the response of a practitioner to the questions related to the management of resources was all **(1)**, then the question put to the practitioner would be to tell the author how they managed, in practical terms, to do what he said they were doing. If they have a formal quality management system, is it part of their procedure to control for example, labour, plant or material?

❻.14 *HYPOTHESES OF THE STUDY*

Hypothesis ①

There is a relationship between the implementation of formal quality management systems based upon BS 5750 and improvement in productivity at the site level.

Testing hypothesis ①

This hypothesis is tested through the construction of the isoquant diagram. The isoquant generated identifies the most productive projects as well as envelopes the unproductive ones. This has further been substantiated by the deployment of the statistical technique of cluster analysis which creates two distinct categories of projects (clusters). Evidence of the fact that QMS and non-QMS projects are distinct entities is sought.

Hypothesis ②

The implementation of formal quality management systems lead to better productivity through greater control over the managerially controllable variables (MCVs) that influence construction productivity.

Testing hypothesis ②

Hypothesis ② is subdivided into two main sub-hypotheses:

The first sub-hypothesis is that productivity improvement is a function of the managerially controllable variables (MCVs) combined.

The second sub-hypothesis is that the implementation of quality management systems leads to greater control over the managerially controllable variables that influence construction productivity.

This second sub-hypothesis has been further subdivided into five sub-hypotheses which define each of the MCVs in turn.

The central factor in all of the sub-hypotheses is **control** over the MCVs. The questionnaire was used to measure and test the degree to which control is or is not present. In the questionnaire, each of the MCVs have been operationalised and translated into managerial activities which should be performed if control is to be present. Practitioners were given a scale of (1 to 5) to express their opinion as the extent to which they believe that their quality management systems cover the managerial issues that are believed to constitute control over each of the MCVs. In other words, to what extent does the QMS help in achieving the objectives sought under each variable, and hence control it.

In the interviews following the questionnaire, more specific questions were put to the practitioners regarding the degree of control performed over the MCVs and how that control is achieved in practice.

Sub-Hypothesis ②.1

Productivity improvement is a function of the Managerially controllable variables (MCVs) combined.

Sub-Hypothesis ②.2

The implementation of formal QMS leads to greater control of the management of resources.

This sub-hypothesis is further subdivided into three sub-hypotheses as follows:

***Sub-Hypothesis* ②.2.1**

The implementation of formal QMS lead to greater control of the management of labour.

***Sub-Hypothesis* ②.2.2**

The implementation of formal QMS leads to greater control over the management of Materials.

***Sub-Hypothesis* ②.2.3**

The implementation of formal QMS leads to greater control over the management of plant.

***Sub-Hypothesis* ②.3**

The implementation of formal QMS leads to greater control over the management of information of the project.

***Sub-Hypothesis* ②.4**

The implementation of QMS leads to greater control over the design and management of the organisation structure.

***Sub-Hypothesis* ②.5**

The implementation of QMS leads to greater control over the management of Training.

***Sub-Hypothesis* ②.6**

The implementation of QMS leads to greater control over the management of Motivation.

❻.15 *METHOD OF ANALYSIS AND HYPOTHESES TESTING*

Hypothesis ①

a) The Isoquant diagram

As a result of the analysis carried out on priced bills of quantities of construction projects, the isoquant diagram is obtained. An isoquant is the line segment connecting the most productive projects (ones which use minimum resources to achieve a fixed amount of output).

The isoquant obtained (see ***chapter*** ❼) identifies the most productive projects as well as enveloping the unproductive ones. As shown in the next ***chapter***, it is formed mainly by QMS project organisations, although some non-QMS ones were present on the isoquant. To further substantiate this distinction, statistical methods were used.

b) Cluster Analysis

Cluster Analysis is a generic term used for a range of statistical techniques used to group objects, persons, or other data into homogenous classes on the basis of their similarities. Therefore, a cluster analysis results in clusters, types, classes or groups. In this study, cluster analysis techniques were used to classify the data (projects) into two homogenous groups. The intention is to have separate categories of projects with similar characteristics grouped with each other. Although the results of the Isoquant diagram was evidence of the existence of two groups, the cluster analysis is seen as a further substantiation of the isoquant diagram.

Cluster Analysis was used on phase I of this investigation to test hypothesis ①.

Test of Hypotheses

The conclusions drawn from these two analysis will be used to test the first hypothesis (hypothesis 1) that implementation of QMS leads to greater productivity. The result of the cluster analysis will serve to further substantiate the isoquant diagram finding that

QMS organisations are distinct from non-QMS ones in terms of their productivity at the site level.

Statistical testing of hypothesis ②

***Sub-hypothesis* ②.1**

The test of this hypothesis is about demonstrating that productivity improvement is a function of the MCVs combined; ie to show, through statistical testing of the field data of the questionnaire that "effective" management of these variables leads to improvement in productivity.

***Sub-hypothesis* ②.2**

The task required in testing this hypothesis is to show that there is **correlation** between the main variables of the study; namely the presence or otherwise of formal quality management systems and the degree of control over the Managerially Controllable Variables (MCVs) that influence construction productivity.

The hypotheses to be tested postulate that the implementation of QMS lead to greater control over the MCVs that influence construction productivity at the site level.

The correlation model chosen for the analysis is **the Spearman correlation model** to show that there is correlation between the degree of control over the MCVs and the status of the organisation from QMS point of view.

❻.15.1 <u>REASONS FOR CHOICE OF CORRELATION TECHNIQUES</u>

Given a database of measured variables, one can use the tool of statistics to test the stated hypothesis, to establish relationships and/or to predict behaviour.

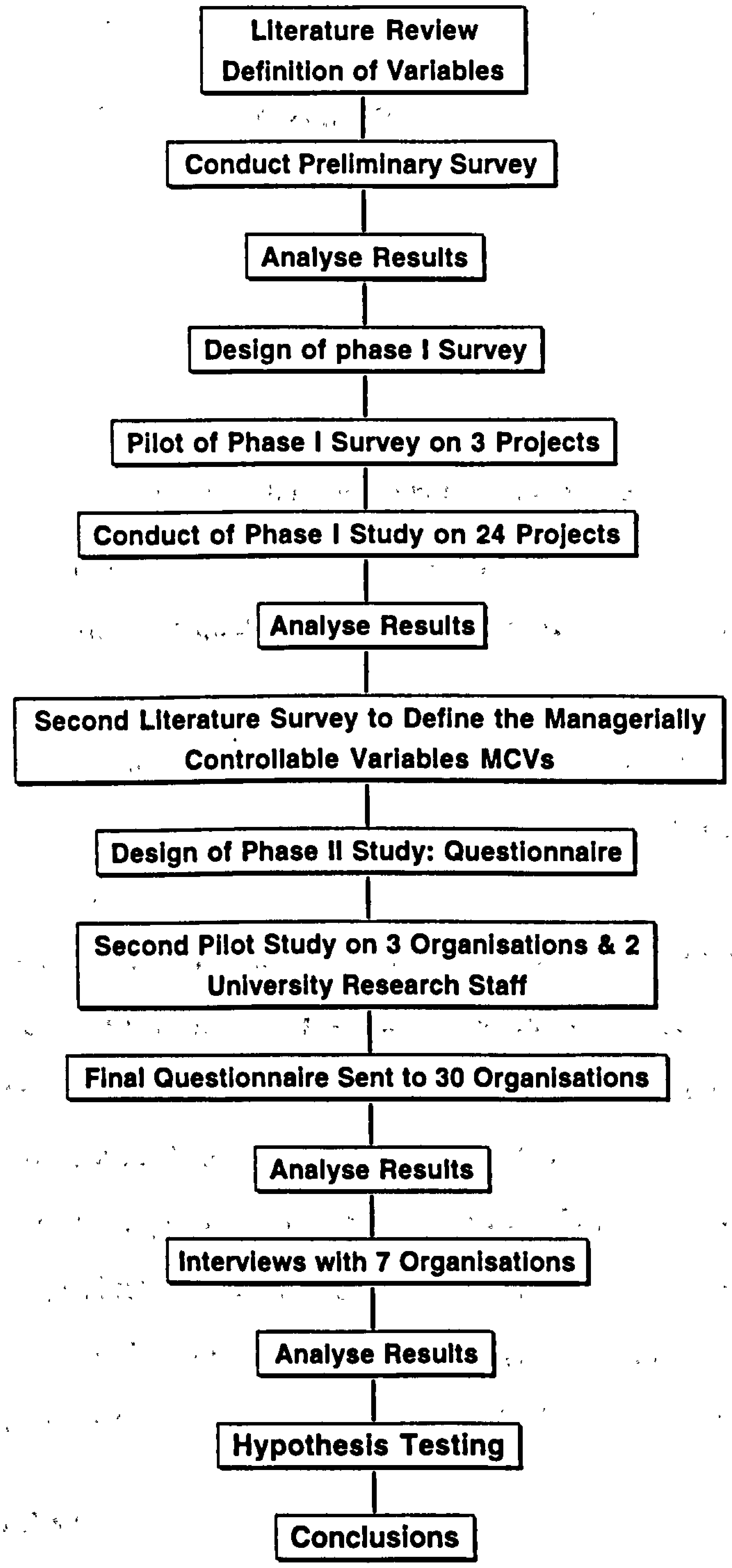
Ireland (1983) states more specifically that "the choice of an appropriate statistical method is governed by the levels of measurement of the variables and the purposes of the researcher".

Relationships between sets of variables can be investigated by using a number of statistical techniques such as the chi-square contingency table, rank-order correlation and product-moment (zero order correlation).

The correlation approach which is very germane to hypothesis testing on this sample is the Spearman rank correlation coefficient (r_s) or sometimes called (Rho) test as the variables measured are non-parametric i.e. ordinal or categorical. Spearman's coefficient is a measure of association which requires that both variables be measured in at least an ordinal scale so that the objects under study may be ranked in two ordered series. The value of r_s is always between -1 and 1. Positive values of r_s suggest that the variables are positively correlated, meaning that **y** increases as **x** increases. Negative values of r_s indicate negative correlation in which y decreases as x increases. Values of r_s close to Zero suggest that the variables are un correlated.

Establishing relationships or associations among a number of variables may not always be a straightforward exercise. Construction is a complex process and no technique will suffice to completely explain the variability among a number of projects. Nevertheless, it is possible to attempt to identify comparatively few variables which help to explain or account for the relationship between quality management systems and construction productivity at the site level.

❻.16 *THE RESEARCH SEQUENCE*



Results and Analysis

Chapter ❼

❼.1 *INTRODUCTION*

This ***chapter*** analyses the relationship between the different variables of the study. The hypotheses will be tested and the relationship between the relevant variables analyzed. The ***chapter*** also reports on the way in which quality management organisations operate compared to the non-quality management ones. It also assesses construction organisations experiences with the new systems and what lessons could be learned from them. The two central hypotheses have been broken into sub-hypotheses. The main statistical techniques used were the Chi-square and the Spearman's correlation coefficient (Rho) tests.

The significance level for accepting or rejecting the null hypothesis is driven from the statistical tables and the **null hypothesis was rejected for having a significance level (P value) of 0.05 or below (see *Appendix D*).** Also the critical values of Chi-square and Rho are derived from statistical tables. As this study is a pioneering one in its attempt to try to assess the impact of quality management systems upon construction productivity at the site level, comparison with other studies may not be possible at this stage. However, the extensive interviews made with the practitioners of the organisations visited will be used to put these findings into context.

❼.2 *HYPOTHESIS* ①

There is a relationship between the implementation of quality management systems and productivity of construction projects at the site level

Null hypothesis

There is no relationship between the implementation of quality management systems and improvement in construction productivity.

***Sub-hypothesis* ①.1**

Construction firms with formal quality management systems in place and those without formal systems are two distinct groups of firms.

Null hypothesis

There is no difference between firms with formal quality systems and those without formal systems.

❼.2.1 TESTING HYPOTHESIS ①

The working definition for productivity adopted by this study is centred around the utilisation of resources theme (see ***chapter* ❸**). It reads as follows: *"Productivity is the optimum utilisation of resources inputs labour, materials and capital in achieving an output acceptable in relation to some standard".*

The approach taken in testing the relationship between the implementation of quality management systems and productivity is to model the productivity of those organisations with formal systems and those without formal systems in terms of their utilisation of resources in achieving a given output. Obviously, the difficulty in obtaining a homogenous output in construction is an obstacle, but has been overcome by the fact that the output is measured in monetary terms (£). For example, for a given work output, the method to be adopted will seek to assess the amount of resources used in achieving that level of output. For example, if we have two firms doing housing projects (and it was found that the first project was of a given value of **M** pounds) for this value of work, the price of the resource inputs should be established. If the first company achieved **M** pounds worth of building by using a labour costing **X1** pounds, materials costing **Y** pounds and plant costing **Z** pounds, and the second company achieved the same work output value of **M** pounds by using less expenditure on resources (labour costing **X1**, material costing **Y1** and plant costing **Z1**); **X1** is less than **X**, **Y1** is less than **Y** and **Z1** is less than **Z**), then the second company will be considered as been more productive than the first.

The device which is going to be used in comparing the resource utilisation of different companies is the drawing of **"isoquants"**.

An isoquant, as defined in ***chapter❻***, is a curve connecting points representing different combinations inputs and producing the same amount of output. In a construction project the inputs are Labour, Plant and Materials. The essence of the methodology is to measure the quantity of resources used in achieving a certain level of output, bearing in mind the difficulty in being able to quantify the construction output in a homogenous manner.

In practical terms, the total value of the resources used in every project is evaluated and divided into its constituent elements labour, plant and materials.

The data for the above analysis was drawn from priced bills of quantities of projects completed between the period of 1988 and 1992 as this is the period during which the quality movement was at its peak. For a given priced bill of quantities, the amount of resources used to achieve the given value of work (output) will be determined and broken into its constituent resources using the **Wessex building prices data book.** A particular feature of this book is that it gives the unit price of each resource divided into its constituent elements. For items in the bill such as Excavations, brickwork and blockwork, the monetary value of the work carried out will be determined. Therefore, for a given output value of work the resources utilised in achieving it can be determined using the Wessex prices book. The steps of this particular analysis is carried out in the same steps described in ***chapter❻***. They were as follows:

1. Identify the cost significant items of this amount of output using the Horner's (1986) 80/20 rule.
2. Break these items into resources- labour, plant and materials using the Wessex data book.
3. Find the total value of each resource used and plot the isoquant for these projects.

The data collected

Twenty four projects were obtained from construction firms with formal quality systems as well as from those without.

As an example of the analysis, for any bill of quantity the following parameters are evaluated:

V2 = the total value of the project (output value of works)
V1 = 80% of the total value of the output
N = number of items in the bill
A = average value = **V1/N**

According to the 80/20 rule, the cost significant items are those items with values greater than A (the average value).

For a given cost significant item of the bill say Excavation of work quantity say **Q sq.m and the rate of output was R.** From the Wessex data book:

net labour price = **L1**
net plant price = **P1**
net unit price = **(L1+P1)**= UP

where:

Net Price: The aim of the Wessex building price data book is to provide builders with a guide to current "net" cost unit prices for building works. A net cost unit price represents the net cost of labour, plant and material without additions for site overheads nor off site office overheads or profits.

Rate is the basic rate used by contractors to determine the unit price of each item of the bill of quantities. For a contractor to develop a rate, he is to compound all four basic types of costs (labour, plant, materials and overheads) in a single rate for a work component or item in the bill. It assumes that the plant, labour cost and overheads are proportional to the quantity (Q) of the work component.

amount of labour used = $L1 \times R / (L1+P1) = L2$
amount of plant used = $P1 \times R / (L1+P1) = P2$
Price of labour used = $L2 \times Q$ = **£ value of labour**
Price of plant used = $P2 \times Q$ = **£ value of plant**

N.B The total values of labour and plant are worked out for every cost significant item in the bill and added up to give the total value of labour and plant used in that particular bill of project.

The above procedure is repeated for all cost significant items and the total value of labour and plant is evaluated for those items in the bill.

To normalise the value of the resources across the sample the total value of each resource is divided by the total value of the project so that the value of the resource is given in the form of a relative weight.

The results of the above analysis is shown below.

The projects comprising this sample are of different sizes and hence it is necessary to normalise resources values across the sample. Therefore, values in the table below are given in terms of the relative weight of each resource (value of the resource divided by the total value of the output). Now, the isoquant diagram is shown in the *Figure* (❼.1) below.

It is evident from *Figure* (❼.1) that the isoquant is formed by seven projects completed by both QMS organisations (quality management organisations) and non-QMS ones. It can be seen from the isoquant curve that the majority of the projects on it (five of the seven projects) on the productive frontier are projects completed by quality management organisations. Another observation in *Figure* (❼.1) is that the QMS projects (black boxes) are clustered around the frontier more than the non-QMS projects which are more dispersed. The points representing projects on the isoquant indicates that the value of the resources mix used in that particular project is less than

Quality		Non-Quality	
Plant	Labour	Plant	Labour
0.1483	0.8360	0.2024	0.6217
0.1899	0.6800	0.2595	0.3984
0.2320	0.5261	0.3636	0.7374
0.2552	0.7684	0.3824	0.5640
0.2871	0.4127	0.3833	0.4004
0.3134	0.5430	0.4046	0.5700
0.3202	0.3929	0.4362	0.5724
0.3273	0.3284	0.4819	0.3370
0.3543	0.4739	0.5041	0.5565
0.3700	0.3201	0.5906	0.3873
0.4181	0.6238	0.6250	0.4035
0.4713	0.3042	0.6368	0.4038

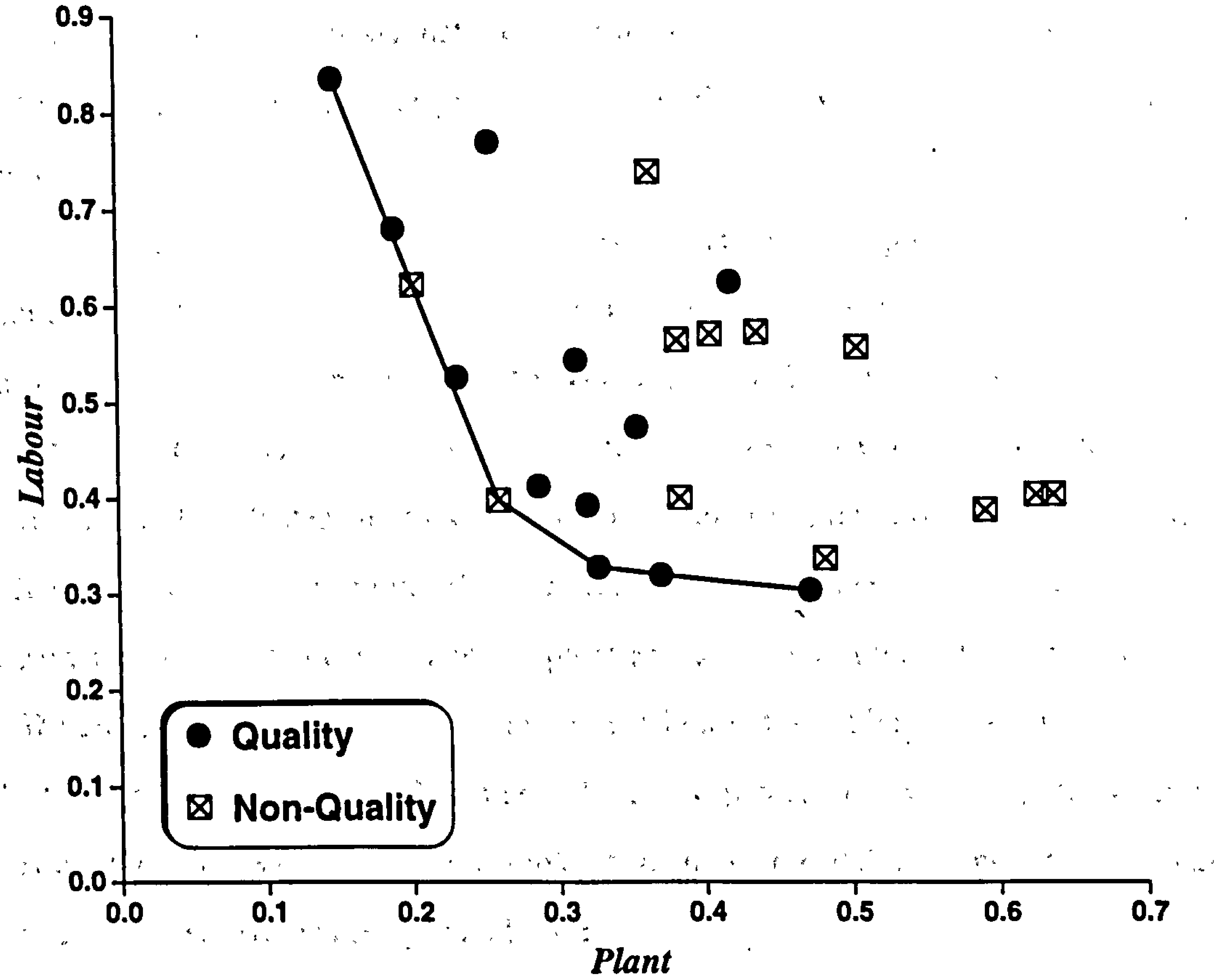


Fig.(❼.1) : The Isoquant Diagram Showing the Productive Frontier other projects to produce the same amount of output. In this particular case about 71% of the projects completed were QMS and were using lesser combinations of resources than the non-QMS projects which used more resources to produce the same output. Therefore, it can be seen that the projects completed by quality organisations are optimum in their utilisation of resources and since the working definition of productivity is centred around the optimum utilisation of resources theme, it could be said that the QMS projects are more productive than the non-QMS ones. Hence, it can be cautiously inferred that there is relationship between the implementation of quality management systems and improvement in productivity at the site level. Based on the above observation the null hypothesis may be rejected.

❼.2.2 TESTING SUB-HYPOTHESIS ①.1

In order to test the hypothesis that the construction firms with formal quality systems and those without are distinct groups of firms, the statistical technique of cluster analysis was used.

What this technique does is to arrange together those points (projects) with similar characteristics and put them in separate clusters. In this particular case, the first cluster was taken at the point where the **D** coefficient changes abruptly to almost its double value (see chart below) between stages **13** & **14** (this is indicated by the shade in the hierarchal cluster analysis table (shown below). Such a big difference in the value of this coefficient implies that the cases (projects) collected up to this point are reasonably similar; but cases after this point are less similar (hence the big difference in **D** value). Therefore, the cases culminating below this point are taken as the first cluster. Obviously, the second cluster is the cases (projects) above this point as there are only two groups of data in this sample. It should be noted that the projects data was entered in the software package as follows:

projects 1 to 12 are quality management firms

projects 13 to 24 are non-quality management firms.

***** HIERARCHICAL CLUSTER ANALYSIS *****

	Clusters Combined			Stage Cluster 1st Appears		
Stage	Cluster 1	Cluster 2	Coefficient	Cluster 1	Cluster 2	Next Stage
1	14	19	0.000000	0	0	2
2	3	14	0.000002	0	1	10
3	1	18	0.000007	0	0	6
4	8	16	0.000060	0	0	11
5	4	17	0.000084	0	0	7
6	1	24	0.000247	3	0	14
7	4	5	0.000369	5	0	18
8	10	15	0.000413	0	0	12
9	11	13	0.000608	0	0	15
10	3	21	0.000762	2	0	17
11	8	22	0.001287	4	0	16
12	10	23	0.001811	8	0	19
13	7	9	0.002177	0	0	15
14	1	2	0.004050	6	0	16
15	7	11	0.006010	13	9	20
16	1	8	0.007700	14	11	19
17	3	20	0.016120	10	0	23
18	4	6	0.020797	7	0	20
19	1	10	0.042943	16	12	21
20	4	7	0.059468	18	15	22
21	1	12	0.141975	19	0	22
22	1	4	0.216546	21	20	23
23	1	3	0.846412	22	17	0

❼.2.3 INFERENCE FROM SUB-HYPOTHESIS ①.1

Due to the formation of these two separate clusters the null hypothesis may be rejected and it may be accepted that construction firms with quality management systems and those without are two distinct groups of firms. **This particular finding now sets the scene for the forthcoming analysis.**

❼.2.4 INFERENCE FROM HYPOTHESIS ①

As pointed out earlier that the most productive isoquant is formed by 71% (5 out 7) QMS projects. In other words about 71% of the QMS used lesser combination of resources to achieve the same level of output. Therefore, it was deduced that the QMS projects were deemed to be more productive than the non-QMS projects. Moreover, the cluster analysis results demonstrated the distinct nature of the QMS and non-QMS projects. Therefore, it could be cautiously inferred at this stage as to the existence of a definite relationship between having a quality management system on the one hand and improvement in productivity at the site level on the other. More importantly, ***the fact that quality management firms and the non-quality management ones are two distinct groups of firms.***

These findings are not contrary to the belief of many quality "gurus" such as Deming (1986), Mefford (1991) and Juran (1988) (see ***chapter* ❷**). As the strategic aims of any quality management system are: **raise standards, reduce costs and win more business;** it would only be logical to see that productivity is improving as a result of quality efforts. The traditional assumption that there exists a trade off between quality and productivity can only hold if the traditional quality programme includes hiring more inspectors and foremen and thus hold the production lines and increase the amount of rework, scrap and waste. But if the quality effort is that of the quality management system driven by its desire to do things *right first time,* waste can be reduced and hence productivity improvement takes place.

❼.3 *SECOND PHASE OF THE INVESTIGATION*

❼.3.1 HYPOTHESIS ②

Productivity improvement is a function of the managerially controllable variables (MCVs) combined.

***Sub-hypothesis* ②.1**

Productivity improvement is a function of the management of resources.

***Null hypothesis* ②.1**

There is no relationship between productivity improvement and management of resources.

The result of the one-sample chi-square test is shown below: Significance level is 0.05.

The table below shows the result of the practitioners response when asked to express their opinion as to the importance of the managerially controllable variables from productivity improvement point of view. The questions were put in such a way as to gauge the practitioners reaction to the given variable as been important from the point of view of improving productivity at the site level (see questionnaire ***Appendix B***).

MCV.1	S.A	A	UD	D	S.D.
Management of Resources	27	3	0	0	0

Where:

S.A = Strongly Agree **A = Agree,** **UD = undecided**

D = Disagree **S.D = Strongly Disagree**

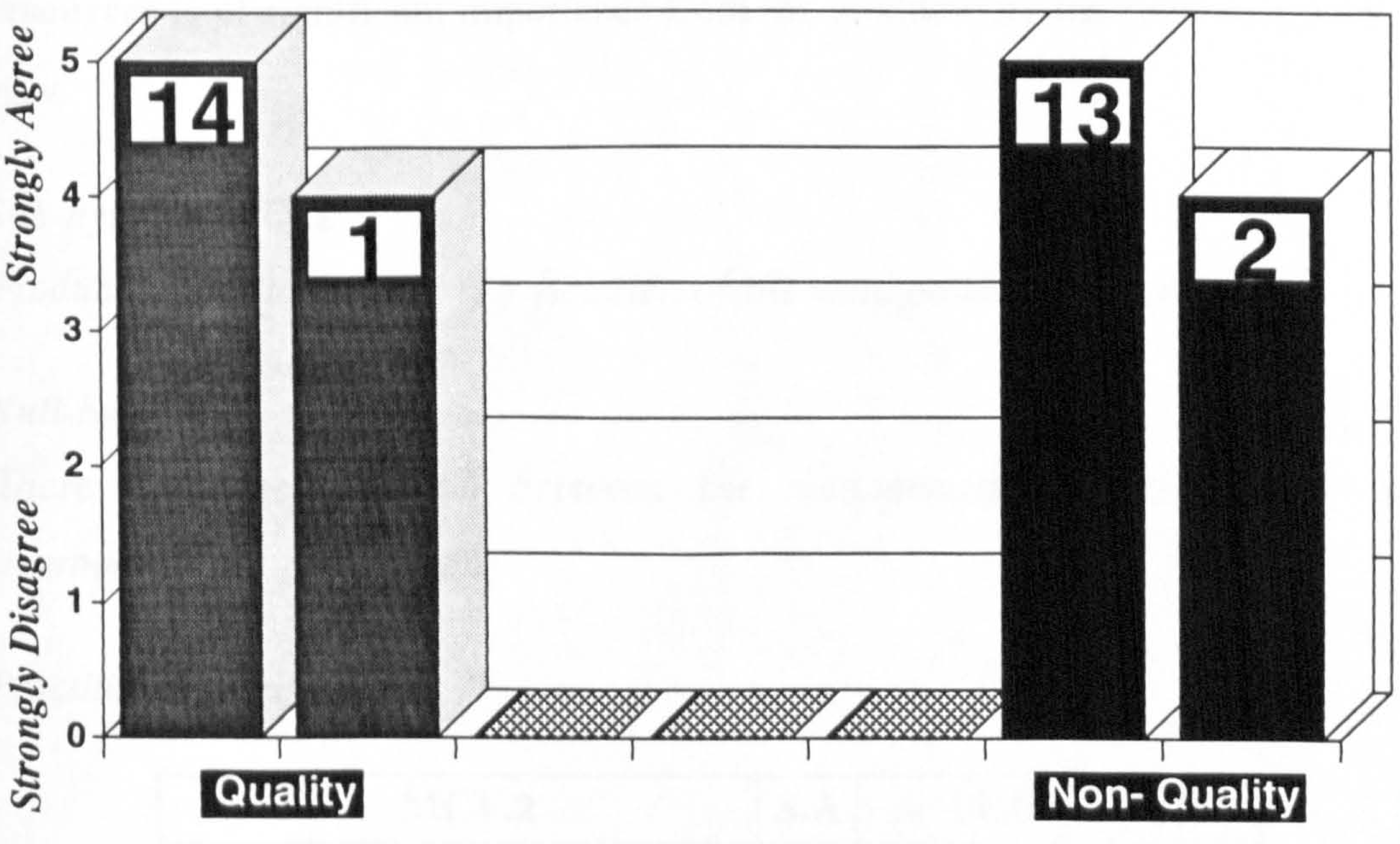


*Fig. (❼.3): **Assessment of Management of Resources as Productivity Improvement Factor***

It is fairly clear from the response of the practitioners that there is across the spectrum agreement on the importance of the MCV variable of **management of resources** as being vital from productivity improvement point of view. This result has been further substantiated by the statistical result of the Chi-square test results shown below.

Result of the one sample chi-square test

MCV.1	Chi-Square	P	D.F
Management of Resources	19.2000	0.000	1

From statistical tables at significance level of 0.05 and degree of freedom (D.F) of 1 the critical value of Chi-sq, is **Cr = 3.84.**

It can be seen that the significance level P is far less than the preset level of P = 0.05 and the Chi square value is bigger than the critical value (Cr=3.84); hence the null hypothesis is rejected. Therefore, it can be confirmed that the **management of resources** is of significant importance from the productivity improvement point of view.

Sub-hypothesis ②.2

Productivity improvement is a function of the management of information.

Null-hypothesis

There is no relationship between the management of information and improvement in productivity.

Practitioners Response

MCV.2	S.A	A	UD	D	S.D
Management of Information	23	7	0	0	0

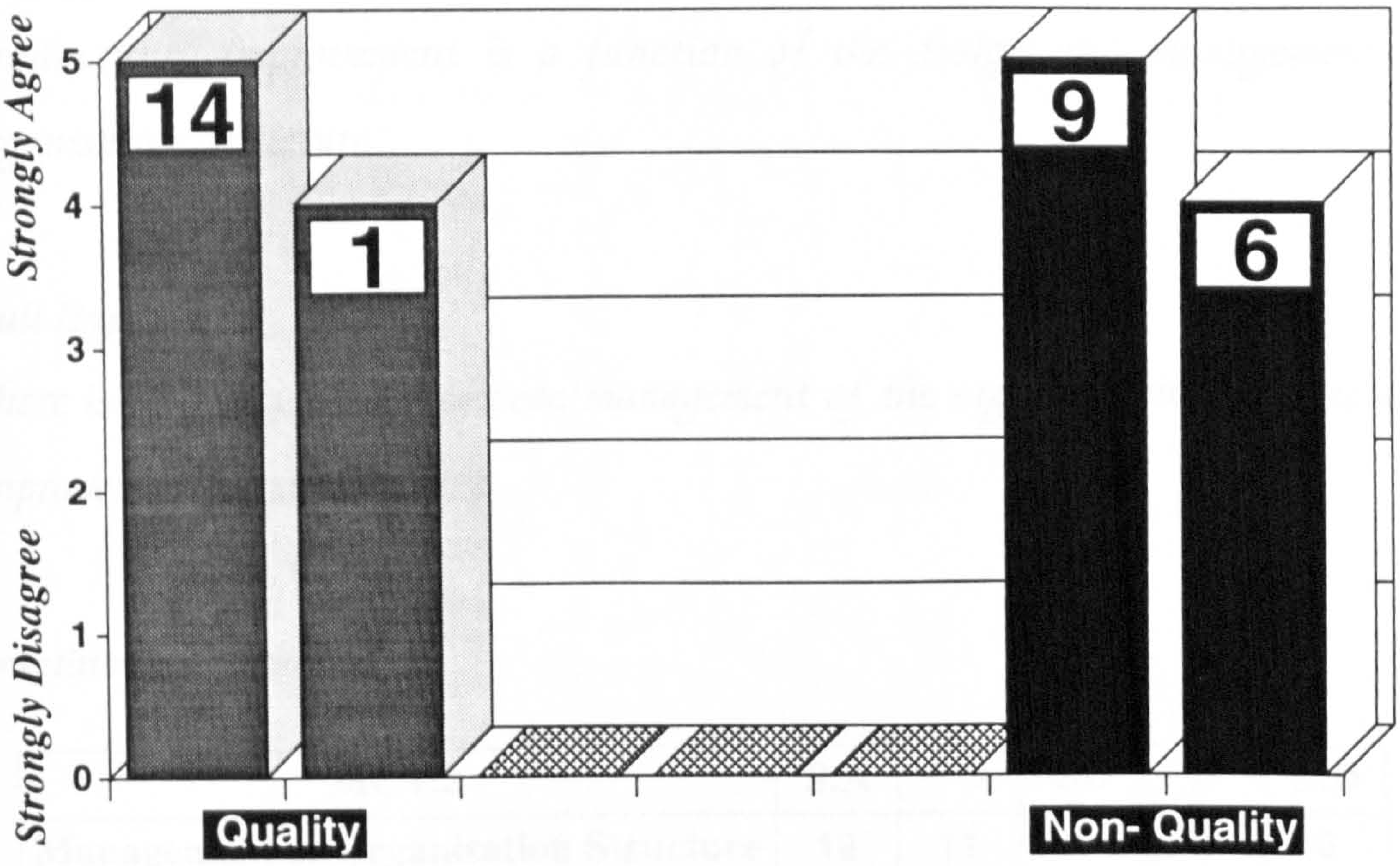


Fig. (❼.4): Assessment of Management of Information as Productivity Improvement Factor

Yet again the response of practitioners with regard to the importance of management of information as a determinant factor of productivity improvement was one of almost full agreement with the above statement. Statistical results below further substantiate that.

MCV.2	Chi-Square	P	D.F
Management of Information	8.533	0.0035	1

The significance level is again **0.0035 < 0.05** and the Chi-square value of 8.53 is greater than the Cr=3.84, hence the null hypothesis may be rejected. Therefore, the significance of the importance of the management of information variable as a determinant of productivity improvement in construction at the site level.

Sub-hypothesis **②.3**

Productivity improvement is a function of the design and management of organisation structure.

Null Hypothesis

There is no relationship between management of the organisation structure and improvement in productivity.

Practitioners response

MCV.3	S.A	A	UD	D	S.D
Management of Organisation Structure	18	11	1	0	0

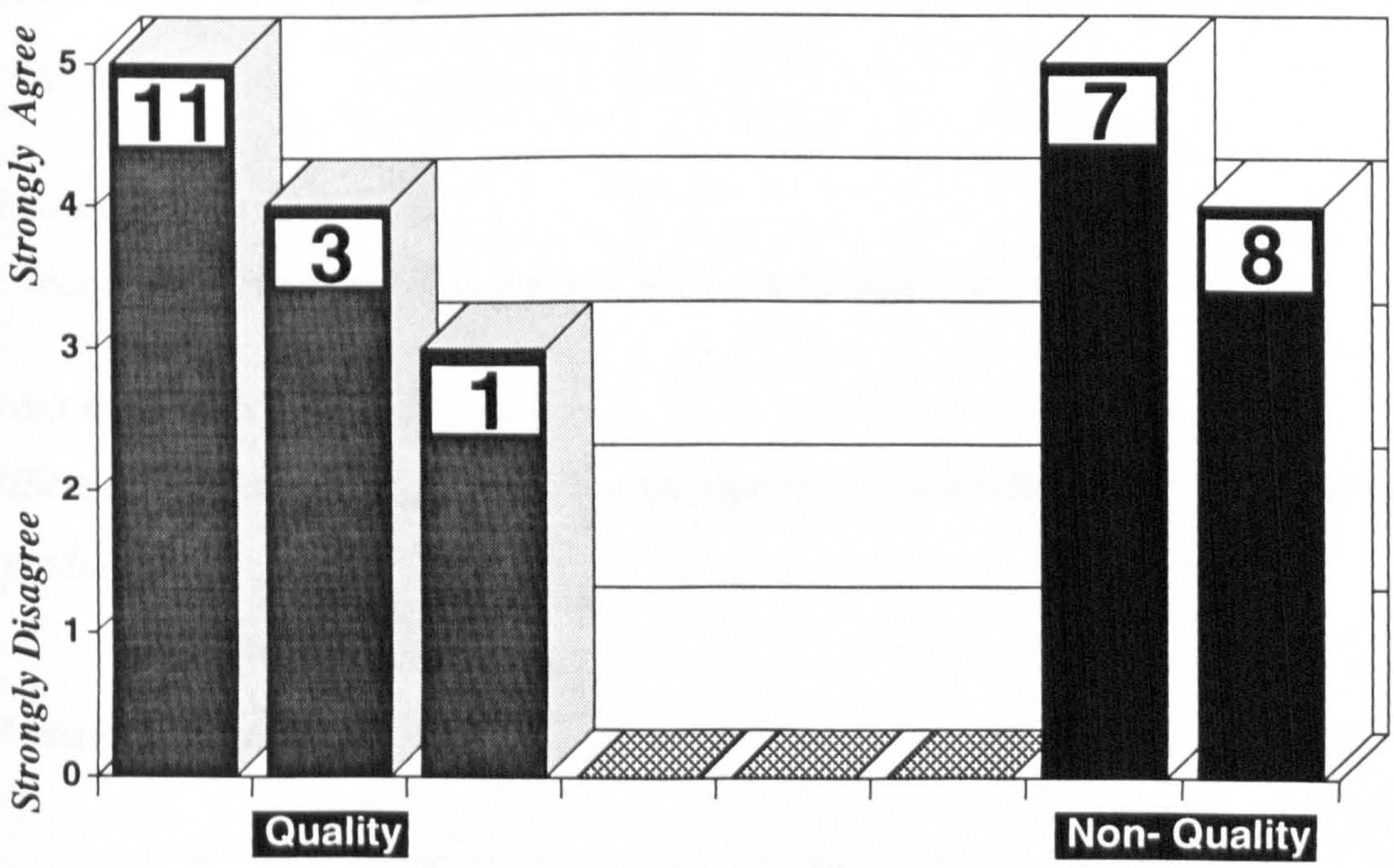


Fig. (❼.5): ***Assessment of Management of Structure as Productivity Improvement Factor***

The response here is also confirming the effect of the organisation structure as a possible source of productivity improvement if managed properly. However, the degree of agreement is less for the first two cases. Again the statistical results show this agreement but to a lesser extent.

MCV.3	Chi-Square	P	D.F
Management of Organisation Structure	14.6000	0.0007	2

The significance level obtained from the one-sample chi-square test result is lower than P=0.05 and Chi-sq. value is greater than the critical Chi-square value of Cr=5.99 (see *Appendix D*). Hence, the null hypothesis may be rejected and the alternative hypothesis accepted. Therefore, it has been confirmed that the management of the organisation structure is a key variable as far as productivity improvement is concerned.

***Sub-hypothesis* ②.4**

Productivity improvement is a function of the management of Training.

Null hypothesis

There is no relationship between the management of training and improvement in productivity.

Practitioners response

MCV.4	S.A	A	UD	D	S.D
Management of Training	19	9	1	1	0

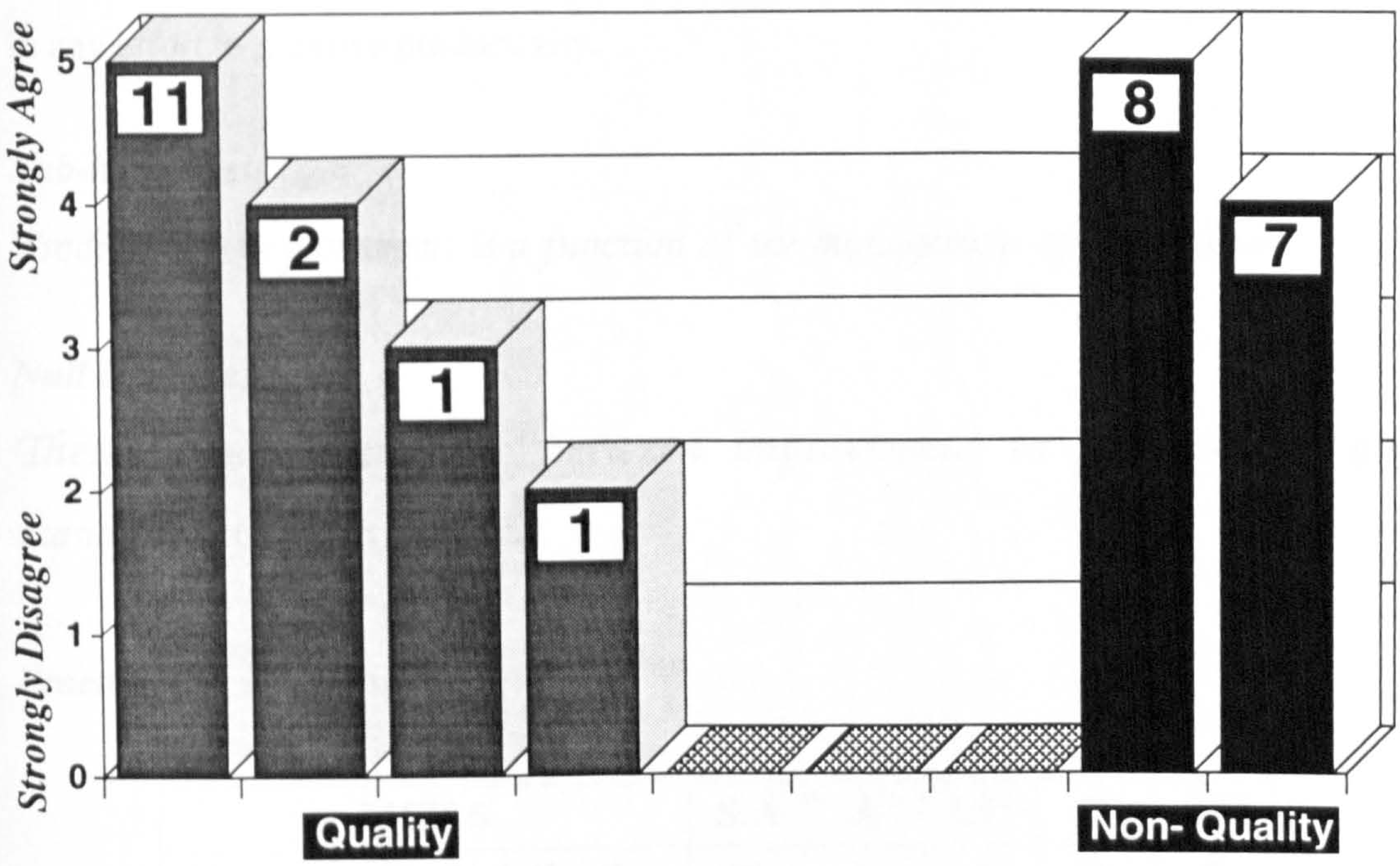


*Fig. (❼.6): **Assessment of Management of Training as Productivity Improvement Factor***

As can be seen from the response the degree of agreement is less than the previous variable. Also, it is the first time a disagreement is detected in the response of practitioners to this particular variable.

The statistical test results yet again confirm the significance of the variable as a determinant of productivity.

MCV.4	Chi-Square	P	D.F
Management of Training	29.2000	0.000	3

The critical value of Chi-square at D.F = 3 and level of significance of 0.05 is **7.82** which is less than 29.2.

Therefore, the null hypothesis may be rejected and the alternative hypothesis accepted.

Therefore, the management of training has been shown to be a determinant factor in any effort to improve productivity.

Sub-hypothesis ②.5

Productivity improvement is a function of the management of Motivation.

Null Hypothesis

There is no relationship between improvement in productivity and management of motivation.

Practitioners Response

MCV.5	S.A	A	UD	D	S.D
Management of Motivation	23	5	2	0	0

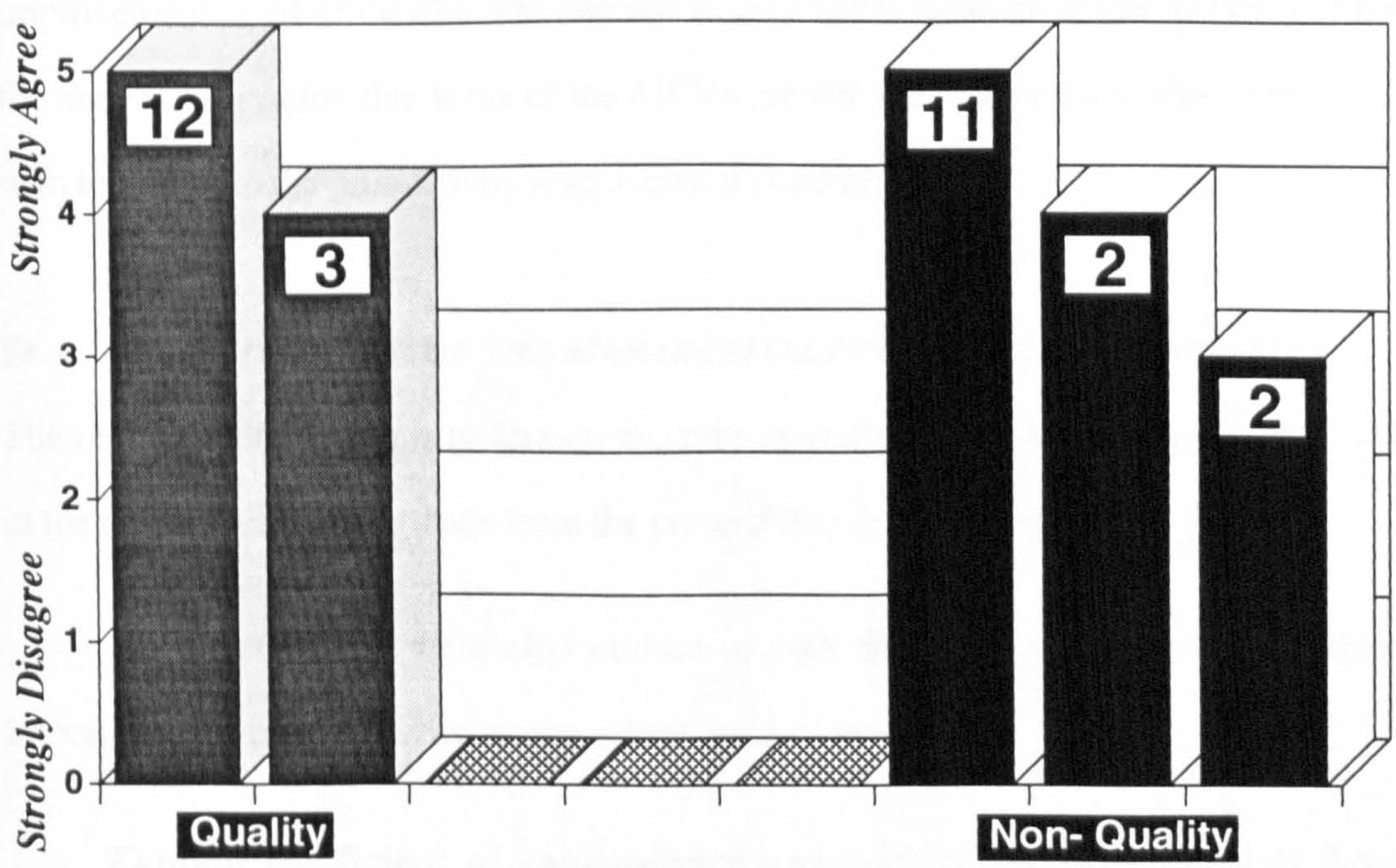


Fig. (❼.7): Assessment of Management of Motivation as Productivity Improvement Factor

One sample Chi-square result

MCV.5	Chi-Square	P	D.F
Management of Motivation	25.8000	0.000	2

According to the one sample chi-square test result the null hypothesis may be rejected (Cr=5.99 < 25.8 & P = 0.000 < 0.05). Therefore, the management of motivation is accepted as a determinant productivity improvement factor.

Again the degree of strength of the response of the practitioner is to some extent less than the first three variables.

In order to gauge the strength of each of the above variable from the productivity improvement point of view, it was decided to do a further statistical test just to confirm the above observation that some of the MCVs are stronger than others when compared with reference to the productivity improvement point of view.

7.4 *PRIORITIZATION OF THE MANAGERIALLY CONTROLLABLE VARIABLES*

The objective of this test is to arrange the managerially controllable variables (MCVs) in the order of their importance from the productivity improvement point of view.

The practitioners were also invited to rank the **MCVs** in the order of their importance from productivity improvement point of view.

Kendall coefficient of concordance was used to give the ranking of these variables and it is found to be as follows:

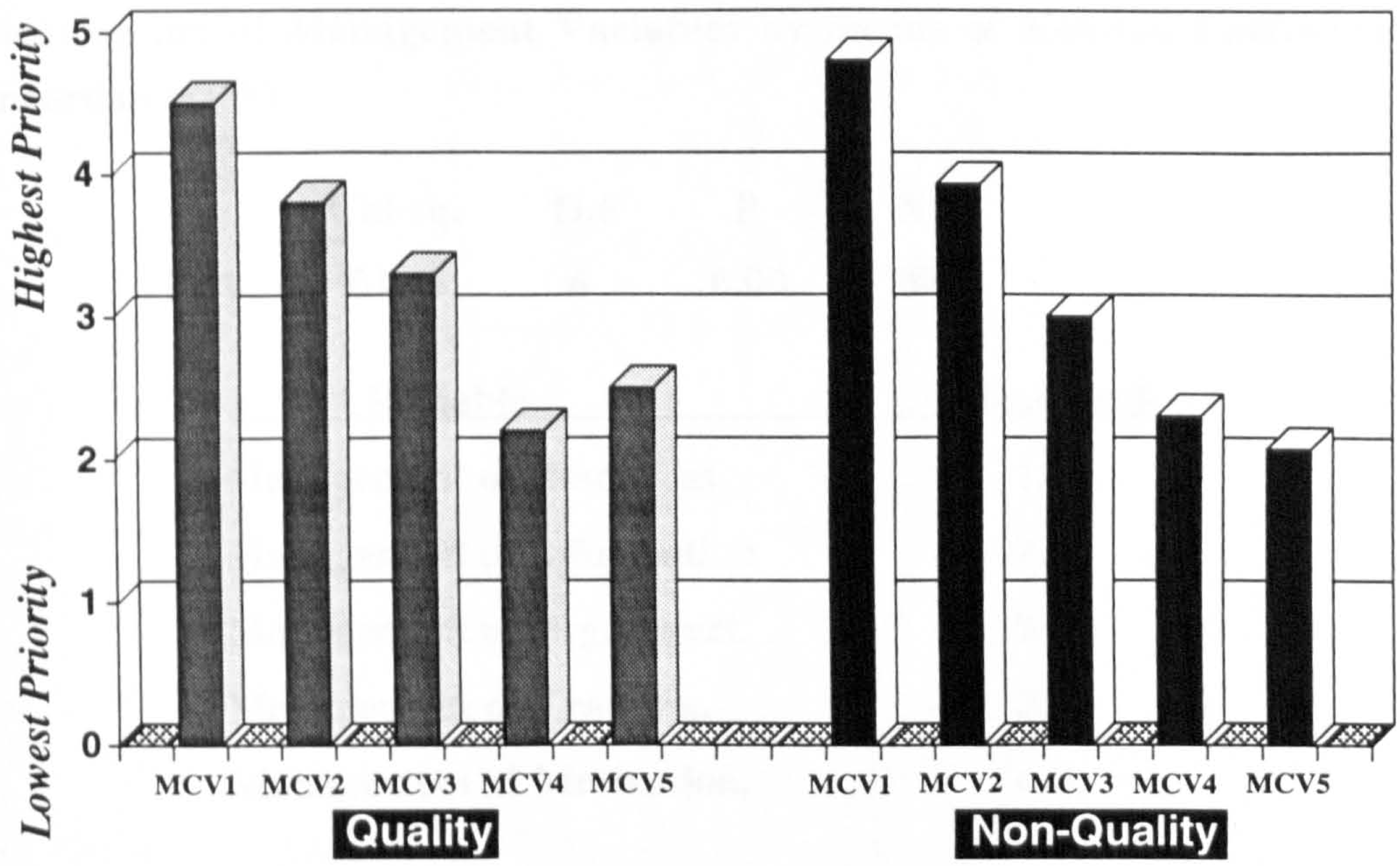


Fig. (❼.8): *Ranking of MCVs as given by Practitioners in different Categories of Firms*

<u>Prioritisation of the Managerially controllable variables as given by practitioners</u>

I. Practitioners Evidence

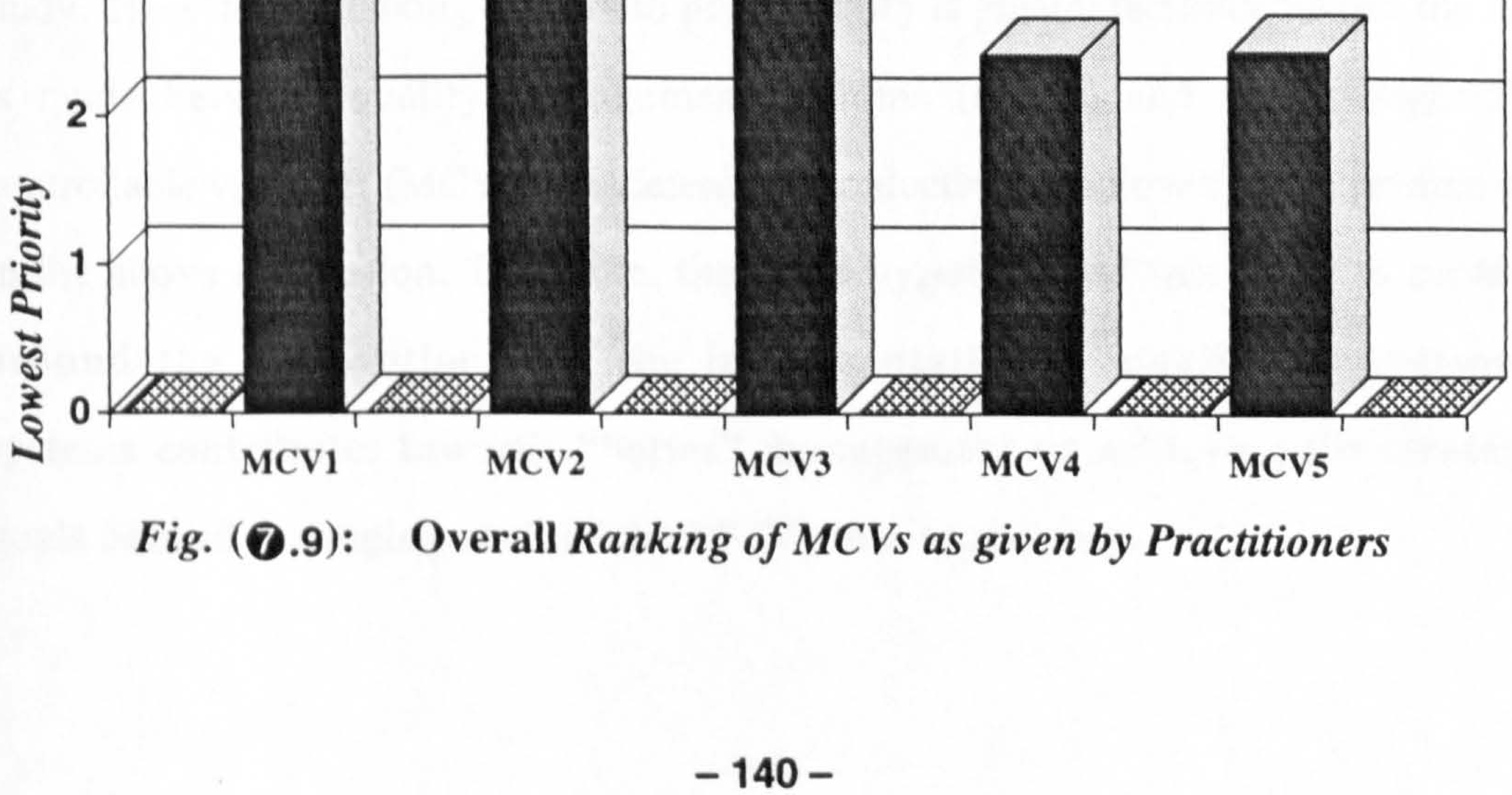


Fig. (❼.9): Overall *Ranking of MCVs as given by Practitioners*

II. Statistical Evidence

Prioritisation of Management Variables by means of Kendall Coefficient of concordance (W)

W	Chi-sq.	D.F	P	N
0.51	61.43	4	0.00	30

Variable	Mean rank
Management of Resources	1.53
Management of Information	2.30
Management of Org. Struct.	3.18
Management of Training.	3.98
Management of Motivation.	4.00

The above order coincides with the ranking given in the questionnaire in which practitioners were invited to put these variables in the order of their importance.

7.5 *CONCLUSIONS TO BE DRAWN FROM HYPOTHESIS* ②

The overall conclusion to be drawn from the foregoing analysis is that productivity is a function of the managerially controllable variables specified above. In other words, any change in these factors is bound to contribute to a change in productivity. This result agrees with the previous results of research into productivity improvement factors by Prokopenko (1987) and Shaddad (1983).

The above conclusion is regarded as a good foundation to build upon for this study. The effort of linking **quality** to **productivity** is greatly facilitated when the link is made between quality management systems (QMS) and the managerially controllable variables (MCVs) that determine productivity improvement as pointed out in the above conclusion. Therefore, **the third hypothesis of this study is centred around the proposition that the implementation of quality management systems contributes towards "better" management or achieving the strategic goals behind managing each of the MCVs in a sound way.**

❼.6 *HYPOTHESIS* ③

The implementation of quality management systems lead to better management of the managerially controllable variables (MCVs) that influence construction productivity.

This hypothesis has been subdivided into five more sub-hypotheses which deal with each variable in turn.

Sub-hypothesis ③.1

The implementation of formal quality management systems lead to better management of resources.

Also this sub-hypothesis is further subdivided into more sub-hypotheses which specifies each resource in turn.

Sub-hypothesis ③.1.1

The implementation of formal QMS lead to better management of labour.

The Null hypothesis

There is no relationship between the implementation of formal quality management systems and better management of labour.

Testing Hypothesis ③

It has been thus far established in hypothesis 2 that productivity improvement is a function of the managerially controllable variables (MCVs) that influence construction productivity. This part of the analysis is seeking to assess the impact of formal quality management systems upon management of the managerially controllable variables (MCVs) that have been shown to determine productivity. As shown in the questionnaire (***Appendix. B***) various points, related to the aims and objectives behind the management of each of the MCVs, have been included and put to the practitioners. The practitioners were asked to express their professional opinions as to whether or not they think their quality management systems help in achieving these aims and objectives.

I. Practitioners Evidence

I.A Questionnaire feedback

It can be seen in the questionnaire that the practitioners were given a scale of (1 to 5) in order to express their opinions regarding the variables involved. If they think that their quality management systems, whether be it formal or informal, helps them in achieving the stated goals and objectives completely, then they say 1. If it helps them in achieving these aims and objectives to a lesser extent they say 2. If they are undecided they say 3. If on the other hand they do not think that their quality systems help in achieving any of the stated objectives they say 4 or 5 depending on the level of disagreement they may have.

The points put to practitioners were addressing key issues related to the key objectives sought after **labour management** and the intention was to find out the extent to which these issues have been addressed within the management systems of those organisations. The issues raised included (see questionnaire ***Appendix B***): the presence or otherwise of a mechanism for identifying the nature of skills required for activities related to the projects on site and thus allocating the appropriate labour to it. Also, producing job specification and offering encouragement for labour to fulfil their personal and career objectives and hence motivating them to apply themselves more in what they do.

I.B Interviews feedback

The interviews were necessary to follow up the practitioners in any ambiguities which were left over in the questionnaire. In this particular case interviews were used to ask the practitioners why they responded the way they did and how in practical terms their quality systems worked.

Testing sub-hypothesis ③.1 (management of labour)

The response of the practitioners to the issues raised with regard to this variable is shown in the histogram below.

As can be seen from the histogram below the response was varied amongst those firms with formal quality management systems in place and those without. The firms with formal quality management systems are shown to express more agreement with the statements that their quality systems help in achieving the stated goals and objectives. In other words, they seem to have managed the MCVs in a better way or to have better control over them. But why? and how this is done? To answer these questions, it was deemed necessary to carry out interviews with the same practitioners who responded to the questionnaires and more or less expressed their view that their formal quality management systems helped them in achieving the stated objectives. The interviews were mainly asking them to elaborate further and to explain how, in practical terms, their formal quality management systems helped them in achieving the stated objectives.

I. Practitioners Response

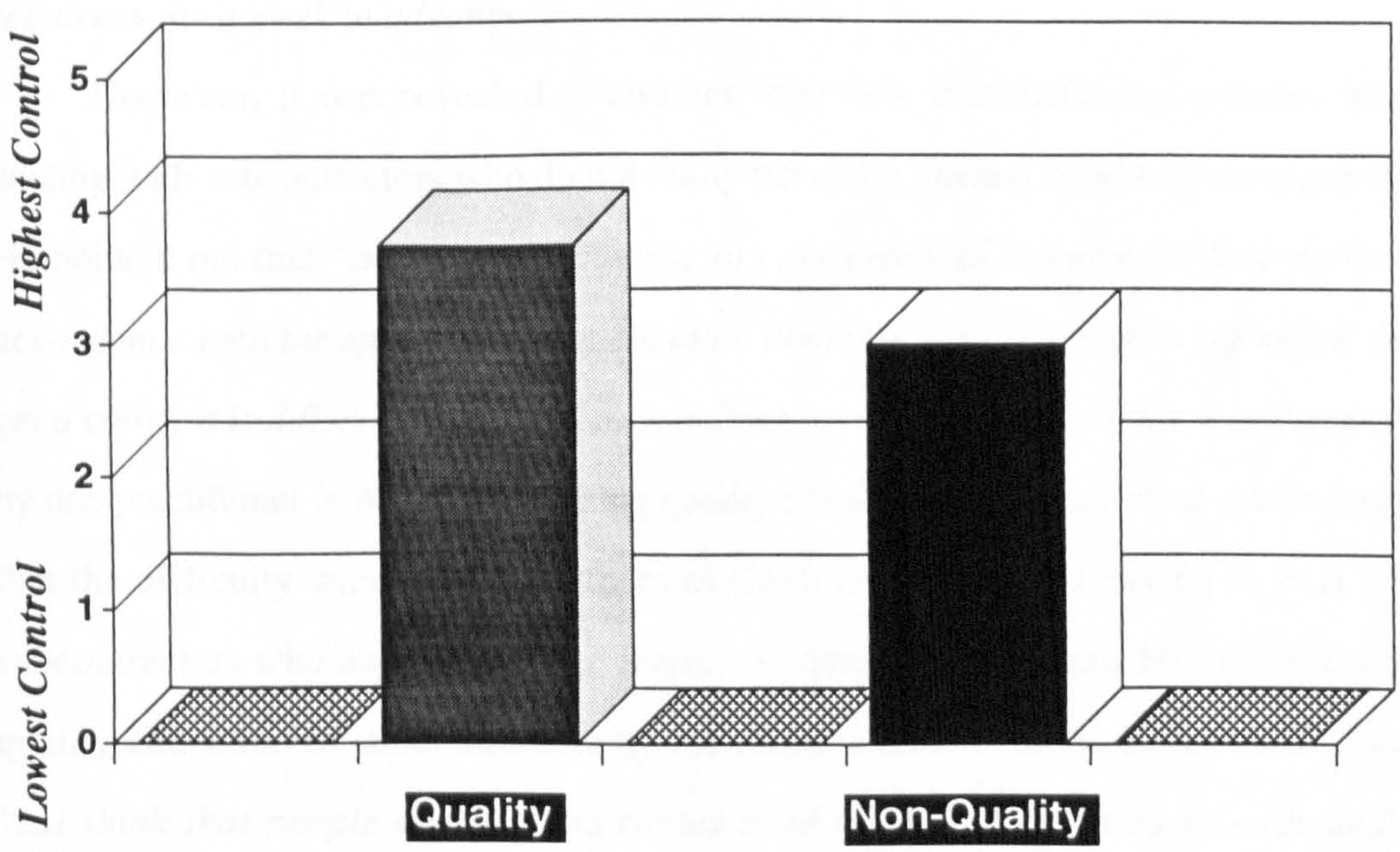


Fig. (❼.10): Degree of Control Over "Management of Labour" as given by Practitioners

Interview response

How is the management of labour done within the framework of formal quality management system?

One respondent of a major quality management organisation pointed out that their labour have more clearly specified duties under the quality management system when compared to the pre-formal quality system era within the same organisation. Moreover, it was indicated by the same respondent that the quality plan which is a project specific quality document does clearly specify **who does what and how** for the workers before they are deployed in their duties. This view was echoed by most of the other interviewees. With regard to the point related to the identification of the nature of the skills required and appointing the appropriate labour to it, three interviewees pointed out that before a quality plan is produced every activity within a project is analyzed in a structured way. He added that *"the analysis will result in obtaining a description of the job required and our in-house labour are told about these requirements a week in advance"*.

However, it was revealed in another interview that difficulty remains when dealing with subcontractors who do not really have any interest in quality management. He pointed out that *"although subcontractors are required to perform their duties in accordance with the specification of the main contractor's quality plan (of which they get a copy), it is difficult to perform such a thing in practice"*. This view was supported by one practitioner in one of the leading quality management organisation who asserted that the difficulty which is facing them as QMS organisation is having to deal with subcontractors who have little or no interest in quality procedures. He calls for more quality education of subcontractors by the construction industry. In his own words: *"...I think that people at the grass routes need to be a little bit more educated in quality matters and doing things right first time"*.

Nevertheless, this issue of subcontractors was seen to be better handled in another QMS organisation which carries out assessment of its subcontractors. One interviewee pointed out that they do a subcontractors assessment procedure. In this so called subcontractor assessment procedure, they analyze the content of the job needing to be carried out and the skills required. The subcontractors are graded for each job content where there is a certain category of subcontractors to be used. A subcontractor graded as 1 in one job may be graded 2 in another. He further added that *"the quality plan issued for each contract produces the appropriate job specification for each job. If a job requires calibration, electrical, plumbing or steel erection, where calibrated equipment is required to be used, subcontractors are required to produce evidence of calibration to have been properly carried out"*. In a third QMS organisation the way subcontractors are dealt with is equally thorough and rigorous. As explained by their quality manager that: *"the activities of the subcontractors are monitored and they are required to provide a quality plan for their part of the job"*.

The activities of the subcontractors are monitored through minuted meetings with them. Coordination and progress meetings could be every two weeks. He further indicated that the performance of the subcontractors is assessed in a scale as follows:

7 to 8	**-------------------**	**Excellent**
5 to 6	**-------------------**	**Good**
3 to 4	**-------------------**	**Fair**
1 or 2	**-------------------**	**Bad".**

Another approach as to how the subcontractors are managed within the quality management system was given by another QMS organisation which explained that they have a data base of QMS-subcontractors, but if they have to deal with non-QMS subcontractors, they set up a system for them or as explained by their representative, *"we tell them at the outset (during interviews) what we do and how we operate and that how they should fit in"*. As for the monitoring of the performance of subcontractors, the representative pointed out that: *"we check on the subcontractors performance during formal meetings in which the following points are specified:*

- **How he is to handle the job?**
- **What resources he has for the job?**
- **What is the degree of supervision required?**
- **How is the programme for completion?**
- **How is he to handle safety?**
- **Production of methods statements?"**

According to the argument put forward by this practitioner it was made clear that every activity carried out by subcontractors is monitored and during formal minuted meetings with them. Moreover, they have record sheets which are checked and non-compliance forms which will be issued if the subcontractor has not complied in any way with the agreed specifications.

From the various approaches given for managing subcontractors, it can be concluded that the problem of having to deal with subcontractors who do not have formal quality systems themselves is a problem which poses a considerable difficulty in the implementation of these systems in practice. However, the problem can be overcome with the stringency and thoroughness outlined in the interviews explained above.

Given the above support for the hypothesis that formal quality management systems help in achieving better management of labour in construction firms, it should be pointed out that some interviewees stated that their systems have nothing to do with the management of labour. "*.. our system has no input as far as labour management is concerned*". However, it should be pointed out that these particular organisations have very limited experience of formal quality systems and as became evident during the interviews they were motivated by external forces (government or clients) to implement the systems. Therefore, their first and foremost objective was to have a marketing tool or as they put it "to get the badge" and not instil a quality culture within their organisations which would reflect itself in the end product.

II. Statistical Evidence

The statistical evidence obtained below points towards rejecting the null hypothesis and accepting the alternative hypothesis. It supports the view that formal quality management systems contributes towards better management of labour working in construction projects.

The result of Spearman's correlation shows strong association between the presence of formal quality management systems and better management of labour.

The result of the Spearman's correlation test

From statistical tables, the critical value of Rho (or r_S) for rejecting the null hypothesis at significance level of 0.05 and number of sample N = 30 is **0.306**.

MCV	Rho	P	N
Management of Labour	0.438	0.000	30

Where:

MCV = Managerially Controllable Variable.

Rho = Spearman's correlation coefficient.

P = significance level.

N = sample size.

From the above result it is clear that the Spearman's coefficient value is **0.438** which is greater than the critical value **0.306** and the significance level (P) is **0.000** which is less than the prefixed significance level of **0.05.** Therefore, the null hypothesis may be rejected and the alternative hypothesis accepted. Therefore, **it can be inferred that the implementation of quality management systems (QMS) lead to better control over the management of labour.**

Sub-hypothesis ③.1.2

The implementation of formal QMS leads to better management of Materials.

The Null hypothesis

There is no relationship between the implementation of formal QMS and better management of materials.

I. Practitioners Evidence

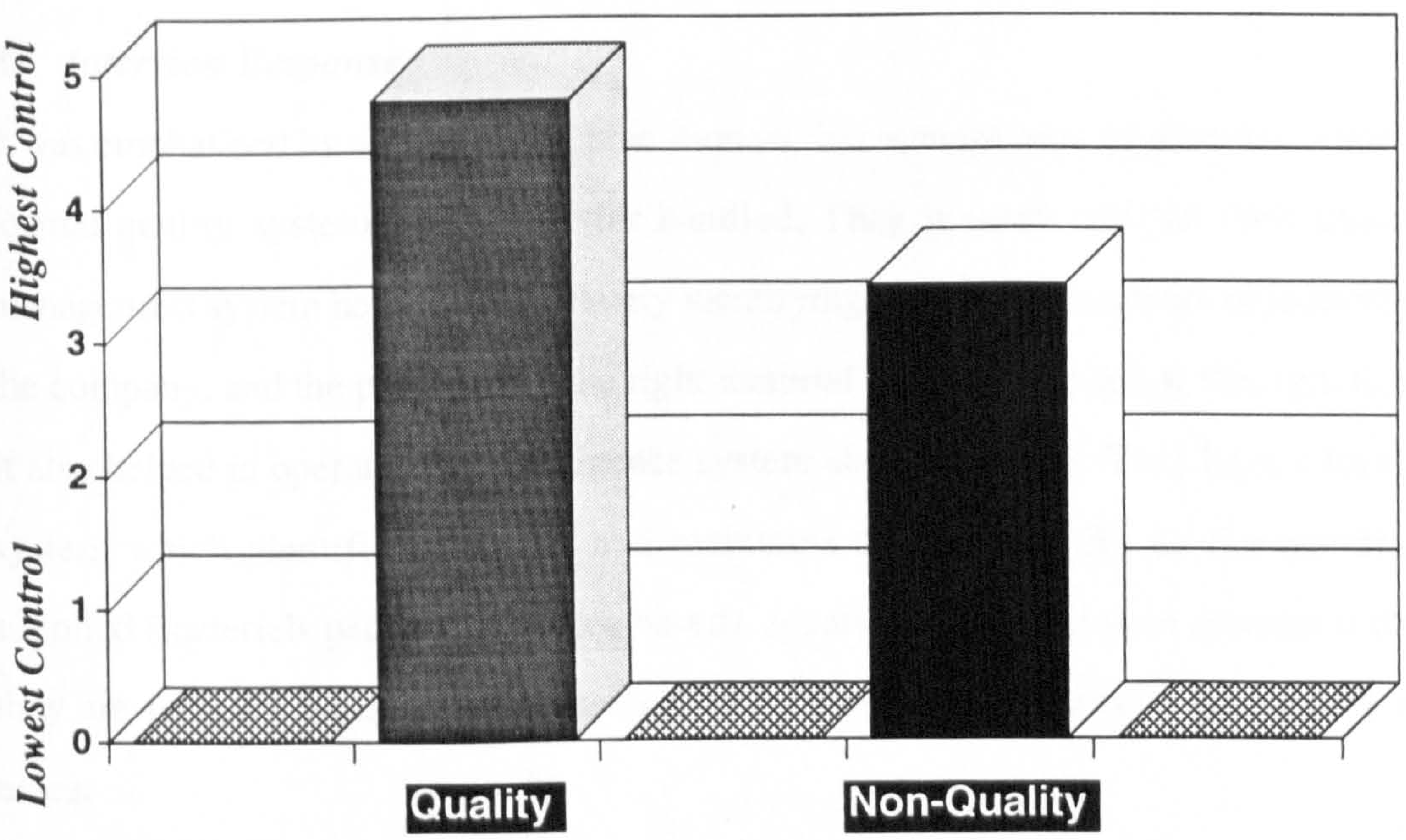


Fig. (❼.11): Degree of Control Over "Management of Materials" as given by Practitioners

From the management of materials point of view, there are two distinct and highly related processes that are required to be performed in the acquiring and using of materials on sites (Canter,1993). These processes are **procurement** and **management from supply to incorporation.** The points raised in interviews with practitioners were addressing these key processes. Questions put to them were related to whether or not their formal management systems help in identifying procurement objectives of their firms, provision of right materials in the right quantities at the right time, etc.. Also whether or not it operates an intelligence system about suppliers to meet the purchasing objectives of their firms.

A. Questionnaire Response

The practitioners response with regard to their agreement as to whether or not their quality systems helps in achieving the desirable objectives related to materials management is shown in the histogram above:

B. Interview Response

It was emphasised by almost all the practitioners that management of materials under a formal quality system is much better handled. They pointed out that their quality management system helps them in clearly identifying the key procurement objectives of the company, and the provision of the right material in the right place at the right time. It also helped in operating an intelligence system about suppliers. They have a formal system which identifies suppliers and maintains rigorous checks on the materials supplied (materials peoples are office based). A salient feature of such systems is that they are formally expressed within work procedures and available to all staff at all times.

It was pointed out in a discussion with a quality manager that at the tender stage, the materials department are required to go to key suppliers identified in their computer system and specify the nature of materials required as well as the time at which they would want it delivered. He also indicated that the list of the suppliers is regularly updated and included in the quality plan. The quality manager also strongly agreed that their quality management system helps them in the management of subcontractors including their measurement of performance. He stated that: *"Again our quality system operates as so called subcontractors procurement schedule which identifies all subcontractors. The subcontractors work is measured on a monthly basis, completed* *and discussed at the management level"*. Moreover, he asserted that each subcontractor is asked to produce a quality plan or a quality policy depending upon the size and cost of the job. In addition to the quality plan they must provide a check list as a monitor to control their performance. In addition to subcontractors procurement schedules, there is also a so called "material procurement schedule". In response to a question as to how such a schedule is put together, he pointed out that *"our contracts managers compile this schedule based on the Bill of Quantities specifications. This schedule is then passed to the materials department; hence the material is ordered to site as needed. eg. not ordering kitchen materials at week one of the project"*.

At one quality management organisation, materials requisition and control is part of their quality manual.

As for management from supply to incorporation, it was revealed in most of the interviews made with practitioners that the QMS requires their site managers to visually inspect all materials deliveries to their sites; similar guidelines are made in terms of the prudent handling of material through storage to final usage. As for the way in which subcontractors are managed it is more or less similar to the labour management case. In addition to the quality plan they must provide a check list as a monitor to control their performance.

The grading of subcontractors is done in the following manner:

Grade 1: Used for very limited and simple work

Grade 2: Complex nature of work of high value

Grade 3: Work for which Subcontractors are required to be QA registered eg. works carried out for the Department of Health to build a working theatre of operations.

Furthermore, the respondent added that: *"we do offer help for subcontractors who are not registered to BS 5750 to produce quality plans we may even give them a copy of ours"*.

Within the quality manual seen at one organisation, it is broken down into five main sections of recommendations related to materials procurement on site:

- Company policy on purchasing.
- Ordering of materials.
- On site progress of orders.
- Receipt of materials on site.
- Materials checking.

However, one quality manager at an organisation which had only one years experience with formal quality systems; pointed out that it costs more money to administer a formal quality system properly and to keep doing all the letter requirements of the standard. He also perceived the formal quality system as "an office procedure" and as having nothing to do with their activities on site. This perception reflects the nature of the implementation of the system at that particular organisation. Apparently the system was purely done as a marketing tool and to convince a third party merely for certification purposes or "getting the badge" and not a strategic approach to initiate and maintain continuous improvement in the end product.

II. Statistical Evidence

Spearman's Correlation test results

MCV	Rho	P	N
Management of Materials	**0.5271**	**0.003**	**30**

From the spearman's result as the **correlation coefficient Rho** is bigger than the critical value of Spearman's coefficient of Correlation specified above 0.5271>0.305) and the significance level $P < 0.05$. Therefore, the null hypothesis may be rejected and strong association between the implementation of quality management systems and better control over management of materials is supported.

Sub-hypothesis ③.**1.3**

The implementation of formal QMS leads to better management of plant.

The Null hypothesis

There is no relationship between the implementation of formal quality management systems and better management of plant.

I. Practitioners Evidence

A. Questionnaire Response

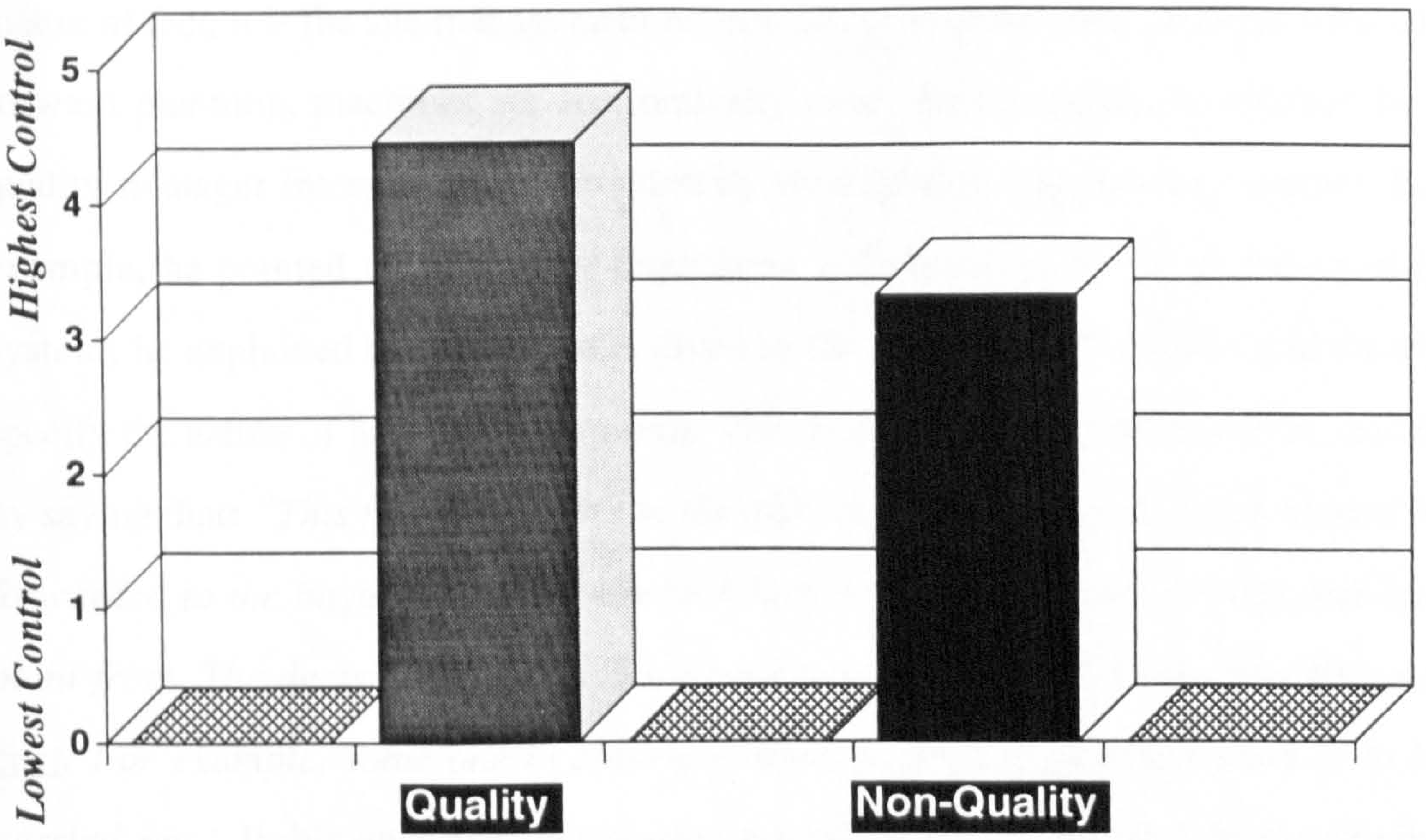


*Fig. (❼.12): **Degree of Control Over "Management of Plant" as given by Practitioners***

The main aims and objectives of managing plant were put to the practitioners (see questionnaire) who were asked to express their opinions as to whether or not their quality systems, whether be it formal or informal, help in achieving them.

The histogram above shows that those companies with formal quality systems have expressed their view more to the effect that their quality system helps in achieving the required objectives than those organisations without formal quality systems in place. However, it is necessary to see why this is the case and this very question was put to practitioners in the interview which followed this questionnaire.

B. Interview Response:

In the interviews which followed the questionnaires, the general consensus of the respondents was pointing towards the fact that QMS can help in providing sites with readily available equipment which is fully maintained and will not let people down. As a matter of fact, it is the site management responsibility to ensure that, through adequate forward planning, machines are economically used. This planning, as claimed by a quality manager interviewed is provided by their quality management system. For example, he pointed out that plant requisition is fully covered within their quality system; he explained that this form is given to the site manager to fill in and clearly specify the nature of his equipment needs. The quality manager continued his remark by saying that: *"This form according to the quality procedure in operation should be forwarded to the buying department which look for hire companies to use and hire plant from. The decision of the buying department is governed by the location and cost. For example, some one in close proximity to the site at which work is to be carried out"*. In his answer to a question regarding the unique role of the buying department within the framework of the quality management system the respondent pointed out that: *"The buying department arranges a bulk order form. The head office arranges his needs within 24 hrs before call off. If a site manager knows his needs of certain plant on Monday then he must give enough notice to head office to arrange for delivery in time"*. Again he pointed out that the procedure for arranging delivery in time is clearly spelled out in the quality plan (which is derived from the quality management system). Therefore, it seems that **Price** and **Proximity** are the two overriding factors in the final decision on the plant hire company to be used.

As far as the economic running of plant is concerned a question was put to the respondent to uncover what determines their decision in either hiring or buying a particular piece of plant and his answer was, as expected, that the length of time for the plant need is the determinant factor. *"It would not be prudent to hire plant for 50 weeks"*.

Another area investigated in the interviews was that of **plant maintenance.** Some interviewees pointed out that their quality systems have nothing to do with the procurement side of plant but with the maintenance side of it. ie their formal quality system offers no help in organising buying or hiring plant; however, it organises the maintenance process more fully. In the discussion made with one quality manager, reference was made to the quality manual and it was pointed out that the quality system requires that the company operates a system whereby checks and calibration with suppliers including a put off period are required. For example, it was stated that *"..at certain specified periods in the quality plan plant are sent back to calibration and brought back to us; in the mean time the plant hire company is required to give us an alternative plant while the first one is being calibrated"*. As far as the plant owned by the company are concerned, it was made clear that they undergo regular checks where it is made sure they are in perfect working condition. It was noted that all these steps form part of the work procedures of the quality plan for any project which, as explained by quality managers, are audited regularly and made sure they are adhered to. Furthermore, in a question regarding subcontractors management of plant, it was explained that the subcontractors are also required to have their equipment calibrated regularly as specified in their quality plan.

Therefore, it was concluded that through quality management procedures the sites would be provided with readily available equipment which is fully maintained and would not let them down. Moreover, the quality system ensured, through adequate forward planning and regular checks and calibrations, that the machines are economically used and kept in good conditions throughout whether they are hired or owned. However, one respondent indicated that their QMS procedures have little to do with the plant procurement procedures in the procurement side, but from the maintenance point of view, it does help in establishing a formal system of checks and calibrations.

Control of Plant

As explained by one quality manager the quality manual has got special procedures for plant control and how to control the quality of service rendered by the plant.

At that particular company and in light of their quality manual recommendations a plant coordinator is appointed by the company to look after the general performance of the plant in service. He circulates a questionnaire to see which plant is being assessed by the company. Sites are fed with plant through the plant coordinator.

The project manager prepares a schedule of plant requirements and passes it through to the plant coordinator who arranges for the most economical way in which the plant could be utilised.

II. Statistical Evidence

Spearman's correlation test results

MCV	Rho	P	N
Management of Plant	0.8192	0.000	30

Significance **P** is less than **0.05** and the Spearman's correlation coefficient is bigger than the critical value specified above. Therefore, the null hypothesis may be rejected and the positive association between the implementation of quality management systems and management of plant is confirmed.

The results show high positive correlation between the above factors and hence point towards a significant role for quality management systems in the management of plant.

Hypothesis ③.2

The implementation of formal quality management systems leads to better management of information.

Null Hypothesis

There is no relationship between the implementation of quality management systems and better management of information.

I. Practitioners Evidence

A. Questionnaire Response

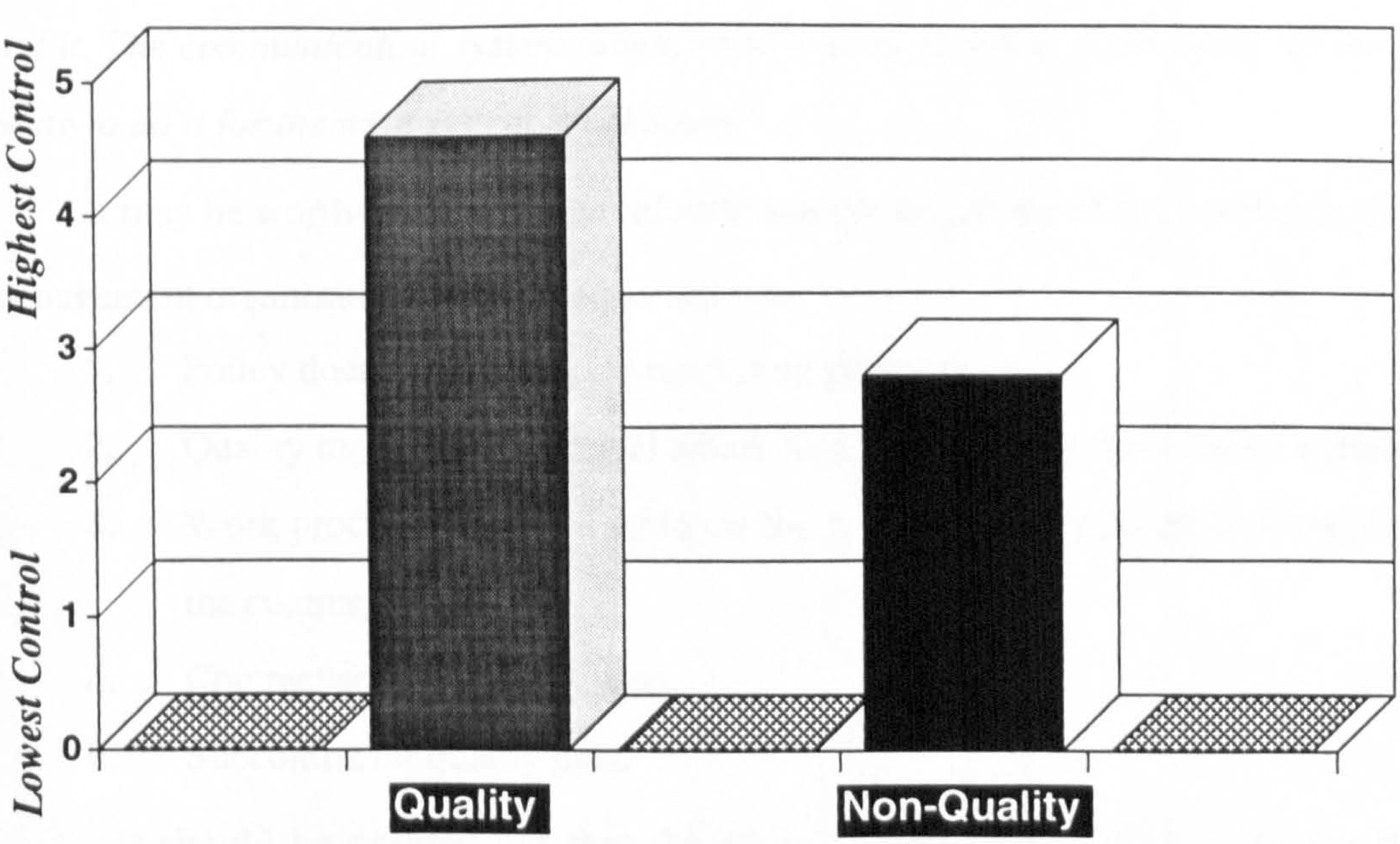


Fig. (❼.13): Degree of Control Over "Management of Information" as given by Practitioners

Once again, key points related to the aims and objectives behind having a sound quality management system were put to the practitioners and their views regarding whether or not their quality systems help in achieving them is shown above.

B. Interview Response

Most of the practitioners interviewed strongly agree that the presence of a formal quality management structure helped in creating a project management information system that provides the sufficient and relevant information when and where needed. It also greatly facilitated the process of decision making and helped them obtaining the required information in the right place at the right time. It was asserted by one of the respondents that the quality management systems helped in all aspects of effective information management. It clearly specifies who is responsible for doing what, who has the required information and how to find a copy of it. "Before the QMS era it was up to the individual manager to give copies to whom he pleased". In the words of another quality manager of a large QMS organisation: "*communication is rendered much better and relevant information at hand, if not the manual will tell you where to find it. The communication system identifies who is to do what, if not done, no one is going to do it for them (ie system breakdown)*".

It may be worth noting that the information system at one of the leading quality management organisations is outlined as follows:

1. Policy document - used for marketing purposes.
2. Quality management manual which highlights the way the system operates.
3. Work procedure manual which is the procedure to be adopted throughout the company.
4. Contract specific quality plan.
5. Subcontractor quality plan.

It should be pointed out that the status "leading" accorded to the quality management organisation referred to above is due to the fact that it was one of the first three to achieve certification to BS 5750. Moreover, the company only used the standard as a framework to build on a culture of continuous improvement which continues to date to constantly review their systems and procedure in search for excellence. However, no other objective criteria was used in this instance to justify this status offered to this organisation.

The view regarding improved communication was echoed by most of the remaining practitioners who confirmed the crucial role of formal quality systems in the proper management of information. It was also pointed out that regular review meetings are held at the management level to ensure compliance of all project's party to requirements".

II. Statistical Evidence

Spearmans test results

MCV	Rho	P	N
Management of Information	0.67	0.00	30

Again the above results show enough grounds for the rejection of the null hypothesis and confirmation of the existence of a strong association between the implementation of quality management systems and better control over management of information variables (Rho is greater than 0.305 and **P** is less than 0.05).

Hypothesis ③.3

The implementation of formal quality management systems leads to better management and design of the organisation structure.

Null Hypothesis

There is no relationship between the implementation of formal quality management systems and the design and management of organisation structure.

I. Practitioners Evidence

A. Questionnaire Response

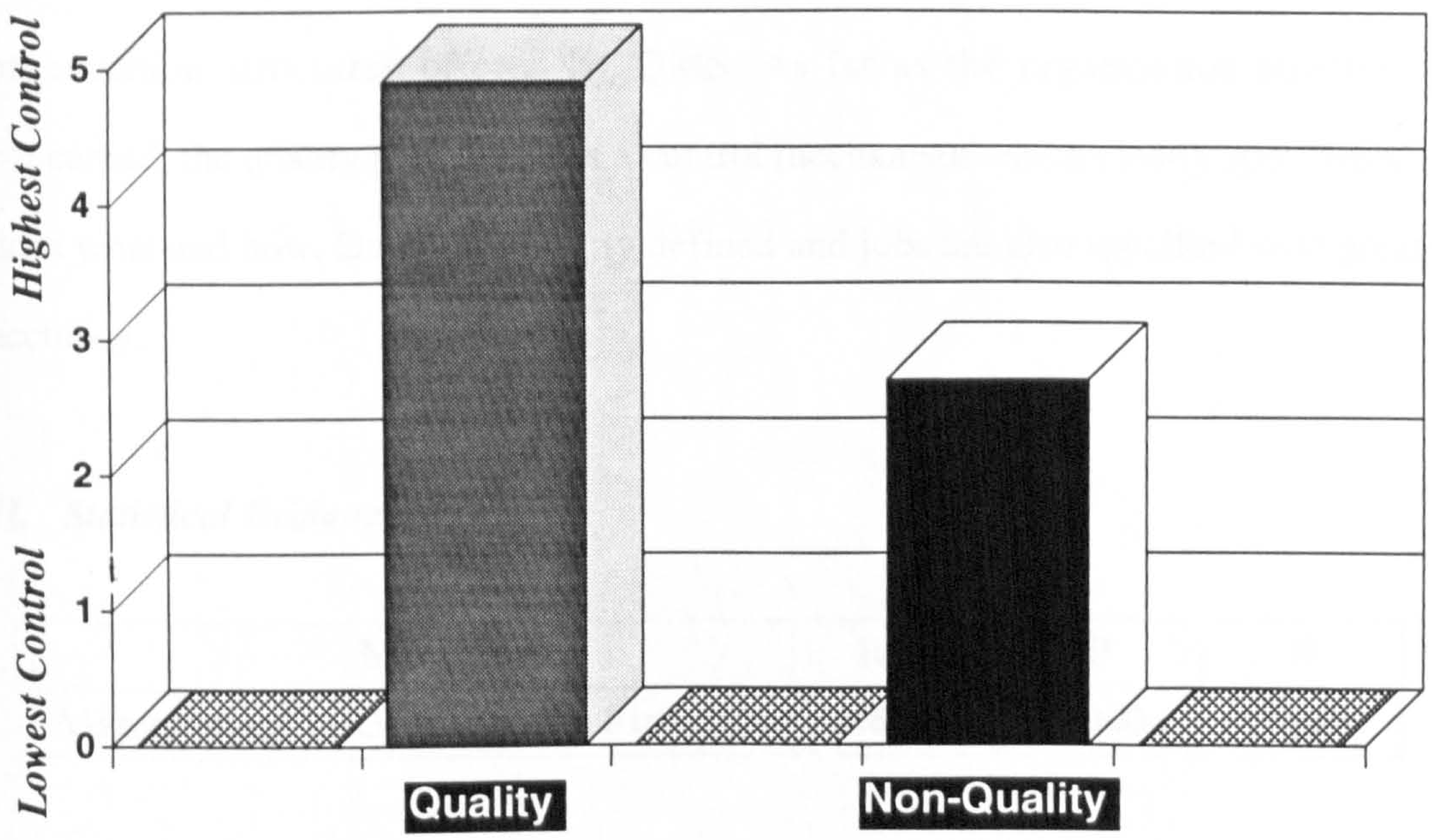


Fig. (❼.14): ***Degree of Control Over "Management of Organisational Structure" as given by Practitioners***

The aims and objectives related to having a sound organisation structure for projects were put to the practitioners and they were asked to express their opinion regarding their quality system and whether or not it helps in achieving these objectives. The response of these practitioners is shown above.

B. Interview Response

The response shown above is not surprising as it was indicated by most of the interviewees that project organisation structures are much better arranged within the framework of QMS. One respondent pointed out that: "..*QMS helps in creating a* *project organisation structure which clearly specifies who does what and how and achieving unity of command, role clarity and clear definition of job scope*". The issue of accountability is also singled out as being better handled within the projects organisation structures offered by QMS. As far as the organisation structure is concerned, the quality plan provides a control mechanism which clearly specifies who does what and how. Duties are clearly defined and jobs are also specified with greater accuracy.

II. Statistical Evidence

MCV	Rho	P	N
Management of Organisation Structure	0.6856	0.000	30

Spearman's coefficient Rho is greater than the critical value specified earlier (0.305) and the significance level **P** is less than 0.05. Therefore, there is ground for rejecting the null hypothesis and accepting that there is a strong association between the implementation of quality management systems and the design and management of organisation structures.

***Hypothesis* ③.4**

The implementation of formal quality management systems (QMS) leads to better management of Training.

The null hypothesis

There is no relationship between the presence of formal QMS and better management of training.

I. Practitioners Evidence

A. Questionnaire Response

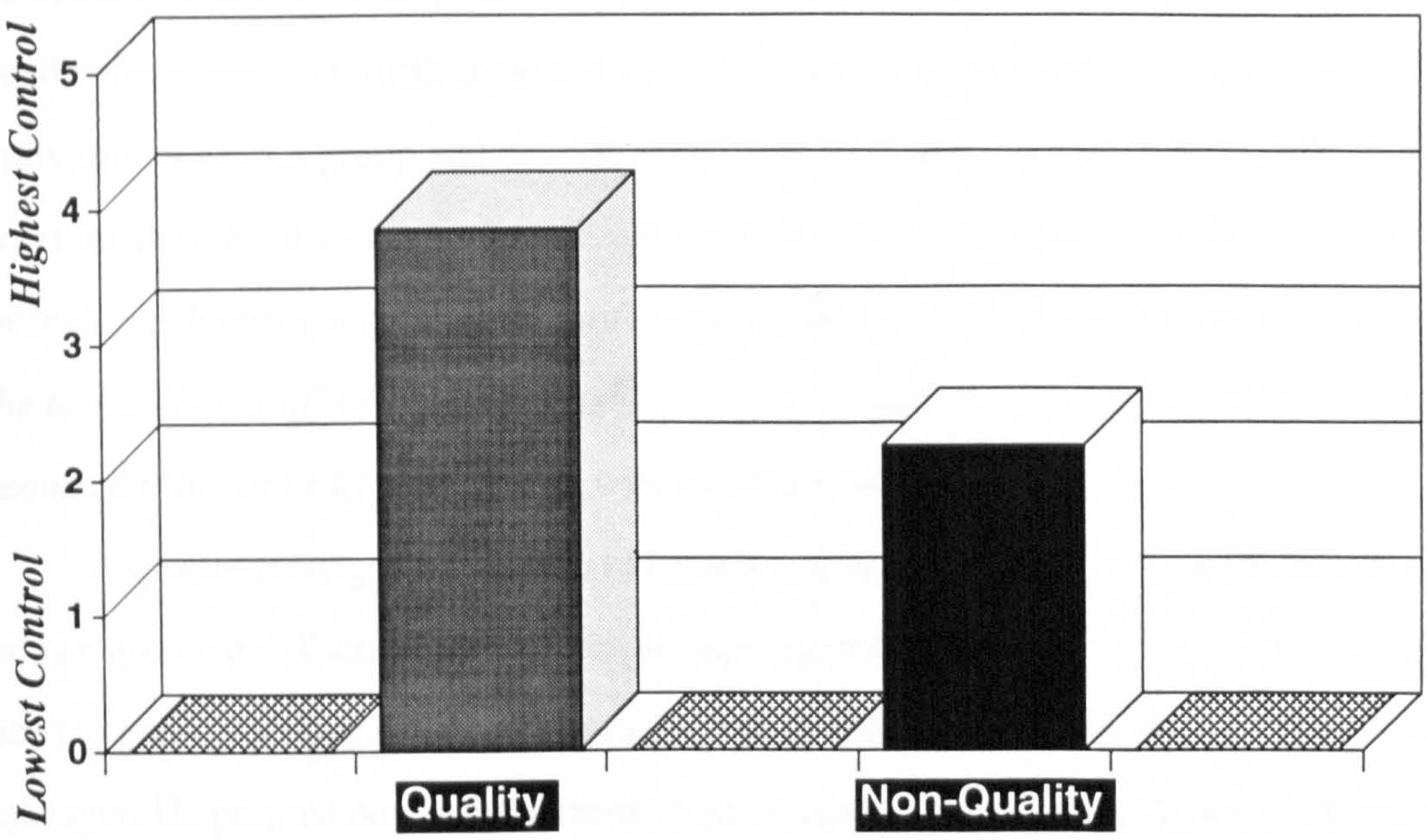


Fig. (7.15): Degree of Control Over "Management of Training" as given by Practitioners

The histogram shown above indicates that the firms with formal quality management systems have better control over management of training than those firms without formal quality systems.

B. Interview Response

The interviewees strongly agreed that QMS provided the training required through formal and informal methods. The training programme is more defined and carried out on a regular basis.

However, it is pointed out by one practitioner that workers mobility in the construction industry is an impediment to effective and long-term training programmes.

It has also been pointed out in most interviews that the implementation of QMS helped in reviewing the performance and progress of foremen on their present jobs as well as providing pointers to their need for future recruitment and promotion purposes. A quality manager at one organisation explained that within their quality system they maintain a record of training that everyone have been doing and identified what training needs there are. He further added that it is his responsibility to meet everyone individually or as a group and discuss with them all aspects of their training needs and whether they need to go on vocational courses. He concluded by adding that "*..the overall mechanism is there to ensure that they have the adequate training to achieve the tasks. Their staff who need further training are usually sent to the CITB to gain the required skills or be kept up to date with developments in their fields".*

A quality manager at one firm indicated that he meets with everyone individually or as a group and discusses with them all aspects related to their training needs; if they need to go on vocational courses then all the arrangements are made through the quality manager. He pointed out that this mechanism is here to ensure that adequate training to achieve required tasks is available. In his own words: **"when an individual cannot operate within the quality system satisfactorily, then the system can easily detect that through the number of "non-conformities committed".** Such non-conformity reports help site managers to know who is in need of training.

The commitment to a sound training programme is a fundamental requirement of the quality management system and hence the commitment to it should be coming right from the top of the organisation. To this effect, in one of the organisations visited, it was explained by their quality spokesman that their **M**anaging **D**irector (MD) reviews annually who has been on training and who has not and this clearly demonstrates the top management commitment to the training of their staff and personnel. He further explained that everyone's record of training is held within the quality documentations and used to provide pointers for the need for further training in the future or for project specific training. Furthermore, management training is also provided, all regional managers get together and have joint sessions of training on managerial issues.

II. *Statistical Evidence*

Spearman's correlation test results

MCV	Rho	P	N
Management of Training	0.7095	0.000	30

According to the Spearman's correlation test results shown (**P** =0.000 < 0.05) and (**Rho** = 0.7095 > 0.305) the null hypothesis may be rejected and the alternative hypothesis accepted. The correlation test results showed yet another strong association between the presence of quality management systems (QMS) and the control over the management of training.

Sub-Hypothesis ③.5

The implementation of formal quality management systems lead to better management of Motivation.

The null hypothesis

There is no relationship between the presence of formal quality management systems and better management of Motivation.

I. Practitioners Evidence

A. Questionnaire Response

The histogram shown below represents practitioners' response to the issues raised within this variable and whether or not their quality system helps in achieving them.

As shown in the ***Figure***, those organisations with formal quality systems are shown to be exercising better control over this MCV of management of motivation variable.

Fig. (❼.16): Degree of Control Over "Management of Motivation" as given by Practitioners

B. Interviews Response

Most of the organisations visited generally agreed that their system encouraged more cooperative spirit and motivated their personnel to achieve more. They also adopted motivational techniques aimed at enhancing the motivation of personnel to achieve more.

In line with the recommendations made by quality experts such as Deming (1986) and Juran (1951) the companies avoided project specific incentive schemes as easy jobs and more complex jobs could not be compared. Instead, **profit schemes** are operated as a more fair system. In such profit schemes certain profit percentages goes to the staff and gets split across the board. This actually ties in well with the Deming philosophy of not having a competitive environment, rather than to create a cooperative one. One quality manager commented that: *"the workers are better motivated now than ever before as it is known who is doing what and why? More cooperative spirit exists and they feel more important"*.

However, in contrast with this view, another site manager emotionally put across his view that a quality management system with their existing setting is a demotivator as opposed to a motivator. His main point of concern was the amount of paperwork generated. Moreover, he also referred to some point within their quality manual such as the requirement of a site manager having to inspect visually all materials delivery to site and he argued that was impossible in real life. A further comment made by this site manager is also related to the paperwork and the manual and he mentioned that at the pre-quality era (which was only last year), he used to spent 75% of his time on site following actual work in progress and only 25% of his time at his site office dealing with paper work . Now in this quality era he spent 75% of his time on his desk dealing with paperwork (to get it right for the certifiers) and only 25% of his time following actual work in progress. Once again these comments by this site manager is nothing but a reflection of the different attitudes people adopt towards quality depending upon the way it had been introduced to their organisations and why it was introduced? At the organisation of this site manager, his firm bowed to pressure exerted by their public clients to be "certified". Therefore, the management of the firm decided to do the absolute minimum to obtain the certificate as market edge and to put the certificate on their letter head, but nothing else. Minimum resources have been put aside to run the quality show in parallel to the existing methods of working. Therefore, what quality means for that particular site manager is a set of procedures and forms to be filled in and shown to third party. In this context, it is not surprising at all to have such a perception which reflects cynicism and scepticism.

II. Statistical Evidence

Spearman's correlation test result

MCV	Rho	P	N
Management of Motivation	0.6935	0.000	30

The above test results points towards the rejection of the null hypothesis and acceptance of the alternative one, ie the association between the presence of QMS and greater control over the management of Motivation. (since **P** is less than 0.05 and Rho is 0.6935 which is more than 0.305).

Based on the above statistical test, it can be accepted that the implementation of quality management systems lead to greater control over the management of Motivation.

❼.7 *CONCLUSIONS OF HYPOTHESIS ③: QUALITY MANAGEMENT SYSTEMS HELP IN THE CONTROL OF THE MANAGERIALLY CONTROLLABLE PRODUCTIVITY VARIABLES (MCVS).*

The statistical test results shown above supported the view that implementation of quality management systems positively control the managerially controllable variables that influence construction productivity. What could be inferred from this finding is that the implementation of quality management systems contributes to productivity improvement of construction projects through better control over the managerially controllable variables that influence it; as productivity improvement was shown to be a function of how well these MCVs are managed (hypothesis ②).

Conclusion and Implications

Chapter ❽

❽.1 *INTRODUCTION*

The aim of this research has been to assess the impact of the implementation of quality management systems upon construction productivity at the site level.

The study started with a review of the quality management philosophy aiming to highlight its salient features and developing what is meant by quality in the context of the construction industry (see ***chapter*** **❷**).

Chapter ❸ dealt with the theme of productivity in general and with particular reference to the construction industry. The various approaches to defining and measuring productivity have been reviewed. The ***chapter*** concludes with a working definition for productivity and a surrogate measure for it at the construction site level.

Chapter ❹ extensively reviewed the literature concerned with the factors influencing construction productivity at the site level. For the purposes of this study these factors have been classified into two main categories; internal factors and external factors. The internal factors are those productivity variables which are controllable by site management and the external factors are those which are considered to be uncontrollable by site management. However, it is fully accepted that such external factors (e.g.. Government policies, the economic environment or the weather) are controllable by management at higher levels such as the company level, the industry level or the national level.

Chapter ❺ investigated the link between quality and productivity and put forward an argument for the existence of such a link. The discussion went further to reject the traditional view that there exists a trade off between the two themes.

Chapter ❻ is dedicated to the research model and the methodology adopted by the study. It attempts to clearly mark the research territory and to describe in detail how the study was designed and carried out.

Chapter ❼ is concerned with the analysis of data, presentation of results, testing the hypotheses and discussing the findings within the context of the construction industry.

*Chapter*❽ of the study is devoted to the conclusions related to the hypotheses and reports on the practical implications of the study.

❽.2 *PHASE I OF THE INVESTIGATION*

The main hypotheses formulated at this phase of the study is the following:

Hypothesis ①

There is relationship between the implementation of quality management systems and productivity improvement at the site level

To test the existence or otherwise of this relationship a sample of housing projects completed by two categories of contractors was selected. One category comprised quality management contractors (those with formal quality systems based upon BS 5750) and the other category included non-quality management contractors (those without formal quality systems).

The aim of the investigation was to measure the productivity of each category of contractors bearing in mind the working definition of productivity which is centred around the resource utilisation theme (see *chapter* ❹). Therefore, the essence of the methodology used is to measure the resources (labour, plant and material) used by each contracting organisation in achieving a given level of output. Estimation of Total Factor Productivity (TFP) was used as a surrogate measure of productivity.

Due to the difficulty in finding data related to the physical measurement of productivity indices, the study had to rely on using the monetary values of these indices in an effort to estimate these values and apply a certain measure of homogeneity of the output. However, this was pointed out as a limitation to this study. Moreover, the main source of data was priced bills of quantities for completed projects between the period of 1988 to 1992. Reliability of this data was a second limitation pointed out in the discussion of these results.

The detailed analysis of data culminated in the construction of the isoquant diagram is defined in the productive isoquant required. A productive isoquant is a curve linking in straight lines the most productive projects and enveloping the less productive ones. As shown in *Fig.* (❼.1) the productive isoquant passed through seven productive projects. Five of those productive projects were quality management projects and two were non-quality management projects. In other words, about 71% of the projects represented on the productive isoquant were completed by quality management organisations and 29% were non-quality management projects. The conclusion to be drawn here is that quality management organisations performed much better from the productivity point of view than their non-quality management counterparts. This finding is considered to be the first indication of the presence of a definite relationship between the implementation of quality management systems and improvement in productivity at the site level.

Further substantiation of this result was sought from statistics. The statistical technique of Cluster Analysis was used in an effort to try and find groups in the data with similar characteristics. Application of the cluster analysis technique resulted in the formulation of two separate clusters of projects dichotomised as being quality or non-quality organisations. Therefore, the inference drawn from the statistical test result is that quality management and non-quality management organisations are two distinct groups.

Therefore, the first hypothesis can be accepted and the conclusion to be cautiously drawn at this stage is that there is a relationship between the implementation of quality management systems and improvement in productivity at the site level.

8.3 *PHASE II OF THE INVESTIGATION*

This phase of the study was concerned with assessing the impact of the implementation of quality management systems upon the control of the Managerially Controllable Variables (MCVs) that influence construction productivity.

As a result of a comprehensive literature search of factors influencing construction productivity, two categories of factors were defined: external factors and internal factors.

The external factors are those influencing construction productivity but lie beyond the realm of site management control. However, it is fully accepted that external factors such as economic indicators or the physical environment are within the realm of management control at a higher level such as the company, the industry or the national level.

On the other hand, the internal factors are defined as those factors which do influence productivity and are falling within the realm of site management control.

Since this study is concerned with the impact of quality management systems upon productivity at the site level, the external factors are considered to be beyond the scope of this study which only concerned itself with the internal factors.

The internal factors are:

- Management of resources
- Management of information
- Management of organisation structure
- Management of training
- Management of motivation

Hypothesis ②

Productivity is a function of the managerially controllable variables (MCVs) combined.

This hypothesis was tested by sampling practitioners opinions on what they think adds to productivity improvement and whether or not the presence of these MCVs is conducive to productivity improvement at the site level. A questionnaire was used to achieve this objective. Moreover, to add to the academic rigour of the analysis, the statistical technique of one sample Chi-square test was performed in an effort to gauge the significance of these variable from the productivity improvement point of view.

Conclusions drawn from hypothesis ②

It was confirmed by practitioners that the presence of the MCVs determines productivity improvement. In other words, they expressed their fullest agreement as to the importance of the MCVs from a productivity improvement point of view.

Furthermore, the statistical test results also demonstrated the significance of the MCVs for productivity improvement.

Therefore, it is accepted that productivity at the site level is a function of the MCVs combined and hence hypothesis two is supported.

Hypothesis ③

The implementation of quality management systems lead to better control over the MCVs that influence productivity and hence to better productivity.

Conclusions drawn from hypothesis ③

The MCVs have been operationalised and tested on practitioners. The opinions of the practitioners were sampled in connection to their view regarding the extent to which the implementation of quality management systems helps in achieving the aims and objectives sought after effective management of each of the MCVs.

Analysis of feedback from practitioners revealed that the implementation of quality management systems lead to better management of the MCVs and hence to better productivity. Moreover, statistical test results showed strong association between the presence of quality management systems and better management or control of the MCVs.

Therefore, the five main conclusions drawn here are:

1. The implementation of quality management systems lead to better utilisation of site based resources.

   The outcome of the interviews emphasised that quality management organisations seemed to have formal procedures for resource management. What previously had been done in an ad hoc way, is now more methodical and systematic.

2. The implementation of quality management systems lead to better control over the management of information.

   Feedback from interviews with practitioners revealed that the presence of formal quality management systems helps in the creation of a project management information system that provides sufficient and relevant information whenever and wherever needed. Consequently, it greatly facilitates the process of decision making and obtaining the required information in the right place at the right time. The consensus of all those interviewed was that the presence of quality management systems helps in all aspects of effective information management in construction projects.

3. The implementation of quality management systems lead to better design and management of organisation structures of construction projects.

   Again the consensus of those interviewed was pointing towards the fact that the presence of formal quality management systems contributes towards the creation of a management structure which clearly specifies who does what and how.

Moreover, the issue of accountability is also singled out as being better handled within the framework of quality management systems.

4. The implementation of quality management systems lead to better control over the management of training.

Practitioners interviewed expressed their strong agreement to the statement that quality management systems provide the training required by staff and operatives through formal and informal methods. The training programme offered by a quality system was described as being more defined and was carried out on regular basis.

However, it was revealed that the issue of workers mobility in the construction industry stood as an impediment in the face of effective and long term training programmes.

5. The implementation of quality management systems lead to better control over management of motivation.

The consensus of practitioners evidence was that the presence of quality management systems enhanced the motivation of construction workers. Nevertheless, there is some dissent to this view. The dissidents considered the presence of quality management systems as a demotivator as opposed to motivator. The main point of concern was in connection with the paperwork generated.

Overall conclusion of hypothesis ③

To sum up the above, it may be concluded that the implementation of quality management systems contributes towards productivity improvement of construction projects through better control of the MCVs that determine construction productivity.

❽.4 *PRACTICAL IMPLICATIONS OF THE RESEARCH STUDY*

In the light of the findings of this study, it may be suggested that quality management systems could be viewed as yet another tool available to construction managers in their efforts to enhance and improve construction productivity.

This study provides empirical evidence concerning the efficacy of formal quality systems in construction and in particular its impact upon construction productivity at the site level. The study showed a unique role of these systems in the effective control of a set of variables that are shown to influence construction productivity.

It was also pointed out by this study that there seem to exist in the UK construction industry a serious misconception amongst practitioners regarding the climate in which such quality systems are implemented. In particular, the association of the whole quality enterprise with a set of procedures or manuals without any change in attitudes or behaviour by the people involved serves to defeat the objective of the quality systems. The study advocates a people oriented approach which instils the quality culture within the staff of a construction organisation, from the senior executive to the bricklayer, all linked in a chain of continuous improvement in search of excellence.

❽.5 *SUGGESTIONS FOR REPLICATION STUDIES*

To replicate this study, an alternative measure for productivity is recommended. Moreover, a larger sample of projects should also be sought. In the author's experience, it proved to be very difficult to obtain priced bills of quantities due to the sensitivity of the information contained therein. However, any measure chosen for productivity has to be centred around direct measurement of resource utilisation. Indirect measurement suffers from inaccuracies and distortion of the resources input to make buildings grow. Direct measurement of resources using activity sampling or otherwise may be suggested.

With regard to the construction organisations' classification into quality and non-quality management organisations, an alternative criteria is recommended. Within the next few years certification to BS 5750 is likely to be commonplace and thus can no longer be considered as evidence of the presence of formal quality systems.

Moreover, not all certified organisations can strictly be considered as quality management due to the varying degrees of awareness of the quality management philosophy among construction personnel (as found in this study). Visits to the organisation before the classification may be very helpful in revealing the true status of those organisations from a quality management point of view. For example, if an organisation certified to BS 5750 was visited, but interviews with their senior management revealed lack of commitment on the part of the senior executive to the whole movement of quality and the aims of continuous improvement, it may be misleading to label such an organisation as a quality management organisation despite its certificate which would have been purely used as a marketing tool. Therefore, what is really needed is a method for distinguishing between organisations.

8.6 *SUGGESTIONS FOR FUTURE RESEARCH WORK (THE WAY FORWARD)*

This study investigated the impact of quality management systems upon the Managerially Controllable Variables (MCVs) combined. Future work may focus on each of the MCVs individually and assess the impact of quality management systems upon each of them in greater depth. Perhaps a causal relationship may be established between having a quality system on the one hand and effectively managing each of the MCVs on the other. This obviously involves developing a particular model for measuring the effectiveness of each MCV.

This study has also shown the different attitudes that many practitioners have towards quality management systems in construction. A study specifically concerned with the assessment of the impact of such attitudes upon the quality management systems performance in both construction and consultant organisations may be worthy of some attention.

Another area of considerable interest and importance is that of the cost of quality. For the management of construction organisations, the cost of quality can be quantified in terms of the expenditure related to the quality system implementation, quality manual preparation, consultancy time, extra staff employed, etc.. However, quantification of the cost of non-quality is not all that simple; in other words, to be able to quantify what it cost not to have a quality system in place. Therefore, a study concerned with the measurement of waste and frequency of rework or scrap can serve to quantify the cost of not doing things right first time as quality experts would suggest. Also broader issues of the loss of reputation and loss of work opportunities have a cost. The result of such study can give empirical evidence about quality management in construction which could either support or challenge the view that the implementation of quality systems lead to improvement in the construction process.

Finally, a comparative study aimed at comparing the quality management practices in the West and in Japan could be very useful in highlighting areas in which both parties could benefit from each other. Such a study should ideally be done by analysing quality practices in similar organisations in the West and in Japan. The impact of quality systems upon construction productivity may be assessed using the MCVs defined in this study to investigate the Japanese and Western approaches in dealing with these MCVs and effectively manage them in search of better productivity.

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Appendix A

An investigation into the impact of Quality Management Systems based upon BS 5750 on site productivity of building contractors

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ABSTRACT

This paper is an extract of a study which seeks to investigate the impact of Quality Management Systems (QMS) based upon BS 5750/ISO 9000, on the site productivity of building contractors in the UK.

Productivity is defined as the relationship between the output generated by a production or service system and the input provided to create that output. The working definition adopted for productivity in the context of this study is centred around the theme of utilisation of resources in a construction setting. The approach to modelling productivity is based upon the notion that it may vary from one project to another depending upon the project manager's ability to produce the same level of output from the utilisation of different levels of resource inputs. The heterogeneity of the construction output made it very difficult if not impossible to come up with a

homogenous measure of output in terms of volume of work. Alternatively, the output measure to be taken is the monetary value of work (£) as money is common to both inputs and outputs. This study used the monetary model and examined the priced bills of quantities for projects completed in the period between 1988 and 1992. The sample of projects is confined exclusively to housing in order to minimise the number of variables involved and to standardise the output as much as possible.

The results values the resources (plant and labour) used to obtain a given amount of construction work. This was then plotted on an isoquant.

The inference to be cautiously drawn from this result at this stage is that there is a relationship between the implementation of Quality Management Systems (QMS) and productivity at the site level.

1. *QUALITY MANAGEMENT IN THE UK CONSTRUCTION INDUSTRY*

The word ***Quality*** has been the buzz word in the UK construction industry for the past decade. Under pressure from clients, particularly Public clients such as the PSA, most construction organisations went down the route to Quality either by choice or under pressure from clients. In preliminary visits made by one of the authors to construction organisations embarking on Quality programmes in the UK it was revealed that those construction organisation which adopted the philosophy of quality management for the strategic objective of continuous improvement, developed the culture within their organisation and educated their staff about the whole concept. Therefore, the shift to quality management systems evolved quite smoothly and well taken in by the staff concerned. On the other hand, the other organisations which just wanted to "*get the badge*"of Quality Assurance, were pushing themselves down a certification route which resulted in certification but in most cases rarely changed management practices.

Whichever route to quality was adopted, people are still trying to assess its impact upon their processes and procedures. A recent study by Langford & Ndili (1991) concluded that companies which implemented Quality Management performed better financially than those who did not. They pointed out that, in general, the adoption and implementation of Quality Management will improve and strengthen the companies financial performance as measured from their financial records. Results of the analysis of data from 37 companies specialised in housing showed that those who adopted quality performed better financially than those who did not. Moreover, statistical testing of the data indicated that there is an association and a positive correlation between quality management and financial performance. However, financial performance may be shaped by external factors over which management or in deed quality management have little or no control.

In an independent study in the US by Burati *et al.*, (1991) in which they reviewed 19 US organisations embarking on Quality management programmes, concluded that "companies which have been implementing Total Quality management for more than five years made considerable savings "which are to be credited to the overall quality effort".

Set against this background, this study is trying to assess the impact of Quality management at the production (site) level. More specifically, it seeks to establish the link, if any, between the implementation of Quality Management systems and achievement of higher productivity. In other words, is there a relationship between quality management and productivity?

2. *MEASUREMENT OF PRODUCTIVITY IN CONSTRUCTION*

In the construction industry measurement of productivity and efficiency tended to be more output oriented as opposed to input oriented. An alternative approach to this output orientation is the input oriented approach suggested by Farrell (1957). Farrell's approach was based on the notion that if one production unit is more efficient than another, it must be using minimum amounts of inputs required to produce a given level of output. Efficiency in this context will be construed as taken by Hillebrandt (1975) as "the optimum utilisation or resources under given conditions".

Definition of productivity as output per unit input is one of the most widely used definitions. However, when partial measures are taken, this can give a misleading picture of the whole concept of productivity. Gold (1990) points out that such partial measures do not give an adequate measure of productivity as a whole, or even the productive efficiency of labour; that increases in output per manhour may or may not reduce unit labour costs.

Bishop (1968) also linked productivity to the utilisation of resources; He writes:

"Productivity is taken as the optimum utilisation of resources to obtain an acceptable goal".

For a construction manager working at the site level productivity means optimum utilisation of resources in achieving the required level of output. From this point of view, productivity is best assessed in terms the resources used. Therefore, the working definition to be adopted by the study, will be centred around the utilisation of resources. From the definition given by the British Productivity institute that it is a ratio of output to input of materials, labour, energy and capital equipment.

Combining the above three definitions will yield the following:

"*Productivity is the optimum utilisation of resource inputs-labour, material and plant- in achieving an output acceptable in relation to some standard*". In other words, productivity is construed as the efficiency with which the resources are being utilised.

Having defined productivity in terms of the utilisation of resources, the second step is to suggest the practical methodology with which it is going to be measured.

To develop a method of measurement for productivity is essentially an econometric problem. Availability and reliability of data is something which could not be ignored. However, surrogate measures may by helpful in estimating the total factor productivity of a particular construction project. For example, total factor productivity refers to comparisons of all inputs with outputs and has been widely accepted as a measure of efficient use of resources. In the context of the construction industry, physical measures of inputs such as labour, materials and plant is generally not available. In the US, Dacy (1965) estimated total factor productivity of the construction industry with indices of building prices, hourly wages, output per manhour and material prices. Adopting a similar procedure Thomas *et al.*, (1990) defined a model for estimating Total factor Productivity. In Thomas's *et al.* (1990) model took the monetary value of output and inputs as it is common to both inputs and outputs.

Total Factor Productivity = £ Total output / £ Total input

Applying this to a construction project, the value of Total factor productivity will be estimated through evaluating the value of output (given in monetary terms) and the monetary value of inputs (labour, plant and materials).

3. *SCOPE AND NATURE OF THE INVESTIGATION*

The scope of the present investigation is defined in terms of assessing the amount of resources used in the 24 housing projects sampled. As indicated above, the monetary values of these resources will be taken as a surrogate measure of the actual values of the resources. The output value for all projects is fixed to a constant value so that it is uniformly applied across the whole sample.

The period chosen for the study is between 1988 and 1992 as it was the period during which most contractors in the UK started achieving their certification to BS 5750. This criteria of certification was selected as an indication of the presence or otherwise of quality management systems within a contracting organisation as it would be impossible to find any practising organisation which would happily admit to not having a Quality system of one sort or another. It is for this reason that this study will rely on certification as the sole indicator of the presence or otherwise of a Quality management system within an organisation despite any reservations that the authors may have about the whole issue of certification the UK.

4. *SOURCES OF DATA AND SAMPLE SIZE*

The primary source of data which is going to be used here is *Priced Bills of Quantities* for projects completed during that period.

The sample was chosen in such a way as to include contractors who achieved certification to BS 5750 as well as those who did not. The sample comprised 12 contractors with BS 5750 and 12 who were uncertified.

5. *ASSUMPTIONS MADE*

As the actual work on site is generally completed by subcontractors, it is assumed that the Quality Management System (QMS) of the main contractors concerned covers all the projects participants including the subcontractors. It is one of BS 5750 requirements that a contractor should produce a Quality Plan which is basically a project control plan specifying who does what and how and gives a full description to the client as to how the whole job is to be carried out and how its requirements will be met. The contractor is also obliged to ask subcontractors to produce similar Quality Plans for their part of the project. In preliminary interviews carried out by the authors with contractors who have QMS systems in place, it was revealed that the practice of requiring subcontractors to produce Quality Plans as well as abide by the general requirements of the QMS system of the main contractor is commonplace. Most of those contractors interviewed asserted that they perceive of their QMS as a comprehensive management system which regulates all matters related to project as well as corporate management. Therefore, what is really assumed here is that *all parts of the work completed is carried out according to BS 5750 guidelines.*

The second assumption made here is that the values given in the priced bills of quantities are the actual prices paid by contractors. Again the basis for this assumption is coming from the philosophy of the Quality Management Systems. The strategic aim of those contractors embarking on a Quality Management Programme is to raise the standards of their output and in the same time reduce the cost of production. If a contractor raised the standard of his output at higher production cost, then he failed to meet the "Quality Criteria" in the first place. Moreover, it is accepted that in the UK the lowest bid is usually the accepted one. Therefore, the basis of the assumption made here suggests that the values entered in the bill of quantities are the most optimum values and that a contractor with a Quality System should be working at the most optimum production cost.

6. *THE ANALYTICAL FRAMEWORK (THEORY OF ISOQUANTS)*

The question posed at this point is how to compare the productivity of projects completed by contractors possessing QA systems and those who do not. To achieve this objective, the theory of Isoquants was used. An Isoquant is a curve connecting points representing different combinations of inputs and producing the same amount of output. The essence of the methodology is to measure the quantity of resources used in achieving the measured value of output. For a given project the value of the resources used in completing cost significant items in the bill are calculated and added up for the whole project. For example, if the total value of a housing project is £ 200,000 and the number of cost significant items is 20. For these items the value of labour is £70,000 and the value of materials is £66000 and the value of plant is £60,000. Given that the total value of the output is 200,000; then the values of these resources are normalised by dividing each resource by the total value of output and hence the relative weight of each resource is obtained:

The relative value of Labour = £70,000 / £200,000 = 0.35
The relative value of Plant = £60,000 / £200,000 = 0.30
The relative value of material = £66000 / £200,000 = 0.33

For a value of work of say £100,000 the amount of labour, plant and materials used is found by multiplying the relative weights above by the given value of £100,000.

Value of labour = 0.35×100,000 = 35,000
Value of plant = 0.30×100,000 = 30,000
Value of material = 0.33×100,000 = 33,000

These values are used to determine the position of the project in the Isoquant diagram. Each project in the sample chosen for this study is represented by a single point in the Isoquant diagram shown in ***Figure*** **(1)**. The position of each project is determined according to the value of the resources used in that project (labour and plant). The diagram for materials is not included as the price and quantity of material is a function of design specifications and not purely a discretionary matter for the project management team. If it were possible to find data regarding materials waste on site, it would have been possible to consider material as a third variable to compare projects. But in the absence of such data it will be misleading to draw conclusions from material usage purely on the basis of quantity used as that may have been due to design specifications.

7. METHOD OF THE ANALYSIS OF THE BILLS OF QUANTITIES

The priced Bills of quantities are analyzed in the following manner:

1. The first step in the analysis is to identify the cost significant items in the bill. These are identified using the Horner's model (Horner, 1986) in which 20% of the items in the Bill of Quantities carry 80% of the total cost.

2. These items are them broken into their constituent resources using the Wessex building price data book. In this index book, the unit price for an item is broken into its constituent resources plant labour and materials. When this step is complete, the exact division of each cost significant item of labour, plant and material is evaluated.

3. The values of labour, plant and materials obtained in step 2 are plotted and hence the Isoquant is drawn.

Quality		Non-Quality	
Plant	Labour	Plant	Labour
0.1483	0.8360	0.2024	0.6217
0.1899	0.6800	0.2595	0.3984
0.2320	0.5261	0.3636	0.7374
0.2552	0.7684	0.3824	0.5640
0.2871	0.4127	0.3833	0.4004
0.3134	0.5430	0.4046	0.5700
0.3202	0.3929	0.4362	0.5724
0.3273	0.3284	0.4819	0.3370
0.3543	0.4739	0.5041	0.5565
0.3700	0.3201	0.5906	0.3873
0.4181	0.6238	0.6250	0.4035
0.4713	0.3042	0.6368	0.4038

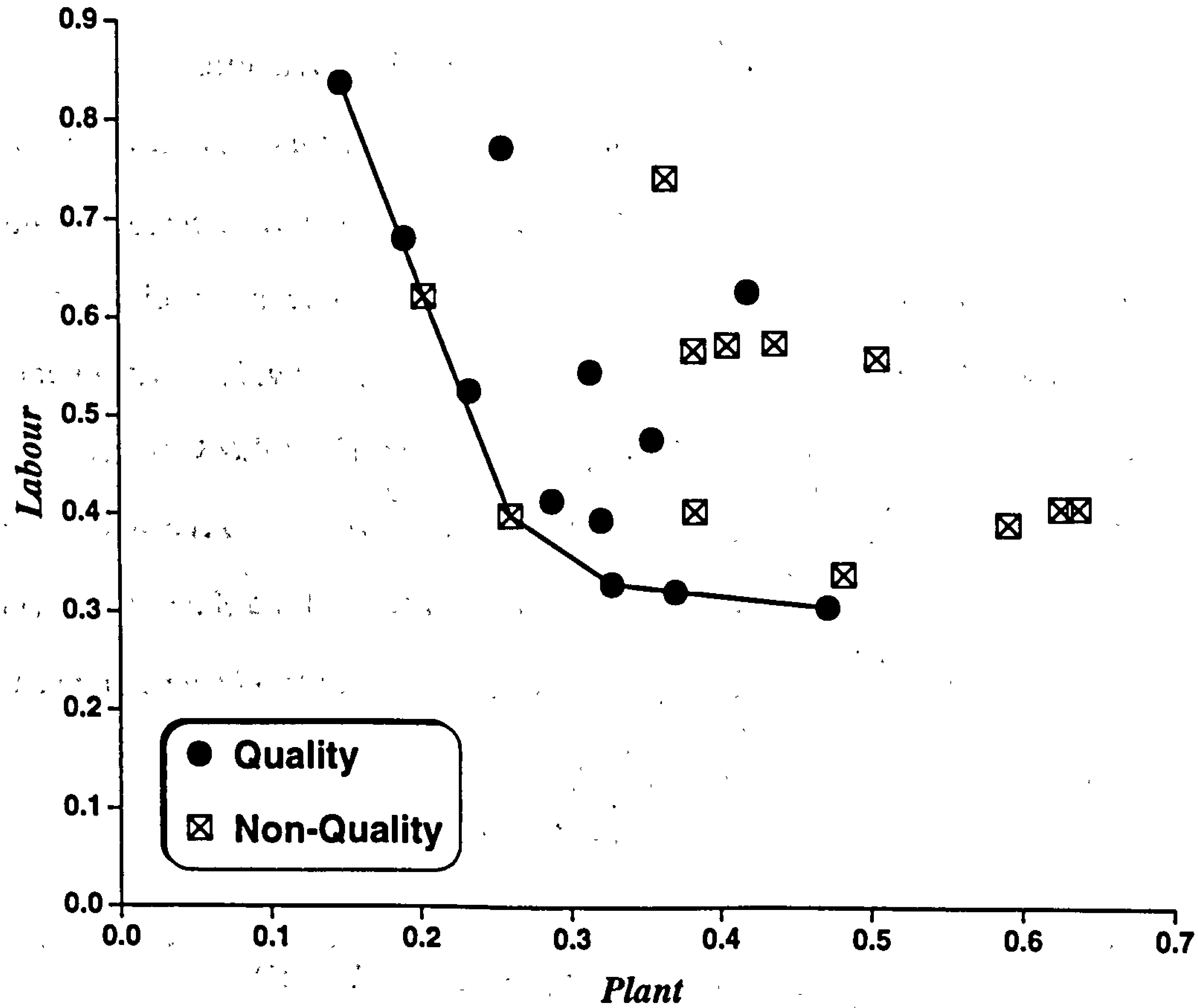

Figure (1)

8. *DISCUSSION OF THE RESULTS*

It is evident from Fig.1 that the Isoquant is formed by seven points which represents projects completed by both QMS and non-QMS contractors. It can be seen from the Isoquant curve that ***FIVE*** out of the ***SEVEN*** projects on the most productive Isoquant are completed by contractors with QMS and two projects are completed by contractors without QMS. Moreover, it can also be seen that the QMS projects (black boxes) are clustered closer to the productive Isoquant and closer to each other whereas the non-QMS projects are more dispersed. Therefore, it was deemed necessary to identify the homogenous groups in the sample statistically and the statistical technique used was ***Cluster Analysis.***

In this particular analysis the first cluster was taken at the point where the coefficient D changed abruptly to almost double its value between stages 13 and 14 (this is indicated by the arrow in the hierarchal cluster Analysis table). Such big difference in the value of this coefficient implies that the cases collected up to this point are reasonably similar, but cases after this point are less similar (hence the big difference in D value). Therefore, the cases culminated below this point are taken as the first cluster. Obviously the second cluster is the cases above this point as we have only two possible clusters in this data.

It should be noted that the cases (projects) data is entered as follow:

Cases 1 to 12 are QMS contractors

Cases 13 to 24 are none-QMS contractors

9. *INFERENCE FROM THE RESULTS OF THE ANALYSIS*

As pointed out earlier from the above diagram that there are seven points (projects) on the productive Isoquant; five (2) of which are QMS projects and two (2) are none QMS. ie about **70%** of the projects on the Isoquant are QMS. Moreover, it can also be seen that the QMS projects, apart from two, are clustered around the productive Isoquant and this was confirmed by the cluster analysis as the two clusters formed in the analysis grouped the QMS projects in one cluster and the non-QMS projects in the other. What could be cautiously inferred at this stage is that there is a definite relationship between having a Quality Management System and improvement in productivity at the production (site) level. However, it is also evident from the results that at least ***TWO*** projects on the Isoquant are completed by non-QMS contractors. In fact the most productive project in this sample is completed by a non-QMS contractor.

10. *FUTURE WORK*

In the case studies which are to follow in this on-going study, these two non QMS contractors will be closely investigated in an effort to inspect their quality management system and to compare and contrast it with that of the QMS contractors.

As for those contractors with QMS and have been shown to be more productive, further two case studies will be carried out to investigate the impact of the QMS upon the so called "managerially controllable factors" that are known to influence construction productivity. Furthermore, it can also be seen from the results that there are two QMS projects which lie far from the productive Isoquant. In order to explain this result further *two* case studies will be carried out to identify the nature of the QMS implementation of these contractors and how it compares and contrast with the more successful ones.

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Appendix B

Questionaire

The following questionnaire is composed of two parts I and II. Part I is designed to give the practitioners (project and/or quaity managers) a chance to express their views as to whether or not they think producutivity can be improved through more effective management of productivity varialbes identified in the literature as being important from improvement point of view. Practitioners are also invited to add any other factors which they believe to be important and not included under the headings given below.

Part II of the questionnaire is designed to assess the imact of Quality management systems based on BS 5750 upon the managerially controllable productivity factors and to see whether or not practitioners believe a formal quality system can provide that effective management mechanism. The productivity factors have been operationalised and translated into management activities which are either covered or not covered in a quality management system. Respondents are asked to indicate this by chosing numbers from 1 to 5 on the scale given. Number 1 = strongly agree will be construed as the highest degree of control over the factors given and 5 as the lowest one.

Please try to respond to <u>all</u> questions in both parts.

Part I

Please indicate whether you agree or don't agree with the following statements by ticking the numbers 1 to 5 where:

1 = Strongly agree, **2** = Agree, **3** = Undecided, **4** = Disagree, **5** = Strongly disagree.

(a) Productivity at the site level can be improved through:

		Strongly agree				Strongly disagree
a1	More effective management of resources (labour, plant, materials, etc.).	1	2	3	4	5
a2	Effective design and management of information systems.	1	2	3	4	5
a3	Effective design and management of the project organisation structure.	1	2	3	4	5
a4	Effective management of the selection and training programmes.	1	2	3	4	5
a5	Effective management of Motivation.	1	2	3	4	5

a6 Please rate the following factors with respect to the priority for productivity improvement: Please make your choice by ranking from 1 to 5; 1 = highest priority and 5 = lowest priority.

***Please add any other factors which you think important and should be included in this list.**

- Management of Resources. ☐
- Management of Information. ☐
- Design and management of organisation structure. ☐
- Management of Training. ☐
- Management of Motivation. ☐
- Other (please specify). ☐

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Part II

Please state your opinion as to whether or not you agree with the following statements related to the influence of your Quality management systems upon construction productivity:

B.1 Management of Resources at the site level

(a) Labour Management: Your Quality management system helps in:

	Strongly Agree				Strongly Disagree
a1. Identifying the nature of skills required for every activity on site and hence allocate the appropriate person(s) to it.	1	2	3	4	5
a2. Achieving better selection of staff after consideration of their skills, abilities and the work environment.	1	2	3	4	5
a3. Producing the appropriate job specification for each job to be carried out on site.	1	2	3	4	5
a4. Offering encouragement for people to fulfil their own career and personal objectives.	1	2	3	4	5

b) Management of Materials: Your Quality management system helps in:

b1. Identifying key procurement objectives of the company; provision of the right materials at the right time etc..	1	2	3	4	5
b2. Meeting purchasing objectives in the way of operating an intelligence system of about suppliers.	1	2	3	4	5
b3. Achieving the key objectives of any purchasing deal, namely; quality, price and delivery (time factor).	1	2	3	4	5
b4. Management and control of subcontractors including measurement of their performance against an agreed programme and budget.	1	2	3	4	5

(c) Management of Plant: Your Quality Management System helps in:

c1. Providing your sites with readily available equipment which is fully maintained and will not the people down.	1	2	3	4	5
c2. Ensuring, through adquate forward planning, machines are used economically and kept in good condition via regular checks.	1	2	3	4	5

B.2 Management of Information

Your Quality management system helps in:

a) Creating a Project Management Information System PMIS that provides the sufficient and relevant information when and where needed. 1 2 3 4 5

b) Enhancing and facilitating the process of decision making by providing the relevant information at the required time/place. 1 2 3 4 5

B.3 Design and Management of Organisation Structure

Your Quality management system helps in:

a) Creating a project organisation structure which clearly specifies who does what and how. 1 2 3 4 5

b) Achieving key dimensions such as unity of command, role clarity delegation of responsibility and definition of job scope. 1 2 3 4 5

B.4 Management of Training and Selection:

Your Quality management system helps in:

a) Providing the training required through formal and informal methods of learning including hands on experience. 1 2 3 4 5

b) Reviewing the performance and progress of foremen, craftsmen, on their present jobs and provide pointers to their need for further training, and specifying in advance the job requirements for future recruitment and promotion purposes. 1 2 3 4 5

c) Providing a training programme that influences the skills, knowledge, and attitudes of operatives and staff. 1 2 3 4 5

B.5 Management of Motivation

Your Quality management system helps in:

a) Encouraging cooperative spirit and inviting personnel to take part in decision making and job planning. 1 2 3 4 5

b) Adopting motivational techniques aimed at enhancing the motivation of personnel to achieve more. 1 2 3 4 5

c) Structuring the various aspects of job content; for example, by increasing the job responsibilities, achieving variety of tasks and employee autonomy. 1 2 3 4 5

Many thanks for your cooperation in completing this questionnaire.

Copies of Letters sent to Practioners of Different Organisations

Appendix C

Dear sir/madame,

RE: A Study Into the Impact of Quality Assurance Upon Construction Productivity of Contractors' Organisations Specialised in Housing Projects:

I am a PhD student at the department of civil Engineering, University of Strathclyde working under the supervision of **Prof. D. A Langford.** The above mentioned study forms the basis of my PhD work in which the relationship between the implementation of Quality Management Systems and improvement in construction Productivity is investigated.

The methodology chosen by this study for measuring the construction productivity of contractors organisations involves detailed analysis of the **priced bills of Quantities** of projects completed by those contractors. Moreover, meaningful assessment of the impact of QA systems upon the productivity of such contractors would imply that the sample chosen should include contractors who have QA systems as well as those who do not.

It is the emphasis of this study to focus exclusively on housing project completed between the period of 1988 to 1992.

I should be most grateful if it were possible to provide me with some of the **priced bills of quantities** at your disposal for projects completed during that period of time and according to the criteria specified above. It is needless to emphasize that all information provided will be used exclusively for the academic purpose of this study and shall be treated with the utmost confidentiality, if needs be the contractor, the client and the surveyor need not be known only whether the contractor is **certified to BS 5750** is important. Also, I shall be happy to bear the cost of photocopying should that be necessary.

As the theme of the study is currently considered to be highly topical by the construction industry a report of the findings will be sent to your organisation upon request.

Many thanks in anticipation of your kind cooperation,

Yours Sincerely,

Hadi M. A. Eltigani, Tel: 041-552 4400 Ext. 3578

30 September 1993

Dear Sir/Madame,

Please find enclosed a letter from one of my researchers.

As you can see he is engaged in research which seeks to identify whether the movement towards using UK BS 5750 registered contractors result in higher site productivity. It is contended that the product of the research will improve procurement practices in the housing association sector.

I hope you can afford **Mr. Eltigani** your cooperation but should you wish to discuss the matter further then I will be only too pleased to receive your phone calls.

Yours Sincerely,

Prof. D. A. Langford

Dear Sir,

<u>RE</u>: Study into the Impact of Quality Assurance Upon Site Productivity of Construction Contractors:

Further to our recent telephone conversation, I write to brief you on the nature of this study and the information required. In the first part of this research we were engaged in detailed analysis of productivity profiles of those contractors with Quality Assurance systems as well as those without and a certain pattern for productivity was obtained. In this second phase of the investigation we hope to review the quality management system of selected contractors and to see how it helped them in achieving higher productivity as was shown in the first part of the research. It should be noted that certification to BS 5750 is not vital as long as the particular organisation is going down the route to quality management.

As far as the case study to be done with you is concerned, I would like to interview any of your site or project managers who have been recently involved in a housing project.

It would be needless to emphasis that all information obtained will be treated with the utmost confidentiality and only used for the academic purpose of this research which aims to help contractors achieving higher productivity.

I look forward to hearing from you regarding the arrangements which suits you best.

Many thanks in advance,

Yours Sincerely

Hadi M Eltigani, Bsc(Hons), Msc

Researcher in Construction Management

Appendix D

Summary of Statistical Test Results

1. *Prioritistion of the Managerially Controllable Variables (MCVs)*

Method a: **Using Friedman Two-Way Anova**

Variables	Mean Rank
Management of Resources	1.53
Management of Information	2.30
Management of Organisation Structure	3.18
Management of Training	3.98
Management of Motivation	4.00

Cases	Chi-Square	D.F.	Significance
30	72.7143	5	0.0000

✪ ✪ ✪

Method b: **Prioritisation of Management Variables by means of Kendall Coefficient of Concordance (W)**

Variables	Mean Rank
Management of Resources	1.87
Management of Information	2.98
Management of Organisation Structure	4.02
Management of Training	4.88
Management of Motivation	4.92

Cases	W	Chi-Square	D.F	Significance
30	0.5491	82.3625	5	0.0000

2. Results of one sample Chi-square tests on productivity variables to show that practioners agree to its importance from improvement point of view.

2.1 One Sample Chi-square test on: **MCV.1 "Management of Resources"**

Category	Observed	Expected	Residual
1.0	23	10	13
2.0	5	10	−5
3.0	2	10	−8
Total = 30			

Chi-Square	D.F	Significance
25.800	2	0.0000

✪ ✪ ✪

2.2 One Sample Chi-Square test on: **MCV.2 "Management of Information"**

Category	Observed	Expected	Residual
1.0	23	15	8
2.0	7	15	− 8
Total = 30			

Chi-Square	D.F	Significance
8.533	1	0.0035

✪ ✪ ✪

2.3 One Sample Chi-Square test on: **MCV.3 "Management of Organisation Structure"**

Category	Observed	Expected	Residual
1.0	18	10	8
2.0	11	10	1
3.0	1	10	−9
Total = 30			

Chi-Square	D.F	Significance
14.6000	2	0.0007

✪ ✪ ✪

2.4 One Sample Chi-Square test on: MCV.4 "Management of Training"

Category	Observed	Expected	Residual
1.0	19	7.50	11.50
2.0	9	7.50	1.50
3.0	1	7.50	-6.50
4.0	1	7.50	-6.50

Total = 30

Chi-Square	D.F	Significance
29.2000	3	0.0000

✪ ✪ ✪

2.5 One sample Chi-Square test on: MCV.5 "Management of Motivation"

Category	Observed	Expected	Residual
1.0	23	10	13
2.0	5	10	-5
3.0	2	10	-8

Total = 30

Chi-Square	D.F	Significance
25.8000	2	0.0000

✪ ✪ ✪

3. *Summary of Spearman Correlation Coefficients (RHO)*

Variable	N	RHO	Significance
Management of Labour	30	0.4380	0.015
Management of Materials	30	0.5271	0.003
Management of Plant	30	0.8192	0.000
Management of Information	30	0.6668	0.000
Management of Organisation Structure	30	0.6856	0.000
Management of Training	30	0.7095	0.000
Management of Motivation	30	0.6935	0.000