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**An Implementation Model Of A Quality Management Information  
Scheme For Cellular Manufacturing Environments.**

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## ABSTRACT

As today's global competition grows in manufacturing industries companies are forced to work smart in all areas of operations, starting with suppliers and ending with customers. This competition in general requires firms to improve market responsiveness, product quality, use computerised information systems for production planning and control, have more rapid changeovers, reductions in set-up times, work-in-progress reduction and hence throughput time reduction. In order to accomplish these formidable tasks, there are a number of management philosophies available for manufacturing companies. These include just-in-time, flexible manufacturing systems, computer integrated manufacturing, total quality management, concurrent engineering. Implementation of these philosophies, however, requires mass mobilisation encompassing many areas of operations such as production, sales and marketing, suppliers, finance, customer servicing, product design and method engineering, maintenance, personnel and training, etc.

This thesis details a study which evaluates the total quality management philosophy in cellular manufacturing environment. Following this evaluation, a quality management information scheme, which is structured and integrated, has been produced using the Manufacturing Systems Analysis and Design Method. In order to manage smoothly this mobilisation and incorporate the scheme to other integrated functional areas, a new approach namely the Activity Based Implementation (ABI) has also been produced.

Justification of the model from various points of view has shown that the model is expected to address a considerable gap in the area concerned. The model was designed to be used as an integrated part of a system or as a stand-alone scheme by quality practitioners, the management board of organisations implementing TQM and quality management researchers.

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My gratitude to my many friends while undertaking this work who in their own way helped to sustain my determination to complete this thesis.

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*In the name of Allah, the merciful, the compassionate.*

*“... Are those equal, those who know and those who do not know? It is those who are endowed with understanding that receive admonition.”*

*(The Holly Quran, 39/9)*

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## LIST OF ABBREVIATIONS

ABI	Activity Based Implementation
AMT	Advanced Manufacturing Techniques
BAe	British Aerospace
BPR	Business Process Re-engineering
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CFA	Company Flow Analysis
CIM	Computer Integrated Manufacturing
CM	Cellular Manufacturing
CNC	Computerised Numerical Control
CU	Cranfield University
CWQC	Company Wide Quality Control
DCAPL	Dow-Corning Australia Pty Ltd.
DFD	Data Flow Diagrams
DSS	Decision Support Systems
FA	Functional Analysis
FFA	Factory Flow Analysis
FMS	Flexible Manufacturing Systems
GA	Group Analysis
GT	Group Technology
ICAM	Integrated Computer Aided Manufacturing
IDEF	ICAM DEFinition
IMS	Information Management Systems
IQM	Integrated Quality Management
IQMIS	Integrated Quality Management Information Scheme
IS	Information Systems

IT	Information Technology
JIT	Just In Time
LA	Line Analysis
LAN	Local Area Network
LDS	Logical Data Structures
LMU	Leeds Metropolitan University
MEC	Microelectronics Centre
MIS	Management Information Systems
MRP	Material Requirements Planning
MRPII	Manufacturing Resource Planning
MSAD	Manufacturing Systems Analysis and Design
NWG	Natural Work Groups
OPT	Optimised Production Technology
PC	Personal Computer
PDCA	Plan Do Check Act
PFA	Production Flow Analysis
QA	Quality Assurance
QC	Quality Control
QFD	Quality Function Deployment
QIS	Quality Information Store
SADT	Structured Analysis and Design Technique (Trade Mark)
SPC	Statistical Process Control
SQC	Statistical Quality Control
SSADM	Structured Systems Analysis and Design Method
TA	Tool Analysis
TQC	Total Quality Control
TQM	Total Quality Management
WIP	Work In Progress

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# CHAPTER ONE

## INTRODUCTION

### 1.1 INTRODUCTION

Today's highly competitive manufacturing environments encourage companies to work smart rather than, or as well as, work hard. This applies not only in isolated areas of operation but in every area of operation starting with suppliers and ending with customers, inspired by the total management philosophy. One of the key factors in this is information. Information should be defined, recognised and designed structurally as a key resource for all levels of management and operations.

In this new era, a good quality management scheme is seen as the key to success. Manufacturers have now concentrated on quality as a contemporary competitive advantage in the international market. Total quality management (TQM) has received attention world-wide and has evolved primarily because of new expectations of the industry from the customers (Lakhe and Mohanty, 1994). In addition, using TQM in the right way can broaden the frontiers of a company. It is also required that companies should be careful about certain aspects when it comes to the implementation of Total Quality Management. For example, as is identified by Bertram (1991), Kanji and Asher (1993) and Oakland (1989, 1993), it is very difficult to apply TQM if top management fails to recognise its importance. Bertram notes that the lack of top level commitment is the main reason for the upwards of 80 % failure rate of TQM programmes. Another important factor in implementing a TQM programme is communication. Quimby et al. (1991) define communication as encompassing all the functions to support



quality improvement. They argue that quality is about change, change is about behaviour and behaviour is about communication. Thus any interaction that increases the probability of changed behaviour is taken as the meaning of communication.

Gundogan and Kay (1995a) have summarised that in general the basic concepts of TQM are seen as customer satisfaction, continuous improvement, total quality control, continuous education and training, and total employee involvement. They point out that structural changes are required for the successful implementation of TQM, and these changes are not easy because of their effects on other manufacturing management areas such as production planning and control, maintenance, product design and engineering.

Many organisations are still unclear about the elements of TQM and its application. Although there are many models explaining TQM, there is not any common method or procedure for the application of it. It may be because of various factors to be taken into account for different manufacturing environments. This confusion, therefore, should be reduced for a successful implementation of the TQM. In order to reduce the confusion, it is required to look at various areas where the causes may be rooted. Apparently, this would lead the study to research non-quality areas or functions as well as quality management activities.

## 1.2 STUDY BACKGROUND

Throughout the last two decades, there has been an increase in awareness and use of quality improvement activities. Feigenbaum (1983) describes these changes as

one of the most rapidly growing trends in modern industrial memory. Oakland (1989), on the other hand, describes it as the quality revolution. This changing focus of quality has been documented by many quality practitioners. The definition of quality given by ISO8402 (1994) is the “totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs”. Quality management (ISO8402, 1994), on the other hand, is defined as “all activities of the overall management function that determine the quality policy objectives and responsibilities, and implement them by means such as quality planning, quality control, quality assurance and quality improvement within the quality system”.

The importance of quality management is being increasingly recognised, and has been adopted in many industries, particularly in developed economies (Lakhe and Mohanty, 1994). With the recognition of the importance of quality, TQM is seen as one of the most reliable methods of achieving high quality, and also as a way of gaining a competitive edge. Furthermore, the famous quality practitioner Juran (1985) sees no future without TQM. Various reasons for the evolution of TQM can be found in the summary given by Lakhe and Mohanty (1994).

However, many difficulties are appearing in the implementation of the TQM philosophy. There is a problem with the implementation rather than TQM itself. Researchers such as Evans (1995), Zairi, Letza and Oakland (1994), Burr (1993), Kennerfalk and Klefsjo (1995), Dahlgard, Kristensen and Kanji (1994) argue that many failures of TQM can be traced back to poor implementation. Kurimoto (1991) is of the opinion that a TQM philosophy can be fully implemented only by the co-ordinated action of people, machines, systems and information flow. i.e. total integration, to satisfy corporate objectives. On the other hand, it is realised that there are numerous approaches through which it can be applied. It is, therefore, not a surprise that many companies experience problems even deciding

on where to start. This situation is described as total quality paralysis by Kanji (1990) and as disillusionment by Oakland (1993).

The application of TQM requires big changes in certain aspects of traditional management (Kanji and Asher, 1993), because the implementation of TQM affects other non-quality areas as well. Another obstacle is the structure of the organisation which wants to adopt a TQM strategy (Kennerfalk and Klefsjo, 1995). Kennerfalk and Klefsjo then point out some factors to be considered in restructuring the organisation. These factors are decentralisation, team work, customer-supplier chain, flexibility and horizontal communication which are also the major factors considered in cellular manufacturing applications. Burr (1993) argues that it is also quite important to define the environment in which TQM is to be applied. As such, it is necessary to have an integrated and structured implementation model to manage an effective application. Information technologies (IT) i.e. information systems (IS) can play a key role in filling this gap to produce such a model for certain manufacturing environments i.e. cellular manufacturing. Grogan (1995) also points out that IT has a great part to play in the quality management arena, particularly with respect to TQM. It can make real gains for organisations and is often seen as a facilitator of change (Grogan, 1995).

The terms Group Technology and Cellular Manufacture, where this research is based, will be assumed to have the same meaning. The definition of cellular manufacturing produced by Gaither et al. (1990) is quite similar to the definition given by Burbidge (1987) for GT. Hence in this research the definition of cellular manufacturing is a form of production that groups machines, tooling, people and materials into manufacturing cells. Each cell produces a family of similar parts, with all the parts in the family having the same characteristics.

TQM is not a straitforward quality management philosophy which generally keeps the status-quo. The application of it requires change which may well affect primarily the manufacturing method itself. Should these two are not compatible, the required changes may well become reasons for failures of TQM programmes. The implementation models developed so far, can help to establish a TQM understanding, but no research has yet come-up with an implementation information model which is based on the strengths of a manufacturing environment and using information technologies. The aim here is to alleviate the weaknesses of Total Quality Management with the strengths of Group Technology (Cellular Manufacture) which is seen as a good implementation starting point.

Another production management philosophy called Just-In-Time (JIT) will also be mentioned from time to time in this research. The term Just-In-Time is described as systems of production control in which products are only made when required for delivery to customers, parts are only made when required for assembly and materials are only made or received from suppliers when required for processing (Burbidge, 1987).

This research hopes to reduce the confusion mentioned earlier by developing a structured quality management information model encompassing the TQM philosophy. This will assist in the formulation and establishment of the most integrated TQM implementation approach for cellular manufacturing organisations. It can be understood, therefore, that the research lies at the intersection of three areas of study. As is seen in figure 1.1 these areas are the TQM philosophy, Group Technology and Information Systems. The Integrated Quality Management System will employ TQM as a base philosophy and will be looking at quality management activities. Information Systems will be used to

build such a model. Such an integrated Quality Management System will be broken down systematically and structurally into smaller and easily manageable portions by IS methods. The model will be initially developed for Cellular Manufacturing environments which may be considered as a good base to increase the probability of a successful TQM application. These issues will further be discussed in the chapter three dealing with the methodology.

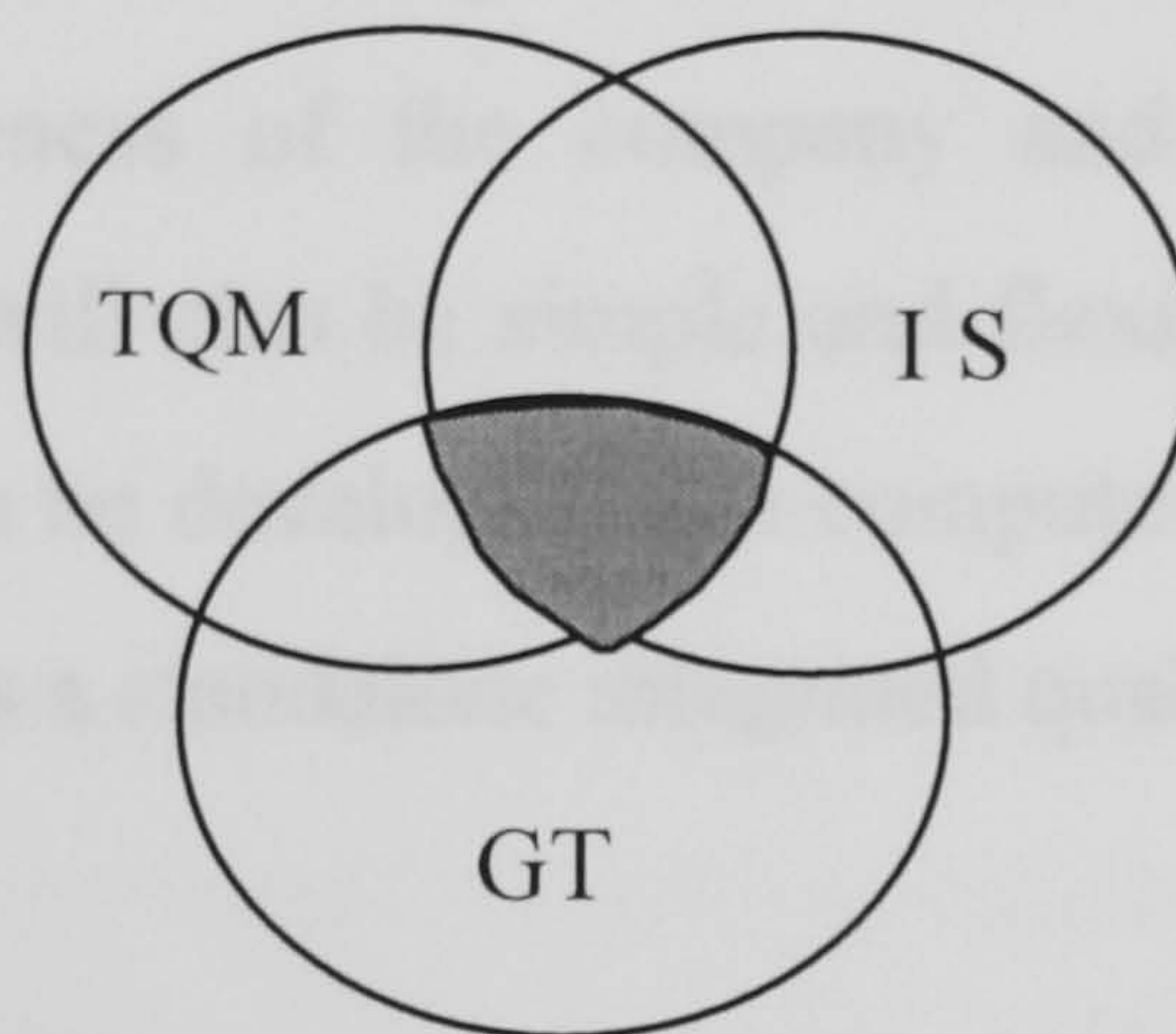


Figure 1.1 Intersection of the three areas of study

### 1.3 THE OVERALL OBJECTIVES

As mentioned earlier, throughout the 1980s and 1990s, there has been an increased growth in the awareness and use of quality improvement activities. A major problem then facing companies when deciding to implement TQM is that there are numerous approaches through which it can be implemented.

The overall objective of the research is to produce an integrated quality management information system (the model) for cellular manufacturing (Group Technology) environment. This quality management information model is to be structured to allow users to easily adopt the model into their environments at each

level of activity. This model will contain diagrammatic and other modelling techniques to give a more precise definition which is understandable by both users and developers. The model will be broken (structured) into small well-defined activities and will specify the sequence and interaction of these activities. Integration will be a main feature of the model and will be found in three categories. It will be integrated to production stages, functional departments and manufacturing goals (business aims). Integration of the information model is expected to eliminate time consuming and non-value added operations which slow-down the responsiveness of the company and create the hidden cost contribution. The model will also be simple and flexible enough to be open to developments. It may then be developed as a computer aided module which fits into the current system or as a standalone integrated quality management scheme.

#### 1.4 STRUCTURE OF THE THESIS

This research is based on three main areas of study; Total Quality Management, Cellular Manufacturing environment, and Information Systems Modelling. The integrated quality management implementation model will be produced at the intersection of these three areas.

This chapter has outlined a brief introduction to the research. It has provided definitions of the terms which are going to be used in the research, identified the objectives and the methodology has been briefly described.

The literature review of the three main areas of the study are covered in depth in chapter two. This covers how the idea emerged, where it came from, what people

have experienced, where it is leading, etc. Some successful applications of TQM implementation are also demonstrated.

Chapter three gives the research aims and the methodology in detail. Current implementation methods are evaluated to show weaknesses, strengths and gaps. The research hypotheses are outlined in this chapter together with the testing methods of the hypotheses.

Chapter four explains what the new Activity Based Implementation (ABI) approach is and how the new integrated implementation model is to be built.

Justification of the implementation model is the main focus of chapter five. The model is tested from various standpoints such as validation during the modelling session, goodness i.e. information circularity of the model, structured walkthroughs and expertise reviews. A survey is also carried-out within this context.

General discussions about the model will take place in chapter six. This chapter also gives conclusions and recommendations together with the statement of further research opportunities.

References are gathered at the end of the thesis. A comprehensive set of appendices is also given at the end. These relate to the development of the model as described in chapter four. (The whole model with all its diagrams can be found in two appendices: Data Flow Diagrams and Logical Data Structures).

## **CHAPTER TWO**

### **THE LITERATURE REVIEW**

#### **2.1 INTRODUCTION**

In this chapter three main areas of the study, total quality management, group technology and information systems have been reviewed.

In the first section, changes in the understanding of TQM are reviewed. A retrospective analysis and many definitions of TQM provided by various quality practitioners are given. A number of TQM approaches are also discussed regarding structured and integrated management systems. Some prominent TQM models are analysed in another section under the banner of Total Quality Management models. These are the models produced by Kanji and Asher (1993), Oakland (1989, 1993), Sohal et al. (1989) and Zairi (1991). In the TQM applications section, some of the actual implementation of TQM in various manufacturing corporations are given in detail. Their successes and achievements are discussed within the context of the research.

The second element of the model , a review of cellular manufacturing is given with a retrospective evaluation. Various definitions of Group Technology i.e. cellular manufacture, are considered and the development of GT evaluated. Numerous applications of GT are also discussed with reference to simplification and integration.



Lastly, requirements for structured information systems are discussed in detail. Various methods for structured information systems are defined and how and why each are to be applied is described briefly.

## 2.2 TOTAL QUALITY MANAGEMENT

It was the industrial revolution which took place in the late 1800s and the computer revolution in the early 1980s. It is now the turn of the quality revolution, a period of change affecting every type of business, enterprise, organisation, and person (Oakland, 1989). Quality has been around for a long time and has progressed from stages of playing a purely relative role (inspection) to its prominence in the era of mass production (Zairi, 1991). The concepts of quality and quality management had not been fundamentally changed for centuries but many great changes have taken place since the Second World War (Kanji and Asher, 1993). Stuelpnagel (1993) even argues that the same principles as today's total quality management were being used by Henry Ford some eighty years ago. The term Total Quality Management was initially coined in 1985 by the US Naval Air Systems Command to describe its Japanese style management approach to quality improvement (Bemowski, 1992).

There are a number of definitions of TQM. Feigenbaum (1961, 1983) gave a definition of total quality control which is generally seen as a base for modern TQM definitions. Feigenbaum defined Total Quality Control as an "effective system for integrating the quality-development, quality-maintenance, and quality improvement efforts of the various groups in an organisation so as to enable marketing, engineering, production, and service at the most economical levels which allow for full customer satisfaction". Pfau (1989) gives a very common

definition of TQM, namely “an approach for continuously improving the quality of goods and services delivered through the participation of all levels and functions of the organisation”. Within the strategic management context Atkinson (1990) describes it as “a strategic approach to producing the best product and service possible through continuous innovation”. British quality guru Oakland (1993) describes TQM as an approach to “improving the competitiveness, effectiveness and flexibility of a whole organisation”. It is essentially a way of planning, organising and understanding each activity and depends on each individual at each level. TQM is also a way of ridding peoples’ lives of wasted effort by bringing everyone into the processes of improvement, so that results are achieved in less time.

TQM has been defined as the continuous performance improvement of individuals, groups and organisations (Kanji and Asher, 1993). What differentiates TQM from other management processes is the emphasis on continuous improvement. There are four general principles associated with TQM: delight the customer, management by fact, people based management, and continuous improvement.

There is also an internationally accepted definition of TQM (ISO8402, 1994). It is the management approach of an organisation, centred on quality, based on the participation of all its members and aiming at long term success through customer satisfaction, and benefits to all members of the organisation and to the society.

However, perhaps the most comprehensive definition of TQM is the one produced by the former British Quality Association : “Total Quality Management is a corporate business management philosophy which recognises that customer

needs and business goals are inseparable. It is applicable within both industry and commerce. It ensures maximum effectiveness and efficiency within a business and secures commercial leadership by putting in place processes and systems which will promote excellence, prevent errors and ensure that every aspect of business is aligned to customer needs and the advancement of business goals without duplication or waste of effort". Throughout the thesis this comprehensive definition will be used as the definition of TQM philosophy.

The methods for implementing TQM are found in the teachings of the quality gurus. As is shown by figure 2.1, most quality leaders divide TQM into a number of elements. Many of these elements such as management commitment, continuous improvement, customer - supplier chain, leadership and team work are essentially common elements. Failure - Cause Analysis is another main element which is indicated in different forms such as Root Cause Removal (Crosby, 1979), Cause Effect Analysis (Ishikawa, 1985), Reduction of Errors (Juran, 1993, 1994). Systems and Company - Wide Application also play important role in the prescriptions of Feigenbaum (1961, 1983), Hutchins (1988, 1990), Ishikawa (1985), Oakland (1989, 1993, 1995), Deming (1986), Pfau (1989) and Crosby (1979). These elements, however, are not to be seen as rigid implementation steps or tablets (Ghobadian and Speller, 1994). In practical terms it is generally accepted that there are three aspects of TQM which relate to the manufacturing industry (Rogerson, 1992).

**The Commitment;** TQM's success or failure depends on the commitment of the staff to the concept and on the acceptance of the staff for the need for the resulting culture change.

**The Management System;** Which is needed to ensure that the quality aims are followed consistently and that the company conducts its business in a controlled, systematic way.

**The Tools and Techniques;** which are used to measure the achievement and enhancement of quality, through various measurement methods which give quantitative information.

Quality assurance is the method to demonstrate to customers that their quality needs have been met. Quality control consists of physical control actions. Quality control is, therefore, an integrated part of quality assurance. TQM embraces both quality assurance and quality control concepts, but is much broader in its scope to cover all aspects of a business (Rogerson, 1992). Rogerson pointed out the necessity for the systems and measurement techniques to be integrated into a management scheme for continuous quality improvement.

As more companies try to achieve total quality, this moves them to strategies where quality is a qualifying criterion rather than an order winner (Voss, 1990). A strategy of using quality as a qualifying criterion can be pursued when high levels of quality have been achieved. Voss defines this significant manufacturing strategy as “having very high levels of quality and continuous improvements and accepting quality as an order qualifying criterion”. The nature of this strategy is to build on high quality levels by achieving TQM and then start competing on price, product, etc. Implementation of this manufacturing strategy substantially differentiates products on quality through changes in some aspects of quality. This has been done repeatedly by the Japanese in industries, such as the manufacture of television, motor vehicles and electronic components.

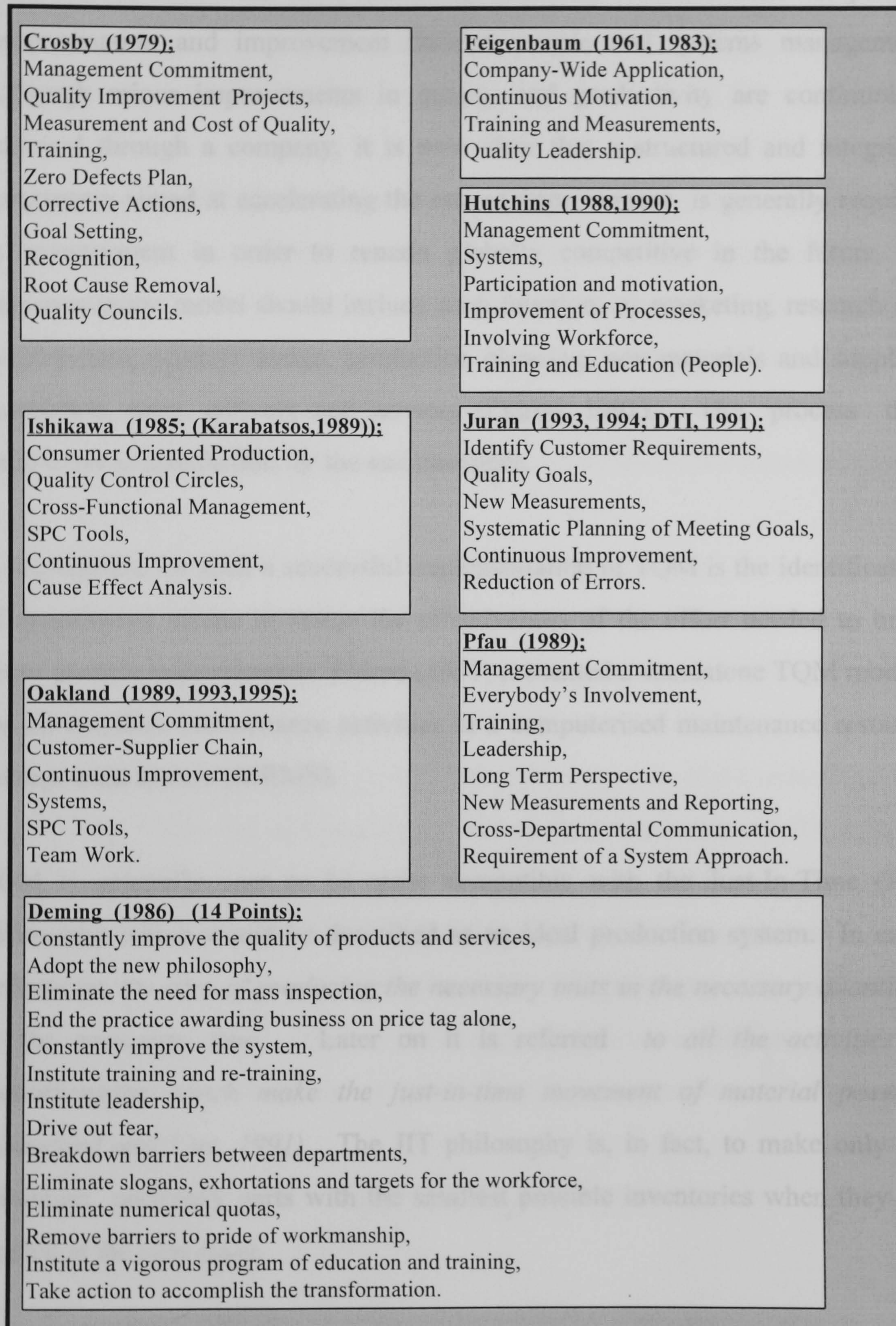


Figure 2.1 Major elements of TQM as given by different quality leaders

TQM can also be seen as a technology software which focuses on process standardisation and improvement through people and systems management. Although minor improvements in quality and productivity are continuously achieved through a company, it is now clear that a structured and integrated programme aimed at accelerating the rate of improvement is generally required by management in order to remain globally competitive in the future. An implementation model should include such functions as marketing, research and development, product design, production planning, raw materials and supplies, production, sales, delivery and services (Eldred, 1991). The process then culminates in satisfaction for the end customer.

A prerequisite for such a successful implementation of TQM is the identification of quantitative means to assess the effectiveness of the effort needed to bring about process improvements. Eldred (1991) presented a standalone TQM module for intermediate maintenance activities in a computerised maintenance resource management system (MRMS).

TQM is generally seen to be quite compatible with the Just-In-Time (JIT) philosophy which would be described as an ideal production system. In early definitions; *the idea of producing the necessary units in the necessary quantities at the necessary time.* Later on it is referred *to all the activities of manufacturing which make the just-in-time movement of material possible (Crawford and Cox, 1991).* The JIT philosophy is, in fact, to make only the minimum necessary parts with the smallest possible inventories when they are needed at the next stage.

Although in many manufacturing industries it is accepted as a good productivity improvement programme, it is generally difficult to write down a definition of

JIT for all types of organisations. This is because of the range of products, services and organisation structures leads to different impressions of the nature and scope of JIT (Oakland, 1989).

Lumnus et al. (1992) point out that JIT is based on the continuous elimination of waste and consistent improvement in productivity, although many people concentrate on the inventory reduction side of JIT philosophy. Lumnus et al. (1992) state when JIT is not JIT is when companies lack a commitment to total quality. They recognise that quality teams are evidence of a true commitment to quality. Employees should monitor their own processes with a training in basic quality control tools.

There are many organisations throughout the world that want to introduce or practice JIT management principles. JIT can be considered as a broad management philosophy as mentioned earlier, which results in inventory reductions. Oakland (1989) says JIT fits well under the TQM umbrella since many of the ideas and techniques are very similar and moreover JIT will not work without TQM in operation. Similarly Menon (1992) says successful implementation of JIT systems are dependent on successful implementation of TQM systems. So it seems that to achieve the JIT philosophy it is necessary to apply TQM successfully. Menon (1992) argues TQM is a shop-floor and people oriented philosophy which shows practical and systematic ways to achieve its goals.

### 2.2.1 TOTAL QUALITY MANAGEMENT MODELS

Today, there are a number of models representing TQM as a philosophy which reflects modern competitiveness. To manage quality as a competitive weapon the whole picture must be understood clearly otherwise it would lead to a total quality disillusion (Oakland, 1989,1993).

As is understood the TQM philosophy is a firm foundation, although there are problems in its application (Bemowski, 1995). Moreover, from the early plant visits (Appendix C, Part A) and discussions with various experts it was possible to identify that there is a need for a simple and integrated TQM implementation procedure which can be established in a company or can be a compatible standalone management system for assuring quality. The rewards of establishing a quality company are immense. Kanji and Asher (1993) give examples of the growth, profitability and image that Marks & Spencer and British Airways have achieved by focusing on quality. Many quality researchers including Kanji and Asher (1993), Kanji (1993), Oakland (1995), Hutchins (1990), Pfau (1989) consider TQM as the route to creating a quality company with the complete commitment and dedication from the top. However, when it comes to the implementation stage, a managing director will find the task of quality improvement across the whole company daunting and s/he will get very little comfort from the teachings of the quality gurus. Even just deciding where to start is so difficult that one may never get off the starting block. As mentioned earlier, this condition is common and Kanji (1990) has developed the name 'total quality paralysis' for it.



### *Kanji and Asher Model*

Kanji and Asher (1993) have proposed a four stage model to develop TQM implementation in an organisation;

Identification and Preparation, identify and collect information in the prime areas where improvement will have most impact on the organisation's performance. Prepare the detailed basic work for the improvement of all the organisation's activities.

Management Understanding and Commitment: prepare and adopt the objective and methodology of TQM all the time for management.

Scheme for Improvement: establish a proper scheme of training and communication to resolve quality issues by involving all management and supervision.

New Initiative, New Target and Critical Examination: start new initiatives with new targets, indicate supplier and customer links in the quality chain and obtain information about progress.

Furthermore, without the data to make informed decisions, without total commitment from the top, without the strength of a united and co-ordinated middle management, the implementation is most likely to fail (Kanji and Asher, 1993). They argue that these four stages mentioned are musts and there are no short-cuts (every stage must be worked through). In their model many requirements such as cultural change, commitment, trade-off between quality and

cost, error free work as standard, are presented. They consequently give solutions and hints to satisfy these requirements (Kanji and Asher, 1993).

### *Oakland Model*

Another prominent model is the Oakland model (1989,1993) which is characterised as a pyramid, figure 2.2, representing five distinct components;

Management Commitment: it is identified that senior management commitment is a prerequisite for success and this has to be reflected by the levels of investment in the required area and the amount of risk taken for the achievement of success.

Customer Supplier Chains: This is seen at the heart of the pyramid and is considered as a propeller for process ownership, management and improvement.

Systems: This is the documentation of procedures and standards of doing things right first time and every time.

Statistical Process Control (SPC) Tools: To measure and control conformance to customer requirements and agreed standards.

Team Work: A culture of continuous improvement.

Oakland points out that employees will not be motivated towards continual improvement in the absence of commitment to quality from top management, an organisational quality climate and a team approach to quality problems.

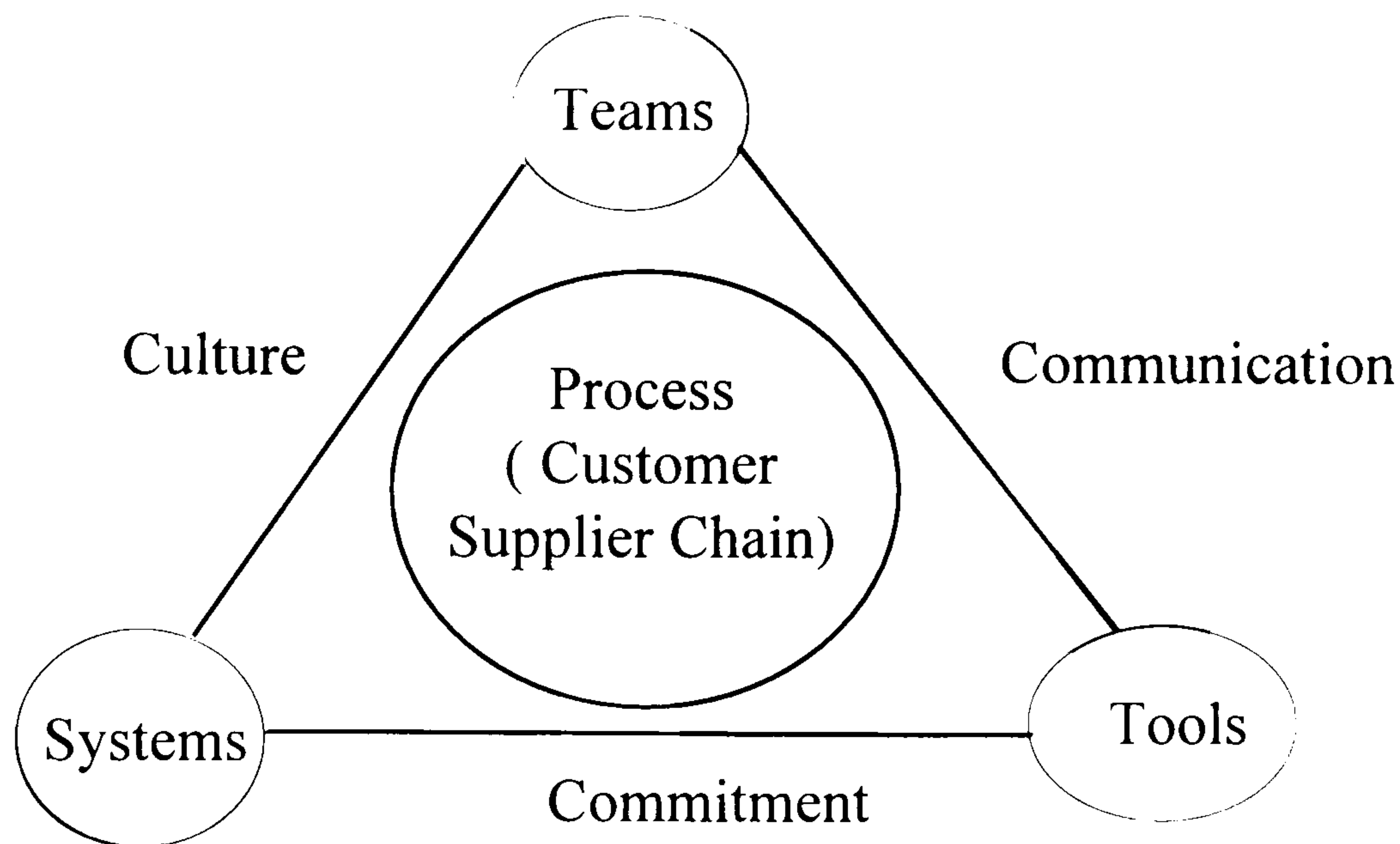


Figure 2.2 Oakland's TQM Model

It is proposed by Oakland (1989, 1993) that a well operated, documented quality management system would provide the necessary foundation for the successful application of SPC and teamwork. For a successful implementation of TQM several things need to be done by all concerned in order to avoid total quality disillusionment (i. e. paralysis). Some examples are following;

- avoid underestimating the commitment required,
- emphasise the long and slow journey to TQM,
- prevent TQM being used as an instant solution to a particular problem.

For the implementation, Oakland developed a procedure which contains a mixture of ideas supported by the various quality gurus. There are thirteen steps in Oakland's approach to TQM implementation:

- 1- Understanding quality,
- 2- Commitment to quality.
- 3- Policy on quality.
- 4- Organisation for quality,
- 5- Measuring costs of quality,
- 6- Planning for quality,
- 7- Design for quality,
- 8- Systems for quality,
- 9- Capability for quality,
- 10- Control for quality,
- 11- Team work for quality.
- 12- Training for quality and
- 13- Implementation of TQM.

These thirteen stages are presented as a gradual progression towards implementing a TQM based culture.

#### *Sohal, Tay and Wirth Model*

Another practical model based on experiences was proposed by Sohal, Tay and Wirth (1989) as is shown in figure 2.3. They outline that continuous improvement in quality has to come from an integrated approach of controlling quality via tactical action plans in different operations of the business cycle. Although this model discusses quality in terms of total quality control rather than total quality management, at various stages “control” means the management of quality.

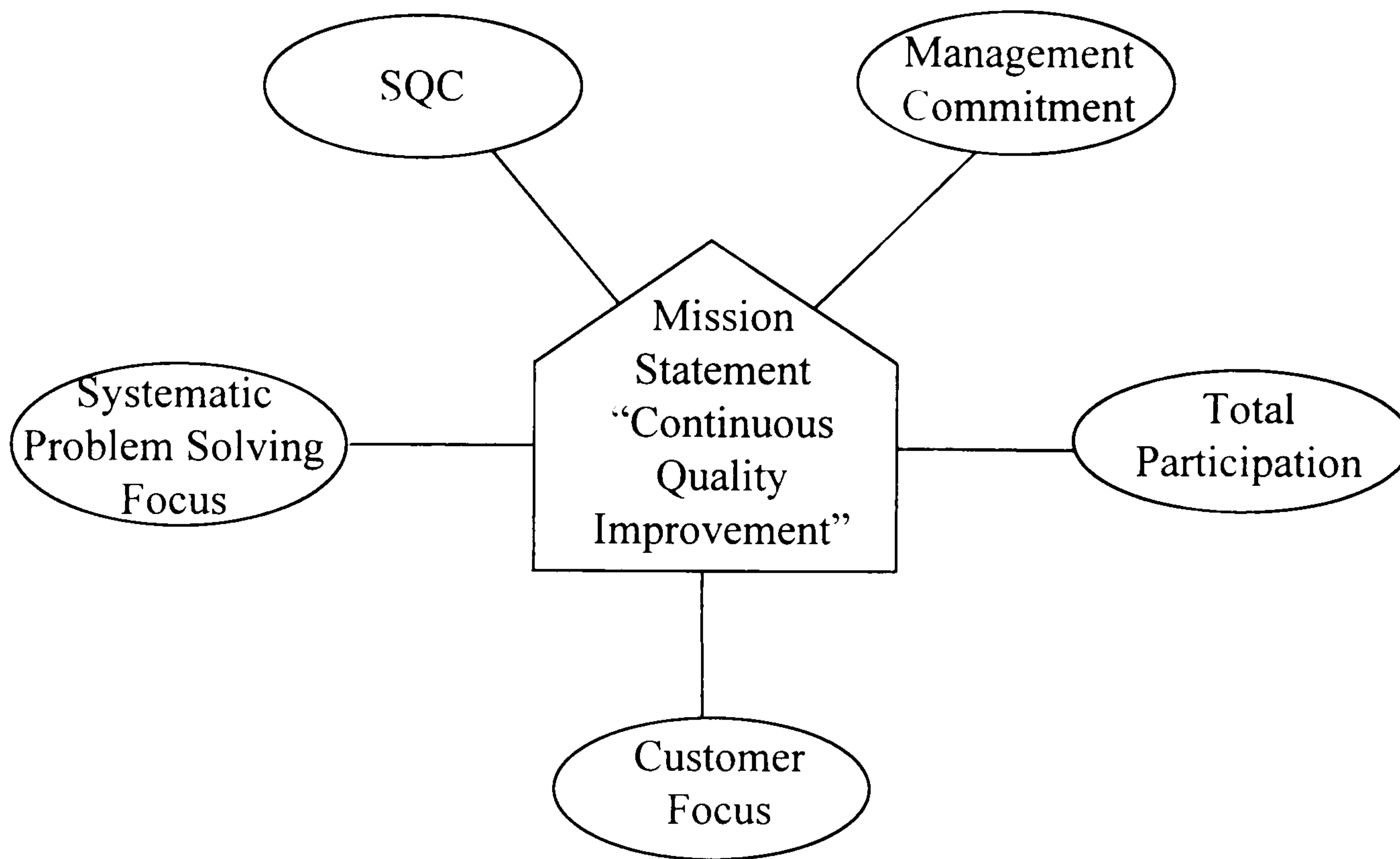


Figure 2.3 The TQM model of Sohal, Tay and Wirth

The five significant elements of this model are:

Customer focus: all individuals in the organisation have to focus on the quality of the process in delivering services to the internal and external customers.

Management commitment: changing attitudes and expectations and establishing systems for quality measurement and control.

Total participation: workers on the shop floor should be the ones to be encouraged to improve the process.

Statistical quality control: using various statistical techniques to analyse collected data and solve various problems.

Systematic problem solving process: relying on Deming's famous Plan Do Check Act (PDCA) cycle which is shown in figure 2.4 to improve the whole business process.

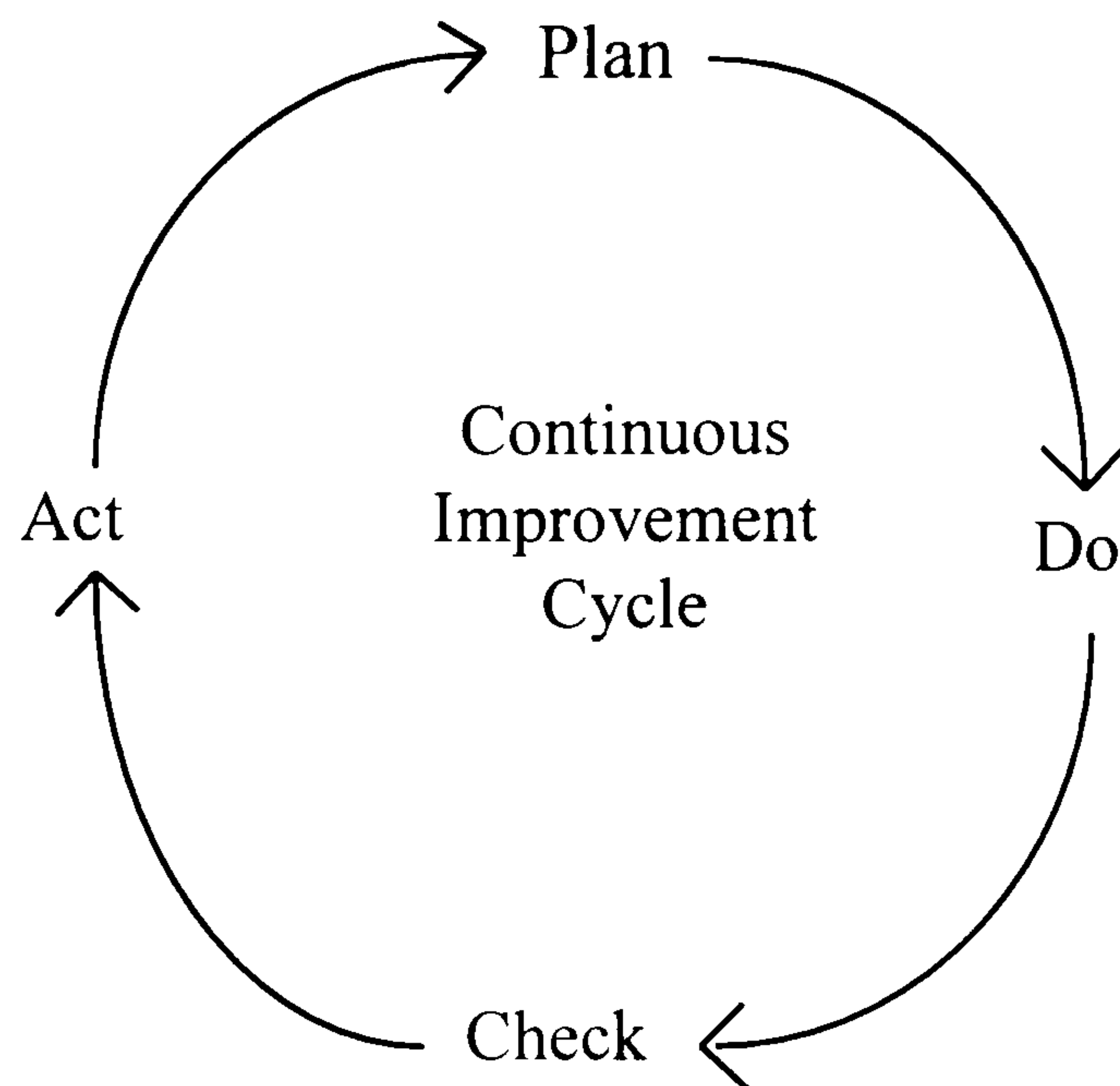


Figure 2.4 Deming's PDCA Cycle

### *Zairi Model*

Research by Zairi (1991), on the other hand, proposed a TQM model at three levels, figure 2.5.

The top: this resembles the roof of a building which is perhaps the most important part since it shields the organisation from adverse external factors and protects it all the time. This part should not deteriorate. A steady state management resulting from previous successes can lead to an erosion and deterioration in the organisation concerned. Hence in this respect, the activities of senior managers in planning for quality, having a vision for the future of their

organisations and in aspiring for world class competitiveness are thought to be crucial.

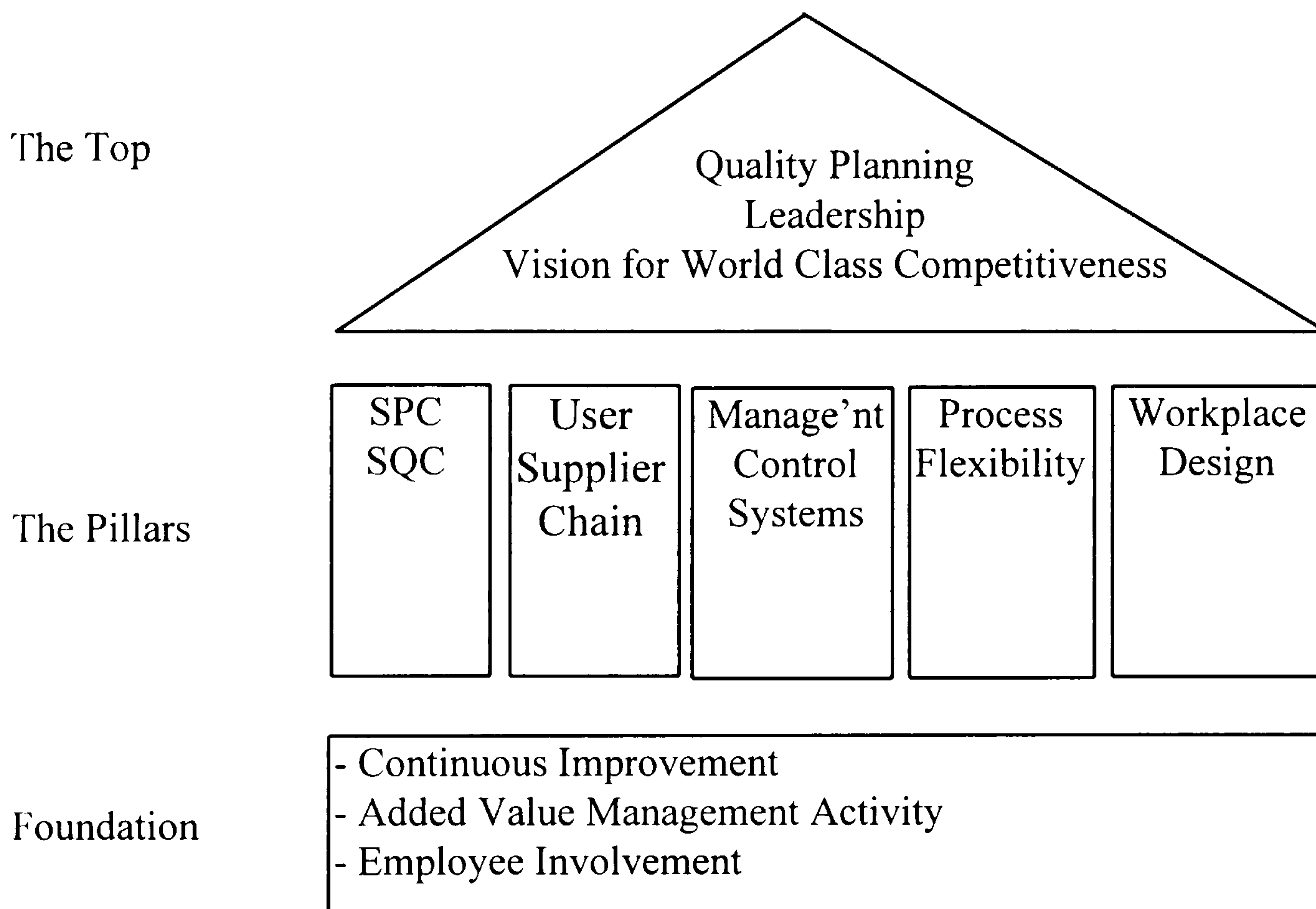


Figure 2.5 Zairi's TQM Model

The pillars: these are represented by various quality assurance tools (like SPC, SQC, BS5750), user supplier chain, management control systems (OPT, MRPII, JIT), process flexibility, (FMS, CNC, AMT, CIM, CAD/CAM) and workplace design like layout, methods, ergonomics, safety etc. It is believed that these building blocks determine the strength, safety and security of the whole organisation and, therefore, management should be interested in strengthening and adding extra pillars. Zairi defends that a weakness in one area will have a disastrous effect on the TQM programme as a whole and, therefore, proposes that

organisations need to consider their TQM implementation strategy for every aspect of the business.

The foundation: this consists of continuous improvement which involves introduction of change, flexibility and adaptability, employee involvement, and added value management activities.

As is understood clearly the TQM philosophy and its elements are well-expressed through different models. When it comes to the implementation of TQM, the messages are not as clear as explanations of the philosophy. For example Zairi argues that quality cannot be purchased as a package. The implementation of TQM is a unique experience to individual organisations and the ideas of individual gurus will not necessarily be enough to solve all the problems. He then proposes the idea of adopting a strategy based on a mixture of ideas from the various quality gurus. An example of this, produced by Oakland, was shown in the previous section.

### 2.3 TOTAL QUALITY MANAGEMENT APPLICATIONS

In a research carried out recently by the magazine Quality Progress (Bemowski, 1995), to find out whether TQM is on solid ground. It is then concluded that the TQM is a firm foundation. Dobbins (1995) argues TQM almost always works after the right methods to implement it have been found. He claims that many TQM efforts have failed because people mistook implementation methods, not the TQM philosophy, for the goal they needed to achieve. Dobbins also complains about the failure of the methods has been mistaken for the success or



failure of the philosophy. Similarly Bohan (1995) points out that TQM efforts run into trouble when some of these methods are used inappropriately.

Here are some application examples describing how TQM principles and tools have been successfully implemented in organisations of various types and sizes.

#### *Xerox Microelectronics Centre (MEC) in the USA*

In 1983, the top management of Xerox reflected the corporate commitment to quality in its quality policy statement which indicates that Xerox is a quality company and quality is customer (internal and external) satisfaction (Naguib, 1992). In 1986, the leadership of MEC decided to implement TQM with full participation of all employees at all levels. To provide a solid foundation for the implementation, senior management conducted a comprehensive system analysis of the MEC organisation and came up with the need for re-organisation and with some operations to be re-structured in order to use resources effectively and improve communication. They then established a quality council and launched an education and training programme, followed by the introduction of statistical quality control (SQC) techniques at MEC in the consequent phases.

MEC has been implementing TQM since then. To meet the challenges of the new era, the management team of Xerox MEC developed a continuous improvement plan based on the following five manufacturing strategies; **Total Quality Management**, Just In Time, Total Productive Maintenance, Activity Based Costing, and Total Employee Involvement. These are seen as interdependent, long term manufacturing strategies.

Involvement in the planning process and involvement in the implementation process were the two main aspects of employee involvement in the MEC. Several types of teams (functional teams, self managed work teams and multi-functional teams) were formed to execute the quality improvement plans and ensure maximum participation of all workers.

Since the introduction of the TQM process in the MEC operations in 1986, the following results were achieved by 1991;

- improved wafer probe yield by 6 to 74 %,
- improved product quality; customer returns were reduced drastically,
- improved productivity (units shipment increased by 114% while the workforce was reduced by 24%),
- increased profitability by 142%,
- on time delivery achieved,
- improved customer satisfaction,
- improved employee satisfaction,
- team work recognition at the corporate level.

Rank Xerox (UK) has also won back the market share which once had been lost to the Japanese as a result of substantial progress in quality improvement and total dedication to TQM (Kanji and Asher 1993).

The MEC plant manager now sees the quality as a race without a finish line. A focus on quality has made Xerox a stronger company, and they are on a mission of continuous quality improvement which is a long and never ending journey. To fulfil this mission, their continuous quality improvement efforts currently include the following;

- Expand and upgrade the education and training programme.
- Extend total employee improvement,
- Standardise manufacturing processes and operational procedures.
- Enhance the involvement of both internal and external suppliers in the TQM process etc. .

A number of barriers which slow down the rate of progress were also noted. They included;

- Continuous improvement must be done at a reasonable pace to allow it to stabilise and sustain the new changes before new improvement activities begin,
- Keeping balance between the new TQM process oriented approach and the old results oriented approach,
- Managers adaptation to their new role in the TQM culture is vital,
- Appearance of new organisational barriers.

The above achievement has not resulted entirely from the implementation of TQM, but TQM can be considered a major contributing factor. The basic concepts of TQM are seen as customer satisfaction, continuous improvement, total quality control, continuous education and training, and total employee involvement. Naguip (1992) stresses that the TQM process could not be implemented without top management commitment and involvement.

When it is looked at on its own, TQM implementation has passed through five phases: top management commitment, analysis of the organisation, quality council establishments, education and training, statistical quality control (SQC)

introduction and employee involvement. Traditionally, this organisation consisted of five vertical functional groups with weak horizontal links. Organisational system analysis indicated a number of shortfalls in this type of organisations which included poor communication, lack of integration, lack of ownership, poor operational control, and lack of business focus based on customer-supplier relationships. In order to alleviate these shortfalls, MEC was re-organised into four modules and a Product Delivery group. Additionally, to achieve an improved integration, MEC management concentrated on quality councils and employee involvement.

*Dow-Corning Australia Pty Ltd (DCAPL, Chapman et al., 1991)*

Another implementation example is from Australia. The major push for implementation originated from a visit to the parent company operations in the US by the Down-Corning Pacific area president.

TQM implementation at DCAPL progressed in three major stages: foundation creating environment, development and cultural change and consolidation and sophistication. In 1988 Natural Work Groups (NWGs) were established to allow groups of employees working in the same area to meet on a regular basis, with the objective being discussion, analysis and implementation of solutions to problems which were identified in the day to day operations of the sections concerned. Interdepartmental quality planning teams have been established to cross departmental barriers to problem recognition and solution implementation. Quality councils were established to monitor the movement at the interdepartmental senior management level. Quality councils meet on a monthly basis, NGWs meet on a weekly or even daily basis. Quality planning teams meet

irregularly but usually somewhere between the frequency of NWGs and quality councils.

DCAPL has established incentives for quality activities including company awards, plaques and a company quality medal. During the early stages of the implementation a common problem was found in that a number of groups were able to identify current and potential problems but lacked the ability to analyse effectively the problem, examine possible solutions and select the one with the most potential. This was overcome by developing a methodology to assist groups in undertaking these phases of quality improvement. The greatest strengths of the TQM implementation at DCAPL were the commitment and enthusiasm of the senior management.

Three of the major problems confronted in the implementation were the general low level of education among plant operators, the lack of leadership skills in most staff which led to ineffective team meetings, and the lack of integration. The first two were improved through various skill development and team building projects. In order to overcome the lack of integration, inter-departmental quality planning teams were established and similar to the previous case, an organisational restructuring was also conducted. Other problems were the lack of direct communication and insufficient data analysis and reporting system.

For the future, TQM is seen as the philosophy to improve and maintain productivity levels sufficient to overcome the difficult economic times. DCAPL plans to incorporate the principles of Just-In-Time production into its operation in the near future. Computerisation of operations in these new activities is extremely important and TQM activities are wanted to be easily integrated with future plans.

### *British Steel, Teesside*

Another example of the TQM implementation is the case of British Steel, Teesside (Kanji and Asher, 1993). A TQM consultant team was introduced to the company to co-ordinate and establish implementation activities, which undertook an extensive study to find out why and where the main quality problems arose? The company had existing extensive quality systems, many specific to particular customers. No analysis was carried out of these systems. Initial studies carried out by the team were called the diagnostic phase. Then the top team workshop phase took place. The objective of this phase was to develop personal and collective commitment to ensure TQM is successful in British Steel in Teesside. Then the following phases took place : diagnostic feedback to managers; TQM introduction courses; TQM training of management; problem identification, task forces and action teams; supervisor training; non-management training; measures; organising for TQM; communications. Some of the task forces which were set up to gain some early successes and act without having to wait for training to be completed, were as follows;

- to improve the communication of the TQM process,
- to improve the reporting flow between finance and works,
- to set agreed measures for material quality, etc.

And some of the benefits gained were as follows:

- reduction in cross-functional barriers thanks to functional steering teams.
- increased customer awareness.
- involvement in the company.

➤ establishment of a common language for talking about quality issues.

As is observed in the previous cases. re-organisation, integration (e.g. sales and production), ownership and employee involvement are again major elements of the implementation. Additionally establishing customer awareness and language of quality are other issues of the implementation.

#### *Carnaud Metalbox Perry Wood, Worcester*

The senior managers at Carnaud Metalbox Perry Wood Factory in Worcester, were aware of ideas of the quality gurus and became convinced to apply TQM (Oakland, 1995). The company then discovered that the use of a sound quality management system was important to them and it was an initial step towards TQM. Since establishing a quality system, the company has further progressed on TQM. Focus on continuous improvement, closer relationship with customers and suppliers, and the measurement and improvement of processes are part of this on-going process. Perry Wood has tackled the issue of team organisation of work into customer-driven cell manufacturing where the workforce are organised into self managing groups with clear goals and authority to manage their own processes. Building on the information, they have also embarked upon a major commitment to total productive maintenance which is expected to help improve overall equipment effectiveness.

Here, it is understood that to have a quality management system was a good start for the implementation of TQM. Then again organisational re-structuring into groups and integration (e.g. maintenance) can be considered as the key implementation issues.

### *Pirelli Communication Cables*

Oakland (1995) notes that management commitment, publicity, training and improved working practices are all important elements of a TQM programme, but in themselves they are insufficient to ensure success. The successful application of TQM requires a defined organisational structure which demands and harnesses the potential workforces. A defined organisational structure is essential if TQM is to be successfully applied. Within this context, Pirelli Communication Cables, which is a division of the Pirelli General PLC group, implemented a TQM based organisational structure. They have established teams and groups to manage quality improvement across the company, thereby organising for success. In this way Pirelli Communication Cables have gained considerable benefits of TQM (Oakland, 1995).

Overall, implementation of the TQM philosophy has different features for different establishments. It requires planning, efforts and flexibility. Simply purchasing or implementing another establishment's plan, problem solving process, team structure or TQM training package does not ensure a successful application (Hoover, 1995). So when reports inform that TQM has failed, it is most likely the method of implementation which is failed. However, as is seen in various cases, there are a number of major common elements of a successful implementation method. These elements have different degrees of importance to different establishment according to organisation's structure, flexibility and ability of integration. Mainly, after the management commitment, re-structuring of the organisation (generally re-structuring into groups, cells or teams) emerges as one of the most important issues towards a successful implementation. Sohal



(1994) even argues that re-structuring results in improved communication, product and customer focus for all teams, and flexibility in all aspects of the organisation.

Re-structuring and other key elements require change which also affects many other areas such as production management, maintenance management, etc. On the other hand, there is a production management method, cellular manufacturing (i.e. Group Technology), restructures the entire manufacturing into cells (i.e. groups) in order to get throughput time reduced, stocks reduced, employee involvement improved, ownership improved, quality improved, etc. Hence to study this area will certainly result in fruitful discussion and evaluation.

## 2.4 CELLULAR MANUFACTURING

Within the context of cellular manufacturing, “there is considerable disagreement around the world regarding what is a cell” (Ranky, 1990). In this text the word “cell” is taken to be synonymous with “group”. It is however, sometimes preferable to use the word “cell” simply because it indicates an interchangeable and integrated activity block of a more complex system. Burbidge (1987) defined group or cell as an organisational unit designed to complete the manufacture of a specified “family” of components or assemblies, and equipped with all the production facilities needed to do so. A family is the set of parts which is made in a group. Group Technology can also be considered as a multi-process organisation which is found at shop floor level (Towill, 1995). Group Technology in this context is a form of organisation for production factories, which is based on product organisation and for which the smallest organisational unit is the group.

Group Technology, practised in the early twentieth century as isolated manufacturing improvements and not as a proven technology, began to change as industrial researchers realised that batch manufacturing was not going to disappear and that major generic improvements in batch manufacturing were necessary. Snead (1989) showed that this realisation led to the birth of Group Technology. Early development effort was centred on design retrieval systems. Manufacturing process improvement through Group Technology followed later, as researchers such as Mitrofanov and Opitz (Snead, 1989) began their important work. As one of the first researchers Mitrofanov published his famous book entitled 'Scientific Principles of Group Technology' in 1959. During nearly the same era, a second major Group Technology research activity was being conducted under the direction of Opitz at the Aachen Technical University in Germany. Researchers surveyed parts being manufactured by the German machine tool industry. They found that there were many similarities in the parts being manufactured not only within individual companies but also across the entire German machine tool industry (Snead, 1989).

The cell system of manufacture enables a family of components to be manufactured on a group of machines, normally without the components moving out of the cell. Although this does not decrease the actual machining time, Jackson (1978) argues that it enables components to progress speedily from machine to machine thus reducing considerably the inter-operational losses. The throughput time is therefore reduced and the level of work-in-progress is kept to a minimum. It is also said by Jackson (1978) that the reduced materials handling, as compared with a functional layout, gives less risk of damage. Operator familiarity is increased with a known range of components and quality level achievement is improved. Thus a cell system of manufacture is seen as a highly

significant improvement upon the functional layout based manufacturing systems by many researchers such as Jackson (1978), Snead (1989), Burbidge (1989), Johnson, (1992), Laughlin (1995).

Group Technology is generally accepted as synonymous with cellular manufacture where the groups (or cells) relate not only to components, but to people and their equipment (Mechanical Engineering EDC, 1975). Gaither et al. (1990) defined Cellular Manufacturing as a form of production that groups machines, tooling, people and materials into manufacturing cells. Each cell produces a family of similar parts, with all the parts in the family having the same characteristics.

Gallagher and Knight (1986) recognise that Flexible Manufacturing Systems (FMS) are a consequence of logical steps which emerged from the concepts of Group Technology. Snead (1989) outlined that the evolution of Group Technology manufacturing cells was significantly impacted as the concept of automated machine controls was developed. So, there is also a trend that is to refer to new cellular manufacturing concepts as flexible manufacturing. In this text, as described earlier, various Group Technology environments have been gathered together under the general, improved term Cellular Manufacturing.

The basis upon which the concept of Group Technology is built is that there is an experienced base of human knowledge present in all design within manufacturing environments. This experience base views situations in the light of previous experience and uses these experiences to make a judgement to solve the problem at hand. Snead (1989) explains that Group Technology is working to capture this experience base in an organised fashion. The power and usefulness of Group Technology are based on the same general issues as Artificial Intelligence (AI)

expert systems. Like an expert system designer, a Group Technology system designer is concerned about how the data is stored (coding), how the data is used (application programme), and how good the data is (classification).

Burbidge (1989) describes the objectives of Group Technology as to form small organisational units which complete all the set (or family) of products or components which they make, through one or a few major processing stages, such as metal founding, machining, and assembly, and are equipped with all the machines and other processing equipment they need to do so. Among other advantages, GT in most of the cases greatly reduces throughput times thus making it possible to work with low stocks at high rates of stock turnover. GT also makes it possible to produce efficiently in small batches which may also reduce stocks.

Burbidge was a strong advocate of Group Technology and his numerous articles clearly express his opinion that the process organisation is obsolete. Burbidge (1992, 1994a) describes process organisation as the traditional type of manufacturing organisation where each unit specialises in a particular process. He claims that this is gradually being replaced by product organisation in the form of either Continuous Line Flows or Group Technology. Advantages of GT compared with process organisation are shorter throughput times, better quality (fewer rejects), lower materials handling costs, better accountability, easier training for promotion, more opportunities for automation, reduced set-up time and increased morale and job satisfaction. Burbidge (1989) introduced Production Flow Analysis (PFA) as a technique used to plan the change in a factory from process organisation to product organisation and also to plan the change from process layout to product layout. Burbidge also provides the definition of PFA as a technique for finding the families (sets of parts) and

groups (related sets of machines and other facilities) for Group Technology. PFA starts in large companies by simplifying the flow between factories as divisions using company flow analysis (CFA). It then finds the best division of each factory into departments and simplifies the material flow between them using factory flow analysis (FFA). Next, it plans the division of the departments into groups with group analysis (GA). Furthermore line analysis (LA) is used to study the flow of materials between the work centres in a group. Finally, to plan operation sequencing and to find sets of parts suitable for automation, tooling analysis (TA) is used. These first three analyses of PFA are illustrated on figure 2.6 at company, department and group levels. Burbidge (1992) claimed that if PFA is used for planning Group Technology, it is generally possible to find a total division of machines into groups, and of parts into associated families. With very few exceptions, these groups complete all the parts in the sets of parts they make. Then he concludes that it is generally possible to change from process organisation to Group Technology. However, Wei (1992) discusses Burbidge's assertion and asks if GT outperforms process organisation in all conditions and if it is always economical or practical to achieve cell independence.

Wei then concludes that each specific situation has its own optimal degree of cell independence which balances all the trade-offs involved. Burbidge (1994b&c) in return, explains the difference between a Group Technology "group" and a "cell". A group can consist of many cells which are in practice generally understood as a smaller unit to form a single "workcentre". He argues that the full benefits will not be achieved until a total change to GT has been completed and the administration, payment, production control and other systems have been changed to suit the new organisation. Burbidge then concludes that it is not difficult or expensive to change from process organisation to GT.

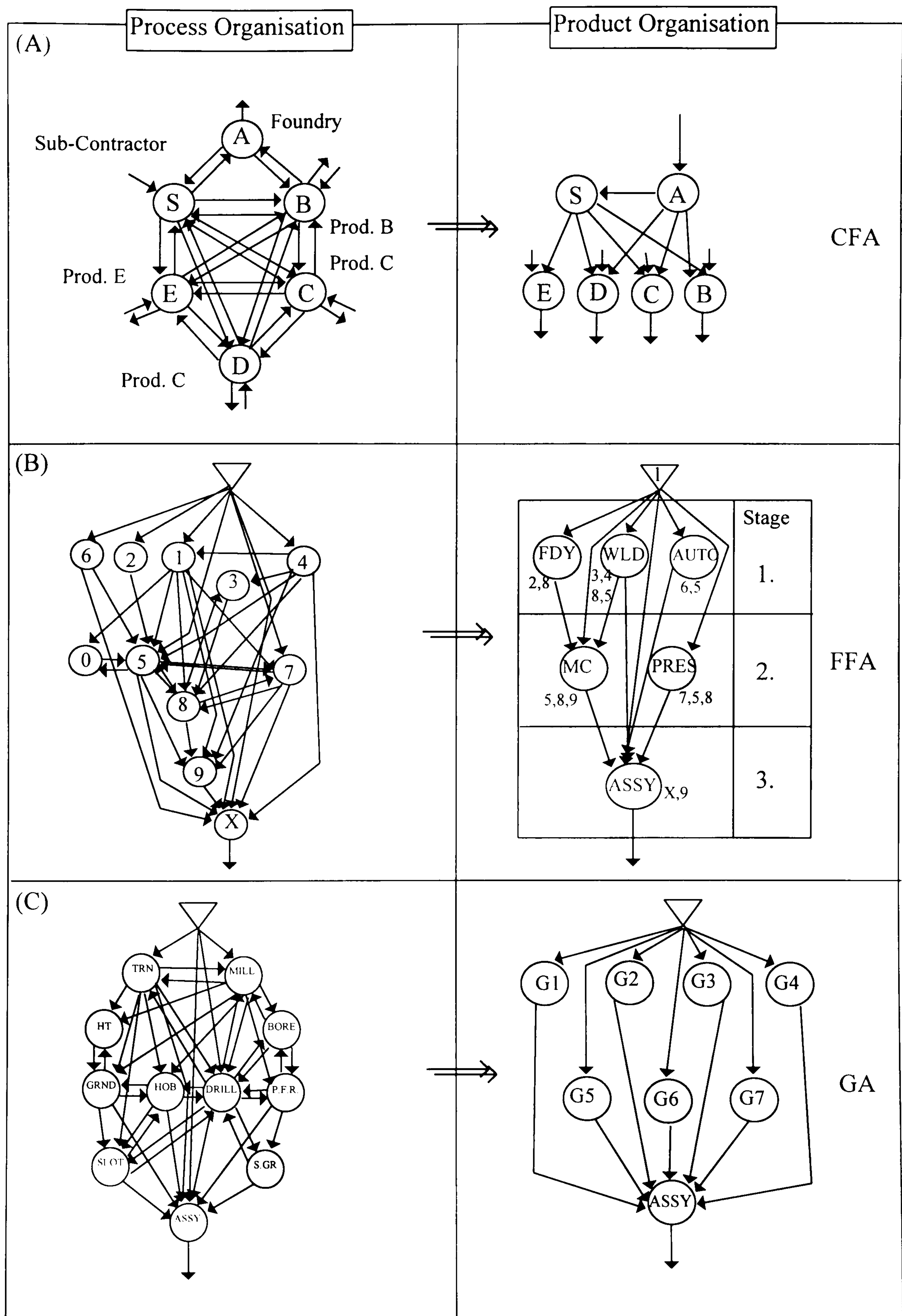


Figure 2.6 From process organisation to product organisation (Burbidge, 1989);  
 (A) Company Level (B) Department Level (C) Group Level

There are a lot of cases which show that better quality management can be achieved by Group Technology i.e. cellular manufacture. Wemmerlov and Hyer (1989) found that to improve quality was one of the five most common reasons for establishing cells. With a Group Technology application in their plant Welke and Overbeeke (1988) also realised that cellular manufacturing was one of the best vehicles to implement JIT manufacturing and total quality control. It allows for a total plan and acts as a way of tying all the strings together. Getting started in cellular manufacturing requires a long term commitment on the part of management, engineering, and most importantly, the shop floor. From the very beginning, shop floor people need to be involved as equal team members. It must be clearly visible that all levels of management support the cellular concepts and the implementation teams. Quality will also become more critical because parts that used to sit in work in progress (WIP) inventories will now go directly to the next process. The contribution of each employee assigned to the cell will become more apparent to all, since teamwork is very critical. A group incentive of some type could be considered in order to reward employees for working together to achieve maximum throughput of quality products through the cell. They concluded that a compact cellular manufacturing environment with employees who have ownership over the operations will drastically reduce lead times and inventories and almost certainly increase quality.

Shifrin and Mecham (1991) claim that Total Quality Management techniques are making new inroads in Europe as well with increasing emphasis on employee participation, concurrent designs and the rewarding of employees. They point out that some aspects of TQM have been in use for many years although not necessarily by that name. An example of a company within Europe is British Aerospace, which has organised production operations into cells driving responsibility for product quality down to the shop floor level. The commercial

aircraft manufacturing facility in Hatfield (now used as a training place) had been divided into six manufacturing centres, each comprising a number of cells and support services including engineering, logistics and inspection functions. Within the cells, employees were responsible for inspecting their own work and results. Staff gained experiences in the process of quality improvement meetings. BAe then claimed that they had saved, from those little improvements, millions of dollars.

Kumar and Hanjinicola (1993) have reported a number of benefits from the implementation of cellular manufacturing in Champion Irrigation Products in Los Angeles. They reported as well as a 70% reduction in work-in-progress inventory, reduction in materials movement, improvements in production planning and control, and improvements in quality. The percentage of rejects has dropped considerably, and responsibility for quality inspection has been given to the workers in the cells. Quality has also become a central issue.

The Shalibane Company of Camberley has also introduced Group Technology, and Burbidge and Halsall (1994) have reported similar benefits. Stocks were reduced by 60% , sales and output were increased by 33%, rate of return on investment was increased by 24%. In addition to these measurable benefits, there were other benefits which are difficult to quantify. Among these were improved morale, job satisfaction and better accountability. This was mainly because groups complete all the parts they make, and the group leader can be made responsible for quality.

Northern Telecom introduced Group Technology to the DMS-100 Switching Division in North Carolina. Taheri (1990) has reported more than \$2M in annual cost savings from the reduction of overhead and WIP inventory (82%), as well as



improvement in throughput (by more than 50%) and quality (visual inspection by 70%). Taheri (1990) considered the success was dependent on the degree of flexibility which is placed on the planning and development of the operations system. In the implementation of Group Technology they had to re-consider and arrange accordingly many issues such as eliminating departmental barriers, team building, establishing a flexible workforce, avoidance of many variations in selecting manufacturing equipment, simplification of operations. Emphasis on flexibility also produced a new set of criteria which were incorporated in all the issues mentioned.

Watervliet Arsenal Co. , NY, (Baran, 1991) ventured into Group Technology because of overseas competition, customer demand for greater precision, and requirements for shorter delivery times. Group Technology implementation was main part of a project including modernising facilities, refurbishing machine tools, and purchasing equipment. Baran (1991) outlined that the implementation of the programme had doubled the capacity, reduced machines in the shop floor and improved productivity by 22%. Further benefits are expected as GT manufacturing goes on line.

Pesch et al. (1993) have toured and studied Allen-Bredley's Milwaukee plant, Deere & Co. 's FMS tractor plant, Apple's Macintosh plant, and IBM's printer plant from the standpoint of Computer Integrated Manufacturing (CIM). They found the Group Technology application to be a good response to plant complexity. They have shown that Group Technology cells typically enhance plant performance by reducing material-handling costs, cutting WIP inventory, slashing overall throughput time, and improve quality. Moreover, they have also noted a drawback to the GT approach, the cost of purchasing additional equipment to create dedicated cells. They then immediately add the opportunity

of purchasing lower cost used equipment. However, this sort of cost is not a likely cost according to Burbidge (lecture notes 1990), who has always introduced Group Technology to the existing machinery and factory. He has claimed that it is always possible to find a division into groups and families. There may be a small percentage of exceptional parts which do not fit the new groups. Burbidge suggests that these exceptional parts must be eliminated by either re-planning the processing operations or by buying the parts instead of making them.

House (1990) explained ICL's approach to manufacturing solutions, covering all aspects of company operation, from corporate strategy formulation, to implementation on the shop floor. Four central constructs underpin the whole philosophy: integration, just-in-time manufacturing, employee involvement, and total quality management. He claims that these are gathered under the name of World Class Manufacturing. On the other hand, Ronen and Pass (1992) claim that World Class Manufacturing is in fact the American version of the combination of JIT and GT. JIT here is not claimed as a method of inventory management, rather it is considered as a total business philosophy. The TQM is considered as the most important aspect of manufacturing. House (1990) believes the price of non-conformance in most companies is to be around 30% of turnover, and thus massive improvements in profitability can be obtained by pursuing the goal of TQM. He sees the question not as providing hardware but a complete support service, from facilitation of the strategy to implementation and achievement of targeted objectives.

## 2.5 REQUIREMENTS FOR STRUCTURED AND INTEGRATED INFORMATION SYSTEMS

Perkins and Perry (1992) realised that in many firms the quality and purchasing functions are separate. Such a separation is eliminating a valuable interchange of information between the functional entities. There are three strategies available for firms seeking to make quality a more important part of their source selection process. The first is to shout that quality is important, develop slogans and create enough confidence in the mind of suppliers that you are serious. However, the results from this method are usually short lived. The second is to find a measure, collect information, and report back to the supplier. Whether or not this measure is representative of the quality being achieved, it creates an impression that steps are being taken to improve quality. The third is to integrate all available measures into something resembling a composite quality management system. The effort is aimed at overall improvement of the processes. Full implementation may not be practical for all firms because of the expense of development and maintenance. However if such a system can be structured, it can usually be seen that there are one or two dimensions of quality which exert the largest influence on the cost structure or the competitiveness of the company. Most of the suppliers would also welcome such systems because they will be rewarded with more business.

De Cieri et al. (1991) point out the importance of integration of quality policy, materials, machines, people and methods. In applications they mention the importance of the following steps: formation of TQM committees (teams), training those teams, consultation with unions and organisational restructuring around processes rather than departments. They think Deming's plan, do, check, act (PDCA) is used as a successful application tool of a process improvement in

companies. De Cieri et al. (1991) state that these are related to only a single incident of process improvement, rather than providing information regarding the overall picture, and also stress the importance of an overall information picture. Difficulties with TQM applications, they see, are; to have a clear objective is vital but difficult to achieve, to find the time to perform all of the necessary tasks adequately, employees feel threatened by changes, if an immediate superior does not understand TQM then adoption is difficult for any individual employee. The appropriate measures and assessment tools must be utilised. De Cieri et al. (1991) list the critical success factors as; key people (facilitators) need to be appointed on a full time and long term basis, continuous improvements are needed, change must be demonstrated, good communication is important, worker involvement is essential. It is concluded that TQM is an overall philosophy which provides a means of managing processes throughout the organisation. A comprehensive implementation of TQM involves improvements in all departments, of all processes, through standardisation and management of variation. De Cieri et al. (1991) finally propose that TQM programme structuring should start with a corporate policy which reconciles customer needs with corporate goals. Then the policy must be elaborated into a number of business aims. Continuous improvement requires a dynamic approach and regular reviewing of the adequacy of the system and measurements.

Knorr and Thiede (1991) show that new advances like flexible manufacturing systems (FMS), JIT, TQM have yielded astounding increases in quality, productivity, and customer satisfaction. They suggest executives should make three major strategic changes for these technologies to succeed. Initially, adopt an enterprise viewpoint to include customers, suppliers and distributors, then make production the hub of the enterprise. Finally, structure the enterprise to respond rapidly to the full spectrum of customer demands. They expect four

revolutionary changes to happen; simultaneity, flexibility, self-management and continuous improvement. Information systems can be seen as the nerves of enterprises. In the past, information strategy has been limited to a narrow concept of customer integration of design and production, with separate systems for other functions. The new strategy is the computer integrated enterprise. The goal is to close all information loops in an enterprise on a meaningful, real time basis which makes possible simultaneity. If information loops are not closed, it means that some of the information is flowing to a particular place and is being accumulated there without feed back for further improvements. Ultimately, it should be focused on building a new corporate centre of constant innovation, self management, and enterprise integration as a strategy for the future.

Roberts (1990) argues about the importance of management information system (MIS) departments in companies to contribute to the success of a manufacturing. He describes some functions and user requirements of a prospective MIS for manufacturing. He suggests that the systems should consider not only dollar value but also activity. Developing an in-house system ensures that the system interfaces with other applications and provides the users with exactly what they want. So the integration comes naturally with the application of an MIS.

However, there are also some researchers who talk about information systems which are suitable for Material Requirement Planning (MRP) systems. MRP is a method of ordering in which the ordering of parts is based on explosion from a periodic programme. Each part generally has a different order quantity and is treated as an independent item for control. Explosion goes back to the placing of purchase orders. Malley and Ray (1988) explain that a decision support system (DSS) can be developed which assists in plant layout design, calculates optimal lot sizes for different production processes, evaluates suppliers and monitor

supplier performance. Additionally, MIS on the production floor can be simplified and adjusted by MRP systems for more efficient management of inventories. They claim the simplification in MIS, rather than in manufacturing itself, should be realised. It would be very difficult to talk about continuous improvement, if the simplification of manufacturing processes is not mentioned.

The design and implementation of information systems to support manufacturing management systems must recognise the issues associated with implementation of change ; integration of MIS with a firm's strategic plan, impact of change on production workers, and the use (what information and output will be needed) of an information system. Malley and Ray (1988) conclude that the information system which supports these processes must also change in a fundamental way.

Schnitt (1993) points out the requirement of information systems which will cope with the new structure and human resource policies. Manufacturing firms usually develop complex software systems and maintain a costly team of computer specialists and engineers to run the system and keep it up to date. Ronen and Pass (1992) point out that one of the main causes of failure of these complex software systems is the use of the traditional information systems methodologies, which were developed for financial applications, and which are unsuitable for the manufacturing organisations. They summarise the difficulties of management information systems (MIS) in manufacturing environments, such as large quantities of dynamic and unreliable data, complex and uncertain environments, and an informal work environment.

Ronen and Pass (1992) point out the need for a different methodology for the development and implementation of MIS in manufacturing environments. They discuss the benefits of new technologies from the information systems standpoint.

They propose that there should be a successful simplification in order to develop a strong manufacturing MIS. They see the systems based on group technology, just-in-time or synchronised manufacturing are more successful as shop floor control tools than those based on the MRPII philosophy. Systems analysis and design should be done by a professional, well acquainted with the field of manufacturing. They also stress the importance of integrated information systems in simplified manufacturing environments to achieve business goals such as high quality standards.

### 2.5.1 MANUFACTURING SYSTEMS ANALYSIS METHODS

It can be understood from earlier discussions that there is a great need for an information system which is simple, integrated and structured. Integration can be achieved in all stages of production, functional departments and manufacturing goals. In structured information modelling, simplification takes place both in manufacturing environments and information systems.

An information system is a system designed to support human activity. Beynon-Davies (1993) distinguished between three levels of information systems: informal, formal and technical information systems. Informal information systems consist of systems of norms, values and beliefs. Formal information systems consist of systems of rules and regulations. Technical information systems are systems of data and processes. Although it is mainly formal and technical information systems which are concerned in applications, formal and informal information systems are also to be considered where necessary.

Ashworth and Goodland (1990) claim that there is a basic assumption that systems have an underlying generic data structure which changes very little over

time, although processing requirements may change. Within the manufacturing systems analysis and design method, the data mentioned is structured and modelled from an early stage. The representation of this data structure is checked against the processing and reporting requirements and finally built into the system's architecture.

Since the first use of computers there have already been many changes in what organisations seek to achieve with computer-based information systems and how such information systems are created. Lewis (1994) states that those changes have been realised by many different factors. Any purely technological history of the field would be an inadequate explanation of either past events or present concerns. Lewis (1994) then supports the most common contention that the Information Systems field is a combination of two primary fields, computer science and management, with a large number of supporting disciplines such as statistics, political science, sociology, philosophy, mathematics, engineering.

Bytheway (1994), on the other hand, divides the last 30 years into three eras to explain the evolution of the modelling techniques. In the 1960s the focus was quite technical. Software technology was rapidly improving to write, compile and run computer programmes. Management at this stage had a very blurred vision of what was going on. In the 1970s, computer people realised that computer systems were actually just a part of business systems and then they raised their sights from the level of programming to the level of systems analysis and design methods. Management at this stage focused on the lifecycle approach to systems development which revealed the need to do analysis first, design and programming second, and testing at the end. In the 1980s technology focus was on the methods for business analysis and strategic analysis. Most large companies invested heavily to train their staff in these analysis techniques.



Management's attention was on the strategic issues towards commercial advantages.

Bytheway (1994), moreover, gives a few examples about the acceptance of information systems. Firstly, investments by the British National Health Service for the introduction of standardised data structures at all operational levels so as to provide better management information and a better end product: healthier patients. Another example comes from the national defence bodies in both the UK and in the USA. They are now building models of the information that is used in operational and non-operational systems, so as to provide greater efficiency and effectiveness in their strategic information systems. Bytheway (1994) then asserts that currently software products are increasingly based upon standard models for how businesses should operate, and software producers are planning a whole new generation of sophisticated packages which are at the same time more integrated and more flexible in use.

The logical data analysis model, an integrated quality management system, assists in giving precise (structured) information that is understandable by both the users and facilitators or developers. The logical design could be implemented on any hardware or suitable software, in other words, the logical design is implementation independent.

Moreover almost all of the application failures can be overcome within the time and simplicity of a structured system. This information system mentioned can be built up and can be organised to suit an individual plant's requirements to maximise efficiency in quality and productivity.

## 2.5.2 CURRENT SYSTEMS ANALYSIS METHODS

In order to investigate existing systems and to develop new ones, many methodologies have been developed in several countries. Most of these methodologies break up the total design process into a set of broad phases. Usually, there is not any set of rules to define what these phases are. These phases generally are arbitrary and represent the observations of designers as they go through the process (Wu, 1992, 1994). Some of these methodologies such as GRAI, IDEF and SSADM have gained a stable position as systems analysis methods in the industry. The first work on developing structured Systems Analysis and Design Technique (SADT) was carried out by Ross (1977). Ross and Schoman (1977) state that a structured analysis and design method is an organised sequence of diagrams, each with a supporting text. An overall diagram represents the whole subject. Each lower level diagram shows a limited amount of detail about a well-constrained topic and connects exactly into higher level portions of the model in order to preserve the logical relationship of each component to the total system. A complete SADT model represents the structure of a system through the use of activity diagrams, data diagrams, node lists and data dictionary, of which the first two are graphical tools.

### *Graphical Results and Activities Inter-related (GRAI)*

This methodology, known as the GRAI, was developed by the GRAI Laboratory at the University of Bordeaux in the late 1970s in order to meet the needs of analysis and design of production management systems, particularly decision systems (Ridgway, 1992). Doumeingts (1985) presented a GRAI model, which allowed the design of a specific production management system, organised with a

hierarchy of decentralised decision centres. The GRAI methodology does not represent the system activities, but does analyse the structure of decision centres and flow of information within this structure. The idea behind the methodology is that decisions start and terminate events within a production management system, and these events will determine the performance and operating characteristics of the system. Because production systems are dynamic systems, decisions will be appropriate for given time states (horizons), before the decisions can be adapted. This is reflected by a time period which represents the frequency with which decisions are reviewed. This philosophy is used to produce a GRAI model (McCarthy et al., 1994). A GRAI model represents the operation of each decision centre in terms of their activities, the time frame of operation, the decision made and the information used.

The GRAI methodology consists of two graphical parts; GRAI grid and GRAI net. The GRAI grid is a top down description of the structure of decision centres showing a hierarchy of time horizons and periods as rows in the grid and functions as columns in the grid. The GRAI net relates decisions identified in the GRAI grid to the information and resources required to execute the decision. Decomposition to expose greater detail is accomplished by exploding the overall grid into detail grids (Colquhoun et al., 1993).

GRAI Laboratory continued to develop other methods such as GRAICO, GIM, ECOGRAI to complement the GRAI methodology. GRAICO is used to analyse the lowest levels and acts as an interface between the upper level management function and physical system (Basaglia and Guida, 1994). GIM is a GRAI Integrated Method. It is used to consider simultaneously the decisional, physical and informational aspects of a manufacturing system (Doumeingts et al., 1992).

ECOGRAI is developed for the design of performance measurement systems for industrial organisations (Doumeingts et al., 1992).

### *ICAM Definition (IDEF)*

IDEF is an acronym for the ICAM (Integrated Computer Aided Manufacturing) definition methodology. It was developed for the US Air Force factory modernisation programmes in the early 1980s in order to get maximum benefits of new advanced manufacturing techniques such as CAD and CAM, and to decrease costs and manufacturing complexity. The ICAM programme was formalised with the objective of realising the benefits of integrating the sub-systems of manufacturing (Calquhoun et al., 1993). Basically, IDEF is a modelling methodology specifically developed for use in the modelling of functions of complex and inter related systems. It was derived from the Structural Analysis and Design Technique, SADT (Sarkis and Lin, 1994).

This methodology consists of three basic levels; IDEF0, IDEF1 and IDEF2. IDEF0 is a technique that can be used to specify completely the functional relationships of any manufacturing environment. IDEF1 is used to describe the relationship between data items in the environment, such as what information is currently managed in the organisation, which problems are caused and what information required. IDEF2 deals with a system's dynamic behaviour. It is used for the development of simulation models for a CIM system (Mackulak, 1984, Wu, 1992, 1994).

IDEF0 is a modular top-down approach concentrating on displaying the relationships between different functions in any manufacturing environment. It is

used to produce a function model which is a structured representation of the functions, and the flow paths of information and objects which interrelate those functions. The basic element of an IDEF0 diagram is a box showing inputs, outputs, controls and mechanisms of every process. Different processes are connected to each other using arrows and forming a diagonal row of boxes. The output of a process can either be an input or control of another process. It begins the description process by modelling the system as a whole at the highest level and then decomposing this model level by level to describe each of the sub-functions within the system hierarchy.

*Structured Systems Analysis and Design Method (SSADM) and Manufacturing Systems Analysis and Design (MSAD) Method*

SSADM was originally developed to adopt a standard Information System (IS) development method for use in UK government projects. Some customers, particularly the government and military, insist on the use of this particular methodology. The SSADM method has been adopted as a standard method for the analysis and design of information systems for British Government projects (Tannock, 1992). This gave SSADM a large foothold in the market of structured systems analysis methods. Since then, it has been updated leading to the current version, number 4. It now occupies a dominant market position and is in many ways the de facto standard for systems development (Weaver, 1993).

SSADM is a data driven method. Its main concern is to show the information flows between different processes and where information is stored. The change of information and material flow is shown by defining the processes that change them. The idea of SSADM is based on the fact that a system is based on an

underlying, simple data structure that changes little over time, although processing requirements may change (Ashworth and Goodland, 1990). That static structure of the system can easily be investigated using SSADM. Missing information is the first thing to look for in the diagrams.

Ashworth and Goodland (1990) also point out that the SSADM is a mature method, there is a large amount of flexibility within it, and it is easy to integrate to any other (outside) functional areas. With the help of the SSADM, the entire system development is carried out using a simple methodology which is meant to allow the full complexity of the project to be broken down into manageable portions. The SSADM is comprehensive in taking the designer through the development of a system which is suitable for use with many aspects of an advanced manufacturing system design (Wu, 1992, 1994). It consists of three diagrams; Data Flow Diagrams (DFD), Logical Data Structure (LDS) and Entity Life History (ELH). The DFD shows the flows of data, the processes of the system and where the data is stored. The LDS shows data entities and their relationships in the system. The ELH shows how entities change during their life from creation to deletion.

Another methodology, which is similar to SSADM, is Manufacturing Systems Analysis and Design (MSAD) which was developed for mainly manufacturing environments (Patridge, 1989). The MSAD methodology uses similar nomenclature and techniques to the SSADM's. Appendix 2.1 shows the nomenclature of MSAD based on the lecture notes of Patridge (1989) and of SSADM based on Ashworth and Goodland's book (1990). In conjunction with the SSADM, MSAD methodology employs three techniques to different degrees; Functional Analysis, Data Analysis and Logical Data Structure. Functional Analysis is used to find out external and internal functional areas of the system

concerned. Data Analysis produces Data Flow Diagrams (i.e. Activity Diagrams) and Logical Data Structure shows data entities and their relationships in the system (figure 2.7). Detailed information regarding these techniques can be found in Ashworth and Goodland (1990), Gandoff (1989) and Bytheway (1994). As is seen in figure 2.7 these three analyses would be carried out until the model is stabilised. From the information systems point of view it means that every bit of the information in the model is flowing continuously through the scheme.

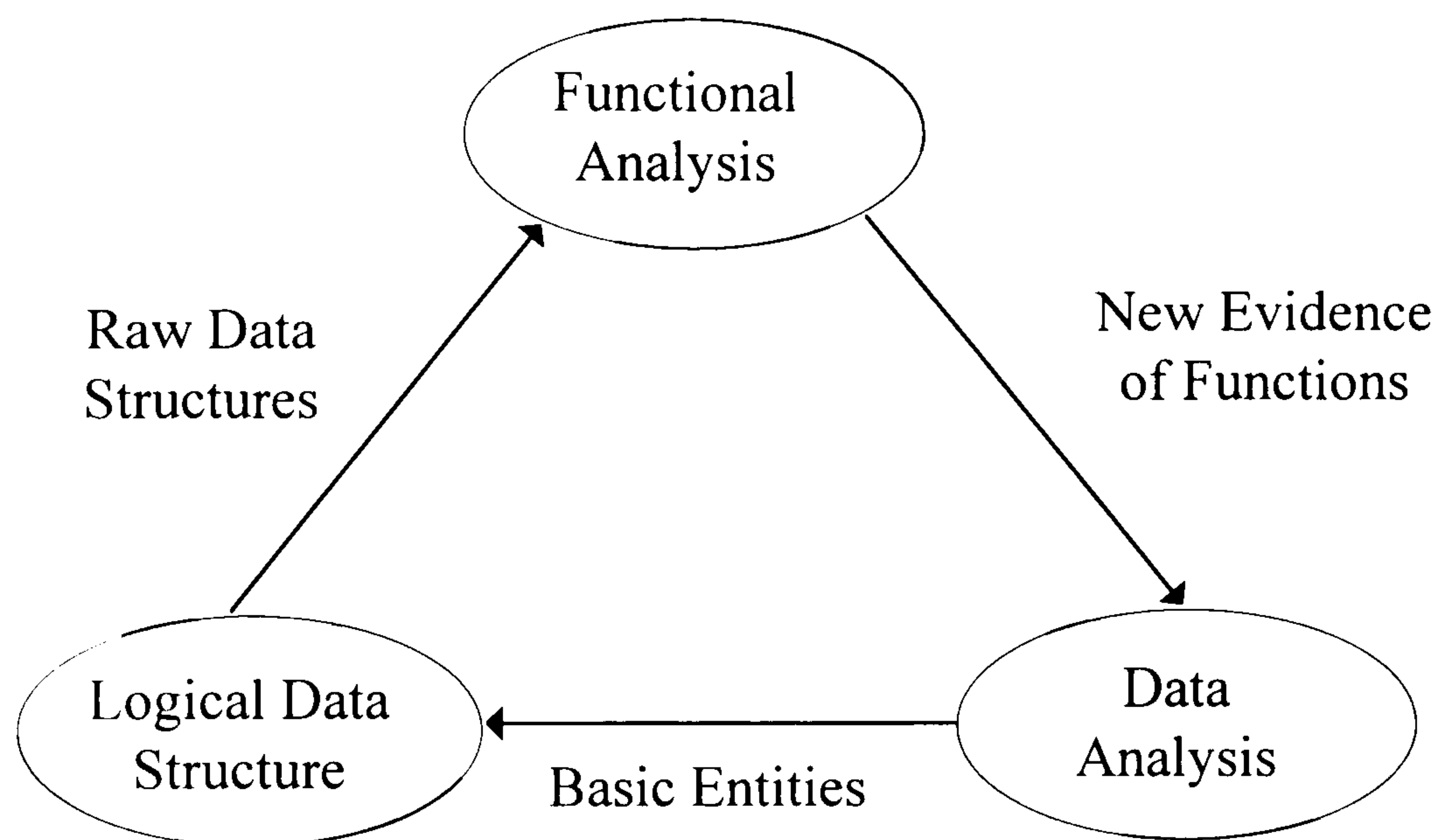


Figure 2.7 The three components of a business modelling method.

## 2.6 DISCUSSION OF THE LITERATURE REVIEW

As is understood throughout the literature survey, TQM has a competitive advantage if it is used in an appropriate manner. TQM has a solid foundation and there are a number of models explaining the philosophy from various angles or in various contexts (Kanji and Asher, 1993, Oakland, 1989, 1993, 1995, Zairi, 1991, Sohal et al., 1991 models). The main elements of the TQM philosophy were given as management commitment, continuous improvement, customer - supplier

chains, integration, quality management systems, team work, tools and techniques, and employee involvement. As is also realised, these elements required a total change in the establishment for a successful implementation. In fact, the need to change is a part of prerequisites for achieving manufacturing excellence. Clemson and Alasya (1992) add two more prerequisites as the need to view the company as a whole, and the need for integration of all functions. Moreover, from the previous implementation cases given, it has been seen that major requirements and weaknesses were the need to re-structure, re-organise and integrate, lack of ownership, poor operational control, lack of business focus based on customer - supplier relationships, employee involvement, and the need to have a quality management system. Successful implementation cases have shown that in order to overcome the difficulties mentioned above, two major requirements were given as to re-structure and re-organise into modules, groups or teams (whichever is convenient), and to achieve integration across the company as much as possible. Within the application framework of the TQM philosophy, these major changes are not easy to make. Numerous reasons can be given for the difficulty of these changes according to various manufacturing environments, but two of them have great importance. First of all, these changes are structural changes and affect every area of operations. It is not an overnight process or decision to be made. Perhaps that is why many TQM practitioners (Zairi, 1991, Kanji and Asher, 1993, Naguib, 1992, Early and Godfrey, 1995, etc.) are talking about on-going process or never ending process. Secondly, TQM is a management philosophy. Although there are numerous models explaining the philosophy and stressing the need to change, there is neither any method, nor system explaining how this consecutive change is to be made on the shop floor. For example, re-organising or re-structuring into groups as a solution may well affect the production management method or a resistance to change may well come from the production management system itself. These considerations have



brought the issue of Group Technology to the fore. It has been shown that most of the TQM implementation weaknesses (i.e. requirements) are eliminated by this production management method. Besides major managerial issues such as re-organisation into groups, integration, flexibility and simplification, Group Technology produces other advantages such as team working, employee involvement, increased morale, job satisfaction, and group responsibility for quality which are also key issues for a successful TQM implementation programme. It has also shown that although GT and TQM are treated as two different techniques and usually are implemented separately, they are similar in strategy and complement each other in various ways. The similarities bring the issue of a new strategy to implement TQM in cellular manufacturing in order to alleviate the TQM implementation weaknesses and enhance the probability of success for both, and provide all the benefits claimed for each of them.

However, current manufacturing systems such as flexible manufacturing systems (FMS), cellular manufacturing (CM), and computer integrated manufacturing are highly complex systems. This complexity results in high costs in the implementation and a high possibility of poor system design. These factors together have increased the risks of manufacturing investments. Hence, good manufacturing systems planning and implementation have become more important than ever before. It is no longer enough that systems planning and implementation is left to those people who directly operate or supervise the operation of these systems. Current flexible and integrated manufacturing environments require an integrated implementation team across different functional areas following a disciplined, structured way of implementation. Structured systems analysis have been successfully used for that purpose (Wu, 1992, 1994).

When faced with a complex situation, an analyst will first attempt to reduce the complexity of these problems involved, so that they are of manageable size and can be dealt with effectively. The traditional analytical approach has been based upon a functional perspective, breaking down problems and then analysing individual functions. Optimisation of these separate functions has not generally resulted in optimum performance of the overall system. This separation has also caused communication and integration problems between the different functions. It is now clear that there is more to their success than simply running all their machines at maximum capacity (Wu, 1992, 1994).

On the other hand, the fundamental idea of systems is to recognise and analyse a situation within an overall perspective. Amongst the current common analysis methodologies (GRAI, IDEF, SSADM, SADT) presented above, GRAI is a decision based method and IDEF is function based while SSADM is a data driven method. GRAI is also the only time dependent method showing the real order of processes in the organisation. GRAI investigates the management decision system involving the top managers to the project giving their commitment to the project. Although it is quick to learn and analysis takes less time than others, it is not a structured design method (Chen et al., 1990). It is more a complementary method rather than a structured analysis method as SSADM or IDEF.

SSADM and IDEF are the most used and best known methods. One reason for this may be the fact that they are both government supported, i.e. SSADM is supported by the UK and IDEF is supported by the US, publicly available and non-profit methods. IDEF has received a lot of attention, but it does not appear to be a methodology in the same sense as SSADM or SADT which is the earliest structured system analysis and design method. IDEF seems to be a collection of

tools and there seems to be little use of later versions than IDEF0 (Wu, 1992). This could be because of the easiness of IDEF0 compared to the later versions.

Despite the fact that SSADM and IDEF seem to substitute each other, SSADM gives the more complete picture of the system than IDEF0. Therefore, it is a generally recommended method for structured systems analysis and is the most complete method having the best support in the UK. The main disadvantage of SSADM is that it takes longer to learn and perform analyses compared to the other methodologies. The MSAD Method has the same principles as the SSADM and concentrates on the manufacturing environment. It gives the same picture as SSADM. Entity Life History diagram of SSADM, here, is produced just before the computer application processes. It is not difficult to understand the ELH diagram due to the logical sequence it follows. It is generally left to the last phase where a specific organisation, which is going to implement the information scheme, is known.

As can be understood, there is not a clear cut distinction between the structured analysis and design methodologies. It is believed that any terminology used is acceptable as long as it is reasonably well-defined, prescriptive and consistent. Therefore, for the requirements presented in the beginning of this section, SSADM together with MSAD seems to be an appropriate method to be used. SSADM together with MSAD methods, through its graphical representations would enable a greater understanding of complex relationships, and presents a simple, integrated and structured information scheme for managing quality in cellular manufacturing environments.

## CHAPTER THREE

### RESEARCH AIM AND METHODOLOGY

#### 3.1 INTRODUCTION

This chapter discusses the research aims and the methodology used in this work. Previous implementation literature, theory and practice are evaluated to show clearly the weaknesses and gaps in the implementation of the TQM philosophy. The omissions and today's requirements of an implementation method are identified with respect to future trends i.e. future integration and information system needs.

Based on the evaluation of weaknesses, the research problem is initially stated as how to cover or satisfy these gaps and omissions. Successful achievements of cellular manufacturing are also given. It will be explained how and what features such an information model should have in order to be used in conjunction with Cellular Manufacturing applications. The methodology of constructing such a model is also illustrated.

Testing and justification of the model is discussed in this chapter and some examples about the testing of this type of soft models are given. Four types of common justification techniques and their measures of successes are explained. Finally, conducting a quality management survey based on similar principles to the model is discussed for the justification of the model.

### 3.2 EVALUATION OF THE LITERATURE ON VARIOUS TQM IMPLEMENTATION METHODS

It is very important to have a sound quality management system. Deming (1975) has estimated that approximately 85% of the variation in quality characteristics is caused by faults in quality management systems. It can thus be said that management systems are responsible for the majority of problems associated with defective products and high costs of production and service. This is also clearly stated earlier in the Carnaud Metalbox Perry Wood case.

On the other hand, with the evolution of TQM, more firms have recognised that material costs can represent 50% (Perkins and Perry, 1992) or more of the total cost of production and are working to make tools available for purchasing which will permit application of objective and measurable quality standards. In developing a quality oriented purchasing system, it is important to balance the benefits of quick results against an approach geared towards yielding long term improvement. Firms now recognise the growing move towards improving quality and they suggest practically breaking quality into components or dimensions, then placing emphasis on those which play the largest role in end product performance (Perkins and Perry, 1992).

In manufacturing environments, Menon (1992) stresses the importance of flexibility and claims that to achieve TQM, factories must be built as modules around a stage of production or a number of closely related operations. Each module should have its own control, though there should be an overall control structure. Each of these modules must be manoeuvrable in terms of its location and relationship to other modules, allowing for rapid changes in design, demand

and a low cost for flexibility. The importance of flexibility and the ability to re-organise into groups were also stressed by many researchers such as Naguib (1992), Kanji and Asher (1993), Oakland (1989, 1993), Burbidge (1989, 1992, 1994c), Wemmerlov and Hyer (1989), and others in the previous chapter. Menon furthermore points out that system integration is another one of the important requirements in the TQM process, as is flexibility. He argues that the existing systems for manufacturing are not very flexible (excluding most of the Japanese companies), and do not attempt to go beyond the quality management philosophy where the customer requirements are met. Many Japanese companies are attempting to be as flexible as possible.

Of the many different practices being applied in the modern manufacturing environment, Dean and Snell (1991) found that advanced manufacturing technology, just-in-time inventory control, and total quality management are clearly dominant. It is acknowledged that the core ideas in TQM include doing things right first time, striving for continuous improvement, and devotion to understanding and meeting customer needs. Associated practices include statistical process control (SPC), quality function deployment (QFD) and Taguchi methods. Quality initiatives were understood initially to be limited to the factory floor, but total quality is now understood to apply to all areas of enterprises. Dean and Snell (1991) propose that each of the practices mentioned above represents a different facet of integrated manufacturing, that is the elimination of barriers between different manufacturing operations. Companies can eliminate these barriers in three ways (1) integration of the stages of production, (2) integration of functional departments and/or (3) integration of manufacturing goals. In each case there are three focal techniques which are believed to facilitate integration, namely, Advanced Manufacturing Technique, Just-In-Time and Total Quality Management. They find the companies, in order to integrate the stages of

production, often create cells i.e. groups. The integration of distinct functions is the second key aspect of integrated manufacturing. Advanced Manufacturing Techniques promote functional integration by linking departments electronically and providing access to common databases. Group Technology is a very sound base towards AMT. Total quality control promotes integration by encouraging people to focus on their internal customers and collaboration. Goal integration is the relationship between the three strategic goals of manufacturing (Dean and Snell, 1991); cost, quality, and lead time. In other words employees must pursue multiple goals simultaneously. This possibility was first appreciated when quality experts recognised that poor quality is more costly than good quality, transcending the common-sense trade-off between quality and cost.

Integrated manufacturing eliminates the barriers (Dean and Snell, 1991) between stages and functions that traditionally permitted employees to carry out their jobs in relative isolation. Groups and individuals may thus become more dependent on each others performance and may be required to work more closely, and poor performance may signal the need for organisational adaptation. This is also seen in the previous cases especially in the case of Xerox MEC by Naguib (1992) and Nothern Telecom by Taheri (1990).

Finally, Dean and Snell (1991) have suggested that the relationship between integrated manufacturing and job design is anything but automatic. Their results create serious doubts about the popular assumption that changes in manufacturing practices lead to widespread changes in job design. For example Goodyer and Spraggett (1994) stress the importance of job design in cellular manufacturing. Actually, the results of the study by Dean and Snell suggest that a number of factors in an organisational context may influence the nature of factory work under the new manufacturing paradigm.

Perry (1992) acknowledges that the acquisition of computer-integrated manufacturing (CIM) systems typically involves a complex ranking and evaluation of objective and subjective factors. Quality dimensions of performance, reliability, conformance, durability, and serviceability are likely to be important factors for most decisions to acquire CIM systems. It also requires a great deal of thought and planning to be successful. Perry (1992) realises that the quality factors are particularly difficult to incorporate into the acquisition process in a consistent and unambiguous fashion. The approach introduced in the article by Perry suggests the development and application of an analytical model for those sizeable CIM system acquisitions where quality factors are likely to be important in making the most cost-effective decision. It is clearly understood that this proposed analytical model is said to be an integrated management information system.

In another elaborate study, Gunasekaran et al. (1994) investigating the applications of Group Technology in advanced manufacturing systems, has concluded that there is a need to develop GT models and techniques to achieve more benefits of various advanced manufacturing systems that include Total Quality Management together with JIT and FMS (Flexible Manufacturing System). One of the advantages of GT is to efficiently store and retrieve information related to recurring problems, thereby reducing the research time for information and eliminating the need to solve the problem again (Hyer and Wemmerlov, 1984).

Therefore, a management information system to implement the TQM philosophy within cellular manufacturing would give three advantageous results. Firstly, such an implementation method would receive the benefits claimed for each of



them, hence increase the probability of their successes. Secondly, as is seen in the previous chapter, some of the TQM implementation difficulties (the need to change, integration, flexibility etc.) would be alleviated. Lastly, the structured systems methodology itself would help to deal with the complexity in the manufacturing environment. It gives structural analysis of the current systems and integrates the two at the manufacturing stages, at the functional level and at the objectives. Simplification and flexibility which are desired in a successful implementation, are also two major advantages of an MIS.

### 3.3 THE RESEARCH PROBLEM

It has been seen that current TQM implementation schemes are lacking in their ability to help managers of businesses establish an integrated TQM system. It is found that the implementation methods produced by researchers have neglected production planning and control activities. The researchers in this field have also been using the conventional tools to come up with such an implementation model. These issues have been the source of many of the problems relating to a successful implementation of TQM. The aim of this research is to produce an implementation model which is structured and integrated. In order to produce such a model, a structured systems analysis and design method will be mainly used. It will be based on the cellular manufacturing i.e. Group Technology, environments to have a sound and integrated initiative.

Upon scrutinising the cases published and discussing the issue with companies, it is found that most companies address similar questions:

*From where should we start to implement TQM?*

*Would an integrated, simple and flexible quality management information implementation model do better in cellular manufacturing?*

*If we change one of our functions in the future, how much will the TQM implementation be affected?*

It is clear that companies wanted to employ TQM but they did not know where to start and what to do. They were afraid of “the next stage” i.e. how would it be integrated with current functions? It has been demonstrated that the research literature on the TQM implementation does not deal with these issues, which are the ones that companies need assistance within a structured and integrated context.

### 3.4 THE NEED FOR A NEW IMPLEMENTATION METHOD

Although Information Technology is being used intensively in manufacturing environments, it has not yet been introduced properly to the solutions of quality management problems. Only very recently, researchers (Anonymous, 1995) have started focusing on the importance of IT in TQM systems.

As mentioned earlier, the role of Information Technologies is becoming very important to produce global analysis and to create new methods for industry. Towards total integration, IT plays a key role in establishing new methods. Information systems modelling techniques have improved rapidly because of the

need to represent the functions and processes that occur within the growing number of increasingly complex manufacturing environments.

Ranky (1990) draws attention to the information systems and states that from a Total Quality Information System design and implementation point of view, systems modelling is of crucial interest. Tannock (1992) on the other hand gives some clear direction for any serious attempt to automate quality systems. He suggests that it should be based on a very clear idea of the systems required, particularly with respect to the implications for a TQM culture. Tanock (1992) also warns that it is too important to be left to the computer systems analyst, so the basic systems design should be carried out by the quality experts, using appropriate systems modelling tools. Currently, quality systems design and revision are usually carried out in a relatively unstructured manner using a variety of common techniques such as written descriptions of procedures and the listing of required functions (including flowcharting for complex information flows).

Gunasekaran et al. (1994) propose the application of GT as a good starting point for the design of FMS, JIT, TQM and CIM. Grouping of parts and machines into cells leads to cost savings in set-up time, labour, tooling, rework, scrap, machine tool maintenance and work-in-progress. Other intangible benefits include highly reliable delivery time, higher management efficiency, lower product throughput time, improved response to customers and better product quality.

Furthermore, as stated by Gundogan and Kay (1995a), factories of the future require integration. A simple integrated implementation study needs to be undertaken to assess how to install the TQM philosophy in cellular manufacturing. These two concepts seem to complement each other. If these two techniques can be merged successfully within an implementation model the result

should be a substantial improvement. Integration here is the major task. The management data within the system should be organised in a way which allows the integration at the highest possible level and should be structured to allow for any changes and future developments.

This model should aim at serving the needs of those managers who must create their own information system. Although most of the information system elements tend to find a place in a feasible computer application, there are some which do not need to be placed in a computerised application (Ashworth and Goodland, 1990). Hence another aim would be to help managers understand and play their part in an integrated environment. Frameworks of the model should show managers how the total quality management system will work, how the functions will be integrated and what the user requirements will be and how such a quality management information model will fit in an overall management structure. The degree to which the model succeeds in developing this level of understanding will determine how appropriate the resulting quality management information system will be.

### 3.5 THE NEW MODEL DEVELOPMENT

In order to decide on which method of information system modelling to use, it was important to define clearly the requirements of the manufacturing environment and customers (users) from an implementation model. As is seen from the previous discussions, in cellular manufacturing environments flexibility, integration and simplicity have great importance. Any such model should firstly satisfy these requirements. The model should be flexible enough to be used as a standalone or as a part of a whole system and it should easily accommodate any

change. It should also be able to be integrated to any other function. Users and facilitators should find it easy to understand and to manage. Customers, both internal and external, should be clearly defined within the model.

Systems analysis and design methods seem to be convenient for development of such an implementation model. Quality can easily be improved if the supplier knows exactly what the customer wants (customer-supplier chain). A natural law of systems, in the same way, states that if the outputs of a system do not satisfy the environment, the inputs will cease (Cusins, 1994). Hence systems analysis and design methods should also satisfy the needs of the customer-supplier chain (both internal and external).

A flowchart showing development stages of the implementation model is given in figure 3.1.

Initially the manufacturing environment, where the implementation model is to be applied, was described in detail as a cellular manufacturing environment. As users and facilitators are rarely computer experts, it is then required to scrutinise the quality management activities, including quality assurance, quality control and inspections. In order to understand this in depth, practical as well as theoretical literature were reviewed and some factory visits have also been made. Having established these QM activities, it is then required to find the gaps and omissions i.e. customer requirements in a formal structured context. Simultaneously, it is also important to understand the future trends in manufacturing or factory management.

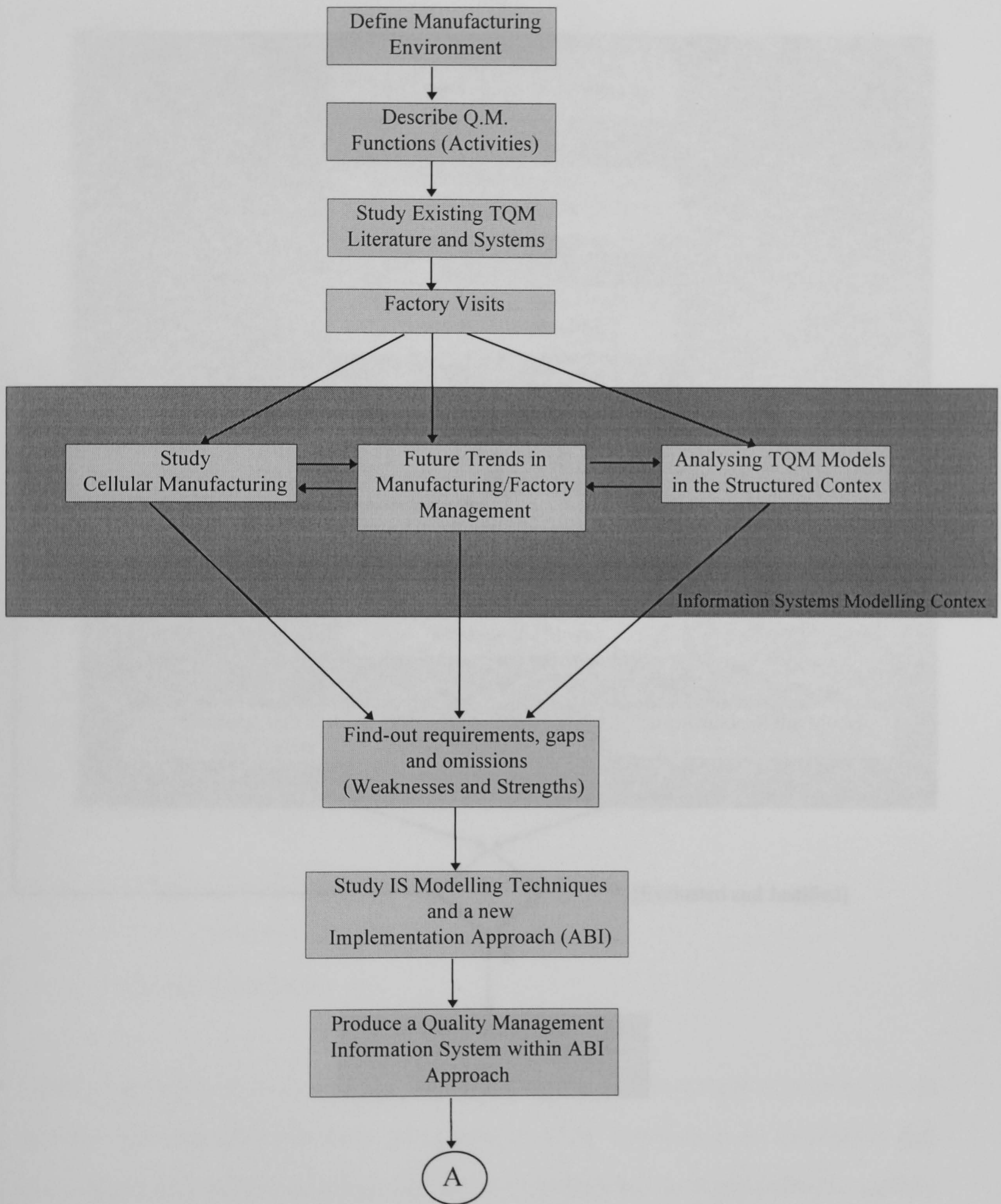


Figure 3.1 Stages of developing an implementation model (continued on next page)

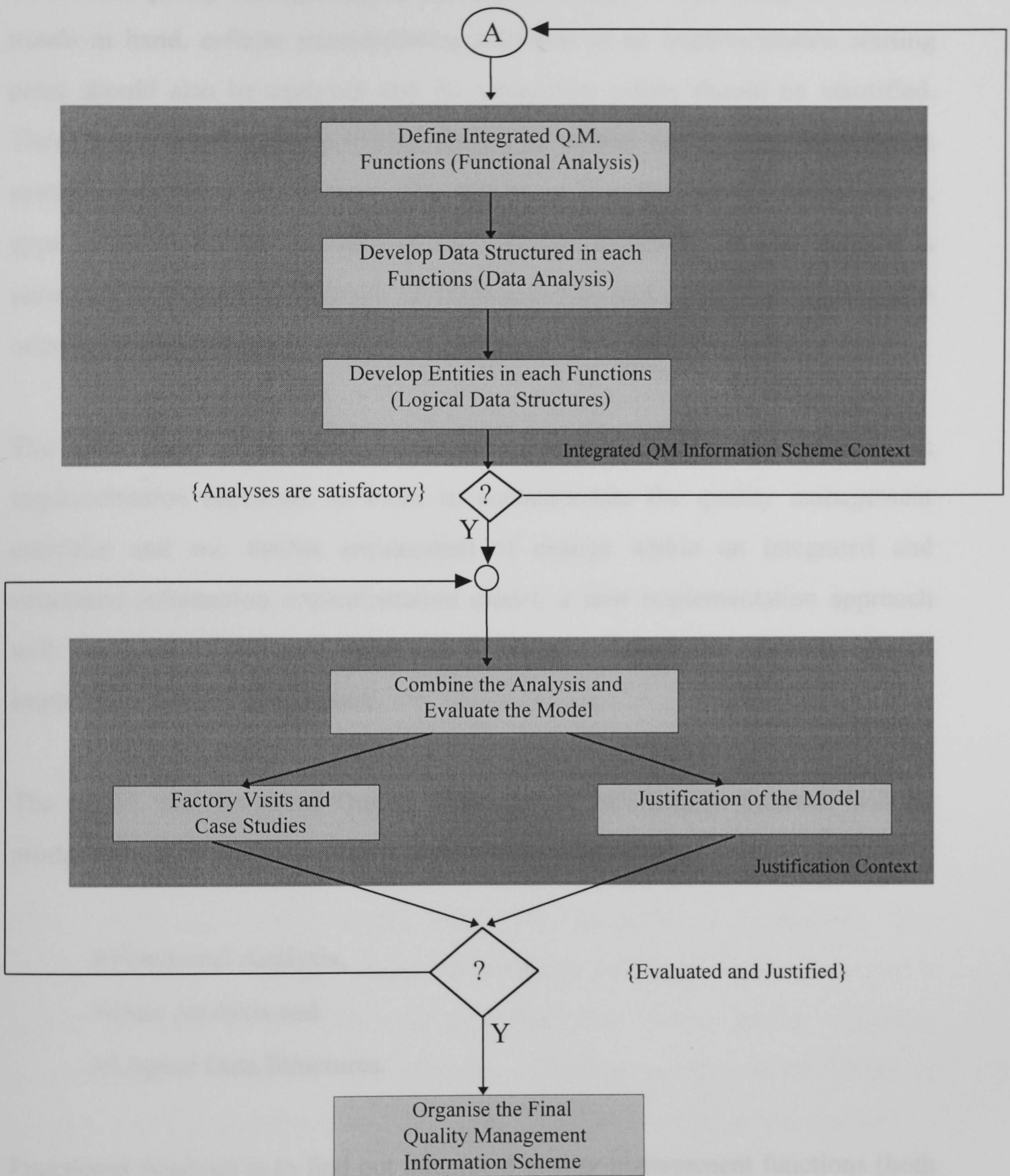


Figure 3.1 Stages of developing an implementation model (continued)

With these quality management activities and manufacturing management future trends in hand, cellular manufacturing activities as an implementation starting point should also be analysed and the interaction points should be identified. These three simultaneous activities should be carried out from an information system modelling point of view. The next stage is to find out the requirements, gaps, weaknesses and strengths of the schemes reviewed. At this stage it is necessary to identify weaknesses of TQM activities and corresponding strengths of cellular manufacturing.

The next stage is to study information systems models and produce an implementation approach. In order to accommodate the quality management activities and any further requirement of change within an integrated and structured information implementation model, a new implementation approach will be used. This new approach is simply called the Activity Based Implementation (ABI) approach.

The model, the Integrated Quality Management Information Scheme, will be produced by the following three analyses mentioned earlier;

- Functional Analysis,
- Data Analysis and
- Logical Data Structures.

Functional Analysis is to find out integrated quality management functions (both internal and external) and their relationships. Data Analysis is to find out a full and refined understanding of the data used and information flows between quality management activities in the system. Logical Data Structures is to find out a full



and refined understanding of the entities and their relationships that are important to an enterprise.

When these three analyses are combined within a logical context, then the next stage is to evaluate. Some factory visits were useful at this stage, firstly to get some more feedback for the model produced, secondly to justify the model through comparisons with Quality Management activities on the shop floor and finally to review it with the experts who have had practical experiences.

Justification or testing was the last stage of the development. Various justification methods will be discussed and carried out.

Finally, the Integrated Quality Management Information Scheme is to be prepared in its final form and the necessary guidelines and conclusions are also to be drawn.

### 3.6 THE CENTRAL HYPOTHESIS

Zairi (1991) argues that quality cannot be purchased as a package. The implementation of TQM is a unique experience to individual organisations and it should be based on a mixture of ideas from the various gurus. A similar conclusion is made by Dale and Lascelles (1990) that because of the variety of starting points and motivations for quality improvement it is not possible to identify a single implementation plan.

The TQM implementation models developed so far have not been based on the strengths of a manufacturing environment to alleviate the weaknesses of their implementation. An inspection of the implementation applications in the previous

sections also reveals the fact that they are mostly isolated or occasional applications. As an analogy, it is far easier to build a house in the country than to re-build a town, and companies that have successfully implemented a management information scheme have failed when attempting to integrate them to form an overall system. Without stretching the analogy too far, a town can arise from uncoordinated and unintegrated construction projects, but only after various alterations can it be made to function as an entirety. This is not to suggest that all applications must be implemented simultaneously, nor that it is absolutely imperative that every application is invariably included in the data processing system. The main objectives of systems analysis are, firstly, to study in depth the aims, problems, gaps and missing bits of existing works i.e. systems, and then to design a system which is open-ended so that further applications can be integrated with it, without duplication of work or records.

Thus the central hypothesis is formulated as follows:

Using the SSADM and MSAD methods an Integrated Quality Management Information Scheme can be developed which

- suits cellular manufacturing environments,
- alleviates current TQM implementation weaknesses through the strengths of cellular manufacturing,
- can easily be structured and integrated with other (non-quality) functions.

In summary, a new integrated quality management implementation model built by a structured systems analysis and design method e.g. MSAD, will do better in

cellular manufacturing because it is able to alleviate current implementation weaknesses.

This hypothesis was addressed and assessed throughout the research.

## 3.7 HYPOTHESIS TESTING

### 3.7.1 INTRODUCTION

Models can be evaluated through a number of dimensions. For example, models can be evaluated for compliance with the structure of the modelling method, for closeness, for completeness and for how well the model represents the domain of the research (Dean et al., 1994).

The main subject of this section is how this new implementation model of an information system is to be justified or tested. Bytheway (1994) remarks that using IT for Quality Management is quite new. Although there is no strict formula to test and come up with some figures, there are two things to be looked at under the title of justification or testing. The first is circularity for goodness, and the second is to get the model reviewed by experts. Nearly the same proposal is made by Perry (1991) and Roes (1993) who consider them as a very useful vehicle to test or validate. Consequently Perry (1991) also argues that there is no standard, universally accepted definition or method which can be used to measure soft models. There are different factors for different models (according to circumstances) to be investigated such as adequacy, consistency, reliability, structuredness, self-descriptiveness, openness to developments.

If the benefits of this type of IT System (i.e. soft models) are studied, it is possible to extract some ideas of justification. For example Semich (1994) groups the information technology (IT) investment benefits into three parts: tangible benefits, intangible benefits and intangible risks. Some of the tangible benefits were given as; improved speed, shortened cycle time, performing 'what-if' analysis. Some of the intangible benefits were identified as; improved reporting, improved analysis, better information request responsiveness. Some intangible risks were given as; staff resistance to change, risk of poor integration, incomplete implementation etc. To quantify these, a score is given to each as to the importance to the organisation of each factor. The factors are rated by a committee made up of people from the affected areas. In that way, an overall score is determined. However, he could not say with what criteria it should be compared, apart from themselves for measuring self-progress of the implementation. What Semich was actually proposing is nearly the same as the proposals made by earlier authors, Bytheway (1994), Perry (1991) and Roes (1993).

Apart from these proposals there are some requirements, weaknesses, gaps and omissions which emerged through the literature review. So the model needs to be tested whether it is satisfying these requirements, alleviating the weaknesses and filling in the gaps and omissions. It might also be looked at various requirements such as information, manpower etc. for an implementation to start (Lijima and Hasegawa, 1992). Moreover, if we can show operators are not solely observers in the system and the proposed model lets them actually be active participators of the change, this will then be another superiority of the model produced as what Taguchi refers to "off-line quality improvement" (Hahn, 1993).

Of course the best method of testing would be the real application in different manufacturing environments, which is beyond the scope of the research. On the other hand, it would be a common mistake to treat such a model according to profit and cost targets as the main business priorities (Dale and Cooper. 1994). Using simulation is also out of the options because of absence of data, criteria or a previous example to compare with. Absence of comparative data is a restriction for mainly numerical justifications. However, as could be understood, there are other justification and testing methods which are emerged throughout the literature survey. These are the validation during the modelling session, goodness of the model, structured walkthroughs and expert reviews. Finally, an industrial survey based on the basic principles of the model would be very helpful for the purpose of justification and testing. These methods encompass almost all of the suggestions and are expected to point to a degree of a success for the implementation model. These opportunities are now discussed in detail.

### 3.7.2 VALIDATION DURING THE MODELLING SESSION

Validation can be carried out, to a large extent, during the modelling session (Dean at al. 1994). This occurs in several ways. The model is discussed by experts during the model development. Elements, gaps and omissions are identified in the current implementations and are considered in the development of the model. These elements are obtained from the literature survey, case studies and real applications. So it can be checked whether these elements identified are included in the model. Inclusion of these elements are expected to avoid a failure and increase the probability of a successful implementation. Because these elements are identified throughout a large scale literature survey, the more elements used in the development, the higher the probability of success will be.

Furthermore, there are quality system requirements identified by such quality standards (i.e. systems) as ISO9000 and BS5750. TQM and these standards are promoted by government bodies and many firms throughout the world. Ho (1993) argues that for companies which are applying TQM, installing ISO9000 is relatively straightforward. It would then be wise to make it certain that the main related elements of these standards are considered in the model. This consideration will not make the model an ISO9000 system but will make it a good base to accommodate these standards in the future if it is required. It will also improve the strength of the model by including the main system requirements of these standards.

### 3.7.3 GOODNESS OF THE MODEL

Goodness is one of the important factors (Bytheway, 1994) to be considered within the context of justification or testing. It is actually the circularity of information through the scheme. There are three techniques which will be found in the systems analysis and design methods. First, Functional Analysis which produces a whole understanding of the functions within a system and provides data structure to the next technique called Data Analysis. In the same way, Data Analysis produces a full and refined understanding of the data used in a system and provides raw input to the process of a Logical Data Structure. A Logical Data Structure produces a full and refined understanding of the entities which are important to an enterprise and provides input to the function analysis. Hence it can be seen in this way that there is a **circular relationship** between the three techniques. It is therefore possible to start with any of the three techniques and proceed around the circle until the model has established itself and stabilised. In other words, every piece of information should flow through the scheme to

complete a circularity for the goodness. So to establish this circularity is a way of testing the **goodness** of the model.

In the traditional methods of developing information models, the existing manual systems were simply transferred to a computer system. Now, it is very important to establish a logical flow of information, before IT resources can be employed (Qurashi et al. 1995). Hence, it can be checked whether every piece of information is flowing through the scheme, without any redundancy, thus achieving circularity. The circularity of information is expected to minimise the risk of leaving gaps in the information flow, minimise the risk of poor integration and improve analysis and reporting facilities of the structured model. A high level of goodness, which means each bit of information is circling through the model, therefore, will increase the probability of success.

#### 3.7.4 STRUCTURED WALKTHROUGHS AND EXPERT REVIEWS

This is another one of the major justification techniques of soft models. Systems should be developed and checked collectively with the people who are potential users and who are experts on the subjects (Perry, 1991, Bytheway, 1994, Dale, 1994, Qurashi et al., 1995). Otherwise, there would be huge isolated islands of very useful information within an organisation (Ziarati and Khataee, 1994, Ziarati et al., 1995). Intuition and evaluation are used to arrive at a conclusion based primarily on the reviewer's own training and experience. Overall vision of experts also provides the capability to identify technical gaps in the model.

Structured walkthroughs i.e. manual simulation, were realised by going through the model, developing or evaluating the points which were found to be

ambiguous. This work will be realised from mainly two points of view: quality management processes and Information Systems.

Some company visits have also been made within this context to have the comments of experts situated in these places. The functional experts of the organisations played a key role in process walkthroughs and interviews.

These reviews generally produced a series of changes that needed to be made to the model. Over time, the model gradually stabilises and it has become more easy and comfortable with the representation. These reviews are expected to contribute to the progress and to direct the model to a successful course of implementation.

### 3.7.5 QUALITY MANAGEMENT SURVEY 1995

As well as interviews, questionnaires are also used between major modelling events as part of the justification or validation process (Perry, 1991). Within the research context a quality management survey would be very useful to find out future trends and the implementation difficulties of current implementation schemes. Furthermore, the following issues can be useful to justify the model produced:

- assessing the current quality management implementations from a systems analysis and design point of view.
  
- drawing conclusions about their successes.



- discovering the level of integration with the other production management schemes,
- speculating on their effects on future developments in manufacturing.
- determining weaknesses and strengths of the current implementation schemes and
- analysing their TQM experiences and future expectations.

All of these elements of a survey would be evaluated within the context of the model produced. Findings and conclusions would be compared with the model produced for the justification purposes. Such an industrial survey will justify practicality and applicability of the model developed. On the other hand, face to face interviews will alleviate the probability of having false data and the danger of misinterpreting them. It is expected to find parallels between the survey results and the main principles of the model. The parallels found will measure the degree of success for the Integrated Quality Management Information Scheme.

## **CHAPTER FOUR**

### **BUILDING THE INTEGRATED QUALITY MANAGEMENT INFORMATION MODEL**

#### **4.1 INTRODUCTION TO THE MODEL**

As is understood from the previous discussions, the changing environments towards the factory of the future require integration. A simple integrated implementation study needs to be undertaken to determine how to install the TQM philosophy in cellular manufacturing. These two concepts seem to complement each other and if these two techniques can be merged successfully within an implementation model, the result should be a substantial improvement.

The major task here is integration. The management data within the system should be organised in such a way to allow integration at the highest possible level and to allow for any changes and future developments. Features which such a scheme gives to management include integration to other systems, delivery of information about quality improvement, and different information about continuous improvement.

In the second section of this chapter, the development of a new implementation approach called activity based implementation, is explained. It is necessary to have a new implementation approach for such an integrated, structured and systematic scheme. This approach also contributes to the advantages of systematic development.

In the third section, the model. i.e. the integrated quality management information scheme, has been built up using circular relationship (see figure 2.7) amongst Functional Analysis, Data Analysis and Logical Data Structures. Having developed the new implementation approach, ABI, the Functional Analysis has been carried out. Then Data Analysis was used to produce all activity diagrams at each level. Functional requirements together with user requirements have been described within this context. In order to come up with new raw data structures, Logical Data Structures has been undertaken for each functional area. This circular development procedure of the model has been used until the scheme was established within the quality management activities.

Finally, a further integration example is given to show that the scheme is capable of being further established throughout the company from suppliers to the customers.

## 4.2 THE NEW ACTIVITY BASED IMPLEMENTATION APPROACH

Discussions of various earlier applications on models showed us that they have more or less four common tactical phases to follow.

Analyse the current situation: Identify and collect information about the areas where implementation will take place.

Senior or top management commitment: Get top management commitment and make sure that management is prepared to adopt the requirements all the time.

Develop a scheme: Based on the previous phases, identify and resolve quality issues by involving all management and supervision in an appropriate scheme.

Evaluations (review and critical analysis): Obtain information to assess the application and make the necessary changes resulting in continuous improvements.

However, in addition, the perception of quality is moving from a traditional quality philosophy towards TQM which could lead to total integration. Traditional quality philosophy focuses on correcting mistakes after they have been made (Ranky, 1990). This philosophy allows mistakes to be made. Quality is generally sacrificed for increased volume and productivity. In broad terms, a traditional quality philosophy is a test and fix philosophy.

By comparison, total quality involves every aspect of the organisation i.e. from suppliers to customer satisfaction. It is a preventive system and aims towards zero defects (six sigma) which would be achieved gradually, not instantly. Six sigma means that products and processes will experience only 3.4 defects per million opportunities or 99.99966 percent good (DSEG, 1992). The traditional role of the quality control manager also moves more from administrator to leader and co-ordinator. In addition to these, the scope of quality control management moves from a departmental to full organisational approach. This philosophy has been carried out in Japan for some time with the move to company wide quality control (CWQC) which is identical to TQM. The total quality understanding is now resulting in the requirements of new management concepts.

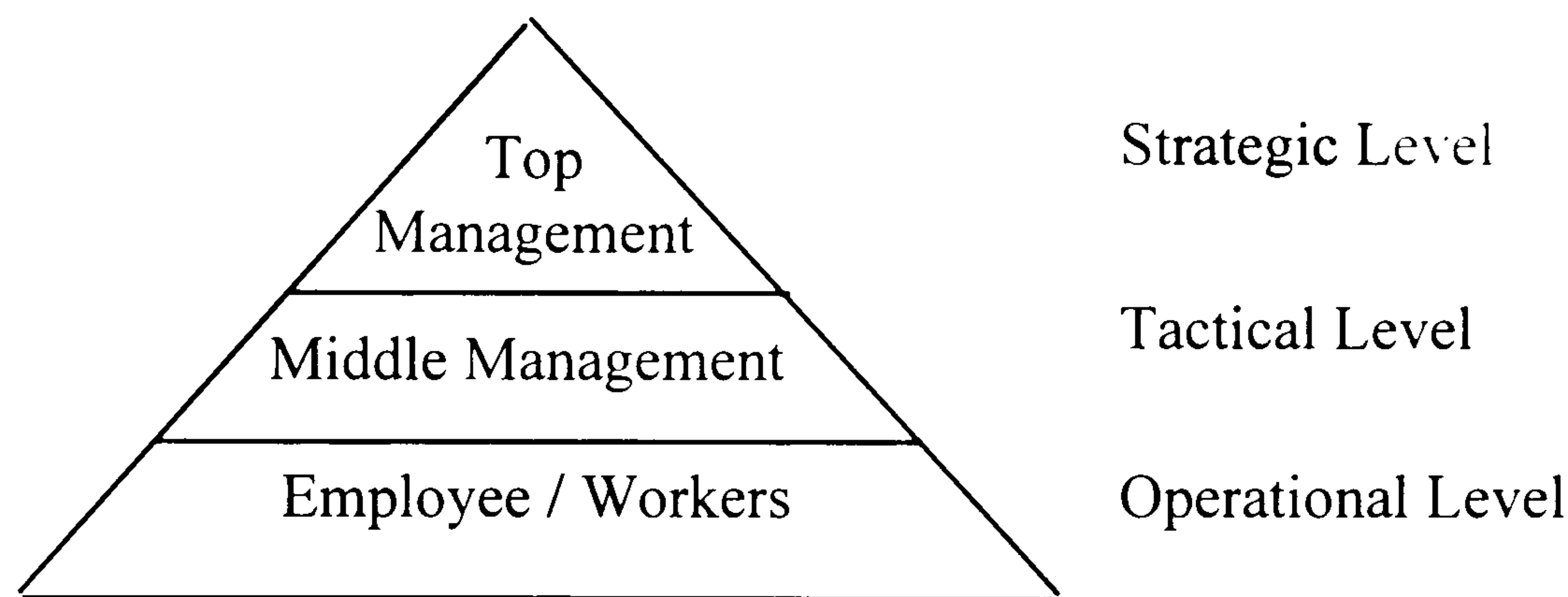


Figure 4.1 The traditional management pyramid

Dahlgaard et al. (1994), for example, criticises traditional western forms of management which divide responsibility for decisions into strategic, tactical and operational levels i.e. the traditional management pyramid as shown in figure 4.1. They propose a new management pyramid which they have claimed takes into account the various criticism of the traditional western management. It is founded on total commitment of management. Figure 4.2 illustrates four sides of their proposed pyramid. These are :

- focus on the customer and the employee,
- focus on facts,
- continuous improvement and
- everybody`s participation.

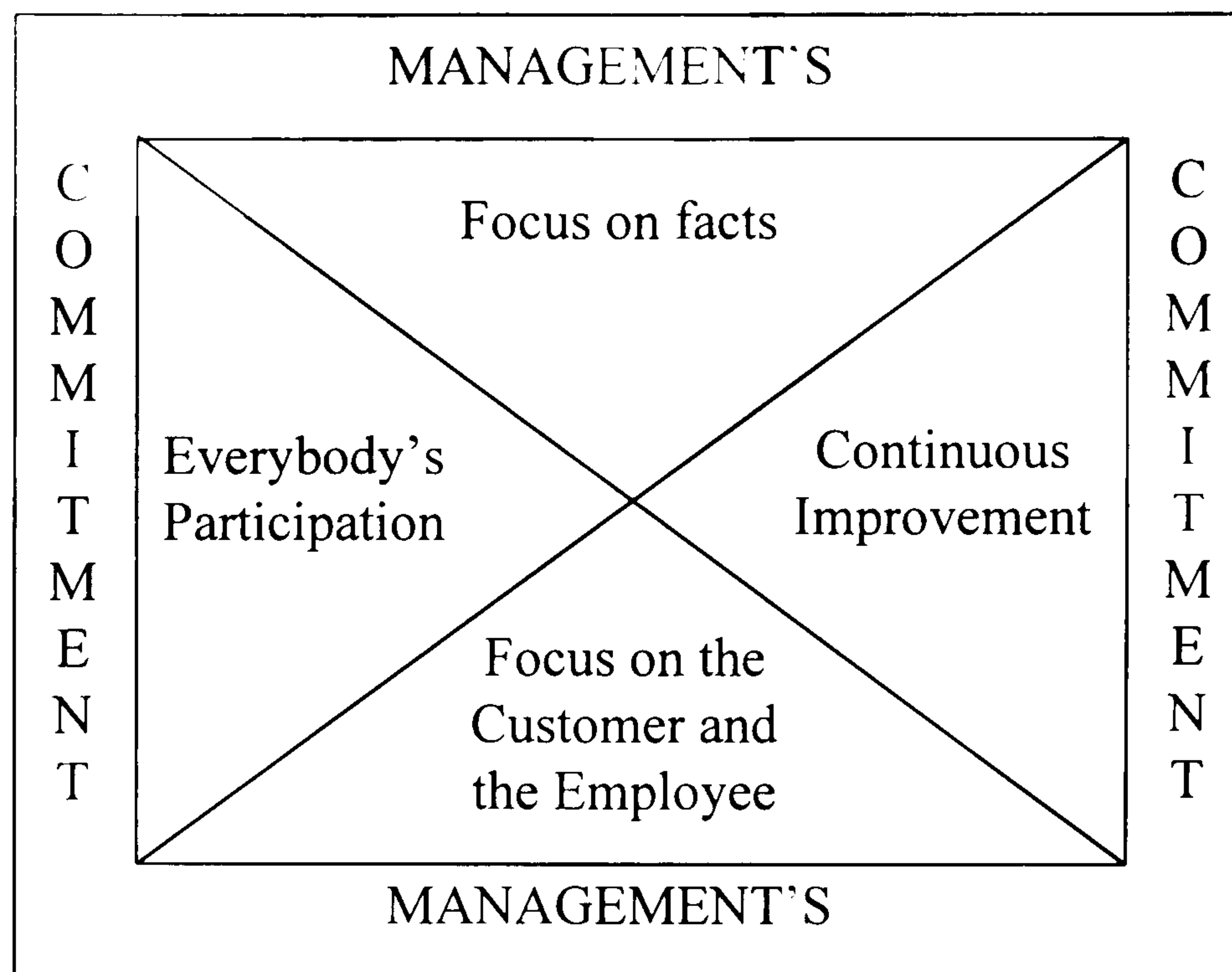


Figure 4.2 New management pyramid constructed by Dahlgaard et al. (1994)

They claim that both answer and solution of quality problems depend on which management pyramid is being adopted. The old form is being regarded as outdated.

Hence, the TQM philosophy has brought the issue of changing traditional management forms. Likewise, changes in the traditional organisational structures are also on the agenda of the new forms of management. Besterfield et al. (1995) argues that the traditional organisational structure does not foster communications across the organisation but rather only up the chain of command. In the traditional organisational structure, each level in the hierarchy performs duties that are organised from the level above, and it causes a lack of flexibility. Skrabec (1994) suggests that the quality control department must be integrated with a total organisational approach towards quality and must give up any form of quality ownership, which rests with all employees. Skrabec (1994)

gives an example of a generic quality control organisation and functions which is shown in figure 4.3.

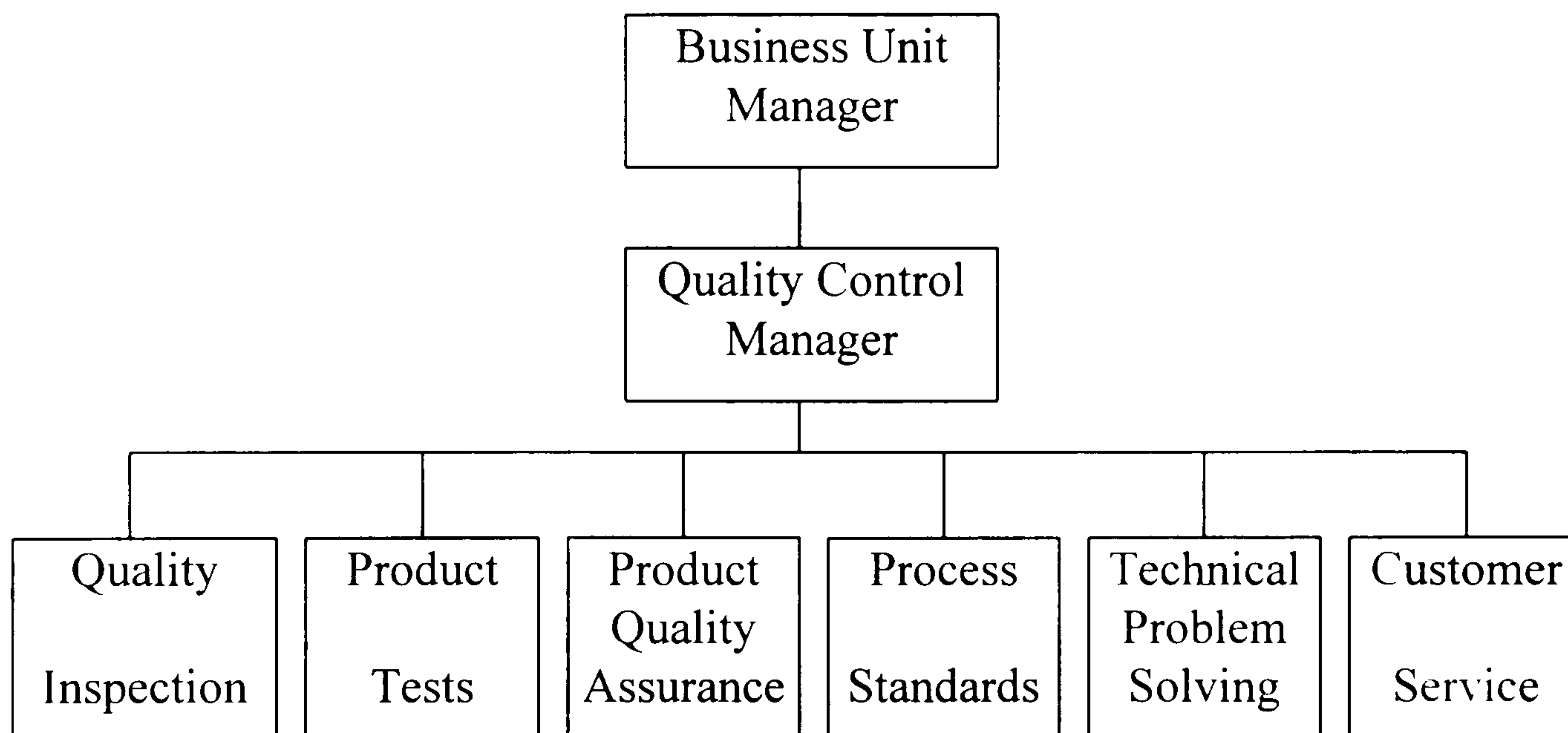


Figure 4.3 A generic quality control organisation

With respect to the traditional quality control, TQM is participative, employee driven and employee owned. Skrabec (1994) explains the inadequacy of this generic type of organisation and gives a cross-functional team approach to tackle TQM. This approach is described in two parts as is shown in figure 4.4. The first part is about inputs and the second part is about functional outputs. All the processes in the functional outputs are to satisfy customers. Although this approach encompasses only quality management functions, the total integration largely depends on the role of leadership and open involvement of the employees. This is the major difference from traditional approaches.

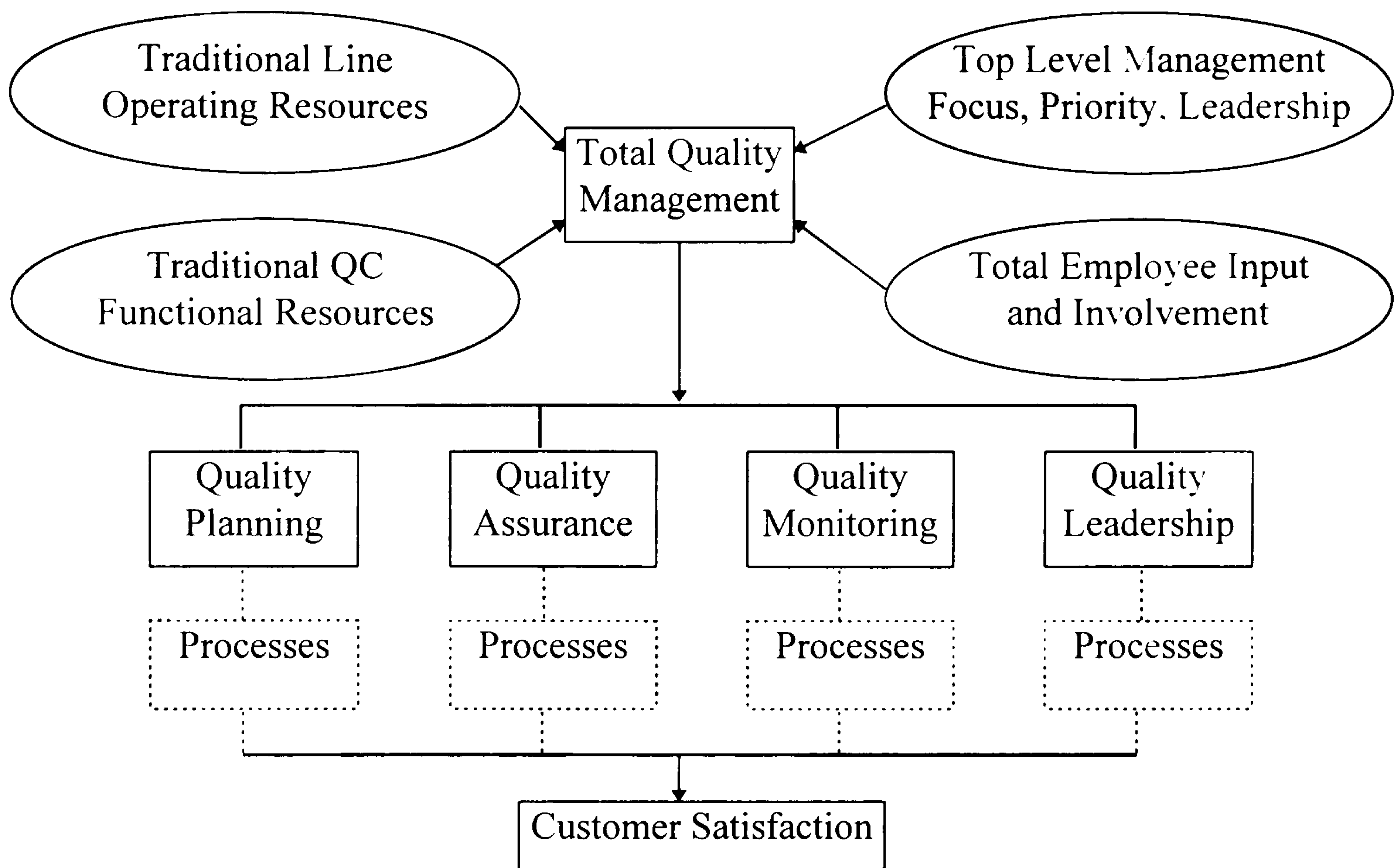


Figure 4.4 A cross-functional quality control organisation

In the implementation phases, new forms of management mentioned above and organisational understandings are not being applied well. This is because generic implementation approaches for these new quality teachings are still dominating the field. In order to get a better solution in the generic implementation, numerous steps should be identified clearly. The more steps are clearly identified, the better the solution is likely to be. Every definitive step fills a gap of probable failure, and these steps are not easily established. It requires the study of many applications and models to identify a new step which will fill in a gap of common failure. So the result of such an approach would be a company or organisation specific solution to implement the TQM philosophy.

In the generic approaches, the questions of “What” are well satisfied. This is a normal procedure of a generic approach i.e. to find out new steps in the



implementation and define them clearly. Although the TQM philosophy requires continuous improvement, a generic approach would discuss the question of how long a TQM programme should last (Oakland, 1989, Zairi, 1991). It is like assessing a discrete function as if it is a continuous function. What happens is that, since it is a discrete function, at every stage of application or implementation, the situation is to be re-described and a very likely question of “What is now?” or “What is next?” is to be answered.

In a very dynamic environment, such as manufacturing, to follow a generic approach may require high attention, commitment and stress as a whole. It is perhaps this approach which makes Zairi (1991) say that a weakness in one area of his TQM model (the building blocks) will have a disastrous effect on the TQM programme as a whole, which makes Oakland (1989), and Kanji and Asher (1993) talk about total quality paralysis and disillusionment, and which makes Naguib (1992) say that TQM is being implemented in the Xerox-MEC operations as a process not as a programme with a beginning and end.

Analysis of these applications and models, from the implementation point of view, leads to three structural pillars for a simple integrated successful implementation model. These are integration, circularity (i.e. implementation flexibility) and structuredness.

**Integration:** Although there are a lot of programmes to implement TQM, there are also a lot of cross-functional and cross-departmental problems associated with them. Additionally, quite a number of quality improvement issues take place outside the quality management functions. For example a quality improvement issue may well take place in the product design and engineering functions which are beyond the quality management functions. Furthermore changing

environments towards the factory of the future and perfection require integration. Kerr (1991) describes the integration of design and manufacture as an objective that is being increasingly pursued world-wide. Deasley (1994) argues that integration is spearheading another industrial revolution and is the future of manufacturing.

**Circularity and Implementation Flexibility:** One of the major problems in TQM applications is to decide how and where to start. Starting a TQM programme is difficult. In starting a TQM programme, Clark (1991) suggests that the strategy adopted should be jointly developed, so everyone has a sense of ownership in the actions taken. Similarly, Bertram (1991) points out that the traditional top-down hierarchical style was founded during the industrial revolution on the disciplined approach, but TQM is based on a more open style of management. It promotes and encourages the involvement of every employee in a programme of continuous improvement.

In order to get everyone involved, the information should flow in a way that everyone can contribute his or her part. There should be an implementation flexibility, to a certain degree, allowing users to start wherever they would like to start. Once started it should eventually lead to a perfect circle where eventually all the requirements of the TQM philosophy are met. This circle clearly involves the top management, middle-management and operators. It is a circular information which is flowing throughout these three levels for continuous improvement. Furthermore, because the scheme is produced within the cellular manufacturing environments, it will also be possible to start the implementation with any cell that seems convenient.

**Structuredness:** Structured systems easily adopt themselves to any changes in an organisation (Ashworth and Goodland, 1990). This is because of the specific requirements of TQM to be defined or described in a way that each function should consist of small well-defined activities which are in a specific sequence and integrated to each other. These activities should be as precise as possible to let both users and developers understand them. The structuredness lets any model be fitted into any level of industry for implementation. Thus a structured model of implementation is expected not to be halted if a change occurs in process, product or organisation.

Structured analysis provides a clear requirement statement that everyone can understand and is a sound base for subsequent design and implementation (Ashworth and Goodland, 1990). Structuredness increases users' perception of methods with the help of various non-technical diagrammatic techniques. It spreads the experience throughout the scheme and helps the scheme to meet the user requirements before it is built.

These three corner stones are the three main pillars of a new implementation approach. It is important to set a new approach rather than having a generic one. Bearing in mind the above discussion, this approach is simply described as Activity Based Implementation (ABI). The ABI approach concentrates on the solution of 'hows', rather than concentrating on 'whats', and its dynamic elements are illustrated in figure 4.5. This approach targets data management activities to simplify, then to integrate to each other, to develop and to have them in control. It is the information which flows through these activities which must be simplified, integrated and controlled. It is also possible to deal with each independent small activity in its own context. Any problem appearing will be

within one of these well-defined activities. It can easily be isolated, so as not to affect others, and then be tackled.

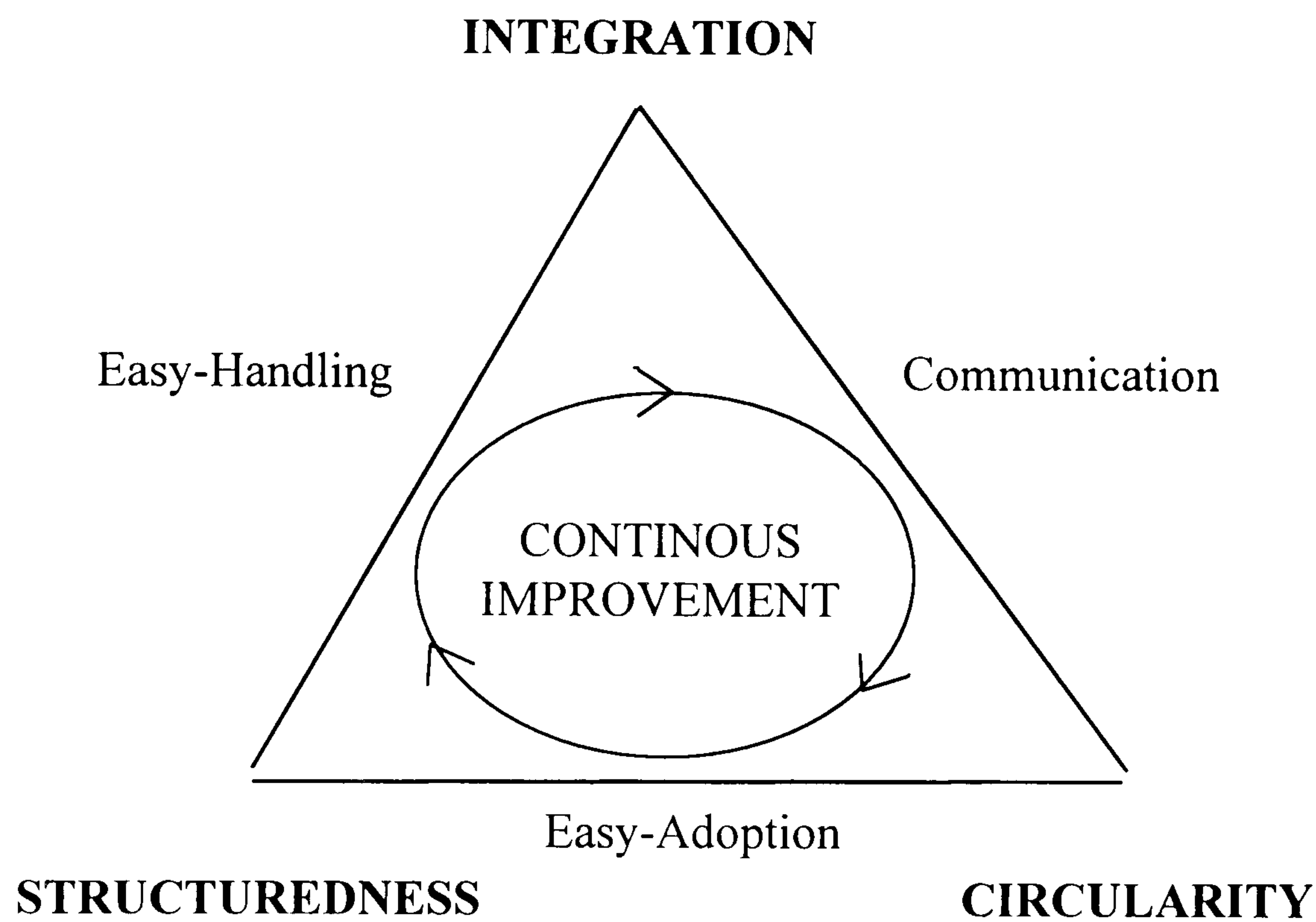


Figure 4.5 The dynamic elements of the ABI approach

Continuous improvement is at the heart of the approach. From the information systems point of view, for each activity there are inputs and outputs which can be seen as suppliers and customers for the specific activity. So, the optimisation of each activity towards the customer satisfaction will create a continuous improvement chain of information.

Furthermore, to tie the three main pillars of the ABI approach to each other in the management context, it is required to have three conventions namely communication, easy adoption and easy handling. These main pillars associated

with the three required ties constitute the breakthrough triangle i.e. figure 4.5. Communication tying integration and circularity makes information flow through the scheme to support quality improvement. In the model, wherever an application starts it goes (communicates) through the integrated scheme. The ABI approach makes employees achieve continuous improvement through circularity and integration. In many applications, there are lots of bits of information left idle as unprocessed, and they should be accommodated within the implementation model with the right communication. Easy adoption is the key factor of the model between the structuredness and circularity pillars. The structured and circular model is easily adaptable to having implementation flexibility.

The integrated and structured model is also easily handled to keep up the ABI approach and to establish cross-functional activities. Each small independent activity of the scheme is well-defined, structured and integrated. These activities consist of cross-functional information necessary for its processes. These features allow each information activity to be easily handled towards continuous improvement. Finally, continuous improvement makes this triangle flow or work as required and planned. Continuous improvement within this approach is sustained by integration, circularity and structuredness together with their associates. In order to develop this new implementation model under the ABI approach, one of the business modelling methods, the Manufacturing Systems Analysis and Design method seemed to be useful in three aspects: it analyses and simplifies the data, integrates the functions, and makes the functions as flexible as possible for any application (Ashworth and Goodland, 1990; Gandoff, 1989).

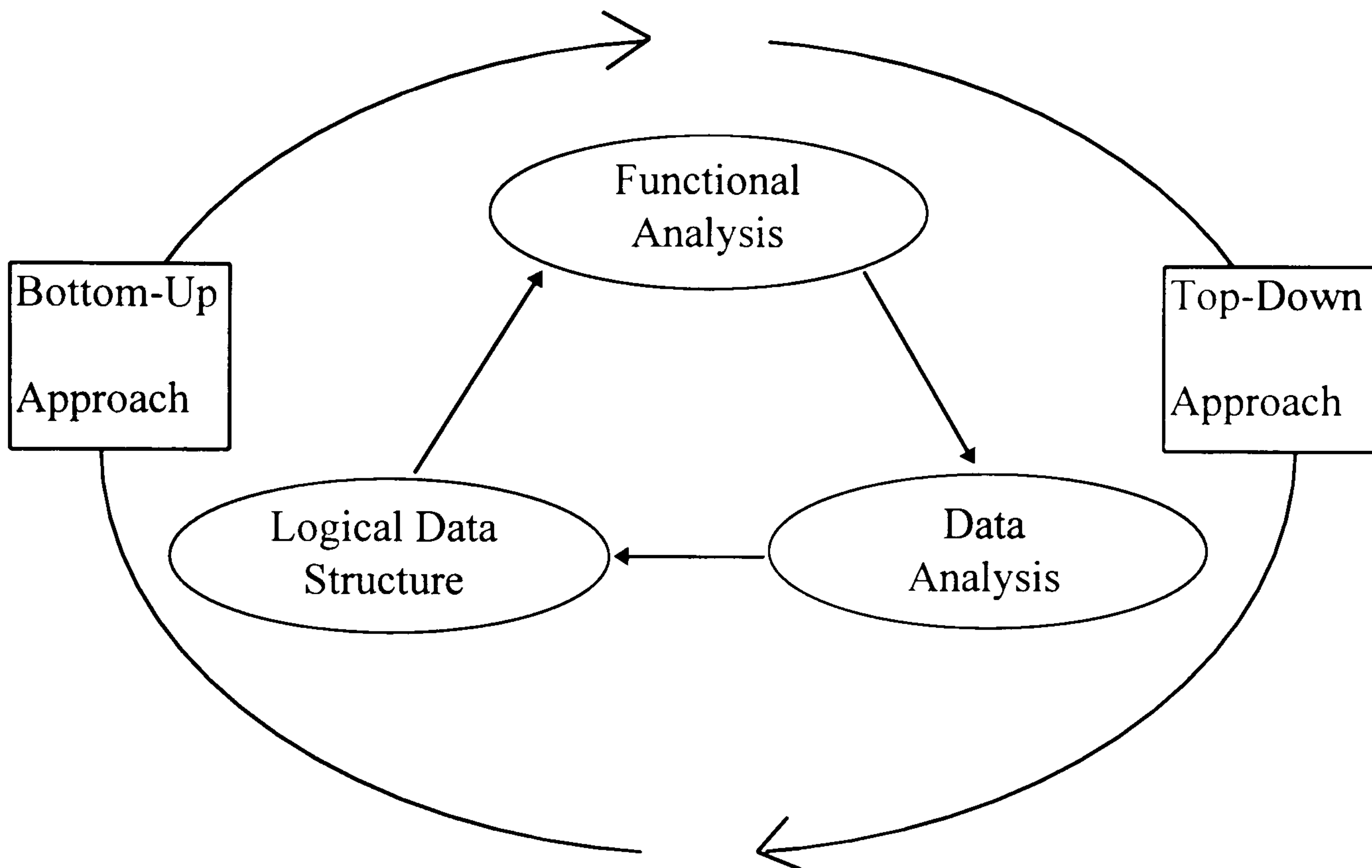


Figure 4.6 Continuous top down - bottom up approach

#### 4.3 THE INTEGRATED QUALITY MANAGEMENT INFORMATION SCHEME

The three business modelling techniques mentioned earlier i.e. Functional Analysis, Data Analysis, and Logical Data Structures, are the main tools to develop the implementation scheme. The circular relationship amongst them can also be explained in terms of top-down and bottom-up approaches. In this case top-down and bottom-up approaches are to be used sequentially and in a continuous manner. Figure 4.6 shows that, at the top, internal and external functional areas of quality management activities are determined and then all activities in each function are structured level by level down to the shop floor. The bottom-up process starts by finding entities within each of the functional areas. Logical Data Structure analysis integrates and inter-relates these entities to

each other to find out new raw data structures. According to new data structures, functional areas are modified and then once again top-down operations start. This process continues until no more structural modification is required. After the implementation scheme is produced, any change requirements will be accommodated within the structured and integrated activities. The three cornerstones of the ABI approach namely integration, circularity and structuredness are used at each stage of development of the model.

In the identification of functional areas, each quality management functional area has been identified with its related other functional areas. Relations amongst these functions have been described in order to establish an integration at the top level. Structures of the main functions have also been set up with respect to quality management activities. The main input to the scheme comes from an external function namely the top management. Information of it flows through the main functions and goes back to its origin completing its circle.

In the Data Flow Diagrams (i.e. Activity Diagrams), quality management information is structured at three levels namely overall, functional and user levels. At the top level, all the functional areas are structured and integrated to each other to allow quality management information to complete its circularity. A context boundary is also given to distinguish quality management functional areas from the others. Then, each quality management functional area is structured down to user level in the same way keeping up the integration and circularity. Thus, the whole activity diagrams represent the implementation model. Having produced the implementation model, the Logical Data Structure analysis is performed to come up with new raw data structures to further evaluate the whole model and establish relationships between data entities.

### 4.3.1 IDENTIFICATION OF FUNCTIONAL AREAS

Quality management functional requirements are divided into two groups: external functional areas and internal functional areas. External functional areas are the external functions or departments that quality management functions have relations with. These relationships with external functions can be one way i.e. delivering or receiving information, or mutual i.e. delivering and receiving information.

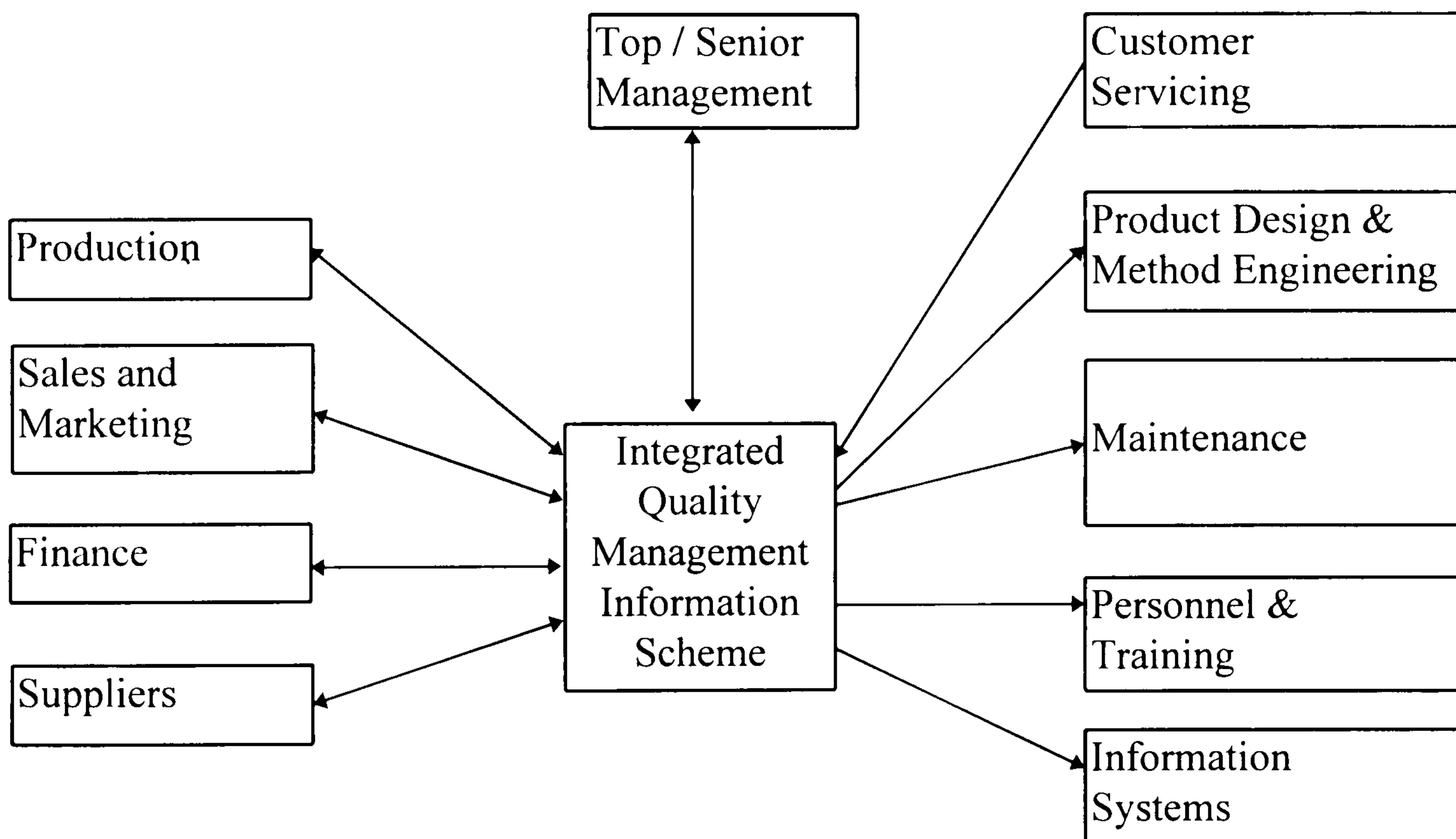


Figure 4.7 External functional relations of The Integrated Quality Management Information Scheme

The following functions i.e. departments can be related to quality management.

- Production
- Sales and Marketing



- Suppliers
- Finance
- Customer Servicing
- Product Design and Method Engineering
- Maintenance
- Personnel and Training
- Information Systems Department

Figure 4.7 shows the information flow between these functions and the Integrated Quality Management (IQM) scheme. As is seen in the figure, the IQM scheme has a mutual relationship with Production, Sales and Marketing, Suppliers and Finance. It receives feedback from Customer Servicing about the product and services being delivered (customer satisfaction). It informs Product Design and Method Engineering, Maintenance, Personnel and Training, and Information Systems Department about the findings through its operations. These outside relationships are very important. Quality is everyone's responsibility. Many quality improvements may well take place outside the quality management area. In this case it is clearly required to define the relationship and information flowing amongst them.

Having the external boundary of the scheme specified, three internal functional areas have been identified within cellular manufacturing. These three areas are:

- Quality Management (Data Analysis),
- Cellular Operations and
- Auditing.

However, in cellular operations there are two functions to be considered from the quality management information systems point of view.

These are:

- Shop Floor operations and
- Corrective Actions.

Hence, there are actually four main functional areas in the quality management system. As is seen in figure 4.8, these are:

- Quality Management (Data Analysis),
- Shop Floor Operations,
- Corrective Actions and
- Auditing.

#### *Quality Management (Data Analysis)*

All data analyses, reports, system works i.e. all office works are carried out within the quality management (Data Analysis) activities. Corporate quality policy or commitment from the top management is detailed out within the quality management function to achieve quality objectives at each level of management. Quality policy is the main input to this functional area. In the same way the main output, quality management reports, go to the top management. It is understood that this is the main quality improvement loop at the highest level. Detailing out the messages of top management down to the shop floor or carrying the messages of the shop floor up to the senior management is again carried out within the quality management functional area.

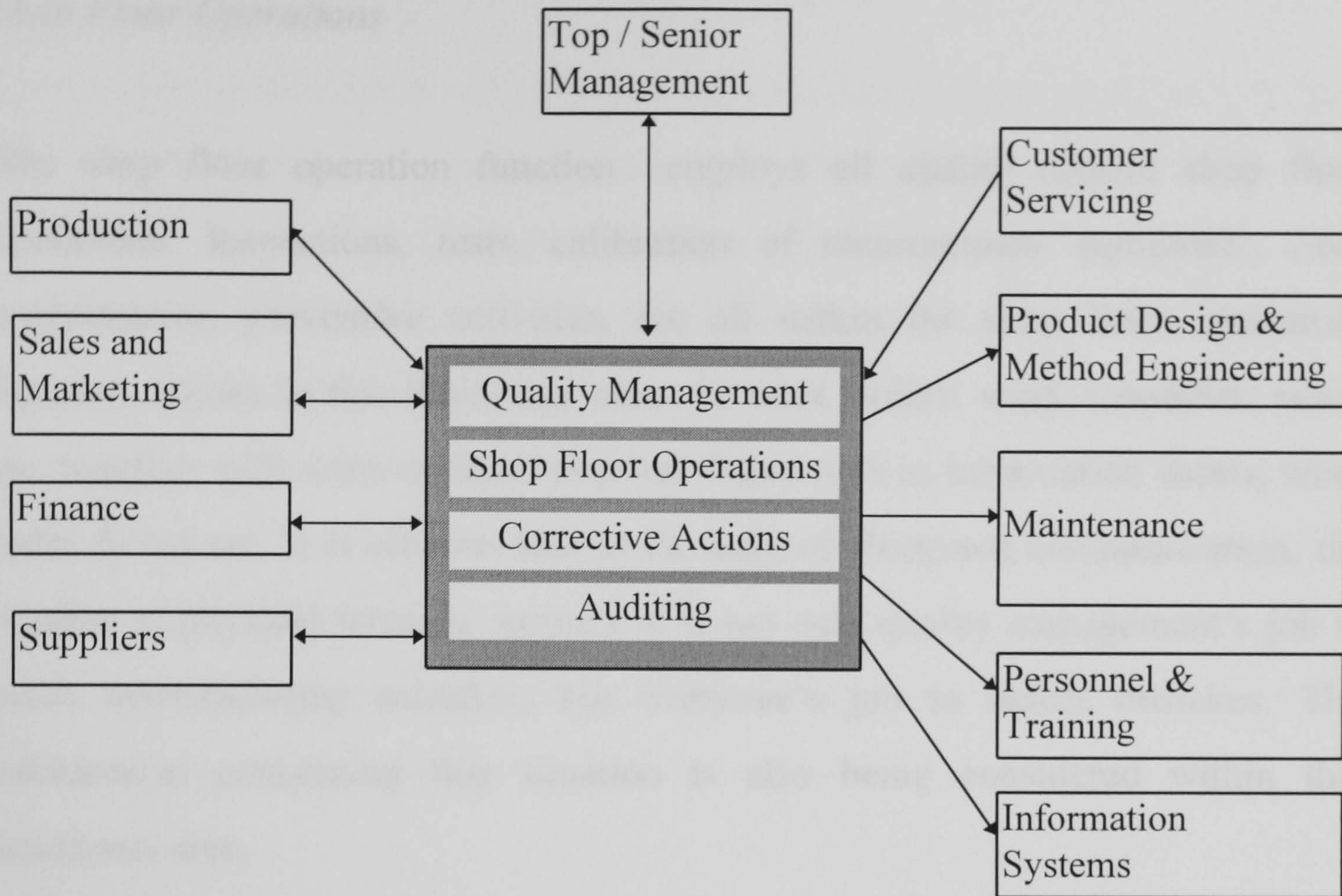


Figure 4.8 Main functional areas of The Integrated Quality Management Information Scheme

As is shown in figure 4.8, IQM has various relationships with external functional areas. As a main internal functional area of IQM, the Quality Management (Data Analysis) function communicates with these external functions such as Production, Sales and Marketing, Suppliers and Finance, etc. The quality management function receives input from customer servicing and feedback from other internal quality management functions. Likewise, other quality functions are fed by Data Analysis to produce a working harmony whilst achieving the quality goals.

## *Shop Floor Operations*

The shop floor operation function employs all quality control shop floor operations. Inspections, tests, calibration of measurement equipment, non-conformance, preventive activities, are all within the shop floor operations function. Inputs to this functional area are work orders, work schedules, tasks, etc. together with some optional physical forms such as information sheets, work order forms etc. It is obvious that in the case of electronic communication, the number of physical forms is reduced. It is not only quality management's job to catch manufacturing mistakes, but everyone's job to detect mistakes. The information concerning this situation is also being considered within this functional area.

## *Corrective Actions*

Corrective actions include all actions taken to eliminate the causes of an existing non-conformity, defect, or other undesirable situation in order to prevent recurrence. Preventive action, on the other hand, is used to improve something that has not gone wrong yet. In other words, preventive action is an action taken to eliminate the causes of a potential non-conformity, defect, or other undesirable situation in order to prevent recurrence, hence preventive actions information is also considered within this functional area.

Although both correction and corrective action are evaluated within the same context, there is a distinction between them. Correction refers to repair, rework, or adjustment and relates to the disposition of an existing non-conformity. Corrective action relates to the elimination of the cause of a non-conformity.

Hence, this is also the function where all non-conformance analysis has been made and corrective actions (including corrections and preventive actions) have been produced, applied and reported. Input to this functional area comes from shop floor operations. The data received are processed and then related bodies are informed accordingly. Having performed the corrective actions, the necessary information goes directly to Product Design and Method Engineering, Maintenance and Personnel / Training. The other external functions may also be informed according to the analyses which are carried out in quality management activities. This is because many quality improvements may take place outside the quality management activities.

### *Auditing*

Quality auditing is the review of activities conducted to compare some aspect of quality performance with a standard for that performance and to thoroughly document any differences. It does not include deciding how the difference is to be remedied, but it highlights them for corrective action. The process of a quality system audit has two primary elements:

- To compare practice with procedures and pick up deficiencies,
- To maximise effectiveness of the management system. This is really a matter of identifying further improvements.

Audits, therefore, are used to evaluate a company's own quality performance and performance of organisation.

### *A Common Quality Information Store (QIS)*

Within these quality management activities information flows smoothly to make the activities work in harmony and to sustain continuous quality improvement. This information should be kept in an organised place. There is consequently a well defined need for an information store that holds all quality related data. This is not a data base in a purely software engineering sense. Rather, it is an information store and is not necessarily computerised. Information stored may sometimes be on hard forms or informal (e.g. report forms, verbal communication). This is what differentiates it from the conventional understanding of databases. QIS draws necessary information from a number of other data sources as well. The primary ones are:

- Material Stores
- Production Data
- Personnel
- Maintenance
- Product Design and Method Engineering
- Suppliers and Customer Services.

Various other sources of data should also be able to communicate information with the quality information store. This communication is not simply a duplication of data held elsewhere but an integration of various data stores to make it appear as one system to the user. Data imported into the QIS fulfils a defined function i.e. to satisfy a user requirement.

### 4.3.2 DATA FLOW DIAGRAMS

Having identified the external and internal functional areas of quality management, the next stage is to establish an information model which integrates all of these functional areas to each other. Communication amongst these functions is set through data flow diagrams. Data flow diagrams, also known as activity diagrams, are a diagrammatic representation of the information flow within a system. This is an important technique of a structured systems analysis and design method. Activity diagrams clearly show the boundaries and scope of the system being represented. As was mentioned earlier, the information model is organised into three levels. Firstly, at the overall level, all functional areas identified are integrated to each other and main input and outputs of the model are described. Then each functional area within the context boundary which shows the quality management activity scope, are structured level by level down to shop floor where the actual users are operating. Each activity diagram is derived from its upper level activity diagram and integrated to it as well as to other same level activity diagrams. In other words, vertical and horizontal integration are realised simultaneously. In fact, each activity diagram which is a part of the model, is also simulating the related actual physical environment through its data relationship and information flow. As is explained by Ashworth and Goodland (1990) activity diagrams show:

- How information enters and leaves the system,
- What changes the information and
- Where information is stored.

Therefore, horizontal and vertical integration of each activity to each other lets each piece of information in the model flow through activities and complete its

journey. The construction of the diagrams and their cross-comparison with the other techniques ensures that all information flows, stores of information, and activities within the system have been considered. Activity diagrams are not process flow charts since they do not describe sequences of processes but simply the information flow of a system without reference to the time or order of events, all in a structured, easily understood, graphical format. They show how the total system fits together.

There are five main components of activity diagrams:

(1) External Sources or Recipients: This is whatever or whoever delivers information to or receives information from the system. Information represented within a system must have been obtained initially from an external source. In the integrated quality management scheme, information is originated from quality policy which is coming from an external source, namely Top Management. An external source or recipient is represented on an activity diagram as an oval containing the name as is shown in figure 4.9.

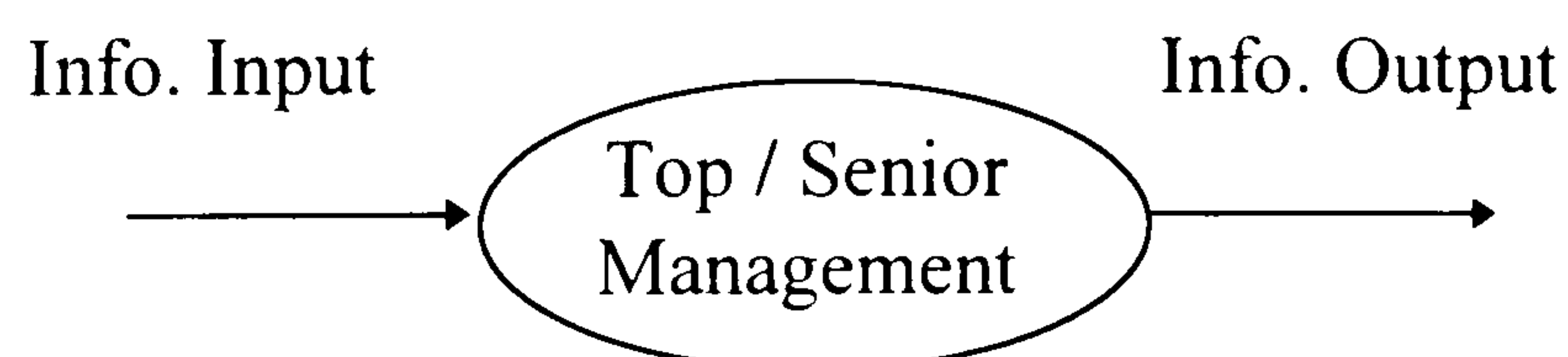


Figure 4.9 An external source or recipient

(2) Processes or Activities: A process or an activity transforms, manipulates or analyses data within the system. Activities are represented by rectangles on an activity diagram. As is shown in figure 4.10 each activity box contains the name of the activity and an activity number.



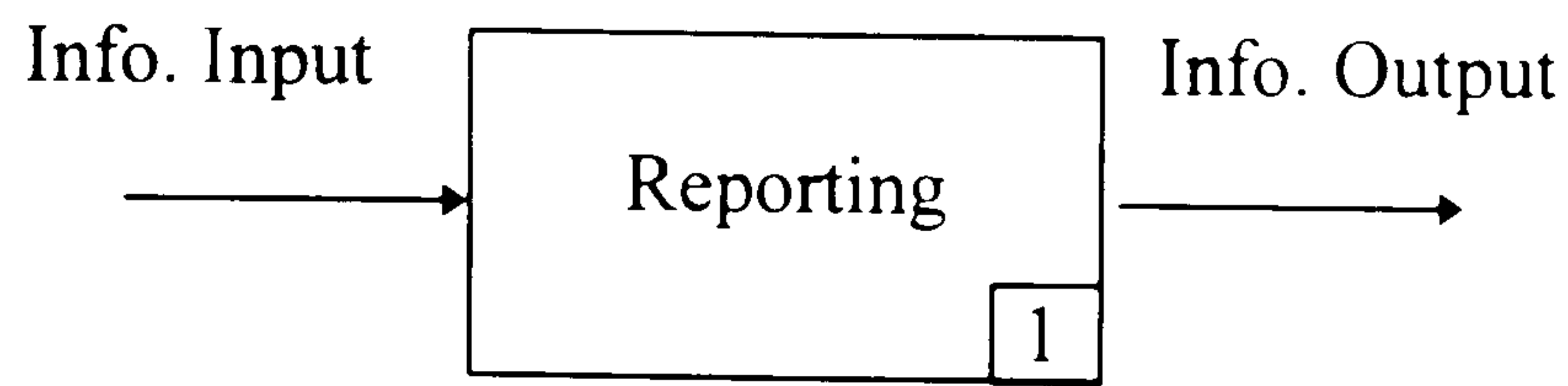


Figure 4.10 An activity box with the activity number.

(3) Data Store: A data store is where information is held for a time within the system. A data store is represented on an activity diagram by an open-ended oval containing the name of the data store as shown in figure 4.11.

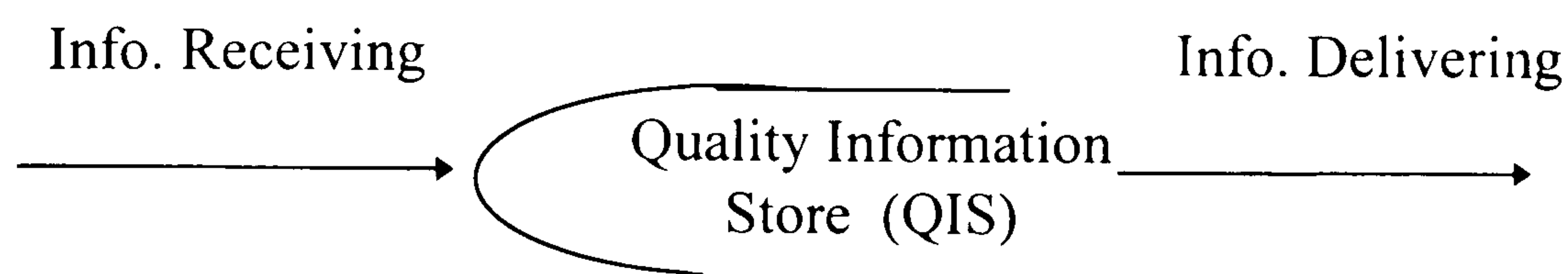


Figure 4.11 An information store representation

(4) Context Boundary: This shows the area borders of an activity diagram. This is represented by a thick rectangle within which all the activities are carried.

(5) Data Flow: This is a line showing information flow in the direction of the pointer. If both ends of the line are pointed, it means two-way communication. The type of lines may vary (dotted, thicker etc.) according to various information flows.

An example showing all five components of an activity diagram is given in figure 4.12. Furthermore, the hierarchical decomposition of the model is given in figure 4.13.

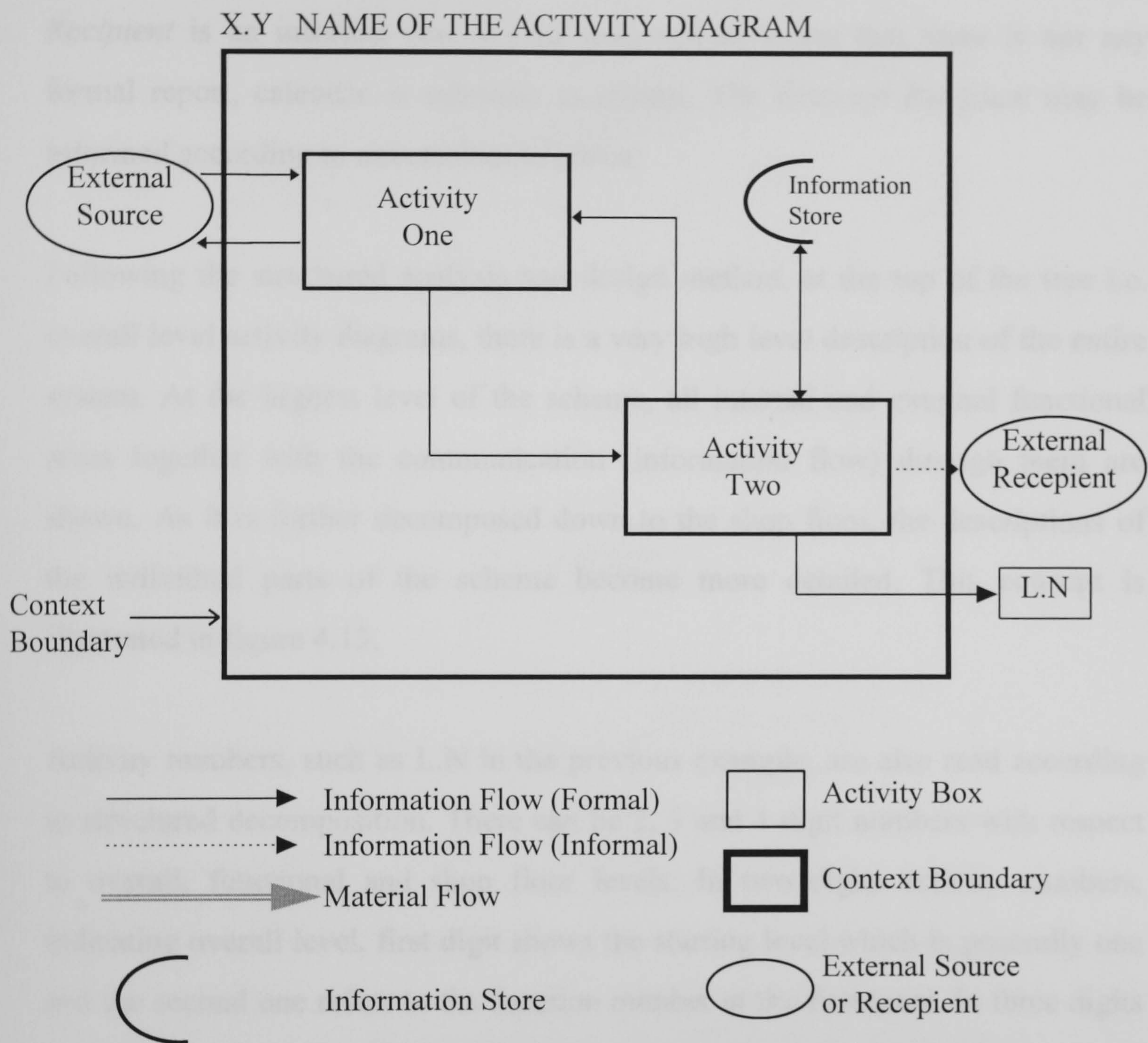


Figure 4.12 An activity diagram with its components

Here, the activity X.Y NAME OF THE ACTIVITY DIAGRAM is shown with its components. An information (input the activity), from an *External Source*, received by *Activity One*. *Activity One* process the information and sends it to the *Activity Two*. *Activity Two* process the information received and informs the results to three bodies; *Activity One*, activity numbered L.N and an *External Recipient*. *Activity Two* also communicates with the *Information Store* during its

processes either to update or to use it. Information going to the *External Recipient* is an informal one (dotted line) which means that there is not any formal report, calendar or schedule to inform. The *External Recipient* may be informed according to circumstances arisen.

Following the structured analysis and design method, at the top of the tree i.e. overall level activity diagrams, there is a very high level description of the entire system. At the highest level of the scheme, all internal and external functional areas together with the communication (information flow) through them are shown. As it is further decomposed down to the shop floor, the descriptions of the individual parts of the scheme become more detailed. This concept is illustrated in figure 4.13.

Activity numbers, such as L.N in the previous example, are also read according to structured decomposition. There can be 2, 3 and 4 digit numbers with respect to overall, functional and shop floor levels. In two digits activity numbers, indicating overall level, first digit shows the starting level which is generally one and the second one refers to the function number at the first level. In three digits activity numbers, indicating functional level, first digit shows the starting level which is again one, the second digit shows the function number, and the third digit shows activity number within the function indicated by the second digit. Four digits activity numbers are read in the same way. For example, in figure 4.13 shaded activities at each level can be referred as 1.B (overall level), 1.B.C (functional level) and 1.B.C.E (shop floor level).

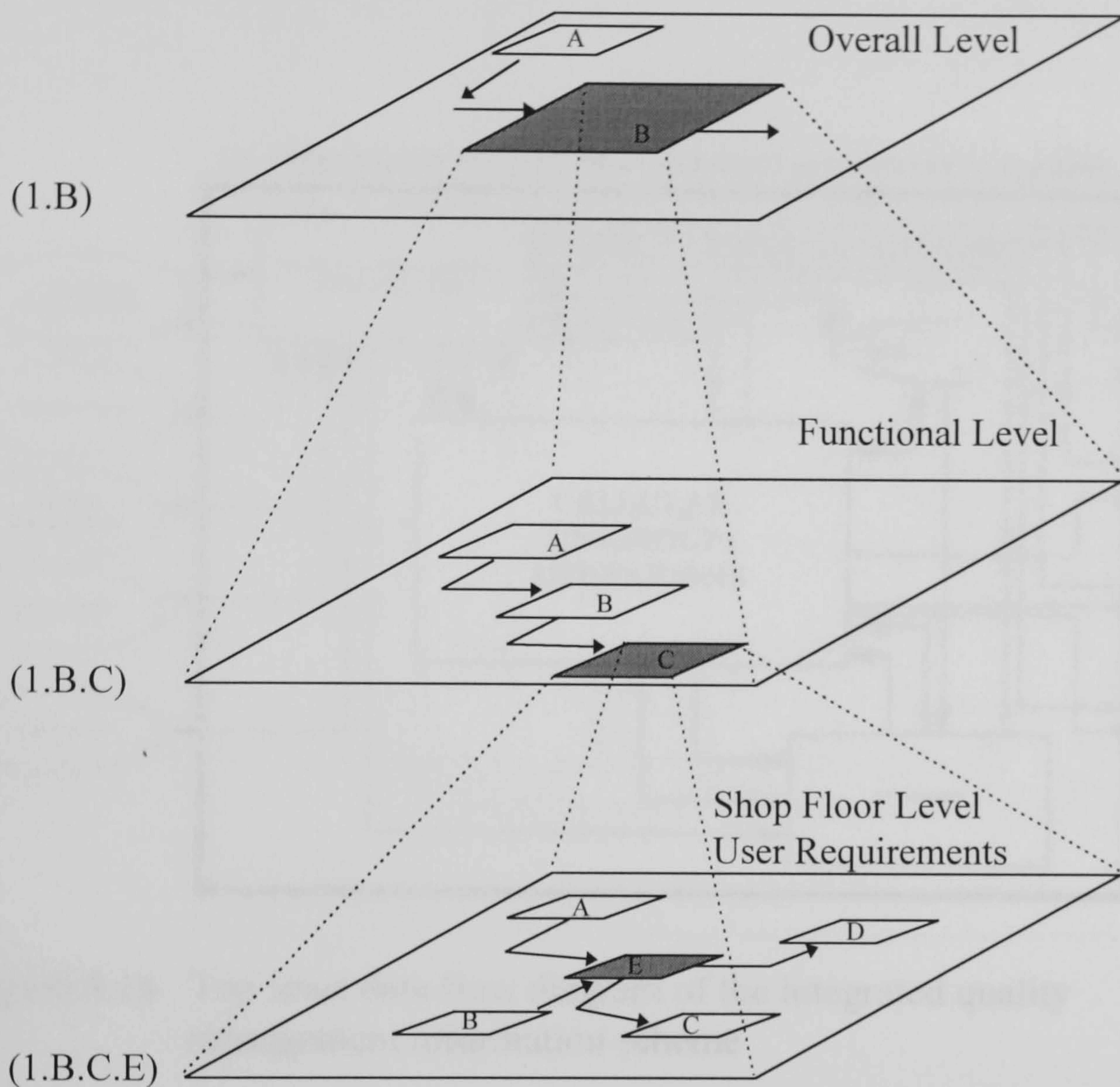


Figure 4.13 Hierarchical decomposition of the information management scheme

All internal and external functional areas of an integrated quality management system were described in the previous section. The top level data flow diagram i.e. activity diagram of the integrated quality management information scheme is given in figure 4.14. Here, the main functional areas are quality management (data analysis), auditing and cellular (in-group) operations.

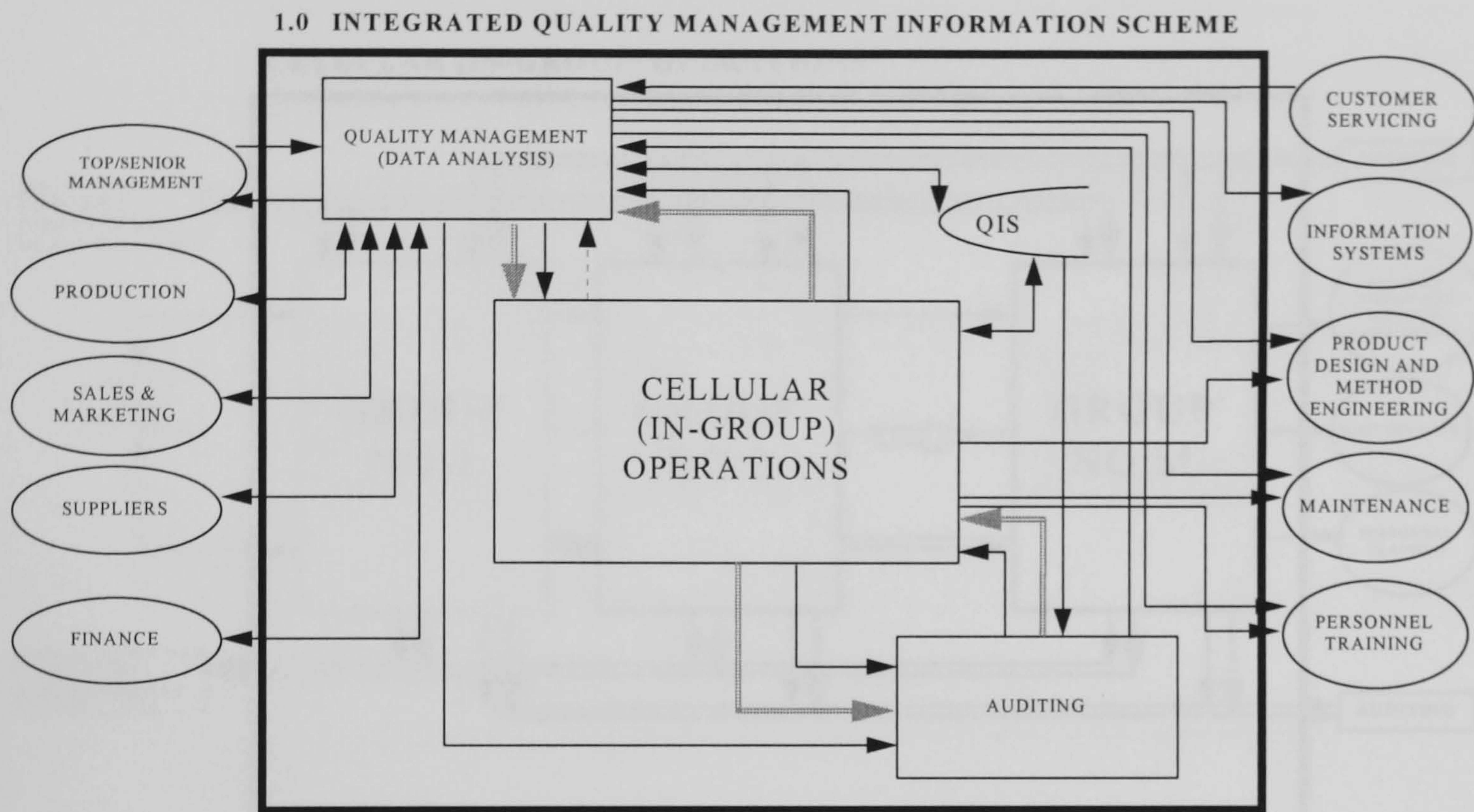


Figure 4.14 Top level data flow diagram of the integrated quality management information scheme

Figure 4.15 Groups in cellular operations

Cellular operations are the quality management activities carried out within the cells (or groups) of group technology. As is seen in figure 4.15, the activity box of cellular operations may contain various groups of cellular manufacturing.

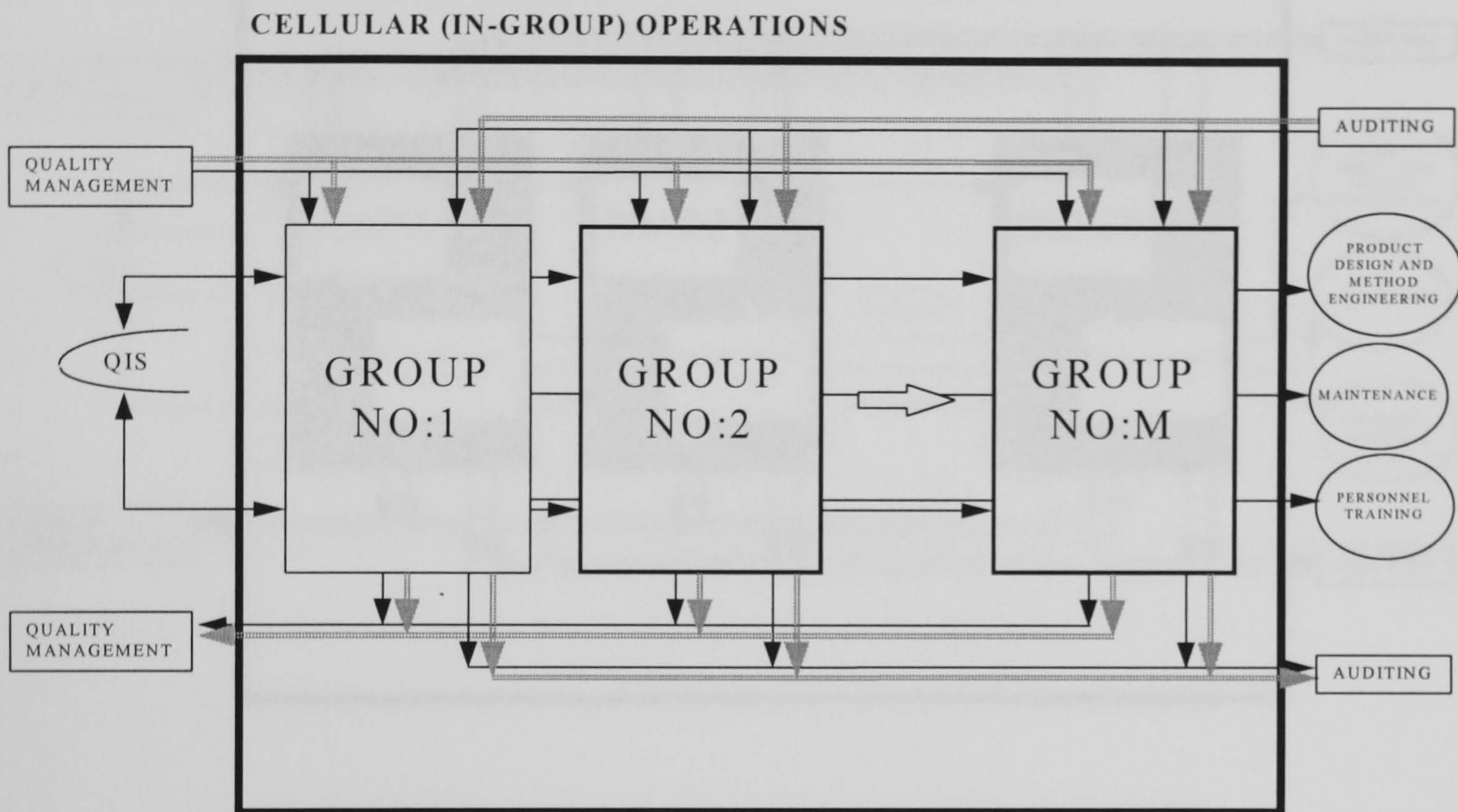


Figure 4.15 Groups in cellular operations

Each group receives information from quality management and auditing activities, processes the information, and finally reports back. Furthermore each group can communicate with the common quality information store, and can directly deliver information to outside functional areas such as Product Design and Method Engineering, Maintenance, and Personnel and Training.

### CELLULAR (IN-GROUP) OPERATIONS

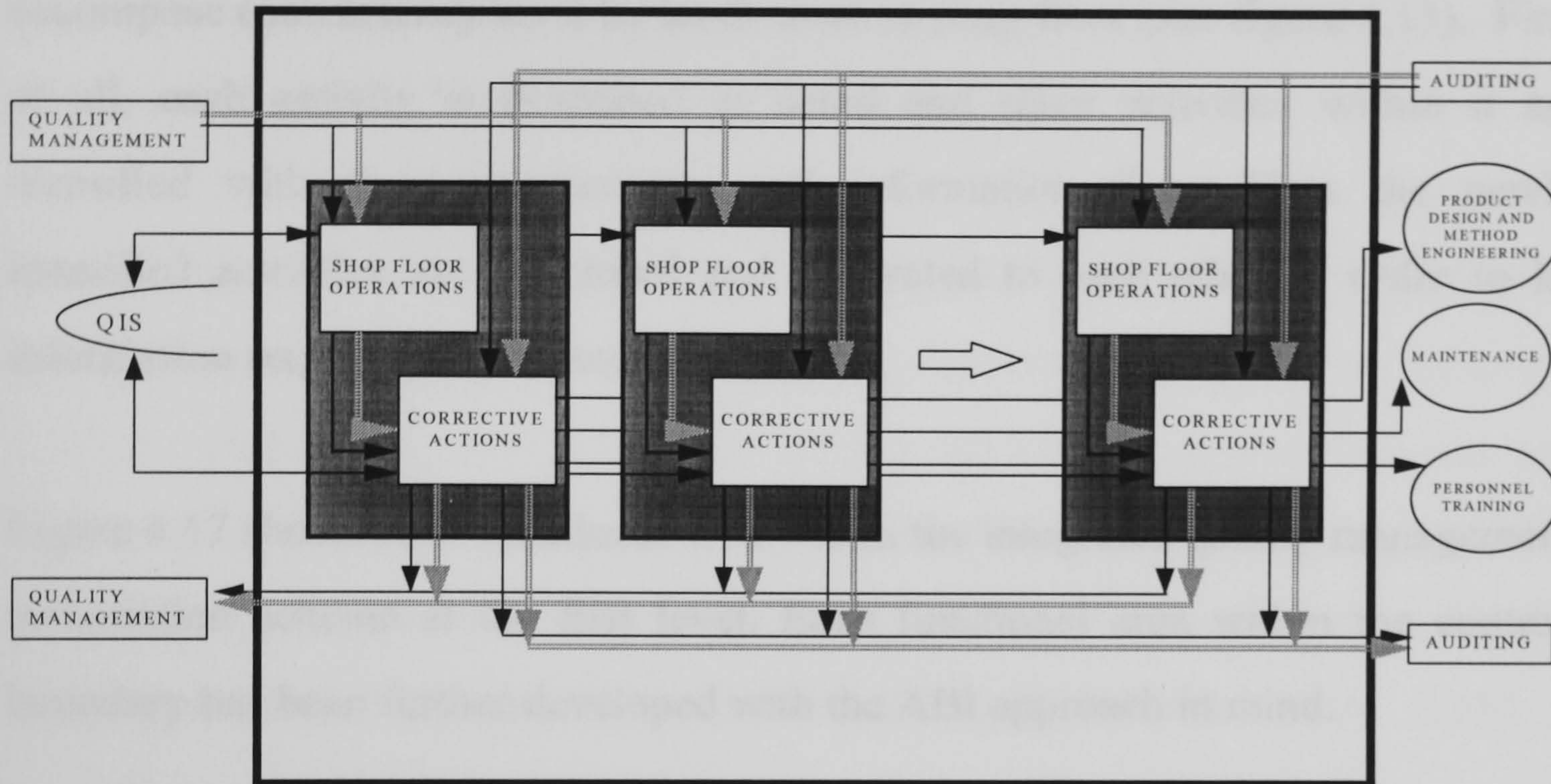


Figure 4.16 Quality management activities within the groups in cellular operations

Figure 4.16 shows that in each group there are actually two main internal quality management functions such as shop floor operations and corrective actions. All the information coming to the group is processed through these functions and delivered back to the related bodies. From the data analysis and design point of view, information flow in each group will be designed, structured and integrated in the same way. Therefore it will be wise for the sake of simplicity to have only one group represented on the activity diagrams. In the application, all groups will communicate through the same information pattern. This allows the overall level of a total quality management information system model to be represented, within a cellular manufacturing environment, based on the MSAD methodology, as illustrated in figure 4.17.

Having systematically constructed the overall level activity diagram showing all internal and external functional areas structured and integrated, the next step is to decompose each activity level by level down to shop floor (see figure 4.13). First of all, each activity is described in detail and other activities within it are identified with their requirements and information flow. Then the newly identified activities are structured and integrated to each other in order to let information required flow through them.

Figure 4.17 shows each functional area within the integrated quality management information scheme at the first level. Each functional area within the context boundary has been further developed with the ABI approach in mind.

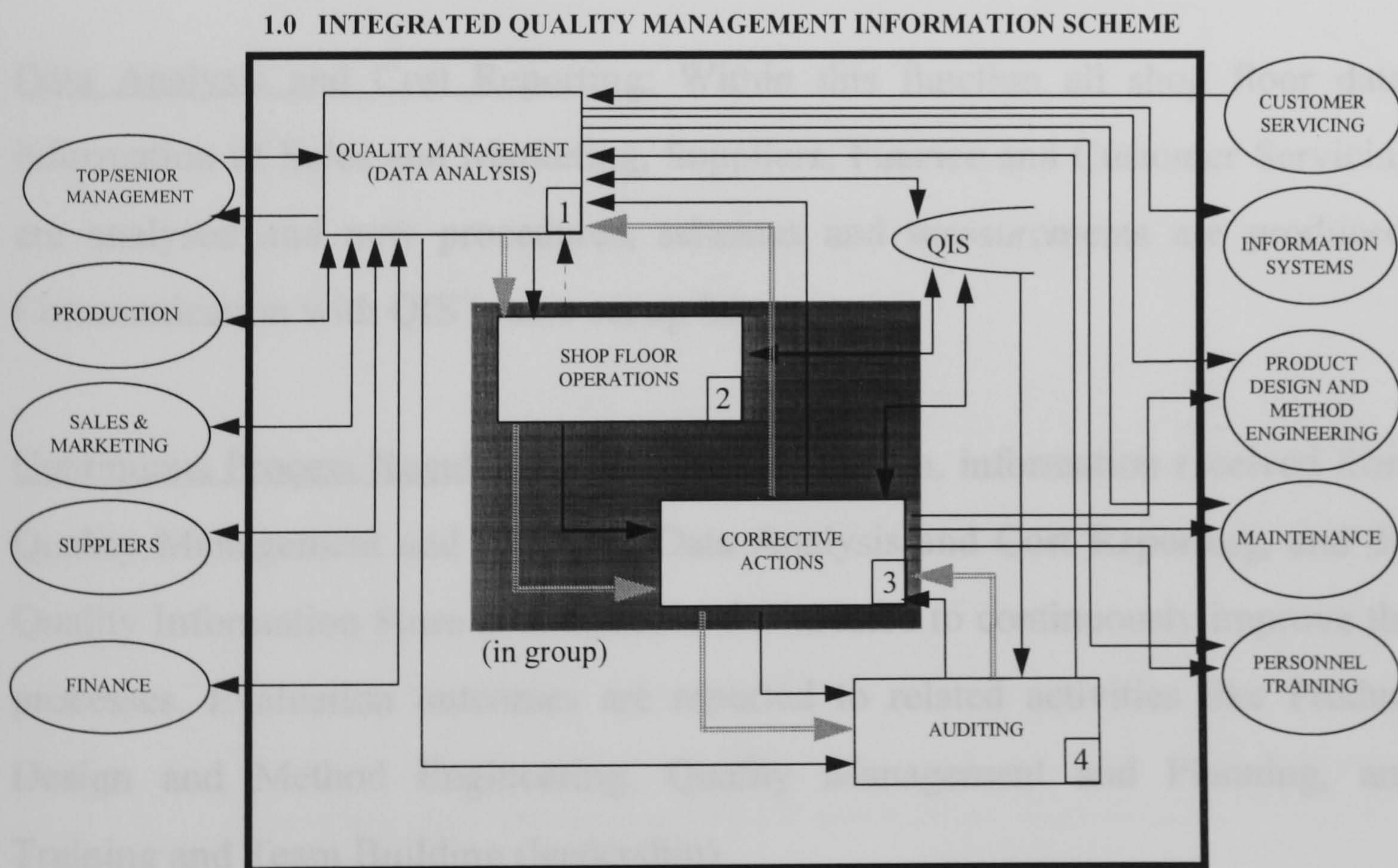


Figure 4.17 Overall level of the integrated quality management information scheme within cellular manufacturing environment



## *Quality Management (Data Analysis and Reporting)*

First of all, all the quality activities of the quality management (data analysis) functional area have been identified and further described. Within the quality management functional area there are five major activities:

Quality Management and Planning: Within this function, the main quality management and planning activities are carried out. All of its activities are initially triggered by the corporate quality policy determined by the top management. A quality management report is also issued for the top management to improve quality policies and to improve top management's commitment in the total quality management. The common quality information store (QIS) is available to be accessed.

Data Analysis and Cost Reporting: Within this function all shop floor data, information of Sales and Marketing, Suppliers, Finance and Customer Servicing are analysed and new procedures, schemes and measurements are produced. Communication with QIS is also set up here.

Continuous Process Regulation: Within this function, information received from Quality Management and Planning, Data Analysis and Cost Reporting, and the Quality Information Store is analysed and evaluated to continuously improve the processes. Evaluation outcomes are reported to related activities like Product Design and Method Engineering, Quality Management and Planning, and Training and Team Building (leadership).

Training and Team Building (Leadership): This is where training requirements highlighted from Continuous Process Regulation are evaluated and applied

harmoniously within the team. The personnel of a group is also considered as a team within this function.

Work Structures and Scheduling: Within this function work structures are improved according to findings of analyses, and Work Schedules are produced from the information supplied.

Finally, all of these activities are structured and integrated to each other to produce, one level down, the Quality Management (Data Analysis and Reporting) activity diagram which is given in figure 4.18.

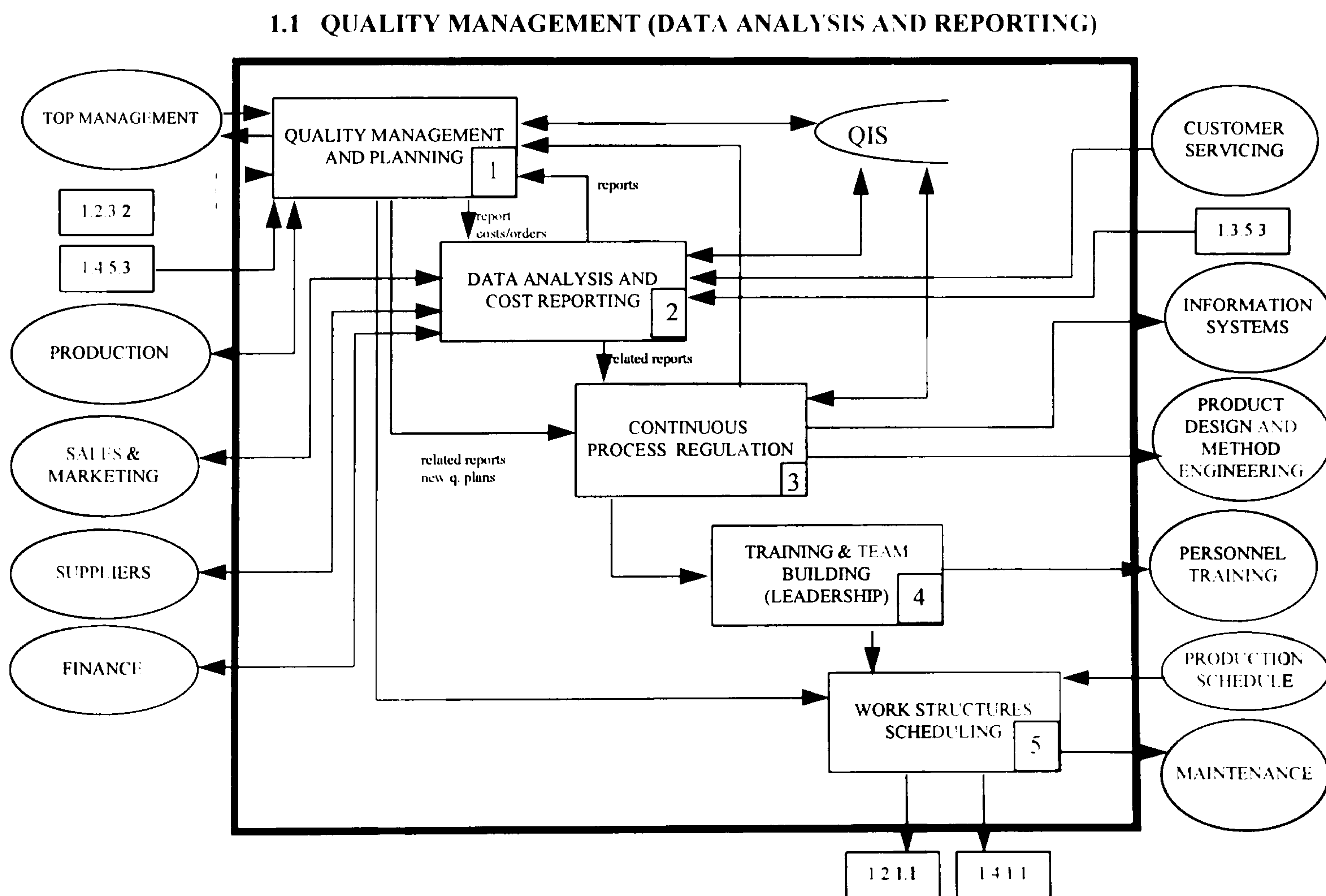


Figure 4.18 Quality management functions (Data analysis and Reporting)

### *Shop Floor (Inspection) Operations*

In the same way, Shop Floor Operations activity diagram has been produced and illustrated in figure 4.19. Major activities involved in the Shop Floor Operations are:

Planning Review and Resource Allocation: Within this function, work orders and tasks are received and the necessary resources to achieve them are allocated.

Customer Requirements and Standards: This function is to review necessary standards and procedures, and to take all customer requirements (internals as well as external ones) into consideration.

Actual Works: Actual physical work like inspections, tests, calibrations, etc. are all conducted here.

Report Process Requirements: This is a preliminary process report to note improvements and failures.

Reporting: This is reporting for non-conformance, discrepancies or new requirements. The reports go to the Corrective Action function.

## 1.2 SHOP FLOOR OPERATIONS (INSPECTION)

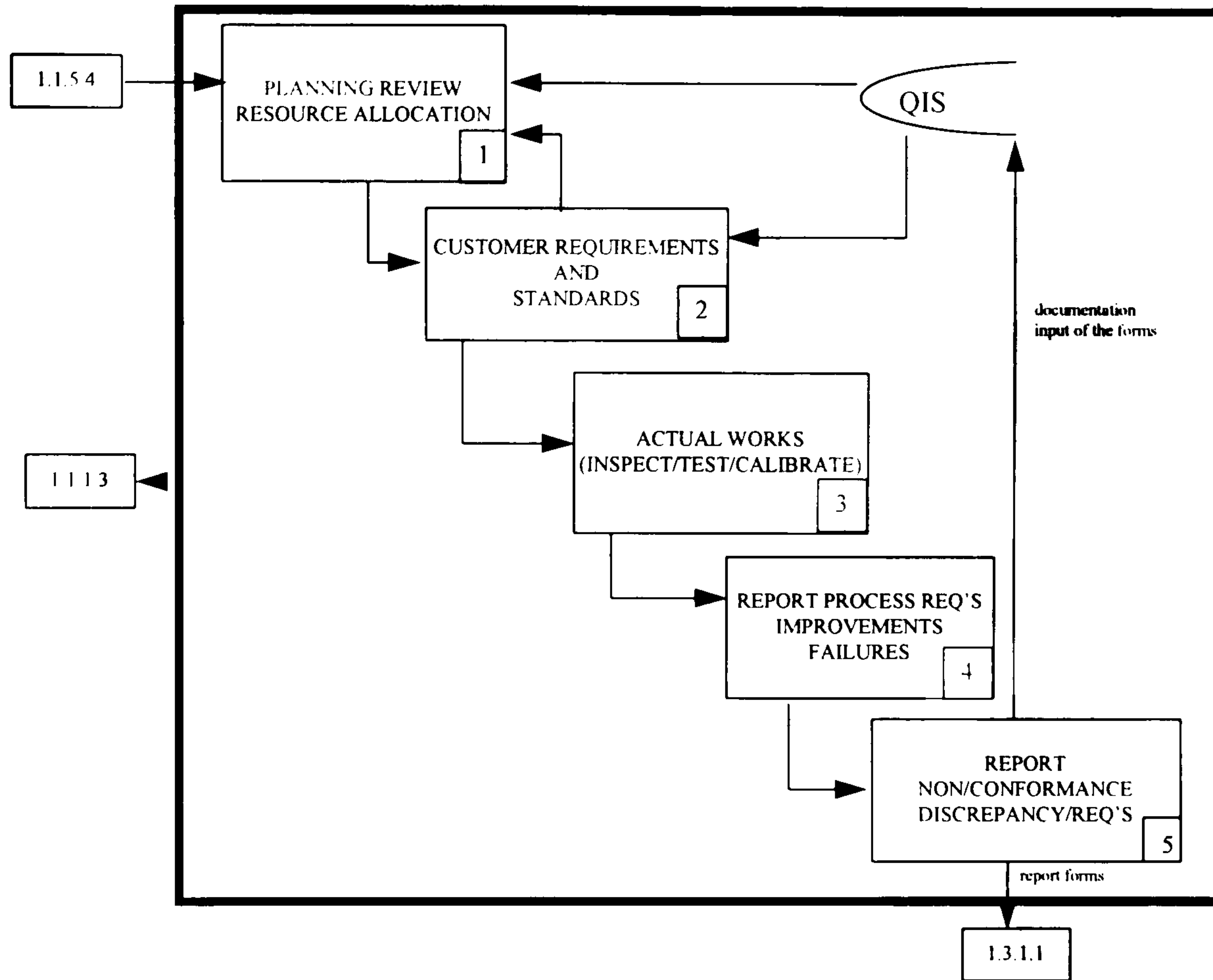


Figure 4.19 Shop floor operations (Inspections)

### *Corrective Action and Verification*

Similarly, the Corrective Action and Verification function is shown in figure 4.20. The major activities involved are:

Report and Plan Review, Resource Allocation: Within this functional area, incoming reports are gathered and an initial review is performed. All necessary resources are identified and allocated.

Reason for Non-conformance: In this function, all failures and non-conformance are analysed, possible causes are identified, and the best possible solution produced.

Trouble Shooting: The actual physical corrective action (i.e fix or disposition) is taken within this functional area.

Material Review Board: This is a cross-functional team to analyse faulty parts, products and processes to drive optimal solutions for them.

Reporting: All the related reporting activities are carried out within this function.

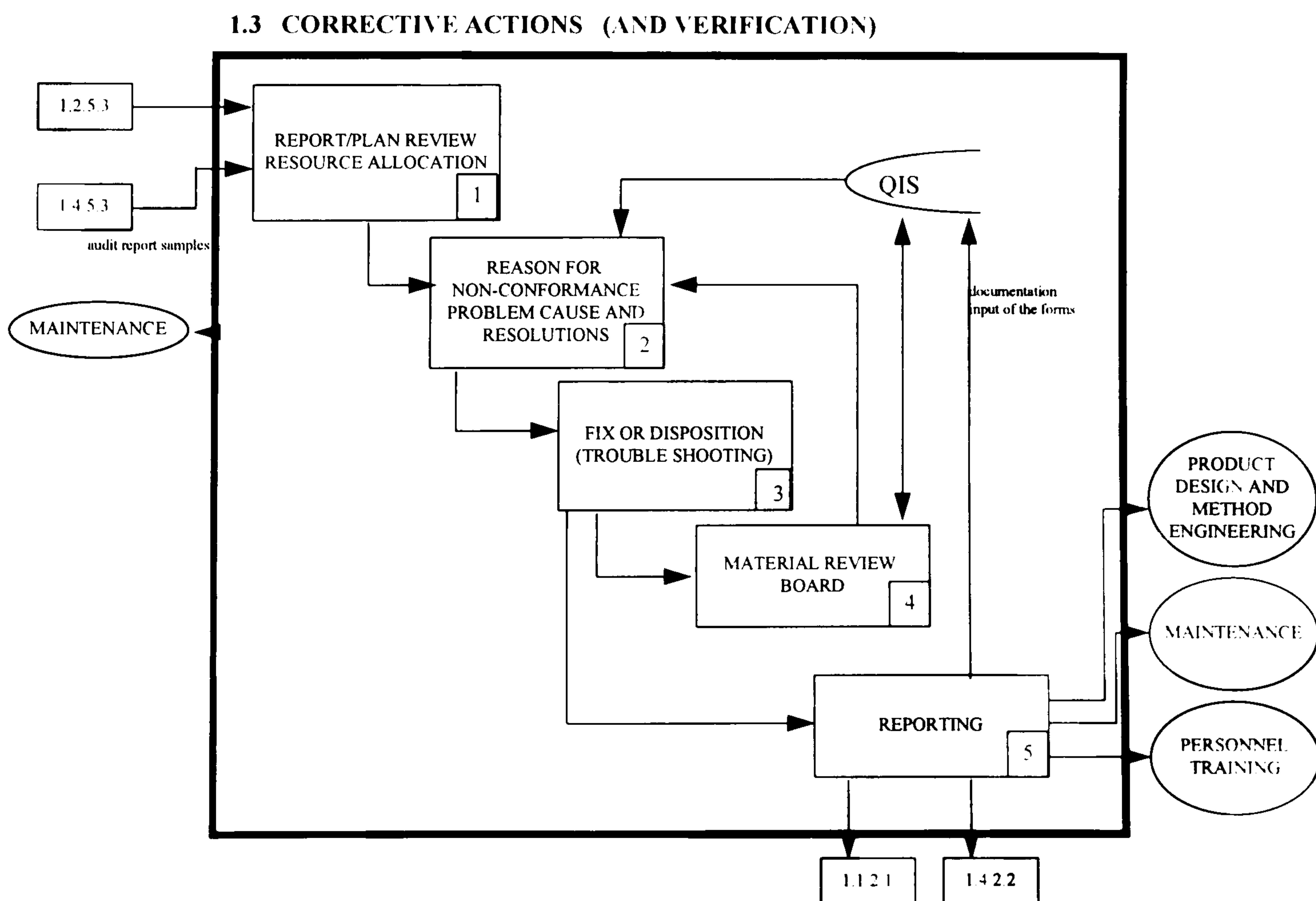


Figure 4.20 Corrective action and verification function

## *Auditing*

Finally, auditing as one of the main internal functional areas of the Integrated Quality Management Scheme is illustrated in figure 4.21. Its major functions involved are:

Initialisation: All the procedures, reports and audit plans are gathered, reviewed and updated.

Auditing: The actual auditing is carried out in this area. All the responses are gathered to make further analyses.

Improvement Analysis and Evaluations: All responses and information gathered are analysed and evaluated within this function to improve procedures, processes and auditing itself.

Reporting: Audit reports are prepared for the Quality Management and Planning function and for the Shop Floor Activities.

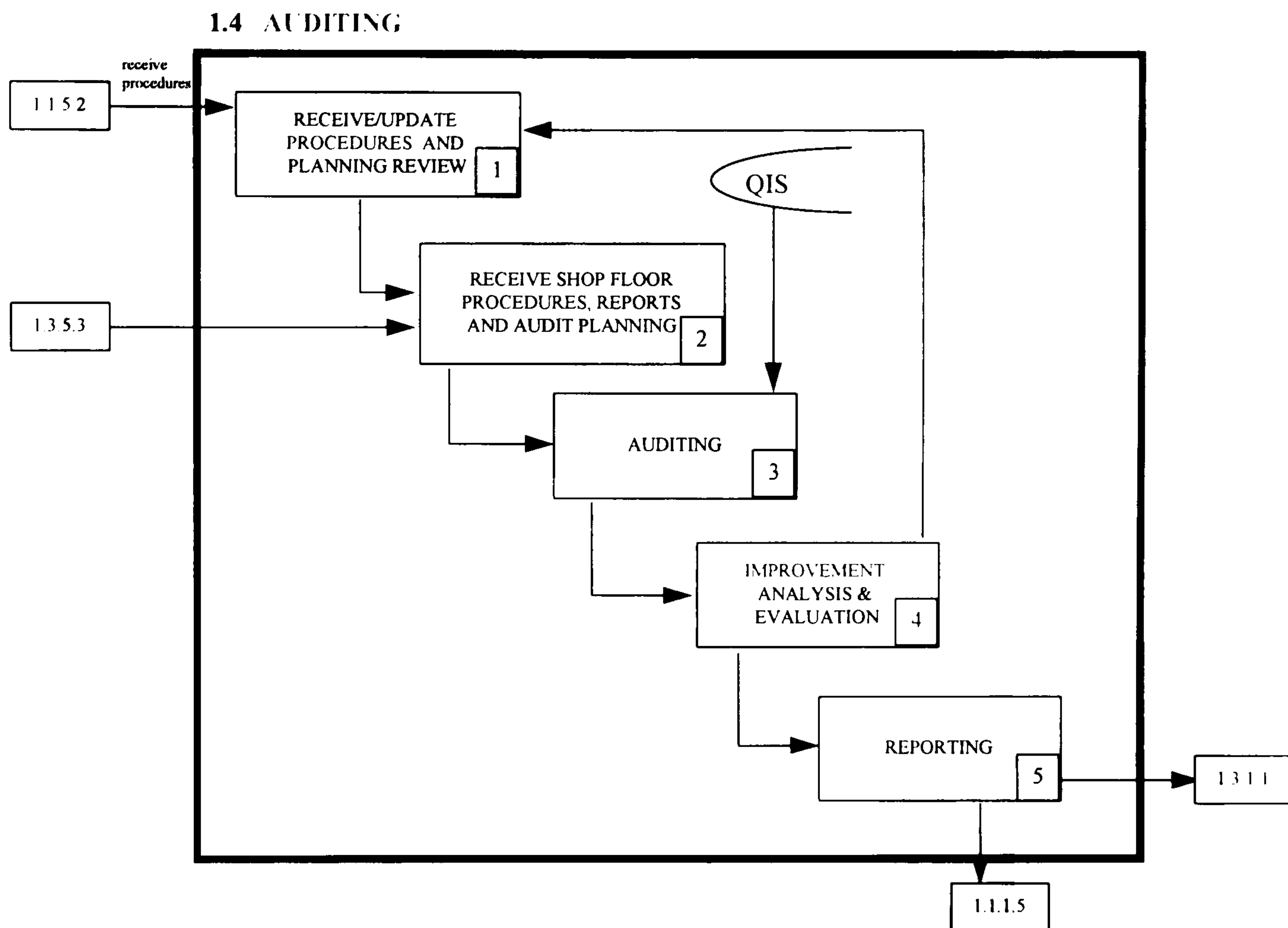


Figure 4.21 Auditing function

These four main internal functions (Quality Management, Shop Floor Operations, Corrective Actions and Auditing) together with the external ones (Production, Sales and Marketing, Customer Servicing etc.) are structured and integrated to each other using the ABI approach to come up with the new implementation model for the cellular manufacturing environment. This implementation model is called the Integrated Quality Management Information Scheme. As is seen, all the processes (activities) are detailed out down to the shop floor within the model.

In the phases of development, evaluation and justification of the model, many inputs as feedback are acquired through:

- expert views,
- case studies,
- published materials,
- plant visits,
- discussions,
- industrial survey and
- structured walkthroughs.

These are going to be discussed in the next chapter in detail. Appendix A shows the complete model in detail with the formal information explanations.

### 4.3.3 LOGICAL DATA STRUCTURES

Logical data structuring is a well known modelling tool. It is an analysis of a system by consideration of the things that are important to it. Originally devised for database design, it is now also used in a number of system development methods. Ashworth and Goodland (1990) explain that the terms entity modelling, data modelling, and entity relationship modelling are all used by different methods to describe a similar approach to logical data structures in SSADM.

Logical data structuring is a tool of structured system analysis and design methods to describe what information is to be held by the system. The aims of logical data structuring can be summarised as (Britton and Doake, 1993):

- to capture all the system data,
- to organise the data into logical groups, and



➤ to map the relationships between data groups.

Logical data structure diagrams are produced for the integrated quality management information system with respect to functional activity diagrams. At the phases of model evaluation, they are extended to meet the requirements of the modified schemes and to further evaluate the scheme according to the results of logical data structures analysis.

There are three basic components of a logical data structure:

Entities: This is a significant thing to the system about which information is to be held. Appropriate attributes are then allocated to each entity. Beynon-Davies (1993) defines an entity as a thing which the enterprise recognises as being capable of an independent existence and which can be uniquely identified.

Relationships: This is an association between two entities that is important to the system. Relationships are normally described as verbs (controlled, scheduled, have, etc.), and entities as nouns (worker, engineer, machine, report, etc.). Relationships are important because they define access from one entity occurrence to another. Thus a relationship between, for example, an engineer and a worker implies that from an occurrence at an engineer, occurrences of workers who receive instructions from him/her can be found. There are various types and degrees of relationships which are all explained in Appendix B.

Data Item: This is the smallest discrete component of the system information that is meaningful.

Next, the logical data structure diagrams of the integrated quality management scheme are described in terms of these three components. Entities are represented as boxes with the names of entities inside them.

Figure 4.22 shows some important entities and their relationship in the quality management (data analysis) functional area. Here, the quality manager receives corporate quality policy. The quality manager has many engineers (crow's leg shows one to many relationships) and analysts. Engineers and analysts produce many work orders. Many engineers and analysts together produce a quality report. A quality manager may have more than one (many) quality report.

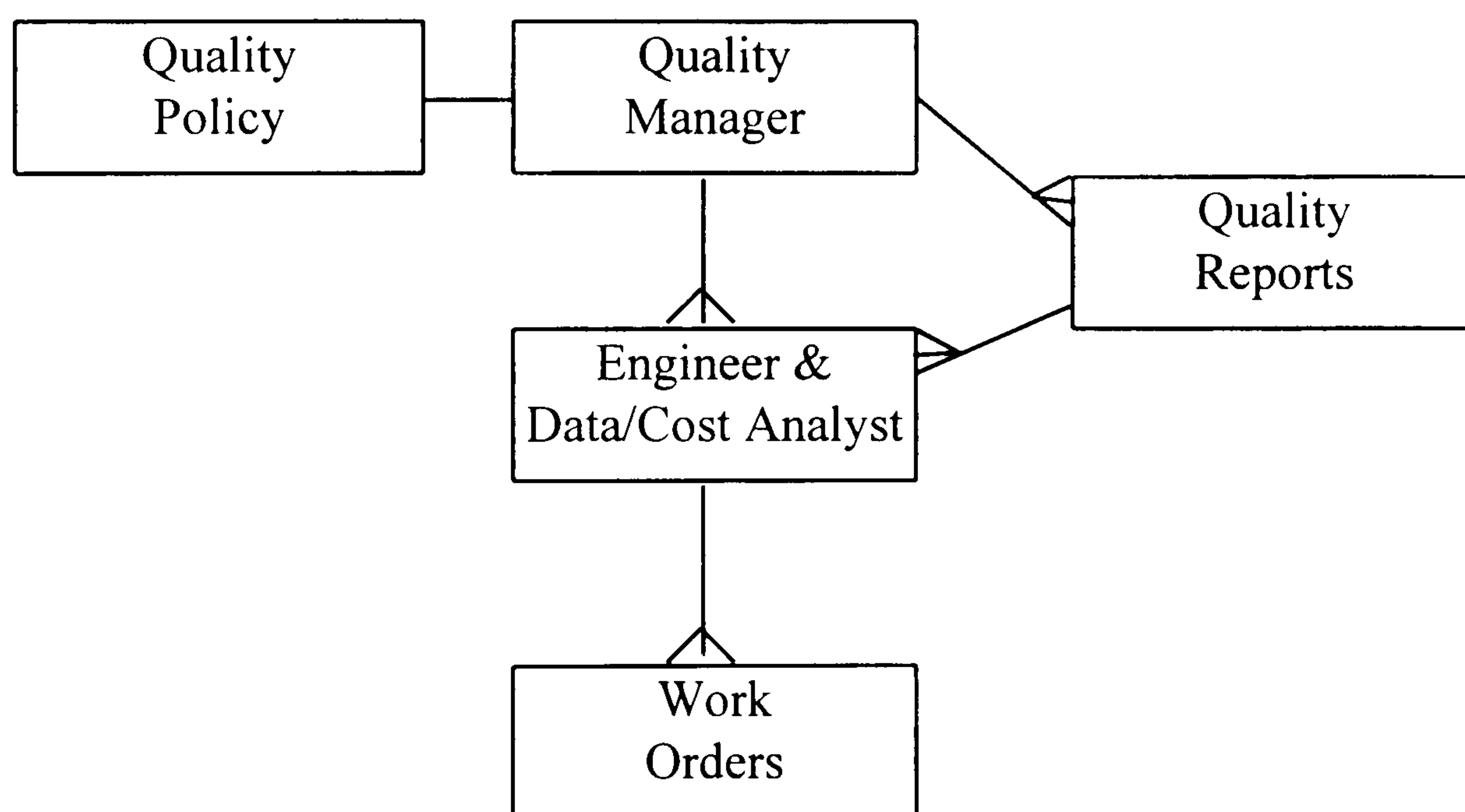


Figure 4.22 Logical data structures of some major entities in the quality management function

In the shop floor operations area, some major entities and their relationships are shown in figure 4.23. A foreman has many work orders and workers. A foreman has also many discrepancies or dispositions to work out. Many workers receive (work on) one work order but detect many discrepancies or dispositions.

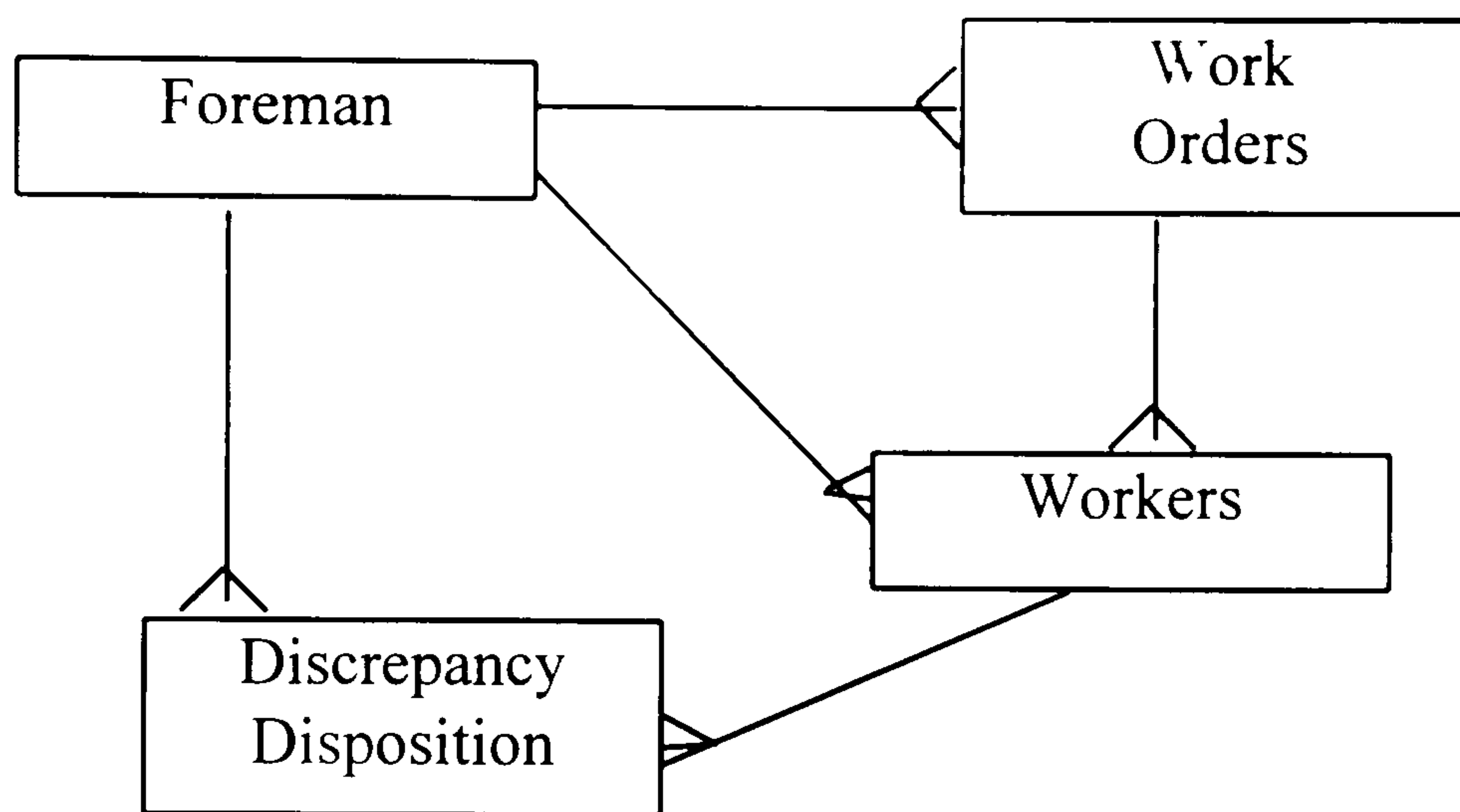


Figure 4.23 Logical data structures of some major entities in the shop floor operations function

Some major entities of the corrective actions function are depicted in figure 4.24. It shows that many engineers and foremen deal with many corrective action reports. A corrective action report can consist of many discrepancies or dispositions. A material review board can consist of many engineers and foremen.

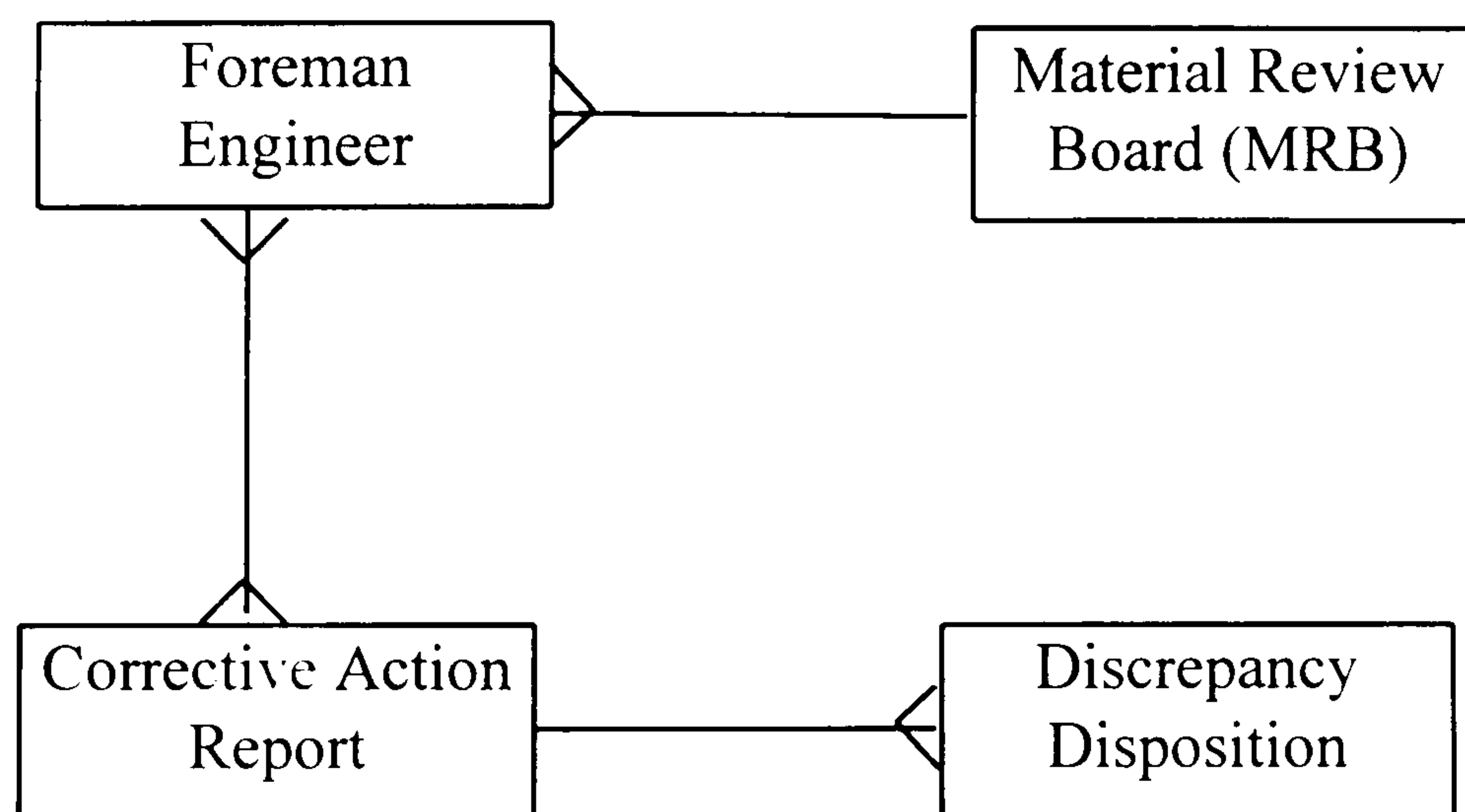


Figure 4.24 Logical data structures of some major entities in the corrective action function

Finally some entities of auditing function and their relationships are illustrated in figure 4.25. It shows that an auditor audits many workers with many work procedures in hand. Many workers can be audited according to many work procedures.

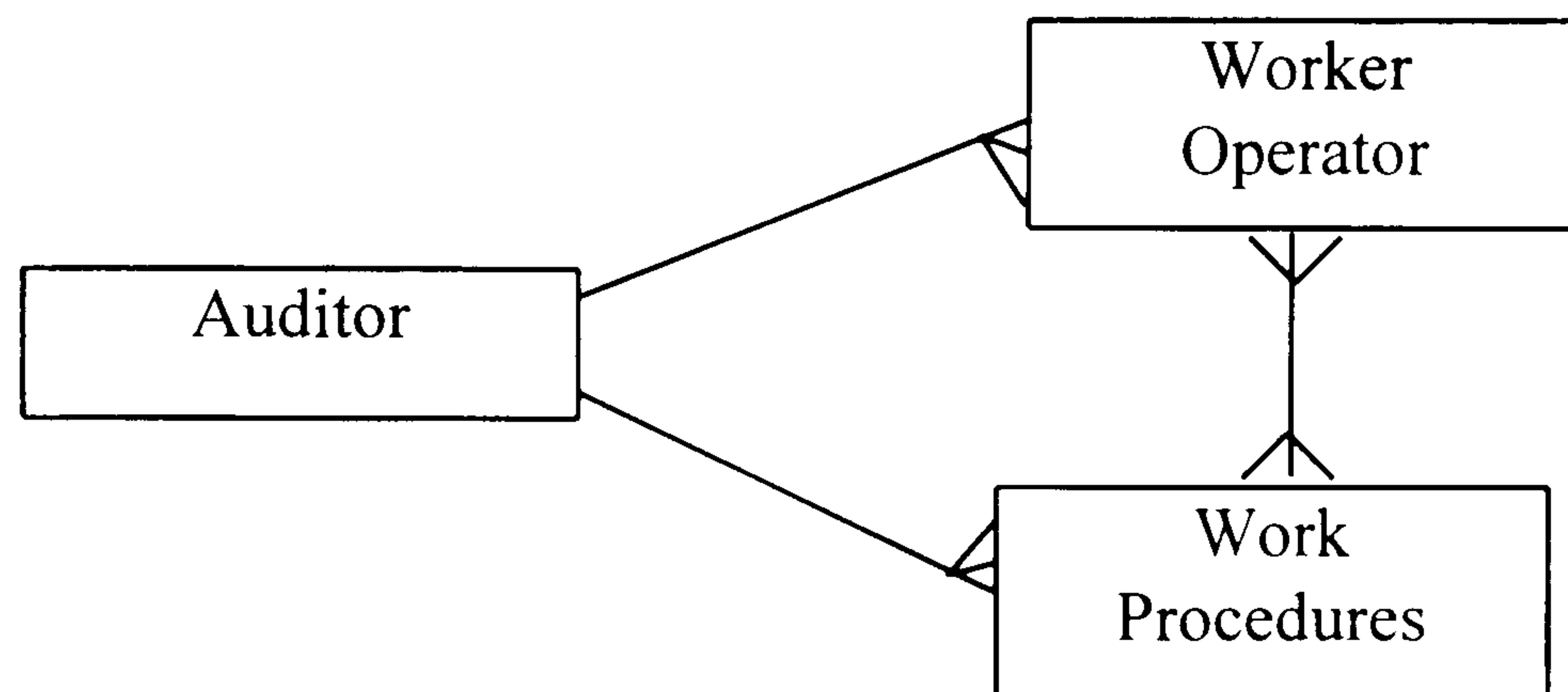


Figure 4.25 Logical data structures of some major entities in the auditing function

Complete logical data structuring diagrams are given in detail in Appendix B with the nomenclature and formal explanations. In the evaluations of the model, logical data structuring resulted in new raw data structures which helped further identification of functional areas. These diagrams, hence, can also be considered as raw data structure supporting elements of the complete scheme given in Appendix A.

#### 4.4 AN EXAMPLE OF FURTHER INTEGRATION

The overall implementation scheme consists of small simplified and independent activities. Each activity is integrated to each other in a structured way. This situation gives the scheme a two-way advantage. The scheme can structurally be

further expanded or the number of activities can be reduced without major change requirements i.e. without disturbing the overall structure.

In other words, at any time in the future, the scheme allows users to integrate new activities, tasks (e.g. boxes indicated as 'N') to the current functions, figure 4.26. In the same way it also allows current activities, tasks to be modified according to circumstances arising within the scheme.

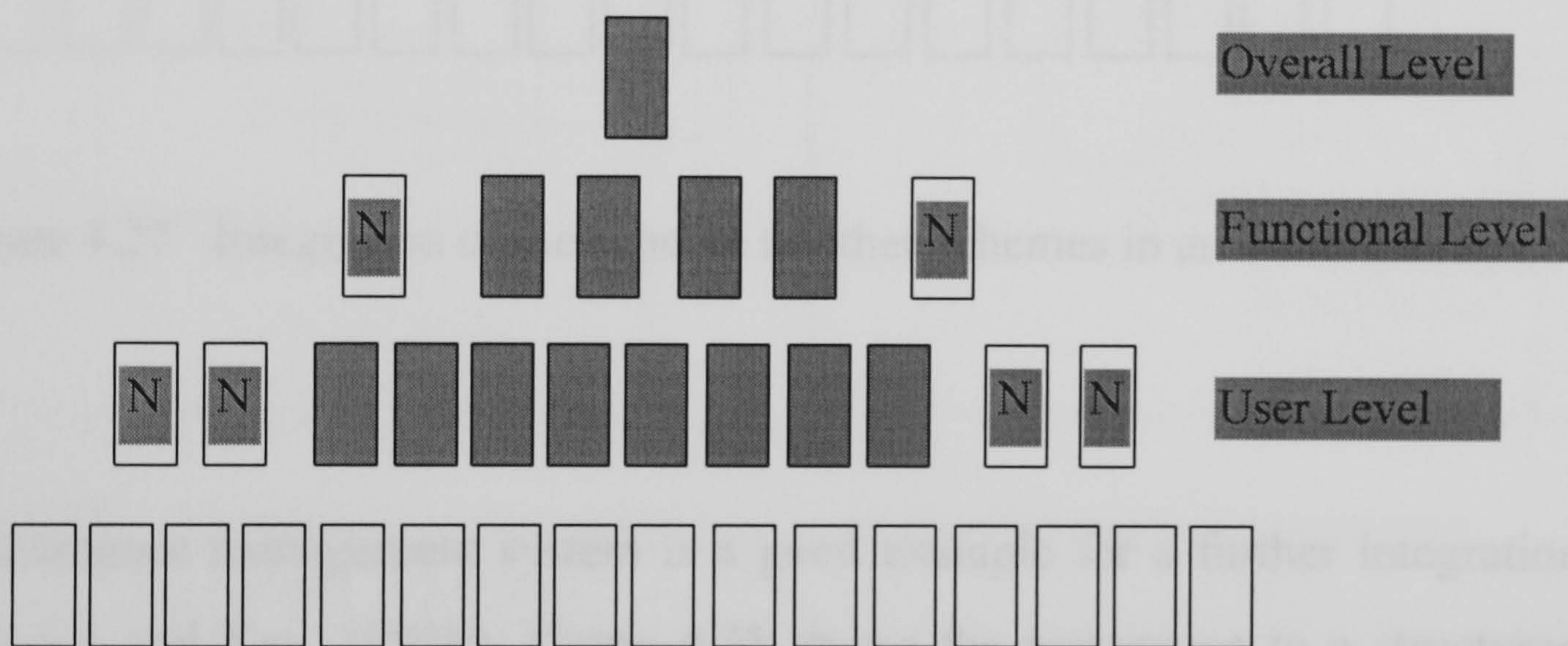


Figure 4.26 Integration of new functions, activities and tasks.

It is also possible to integrate further functional areas to the scheme. All of this integration and development is carried out within the scheme under the TQM philosophy.

Furthermore, with the same approach and philosophy, this structured scheme can be easily integrated to any other schemes. As is shown in figure 4.27, it could easily be a part of a large corporate system, from suppliers to the customers.

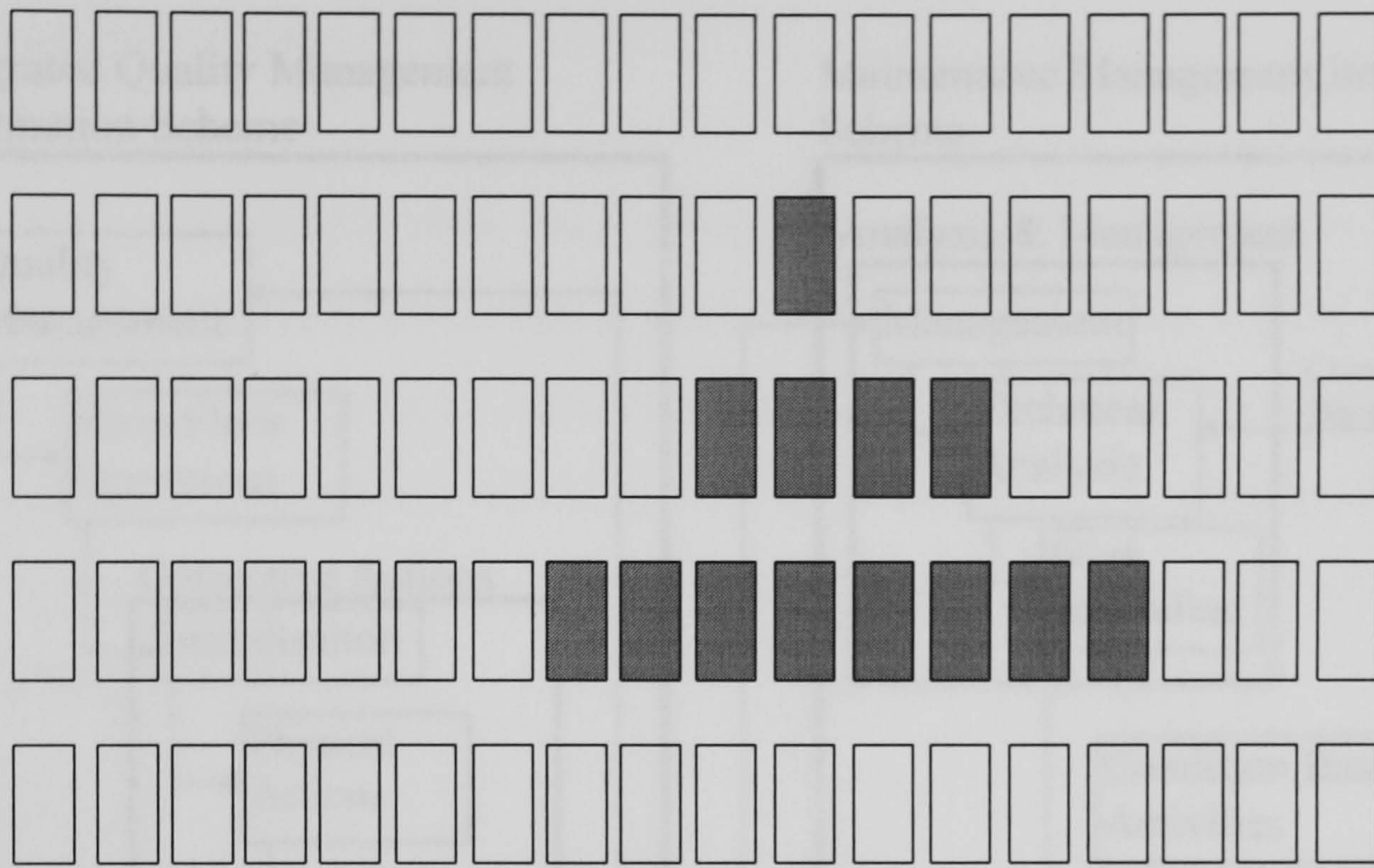
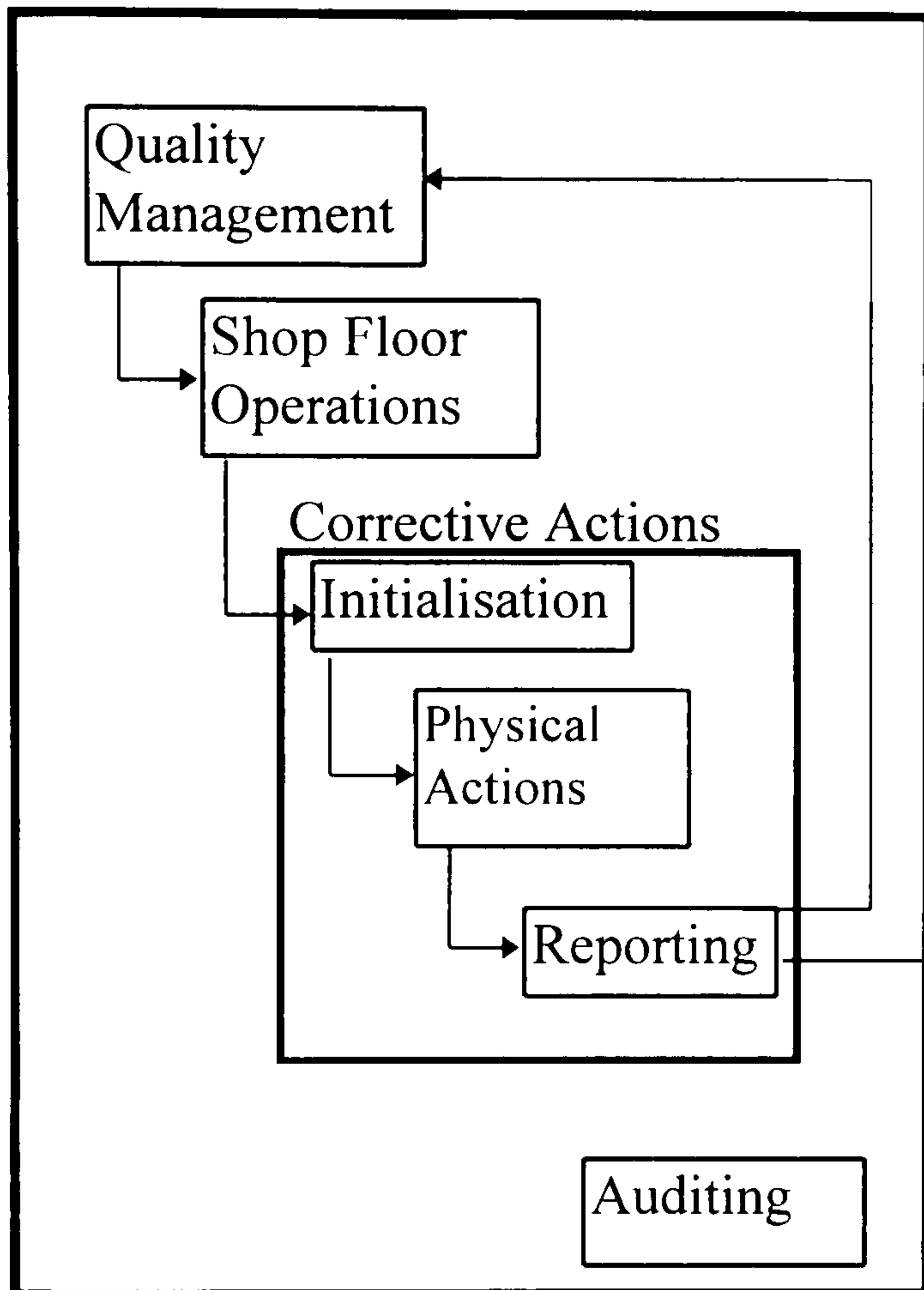


Figure 4.27 Integration of the scheme to other schemes in an establishment

A maintenance management system is a good example for a further integration (Gundogan and Kay, 1995b). Figure 4.28 shows the integration to a structured maintenance management information scheme which is extracted from a group project carried out for Ford of Europe (Campos et al. 1990).

As can be understood from figure 4.28, corrective actions will lead to a corrective action report which will supply information to an external functional area, namely maintenance.

### Integrated Quality Management Information Scheme



### Maintenance Management Information Scheme

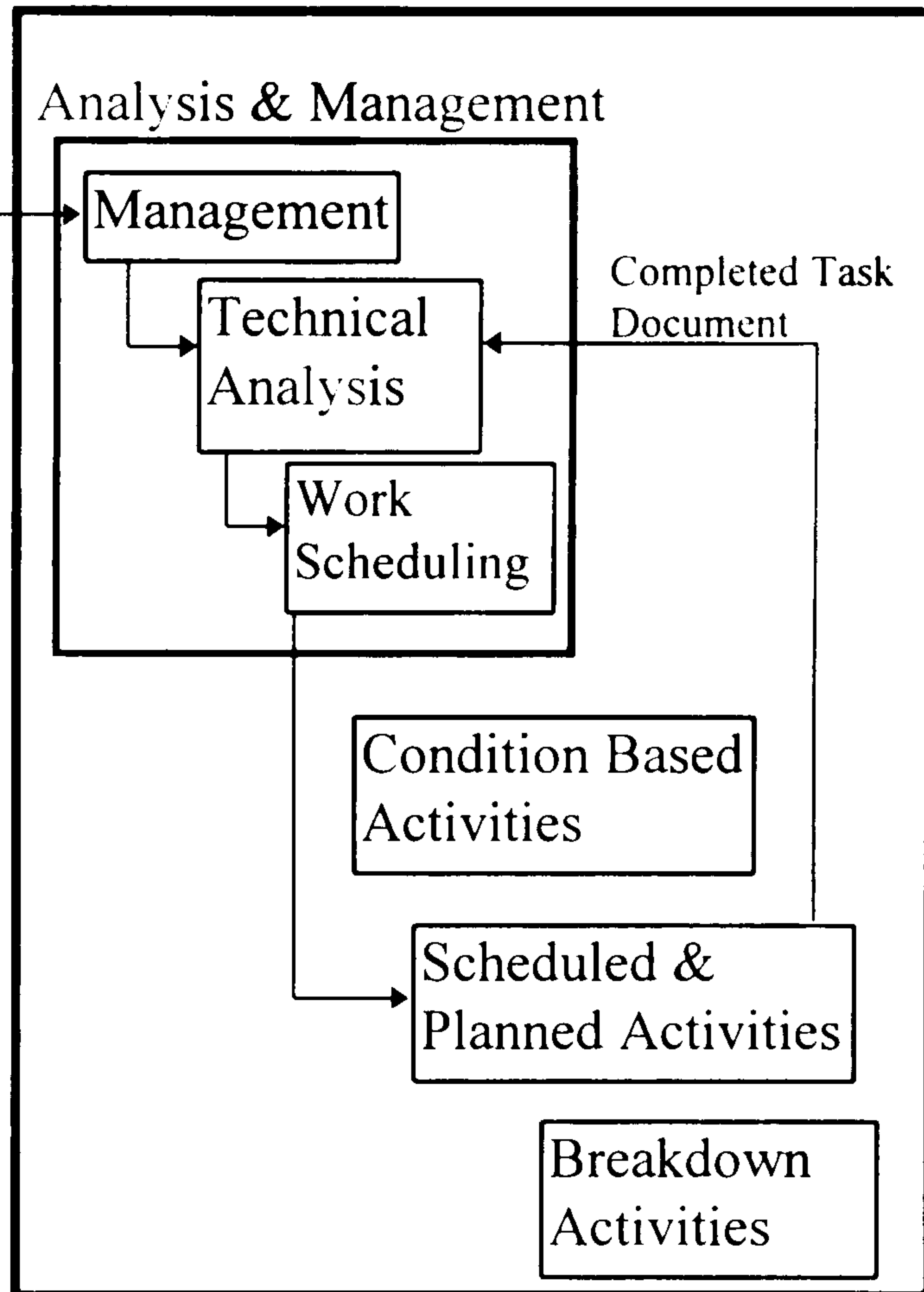


Figure 4.28 An example of the integration to the maintenance management information scheme

This maintenance order or related information is input to a management sub-function in the main Analysis and Management functional area of the maintenance system. The specific information then flows to the Technical Analysis sub-function to be processed and evaluated. After the analysis of the information, it goes to the Work Scheduling Sub-function. Here, a pro-active work plan is produced and a work order set up. This work order is then sent to the function of Scheduled and Planned Activities. As the task is completed, a completed task document is sent back to the Technical Analysis for further evaluation, information storing and reporting purposes. This completes the

activity loop of maintenance information within the maintenance management information scheme.

Therefore, as is clearly seen, quality improvement could take place in an outside functional area which is structured and integrated. In this way, it is also possible to establish a total quality understanding and make quality everybody's job through the establishment. Flowing information through the structured schemes will encourage employees to work through the total quality management philosophy.



## CHAPTER FIVE

### JUSTIFICATION OF THE MODEL

#### 5.1 INTRODUCTION

A quality information system model has been produced to apply a TQM philosophy to cellular manufacturing. To begin with, it is worthwhile to remember that the model lies on the intersection of the three areas namely Information Systems, Total Quality Management philosophy and Cellular Manufacturing. The intersection of these three gives a number of points of view to justify this model.

It is also generally known that any such quality information model requires change. A management system change affects not only quality management activities but also other activities. Thus without taking into consideration those other activities affected, an application is likely to have various difficulties caused by them.

In this chapter, the model is justified through four methods. Firstly, the model developed is presented as a response to the deficiencies in the current research in this area. Positive factors associated with the model to overcome these weaknesses are also presented. Some of these factors are adequacy, consistency, reliability, structuredness, self-descriptiveness and openness to developments. Additionally, elements of the prevalent quality systems are discussed within the model.

The second important justification method is goodness. Goodness and completeness are explained and illustrated in section 5.3 of this chapter. Within this framework, to show the goodness or completeness, an involved example extracted from the model is also given.

Thirdly, many industrial site visits have been undertaken. Discussions which have taken place in these industrial visits are given. Benefits of these discussions are also reflected in the evaluations of the model. Cross-checking validation with industry has also helped to build confidence for the model. Structured walkthroughs i.e. manual simulation have helped the model to be modified according to user requirements.

In the last method, a quality management survey, which was conducted through various manufacturing industries, is presented and its findings are discussed in detail in conjunction with the model. Whilst discussing the survey results, similarities and conflicts with the model are also pointed out within the context of justification.

Finally, these justification methods are evaluated from various angles. A comparative discussion is also given to show the degree of measurement achieved and the satisfaction of requirements identified earlier.

## 5.2 VALIDATION DURING THE MODELLING SESSION

This section consists of two parts. The first part is about quality systems. These are different quality systems of which many companies are trying to pursue. The purpose of a quality system, given by Dale (1994), is to establish a framework of

reference points to ensure that every time a process is performed, the same information, methods, skills and controls are used and applied in a consistent manner. Dale (1994) argues that a documented quality system provides an effective managerial framework. As a requirement for a successful quality management implementation, elements of the prevalent quality systems will be evaluated and justified within the model.

The second part is about other requirements identified in the literature review and discussions. These requirements, omissions, gaps and weaknesses are generally seen as potential reasons for successes or failures of TQM programmes. These issues will be discussed as to whether they are covered and satisfied in the model. Information system models involve many steps and relationships. Models help users understand the work domain, identify improvement opportunities and perform an easy application. Individuals often do not see how the different activities of management are related (Dean et al., 1994). Models can also help in this regard. Different activities, functions or elements may strengthen different aspects of the management activities. Consequently, model completeness and quality are likely to be increased by broad involvement during the modelling session. As is seen in the discussions of the previous cases, having a quality management system was a prerequisite to have a successful implementation (Kanji and Asher, 1993, Kanji et al., 1992, Oakland, 1993, 1995, Zairi, 1991). From this respect it is also important to include as many requirements i.e. quality management activities, as can be found in various manufacturing environments, especially in cellular manufacturing environments.

First of all, Quality systems such as BS5750 and ISO9000 are considered as the most important standards available and are widely applied in the manufacturing industry. These standards are considered and to a certain degree reflected in the

model. Hence, it is made clear that the model is encompassing most, if not all, of the elements of these quality management systems mentioned. Ranky (1990) and Ho (1993) give overviews of these quality management standards with their important elements to assist in establishing total quality and total quality information systems. These main elements of quality systems (BS5750 and ISO9000) are now briefly given and they are justified within the model from two points of view namely;

- existence; if such an element is included in the scheme or not.
- activity; if such an element is defined, structured and integrated to the related parts or functions.

Management Responsibility: To begin with, there must be a quality policy. To achieve the policy objectives, responsibility and authority is needed as part of a structured organisation with established levels of control and inter-relationship. This is the starting point of the model, the integrated quality management information scheme. Corporate quality policy from the top management is the input/output to the scheme (see overall level activity diagram in Appendix A). This policy is then detailed out down to the shop floor and integrated to other functional areas to achieve the quality objectives. A quality management report is produced as a feedback to the top management to evaluate and improve (i.e. satisfy) the corporate policy. This relationship draws the top management's attention to the heart of the quality matters.

Quality System: The quality system is a part of the overall management system. To only state it, does not make it happen, unless the necessary means are established. As is explained in the previous chapter, the scheme is well integrated to the main functional areas of overall management. Starting with the quality

management activities, it is possible to establish a TQM philosophy throughout the company. The scheme is broken down to small, well-defined activities, and each activity receives an input from the previous one and delivers an output to the next one. Each activity has at least one information “supplier” and at least one “customer” as is shown in figure 5.1. This chain is well-established within a structured system. This systematic structure allows any quality system to be accommodated within the model.

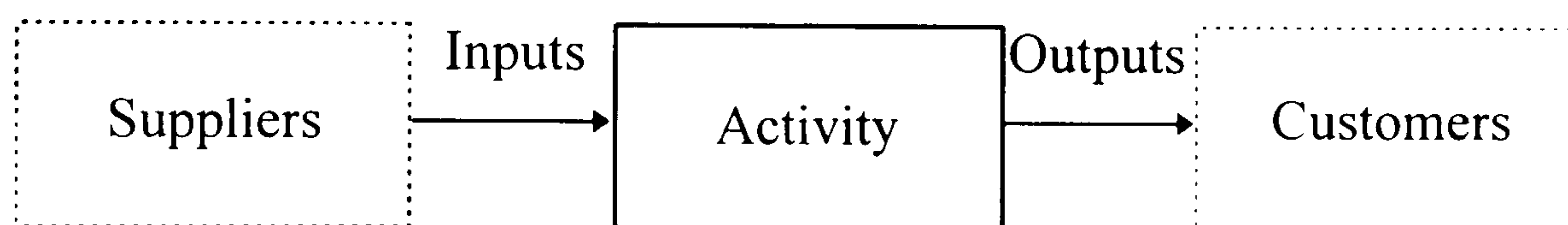


Figure 5.1 Each activity has a customer and a supplier

Controls: Design control, document control, process control and control of non-conforming products are the main elements of this factor. In the model, the Product Design and Method Engineering function is integrated to the scheme for continuous quality improvement activities. Document control is realised through reporting facilities in each main functional area and an overall quality management report is produced to control the overall activities according to the quality policies adopted by the top management. Information Systems are used to improve processes, and improved processes result in better products. The cross-functional team, material review board, within the corrective action function (see figure 4.21) is formed mainly to control and manage the non-conforming

products and to find out possible reasons for the non-conformance by active involvement of members from various departments.

Inspection, Testing and Corrective Actions: These are the main elements (activities) of a quality management system. In the integrated quality management information scheme, inspection and testing are performed in the shop floor operations (see figure 4.19), and corrective action (see figure 4.20) is another internal functional area.

Audits, Training and Customer Services: Auditing is one of the main functional areas of the scheme (see figure 4.21). Training needs are identified, organised and reported throughout various activities in different functional areas. Customer services are considered as an external functional area integrated to the scheme (see figure 4.17).

SPC Techniques: These techniques are easily employed by Data Analysis and Cost Reporting activities (see 1.1 Quality Management (Data Analysis and Reporting) in Appendix A). The scheme actually can accommodate any sort of SPC technique easily, because it is modelling the information flow, not the data characteristics. The information to be used and flowed through the model can be produced by any appropriate SPC technique.

In summary, the scheme encompasses and accommodates the main elements of such quality management systems as BS5750 and ISO9000. Any future consideration to apply any of these standards will be realised relatively easily. This minimises the risk of poor integration and strengthens the model for a successful implementation.

The second part of this section is about the other requirements of a successful quality management implementation programme. From the discussions in chapter two (The Literature Review), the reasons for a possible failure of TQM implementation can be summarised as follows (Oakland, 1989, 1993, 1995, Kanji and Asher, 1993, Zairi, 1991, Sohal et al., 1992, Mann and Kehoe, 1994, 1995, Kasul and Motwani, 1995, Kehoe and Adebajo, 1995, Drensek and Grubb, 1995, etc.);

- lack of top management commitment,
- lack of communication,
- lack of continuous improvement.
- lack of management of change (re-organisation requirements) and
- requirements of new performance indicators or measurements.

These factors may be grouped into three categories;

- management style,
- organisational re-structure and
- quantitative analysis.

### *Management Style*

Top management commitment, communication and continuous improvement can be considered in management style. These elements are not achieved easily unless they are accommodated properly within the management system. These elements are integrated parts of the quality management information scheme. The overall structure of the scheme can be simplified as is shown in figure 5.2. From

the information systems point of view a function (activity) receives external information to start its activities (Ashworth and Goodland, 1990). All quality management information activities are triggered by the top management commitment i.e. active quality policies. Other external functions are integrated parts of the overall system. A very important factor, here, is to have a feed-back mechanism (top level quality management reports) to evaluate and further improve corporate quality policies. This mechanism encourages top management to take an active part in the quality management and incorporate this commitment to other areas leading to the total quality management implementation.

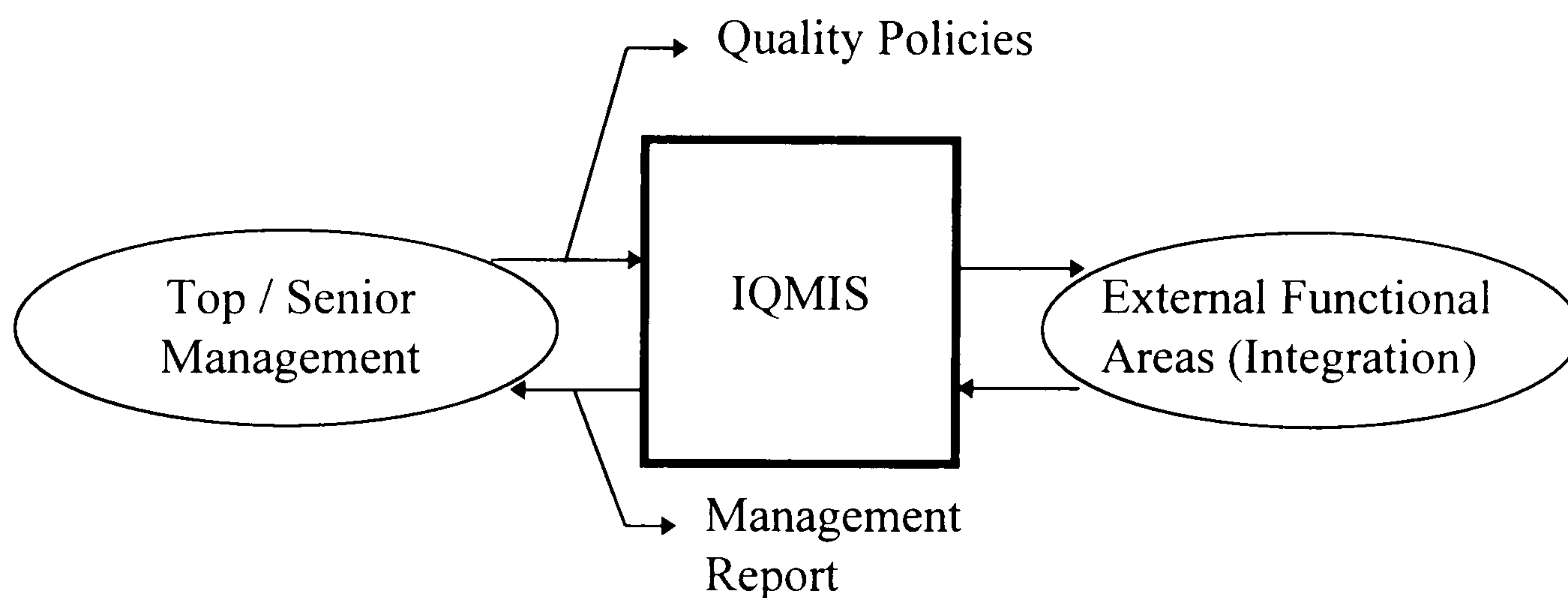


Figure 5.2 Simplified representation of the Integrated Quality Management Information Scheme

Successful communication is also achieved through structured information flows. As was mentioned earlier by Quimby et al. (1991) and Besterfield et al. (1995), communication is about information flow. If there is a communication barrier or break between the two activities, that may well mean that the information flow between these two activities is not well-defined and established. This is clearly illustrating the importance of a structured and integrated information system. Because the information flow is systematically structured throughout the scheme.



communication through this flow can easily and effectively be achieved. Each activity, which has at least one supplier and a customer (see figure 5.1), can be considered as a small independent business unit. This also gives a great flexibility to find out continuous improvement points within each structured activity.

### *Organisational Re-structure*

Requirements for the re-organisation are not easy to apply. These requirements generally affect other functional areas such as, for example, production planning and control. So, any system requiring change should consider the effects being imposed on the other functional areas. TQM philosophy requires change especially in the management style and organisation (Kanji and Asher, 1993, Oakland, 1989,1993). Because of their effects on the shop floor and on the production planning and control, they are not easily established. These changes require flexible manufacturing management systems to be applied. Rigid scheduling systems like MRPII are not flexible enough to employ change easily within themselves (Ziarati and Khataee, 1994). Group Technology here seems to be one of the most important systems and, moreover, initially requires re-organisation i.e. from process organisation to groups. It, therefore, gives a great opportunity to establish and manage the change towards a TQM organisation. It also assists in alleviating many other TQM implementation weaknesses such as team-building, motivation, sense of ownership of the works, functional barriers, etc. (Burbidge, 1989, 1994). Each group can be tackled as a small independent business unit and any convenient one of them can host an initial TQM implementation. Quality management activities, especially in-group quality operations and corrective actions, are also improved by the group technology

applications (Burbidge, 1994. Welke and Overbeeke, 1989. Snead, 1989. Gunasekaran et al., 1994, Pesch et al., 1993).

Group technology simplifies layouts resulting in devolution of control. decreased throughput times, reduced materials handling costs, reduced set-up times. reduced inventory, on time delivery and improved quality. It is seen that many of the advantages of groups may either be weaknesses or requirements of a TQM programme. For example, the following advantages of groups (Anonymous, 1989) are also requirements of a TQM implementation programme;

- eliminating build up of non-conformances that can occur in a batch environment,
- improving the spirit of team work, and
- establishing continuous improvement (Pesch et al. 1993).

On the other hand, although these advantages have been reported by many researchers, the design phase itself of Group Technology i.e. change from process organisation to product organisation, focuses insufficiently on defining and achieving a quality management system within groups (Goodyer and Spragget, 1994, Goodyer et al., 1995). The majority of research about GT focuses only on the grouping of parts and machines (Nimmons et al., 1994). From this respect, the TQM philosophy within the model, strengthens and assures an improved quality with an integrated quality management system.

#### *Quantitative Analysis (New Performance Measures)*

As a final point, new forms of management and organisational structure allow new performance indicators and measurements to be studied thoroughly. This is a

critical issue and may hinder some total quality programme efforts (Oakland, 1993). A survey carried out by the European Centre for TQM argues the existence of a gap between the aspects of performance which managers perceive as being important to measure, and the actual performance measures used (Sinclair and Zairi, 1995). As a flexible system, the group technology organisation builds simplified and independent business units (groups) to tackle the problems easily and to create new frontiers for new performance measurements. Different performance measurements may also be found for different groups. By simplifying, structuring and strictly controlling the groups, any perception gap mentioned by Sinclair and Zairi is expected to be alleviated.

Overall, it has been shown that the modelling session involved many steps and activities which are considered as important requirements of successes or reasons for failures of a TQM programme. These are the current requirements, weaknesses, gaps and omissions identified throughout the literature review and justified in the model. It has also been seen that main elements of the quality systems concerned are accommodated within the scheme in order to make it easily applicable in the related environments. Especially, it is realised that Group Technology gives a great advantage to alleviate the current problems and to meet implementation requirements.

Overall, it has been seen that together with the requirements of quality standards, other requirements emerged through the literature survey have also been considered and accommodated within the scheme. These various requirements or elements were the main factors to contribute to the success of a TQM programme or to avoid a probable failure. These critical factors have been strengthened within the structure of the scheme, and thus, contribute to the success of a future implementation of the model.

### 5.3 GOODNESS OF THE MODEL

Goodness is the circularity of information within the implementation scheme. Information is flowing throughout the scheme without being blocked or being stacked anywhere to be idle or redundant. In this way all the necessary information is processed and improved by related activities leading to a continuous improvement. An information model establishing this circularity is to be considered as a good model. Since the scheme is an information model, it should lead to perfect information flow through the activities to achieve the quality objectives. The structured flow of information should not be blocked by inappropriate processes or design which may well also result in wasted efforts of data gathering and processes.

The integrated quality management information scheme is a data driven model. This means that the data structure changes very little over time, although processing requirements may change (Ashworth and Goodland, 1990). The data used is structured and modelled from an early stage. The representation of this data structure is checked against the processing and reporting requirements and finally built into the quality management functional area. This model assists in giving precise (structured) and circular information that is understandable to both the users and facilitators (developers). Circularity of information promotes the flexibility of the scheme.

In the construction of the scheme, the overall circular relationship is also maintained by the functional analysis, data analysis and logical data structuring (see figure 2.7). At the top, functional analysis is carried out to find all related functions. Structurally, data analysis is carried out within each function to find

out all data and their relationships throughout the activities as well as basic entities. Finally, logical data structuring is carried out to identify new raw data structures to assist further functional analysis.

Consequently, this circular relation stabilises the structured information within the scheme. The information flows through the activities to complete their loops. This circularity makes the information of the scheme to be used as efficient as it could be and becomes a driver for the continuous improvement leading to a good scheme.

In order to give an example for goodness, figure 5.3 shows how a work order information flows through its loop. In order to simplify the work order loop, some of the steps (functions and activities) in figure 5.3 have been removed.

### 1.0 Integrated Quality Management Information Scheme

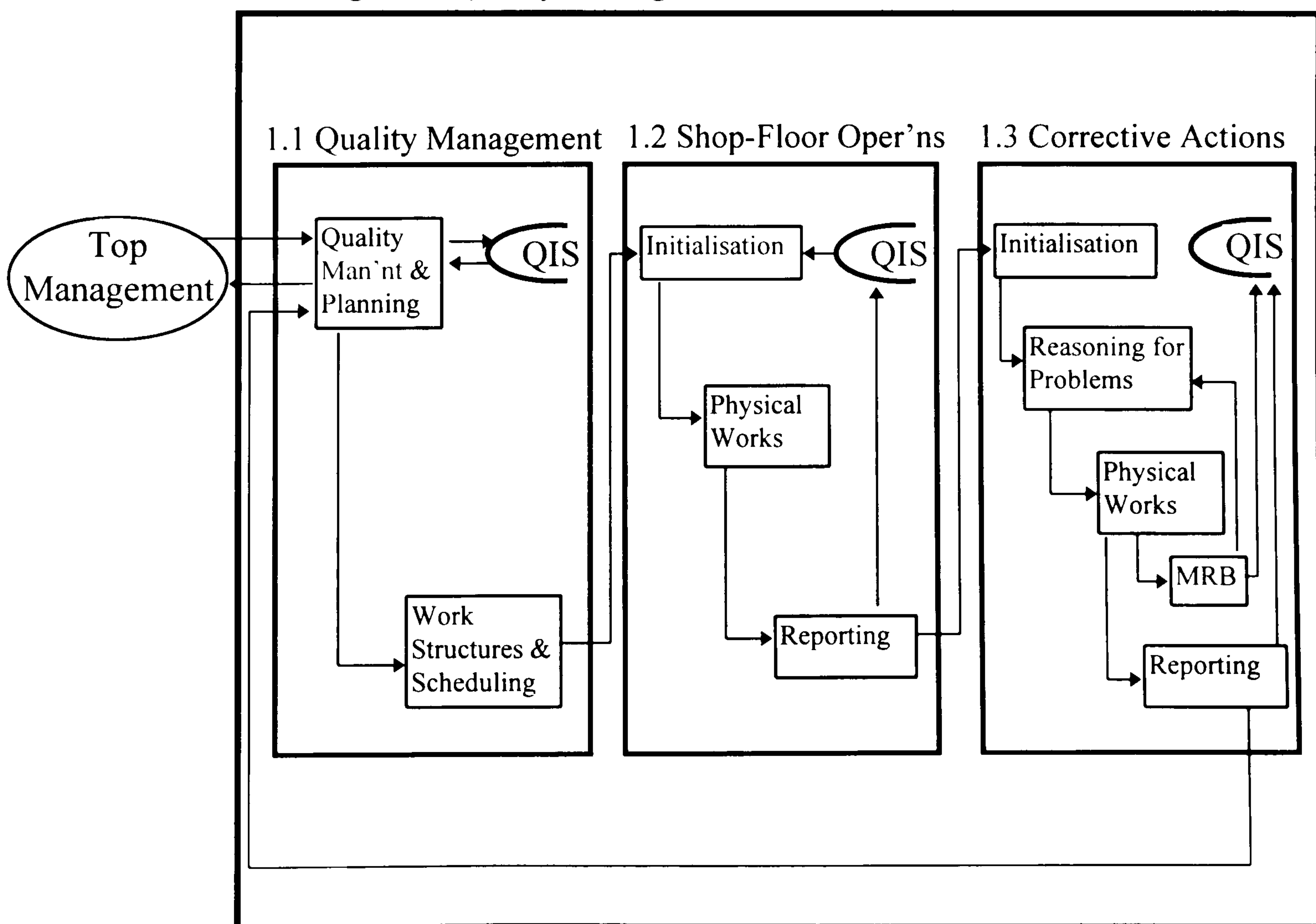


Figure 5.3 Information loop of a work order (Circularity)

As can be seen in figure 5.3, **1.0 Integrated Quality Management Information Scheme**, the work order information is produced, processed and applied within three functional areas, namely **1.1 Quality Management (Data Analysis)**, **1.2 Shop Floor Operations** and **1.3 Corrective Actions**. In **1.1 Quality Management (Data Analysis)** function, a quality “work order” requirement is initiated in Quality Management and Planning Activities, and then upon this requirement a work order information is released to the **1.2 Shop Floor Operations**. Here, having realised the initial planning reviews and resource allocation, actual physical work is performed and then reported to corrective actions. In the **1.3 Corrective Actions** function, possible reasons for problems are studied and resolutions are produced. Then physical Corrective Action work is carried out. A cross-functional team, Material Review Board, is also consulted about the resolutions and trouble shooting. Having done the work, all the activities relating to the initial “work order” information report back to the Quality Management and Planning sub-function resulting in a complete information circle (loop). Another simplified example is given in Appendix E for a Group Technology cell.

This work order information loop is simply shown in figure 5.4. As is seen in the figure, the information flow is a closed loop. The data associated with an activity is structured and integrated i.e. each activity has an input and produces an output. At different stages, information accumulation store (Quality Information Store, QIS) allows data to be shared by any other activity or function. In fact, requirements of these activities or functions determine the quality and quantity of information to be kept in the QIS. Requirements of the next activity will mainly shape the previous activity and will determine the information to be produced. This chain will start with the requirements of top/senior management and end

with the satisfaction of those requirements (see figure 5.2) hence achieving the circularity.

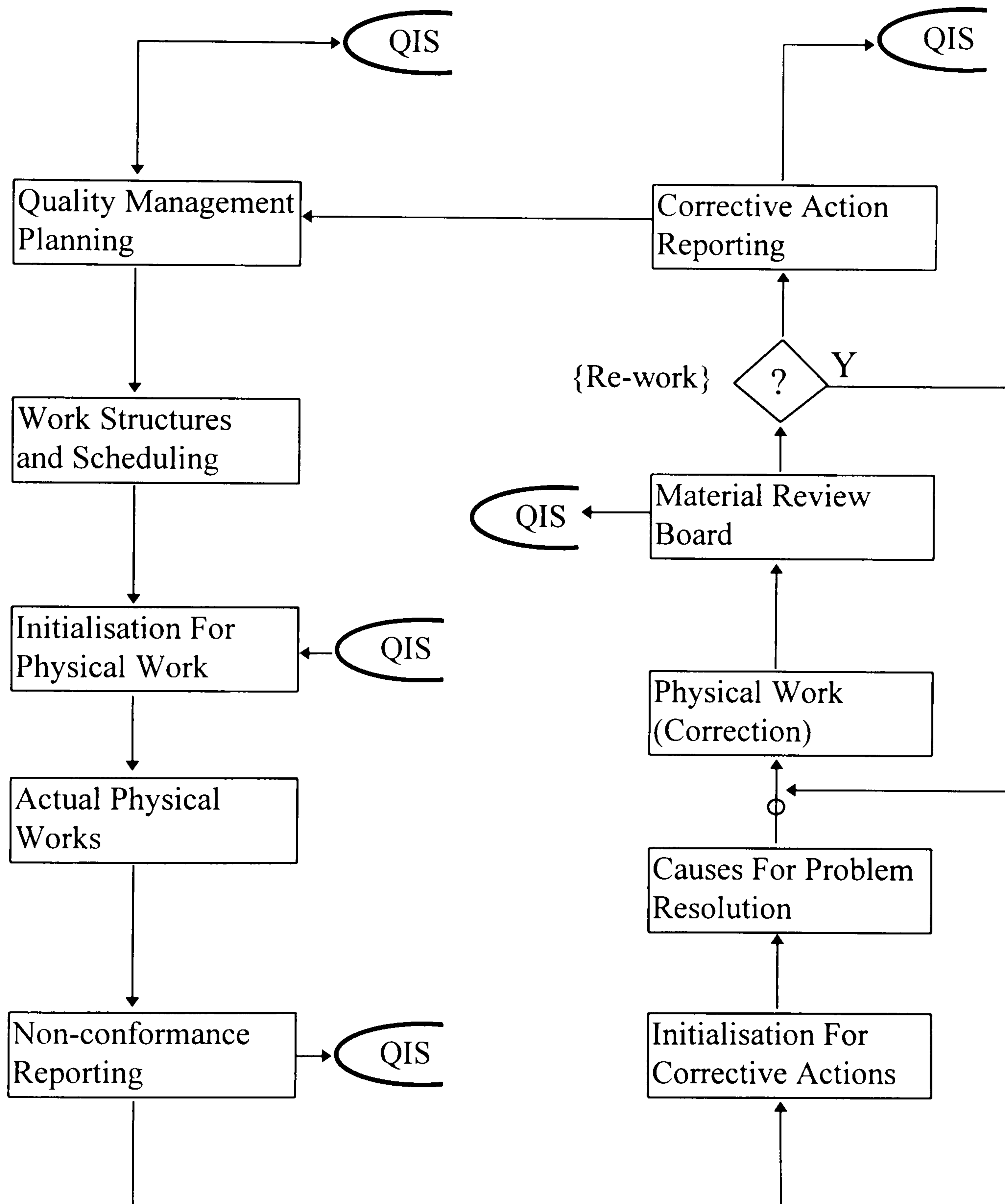


Figure 5.4 A work order information circling (flowing) through the activities

Finally, it can be concluded that all information in the scheme is circling in the same way. It will not allow any information or data redundancy in the scheme

and it will lead to a continuous improvement. Any unnecessary and non-value adding information or data acquired will occur within one activity. That activity will then be a focal point for the improvement. This complete circularity minimises the risk of leaving gaps and redundancy in the information flow and bridges the gap between islands of information, thus results in a good scheme for a successful implementation. It also improves the flexibility of implementation.

#### 5.4 STRUCTURED WALKTHROUGHS AND EXPERT REVIEWS

Structured walkthroughs have been utilised for cross-checking the validation with industry, and expert reviews have been undertaken on the model. In the early stages of modelling, industrial visits were undertaken and some expert views were also obtained to provide some additional external comments regarding the research. The names of the experts and the industrial sites are given in Appendix C, Part A.

On completion of the integrated quality management information scheme, discussions with some experts and some industrial visits were again conducted for cross-checking validation and justification purposes. Appendix C, Part B shows the list of sites and experts visited. Industrial sites have been chosen from various industries such as automobile, aircraft building, machine tools etc., and experts from different background including information technology, quality and manufacturing. The main reasons for these site and expert visits were:

- to justify the implementation scheme produced,
- to identify whether the implementation scheme covers all the quality activities.



- to receive feedback for further evaluation and modification of the scheme, and
- to understand their current implementation and quality management systems.

### *Comments received from industry and experts*

Overall, discussions were quite encouraging and positive with respect to the scheme produced. It was found to be covering every aspect of quality management systems, and even found to be applicable straight away (Mr. Lyne: H.C.Bridgman). Their concerns were also taken as valuable feedback for further evaluation and modifications.

There is a general tendency towards cellular manufacturing application wherever possible. It is seen as an important vehicle for simplification, team building, quality improvement and feeling of ownership (Mr.Marriott, Avdel Systems). It was also realised that it is a great advantage that faults, discovered within the cell, do not get through because measures are taken immediately within the cell. Furthermore, groups allow the management to create a cross-trained flexible workforce which is seen as an important element of the quality management. The integrated quality management scheme based on Group Technology was found to be very useful and beneficial. One of the characteristics of the scheme is that it is a data-driven model. This feature was reflected as one of the recently identified requirements in quality assurance engineering (Mr.Marriott, Avdel Systems).

It is found that group technology in the traditional meaning is outdated, yet a good start towards flexible manufacturing systems which could be seen as the

future of manufacturing systems (Dr.Kurimoto; Mazak). From the quality management point of view, cellular manufacturing gives a great opportunity to have a very flexible, multi-skilled workforce. For example, workers are even encouraged to produce their own operating manuals (Mazak). The result of this is that each worker knows exactly what is going on. Kurimoto (Mazak) pointed out the importance of cultural change and human factor besides the systematisation within the scheme.

In the Ford Enfield plant, workers are now responsible for quality as well as production. The Ford jargon for this is “quality production” (Mr.Warner; Ford). To have an information system is found to be very important. It is also believed that the data processing within an information system is improved. So the scheme also allows for advanced data processing. Warner (Ford) suggested an information systems department, which was missing at that time, should also be considered in the scheme. This department in the Ford Enfield plant, for example, looks after all PCs, telephones and fax machines, supplies software and provides maintenance, maintains such systems as the computer mainframe and LANs, and co-ordinates different programmes. It was then decided to have such an important function integrated to the scheme as an external functional area.

Communication is seen the key to change. Any change programme should be detailed out down to shop floor to show what it means to different levels of employees (Mr.Elenor; Rover Group). The scheme provides such facility with its structured feature. Communication with Production Design and Method Engineering function was found to be extremely important. It is believed in Rover (Longbridge) that 80% of non-conformance cost is committed in the design phase. So the significant function is to get the design right up-front.

because it might be more costly or even impossible to change it later on (Mr. Elenor; Rover Group).

In the old days, Designing, Manufacturing Methods and Production was the sequence of work. New requirements of quality management have changed this to bring the quality issues to the heart of the design phase (Mr. Ball: Vauxhall). So, the integration of these external functions (i.e. Design and Method Engineering) to the scheme has been found to be very appropriate and useful. Another important thing to mention was to have a flexible system which can be used standalone if required. This is because, in some cases, a visual management (engineering) system works better than a computerised one (e.g. cells associated with the production line in Vauxhall). Hence, from this respect, the scheme produced also gives a great and realistic flexibility to be used as a standalone quality management system.

Some of the sites found data gathering as a difficult task and think an information system would help. One of the sites has shown that a structured and simplified system helps workers even produce their own way of data gathering and recording (Mazak). It is also unanimously accepted that decisions should be data-driven.

Total Quality Management covers every activity in an establishment from supplier to customers (Prof. Rogerson; Cranfield University). Since the model is a quality management information scheme with the TQM philosophy, it has been pointed out that the relationships of the scheme with external functional areas are very significant. Another important point is that many quality improvements can be realised outside the quality management functions. These include production, maintenance, design etc., so, it is found to be a strength and a requirement to have

information links established with the external functional areas in order to further quality improvements.

Although it is found that the data flow diagrams looked very complicated, it is subsequently understood that it would be very practical and helpful in the implementation phase (Mr. Lyne, H.C. Bridgman, Mr. Marriott, Avdel Systems).

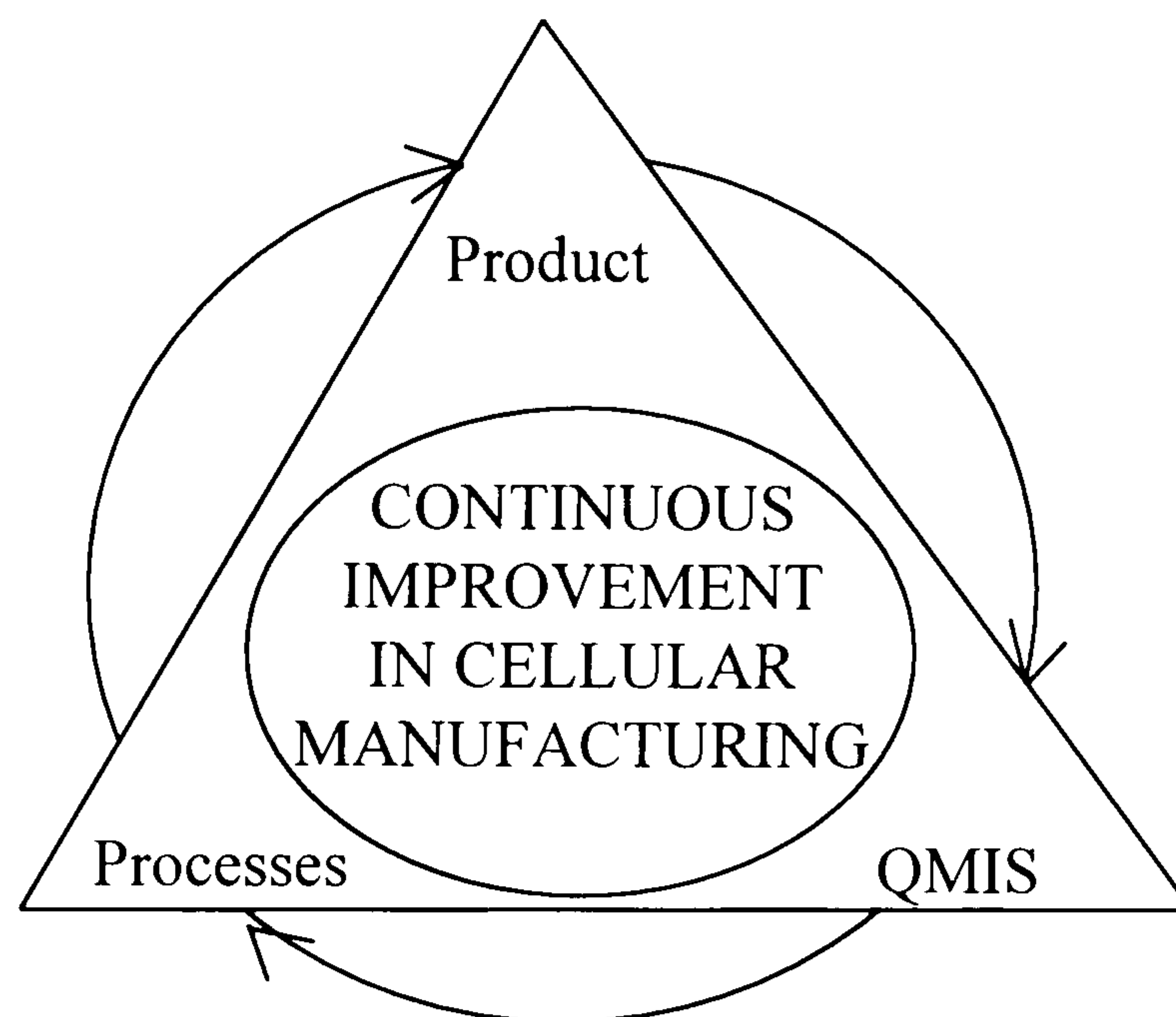


Figure 5.5 Quality improvement via a good quality management system

From the information systems point of view, it is seen that the IS is a potentially important tool to carry the TQM philosophy across industry. Figure 5.5 shows the role of a quality management system for product improvement (Mr.Grogan: LMU). An integrated good quality management system improves processes throughout the establishment. Improved processes result in better products satisfying customer requirements. Consequently, improved products result in new adjustments to the quality management system. This can be seen as triple continuous improvement within groups in Cellular Manufacturing. Continuous improvement is found to be an essential part of the scheme and that is also what

differentiates a TQM philosophy from business process re-engineering (BPR) which is seen as another improvement philosophy (Prof. Bryant: LMU). BPR aims to achieve step improvements in performance by re-designing the processes (Peppard and Rowland, 1995). On the other hand, it is also seen as a way of downsizing whilst simultaneously loading further responsibility and demands on those staff who manage to stay (Bryant and Chan, 1995).

Experts overall vision of the scheme provided the capability to identify technical gaps in the detailed design. During this work, the model has been modified and further developed according to such expert suggestions and industrial requirements as introduction of new functional areas (e.g. Information Systems and Method Engineering) and updating some parts of information flow (e.g. especially audit information flow). As a conclusion, it has been realised that the scheme has been conformed with the suggestions of experts and requirements of the industry, and it is on the right course for a successful implementation.

## 5.5 QUALITY MANAGEMENT SURVEY 1995

This quality management survey, based on the scheme produced, was carried out to;

- assess the current quality management implementations from a systems analysis and design point of view,
- draw conclusions about their successes and weaknesses, and
- find out the level of integration with the other production management schemes and their effects on future developments in manufacturing.

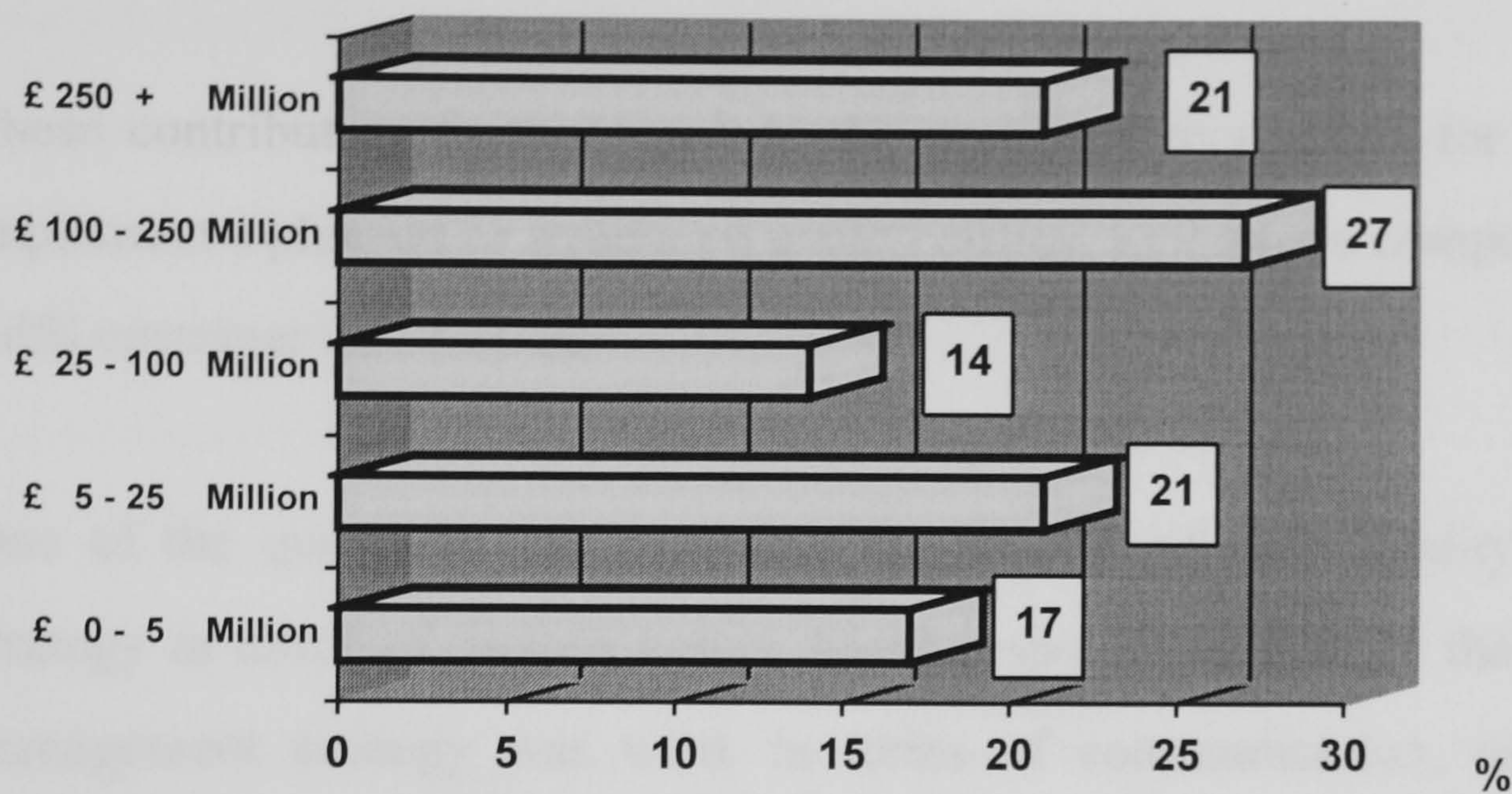


Figure 5.6 Companies surveyed in various sizes

Appendix D shows the questionnaire of the survey. Since most of these questions are emanating from the integrated quality management information scheme produced, the results are expected to a certain degree to justify the scheme. A total of 110 questionnaires were sent out to specific organisations. Thirty two questionnaires were returned resulting in an overall response rate of 29.1%. Of the 32 questionnaires returned, 29 (26.4%) were used in the data interpretation. These manufacturing companies vary in size as shown in figure 5.6.

First of all, 86% of the 29 companies which responded either have, or are expecting to have, a planned or structured quality management policy. As are given below, this requirement stems from various needs;

- An internally determined need for improvement (88%),
- The need to keep pace with competitors (80%) and

- Pressure from customers (68%).

These contributory factors result in the necessary motivation for companies to implement a planned or structured quality policy, to improve competitiveness and fulfil customer satisfaction.

One of the questions was to assess the success of their quality management strategy in terms of various points. Many respondents thought that their quality management strategy was weak in terms of communication, integration and reporting. The scheme produced, on the other hand, is based on various pillars including communication, integration and reporting.

In the implementation section, respondents were asked what were the elements experienced of a new TQM implementation strategy. Respondents were generally experiencing the following elements which were also included in the implementation scheme;

- Involved top management commitment,
- Required good communication,
- Involved entire workforce,
- Required personnel re-training,
- Required change in the organisation structure.
- Required change in the data, and
- Required change in the work patterns.

Respondents were asked to name the functions (or departments) that are integrated or they think should be integrated with a quality management system. These functions (or departments) are mainly the external functional areas of the

integrated quality management scheme. Figure 5.7 shows this integration requirement which can be interpreted as a considerable tendency towards total integration. Currently production, supplier information, and product design and engineering seem to be somehow integrated with quality. In the future, however, maintenance, sales and marketing, personnel training, and production design and engineering seem to be on top of the integration agenda.

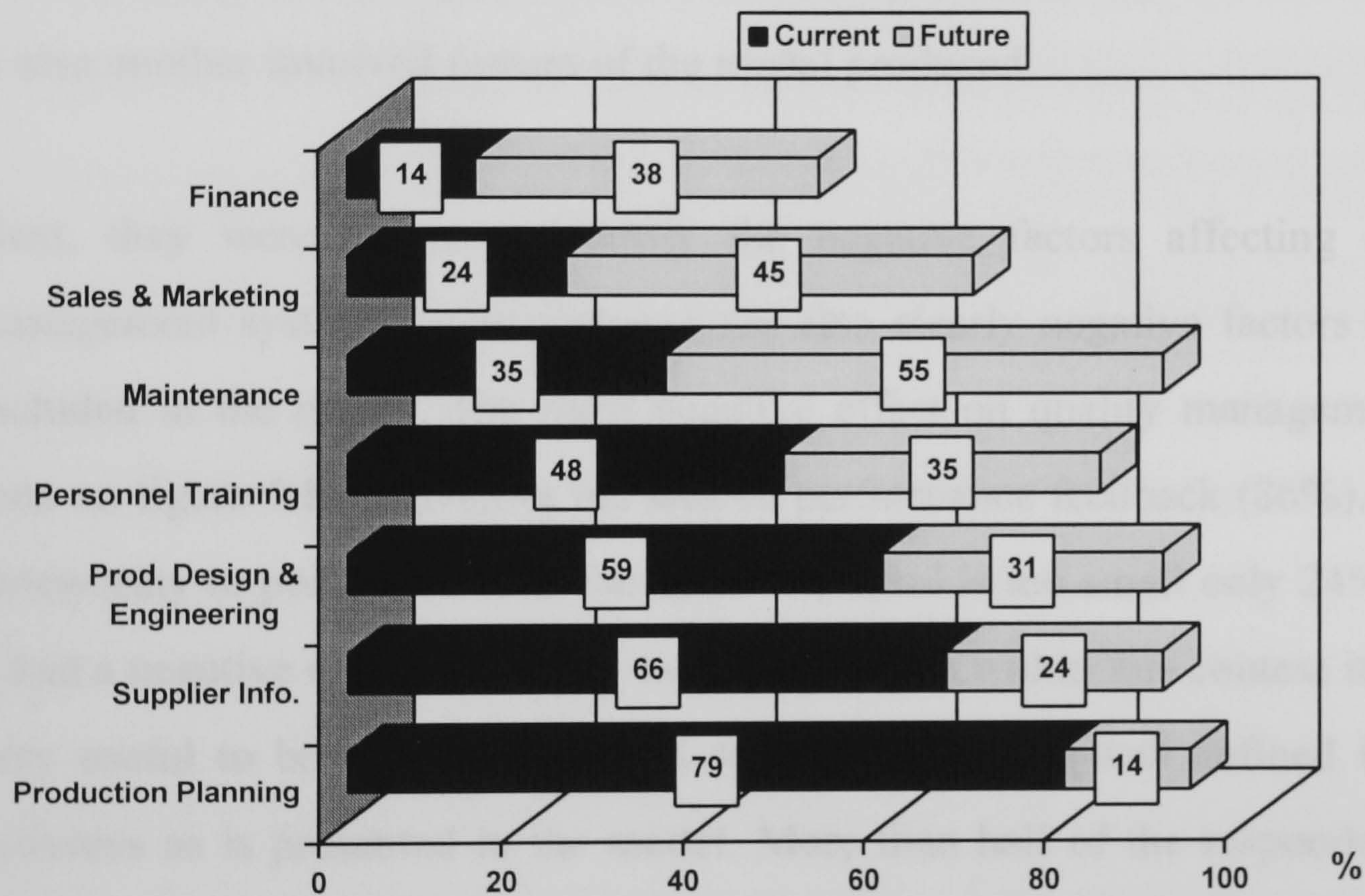


Figure 5.7 Integration requirements; Current situation and future expectation

Respondents were also asked about data gathering on the shop floor and data processing (analysis). Most of them think that the results of this analysis do not affect the top management and quality policies. It affects the top management and quality policies in only 41% of companies. Hence, it was appropriate to set top management relationship as one of the prime integration point i.e. main input-



output of the scheme (see figure 5.1), in order to increase the top management commitment.

Respondents were asked if they had implemented a continuous improvement scheme. The greater majority of the sites (79%) have some sort of a continuous improvement scheme such as quality improvement projects (72%), regular meetings (55%), communication schemes (48%) etc. It is worthwhile to note that most of the schemes require cross-functional operations. This cross-functionality is also another involved feature of the model produced.

Next, they were asked to identify the negative factors affecting a quality management system. These factors were also clearly negative factors not to be included in the model. The most negative effect on quality management, as is seen on figure 5.8, is given as the lack of performance feedback (86%). It is also noteworthy to point out that if the span of control is too small only 24% thought it had a negative effect on quality management. So within this context it could be very useful to break a management scheme into small well defined integrated activities as is presented in the model. More than half of the respondents think that overlapping responsibilities create negative effects on quality management. A scheme with clearly well-defined activities also overcomes this negative effect.

Finally, respondents were asked if they measure customer satisfaction and if so, how. The most important thing for customer satisfaction seems to be monitoring customer complaints (86%). As can also be seen clearly in Appendix A, the scheme produced enlists customer services as one of the main inputs. This also shows that the scheme satisfies this requirement as well. Once the integration is set, the rest is smooth information flow.

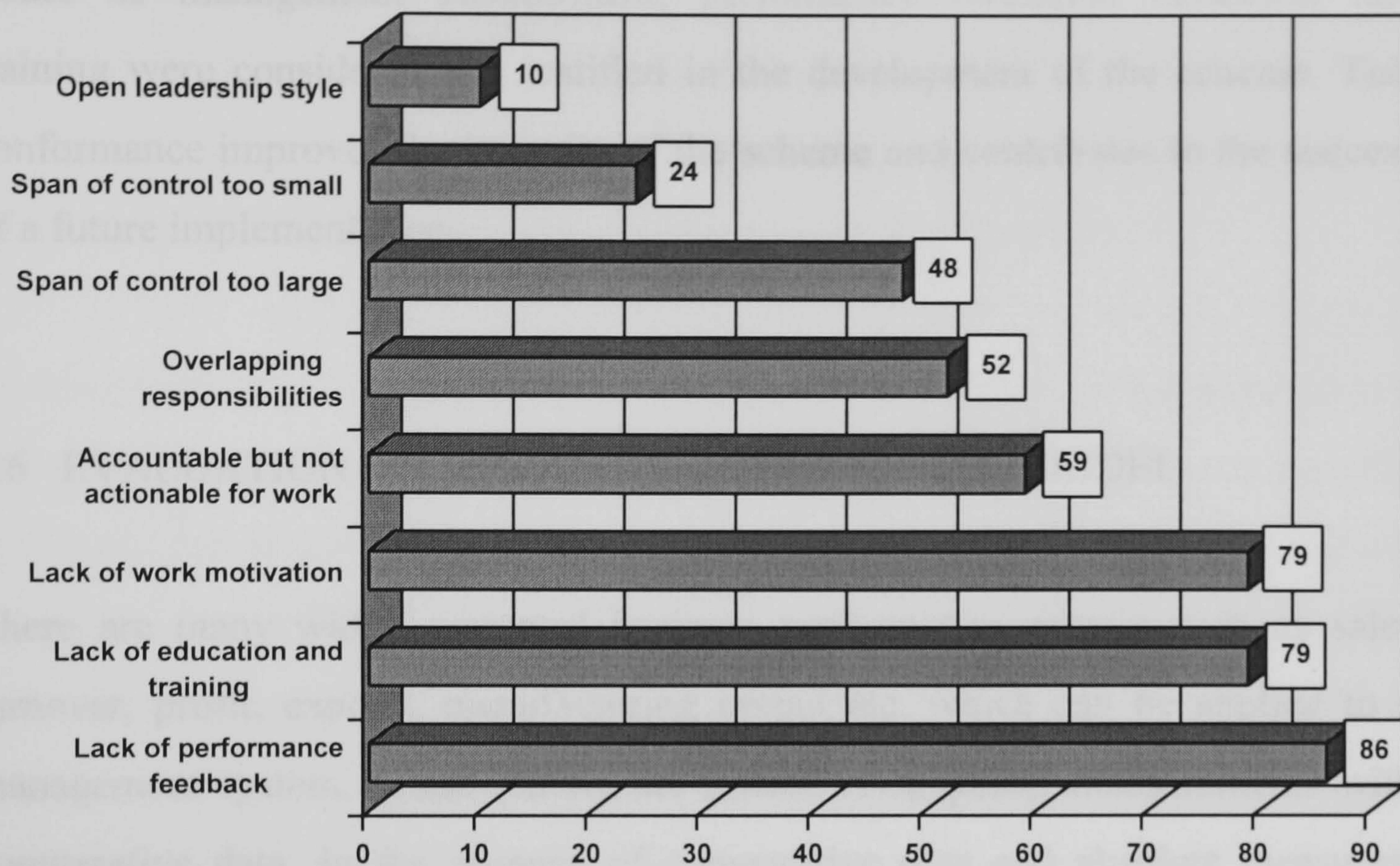


Figure 5.8 Negative effects on the quality management systems %

Overall, the results of the survey gave some interesting and encouraging signals. Companies have started thinking of systematising their quality management and introducing it to non-production departments with an integrated approach. The companies which have experienced a TQM implementation programme, expect in the long term that things will be better, easier and quicker. A considerable number of the respondents who have experienced a TQM implementation consider that it has made a major beneficial change to their organisations. The message of quality as a strategic weapon for contemporary competitiveness seemed to be getting through the manufacturing environment. However there are some areas for concern. The results of quality data analysis do not appear to be influencing top management and quality policies. Lack of performance feedback, work motivation, education and training could jeopardise the commitment to

quality management initiatives. As has been shown in the previous chapters such issues as management commitment, performance feedback, education and training were considered and justified in the development of the scheme. This conformance improves the integrity of the scheme and contributes to the success of a future implementation.

## 5.6 EVALUATION ON THE JUSTIFICATION OF THE MODEL

There are many widely accepted business performance criteria such as sales turnover, profit, exports, manufacturing output etc. which can be applied to a management system. These criteria are results of physical measurements with comparative data. In the absence of comparative data and absolute measures, assessment of such a soft model as the scheme presented in this thesis was carried out in a number of ways. The methods, here, chosen to justify the scheme are the validation during the modelling session, goodness of the model, industrial surveying, structured walkthroughs and expert reviews.

Validation during the modelling session consisted of two parts. Firstly, it was shown that the model covers the main elements of such quality standards (i.e. systems) as BS5750, ISO9000. So the model will have an increased familiarity and value for those establishments related to those quality systems. This is in a way self-assessment (Wiele et al., 1995) against these quality systems i.e. whether quality activities and related results comply with the quality systems concerned. In the second part, requirements, weaknesses, gaps and omissions of TQM programmes which have been identified in the literature review, were assessed against the model. It has also been seen that the model, established and structured systematically in cellular manufacturing, meets the requirements, fills

in the gaps and omissions, and alleviates the weaknesses with the strengths of information systems and cellular manufacturing. Additionally, the design phase of Group Technology, which focuses insufficiently on defining and achieving a quality management system, is also strengthened and improved. This strengthens the model and contributes for a more successful implementation.

In the goodness i.e. circularity of information of the model, it has been shown that every piece of information in the model is flowing continuously amongst the activities. This is a powerful feature which will maintain the systematic structure, communication and continuous improvement. Any non-value adding information will either not be produced or will be questioned at each stage (activity) whether or not it is valuable, in order to get through the scheme. It will also increase the flexibility of implementation with this data-driven characteristic. All of these features increase the degree of success and indicate that it is a good model.

In the structured walkthroughs and expert reviews section, opinions of outside observers have been taken. Overall, it was found to be a good and practically applicable model. External expert reviews were also valuable in the evaluation of the model. The model was evaluated and modified according to some suggestions such as new external functional areas and improving the information flows. Finally, the quality management industrial survey confirmed that the issues concerning the integrated quality management system were the right issues to be chosen, evaluated and accommodated in the model. It has been shown that the requirements, weaknesses, gaps and omissions identified in the research are rightly identified and the model is to cover these issues which were also justifiable by general expectations and views of the industry. Once the implementation starts, there are also some other available justification methods such as internal assessment of the progress of a company against internal

benchmarks. general comparison between the two states of a time interval. analysis of internal and external audit results and self-assessments (Dale, 1994). Furthermore, the activity based implementation (ABI) approach which is built around integration, circularity and structuredness, strengthens those features identified as contributing factors to a successful implementation of TQM. So, the ABI approach also assists in systematically evaluating and developing a successful implementation scheme.

Consequently, it can be said that the model satisfies the current requirements of a TQM philosophy application in the industry. Harnessing this philosophy with a compatible production management system i.e. cellular manufacturing, in a systematic and structured way, gives a great advantage by alleviating the weaknesses and filling in the gaps and omissions. It has been seen that all the evidence points to an improved scheme that should help to ensure a successful implementation.

## **CHAPTER SIX**

### **CONCLUSIONS AND RECOMMENDATIONS**

#### **6.1 INTRODUCTION**

An integrated quality management information scheme has been developed for the TQM philosophy within cellular manufacturing. In order to assist the users and developers an implementation approach simply called the activity based implementation (ABI) has also been produced.

This chapter concludes the research presented in this thesis. It briefly describes and discusses what has been studied, how it has progressed and what has been achieved (problems, objectives, approach and solutions). It evaluates the main findings together with criticism. Requirements of application and recommendations for those organisations which are going to apply the scheme, are given as well as for those organisations which have non-GT environment. Potential users and benefits are also given. Finally, this chapter ends with a proposal of areas where further research would be profitable.

#### **6.2 DISCUSSIONS AND CONCLUSION**

It is seen that there is an abundance of published papers on the TQM philosophy. In spite of this abundance, there is much research reporting implementation difficulties of TQM. When a detailed analysis was carried out, it has been realised that the research reported that the TQM philosophy encompasses every

operation from suppliers to customers but generally failed to give a clear implementation guideline or method.

There is a considerable confusion in the implementation of the TQM philosophy because of its requirements such as total change, management commitment, integration, re-organisation, re-structuring, etc. by different manufacturing environments. These are not easily made without affecting the other systems such as production management systems (Chan and Leung, 1995). The manufacturing method of an organisation can hinder the application of quality activities (Mann and Kehoe, 1995). Hence, the flexibility of manufacturing systems, in order to host these requirements mentioned, becomes important. Any rigid scheduling system, like MRP, would have difficulty to accommodate these requirements and increase the probability of failure of the TQM philosophy applications. It has also been shown that a production management system, namely Group Technology i.e. cellular manufacturing, is addressing those issues which have been generally found difficult in the applications of TQM. On the other hand, insufficiency of the design phase of Group Technology, which does not focus enough on a quality management or assurance system, is covered by the TQM philosophy in order to define and achieve a quality management system. Thus the aim of the research was to develop an integrated quality management information scheme to implement a TQM philosophy within the cellular manufacturing environment. This prime aim of the research has been achieved.

Initially, the research was started by studying the literature on the TQM philosophy. Various TQM definitions, models, practical applications and articles have been scrutinised. Weaknesses of TQM applications have been identified and analysed. Next, as a compatible manufacturing method, the literature on cellular manufacturing has been studied. It has been shown that within traditional

production management systems and manufacturing layouts it is difficult to manage changes required and it is also difficult for employees to become actively involved in the continuous improvement of work processes. It was then seen that many TQM implementation weaknesses were actually addressed by the strengths of the cellular manufacturing environment. A structured information scheme consisting of CM and the TQM philosophy would result in a successful implementation model. Additionally, besides the flexibility, information flow (communication) and integration (cross-functional, inter-departmental works) seemed to be key factors for the future manufacturing environments. Structured systems analysis and design methods are also used to facilitate those factors and to reap the benefits claimed by all.

A simple integrated implementation study needed to be undertaken on how to install the TQM philosophy in cellular manufacturing (Gundogan and Kay, 1995a). These two concepts seemed to complement each other. In order to integrate these two techniques or, in other words, to seed the TQM philosophy within cellular manufacturing, a new approach called activity based implementation was also developed. The activity based implementation approach, is built around structuredness, circularity and integration, and considers and evaluates each activity one by one within a system.

These two techniques have been merged successfully within an information implementation model i.e. the integrated quality management information scheme. The quality management information within the system was organised in such a way as to allow integration at the highest possible level and was structured to allow for any changes and future developments. Industrial visits together with expert views have incorporated the practical experiences into the model and have let it be modified according to their current requirements. The model has then



been justified from various points of view. Because this is a soft model, justification and testing methods have also been chosen accordingly from the literature survey and practical experiences. For example, absence of any figure or criteria to compare with in a simulation test made it be useless for the justification. Methods to test the model have been chosen as the validation during the modelling session, the circularity, structured walkthroughs and expert reviews, and an industrial survey.

In conclusion, it has been seen that the model addresses the weaknesses and gaps of current implementation techniques. Absence of information redundancy (mainly due to the circularity) within the scheme indicates that it is a good model. The model covers all of the quality management activities. This has also been tested by industrial visits for cross-checking validation. Furthermore, the quality management survey 1995 has also been resulted in that the features of the scheme have either parallelism with the industrial trends or meet the industrial requirements. The result is a substantial increase in the probability of a successful implementation of the scheme.

However there are some areas for concern. First of all, development of the model is based on the manufacturing environment only (especially on cellular manufacturing). Because many industries such as services, research and development, etc. are excluded from the research, it is limiting the model to be a general implementation guideline of the TQM philosophy. Another limitation is coming from the production management method itself. Although there are considerable number of companies applying cellular manufacturing, there are also other manufacturing methods such as optimised production technology (OPT) and MRP. From this respect, the implementation method will only be

useful for the companies applying other (non-CM) methods to understand the TQM philosophy and the methodology of the research.

### 6.3 APPLICATION AND RECOMMENDATIONS

This model is aimed at serving the needs of those managers who must create their own information system. It also shows managers how the TQM system will work, how the functions will be integrated and what the user requirements will be. Organisations themselves select and tailor this model to the particular needs of their organisations to be fitted in the overall management structure. It does not prescribe a ready-made information model but gives a practical information scheme to be tailored and adjusted to the particular needs of organisations. However, as is seen earlier, these adjustments may be very easy to make for some establishments. It should be highlighted that the implementation involves complexity and to formulate a standard TQM implementation approach, which will work successfully for all organisations, is difficult if not impossible. The information scheme produced is to further reduce this complexity and implementation difficulties.

One of the best ways of applying the scheme is to start with a convenient cell. All existing quality management information schemes should be studied and then both schemes should mutually be adjusted according to an organisation's specific requirements. These operations should not take a long time, but the following factors can affect the time to be allocated:

- The size and the degree of experience of the establishment.

- Whether the cellular manufacturing is already being applied or is going to be applied (prevalent manufacturing management system).
- Complexity of the processes involved,
- Characteristic of the manpower in general and especially of the manpower allocated for this job,
- Business performance and work methods, and
- Management's attitude towards the implementation.

Once this soft initialisation step is overcome, the rest is dependent on the intensity and complexity of the real quality management operations. It would be wise to take a complete auditing period as an implementation establishment period. This is because all the quality activities are audited for a certain number of cycles a year, generally twice a year. For example, during the first time cycle, all the activities can be established and during the second cycle those activities can be checked and verified.

Although the original research aim was directed at developing a quality management implementation model for cellular manufacturing environments, the resultant model also contains valuable information for all manufacturing organisations planning or implementing integrated quality management systems. However, the scheme is dependent on the strengths of cellular manufacturing (i.e. GT) to alleviate some common causes for failures of TQM implementations. Organisations, which want to apply the model and have non-GT environment, should be very careful about such features as the need to change, re-organisation, team building and flexibility etc. that are naturally presented by GT applications. In order to cover the absence of these features mentioned, a control mechanism or some more functions substituting these features may have to be introduced. On the other hand, those organisations, which have non-manufacturing

environments, can use the model to get a deeper understanding of the TQM philosophy (e.g. its applications, successes and failures etc.) and, within this context, information systems (e.g. systems analysis and design methodologies). In order to apply such a scheme, they should define all their quality management activities together with the related ones. Then, they should produce a similar scheme using the same methodology. Of course, this does not mean that it is going to be a successful scheme. As was the case for non-GT environments, these organisations too should take into account the advantages that are naturally supplied by GT applications.

Having the scheme established, it is necessary to get people used to working within the new structures. If the scheme is adequately supported and rigorously reviewed, the rewards will be substantial.

#### 6.4 POTENTIAL USERS AND BENEFITS

This research gives a clear picture on the main study areas, namely cellular manufacturing, the TQM philosophy and structured systems analysis and design methodologies, for an integrated application. The implementation model, i.e. integrated quality management information scheme, was designed primarily for the following users;

- Individuals responsible for instigating and planning change within organisations. For these individuals the scheme provides practical guidance and advice. The structured nature of the scheme will allow these individuals either to tailor it to the organisational requirements or to further expand it to the other functional areas.

➤ Individuals responsible for performing the physical work and analysis, in other words, the ones at the third level of activity diagrams. For these individuals the scheme is user-friendly and describes the functions, activities or operations clearly and in detail. Information input and output are clearly defined and cross-functional (inter-departmental) integration is well established.

➤ Individuals wishing to gain a greater understanding of TQM, Quality Management Operation and Cellular Manufacturing environments.

➤ Individuals wishing to see the ability of information systems, especially structured systems analysis and design methods, to build such an implementation model.

It is also envisaged that the model will be of great interest to quality practitioners, quality management systems researchers and the management board (or facilitators) of organisations implementing TQM or Group Technology (Cellular Manufacturing).

There are additional potential benefits by using the scheme produced. These include:

➤ flexibility,

➤ integration to other systems or functional areas.

➤ availability of all quality related information interconnected and cross-processed.

- the use of a single common quality information store,
- availability of quality improvement history,
- no duplication of effort to enter or process data,
- user-friendly, easy to learn and quick system.
- advantages of systematic and structural development, and
- flexibility to be a part of a bigger system or to be a standalone system.

## 6.5 FURTHER RESEARCH OPPORTUNITIES

During the literature survey, model development and evaluation phases, a number of areas where further research would increase the knowledge and understanding the processes have been identified. Some of the areas where this scheme also provides a solid foundation would profit from further research. Proposals for future research areas are listed below:

- The model was developed so that its main components can be improved through further research. All other non-quality functional areas can also be studied and detailed out in the same way to result in a complete management implementation system. Furthermore some of its modules can be computerised towards an FMS.
- The model could be adopted and developed as a stand-alone system within a manufacturing management system.
- A sophisticated database and a database management system could be created recording the quality activities used by organisations. The creation

of these would provide important information on the level of usage of quality activities. This information would then be used to change operations to quality operations, and production to quality production.

➤ The scheme was developed by studying the experiences of manufacturing organisations (especially cellular manufacturing).

Although the resultant model contains valuable information for all companies planning or implementing TQM, it would be interesting to research the experiences of service industries. This information then could be used to develop a more comprehensive quality management information model.

Practically, the structured scheme defines a data model and information requirements for the integrated quality management information scheme. As the next step, individual plants can take this scheme and adopt it to their specific quality activities in the office and on the shop floor. Once their information flow is structured, it would then be easy to add further functional areas to the scheme in the same way and to integrate the scheme to other functions. This implementation scheme would also satisfy increasing automation, complexity and, increasingly, integration of various processes and functions at any level.

## REFERENCES

- Anonymous. (1989). 'Simplify then automate for smoother flow'. Modern Materials Handling, vol.44, no.4, 43-51.
- Anonymous. (1995). 'Collecting data the clever way'. Quality Today, (June), 13-18.
- Ashworth, C and Goodland, M. (1990). *SSADM; A practical Approach*. McGraw-Hill Company, Oxford, (Ch. 1-6).
- Atkinson, P. E. (1990). *Creating culture change: The key to successful total quality management*. IFS Publications, (Ch. 1).
- Baran, J.J. (1991). 'Tips on tackling GT-based cells'. Manufacturing Engineering, vol. 106, no. 2, 46-49.
- Basaglia, G and Guida, K. (1994). GIM: An industrial application - Pirelli company. In: *Proceedings for the Dedicated Conference on LEAN/AGILE Manufacturing in the Automotive Industry (27th ISATA)*, Aachen, Germany, 381-388.
- Bemowski, K. (1992). 'The quality glossary'. Quality Progress, vol.25, no.2, 205-207.
- Bemowski, K. (1995). 'TQM: Flimsy footing or firm foundation?'. Quality Progress, vol.28, no.7, 27-28.



Bertram, D. (1991). 'Getting started in TQM'. Total Quality Management, vol.2, no.3, 279-282.

Besterfield, D.H., Besterfield-Micha, C., Besterfield, G.H and Besterfield-Sacre, M. (1995). *Total quality management*. Prentice Hall Inc. NJ. (Ch. 12).

Beynon-Davies, P. (1993). *Information system development*. The Macmillan Press Ltd., London, (Part 1).

Bohan, G.P. (1995). 'Focus the strategy to achieve results'. Quality Progress, vol.28, no.7, 89-93.

Britton, C and Doake, J. (1993). *Software system development: A gentle introduction*. McGraw-Hill International (UK) Limited, (Ch. 1-3, 6).

Bryant, T and Chan, D. (1995). 'BPR- to re-design or not to re-design?'. Submitted to (May) Business Change and Re-engineering.

Burbidge, J.L. (1987). *IFIP Glossary of terms used in production control*. Elsevier Science Publishers B.V., The Netherlands.

Burbidge, J. L. (1989). *Production Flow Analysis for Planning Group Technology*. Oxford science publications, Clarendon Press, Oxford, (Ch. 1-4, 10-11).

Burbidge, J. L. (1990). *Group Technology Lecture Notes*. MSE, COM Cranfield Institute of Technology.

- Burbidge, J.L. (1992). 'Change to group technology: Process organisation is obsolete'. International Journal of Production Research, vol.30, no.5, 1209-1219.
- Burbidge, J.L. (1994a). 'The use of period batch control (PBC) in the implosive industries'. Production Planning and Control, vol.5, no.1, 97-102.
- Burbidge, J.L. (1994b). 'Groups and/or cells'. Production Planning and Control, vol.5, no.6, 558.
- Burbidge, J.L. (1994c). Group technology and cellular production. In: *Proceedings of the tenth national conference on manufacturing research (Advances in manufacturing technology VIII Edited by Case, K and Newman, S)*. Taylor and Francis Ltd., London, 140-148.
- Burbidge, J.L. and Halsall, J. (1994). 'Group Technology and growth at Shalibane'. Production Planning and Control, vol. 5, no. 2, 213-218.
- Burr, J.T. (1993). 'A new name for a not-so-new concept'. Quality Progress, (March), vol. 26, no. 3, 87-89.
- Bytheway, A. (1994). *Business Modelling Lecture Notes*. SOM, Cranfield University.
- Campos, E., Cox, A., Gundogan, M., Harju, J., Honey, L and Knutsson, S. (1990). Development of user requirements for an integrated computer aided maintenance management system for Ford of Europe. CAMMS Group Project Report 1989/90, COM, Cranfield Institute of Technology.

- Chan, L-Y and Leung, W. H-I. (1995). 'Development and implementation of a comprehensive manufacturing system for a medium sized company'. Quality World Technical Supplement, (March). 23-34.
- Chapman, R.L., Clarke, P and Sloan, T. (1991). 'TQM in continuous process manufacturing: Dow-Corning (Australia) Pty Ltd.'. International Journal of Quality and Reliability Management, vol.8. no.5, 77-90.
- Chen, D., Doumeingts, G and Pun, L. (1990). 'An integrated inventory model based upon GRAI tools'. Engineering Costs and Production Economics, vol.19, 313-318.
- Clark, H. J. (1991). 'TQM:getting started'. Total Quality Management, vol.2, no.1, 29-38.
- Clemson, B and Alasya, D. (1992). Implement TQM and CIM together. In: *1992 International Engineering Management Conference: Managing In A Global Environment*, 25th-28th October 1992, Eatontown, NJ, 77-81.
- Colquhoun, G.J., Baines, R.W and Crossley, R. (1993). 'A state of the art review of IDEF0'. International Journal of Computer Integrated Manufacturing, vol.6. no.4, 252-264.
- Crawford, K. M and Cox, J. F. (1991). 'Addressing manufacturing problems through the implementation of JIT'. Production and Inventory Management Journal, no. 1, 33-36.
- Crosby, P.B. (1979). *Quality is free*. Penguin Books, London, (Part 1).

- Cusins, P. (1994). 'Understanding quality through systems thinking'. The TQM Magazine, vol.6, no.5, 19-27.
- Dahlgaard, J.J, Kristensen, K. and Kanji, K.G. (1994). *The quality journey*. Total Quality Management Journal Supplement, Carfax Publishing Co., Oxfordshire, (Ch. 1-4, 18-19).
- Dale, B.G. (1994). *Managing quality*. Prentice Hall International (UK) Ltd., Second edition, London, (Ch. 27).
- Dale, B.G and Cooper, C.L. (1994). 'Total quality management: Some common mistakes made by senior management'. Quality World Technical Supplement, (March), 4-11.
- Dale, B.G and Lascelles, D.M. (1990). 'The use of quality management techniques'. Quality Forum Journal, vol.16, no.14, 188-192.
- De Cieri, H., Samson, D. A and Sohal, A. S. (1991). 'Implementation of TQM in an Australian manufacturing company'. International Journal of Quality and Reliability Management, vol.8, no.5, 55-65.
- Dean, D., Orwig, R., Lee, J and Vogel, D. (1994). Modelling with a group modelling tool: Group support, model quality, and validation. In: *Proceedings of the 27th Hawaii International Conference and System Sciences*, 4th-7th January 1994, 214-223.
- Dean, J. W and Snell, S. A. (1991). 'Integrated manufacturing and job design: Moderating effects of organisational criteria'. Academy of Management Journal, vol. 34, no. 4, 776-804.

- Deasly, P. (1994). 'Integration: a way of life. work and education'.  
Manufacturing Engineer, vol.73, no.5. 209-213.
- Deming, W.E. (1975). 'On some statistical aids towards economic production'.  
Interfaces, vol. 5, no.4, 1-5.
- Deming, W.E. (1986). *Out of the crisis: Quality, productivity and competitive position*. Cambridge University Press, Cambridge.
- Dobbins, R.D. (1995). 'A failure of methods, not philosophy'. Quality Progress,  
vol.28, no.7, 31-33.
- Doumeingts, G. (1985). 'How to decentralise decisions through GRAI model in  
production management'. Computers in Industry, vol.6, no.6, 501-514.
- Doumeingts, G., Chen, D and Marcotte, F. (1992). 'Concepts, models and  
methods for the design of production management systems'. Computers in  
Industry, vol.19, no.1, 89-111.
- Drensek, R.A and Grubb, F.B. (1995). 'Quality quest: One company's successful  
attempt at implementing TQM'. Quality Progress, vol.28, no.9. 91-95.
- DSEG. (1992). *What is six sigma?*. Texas Instruments, TI-29077, F21110,  
The USA.
- DTI. (1991). *The quality gurus- What can they do for your company?*. DTI  
Publications, London.

Early, J.F and Godfrey, A.B. (1995). 'But it takes too long...'. Quality Progress, vol.28, no.7, 51-55.

Eldred, W. A. (1991). A proposed approach to computer-supported TQM in maintenance work induction and accomplishment. In: *Proceedings of the Annual Conference on Computers and Industrial Engineering*, vol. 21, no. 1-4, 123-127.

Evans, R. (1995). 'In defence of TQM'. The TQM Magazine, vol.7, no.2, 5-6.

Feigenbaum, A.V. (1961). *Total Quality Control*. McGraw-Hill Inc., London, (Ch. 1).

Feigenbaum, A.V. (1983). *Total Quality Control*. McGraw-Hill Inc., London, (Ch. 1).

Gaither, N., Fraizer, G. V and Wei, J. C. (1990). 'From job shop to manufacturing cells'. Production and Inventory Management Journal, fourth quarter, 33-37.

Gallagher, C.C and Knight, W.A. (1986). *Group Technology production methods in manufacture*. Ellis Horwood Ltd., England, (Ch. 11).

Gandoff, M. (1989). *System Analysis and Design*. Heinemann Professional Publishing Ltd., Oxford, (Ch. 1-5).

Ghobadian, A and Speller, S. (1994). 'Gurus of quality: A framework for comparison'. Total Quality Management, vol.5, no.3, 53-69.

Goodyer, J and Spraggett, S. (1994). Cellular manufacturing: How to achieve competitive quality through job design. In: *Proceedings of the tenth national conference on manufacturing research (Advances in manufacturing technology VIII Edited by Case, K and Newman, S)*. Taylor and Francis Ltd., London, 189-192.

Goodyer, J., Foyer, P and Spraggett, S. (1995). Cellular manufacturing: Integrating people into the cell design process. In: *Proceedings of the eleventh national conference on manufacturing research (Advances in manufacturing technology IX Edited by Stockton, D and Wainwright, C)*. Taylor and Francis Ltd., London, 247-251.

Grogan, J.F. (1995). The contribution of information technology to quality management. In: *International Conference Proceedings: Maintenance-Reliability-Quality, Edited by McNulty, G.J, 6th-7th April 1995, 53-58, Clare College, Cambridge, England.*

Gunasekaran, A., Goyal, S.K., Virtanen, I and Yli-Olli, P. (1994). 'An investigation into the application of group technology in advanced manufacturing systems'. International Journal of Computer Integrated Manufacturing, vol.7. no.4, 215-228.

Gundogan, M and Kay, J. M. (1995a). An integrated total quality management philosophy within group technology cells. In: *International Conference proceedings: Maintenance-Reliability-Quality, Edited by McNulty, G.J, 6th-7th April 1995, 59-64, Clare College, Cambridge, England.*

- Gundogan, M and Kay, J. M. (1995b). Total quality management philosophy within the group technology cells. In: *Proceedings of The Third International Conference on Computer Integrated Manufacturing (ICCIM'95) and AUTOFACT ASIA '95*, Edited by Winsor, J., Sivakumar. A.I and Gay, R, 11th-14th July 1995, Singapore International Convention & Exhibition Centre, 1337-1344.
- Hahn, G. J. (1993). 'Improve quality with data-driven analytics'. Quality Progress, (October), 83-86.
- Ho, S.K.M. (1993). 'Is the ISO9000 series for total quality management?'. International Journal of Quality and Reliability Management, vol.11, no.9, 74-89.
- Hoover, H.W. (1995). 'What went wrong in US business's attempt to rescue its competitiveness?'. Quality Progress, vol.28, no.7, 83-87.
- House, E. (1990). 'Customer-supplier partnerships in the IT market'. International Journal of Quality and Reliability Management, vol.7, no.2, 39-45.
- Hutchins, D. (1988). *Just-In-Time*. Billing and Jons Ltd., Worcester, (Ch. 1.5).
- Hutchins, D. (1990). *In pursuit of quality - participative techniques for quality improvement*. Pitman Publishing, (Ch. 1-3).
- Hyer, N. L and Wemmerlov, U. (1984). 'Group Technology and productivity'. Harvard Business Review, vol.62, no.4, 140-149.



Ishikawa, K. (1985). *What is total quality control? The Japanese way*. Prentice Hall International, Inc., London, (Ch. 3,5,7,12).

ISO8402. (1994). *Quality management and quality assurance vocabulary*. Second Edition, (E/F/R).

Jackson, D. (1978). *Cell system of production*. Business Books Ltd., London, (Ch. 1, 3-4).

Johnson, P. (1992). 'Unlocking the rewards of cellular manufacture'. Machinery and Production Engineering, (21th February), 32-35.

Juran, J. M. (1985). 'Catching-up: How is the west doing?'. Quality Progress, (November), 17-20.

Juran, J. M. (1993) 'Made in USA: A renaissance in quality'. Harward Business Review. (July-August), vol.71, no.4, 42-50.

Juran, J. M. (1994). 'The century of quality'. Manufacturing Engineering. (September), vol.113, no.3, 10-11.

Kanji, G. K. (1990). 'Total quality management: The second industrial revolution'. Total Quality Management, vol.1, no.1, 3-12.

Kanji, G. K. (1993). 'European master in TQM'. Total Quality Management, vol. 4, no. 1, 91-97.

Kanji, G. K. and Asher, M. (1993). *Total quality management process: A systematic approach*. Total Quality Management Journal Supplement.

- Carfax Publishing Company. Oxfordshire, (Ch. 1-6, 12-13).
- Kanji, G. K, Kristensen, K. K and Dahlgaard, J. J. (1992). 'TQM as a strategic variable'. Total Quality Management, vol.3, no.1. 3-8.
- Karabatsos, N.A. (1989). 'Dr. Kaoru Ishikawa: Quality organiser'. Quality Progress, vol.22, no.6, 20-21.
- Kasul, R. A and Motwani, J. G. (1995). 'Total quality management in manufacturing: Thematic factor assessment'. International Journal of Quality and Reliability Management, vol.12, no.3. 57-76.
- Kehoe, D and Adebajo, D. (1995). Factors affecting quality culture development. In: *Proceedings of the eleventh national conference on manufacturing research (Advances in manufacturing technology IX Edited by Stockton, D and Wainwright, C)*. Taylor and Francis Ltd., London, 499-503.
- Kennerfalk, L and Klefsjo, B. (1995). 'A change process for adapting organisations to a total quality management strategy'. Total Quality Management, vol.6, no.2, 187-197.
- Kerr, R. (1991). *Knowledge-based manufacturing management applications of artificial intelligence to the effective management of the manufacturing companies*. Addison-Wesley Publishing Company. Inc.. Singapore, (Ch. 1-2).
- Knorr, R. O and Thiede, E. F. (1991). 'Making new Technologies Work'.

The Journal of Business Strategy, (January/February), 46-49.

Kumar, K.R and Hadjinicola, G.C. (1993). 'Cellular manufacturing and Champion Irrigation products'. International Journal of Operations and Production Management, vol. 13, no. 9, 53-61.

Kurimoto, A. (1991). 'TQM in an advanced manufacturing environment'. Unpublished, Yamazaki Machinery UK Ltd., Worcester.

Lakhe, R. R and Mohanty, R. P. (1994). 'Understanding TQM'. Production Planning and Control, vol.5, no.5, 426-441.

Laughlin, K. K. (1995). 'Increasing competitiveness with a simplified cellular process'. Industrial Engineering, vol.27, no.4, 30-33.

Lewis, P.J. (1994). *Information Systems Development*. Pitman Publishing, London, (Ch. 4).

Lijima, M and Hasegawa, K. (1992). 'Quality information management for improving productivity in Japan'. International Journal of Technology Management, vol. 7, no. 4/5, 225-234.

Lummus, R. R and Duclos-Wilson, L. (1992). 'When JIT is not JIT'. Production and Inventory Management Journal, no. 2, 61-65.

Maccarthy, I., Ridgway, K and Chodari, A. (1994). A model of the production management systems in a make to stock company. In: *Proceedings of the*

*tenth national conference on manufacturing research (Advances in manufacturing technology VIII Edited by Case, K and Newman, S).* Taylor and Francis Ltd., London, 208-212.

Mackulak, G.T. (1984). 'High level planning and control: An IDEF0 analysis for airframe manufacture'. Journal of Manufacturing Systems, vol.3, no.2, 121-133.

Malley, J. C and Ray, R. (1988). 'Informational and organisational impacts of implementing a JIT system'. Production and Inventory Management Journal, no. 2, 66-70.

Mann, R and Kehoe, D. (1994). 'The quality improvement activities of total quality management'. Quality World Technical Supplement, March, 43-56.

Mann, R and Kehoe, D. (1995). 'Factors affecting the implementation and success of TQM'. International Journal of Quality and Reliability Management, vol.12, no.1, 11-23.

Mechanical Engineering EDC (1975). *Why group technology?*. NEDO, London.

Menon, H.G. (1992). *TQM in new product manufacturing*. McGraw Hill Inc., USA, (Ch. 5-6).

Naguib, H. (1992). The implementation of TQM in a semi conductor manufacturing operation. In: *IEEE/Semi International Semi Conductor Manufacturing*, 15th - 16th June 1992, San Francisco, 63-67.

Nimmons, T., Kay, J.M and Williams, G. (1994). How QFD can help design cellular manufacturing systems. In: *Proceedings of the tenth national conference on manufacturing research (Advances in manufacturing technology VIII Edited by Case, K and Newman, S)*. Taylor and Francis Ltd., London, 179-183.

Oakland, J. S. (1989). *Total Quality Management*. Heinemann Professional Publishing Ltd., Oxford, (Ch. 1,3,5,8,14).

Oakland, J. S. (1993). *Total Quality Management: The route to improving performance*. Heinemann Professional Publishing Ltd., 2nd Ed., Oxford, (Ch. 1, 13-15).

Oakland, J.S. (1995). *Total quality management text with cases*. Butterworth-Heinemann Ltd., London, (Ch. 2,3, C3, C7, 13).

Partridge, J.T. (1989). *Manufacturing Systems Analysis and Design Method Lecture Notes*. COM, Cranfield University.

Peppard, J and Rowland, P. (1995). *The essence of business process re-engineering*. Prentice Hall International (UK) Ltd, (Ch. 1-3).

Perkins, C. A and Perry, J. H. (1992). 'Quality management systems: Alternative approaches to integrating quality factors in purchasing and material management decision making'. Production and Inventory Management Journal, no. 3. 58-62.

- Perry, J. H. (1992). 'Evaluating computer integrated manufacturing systems: The role of quality'. Production and Inventory Management Journal, no.2, 19-23.
- Perry, W.E. (1991). *Quality Assurance For Information Systems*. QED Information Sciences, Inc., USA (Wellesley), (Ch. 9-10).
- Pesch, M.J., Jarvis, L.L and Troyer, L. (1993). 'Turning around the rust belt factory: the \$1.98 solution'. Production and Inventory Management Journal, Second Quarter, 57-62.
- Pfau, L. (1989). 'Total quality management gives companies a way to enhance position in global market'. Industrial Engineering, vol.21, no.4, 17-21.
- Quimby, C., Parker, L. and Weimerskirch, A. M. (1991). 'How, exactly, do you communicate quality?'. Quality Progress, (June), vol.24, no.6, 52-54.
- Qurashi, Z., Biss, T and Polkinghorne, N. (1995). Design of a manufacturing based management information system. In: *Proceedings of the eleventh national conference on manufacturing research (Advances in manufacturing technology IX Edited by Stockton, D and Wainwright, C)*. Taylor and Francis Ltd., London, 499-503.
- Ranky, P.G. (1990). *Flexible manufacturing cells and systems in CIM*. CIMware Ltd., Guilford, Surrey, England, (Introduction and Ch.1).

- Ridgeway, K. (1992). 'Analysis of decision centres and information flow in project management'. International Journal of Project Management, vol.10, no.3, 145-152.
- Roberts, J. W. (1990). 'Systems support of JIT manufacturing'. Information Systems in Manufacturing, (Winter), 22-29.
- Roes, H. (1993). Quality. In: *Systems Engineering. Principles And Practice Of Computer-Based Systems Engineering*, B.Thome (Ed.), John Wiley and Sons Ltd. The UK, (Ch. 7).
- Rogerson, J. H. (1992). 'TQM in the fabrication industry'. Welding & Metal Fabrication, (October), vol. 60, no. 8, 375.
- Ronen, B and Pass, S. (1992). 'Manufacturing management information systems require simplification'. Industrial Engineering, (February), 50-53.
- Ross, D. T. (1977). 'Structured analysis (SA): A language for communicating ideas'. IEEE Transactions on Software Engineering, vol.SE-3, no.1, 16-34.
- Ross, D. T and Schoman, K. E. (1977). 'Structural analysis for requirements definition'. IEEE Transactions on Software Engineering, vol.SE-3, no.1, 6-15.
- Sarkis, J and Lin, L. (1994). 'An IDEF0 functional planning model for the strategic implementation of CIM systems'. International Journal of Computer Integrated Manufacturing, vol.7, no.2. 100-115.

- Schnitt, D. L. (1993). 'Re-engineering the organisation using information technology'. Journal of Systems Management, no.1. 14-20.
- Semich, J. W. (1994). 'Here is how to quantify IT investment benefits'. Datamation, (January), vol. 40, no. 1, 45-48.
- Shifrin, C. A and Mecham, M. (1991). 'TQM allows European aerospace firms to devote new attention to quality'. Aviation Week & Space Technology, (December 9), 66-67.
- Sinclair, D and Zairi, M. (1995). 'Performance measurement as an obstacle to TQM'. The TQM Magazine, vol.7, no.2, 42-45.
- Skrabec, Q.R. (1994). 'Integrating quality control and inspection into your total quality management system'. Total Quality Management, vol.5, no.5, 321-327.
- Snead, C.S. (1989). *Group Technology: Foundation for competitive manufacturing*. Van Nostrand Reinhold Co. Ltd., London, (Ch. 2-3, 9-12).
- Sohal, A. (1994). Improving communication, focus and flexibility through restructuring. In: *Advances In Agile Manufacturing, Edited by Kidd, P.T and Karwowski, W*, IOS Press, Oxford, 566-569.
- Sohal, A.S., Tay, G.S and Wirth, A. (1989). 'Total quality control in an Asian division of a multinational corporation'. International Journal of Quality and Reliability Management, vol.6, no.6. 60-74.



- Stuelpnagel, T. R. (1993). 'Deja vu: TQM returns to Detroit and elsewhere'. Quality Progress, (September), 91-95.
- Taheri, J. (1990). 'Nothern Telecom tackles successful implementation of cellular manufacturing'. Industrial Engineering, (October), vol.22, no.10, 39-43.
- Tannock, J.D.T. (1992). *Automating quality systems*. Chapman and Hall, London. (Part 1-2).
- Towill, D. R. (1995). 'Back to production management'. Manufacturing Engineer, vol.74, no.2, 66-71.
- Voss, C. (1990). 'Quality in a manufacturing strategy'. The TQM Magazine, (June), 149-152.
- Weaver, P.L. (1993) *Practical SSADM 4*. Pitman Publishing, London, (Ch. 1-2).
- Wei, J.C. (1992). 'A note on 'change to group technology''. International Journal of Production Research, vol.30, no.5, 1221-1222.
- Welke, H. A and Overbeeke, J. (1988). 'Cellular manufacturing: A good technique for implementing JIT and TQM'. Industrial Engineering, (November), 36-41.
- Wemmerlov, U and Hyer, N. L. (1989). 'Cellular manufacturing in the US industry: A survey of users'. International Journal of Production Research, vol.27, no.9, 1511-1530.

- Wiele, T.V., Dale, B., Williams, R., Kolb, F., Luzon, D.M., Schmidt, A and Wallace, M. (1995). 'State of the art study on self assesment'. The TQM Magazine, vol.7, no.4, 13-17.
- Wu, B. (1992). *Manufacturing systems design and analysis*. Chapman & Hall. London, (Ch. 3,6).
- Wu, B. (1994). *Manufacturing systems design and analysis*. Second Edition Chapman & Hall, London, (Ch. 3,5,7).
- Zairi, M. (1991). *Total quality management for engineers*. Woodhead Publishing Ltd., Cambridge, England, (Ch. 2,3,11).
- Zairi, M., Letza, S. R and Oakland, J. S. (1994). 'Does TQM impact on bottom-line results?'. The TQM Magazine, vol.6, no.1, 38-43.
- Ziarati, R and Khataee, A. (1994). Integrated business information system (IBIS) - A quality led approach. In: *Proceedings of SHEMET International Conference*, The UK, 297-305.
- Ziarati, R., Khataee, A and Onifade, B. (1995). Data communication in industrial management information systems. In: *Proceedings of the eleventh national conference on manufacturing research (Advances in manufacturing technology IX Edited by Stockton, D and Wainwright, C)*. Taylor and Francis Ltd., London, 499-503.

## **APPENDIX A**

### **DATA FLOW (ACTIVITY) DIAGRAMS AND NOMENCLATURE**

# THE IMPLEMENTATION MODEL FOR AN INTEGRATED QUALITY MANAGEMENT INFORMATION SCHEME

## INTRODUCTION

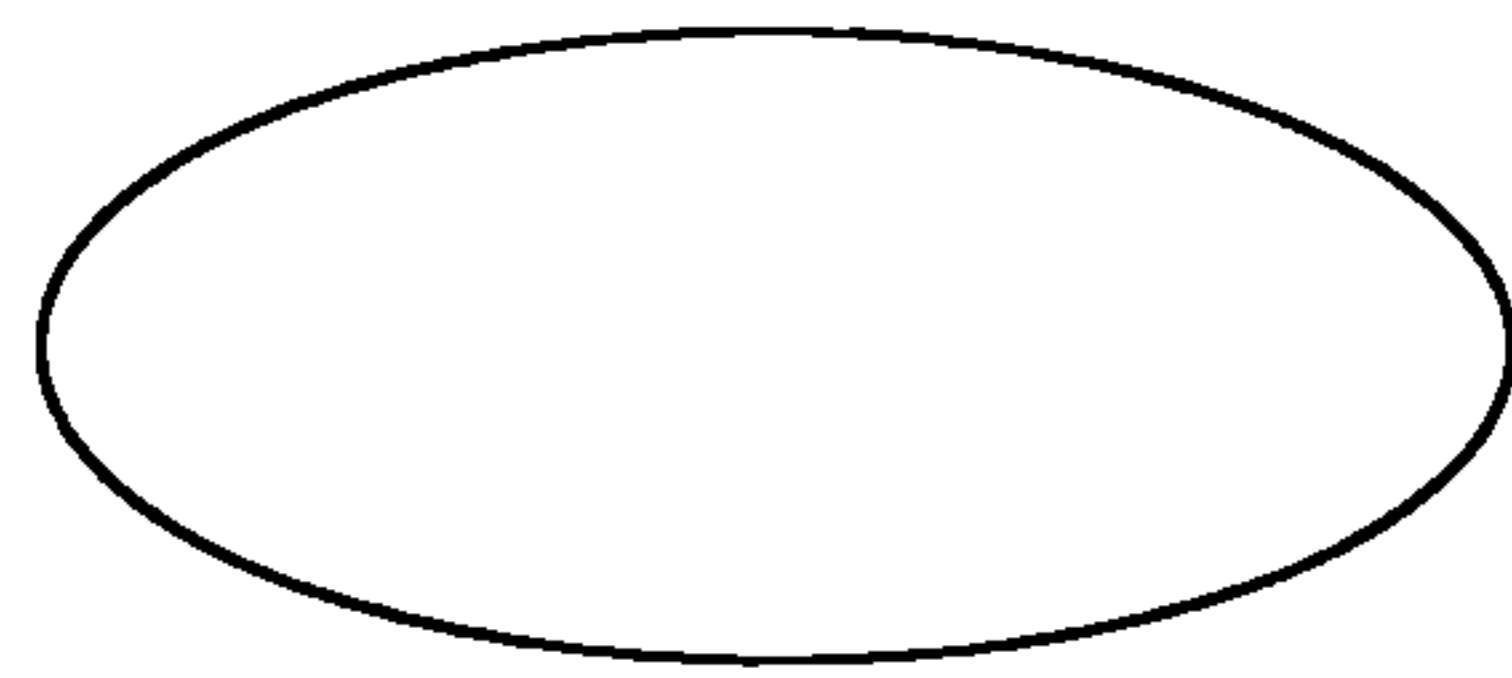
Structured Systems Analysis and Design Method (SSADM) is used in conjunction with the Manufacturing Systems Analysis and Design (MSAD) method to produce the implementation model. Data Flow Diagrams also known as activity diagrams, are a diagrammatic representation of the information flow within a system. These diagrams show:

- How information enters and leaves the system,
- What changes the information and
- Where information is stored.

Activity diagrams clearly show the boundaries and scope of the integrated quality management information scheme. The construction of the diagrams and their cross-comparison with the other techniques ensures that all information flows, storage of information, and activities within the context have been considered. These diagrams are not process flow charts since they do not describe sequences of processes but simply the information flow of a system without reference to time or the order of events, all in a structured, easily understood, graphical format. They show how the total system fits together.

## NOMENCLATURE

There are five main components of the activity diagrams:



(1) External Sources or Recipients: An external source or recipient, i.e. external functions or processes, are represented on an activity diagram as an oval containing their titles. These are therefore whatever or whoever delivers information to or receives information from the system.

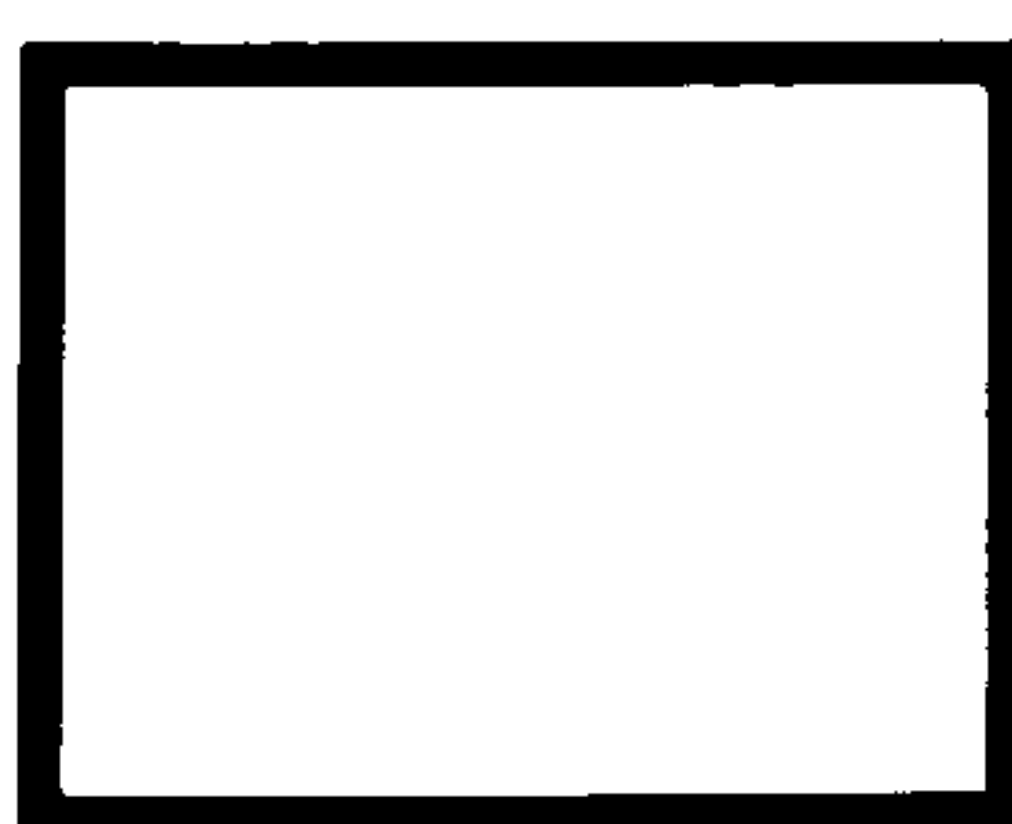
Information represented within a system must have been obtained initially from an external source. In the integrated quality management information scheme, information is originated from quality policy which is coming from an external source (functional area) namely Top Management.



(2) Processes or Activities: Activities are represented by rectangles on an activity diagram. Each activity box contains the name of the activity and an activity number. A process or an activity transforms, manipulates or analyses data within the system.

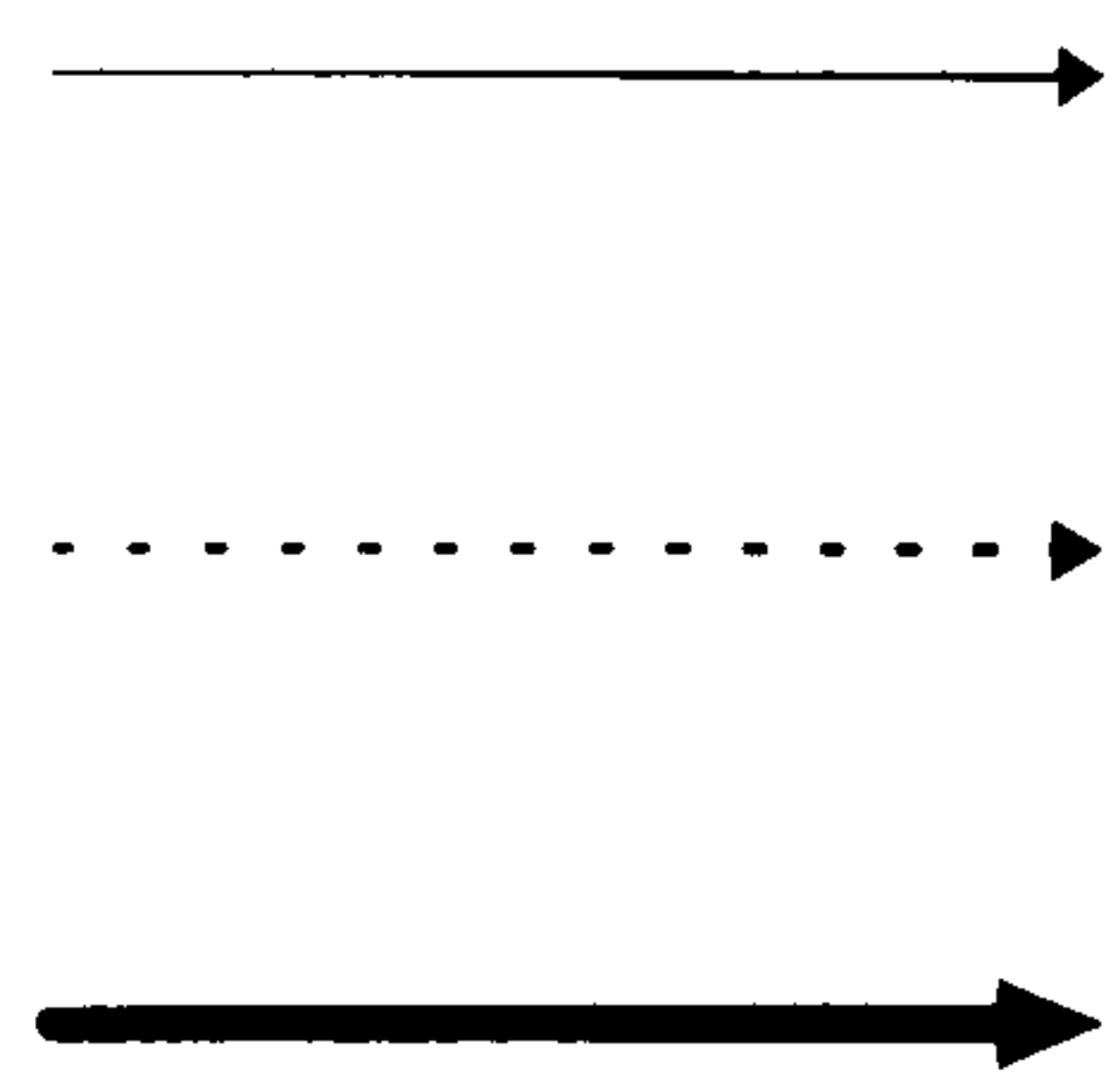


(3) Data Store: A data store is represented on an activity diagram by an open-ended oval containing the name of the data store. A data store is where information is held for a time within the system.



(4) Context Boundary: Context boundary is represented by a thick rectangle within which all the activities are carried. This shows the area borders of an activity diagram.

(5) Data Flow: This is a line showing information flow in the direction of the pointer. If both ends of the line are pointed, it means two-way communication. The type of lines may vary according to various flows. The normal line shows information flow. The dotted line shows an informal information flow. The thicker line shows a material flow associated with the information.



Here, within the integrated quality management information scheme, material flows will not be elaborated. However, it will be shown on the overall level of activities just to remind facilitators or developers of their existence, and it is up to the individual organisations to detail these whilst tailoring the model to their specific requirements.

All internal and external functional areas of the integrated quality management information scheme were described in the main text. The top level data flow diagram i.e. activity diagram of the model is given in figure A.1. Here, the main functional areas are quality management (data analysis), auditing and cellular (in-group) operations.

Cellular operations are the quality management activities carried out within the cells (or groups) of group technology. As is seen in figure A.2, the activity box of cellular operations may contain various groups of cellular manufacturing. Each group receives information from quality management and auditing activities, processes the information, and finally reports back. All the information coming to the group is processed through these functions (see figure A.3) and delivered back to the related bodies. From the data analysis and design point of view,

information flow in each group is designed, structured and integrated in the same way. Therefore, for the sake of simplicity, it was decided to have only one group represented on the activity diagrams. In the application, all groups will communicate through the same information pattern. This allows the overall level of total quality management information system model to be represented, within a cellular manufacturing environment, based on the SSADM and MSAD methodology, as illustrated in figure A.4.

Hereafter, all activity diagrams constituting the implementation model will be explained in the formal jargon of structured systems analysis and design methodologies. Each activity diagram contains a boundary context, activities within the boundary context, and information input and output. All of these will be explained respectively for each activity diagram.

1.0 INTEGRATED QUALITY MANAGEMENT INFORMATION SCHEME

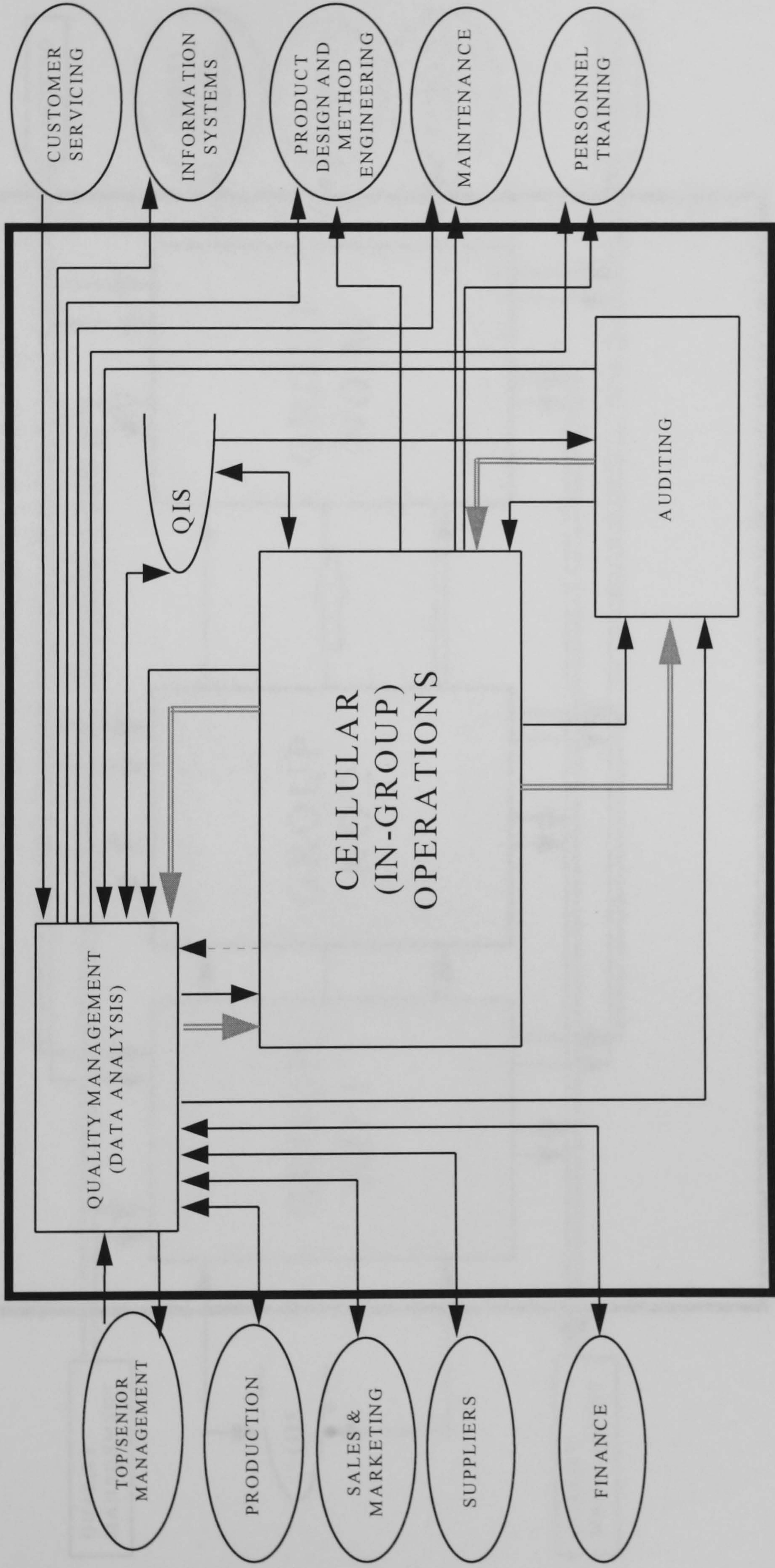


FIGURE A.1



CELLULAR (IN-GROUP) OPERATIONS

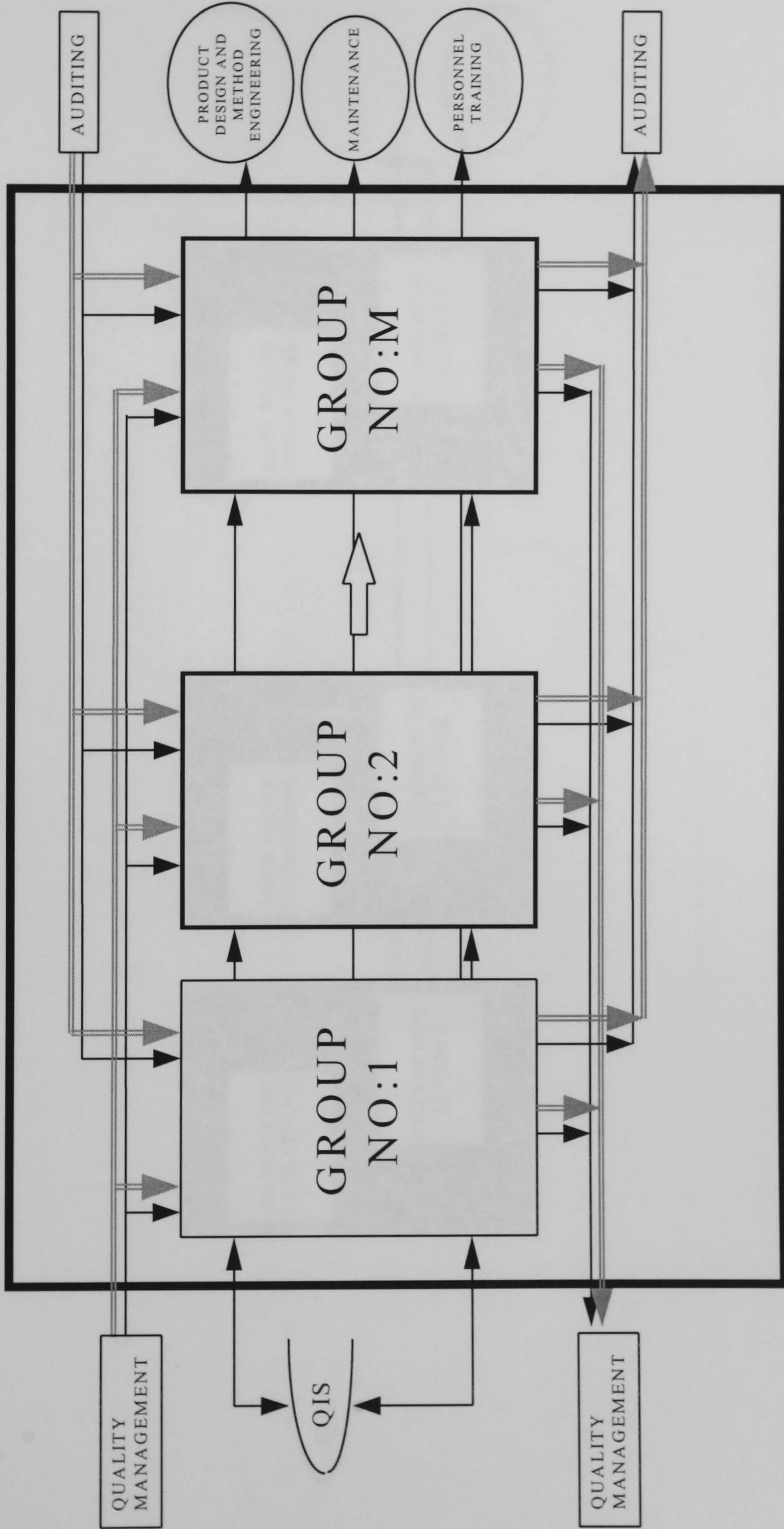


FIGURE A.2

# CELLULAR (IN-GROUP) OPERATIONS

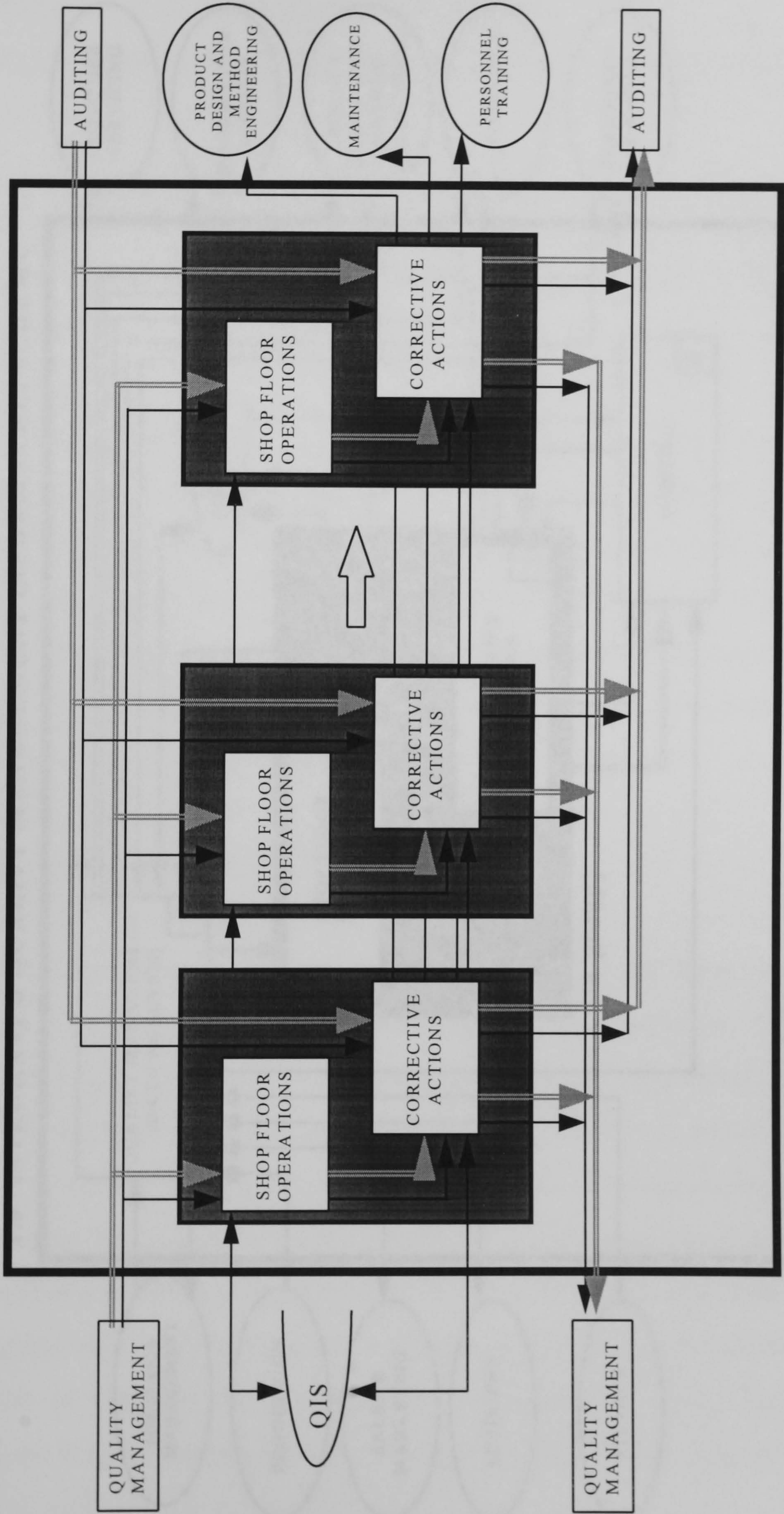


FIGURE A.3

1.0 INTEGRATED QUALITY MANAGEMENT INFORMATION SCHEME

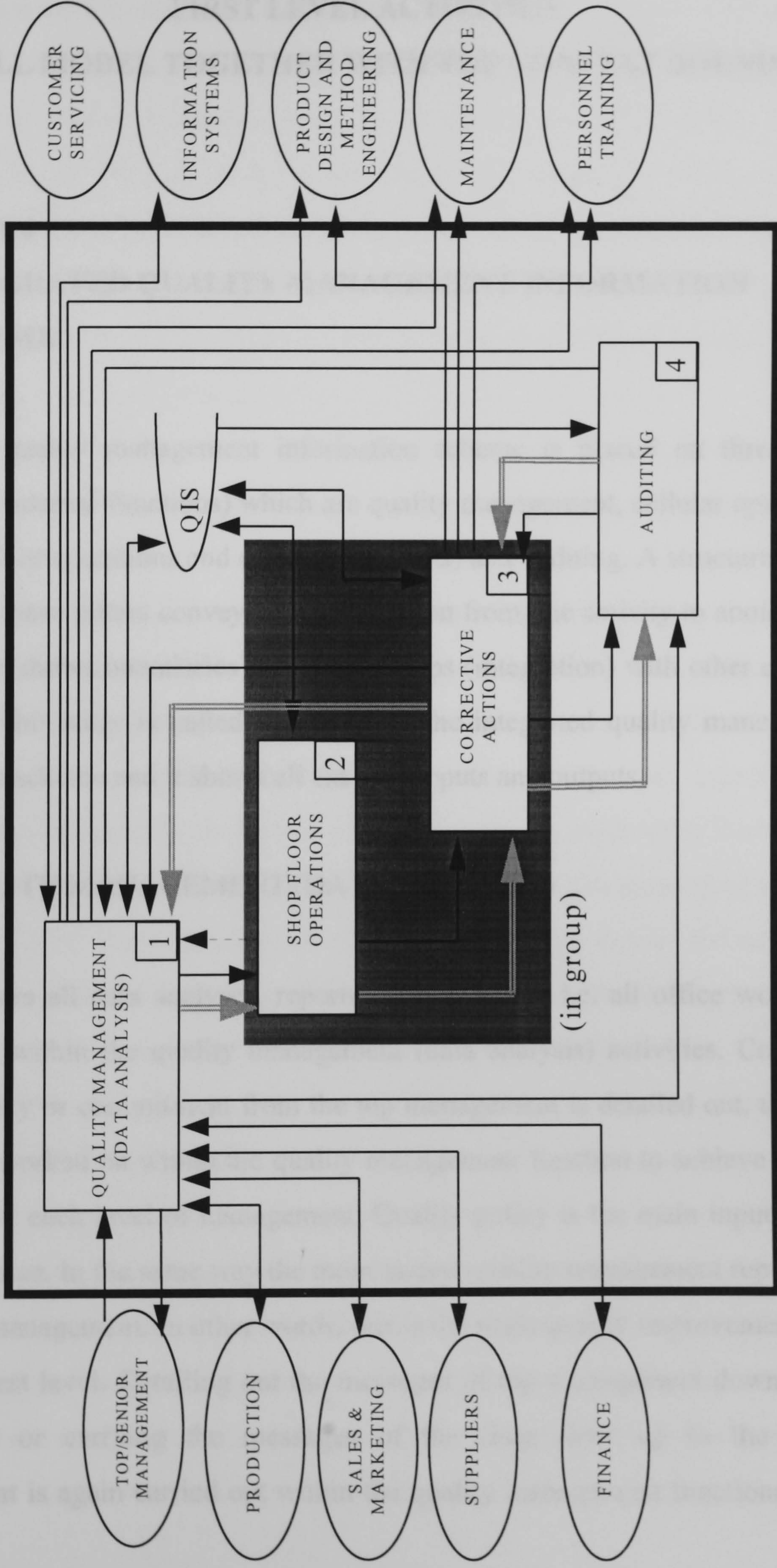


FIGURE A.4

## **FIRST LEVEL ACTIVITIES**

### **OVERALL MODEL TOGETHER WITH THE CONTEXT BOUNDARY**

#### **FIGURE A.4**

#### **1.0 INTEGRATED QUALITY MANAGEMENT INFORMATION SCHEME**

Integrated quality management information scheme is placed on three main pillars (i.e. internal functions) which are quality management, cellular operations (i.e. shop floor operations and corrective actions) and auditing. A structured stage on each of these pillars conveys the information from one activity to another and furthermore shows boundaries and relationships (integration) with other external functions. This stage is called first level of the integrated quality management information scheme and it shows all external inputs and outputs.

#### **1.1 QUALITY MANAGEMENT (DATA ANALYSIS)**

This is where all data analyses, reports, system works i.e. all office works are carried out within the quality management (data analysis) activities. Corporate quality policy or commitment from the top management is detailed out, then the details are worked on within the quality management function to achieve quality objectives at each level of management. Quality policy is the main input to this functional area. In the same way the main output, quality management reports, go to the top management. In other words, this is the main quality improvement loop at the highest level. Detailing out the messages of top management down to the shop floor or carrying the messages of the shop floor up to the senior management is again carried out within the quality management functional area.

As is shown in the diagram, IQMIS has various relationships with external functional areas. As a main internal functional area of IQMIS, the Quality Management (Data Analysis) function communicates with these external functions such as Production, Sales and Marketing, Suppliers and Finance, etc. The quality management function receives input from customer servicing and feedback from other internal quality management functions. Likewise, other quality functions are fed by Data Analysis to produce a working harmony whilst achieving the quality objectives.

## 1.2 SHOP FLOOR OPERATIONS

This is the function which employs all quality control shop floor operations. Inspections, tests, calibration of measurement equipment, non-conformance, preventive activities are all within the shop floor operations function. Inputs to this functional area are work orders, work schedules, tasks, etc. together with some optional physical forms such as information sheets, work order forms etc. It is obvious that in the case of electronic communication, the number of physical forms is reduced. They process all orders or tasks, and key-in the necessary preliminary results or information to the common quality information store (QIS), then also pass the results with the forms to corrective action functions.

## 1.3 CORRECTIVE ACTIONS

Corrective actions include preventive actions and all actions taken to eliminate the causes of an existing nonconformity, defect, or other undesirable situation in order to prevent recurrence. Although both correction and corrective action are evaluated within the same context, there is a distinction between them. Correction refers to repair, rework, or adjustment and relates to the disposition of an existing

nonconformity. Corrective action relates to elimination of the cause of a nonconformity.

Hence, this is also the function where all non-conformance analysis has been made and corrective actions (including corrections and preventive actions) have been produced, applied and reported. Input to this functional area comes from shop floor operations. The data received is processed and then related bodies are informed accordingly. Having performed the corrective actions, the necessary information goes directly to Product Design and Method Engineering, Maintenance, and Personnel and Training. The other external functions may also be informed according to the analysis which is carried out in quality management activities. This is because many quality improvements may take place outside the quality management activities.

#### 1.4 AUDITING

Quality auditing is the review of activities conducted to compare some aspect of quality performance with a standard for that performance and to thoroughly document any differences. It does not include deciding how the difference is to be remedied, but it highlights them for corrective action. The process of quality system audit has two primary elements: to compare practice with procedures and identify deficiencies, and to maximise effectiveness of the management system. This is a matter of identifying further improvements. Audits, therefore, are used to evaluate the company's own quality performance and performance of organisation. They receive special activity information from shop floor and company process standards (how to do the things) from management as well as shop floor bodies.

1.1 QUALITY MANAGEMENT (DATA ANALYSIS AND REPORTING)

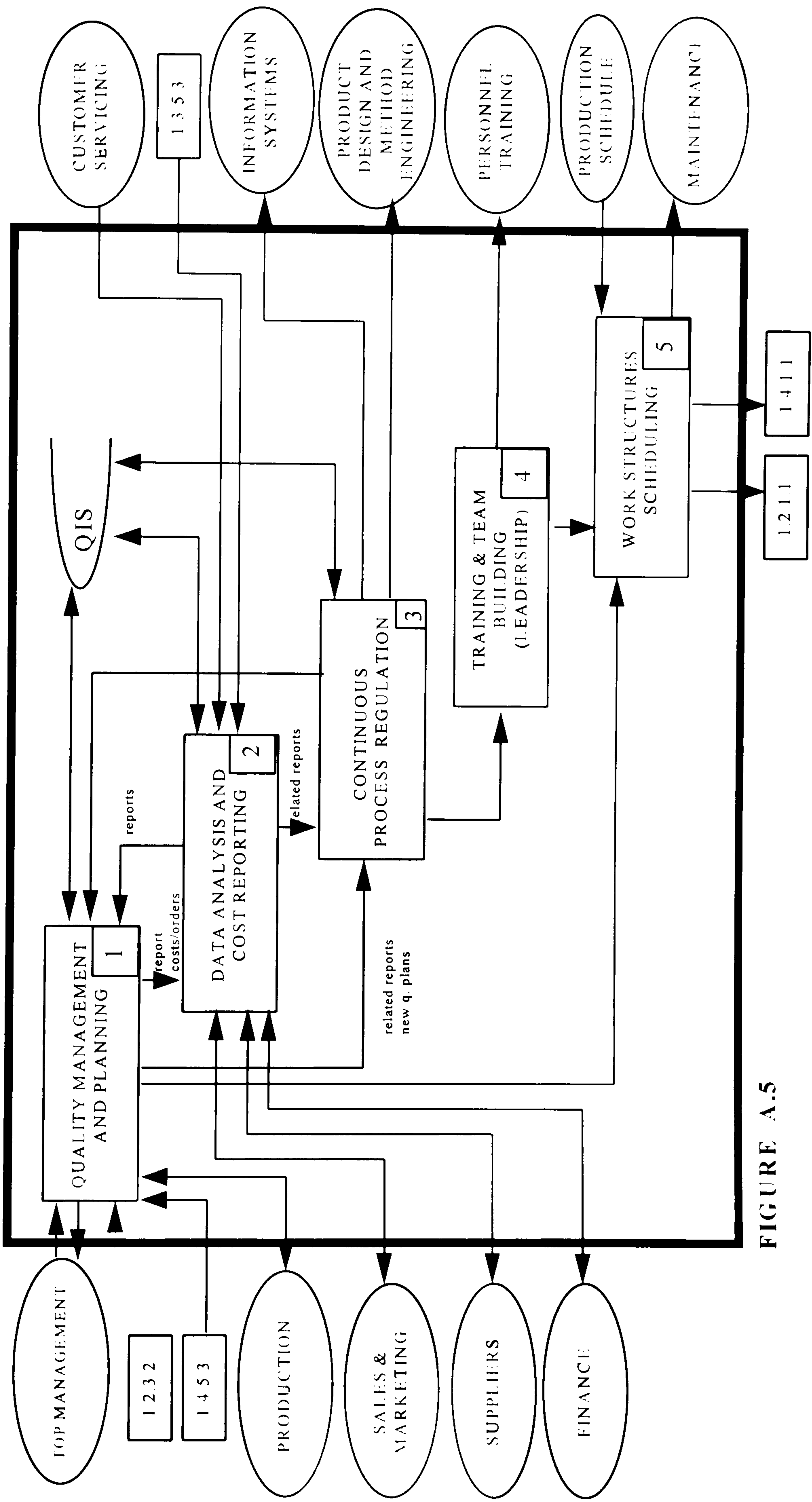


FIGURE A.5

## **SECOND LEVEL ACTIVITIES**

### **FUNCTIONAL ANALYSIS (FUNCTIONAL REQUIREMENTS)**

This step is called functional analysis. All functions on the overall model namely quality management (Data analysis), shop floor operations, corrective actions and auditing are defined, specified and analysed in a structured and integrated way.

#### **FIGURE A.5**

##### **1.1 QUALITY MANAGEMENT (DATA ANALYSIS)**

###### **1.1.1 QUALITY MANAGEMENT AND PLANNING**

This function manages and plans quality, based on the quality policy which is determined by the top or senior management. They receive information from shop floor operations, production and from other management activities like Data Analysis and Cost Reporting and Continuous Process Regulations. They issue plans, orders and reports to the other management activities namely Data Analysis and Cost Reporting, Continuous Process Regulations, and Work Structures and Scheduling. They also report back to the top or senior management about the overall quality issues. They have access to the common quality database.

###### **1.1.2 DATA ANALYSIS AND COST REPORTING**

This is where all shop floor data, information of Sales and Marketing, Suppliers, Finance and Customer Servicing are analysed, and where new procedures and



schemes are produced. They report back to Management and Planning for further actions and improvement. They also send a partial report to Continuous Process Regulation. The common quality information store is accessible here.

### 1.1.3 CONTINUOUS PROCESS REGULATION

Within this function information is received from Management and Planning. Data Analysis and Cost Reporting and Quality Database are analysed and evaluated to improve the processes. Evaluation outcomes will be reported to related activities like Information Systems, Product Design and Method Engineering, Management and Planning, and Training and Team Building (Leadership).

### 1.1.4 TRAINING AND TEAM BUILDING (LEADERSHIP)

This is where training requirements coming from Continuous Process Regulation are implemented and harmony within the teams evaluated. Related information is delivered to the Personnel and Training department, and Work Structures and Scheduling activities.

### 1.1.5 WORK STRUCTURES AND SCHEDULING

They receive plans from Management and Planning, Training and Team Building, and Production Schedule. Work structures are improved and work schedules are produced in this area. They are then sent to Shop Floor Activities, Maintenance, and Auditing Activities.

## 1.2 SHOP FLOOR OPERATIONS (INSPECTION)

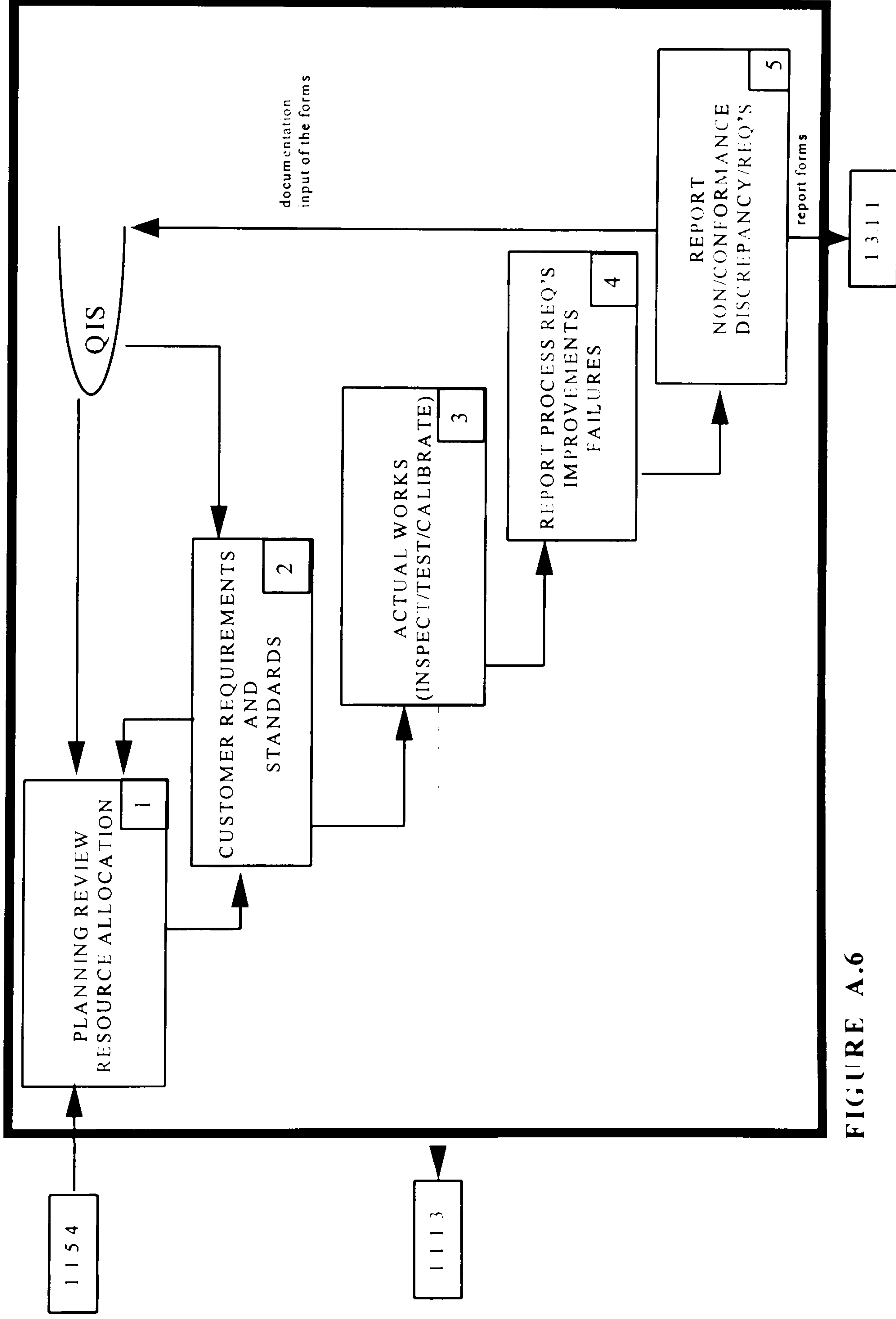


FIGURE A.6

## **FIGURE A.6**

### **1.2 SHOP FLOOR OPERATIONS (INSPECTION)**

#### **1.2.1 PLANNING REVIEW AND RESOURCE ALLOCATION**

Within this area work orders and tasks are received. They are reviewed and necessary resources are then allocated to perform the job. They have access to QIS to retrieve related information. They also receive customer requirements.

#### **1.2.2 CUSTOMER REQUIREMENTS AND STANDARDS**

They receive work orders and tasks reviewed or updated. Necessary arrangements are then made to meet the customer requirements. QIS is also accessible.

#### **1.2.3 ACTUAL WORKS**

Final work orders and tasks updated are received. They carry out the actual works like inspection, measurements, tests, preventive activities, calibration and tests of inspection equipment etc. From the practical point of view, they inform Management and Planning about some recommendations which might affect quality policy or planning.

#### 1.2.4 REPORT PROCESS REQUIREMENTS (IMPROVEMENTS AND FAILURES)

They receive actual work results and make analysis to find out process requirements (improvements and failures). They keep track of the processes.

#### 1.2.5 REPORTS (NON-CONFORMANCE, DISCREPANCY AND REQUIREMENTS)

They receive action reports together with the actual work results, and report non-conformances and requirements to the management through the corrective actions. They key-in a preliminary report to QIS for the documentation (to disseminate an early warning if necessary).

### 1.3 CORRECTIVE ACTIONS (AND VERIFICATION)

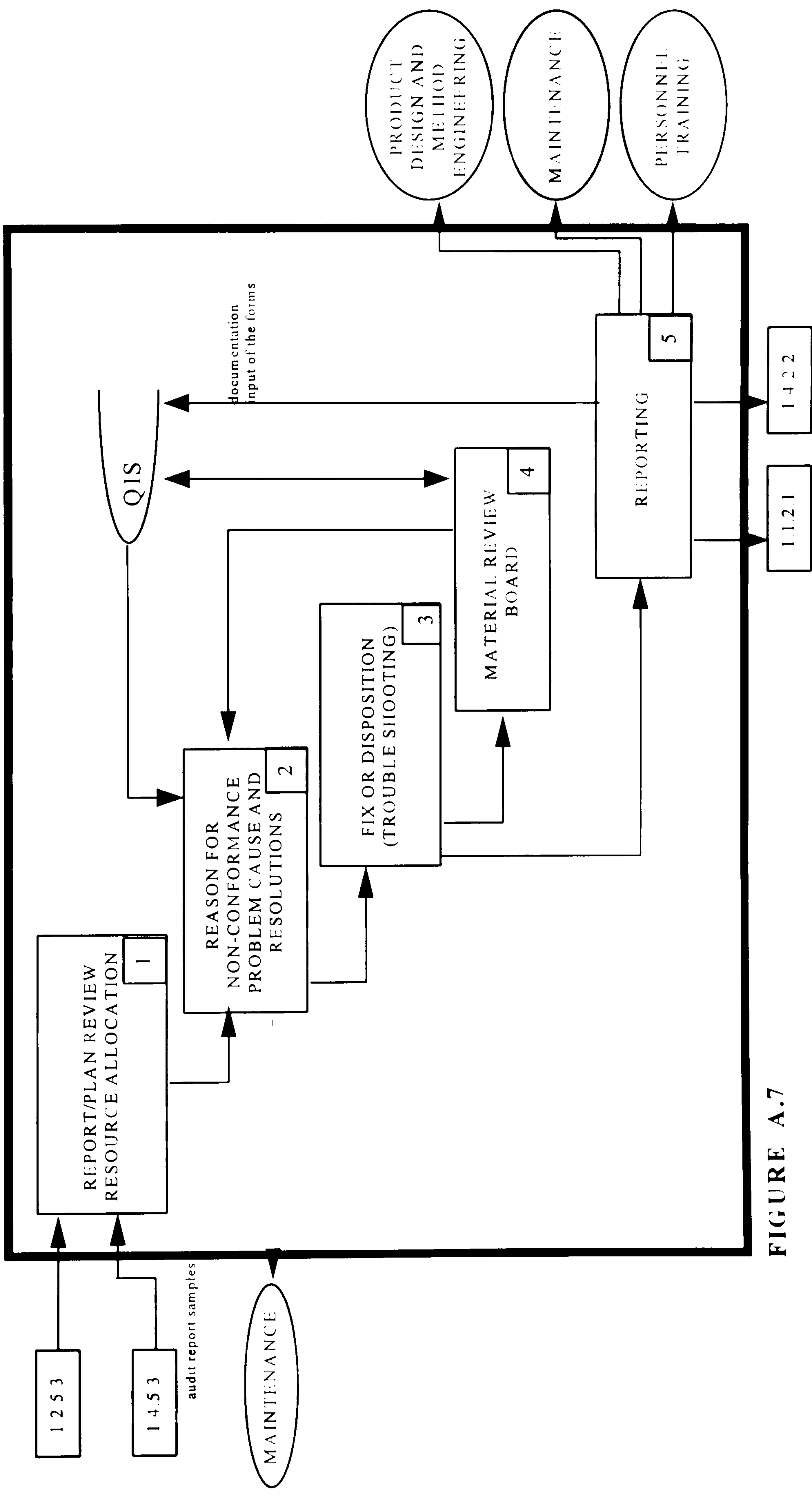


FIGURE A.7

## **FIGURE A.7**

### **1.3 CORRECTIVE ACTIONS (AND VERIFICATION)**

#### **1.3.1 REPORT OR PLAN REVIEW, AND RESOURCE ALLOCATION**

Within this functional area, inspection results and audit report samples are gathered and an initial review is carried out. All necessary resources have also been identified and allocated.

#### **1.3.2 REASON FOR NON-CONFORMANCE (PROBLEM CAUSES AND RESOLUTION)**

In this process all failures and non-conformances have been scrutinised, causes identified, and then the best possible solution (fix or disposition) has been found.

#### **1.3.3 FIX OR DISPOSITION (TROUBLE SHOOTING)**

The actual corrective action is taken within this functional area.

#### **1.3.4 MATERIAL REVIEW BOARD**

In this area faulty parts and materials are analysed and decisions are made whether to scrap or repair or use them as they are. If a decision is taken, the procedure to justify this also written.

### 1.3.5 REPORTING

All shop floor quality reports are produced and keyed-in to the QIS. Related departments have also been informed about the results.

# 1.4 AUDITING

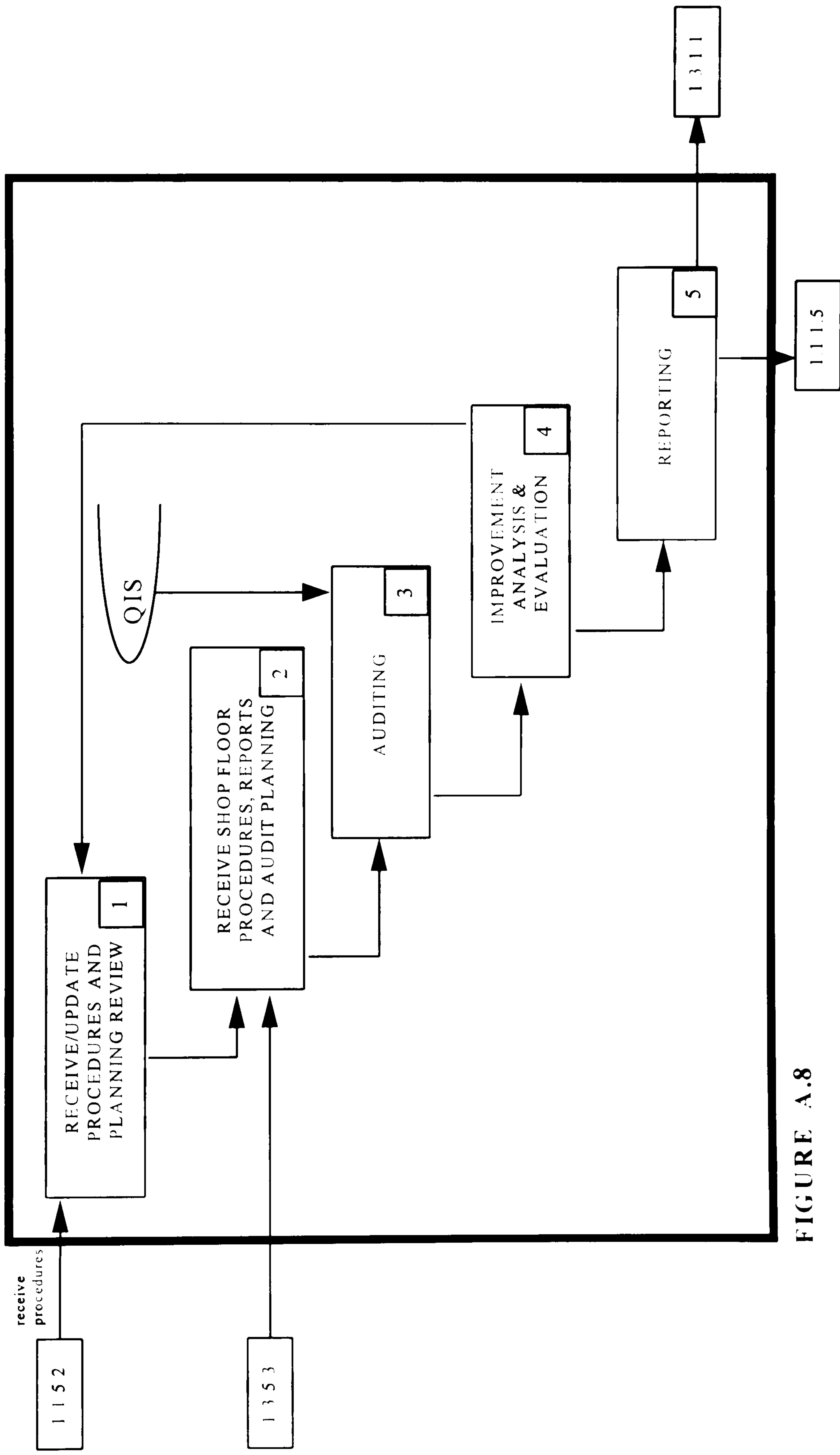


FIGURE A.8



## **FIGURE A.8**

### **1.4 AUDITING**

#### **1.4.1 RECEIVE AND UPDATE PROCEDURES AND PLANNING REVIEWS**

Within this function all procedures are received and updated according to new findings and plans are reviewed harmoniously.

#### **1.4.2 RECEIVE SHOP FLOOR PROCEDURES AND REPORTS AND AUDITING PLANNING**

All shop floor procedures and reports are gathered within this function. Audit plans are reviewed and updated according to the reports.

#### **1.4.3 AUDITING**

The actual auditing is carried out in this area. All responses are gathered for further analysis.

#### **1.4.4 IMPROVEMENT ANALYSIS AND EVALUATION**

All responses and information gathered are analysed and evaluated in this function to improve auditing and other procedures. Planning Review activities are also informed about these evaluations.

#### 1.4.5 REPORTING

Audit reports are prepared for the Management and Planning. Audit samples are also prepared for the shop floor activities.

# 1.1.1 QUALITY MANAGEMENT AND PLANNING

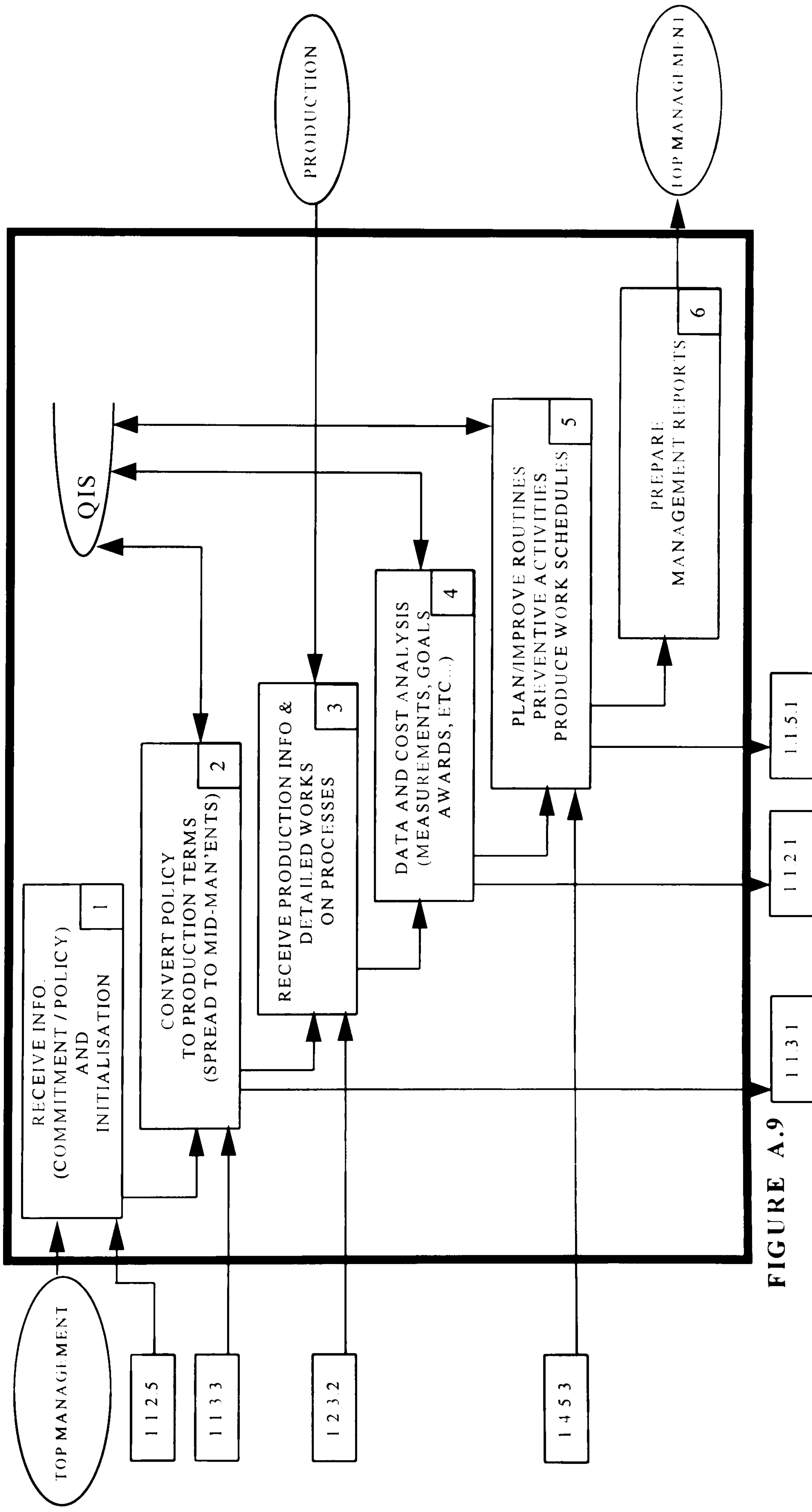


FIGURE A.9

## **THIRD LEVEL ACTIVITIES**

### **DATA ANALYSIS (USER REQUIREMENTS)**

This level is generally called user requirements. All the processes on the previous functional areas are defined, specified and analysed in a structured and integrated way to produce user requirements for the implementation model.

#### **FIGURE A.9**

#### **1.1.1 QUALITY MANAGEMENT AND PLANNING**

##### **1.1.1.1 RECEIVE INFORMATION AND INITIALISATION**

They receive quality policy/commitment from top/senior management and reports from Data Analysis and Cost Reporting. They do initial classification and checks and then proceed to the second step.

##### **1.1.1.2 CONVERT POLICY INTO PRODUCTION TERMS (SPREAD TO MIDDLE MANAGEMENT)**

Having policy and reports in hand, they receive further requirements from the Continuous Process Regulations and then convert the policy into production terms to enable everybody at every level to understand it. They inform the continuous process regulations about the new evaluations. QIS is also accessible.

### 1.1.1.3 RECEIVE PRODUCTION INFORMATION AND DETAILED WORKS ON PROCESSES

They receive information from production and shop floor operations and they then detail the quality works and plans on processes. They inform detailed tasks to the next step.

### 1.1.1.4 DATA AND COST ANALYSIS

They receive the detailed tasks and set new goals for every process and functional area. Various criteria for measurements are also set here. Cost analysis of the tasks are made and a rewarding scheme for each process necessary is established. QIS is also accessible. Information output is sent to both the management Data Analysis and Cost Reporting, and Routines Improvement activity for evaluation.

### 1.1.1.5 PLAN AND IMPROVE ROUTINES, PREVENTIVE ACTIVITIES AND PRODUCE WORK SCHEDULES

They receive detailed information about the processes and try to find out further improvement points for the routine works. Preventive activities are planned, work schedules are produced, and then related information is delivered to the Work Scheduling function. QIS is also accessible

#### 1.1.1.6 PREPARE MANAGEMENT REPORT

They receive all the information necessary and prepare very sophisticated management reports. Furthermore the classification of the reports to address different levels of management and managers is also carried out.

1.1.2 DATA ANALYSIS AND COST REPORTING

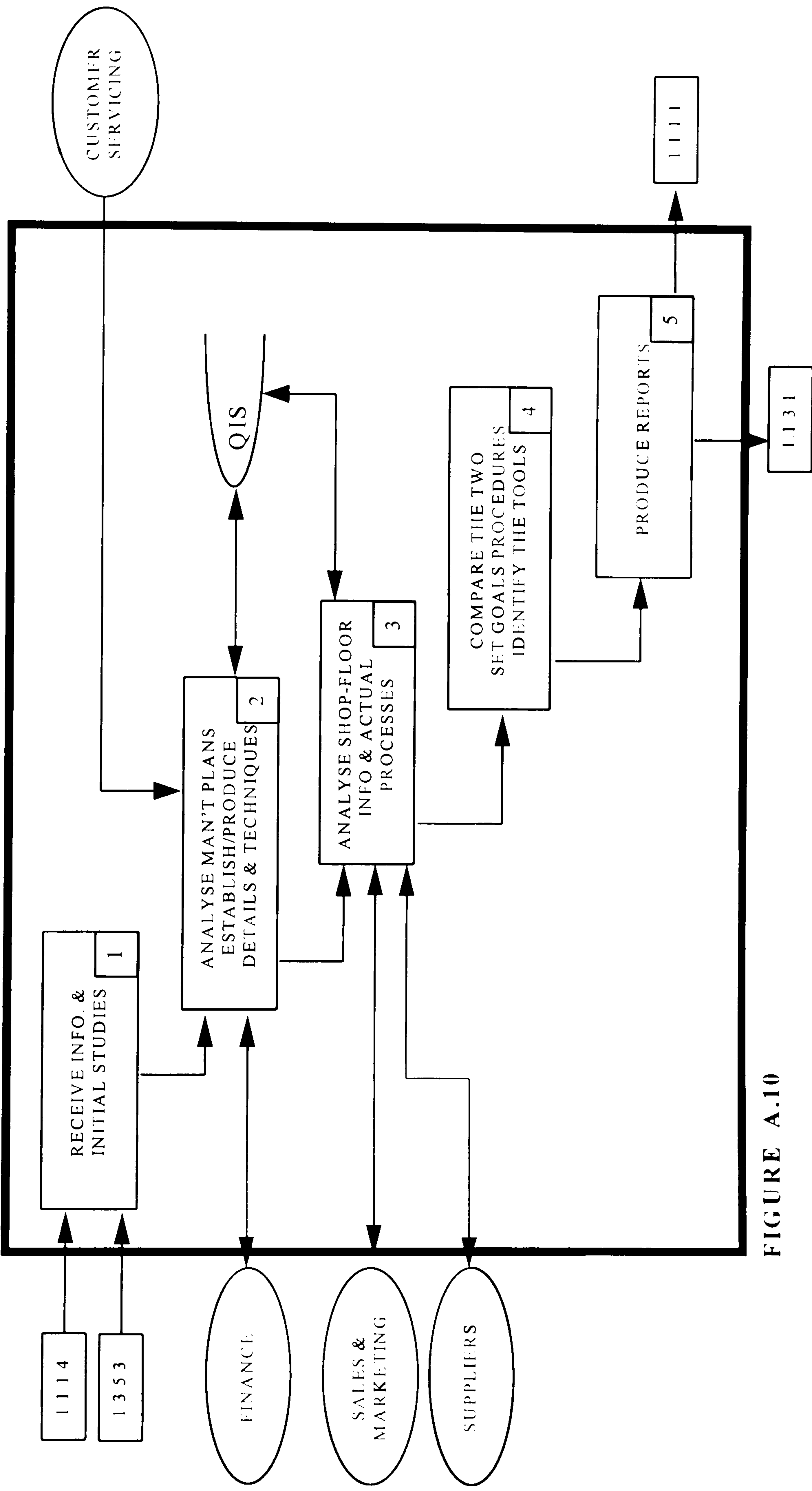


FIGURE A.10

## **FIGURE A.10**

### **1.1.2 DATA ANALYSIS AND COST REPORTING**

#### **1.1.2.1 RECEIVE INFORMATION AND INITIAL STUDIES**

Within this process, quality plans and management reports are received and then an initial study to match and classify the information received is performed.

#### **1.1.2.2 ANALYSE MANAGEMENT PLANS, ESTABLISH AND PRODUCE DETAILS AND TECHNIQUES**

They start analysing and evaluating the plans with the information produced by Finance and Customer Servicing. They set up new measurement techniques and detail the plans. Information about the expected costs and necessary plans is also delivered to the Finance Department. QIS is accessible.

#### **1.1.2.3 ANALYSE SHOP FLOOR INFORMATION AND ACTUAL PROCESSES**

Having the detailed quality plans and performance measurement techniques in hand they retrieve shop floor information from QIS. They also communicate with the Sales and Marketing and Suppliers functions to further evaluate the information.



#### 1.1.2.4 COMPARE THE TWO, SET GOALS AND PROCEDURES, AND IDENTIFY THE TOOLS

They will compare and analyse all the information received and set new goals and procedures for each specific operation. Which quality assurance tools are to be used and how they should be used will be identified. It will also be determined what the rewarding system and rewards will be.

#### 1.1.2.5 PRODUCE REPORTS

They will produce pre-determined management reports for the Management and Planning, and related reports for the Continuous Process Regulations.

1.1.3 CONTINUOUS PROCESS REGULATIONS

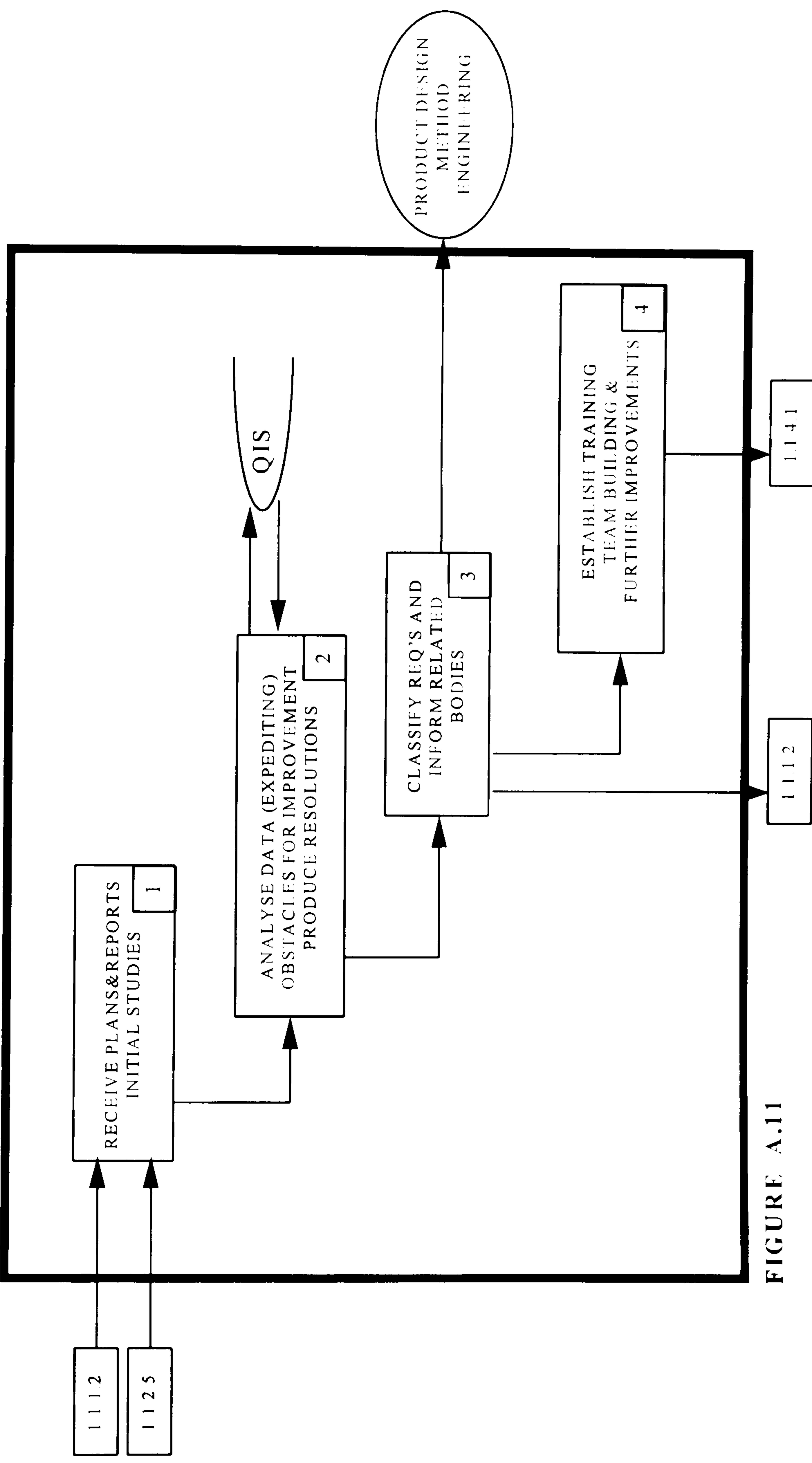


FIGURE A.11

## **FIGURE A.11**

### **1.1.3 CONTINUOUS PROCESS REGULATIONS**

#### **1.1.3.1 RECEIVE PLANS AND REPORTS; INITIAL STUDIES**

Receive related reports from data and cost analysis and quality policy/plans from Management and Planning. Classify each processes and initialise analysis.

#### **1.1.3.2 ANALYSE DATA (EXPEDITING), OBSTACLES FOR IMPROVING, PRODUCE RESOLUTION**

They receive all information for each processes and study it to improve or abolish barriers for further improvement. Remedies for non-conformances are produced in this area. QIS is also accessible.

#### **1.1.3.3 CLASSIFY THE REQUIREMENTS AND INFORM RELATED BODIES**

Based on the previous analyses, group the requirements and make them easily understandable to the related activities. Inform Product Design and Method Engineering, and Management Planning about the requirements.

#### 1.1.3.4 ESTABLISH TRAINING, TEAM BUILDING AND FURTHER IMPROVEMENTS

According to new requirements and evaluation, determine training requirements in particular areas, identify weaknesses in teams and establish the requirements to set up new teams with their rewarding and measuring tools. Make recommendations for the next activities.

1.1.4 TRAINING AND TEAM BUILDING (LEADERSHIP)

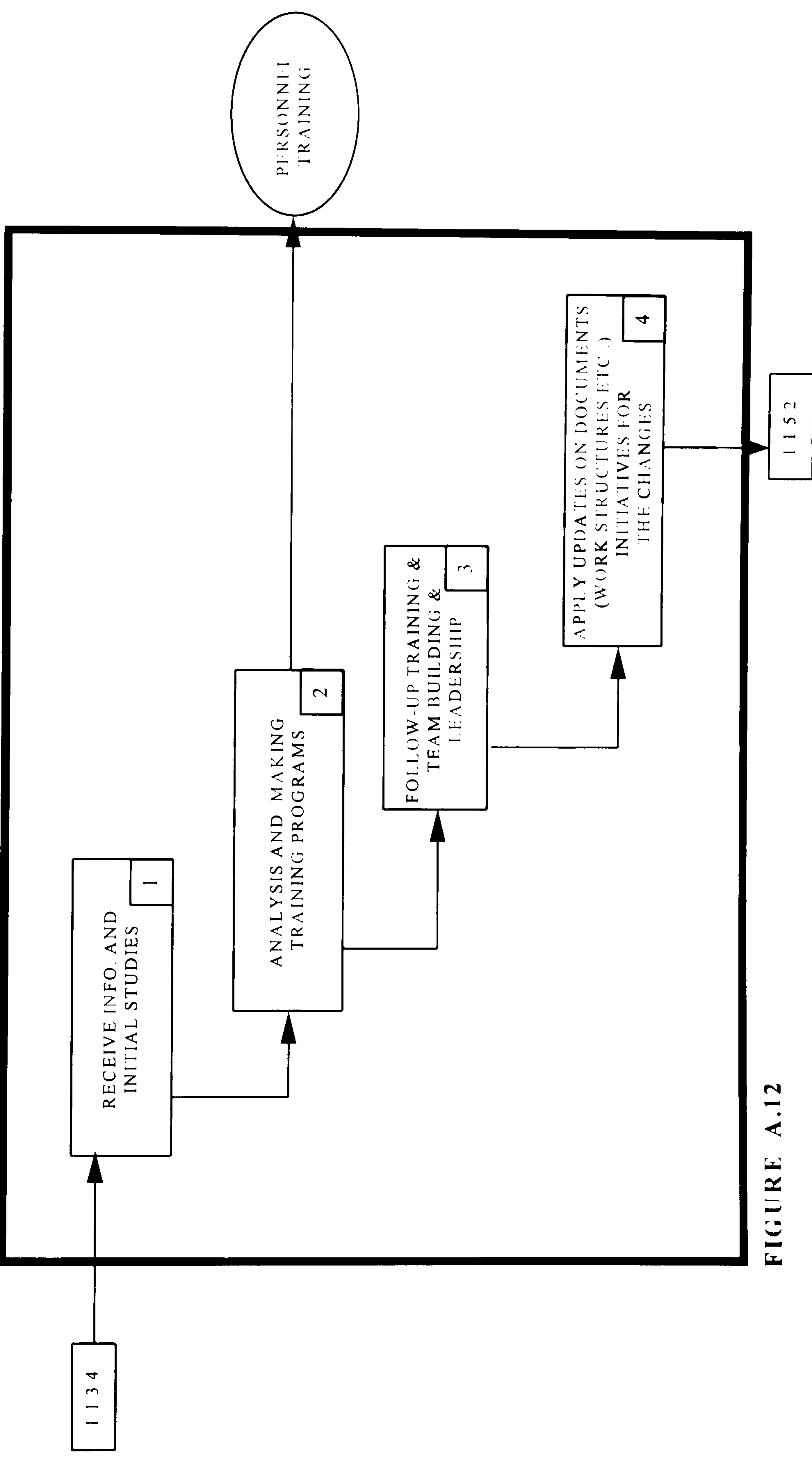


FIGURE A.12

## **FIGURE A.12**

### **1.1.4 TRAINING AND TEAM BUILDING (LEADERSHIP)**

#### **1.1.4.1 RECEIVE INFORMATION AND INITIAL STUDIES**

Receive information on Training and Team Building. Combine it with the existing documentation and group them according to the need.

#### **1.1.4.2 ANALYSIS AND MAKING TRAINING PROGRAMMES**

Analyse the information with the existing knowledge and make detailed training programmes, identifying skilled manpower requirements if necessary, also inform Personnel Training of these programmes and requirements.

#### **1.1.4.3 FOLLOW-UP TRAINING, TEAM BUILDING AND LEADERSHIP PROGRAMMES**

Update the information and documentation accordingly, and then evaluate the programmes. Study the information and keep-up trends. Follow-up training, team building and leadership programmes made earlier.

#### **1.1.4.4 APPLY UPDATES ON DOCUMENTS (WORK STRUCTURES ETC.), INITIATIVES FOR THE CHANGES**

Try to apply the updated information on work structures and work schedules. Establish initiatives for the change requirements emerged.

1.1.5 WORK STRUCTURES AND SCHEDULING

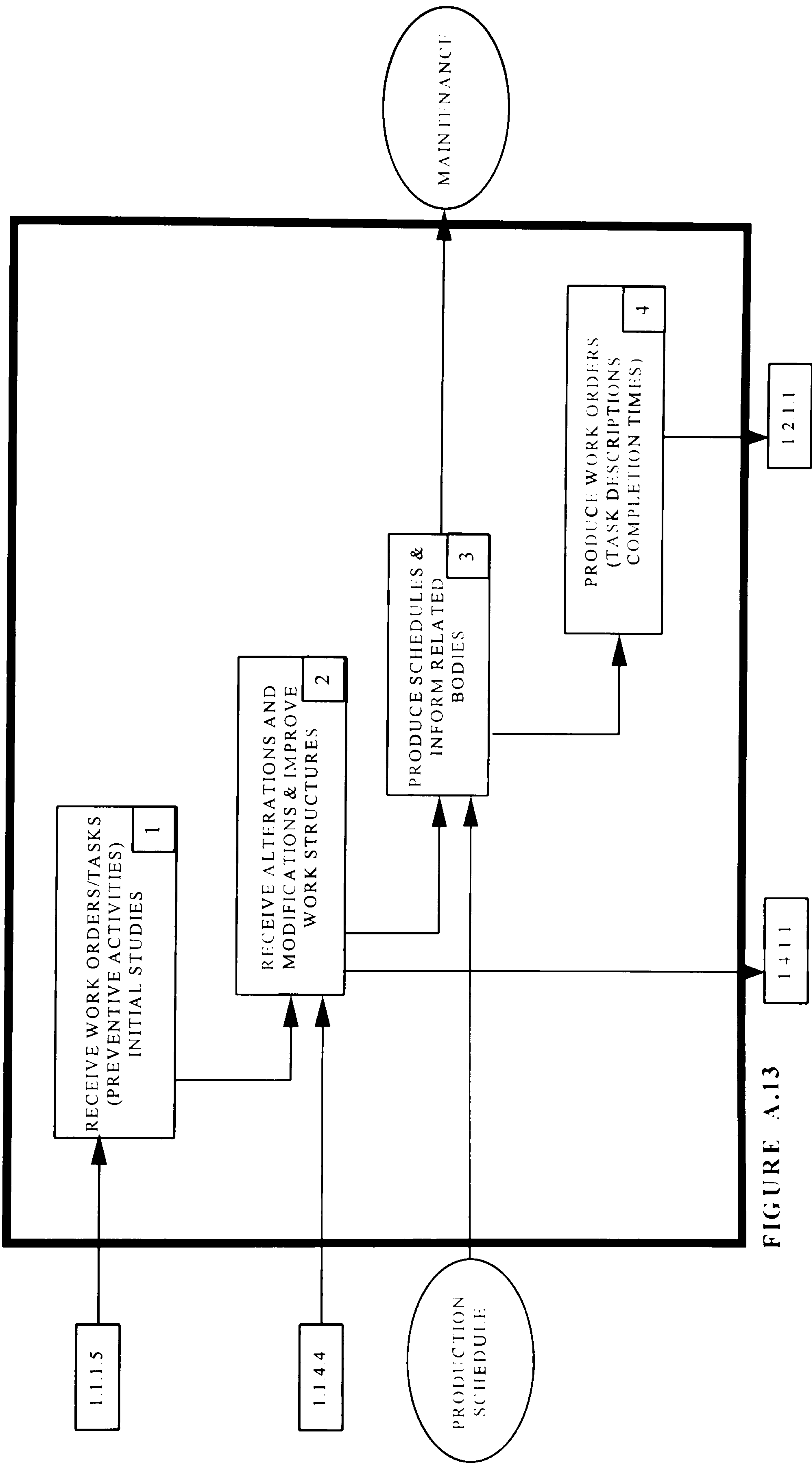


FIGURE A.13

## **FIGURE A.13**

### **1.1.5 WORK STRUCTURES AND SCHEDULING**

#### **1.1.5.1 RECEIVE WORK ORDERS/TASKS AND INITIAL STUDIES**

Receive work orders and tasks, preventive activity orders from Management and Planning and then initialise the work.

#### **1.1.5.2 RECEIVE ALTERATIONS AND MODIFICATIONS AND IMPROVE WORK STRUCTURES**

Receive orders from Management and Planning, and recommendations from Work Structures and Scheduling. Modify and improve work structures. Inform Auditing about the new modifications made and proceed to the next step.

#### **1.1.5.3 PRODUCE SCHEDULES AND INFORM RELATED BODIES**

Receive work orders and tasks to be completed and obtain production schedule from Production. Produce work schedules and inform maintenance as well.

#### **1.1.5.4 PRODUCE WORK ORDERS (TASK DESCRIPTIONS AND COMPLETION TIMES)**

Receive schedules and produce updated and improved work orders. Describe the improved tasks and attach new completion times to them, then inform the shop floor operations.



1.2.1 PLANNING REVIEW AND RESOURCE ALLOCATION

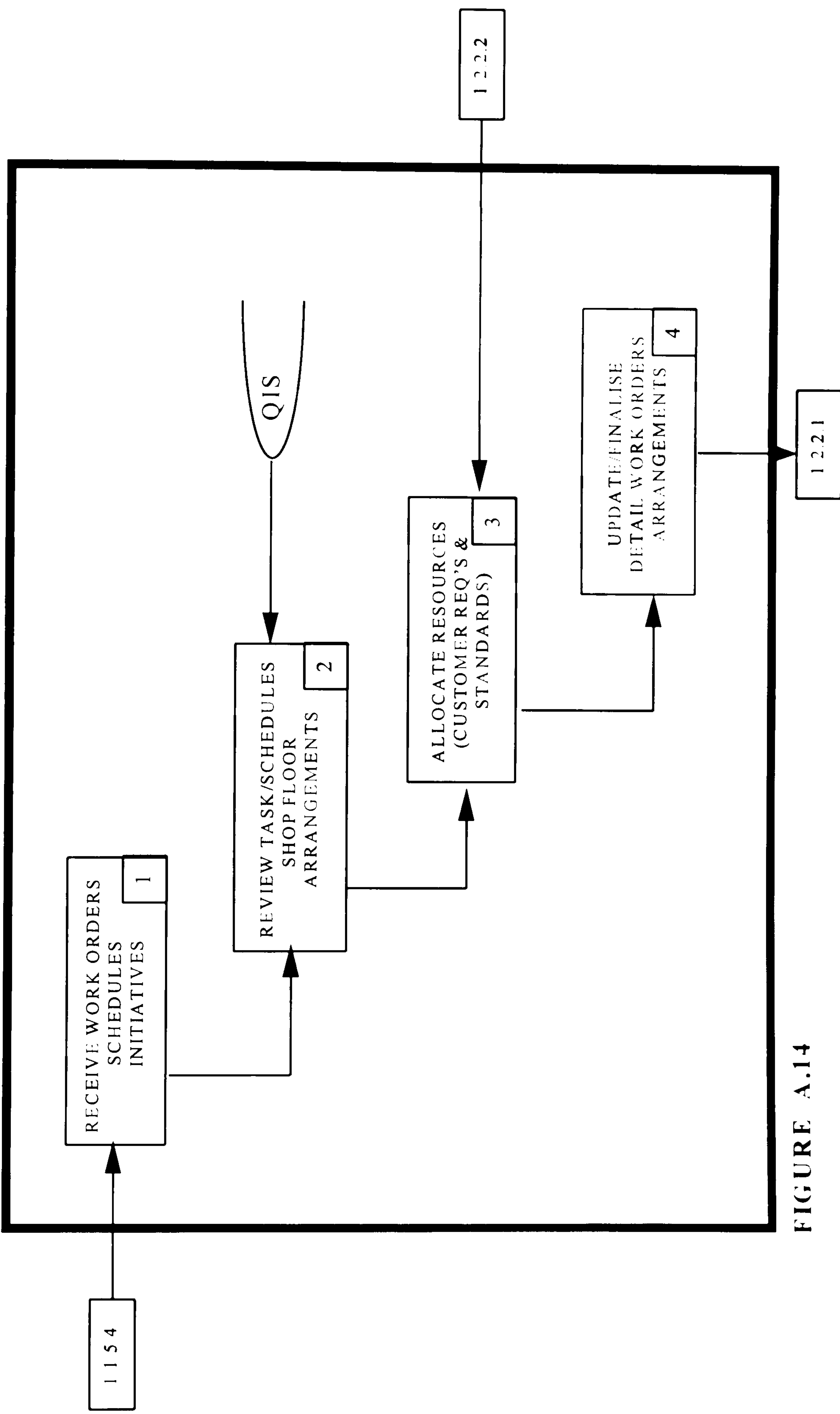


FIGURE A.14

## **FIGURE A.14**

### **1.2.1 PLANNING REVIEW AND RESOURCE ALLOCATION**

#### **1.2.1.1 RECEIVE WORK ORDERS, SCHEDULES AND INITIATIVES**

After receiving work orders, tasks, schedules, an initial review is made. Information is then classified accordingly for the next step.

#### **1.2.1.2 REVIEW TASK AND SCHEDULES, SHOP FLOOR ARRANGEMENTS**

Having information ready on the QIS, they study the tasks and schedules, and list any necessary shop floor arrangements.

#### **1.2.1.3 ALLOCATE RESOURCES (CUSTOMER REQUIREMENTS AND STANDARDS)**

They receive standards and improved customer requirements. Resource allocation necessary to carry out the job is also made in this area..

#### **1.2.1.4 UPDATE AND FINALISE, DETAIL WORK ORDERS AND ARRANGEMENTS**

Having satisfied all the necessary requirements, they detail, update and finalise work orders, tasks and schedules, and check all arrangements.

## 1.2.2 CUSTOMER REQUIREMENTS AND STANDARDS

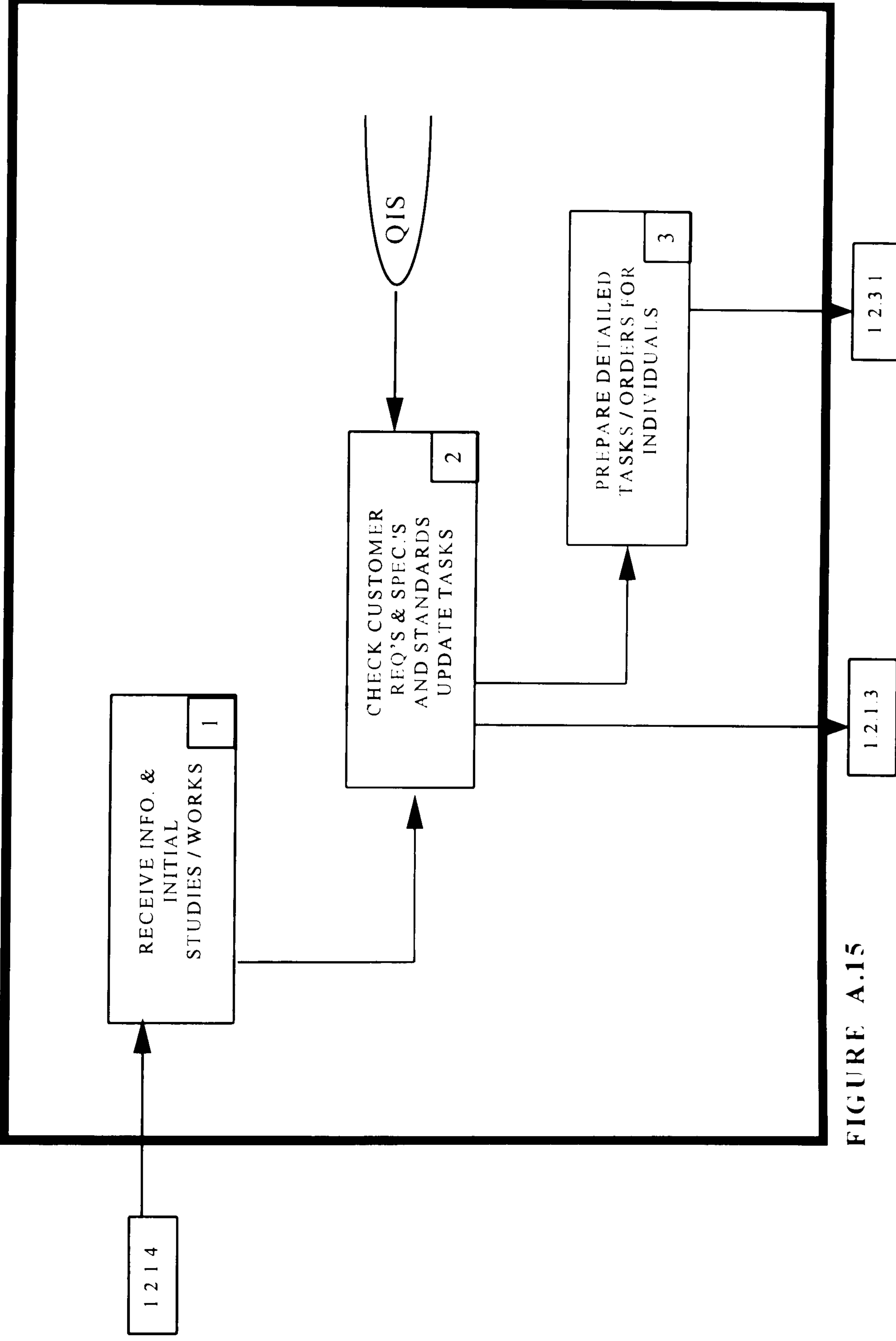


FIGURE A.15

## **FIGURE A.15**

### **1.2.2 CUSTOMER REQUIREMENTS AND STANDARDS**

#### **1.2.2.1 RECEIVE INFORMATION, INITIAL STUDIES AND WORKS**

They receive reviewed information and make an initial study on the standards and customer requirements.

#### **1.2.2.2 CHECK CUSTOMER REQUIREMENTS, SPECIFICATIONS AND STANDARDS, AND UPDATE TASKS**

They find out specified user (next step customer) requirements and necessary standards. Then, the tasks considering user requirements are updated. The Planning Review is informed about the standards and customer requirements. QIS is also accessible.

#### **1.2.2.3 PREPARE DETAILED TASKS AND ORDERS FOR INDIVIDUALS**

They receive updated and completed workorders or tasks. These are detailed out for the actual physical work, and to the individuals who are going to be involved in the work.

1.2.3 ACTUAL WORKS (INSPECT/MEASURE/TESTS/CALIBRATION...)

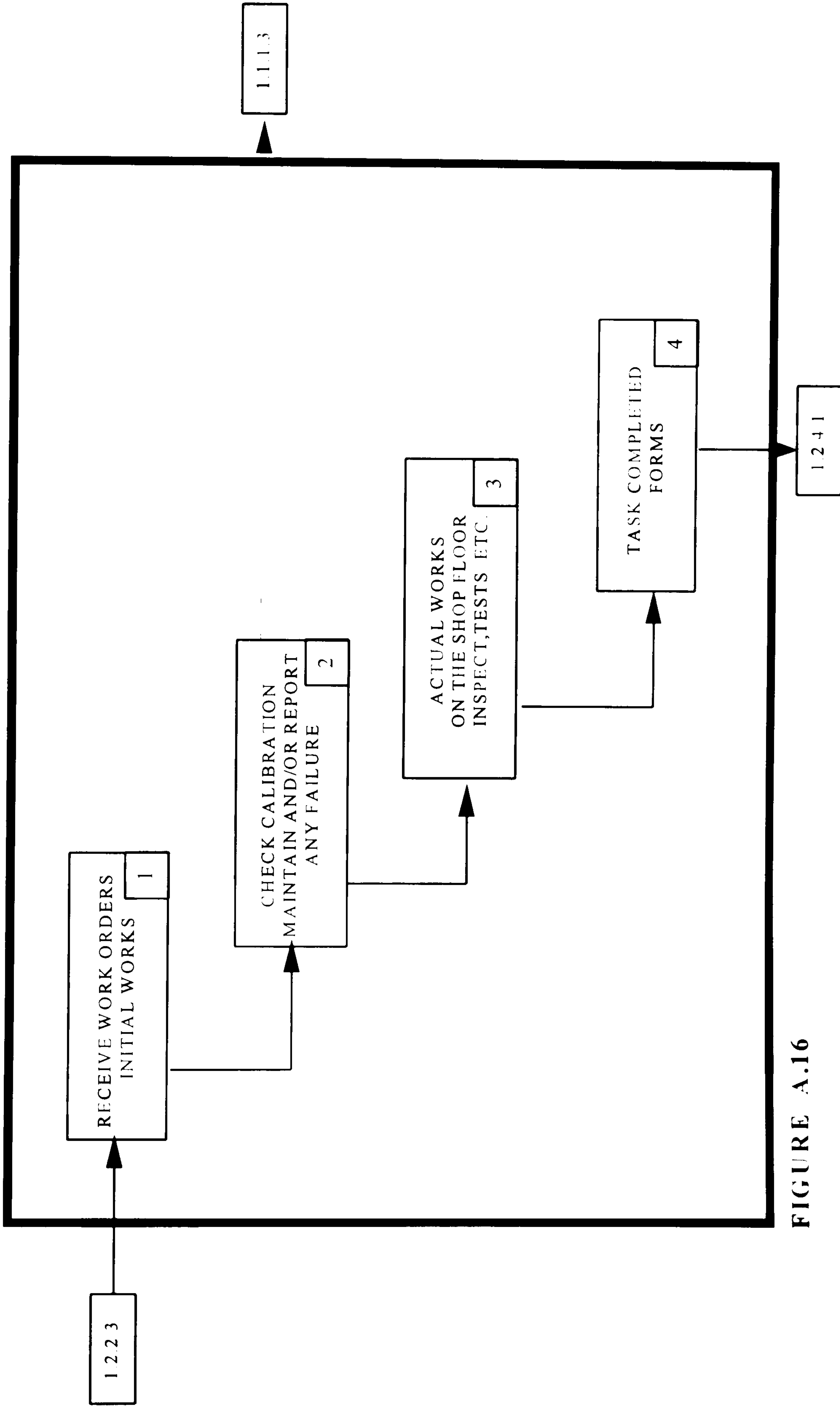


FIGURE A.16

## **FIGURE A.16**

### **1.2.3 ACTUAL WORKS (INSPECT, MEASURE, TEST, CALIBRATE, ETC.)**

#### **1.2.3.1 RECEIVE WORK ORDERS AND INITIAL WORKS**

They receive work orders and do some initial review or study on these workorders. The information received is also categorised.

#### **1.2.3.2 CHECK CALIBRATION, MAINTAIN OR REPORT ANY FAILURE**

They check the equipment to be used and check the calibration of equipment. Report any failure. Remedy the failure if it is simple or inform the Management for further action.

#### **1.2.3.3 ACTUAL WORK ON THE SHOP FLOOR (INSPECT, TEST, ETC.)**

Do the actual physical work according to the updated procedures. This work consists of mainly inspection, testing, and simple calibrations.

#### **1.2.3.4 TASK COMPLETED FORMS**

Having done the actual physical work, complete the forms accordingly and then proceed to the next step.

1.2.4 REPORT PROCESS REQUIREMENTS / IMPROVEMENTS

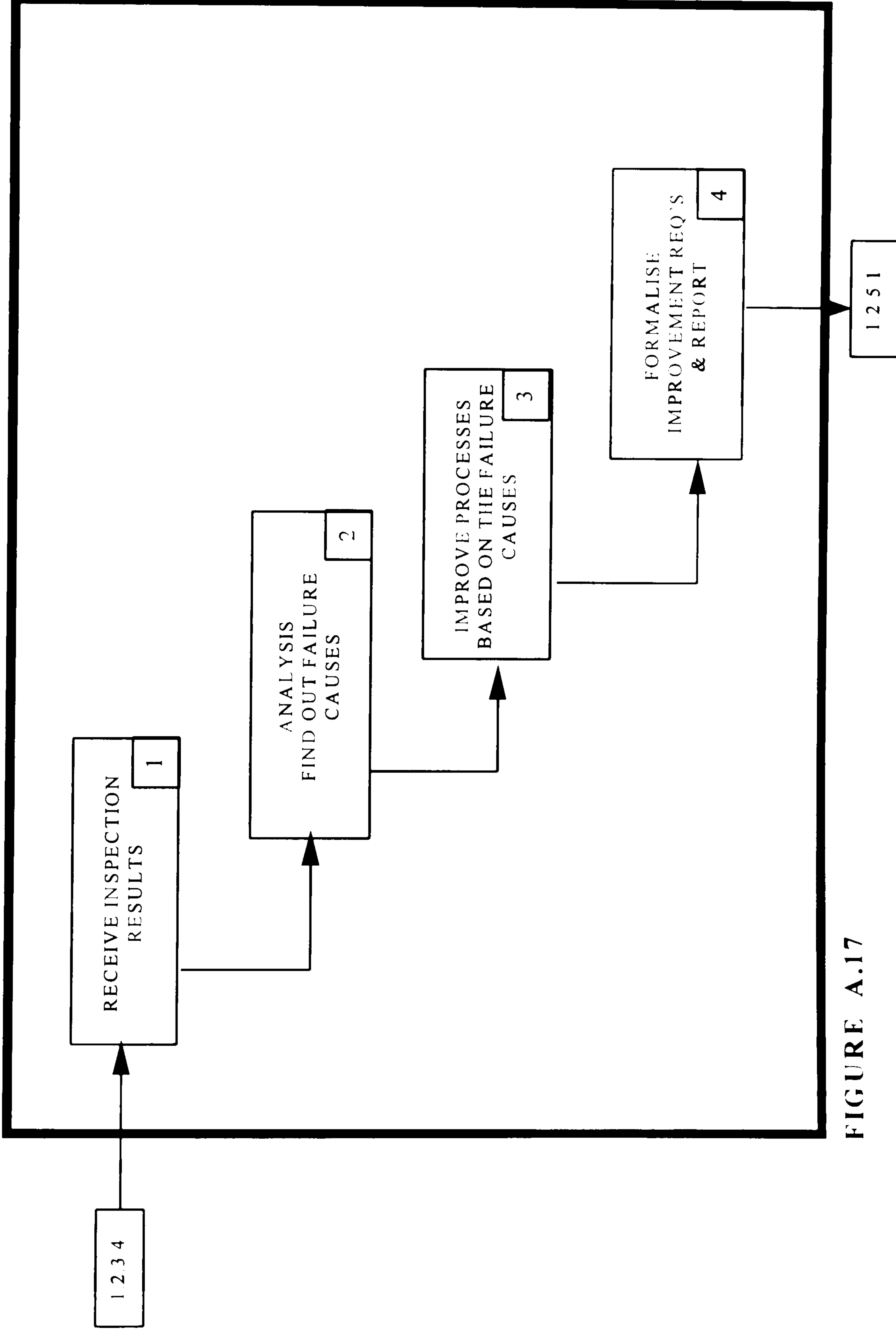


FIGURE A.17

## **FIGURE A.17**

### **1.2.4 REPORT PROCESS REQUIREMENTS AND IMPROVEMENTS**

#### **1.2.4.1 RECEIVE INSPECTION RESULTS**

They receive inspection results and task completed forms and make an initial review. The information is also classified.

#### **1.2.4.2 ANALYSIS AND FIND OUT FAILURE CAUSE**

They analyse the inspection results and identify failure causes. They employ different tools to discover root causes and monitor similar problems.

#### **1.2.4.3 IMPROVE PROCESSES BASED ON THE FAILURE CAUSES**

Having identified the causes of the inefficiencies, they improve the related processes based on the past data and the customer requirements. The measures taken to improve the processes are also listed.

#### **1.2.4.4 FORMALISE IMPROVEMENT REQUIREMENTS AND REPORT**

Having established all the improvement requirements, they put them in a special form to make the next steps easier. All the improvement activities are reported.



1.2.5 REPORT NONCONFORMANCE (DISCREPANCY OR REQUIREMENTS)

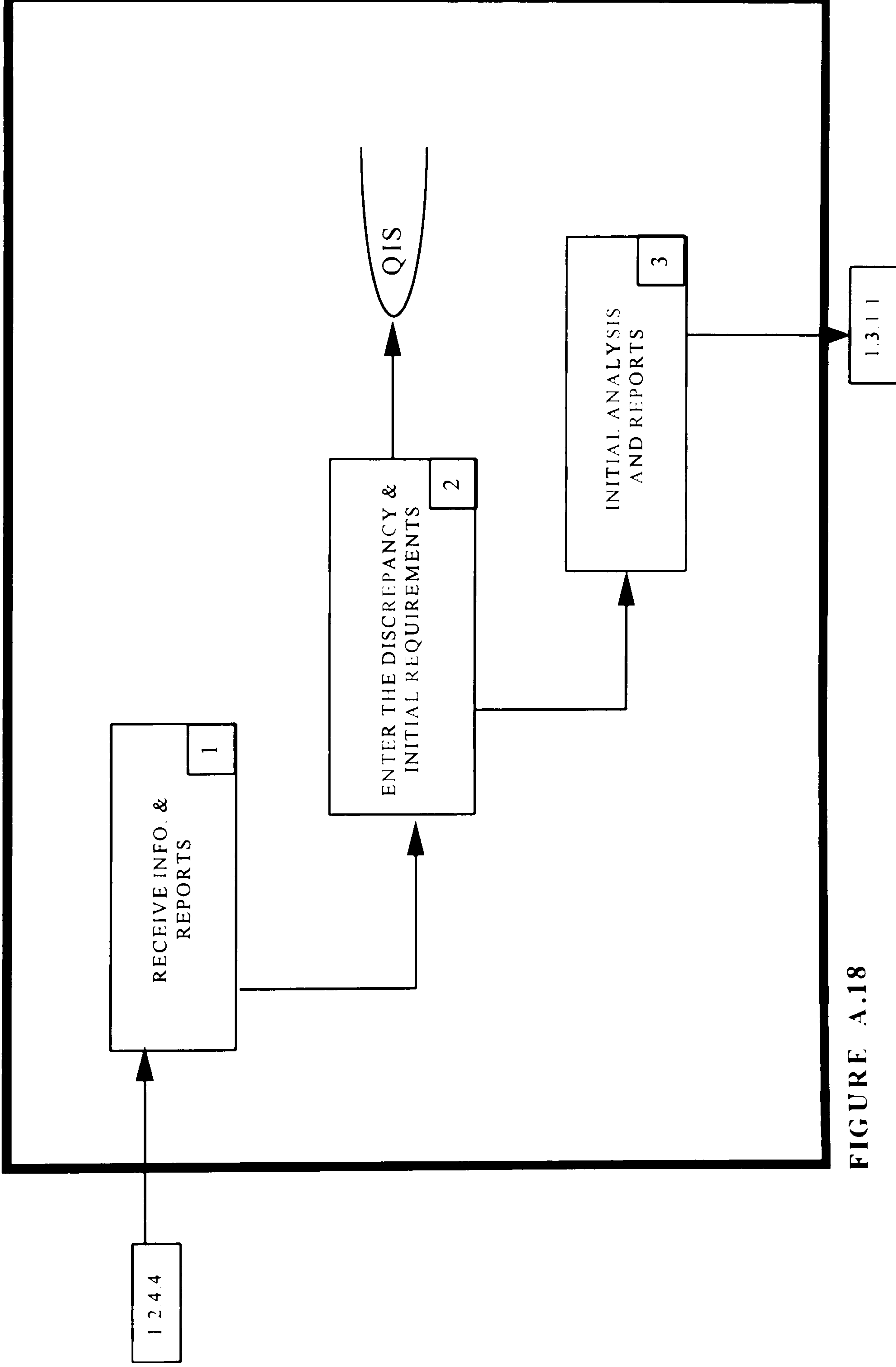


FIGURE A.18

## **FIGURE A.18**

### **1.2.5 REPORT NON-CONFORMANCES (DISCREPANCY OR REQUIREMENTS)**

#### **1.2.5.1 RECEIVE INFORMATION AND REPORTS**

They receive inspection results, task completed forms, and make an initial review and classification.

#### **1.2.5.2 ENTER THE DISCREPANCY AND INITIAL REQUIREMENTS**

They key-in the results to the QIS and identify the initial requirements for the corrective actions.

#### **1.2.5.3 INITIAL ANALYSIS AND REPORTS**

They make initial failure-cause analysis and produce an initial report. If a simple and limited corrective action is going to take place then it should be neatly described.

1.3.1 REPORT PLAN REVIEW / RESOURCE ALLOCATION

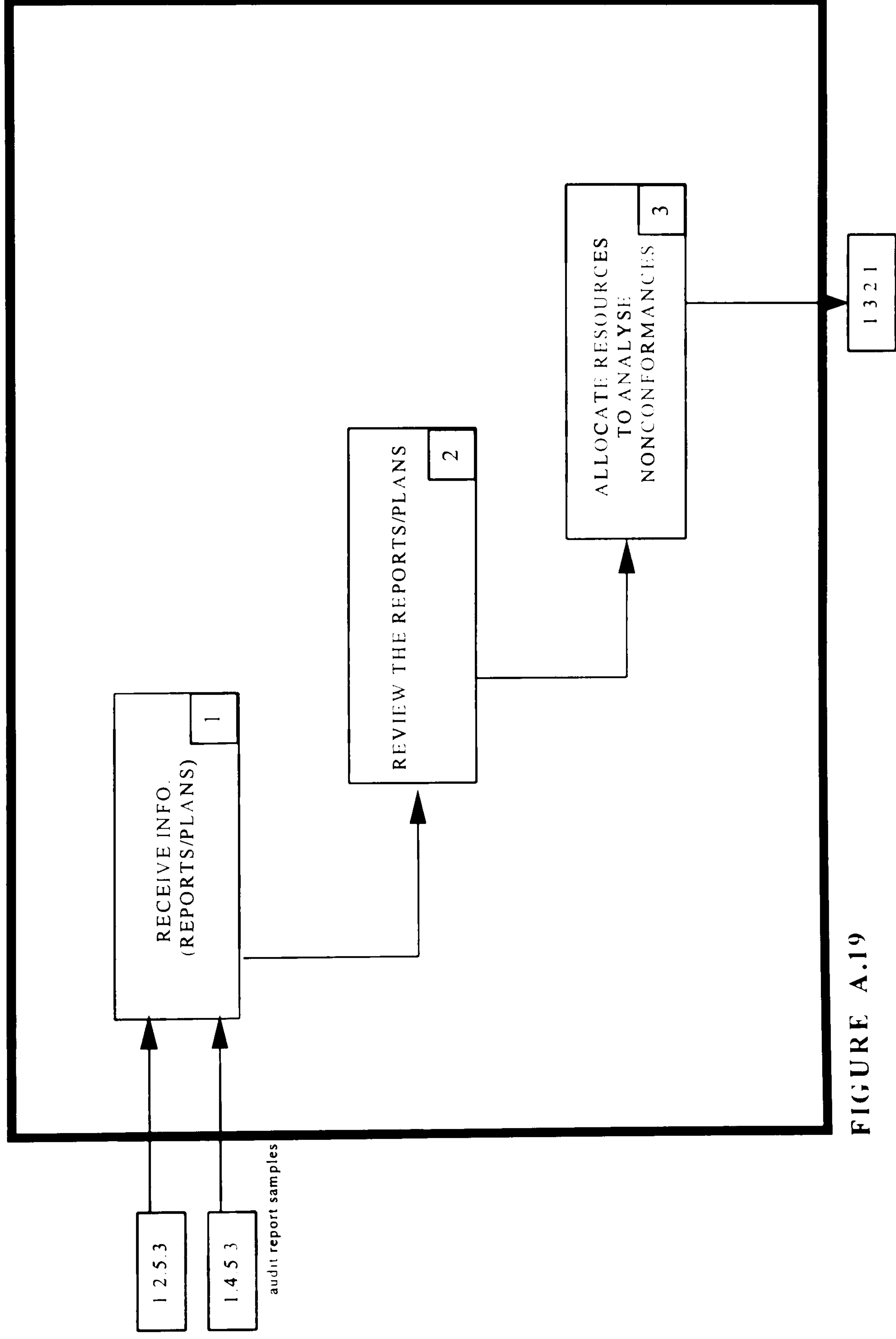


FIGURE A.19

## **FIGURE A.19**

### **1.3.1 REPORT PLAN REVIEW AND RESOURCE ALLOCATION**

#### **1.3.1.1 RECEIVE INFORMATION (REPORTS AND PLANS)**

They receive information of the inspection results and of the audit report samples. The information received is then classified.

#### **1.3.1.2 REVIEW THE REPORTS AND PLANS**

They study the reports and find out the resources required. Availability of the resources including manpower allocation is confirmed.

#### **1.3.1.3 ALLOCATE RESOURCES TO ANALYSE NON-CONFORMANCES**

They receive the initial study and allocate mentioned resources to analyse the failures and identify the remedies.

1.3.2 REASON FOR NON-CONFORMANCE/PROBLEM CAUSE & RESOLUTION

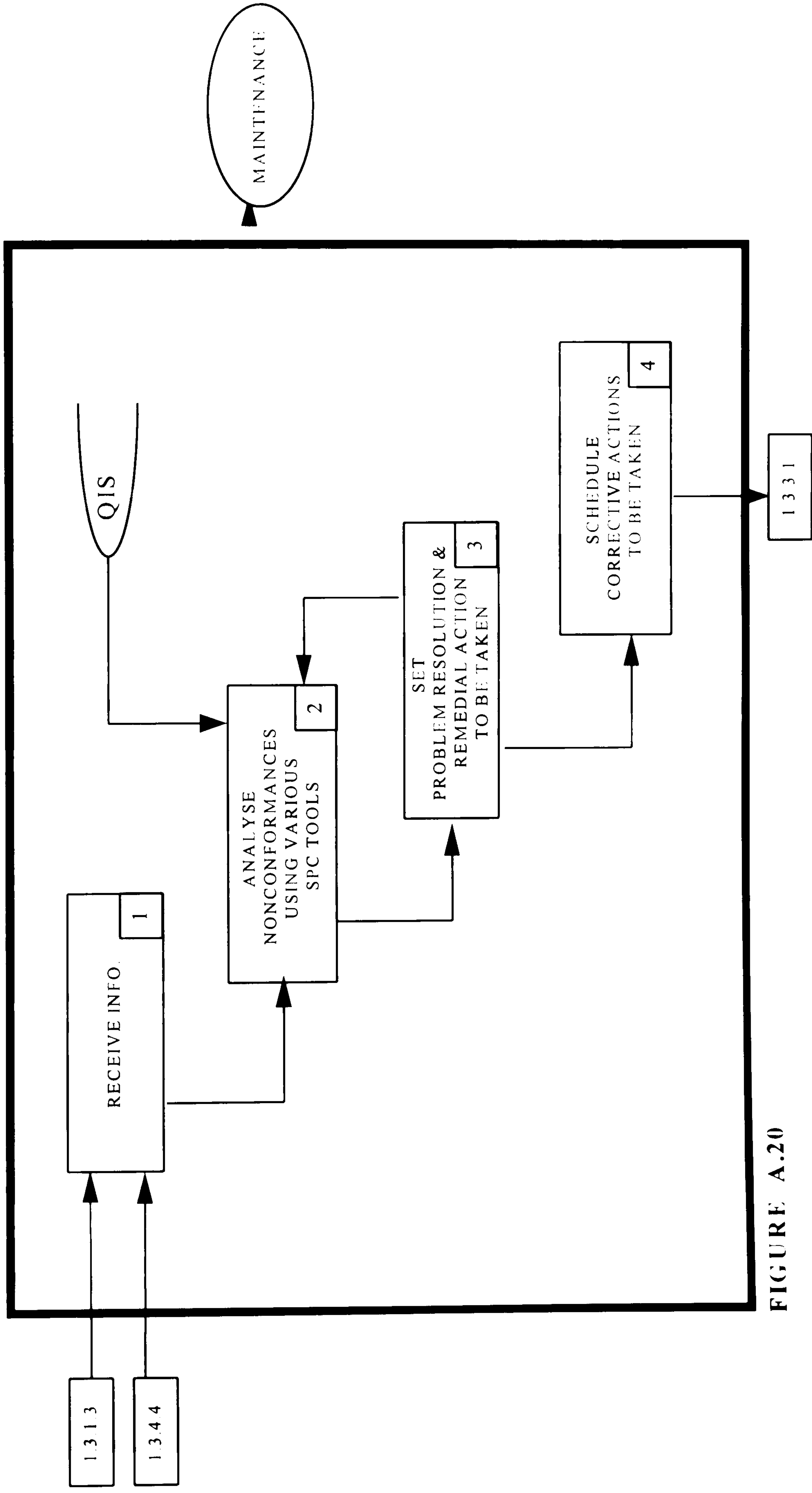


FIGURE A.20

## **FIGURE A.20**

### **1.3.2 REASON FOR NON-CONFORMANCES, PROBLEM CAUSE AND RESOLUTION**

#### **1.3.2.1 RECEIVE INFORMATION**

Receive information from the initial review and resource allocation activities. Information about faulty parts is also received from the Material Review Board.

#### **1.3.2.2 ANALYSE NON-CONFORMANCES USING VARIOUS SPC TOOLS**

They study non-conformances based on the various criteria. Analysis starts with the past data using SPC tools to understand the causes and effects. They receive alternative suggestions for solutions of the causes. An informal relationship is established with the Maintenance department. QIS is also accessible.

#### **1.3.2.3 SET PROBLEM RESOLUTION AND REMEDIAL ACTION TO BE TAKEN**

The best solution is produced on assessments of the results of the analysis of the causes. They then produce the procedures for the corrective action. They justify and verify their remedies.

#### **1.3.2.4 SCHEDULE CORRECTIVE ACTIONS TO BE TAKEN**

Once the procedures are completed, corrective actions to be taken according to various criteria are also scheduled.

1.3.3 FIX OR DISPOSITION (TROUBLE SHOOTING)

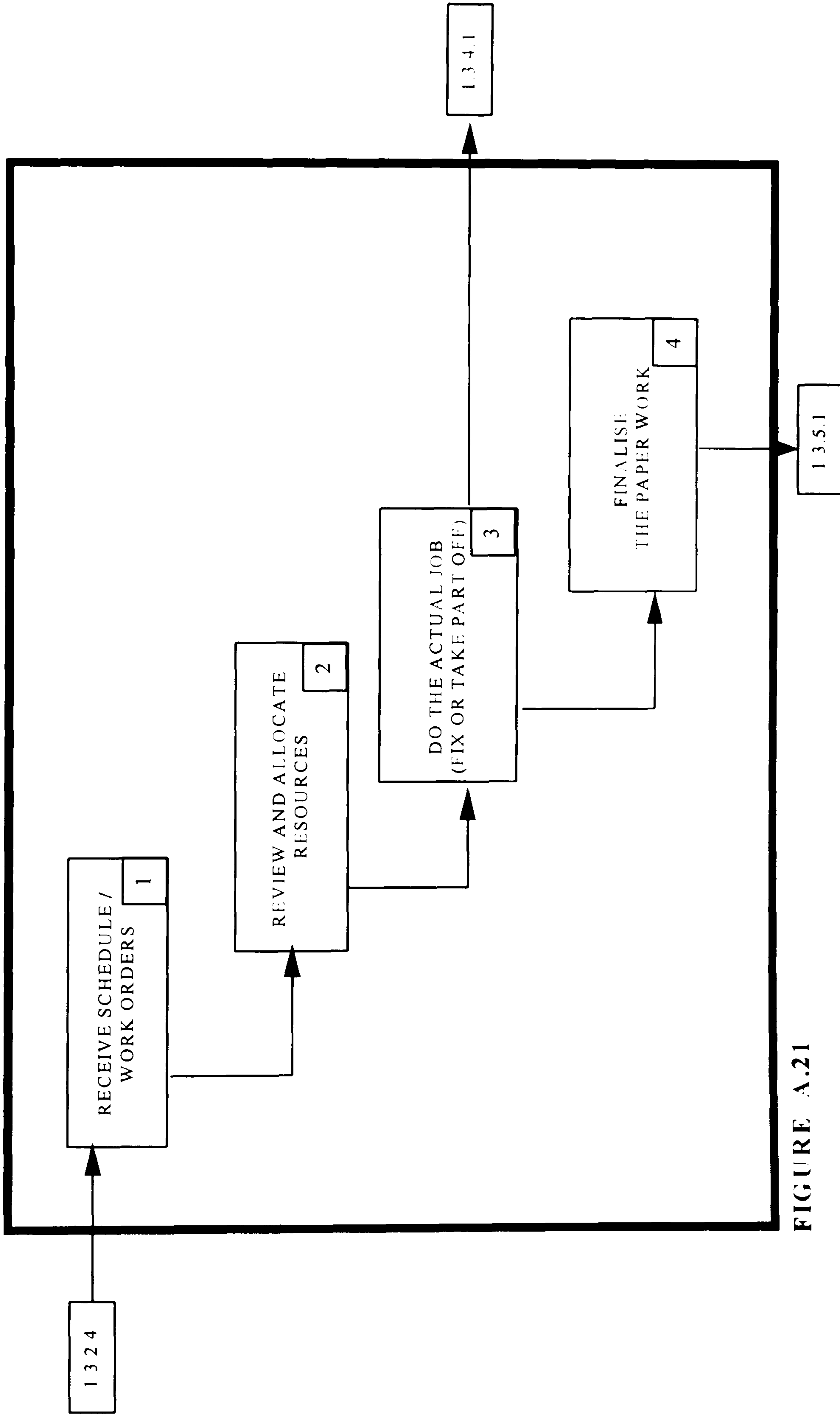


FIGURE A.21

## **FIGURE A.21**

### **1.3.3 FIX OR DISPOSITION (TROUBLE SHOOTING)**

#### **1.3.3.1 RECEIVE SCHEDULE AND WORK ORDERS**

They receive corrective action schedules, work orders and procedures. The information is then classified.

#### **1.3.3.2 REVIEW AND ALLOCATE RESOURCES**

They review the information and allocate the necessary resources to overcome the failures. These are mainly material and manpower resources.

#### **1.3.3.3 DO THE ACTUAL JOB (FIX OR TAKE PART OFF)**

They apply corrective action procedures on the non-conformances. The non-conforming parts are fixed, changed or taken off to the Material Review Board.

#### **1.3.3.4 FINALISE THE PAPER WORK**

They complete the task forms and close the open non-conformance reports. The reports are kept until they are completed.



### 1.3.4 MATERIAL REVIEW BOARD

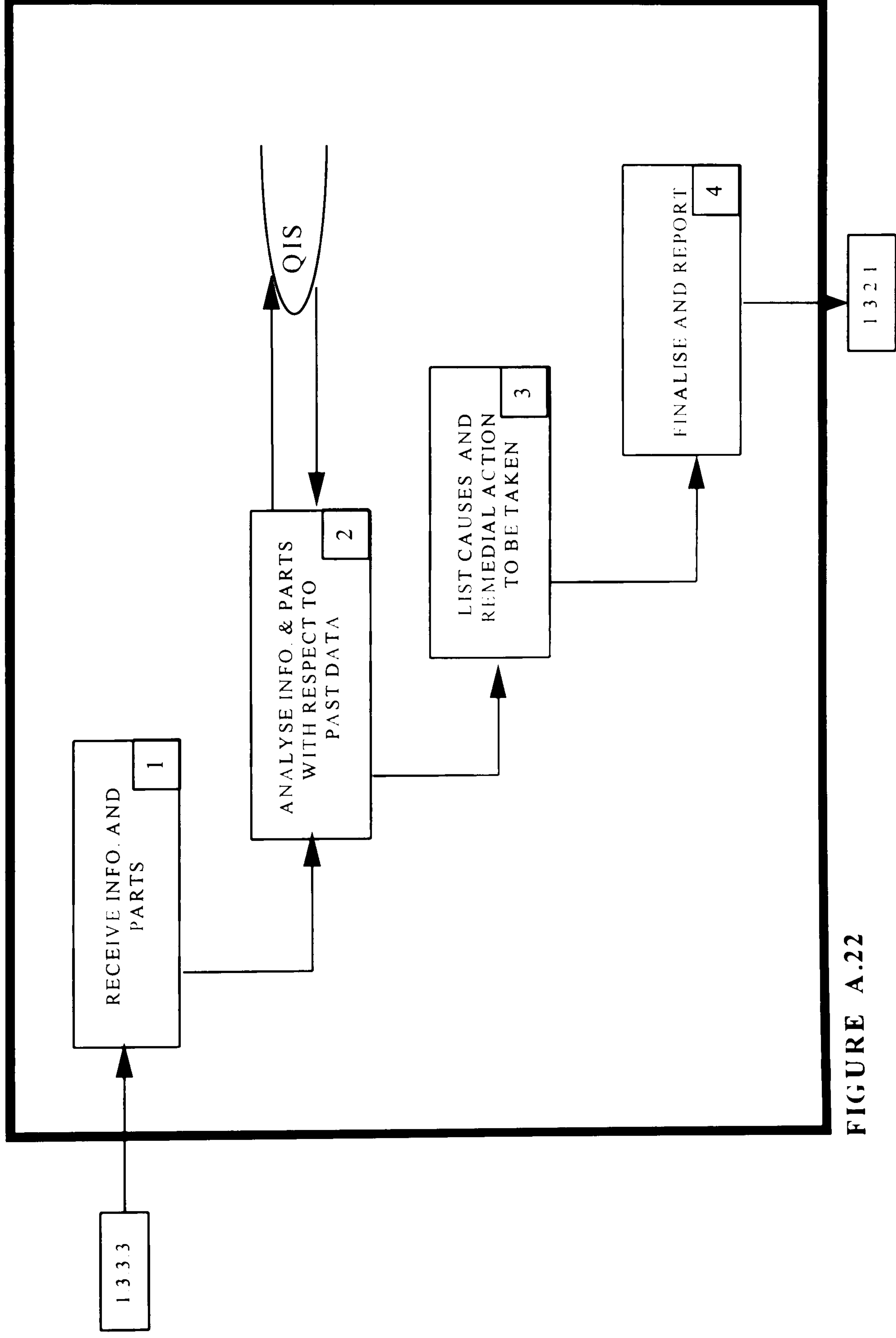


FIGURE A.22

## **FIGURE A.22**

### **1.3.4 MATERIAL REVIEW BOARD**

#### **1.3.4.1 RECEIVE INFORMATION AND PARTS**

They receive non-conformance information together with the faulty parts. An initial review of information and a check of the part is carried out.

#### **1.3.4.2 ANALYSE INFORMATION AND PARTS WITH RESPECT TO PAST DATA AND MECHANISMS**

They analyse the part and find out the cause for the fault. QIS is accessible in this area. The mechanisms of the part are also analysed to find out whether it can perform the job which it was designed.

#### **1.3.4.3 LIST CAUSES AND REMEDIAL ACTION TO BE TAKEN**

They list all causes and produce a solution for the non-conformance. A decision either to use as is, rework or scrap the part is also made in this area.

#### **1.3.4.4 FINALISE AND REPORT**

They finalise their works and make their decision. Then a report justifying the decision together with any further corrective actions needed is produced.

### 1.3.5 REPORTING

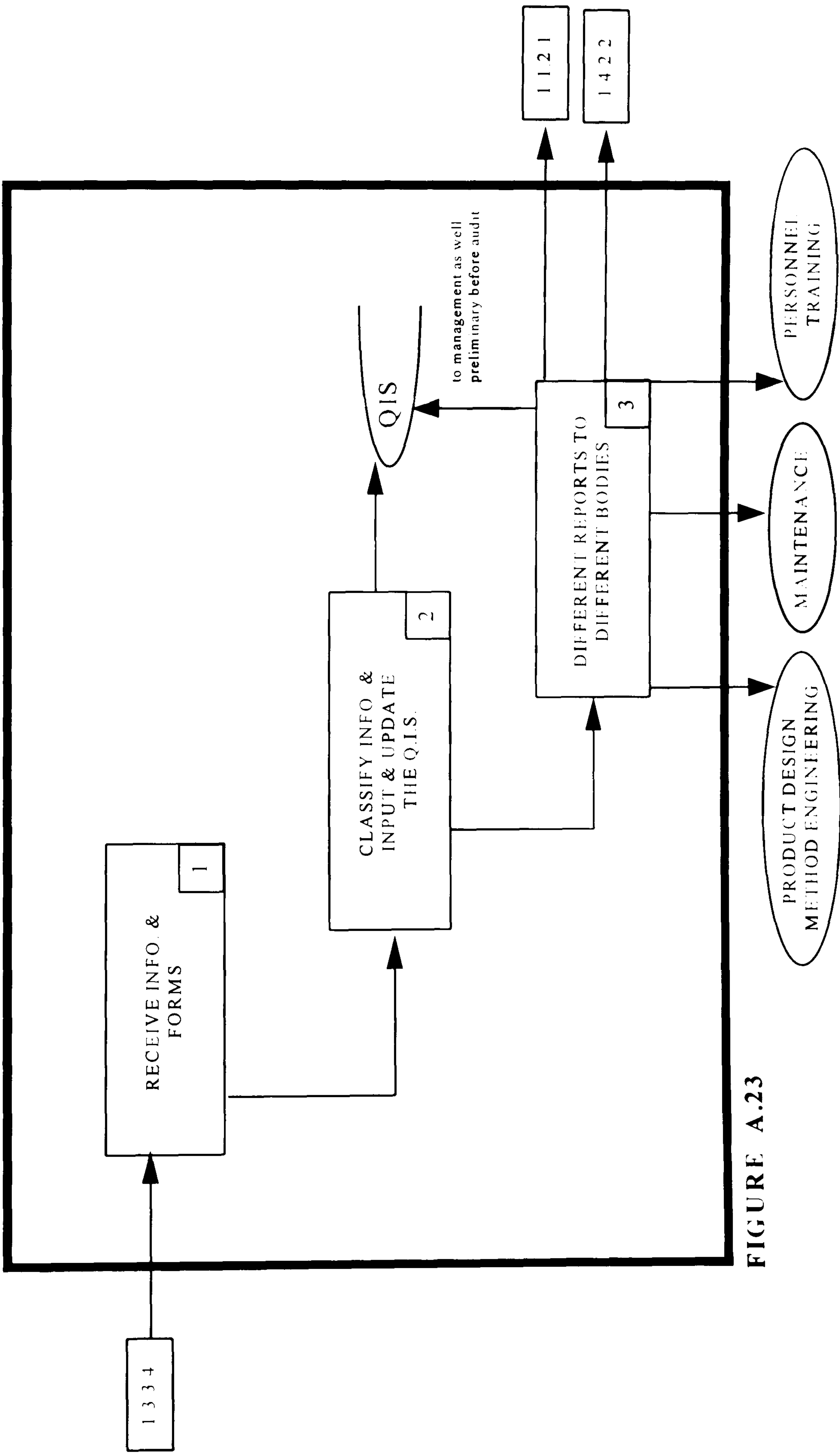


FIGURE A.23

## **FIGURE A.23**

### **1.3.5 REPORTING**

#### **1.3.5.1 RECEIVE INFORMATION AND FORMS**

They receive the final information on the non-conformances or fixation within the corrective action context.

#### **1.3.5.2 CLASSIFY INFORMATION AND UPDATE THE QIS.**

They classify the information and in preparation for different reports. Related information on QIS is updated according to the new results and reports produced.

#### **1.3.5.3 DIFFERENT REPORTS TO DIFFERENT BODIES**

They produce different versions of the report to different bodies. Some reports are key-in QIS to inform the Management Planning in advance. Related forms are sent to Production Design and Method Engineering, Maintenance, and Personnel and Training departments. Related audit report forms are also detailed.

1.4.1 RECEIVE AND UPDATE PROCEDURES & PLANNING REVIEW

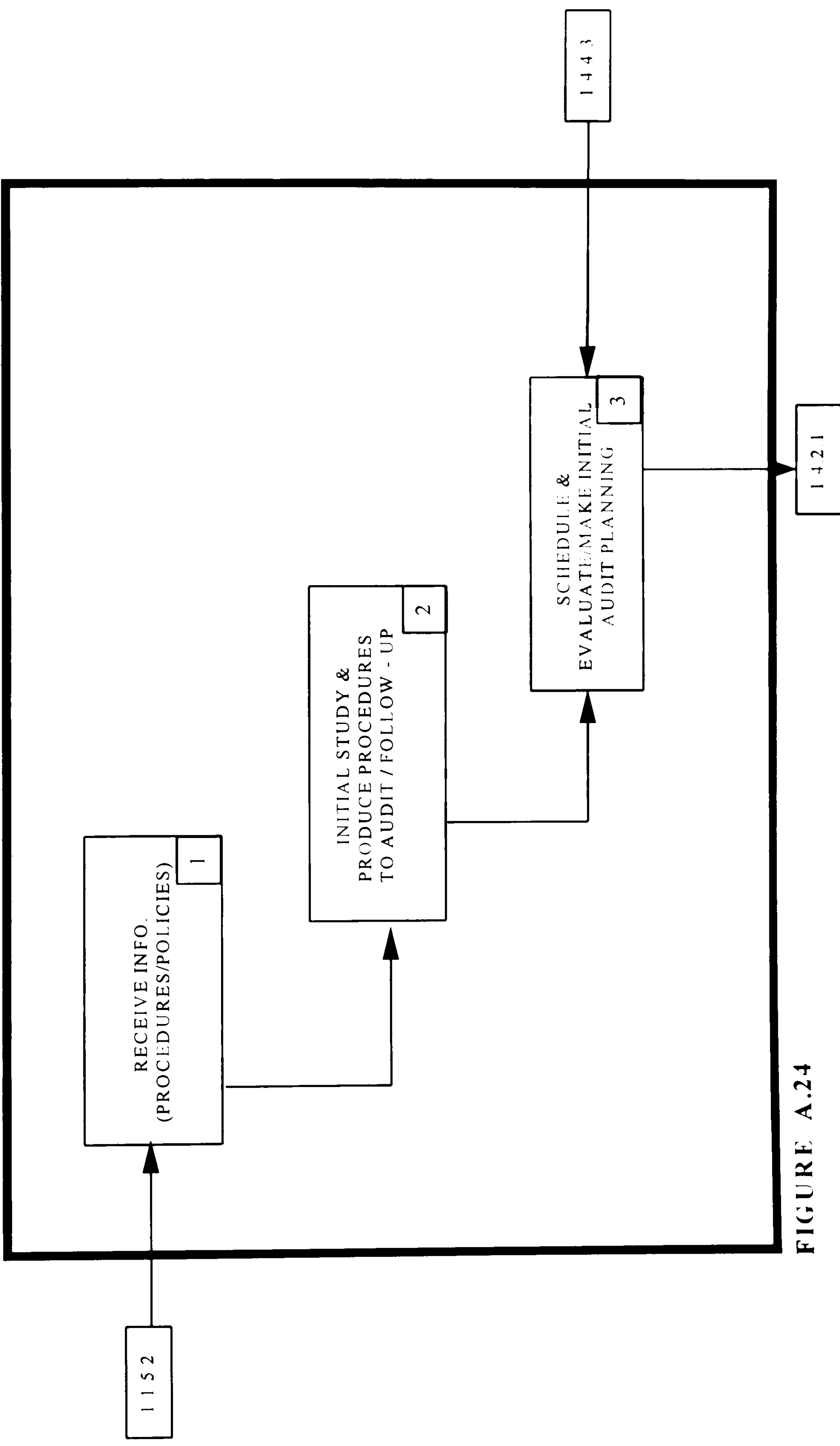


FIGURE A.24

## **FIGURE A.24**

### **1.4.1 RECEIVE AND UPDATE PROCEDURES AND PLANNING REVIEW**

#### **1.4.1.1 RECEIVE INFORMATION**

They receive information about quality policy and all procedures from the Management and Planning.

#### **1.4.1.2 INITIAL STUDY**

An initial study on the procedures is carried out before audits, and an initial audit and follow-up policy is produced.

#### **1.4.1.3 SCHEDULE INITIAL AUDIT PLANNING**

They schedule the audit plans and evaluate the existing plans with respect to the information coming from the Improvement Analysis and Evaluation.

1.4.2 RECEIVING SHOP FLOOR PROCEDURES, REPORTS AND AUDIT PLANNING

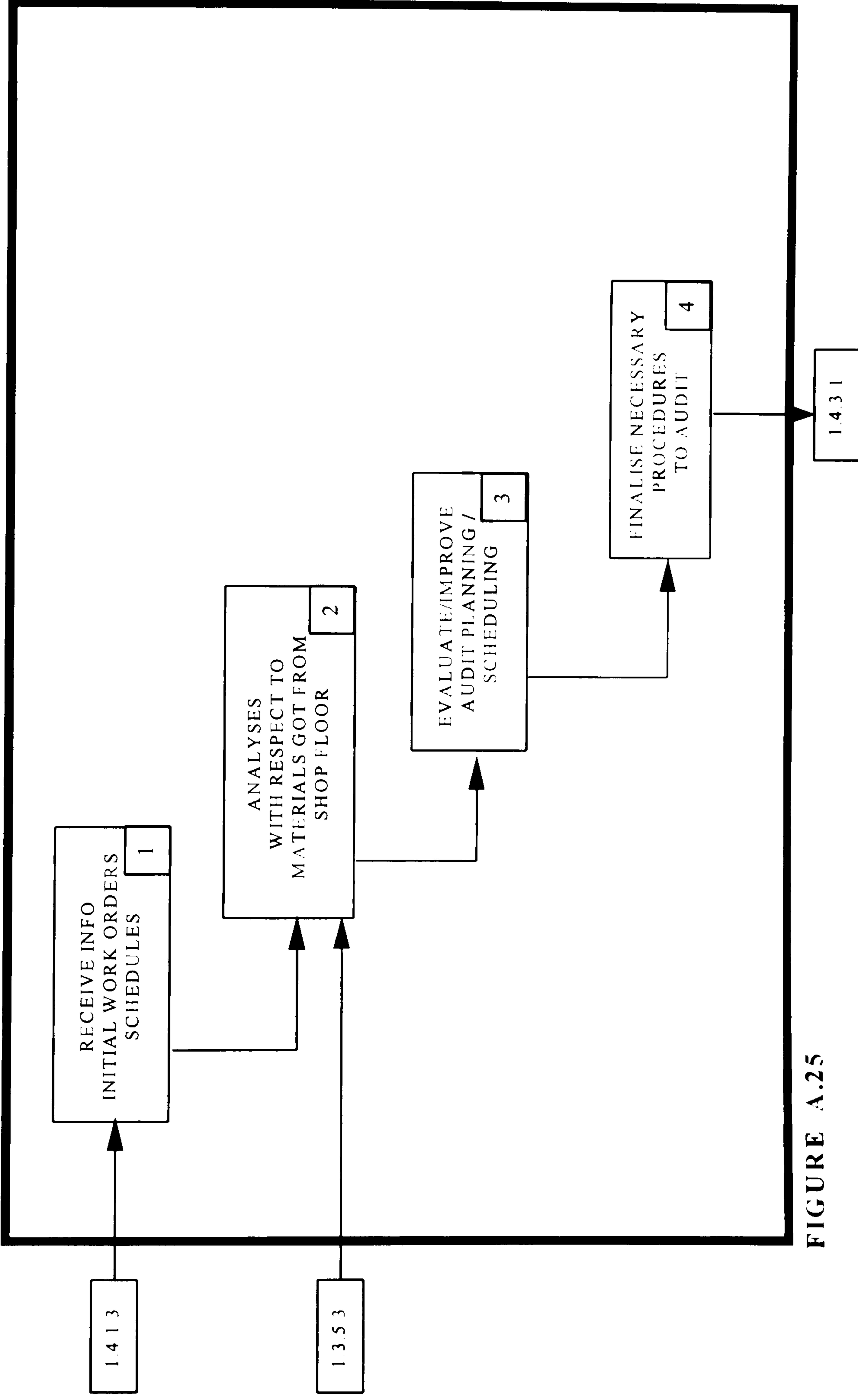


FIGURE A.25

## **FIGURE A.25**

### **1.4.2 RECEIVING SHOP FLOOR PROCEDURES, REPORTS AND AUDIT PLANNING**

#### **1.4.2.1 RECEIVE INFORMATION**

They receive draft audit work orders and schedules from initial audit planning and after receiving them they proceed to the next step.

#### **1.4.2.2 ANALYSES**

With respect to past data, they analyse the information received according to the data and forms for the shop floor operations.

#### **1.4.2.3 EVALUATIONS**

They evaluate the existing audit plans, tasks and schedules, which are then improved upon by the use of these evaluations.

#### **1.4.2.4 FINAL ADJUSTMENTS**

They finalise audit plans and procedures. Audit tasks and work orders are then produced.



### 1.4.3 AUDITING

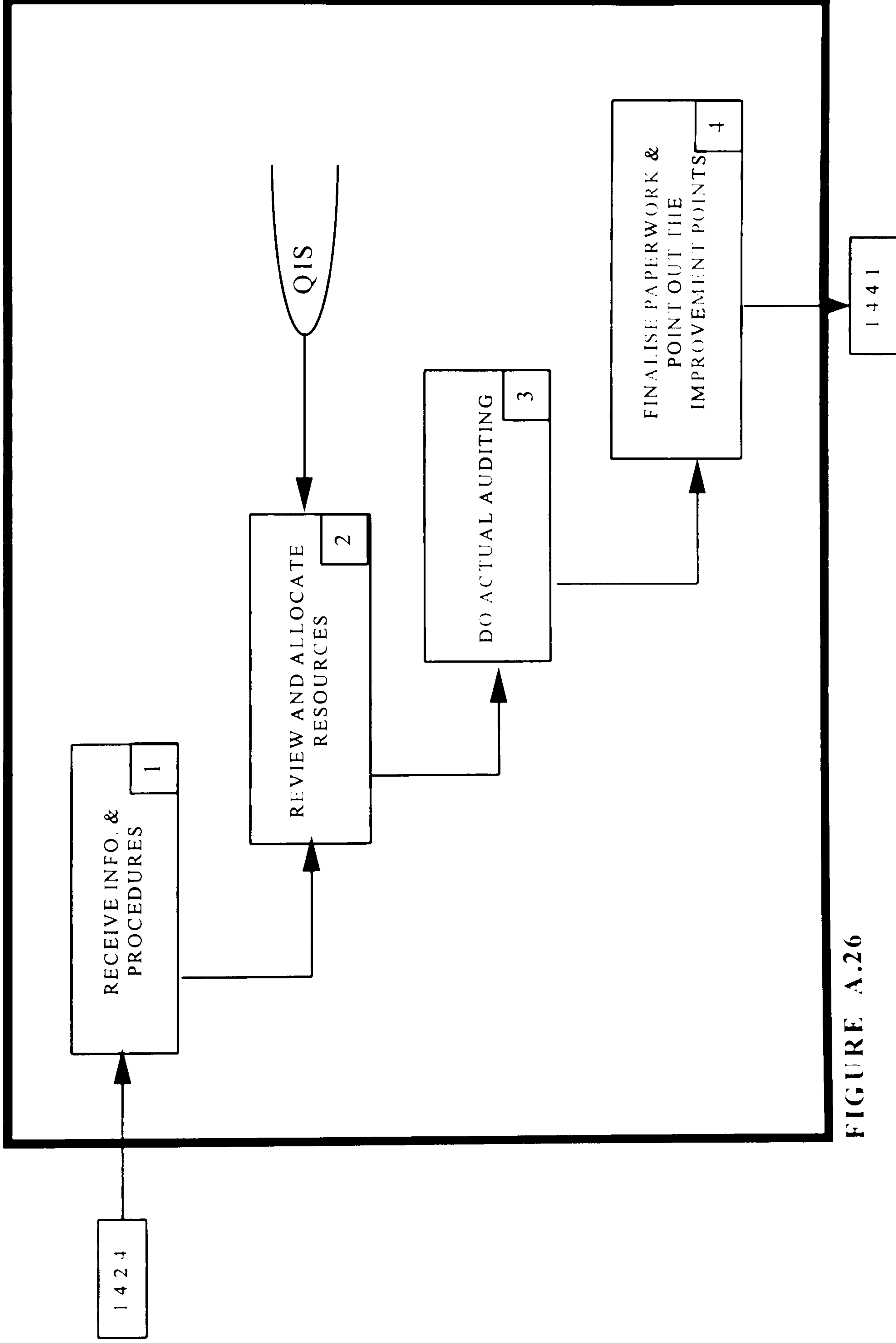


FIGURE A.26

## **FIGURE A.26**

### **1.4.3 AUDITING**

#### **1.4.3.1 RECEIVE INFORMATION**

They receive finalised plans, schedules, audit orders, and procedures. An initial classification is also made.

#### **1.4.3.2 RESOURCE ALLOCATION**

They review procedures and make resource allocation for the actual auditing. This is mainly manpower allocation.

#### **1.4.3.3 ACTUAL AUDITING**

They do actual auditing according to the procedures and plans. This may be carried out in two ways. One is by analysing the reports and task completed forms, and the other is by speaking to those involved.

#### **1.4.3.4 FINALISE AUDITS AND PAPERWORK**

They complete audits, fill in the forms and make initial identification of possible points for improvement.

### 1.4.4 IMPROVEMENT ANALYSIS AND EVALUATION

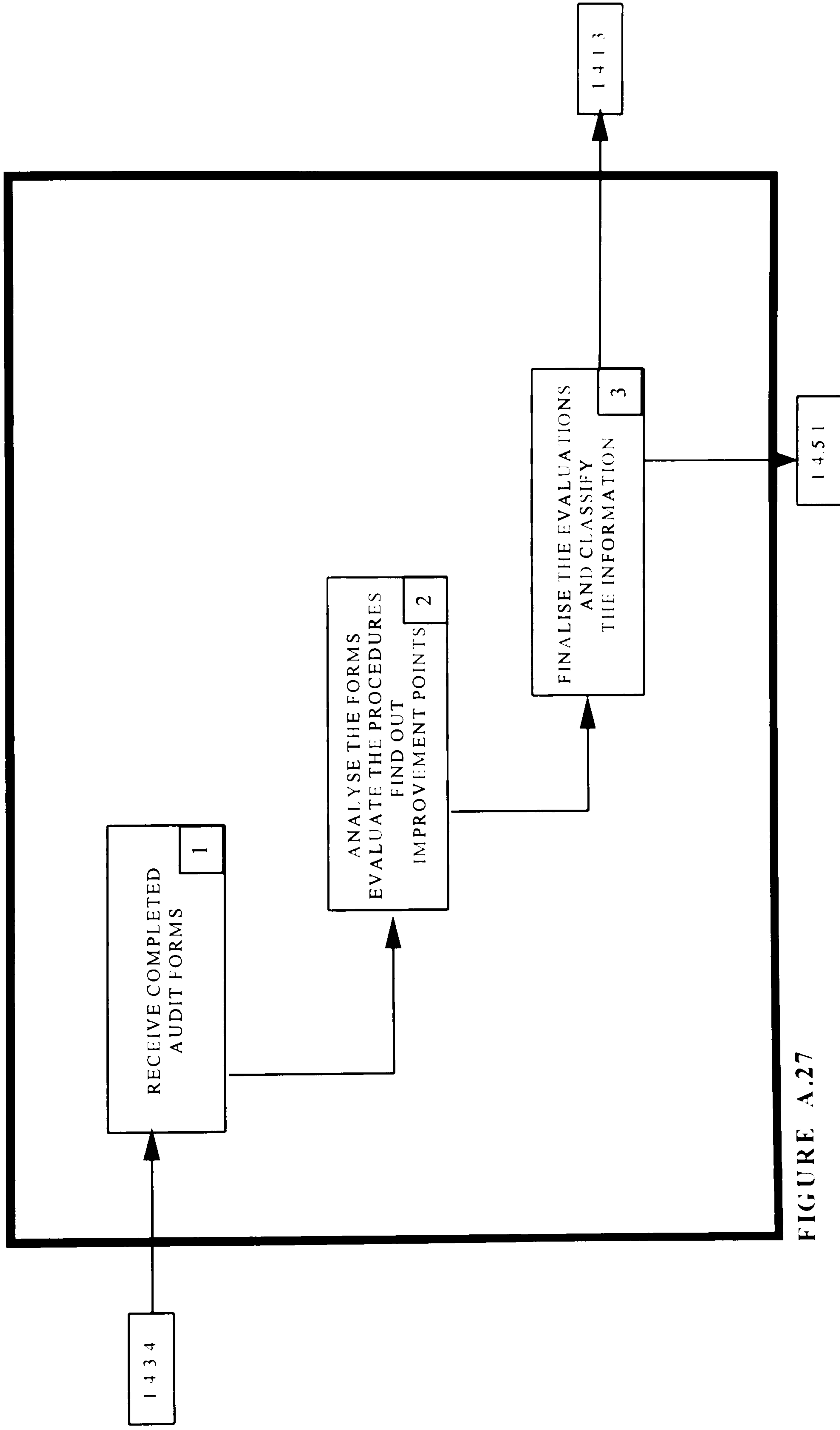


FIGURE A.27

## **FIGURE A.27**

### **1.4.4 IMPROVEMENT ANALYSIS AND EVALUATION**

#### **1.4.4.1 RECEIVE AUDIT FORMS**

They receive completed audit information together with the initial analysis and then review them.

#### **1.4.4.2 EVALUATIONS**

They analyse the information (forms) and evaluate the procedures to find out prevalent and potential improvement points.

#### **1.4.4.3 FINAL PREPARATION**

The evaluation is finalised and the information obtained is classified. The Scheduling and Initial Audit Planning process is informed about the results. Then the information is delivered to Reporting.

# 1.4.5 REPORTING

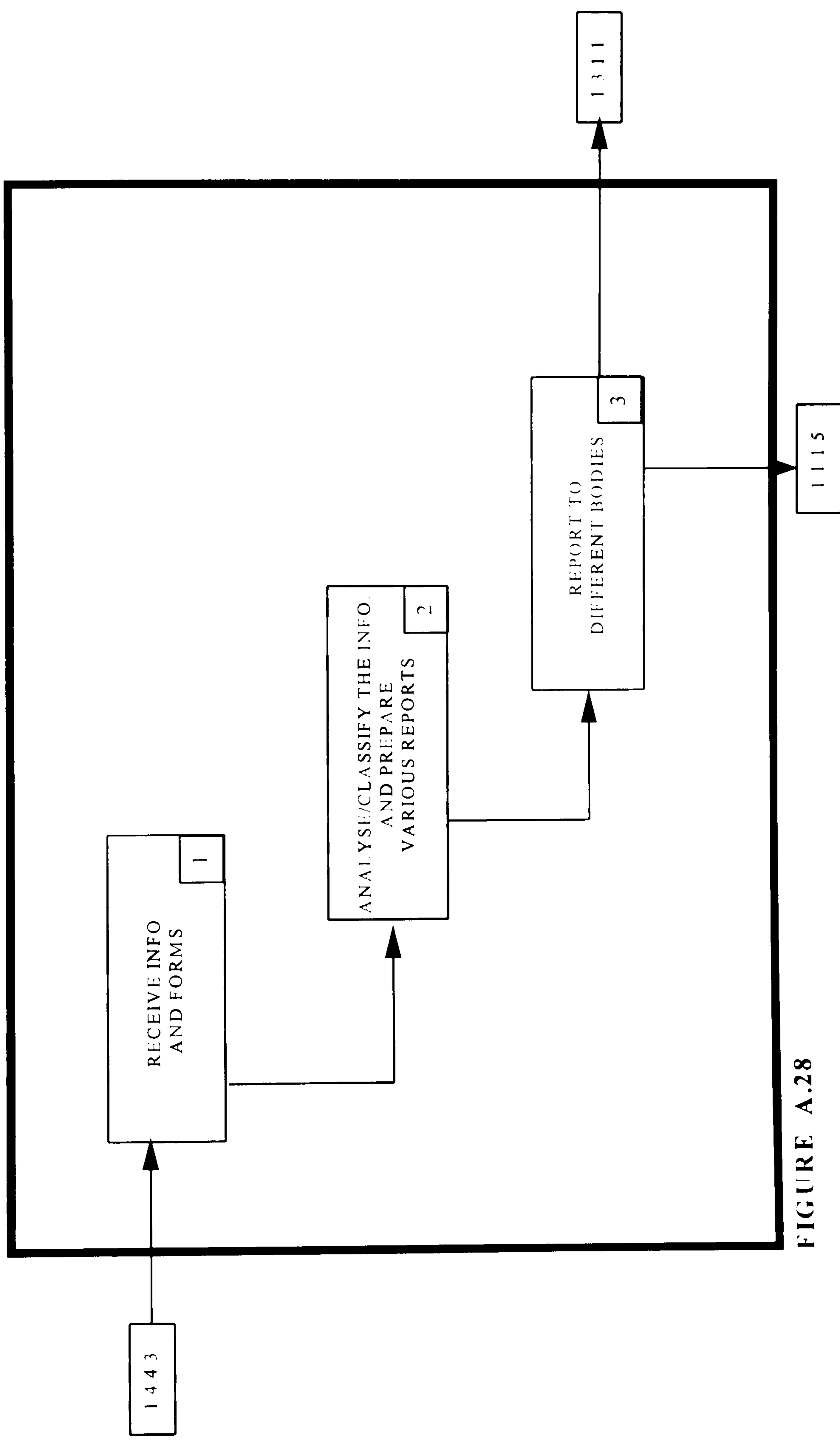


FIGURE A.28

## **FIGURE A.28**

### **1.4.5 REPORTING**

#### **1.4.5.1 RECEIVE INFORMATION**

They receive all audit information and initial findings with the evaluations made. An initial study on the information is made.

#### **1.4.5.2 ANALYSE THE INFORMATION AND PREPARE VARIOUS REPORTS**

They further analyse and disseminate the information in order to prepare different reports for various functions, levels and bodies.

#### **1.4.5.3 REPORTS TO DIFFERENT BODIES**

They prepare different level of reports to different bodies. These reports are sent to the Management and Planning as well as to the shop floor. New sample audit forms are also sent with these reports.

## **APPENDIX B**

### **LOGICAL DATA STRUCTURES AND NOMENCLATURE**

# THE IMPLEMENTATION MODEL FOR A QUALITY MANAGEMENT INFORMATION SCHEME

## (LOGICAL DATA STRUCTURES)

### INTRODUCTION

Structured Systems Analysis and Design Method (SSADM) is used in conjunction with the Manufacturing Systems Analysis and Design (MSAD) method to produce the implementation model. Logical Data Structures are sometimes referred to as entity analysis. It is a well known technique which is an analysis of a system by consideration of the things that are important to it. Logical data structuring is a tool of structured system analysis and design methods to describe what information is to be held by the system. The aims of logical data structuring can be summarised as to;

- capture all the system data,
- organise the data into logical groups, and
- map the relationships between data groups.

Logical data structure diagrams were produced for the integrated quality management information scheme with respect to functional activity diagrams.

There are three basic components of logical data structures:

Entities; This is a significant thing to the system about which information is to be held. Appropriate attributes are then allocated to each entity. An entity can also



be defined as a thing which the enterprise recognises as being capable of an independent existence and which can be uniquely identified.

Data Item: This is the smallest discrete component of the system: information that is meaningful.

Relationships: This is an association between two entities that is important to the system. Relationships are normally described as verbs (controlled, scheduled, have, etc.), and entities as nouns (worker, engineer, machine, report, etc.). Relationships are important because they define access from one entity occurrence to another. Thus a relationship between, for example, an engineer and a worker implies that from an occurrence at an engineer, occurrences of workers who receive instructions from him/her can be found.

The logical data structure diagrams of the integrated quality management scheme are described in terms of these three components. Entities are represented as boxes with the names of entities inside them.

There are various types and degrees of relationships. They can be: One to One, One to Many, Many to One, Many to Many. Optional, Exclusive, Recursive. The many relationship refers to many entities of the same type.

One to Many Relationship: A one to many relationship example between an engineer and a worker is shown in figure B.1. In this example an engineer can be responsible from many workers or many workers can work under the control of one engineer.

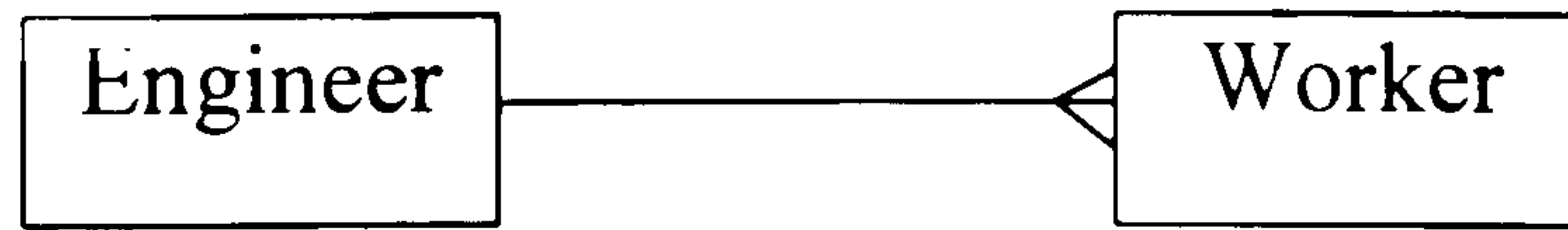


Figure B.1 One to many relationship

Many to Many Relationship: An example between a worker and a procedure is shown in figure B.2. This shows that many workers can work with "many" procedures and vice-versa.

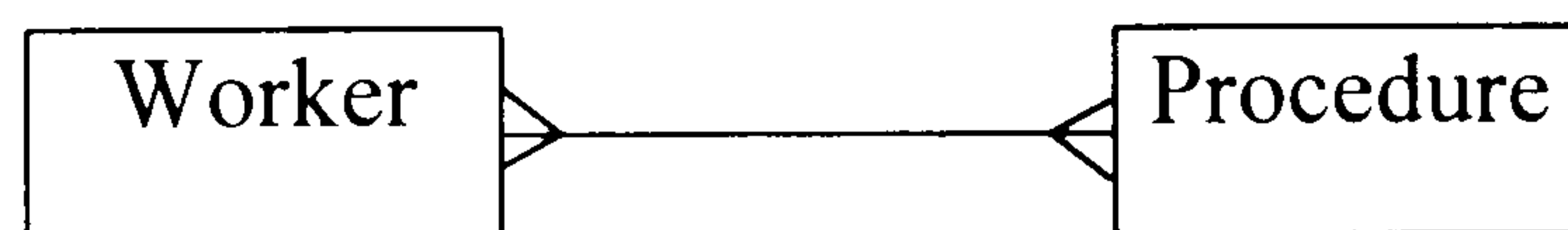


Figure B.2 Many to many relationship

Optional Relationship: The optional relationship is represented by a circle on the crow's leg (figure B.3). This relationship indicates that an occurrence of the detail can exist without its corresponding master. In other words, for the manager, using the database is optional.

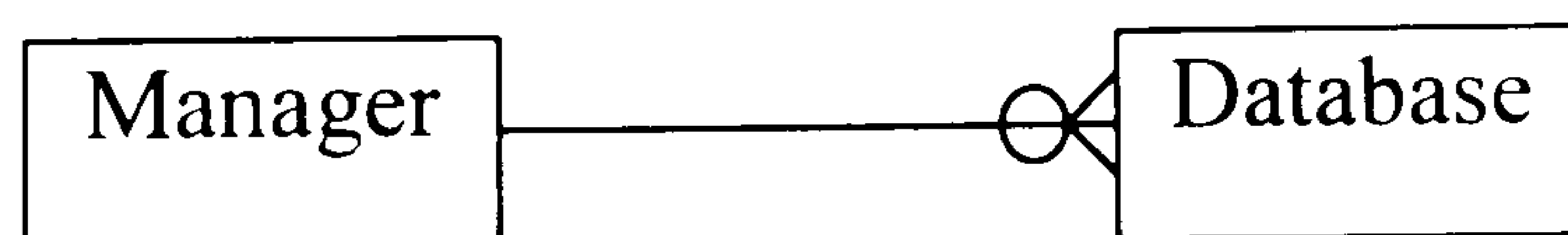


Figure B.3 Optional one to many relationship

Exclusive Relationship: An exclusive relationship occurs when the existence of one relationship precludes the existence of another. As is shown in figure B.4, a worker can be using the tool or can be receiving instructions from the engineer but not both at the same time.

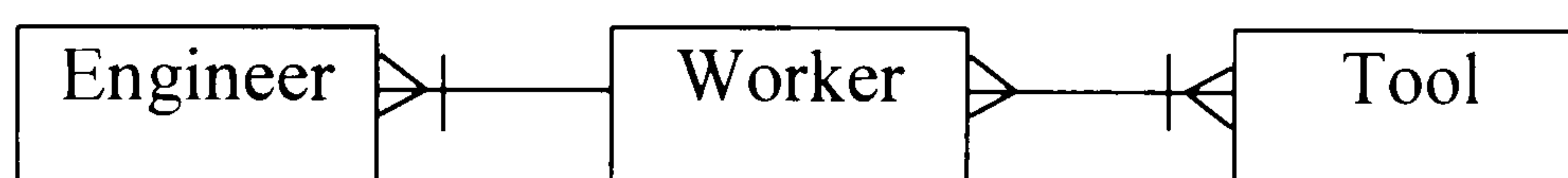


Figure B.4 Exclusive Worker-Engineer-Tool relationship

Recursive Relationship: An entity occurrences have direct relationships with other entity occurrences of the same type. This sort of relationships are named recursive relationship. In figure B.5, a schedule entity having a recursive relationship is given.

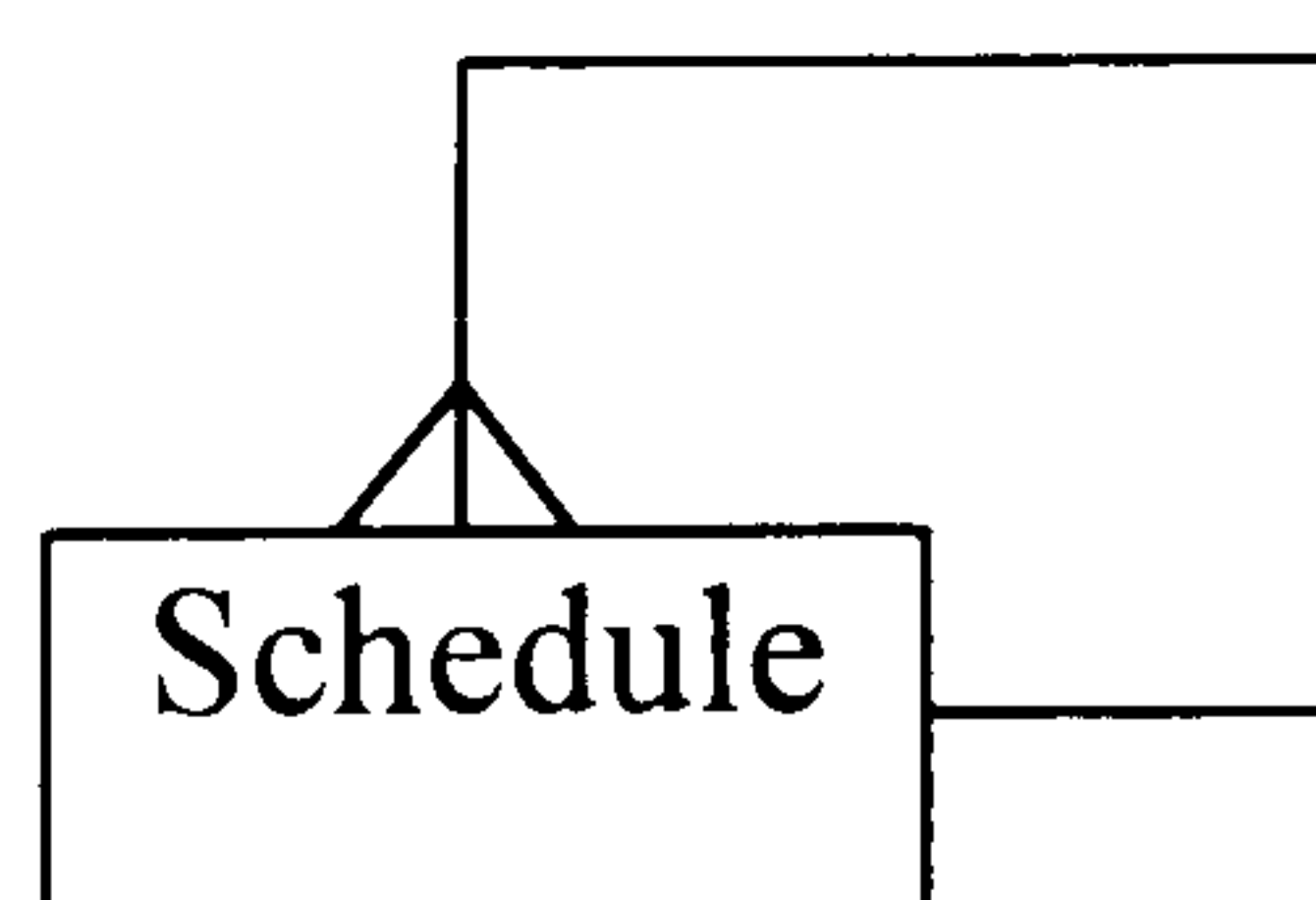


Figure B.5 Recursive relationship

## LOGICAL DATA STRUCTURES OF THE INTEGRATED QUALITY MANAGEMENT INFORMATION SCHEME

As mentioned previously, in the IQMIS there are four internal functional areas. Entities and their relationships are following.

### QUALITY MANAGEMENT (DATA ANALYSIS) FUNCTION

In the quality management (data analysis) functional area there are twenty entities. These are; Quality Policy, Quality Information Store (QIS), Production Schedule, Sales and Marketing Information, Supplier Information, Financial Information, Customer Information, Audit Reports, Quality Reports, Engineer and Data and Cost (D/C) Analyst (i.e. Technical Analyst), Work Scheduler (Structures), Product Design, Personnel Department, Maintenance Department, Management Reports, Tools' Information, Training (Procedures and Requirements) Programmes, Work Structures, Work Orders, and Quality Manager. The entity relationship diagram is shown in figure B.6.

**Entity Quality Manager** has direct authority from the top/senior management to implement the quality policy they produce. Quality and management reports along with information from the maintenance and personnel departments, are received together with training programmes. Training programmes are also ordered to be set up. The manager has many engineers and D/C analysts (i.e. Technical Analyst), and has access to the common quality information store.

**Entity Quality Policy** is issued by the top/senior management and is sent to quality management.

**Entity Maintenance Department** informs the quality manager and work schedulers (structures) about many of their activities. Information is also included in management reports.

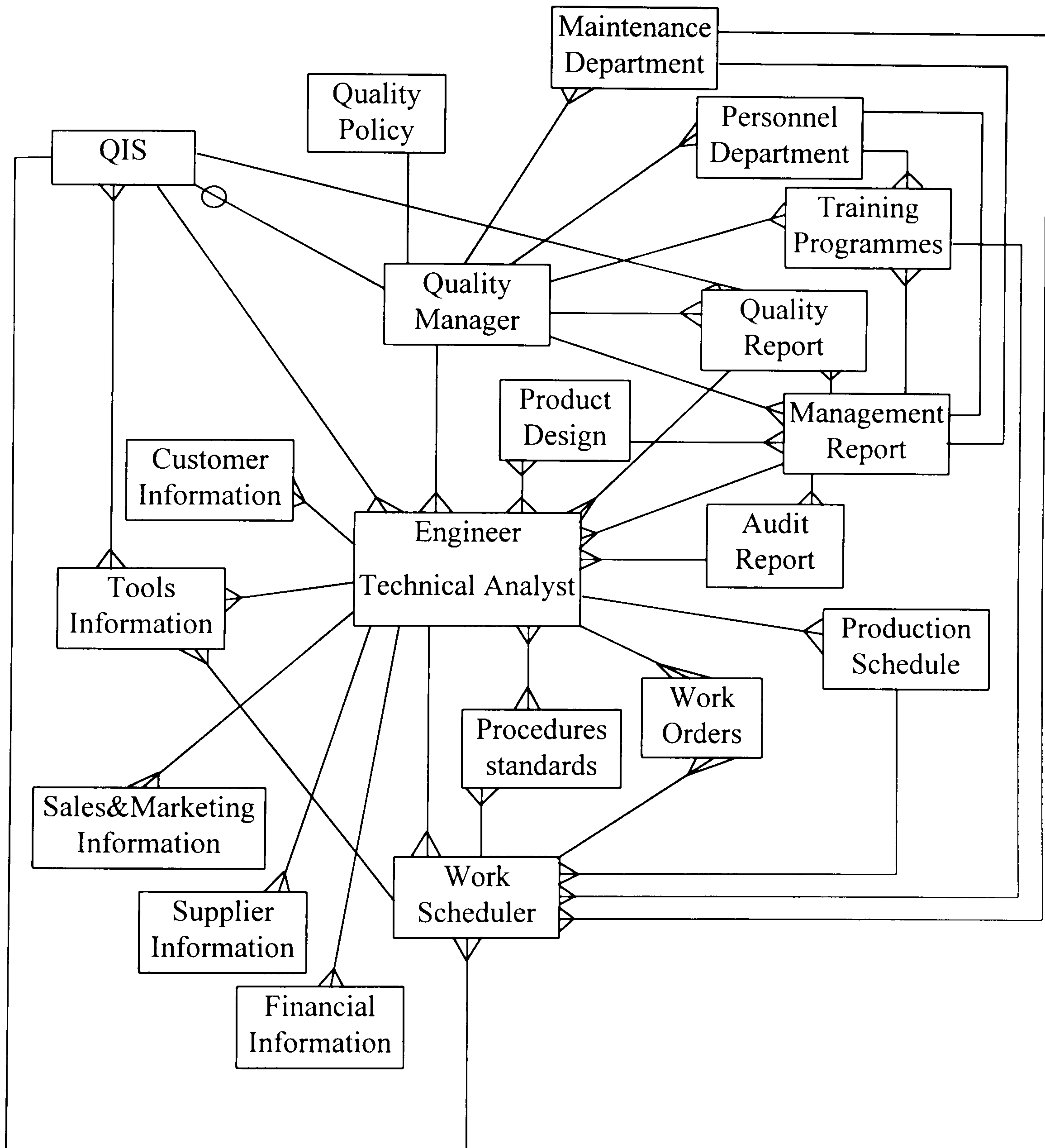


Figure B.6 Entity relationship for Quality Management (Data Analysis)

**Entity Personnel Department** is responsible to the setting up of many training programmes. It receives related management reports for details. They also receive many orders from the quality manager.

**Entity Training Programme** goes to many work schedulers. Training programmes are produced by personnel department, and are included in the management report as well as sent to the quality manager.

**Entity Quality Report** goes to many engineers and D/C (i.e. Technical) analysts. These are mentioned in the management reports. All quality reports are in the common quality database and are also received by the quality manager.

**Entity Management Report** contains information from the personnel, maintenance departments and training programmes. It also contains quality reports and audit reports. It is made up by engineers and data/cost analysts. Many management reports go to the quality manager.

**Entity Product Design** receives many related partial management reports, and receives many advice on various products.

**Entity Audit Report** goes to many engineers and D/C analysts and audit reports are placed within a management report.

**Entity Engineer and Data/Cost (D/C) Analyst (i.e. Technical Analyst)** issue many work orders. They receive many production schedules. Many of them receive an audit report, a management report as well as a quality report. Works of many engineers and D/C analysts result in various suggestions on various products. All engineers and D/C analysts receive orders from the quality

manager. All engineers and D/C analysts have access to the common data store . They receive information from various customer groups and have all the necessary information about the tools. They also have all necessary information about the sales and marketing, and the suppliers and finance. An engineer or a D/C analyst is in contact with many work schedulers. They also set up many procedures and have access to many standards.

**Entity Quality Information Store (QIS)** includes all quality reports. It answers inquiries of work schedulers. It also contains different types of tools' information in different directories. It answers all inquiries of engineers and D/C analysts and is also ready to answer any question raised by the quality manager.

**Entity Production Schedule** goes to many work schedulers. Many production schedules are either issued or received by engineers and D/C analysts.

**Entity Work Orders** are issued by the engineer or D/C analyst, and many of them also go to work schedulers.

Many **Entity Procedures (Standards)** are either produced by engineers and D/C analysts or received by them. They also go to a work scheduler.

**Entity Work Scheduler (Structures)** has access to many work orders and procedures and/or standards. All work schedulers receive a production schedule. They also receive necessary information from the maintenance and the training departments. All work schedulers have access to the common quality information store. A work scheduler has different types of tool information.

**Entities of Customer Information** from various customer groups goes to an engineer or a technical analyst.

**Entity Tools Information** goes to an engineer or a technical analyst. Information of many types of tools are stored in different directories of the common quality information store. Many sets of information tools go to a work scheduler.

**Entity Sales and Marketing Information** from various sales and markets goes to an engineer or a D/C analyst.

**Entity Suppliers Information** from various supplier groups goes to an engineer or a D/C analyst.

**Entity Financial Information** in different forms goes to an engineer or a D/C (i.e. Technical) analyst.



## SHOP FLOOR OPERATIONS FUNCTION

There are ten entities in shop floor operations. These are Plan/Schedule. Quality Information Store (QIS), Standards and Customer Requirements (CR). Tool, Worker, Engineer/Foreman, Quality Report, Work Procedures (Task Description), Work Orders, Discrepancy/Disposition (D/D). The entity relationship diagram is shown in figure B.7.

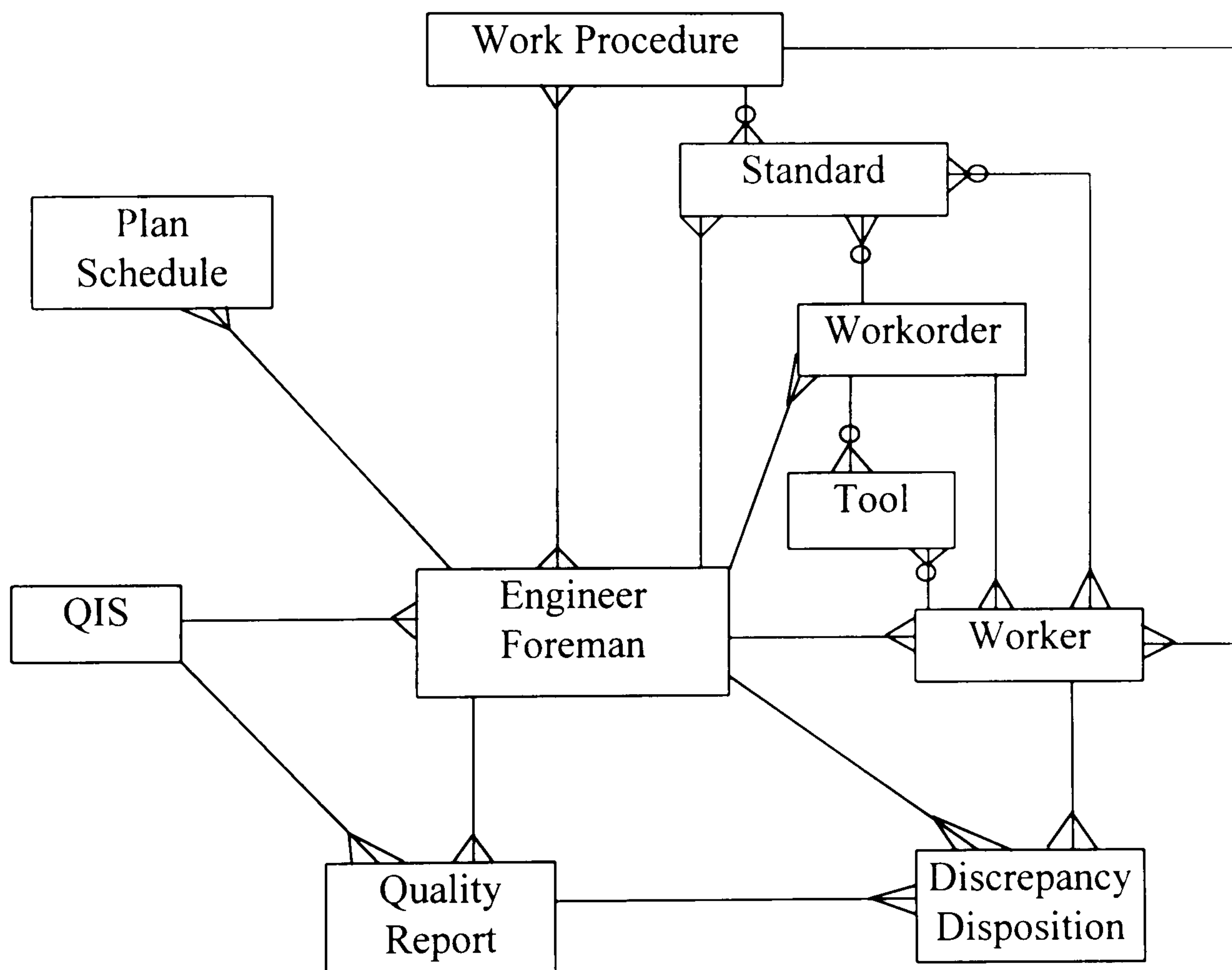


Figure B.7 Entity relationship for Shop Floor Operations

**Entity Worker** can find many discrepancy/disposition (D/D) in his/her quality control operations. All workers have their own work procedures. They also have optional standards of the products concerned. Workers receive work order. They use optional tools whilst performing their jobs. Workers are directed or instructed by an engineer or a foreman.

Many **Entity Tools** may optionally be used by a worker or they may be put on work orders to be used optionally.

**Entity Work Orders** goes to workers or different groups of workers. Work orders may specify tools to be used. Many work orders are issued by the engineer or foreman. A work order can also include some standards.

**Entity Standards** are followed-up by the engineer or foreman. Many optional standards may be in the work procedures and work orders. They may also be directly in workers' hands.

**Entity work procedure** goes to workers. Many work procedures can be produced by various engineers and foremen. A work procedure may optionally include some standards as well.

Many **Entity discrepancy/disposition (D/D)** are written by the engineer/foreman. These are discovered by a worker. Some of the D/D constitute a quality report.

**Entity Quality Report** consists of many similar D/Ds. Many quality reports are written by the engineer or a foreman and they are all stored in the common QIS.

**Entity Quality Information Store (QIS)** is accessible to engineers and foremen for any inquiries about any quality report.

Many **Entity Plan/Schedule** go to an engineer or to a foreman.

**Entity Engineer/Foreman** instructs or directs many workers. Engineer/foreman issues many work orders and supplies many standards. Engineers supply the work procedures. An engineer or a foreman receives plans and schedules, deals with many D/D and quality reports. All engineers and foremen have access to the common QIS.

## CORRECTIVE ACTIONS FUNCTION

In corrective actions there are ten entities. These are Quality Information Store (QIS), Plan/Schedule, Tool, Audit Report, Quality Report, Corrective Action (C/A) Report, Worker, Engineer/Foreman, Material Review Board (MRB), Discrepancy/Disposition (D/D). The entity relationship diagram is shown in figure B.8.

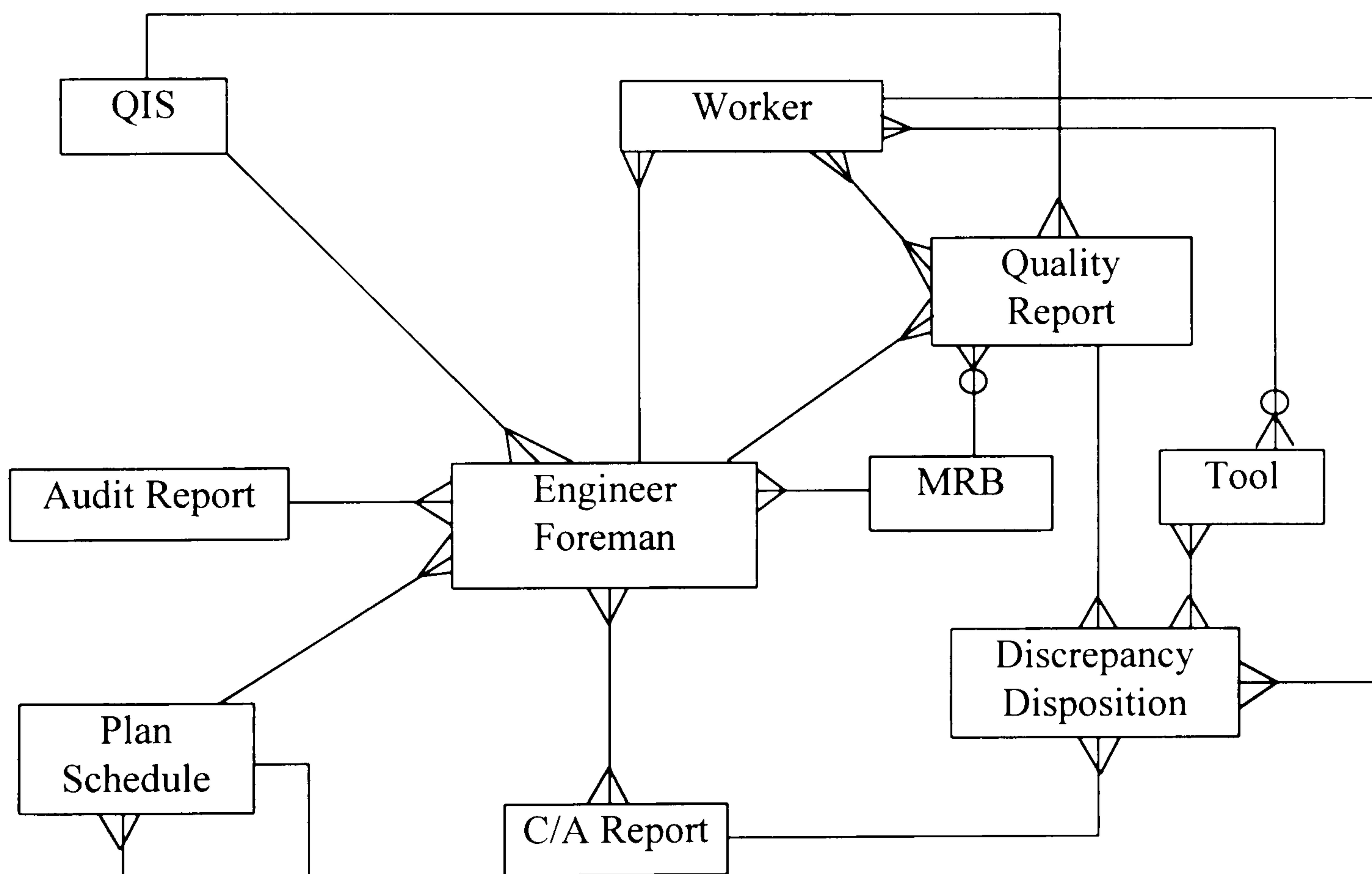


Figure B.8 Entity relationship for Corrective Actions

**Entity Worker** can work on many D/D. Workers or groups of workers can have many quality reports to work on. Whilst doing the job, workers may optionally use many tools. Many workers have orders or instructions from an engineer or a foreman.

**Entity Quality Report** is written for various D/D. Quality reports may go to MRB to be analysed by experts. Many quality reports are followed-up by an

engineer or a foreman and can be worked by workers or different groups of workers. All quality reports are stored in the common QIS.

Many **Entity Discrepancy/Disposition** can be written by an engineer and can be placed in a quality report or a Corrective Action (C/A) report. Each worker can deal with many D/Ds, and many D/Ds require different types of tools.

**Entity Material Review Board (MRB)** consists of engineers and foremen. They can optionally have quality reports to study.

Sets of **Entity Tool** can be used for many D/D. These different types of tools may optionally be used by different workers.

**Entity Corrective Action (C/A) Report** consists of many D/D and a number of these reports can go to different engineers and foremen.

**Entity Quality Information Store (QIS)** contains quality reports and are open to engineers and foremen for any inquiries.

**Entity Audit Report** goes to many engineers and foremen.

**Entity Plan/Schedule** also goes to many engineers and foremen. A plan/schedule can be re-performed or modified according to corrective actions.

**Entity Engineer/Foreman** give instructions to many workers and follow-up many quality reports. Many engineers and foremen can take a place in MRB. An engineer or a foreman can study many D/Ds. Engineers and foremen deal with many C/A reports and have access to the common QIS.

## AUDITING FUNCTION

In the auditing operations there are six entities. These are Work Procedures, Plans/Schedule (including audit plans and work plans), Auditors, Reports (audit reports), Forms (audit forms), Workers/Operators. The entity relationship diagram is shown in figure B.9.

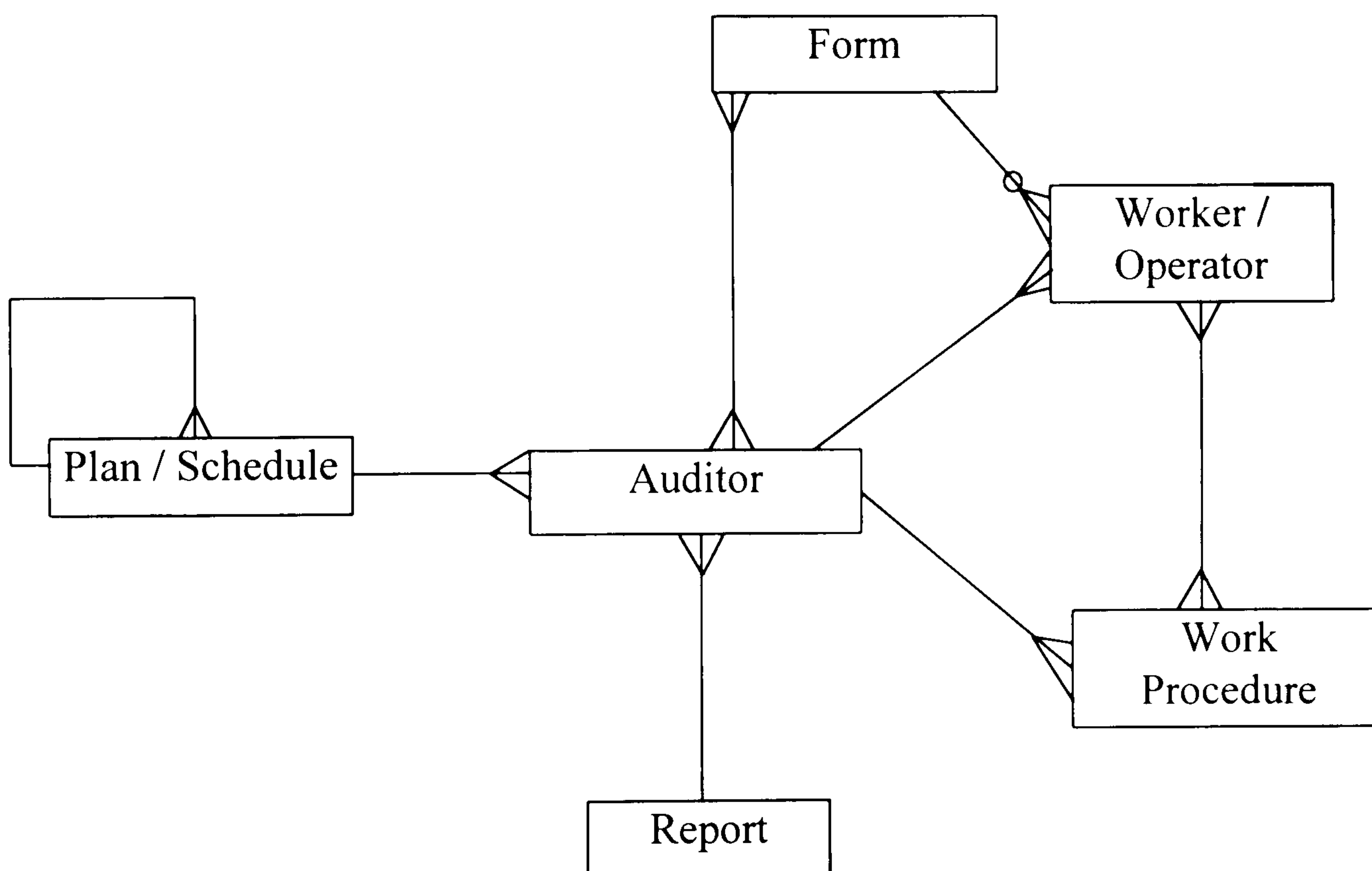


Figure B.9 Entity relationship for Auditing activities

**Entity Worker/Operator** or each group of worker/operator has an audit form to fill in. Many workers are audited by the same auditor and workers have the responsibility to follow different work procedures.

**Entity Form** may optionally include many workers/operators. The form is produced by many auditors.

**Entity Plan/Schedule** goes to many auditors. A plan/schedule can also produce many plans and schedules within itself.

Many **Entity Work Procedures** go to a number of auditors and to different workers in order to allow them to form audit plans and procedures.

**Entity Auditor** can audit many workers with many work procedures in hand. Auditors can have numerous forms and similar plan and schedule. An audit report can include many audit results.

**APPENDIX C**

**LIST OF COMPANIES AND EXPERTS VISITED**



PART A : EARLIER MEETINGS

Professor J. H. Rogerson  
School of Industrial and Manufacturing Science  
Cranfield University

Mr. A. Bytheway  
School of Management  
Cranfield University

Mr. O. Irfanoglu  
Method Engineer  
Turkish Aerospace Industries, Ankara  
( A co-production of Lockheed for F16 fighter planes.)

Mr. M. Ozdemir  
Civil Engineer  
ERG Group of Companies, Ankara  
( A world-wide group in engineering, construction works, industrial complexes,  
manufacturing of heavy construction equipment and manufacturing of the same.)

Mr. S. Yamac  
Project Manager  
Defence Industries Undersecretariat, Ankara  
( A governmental body for co-ordinating defence industry investments.)

Bac Centre  
Building 42a, Cranfield University, MK43 OAL

PART B : LATER MEETINGS

Professor T. Bryant  
Faculty of Information and Engineering Systems  
Leeds Metropolitan University

Mr. J. F. Grogan  
Faculty of Information and Engineering Systems  
Leeds Metropolitan University

Professor J. H. Rogerson  
School of Industrial and Manufacturing Science  
Cranfield University

Mr. T. Warner  
Product Team Manager  
Ford Motor Company, Enfield.

Mr. R. Elenor  
Program Mgt - JIT/DE  
Rover Group, Longbridge, Birmingham.

Mr. N. Ball  
Quality Network Manager  
Production Systems  
Vauxhall Motor Company, Luton.

Dr. A. Kurimoto

Principal Engineer

Mazak Machine Tools

Yamazaki Machinery UK Ltd.

Mr. O. Irfanoglu

Method Engineer

Turkish Aerospace Industries, Ankara

( A co-production of Lockheed for F16 fighter planes.)

Mr. C. C. Ipek

Senior Systems Analyst

Microwave Electronic Systems Inc., Ankara

(A joint venture producing aircraft electronic systems)

Mr. N. Marriott

Quality Assurance Engineer

Avdel Systems Ltd., Hertfordshire

(Avdel specialises in the design, manufacture, and marketing of engineered fastening and assembly systems world-wide, supplying to all engineering sectors including Aerospace, Automotive, Commercial Vehicles, Electronics and Domestic Appliances.)

Mr. G. W. R. Lyne

Quality Assurance Manager

H C Bridgman and Co. Ltd.

(Bridgman supply doors and doorsets to major users in the UK and overseas including D.O.E., D.O.D., Nuclear Electric, C.E.G.B., leading Local Authorities and many National and International Contractors.)

Mr. S. Yamac

Project Manager

Defence Industries Undersecretariat, Ankara

( A governmental body for co-ordinating defence industry investments.)

**APPENDIX D**

**QUESTIONNAIRE OF THE QUALITY MANAGEMENT SYSTEMS  
SURVEY 1995**

## QUALITY MANAGEMENT SYSTEMS SURVEY 1995

Dear Fellow MGA Member,

20 January 1995

I am researching a new implementation model of Total Quality Management (TQM). As part of this research, a survey has been prepared to find out basic understanding and approaches to a successful TQM implementation in various industries.

I would be grateful if you can find a few minutes to complete this survey and to return it by **20 February 1995** to: (A freepost envelope is enclosed)

M. GUNDOGAN  
SIMS, BUILDING 30  
FREEPOST  
CRANFIELD UNIVERSITY, CRANFIELD  
BEDFORD, MK43 7BR

The survey has the following objectives:

- to identify organisations that have specific quality policies or interests.
- to determine which factors lead to a successful quality management implementation,
- to seek your opinion on future trends in quality management systems in various industries,
- to establish a link for a face to face interview on a newly developed strategy to implement TQM.

I will send all participants an executive summary of the results of the survey. To those UK participants who are willing to have a face to face interview of around one hour, there will be much more information available. Please make sure that you tick appropriate box at the end of the survey. These interviews will take place wherever convenient for yourself.

Thank you very much for your support.

Yours sincerely

Mete Gundogan  
MSE 1989/90

# QUALITY MANAGEMENT SYSTEMS SURVEY 1995

## 1- COMPANY INFORMATION

RESPONDENT'S NAME \_\_\_\_\_ POSITION \_\_\_\_\_

COMPANY NAME \_\_\_\_\_

OPERATING UNIT \_\_\_\_\_

LOCATION \_\_\_\_\_

MAJOR PRODUCTS/SERVICES \_\_\_\_\_

### TURNOVER BAND

PLEASE TICK	
£ 0 - 5 million	
£ 5 - 25 million	
£ 25 - 100 million	
£ 100 - 250 million	
£ 250 + million	

*For all the remaining questions please tick all of those that apply to you or your company.*

Do you or will you have a planned or structured quality policy?

Yes	No
-----	----

If YES, did these or will these policies result from	PLEASE TICK	
	YES	NO
An internally determined need for improvement		
The need to keep pace with competitors		
Pressure from customers		
The need for departmental integration		
Others (please specify):		

Please rate how successful you feel your overall Quality Management strategy is in terms of :

	Low	Middle	High	Negligible
Profit				
Growth				
Integration				
Easy of application				
Implementation				
Communication				
Reporting				
Customer Satisfaction				

## 2- IMPLEMENTATION

In a new Total Quality Management implementation strategy, which of the following statements describe your company's experience (or what you expect will happen):

	EXPERIENCE	EXPECTATION
Required total change		
Needed external assistance to manage change		
Involved major time commitment		
Involved major financial commitment		
Involved top management commitment		
Required personnel re-training		
Required change in the organisation structure		
Required change in the work patterns		
Required change in data		
Required good communication		
Involved entire workforce		
Involved management only		
Complex and sophisticated		
Easier than anticipated		
Quicker than anticipated		
Harder than anticipated		
Took longer than anticipated		
Has made a major beneficial change to the organisation		
Has made little change to the organisation		



3- INTEGRATION

Which of the following functions are integrated, or you think should be integrated, with quality?

	CURRENTLY		FUTURE	
	YES	NO	YES	NO
Production				
Sales & Marketing				
Supplier Information				
Finance				
Product Design and Engineering				
Maintenance				
Personnel Training				

4- DATA

Which of the following sentences applies to your company;

Required quality data are gathered on the shop floor	
The data is then processed in the supervision / mid-management	
The results affect top management and quality policies	
Data collection is incomplete	
Data processing is unsatisfactory	

5- CONTINUOUS IMPROVEMENT

On this site do you have a continuous improvement scheme?

YES	NO
-----	----

If YES, how is your continuous improvement scheme implemented	PLEASE TICK
Using SPC tools	
Zero defects (6 sigma) philosophy	
Benchmarking	
Regular meeting	
Communication	
Quality improvement projects	
Others (please specify):	

6- TRAINING AND HUMAN RESOURCES

Do any of the following factors have a negative effect on quality?

	YES	NO
Overlapping responsibilities		
Being accountable but not actionable for work produced		
Span of control too small		
Span of control too large		
Open leadership style		
Lack of education and training		
Lack of performance feedback		
Lack of work motivation		

7- CUSTOMER SATISFACTION

Do you measure customer satisfaction through;

	YES	NO
Use of a scientific survey method		
Monitoring customer complaints		
Analysing product returns/warranties		
Analysing customer queries		
Asking customers to complete an installation record or service card		
Comparing your products against the competition		
Doing post pack audits		

8- FACE TO FACE INTERVIEW

Would you like to have a meeting to discuss a new implementation strategy ?

YES	NO
-----	----

Tel No: \_\_\_\_\_

*Thank you for taking time to complete the survey.  
comments you wish to make.*

*Please attach any additional*

## QUALITY MANAGEMENT SYSTEMS SURVEY 1995

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Yours sincerely

Mete Gundogan  
MSE 1989/90

## 6- TRAINING AND HUMAN RESOURCES

Do any of the following factors have a negative effect on quality?

	YES	NO
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Being accountable but not actionable for work produced		
Span of control too small		
Span of control too large		
Open leadership style		
Lack of education and training		
Lack of performance feedback		
Lack of work motivation		

## 7- CUSTOMER SATISFACTION

Do you measure customer satisfaction through;

	YES	NO
Use of a scientific survey method		
Monitoring customer complaints		
Analysing product returns/warranties		
Analysing customer queries		
Asking customers to complete an installation record or service card		
Comparing your products against the competition		
Doing post pack audits		

*Thank you for taking time to complete the survey. Please attach any additional comments you wish to make.*

## **APPENDIX E**

### **AN EXAMPLE OF THE SCHEME WITHIN A GROUP TECHNOLOGY CELL**

This is a simplified example to show how the scheme would be established within a group technology cell. Figure A.4 in Appendix A shows the entire scheme with its integration points / flows to outside functional areas. Activity boxes within the shaded area show in-group operations. They are respectively Shop Floor Operations and Corrective Actions.

In this example, let us assume an inspection work order of checking diameters of holes on a specific part at a specific drilling machine, is issued by the Quality Management (see figure A.5 in Appendix A) and is sent to a group. This could be sent via a computer link (on-line) or on a piece of paper explaining the work to be performed. In this kind of work orders, in order to identify the work, there should be sufficient information such as group number, part number, machine number, operation number, procedures, etc. Within the scheme, figure E.1 shows a modified information flow for such a specific work order in a group.

The initialisation box of the Shop Floor Operations in Figure E.1 covers the following activities;

1.2.1 Planning Review and Resource Allocation (see figure A.14 in Appendix A) and

1.2.2 Customer Requirements (in this example internal customers) and Standards (see figure A.15 in Appendix A).

In this example, when the group receives the work order of checking diameters of holes, an initial review is undertaken to compare it with other tasks. A practical schedule within the group is made and the necessary resources such as time, manpower, procedures, standards, testing equipment, etc. are allocated.

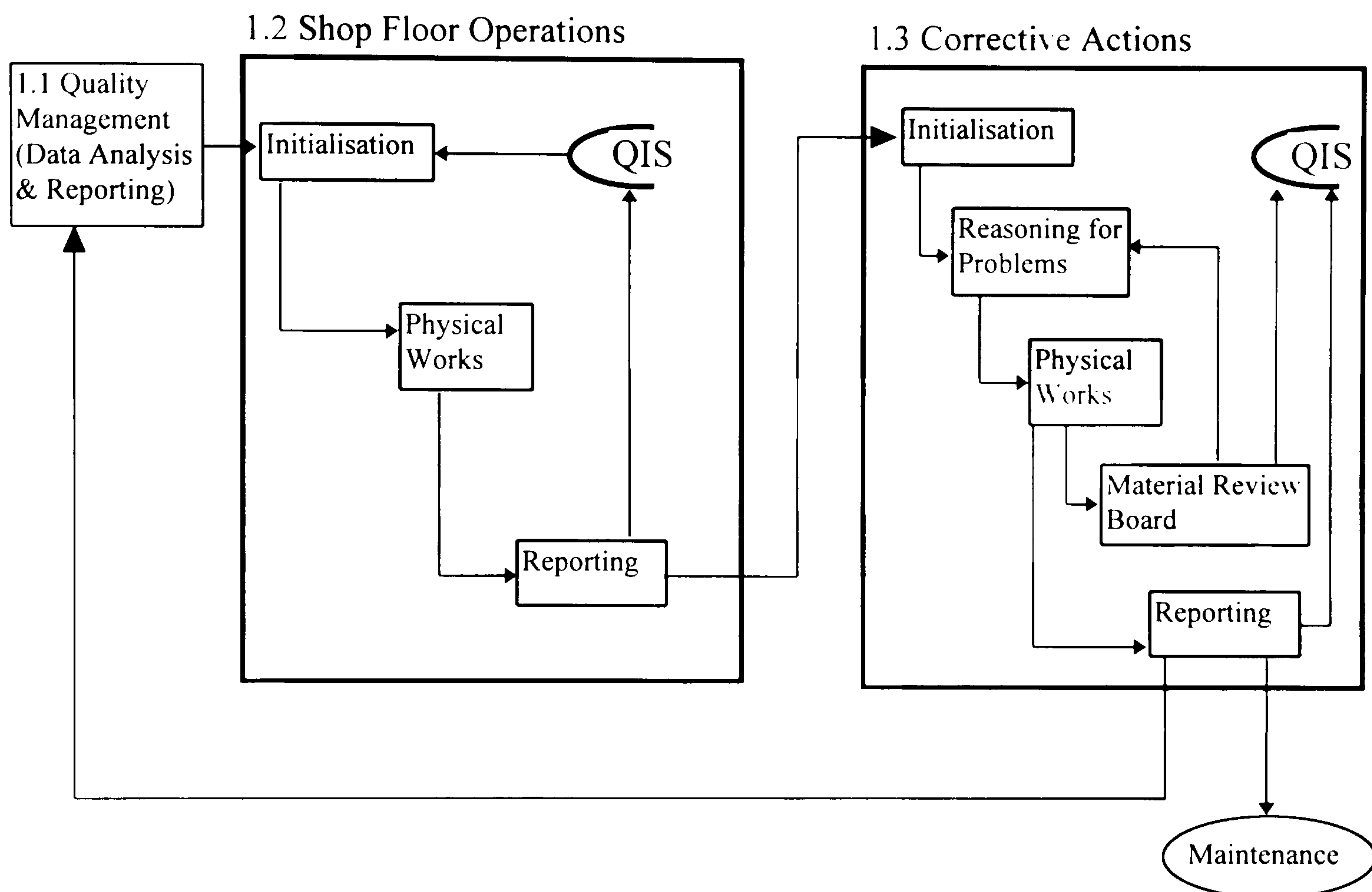


Figure E.1 Modified information structure of a non-conformance in a group

The next step, as can be seen in figure E.1, is the actual Physical Works. With the equipment in hand, the diameters of holes are measured on the specific parts. If measurements conform with the specifications, there is no need for any corrective action at that moment. So an inspection report as a task completed document is sent back to the management (see figure A.5 in Appendix A) as a hard copy or via a computer link (on-line) for further analysis or for future requirements. The work order issued could also be used for this purpose.

However, if there are some holes which are non-conforming with the specification, then this non-conformance should initiate a separate non-

conformance report, let us to say a Quality Improvement Report (QIR). Such a non-conformance report, QIR, should include sufficient information to chase the non-conformance and should include necessary fields (spaces) to be filled in by the Corrective Actions function. An example report would be formed as is shown in figure E.2.

QUALITY IMPROVEMENT REPORT					REPORT NO:
Company:	Factory:	Group:	Machine Name:	Machine Number:	
Work Centre:	Operation Number:	Part Name:	Part Number:	Serial Number:	
Part Supplier / Manufacturer:		Equipment:	Category:	Type:	
DISCREPANCY OR REQUIREMENTS :					
<i>Diameters of holes on part abc12345 at machine xy98 are less than spec. aa12x.</i>					
Number of Inspection:		Number of Rejection:		Department(s) to be Informed:	
Initiator:	Date:		Stamp / signature:		

Figure E.2 A sample quality improvement report showing a non-conformance

At this stage, in order to identify the discrepancy or requirements and to report correctly (see figure A.17 and figure A.18 in Appendix A) some questions such



as what it is non-conforming, why it is non-conforming, what it should be and what the exact location is, etc. would be very helpful.

A QIR could be consisted of several identical pages attached to each other, i.e. for carbon copies, to enable related bodies to be informed when required. A copy of it, for instance, can be torn out to be given to a terminal operator to key in the initial information on the computer or to be sent to management for initial information for further considerations.

Within the Corrective Actions function in figure E.1, this QIR is received as a work order. An initial review is undertaken on it and then reasons for non-conformance are sought (see figure A.20 in Appendix A). The processes and related activities are analysed, firstly, to find out a resolution for the non-conforming part (because of the discrepant holes) and secondly to identify some quality improvement points in the processes. When a resolution (fix or disposition in figure E.3) is achieved, then physical work is performed to fix the discrepancy. In this example, let us assume hole diameters are smaller than the requirements. In that case the resolution can be a re-work. This resolution and its procedure are then written in the Fix or Disposition part of the QIR, in figure E.3. Alternatively, a corrective action analyst may want to take the case to the Material Review Board which is a cross-functional team (see figure A.22 in Appendix A). In this board, the QIR with the related parts are analysed. For the case of smaller holes, such an analysis may not be required. However, in more complicated examples such as elongated holes, technically critical parts, expensive materials or composite materials etc., the Material Review Board is required to produce an optimal solution such as re-work, repair or use as is.

QUALITY IMPROVEMENT REPORT					REPORT NO:
Company:	Factory:	Group:	Machine Name:	Machine Number:	
Work Centre:	Operation Number:	Part Name:	Part Number:	Serial Number:	
Part Supplier / Manufacturer:		Equipment:	Category:	Type :	
DISCREPANCY OR REQUIREMENTS :					
<i>Diameters of holes on part abc12345 at machine xy98 are less than spec. aa12x.</i>					
Number of Inspection:		Number of Rejection:		Department(s) to be Informed:	
Initiator:		Date:		Stamp / signature:	
FIX OR DISPOSITION :					
<i>Re-work per procedure ABC75.</i>					
Part Cost :	Number of Re-work:	Number of Repair:	Number of Scrap:	Number of Accept.:	
Labour Hrs.:	Completed By:		Completion Date:	Approved By:	

Figure E.3 A sample quality improvement report showing a non-conformance and corrective actions

Having identified the Fix or Disposition and its procedure, the physical correction works are performed. Then the QIR, as the task completed document, is closed and is sent back to Quality Management or keyed in the computer (on-line) for further analysis or future requirements. If improper maintenance is found to be the reason for the discrepancy, then either a hard copy of the report showing related information is sent to Maintenance Management or alternatively, if the two information systems are linked to each other, as soon as the QIR is keyed in the computer a specific field (a data item) of it can be designed as a trigger mechanism to transfer related information to a maintenance management database.

Furthermore, besides the cellular operations, there is also a link between the Quality Management (Data Analysis) and the Maintenance Management functions as is shown in figure A.4 in Appendix A, for the sake of improving maintenance management function. As a result of data analyses (mainly analyses of quality improvement reports, QIRs), Maintenance Management is also to be informed by the related quality management reports in detail.

**APPENDIX F**

**PUBLISHED PAPERS**

**PAPER 1 : (PUBLISHED)**

Gundogan, M and Kay, J. M. (1995). 'An integrated total quality management philosophy within group technology cells. In: *International Conference proceedings; Maintenance-Reliability-Quality*, 6th-7th April 1995. Clare College, Cambridge, England.

**PAPER 2 : (PUBLISHED)**

Gundogan, M and Kay, J. M. (1995). 'Total quality management philosophy within the group technology cells. In: *Proceedings of The Third International Conference on Computer Integrated Manufacturing (ICCIM'95) and AUTOFACT ASIA '95*, 11th-14th July 1995, Singapore International Convention & Exhibition Centre.

**PAPER 3 : (ACCEPTED)**

Gundogan, M and Groves, G and Kay, J.M. (1995). 'TQM: A way towards total integration'. Submitted to Total Quality Management.

# AN INTEGRATED TOTAL QUALITY MANAGEMENT PHILOSOPHY WITHIN GROUP TECHNOLOGY CELLS

**Mete Gündogan** <sup>+</sup>  
**and**  
**John M. Kay** <sup>\*</sup>

<sup>+</sup> **Engineering and Management of Manufacturing Systems, Ph.D. Student**  
<sup>\*</sup> **Professor of Manufacturing Systems Engineering**

**CRANFIELD UNIVERSITY**  
**SCHOOL OF INDUSTRIAL AND MANUFACTURING SCIENCE**  
**Cranfield, Bedford, MK43 0TD, The UK**

## ABSTRACT

Manufacturers have now focused on quality as defined by the customer as a contemporary competitive advantage in the international market. This shift brought issues of examining and re-engineering the key business processes to improve organisational performance. Together with information systems, integration is one of the key factors throughout these operations. To achieve these objectives, however, it is required to combine the latest advances in information and knowledge engineering technology with completely new forms of manufacturing management philosophies and organisational design. This paper will describe the need for such a study with a retrospective analysis of TQM implementation methods and cellular manufacturing (i.e. Group Technology) environments. An integrated quality management information system related to other management bodies, is then proposed with a new approach called Activity Based Implementation. The new implementation system will be designed mainly by the Manufacturing Systems Analysis and Design method in conjunction with other Information Technologies.

## INTRODUCTION

### **The Total Quality Management (TQM)**

The definition of total quality management (TQM) that is given by the British Quality Association is: *Total Quality Management is a corporate business management philosophy which recognises that customer needs and business goals are inseparable. It is applicable within both industry and commerce. It ensures maximum effectiveness and efficiency within a business and secures commercial leadership by putting in place processes and systems which will promote excellence, prevent errors and ensure that every aspect of business is aligned to customer needs and the advancement of business goals without duplication or waste of effort.* There are also a number of definitions for TQM.

For example British quality guru Oakland (1993) defines TQM as an approach to improving the competitiveness, effectiveness and flexibility of a whole organisation. It is essentially a way of planning, organising and understanding each activity, and depends on each individual at each level. Kanji and Asher (1993) think that the TQM is about continuous performance improvement of individuals, of groups and of organisations. What differentiates TQM from other management processes is the emphasis on continuous improvement. These new approaches also lead many authors (e.g. Dahlgaard, Kristensen and Kanji, 1994) to criticise the prevalent management understanding in the West. It is believed that the traditional Western forms of management which are based on a philosophy which divides responsibility for decisions into strategic, tactical and operational levels, are totally inadequate for modern, complex companies, since they do not give the connection between top management and the main processes at the bottom responsible for customer satisfaction. From these and other signals, it is clear that the factory of the future also requires the management of the future by the year 2000.

In practical terms it is generally accepted that there are three aspects of TQM relating to the manufacturing industry as is described by Rogerson (1992); the commitment, the management system, and the tools and techniques. TQM is believed to embrace both quality assurance and quality control concepts but it is much broader in its scope to cover all aspects of a business. Today, there are a number of models representing TQM as a philosophy reflecting modern competitiveness. From the discussions of various quality management researchers (such as Kanji and Asher, 1993; Oakland, 1989 and 1993; Zairi, 1991) and various implementations it can be concluded that in general the basic concepts of TQM were seen as customer satisfaction, continuous improvement, total quality control, continuous education and training, and total employee involvement. The implementation of it generally requires structural changes and these changes are not easily made because of their effects on the other manufacturing management areas like organisational changes, cultural changes, behavioural changes, system changes etc. Any deficiency within one of these items is likely to be a cause for a failure. These items have a relationship with not only quality management but also production planning and control systems. It would therefore be ideal if this new implementation model is compatible with a manufacturing management technique as well. For instance Group Technology attacks most of these problems with a structural organisational change.

Furthermore these types of total strategies are gaining ground in this new-era management. For example, within the similar principles of TQM, maintenance management is becoming increasingly important as both the complexity and cost of downtime increases (Mills, 1989). It is generally seen to be essential to have healthy equipment and machinery up and running (Valenti, 1991), as a

requirement for the next generation factory management systems. Cummings (1993) listed current day maintenance strategies some of which have a similar philosophy to the quality management strategies, e.g. increase the commitment, upgrade the overall skills and flexibility of the maintenance tradesmen, increase the involvement of operations personnel. Moreover in a recent study of benchmarking Chen (1994) found out that preventive maintenance has become more and more important with the new Japanese philosophies of Just-In-Time (JIT) and TQM. JIT requires high machine availability (i.e. good preventive maintenance) and TQM requires machines to be in excellent working condition.

### **Cellular Manufacturing ( The Group Technology)**

The objective of Group Technology (GT) is to form small organisational units which complete all the set (or family) of products or components which they make, through one or a few major processing stages, such as metal founding, machining, and assembly, and are equipped with all the machines and other processing equipment they need to do so (Burbidge, 1989).

According to an Ingersoll Engineers' survey (Johnson, 1992), by 1990 over half of UK engineering companies had implemented Cell Manufacture in some part of their business and they have seen improvements in performance. Total employee participation in such a system is very high. Johnson (1992), for instance, defines this participation as a trick which is to make a large business have little businesses inside it. Application of GT requires organisational and layout changes, hence, creating a big opportunity for a new management philosophy to be implemented within. The groups are, as is usual with GT (Burbidge, 1994), responsible for their own; inspection, operation, scheduling, dispatching, setting-up, tool storage, deliveries and progressing of customer orders. In addition to the measurable economic benefits, Burbidge (1994) states that there are other benefits which are difficult to qualify. Among these are better accountability and improved morale and job satisfaction. Hence a suitable quality management system broken down to cells will already inherit some advantages which are mentioned earlier by some authors, which would otherwise be possible failure causes of a TQM application. With the GT applications, companies have also challenged many accepted beliefs and have adopted new ways of thinking. For instance cellular manufacturing application at Champion Irrigation Products (Kumar and Hadjinicola, 1993) have challenged functional integration of the factory and age-old procedures. They later on realised that the integration of two functions could yield operational efficiency. Additionally quality had become a central issue. It had also been similar motives that made Watervliet Arsenal Co. ventured into GT (Baran, 1991). Among other advantages, with the GT application in their plant, Welke and Overbeeke (1988) realised that cellular manufacturing is one of the best vehicles available to implement JIT manufacturing and total quality control. Simplicity seems to be a major key for



creating GT-based cells and for the factory of the future. The more simple it becomes the more integrated it is required to be. For instance Deeming (1993) was surprised by the simplicity of the methods of control and the total commitment by the operator and the supervision in his first visit to Japan. Besides simplicity, in manufacturing environments, Menon (1992) stresses the importance of flexibility as well.

Hence, changing environments towards the factory of future requires integration. Kerr (1991) stated that the integration of design and manufacture is an objective that was being increasingly pursued world wide. A simple integrated implementation study needs to be undertaken on how to install the TQM philosophy in cellular manufacturing. These two concepts seem to complement each other. If these two techniques can be merged successfully within an implementation model the result should be a substantial improvement. Integration here is the major task. The management data within the system should be organised in a way which allows the integration at the highest possible level and should be structured to allow for any changes and future developments.

### **ACTIVITY BASED IMPLEMENTATION APPROACH**

For structural integration of these two techniques or in other words to seed the TQM philosophy within GT, a new approach needs to be developed, rather than using one of the generic approaches. Analysis of the implementations and models lead to three structural pillars for a simple integrated successful implementation model. These are integration, circularity (i.e. implementation flexibility), and structuredness.

Integration: Although there are a lot of programmes to implement TQM, there are also a lot of cross functional and cross departmental problems associated with them. These borders should be well-defined in order to minimise inter-departmental and inter-functional barriers.

Circularity: One of the major problems in TQM applications is to know how and where to start. There should be an implementation flexibility allowing users to start wherever they would like to start. Once started it should not be a problem, if as is stated by Irfanoglu (1994), top down, bottom up or both approaches are used for the implementation. It should also gradually lead you to a perfect circle where eventually all the requirements of TQM are met. In cellular environments, since each cell will be treated as a small business, it will be possible to start the implementation with any cell that seems convenient.

Structuredness: this is to do with the specific requirements of TQM to be described in a way so that each function consists of small well defined activities

which are in a specific sequence and interacting to each other. These activities should be as precise as possible to let both users and developers understand them. This structuredness should let any model fit into any level of industry to be implemented. Ashworth and Goodland (1990) argue that structured systems easily adopt themselves to any changes in an organisation. Hence a structured model of implementation is expected not to be halted if a change occurs in process, product or organisation.

Having these three pillars placed, we now come to a certain point that rather than having the generic approach, a new approach of implementation should be developed. Bearing in mind the above discussion this can simply be defined as an activity based approach of implementation (or Activity Based Implementation, ABI). With this ABI approach, rather than concentrating on the solution of 'whats', the concentrations will be on 'hows'. The ABI approach targets data management activities to integrate to each other, to develop and to have them in control. So it is the information which flows through these activities which must be simplified, integrated and controlled. It will be possible to deal with each independent small activity in its own context. Any problem appearing will be within one of these well defined activities. It can easily be isolated not to affect others and then be tackled.

To tie these three main pillars to each other in the management context we need three further conventions namely easy handling, communication and easy adoption. These three main pillars associated with the three supporting ties constitute the breakthrough triangle as depicted in Figure 1. Furthermore continuous improvement makes this triangle flow or work as required/planned. Continuous improvement is sustained by integration, circularity and structuredness together with their associates.

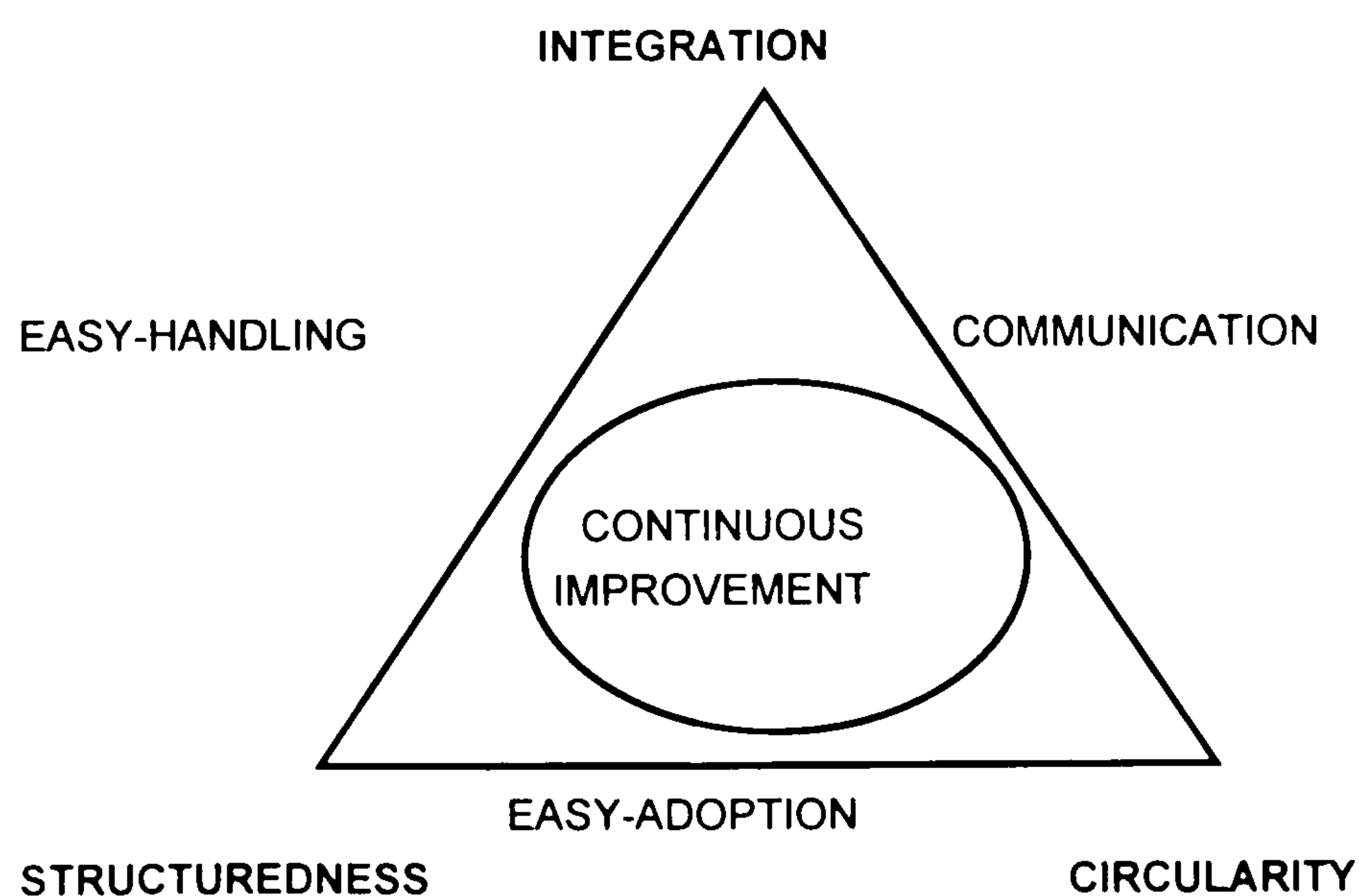


Figure 1: The dynamic elements of the ABI approach

To develop this new implementation model, one of the business modelling techniques, Manufacturing Systems Analysis and Design, seems to be useful in three aspects; it analyses and simplifies the data, integrates the functions, and makes the functions as flexible as possible for any application (Ashworth and Goodland, 1990; Gandoff, 1989).

### **An Integrated Quality Management Information System**

At the first level, the proposed model is seen in Figure 2 in detail. There are three main activities within the system as Quality Management, Cellular Operations, Auditing and a common Quality dataBase (Q.dB.) which holds all the quality management information.

The following departments (functions) should be related to the quality management system; Production, Sales&Marketing, Suppliers, Finance, Customer Servicing, Product Design&Engineering, Maintenance, Personnel&Training. As is seen in Figure 2, the IQM Information System has a mutual relationship with Production, Sales&Marketing, Suppliers, and Finance. It has feedback from Customer Servicing about the product and services being delivered (customer satisfaction). It informs Product Design&Engineering, Maintenance and Personnel&Training about the necessary developments through its operations.

Quality Management (Data Analysis) is where all data analysis, reporting, system works (i.e. all office works) are carried out. They receive quality policy or commitment from top/senior management and they report back about the quality management activities. This is the main input/output of an IQM model. Quality Auditing is a review of activities conducted to compare some aspect of quality performance with a standard for that performance.

### **Cellular (In-Groups) Operations**

As is seen in Figure 3, each cell within the Cellular Operations boundary context is treated as a small business and the information flow is also set-up accordingly. Each cell is fed by information and materials in the similar way. Shop Floor Operations employs all quality control shop floor operations. Inspections, tests, calibration of measurement equipment, quality preventive activities are all within this functional area. They receive information, orders, work schedules, tasks, etc.. together with materials (including information papers, forms. etc.). They process all orders/tasks and key-in the necessary preliminary results/information to a common Q.dB., and also pass the results with the paperwork to corrective action functions.

Corporation, he distinguished some business that had been identified as faulty as fail had nevertheless been carried over into new machines, model after model. Instead of making design engineers work on them, Xerox had created a first service force they could dispatch to railway stations.

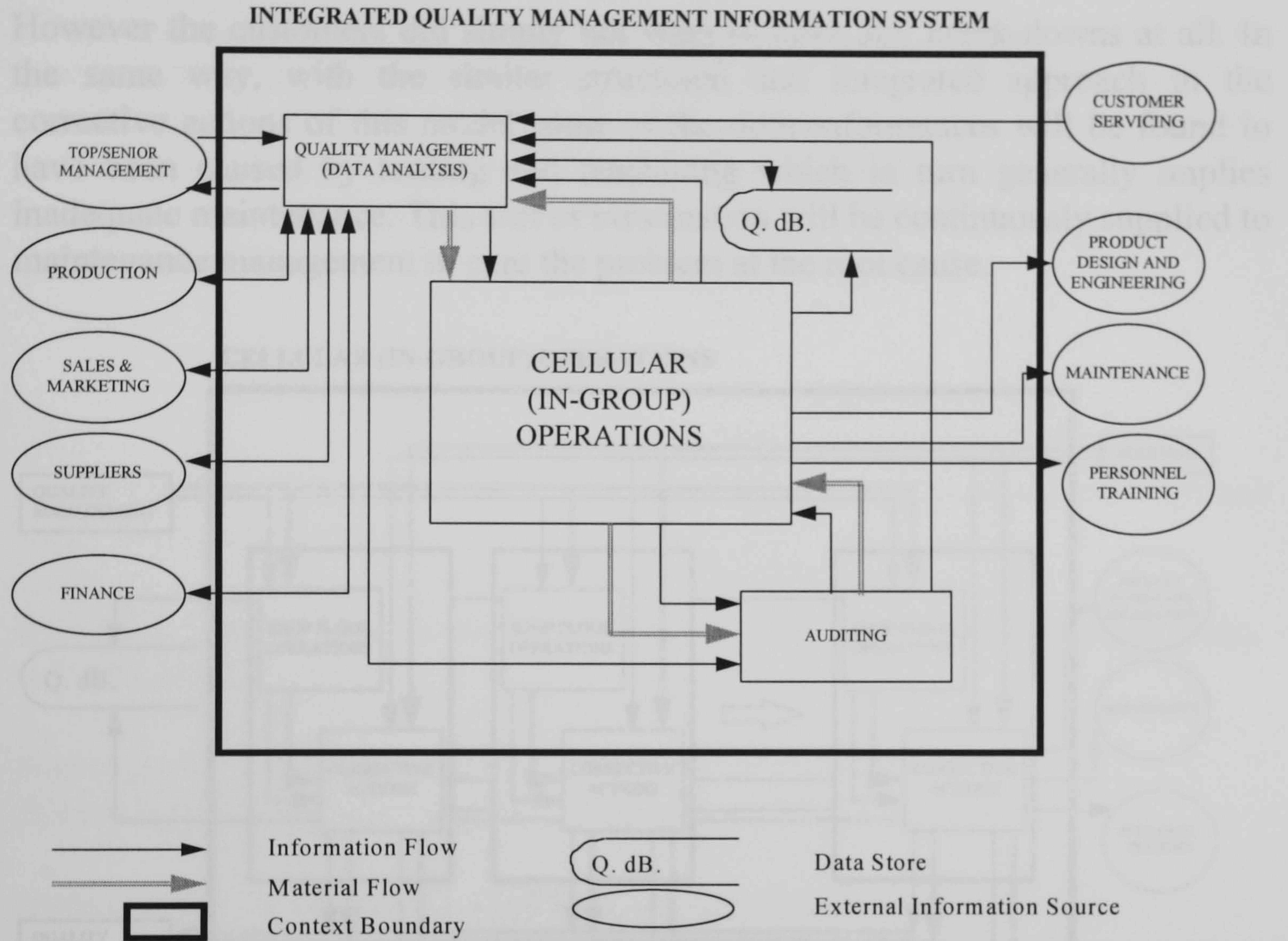


Figure 2: First level activities in the Integrated Quality Management System

Corrective Actions is the function where all non-conformance analysis is undertaken and corrective actions are produced, applied and reported. According to the outcome of analysis and operations, they also report to related bodies such as Product Design and Engineering, Maintenance and Personnel Training. Within this area of activities, a multi-skilled team called the Material Review Board (MRB) analyses faulty parts&materials to make a decision whether to scrap, repair or use as is. If a decision is taken, then the procedure for it has also to be written by the MRB.

In order to appreciate the importance of some of the information going to other than quality departments, let us have a closer look at the following example. When Juran (1993) was examining the quality practices in the Xerox

Corporation, he distinguished some features that had been identified as likely to fail had nevertheless been carried over into new machines, model after model. Instead of making design engineers work on them, Xerox had created a field service force they could dispatch to restore service.

However the customers did simply not want to have any break-downs at all. In the same way, with the similar structured and integrated approach in the corrective actions of this model some of the nonconformances will be found to have been caused by tooling and machining which in turn generally implies inadequate maintenance. This sort of information will be continuously supplied to maintenance management to cure the problem at the root cause.

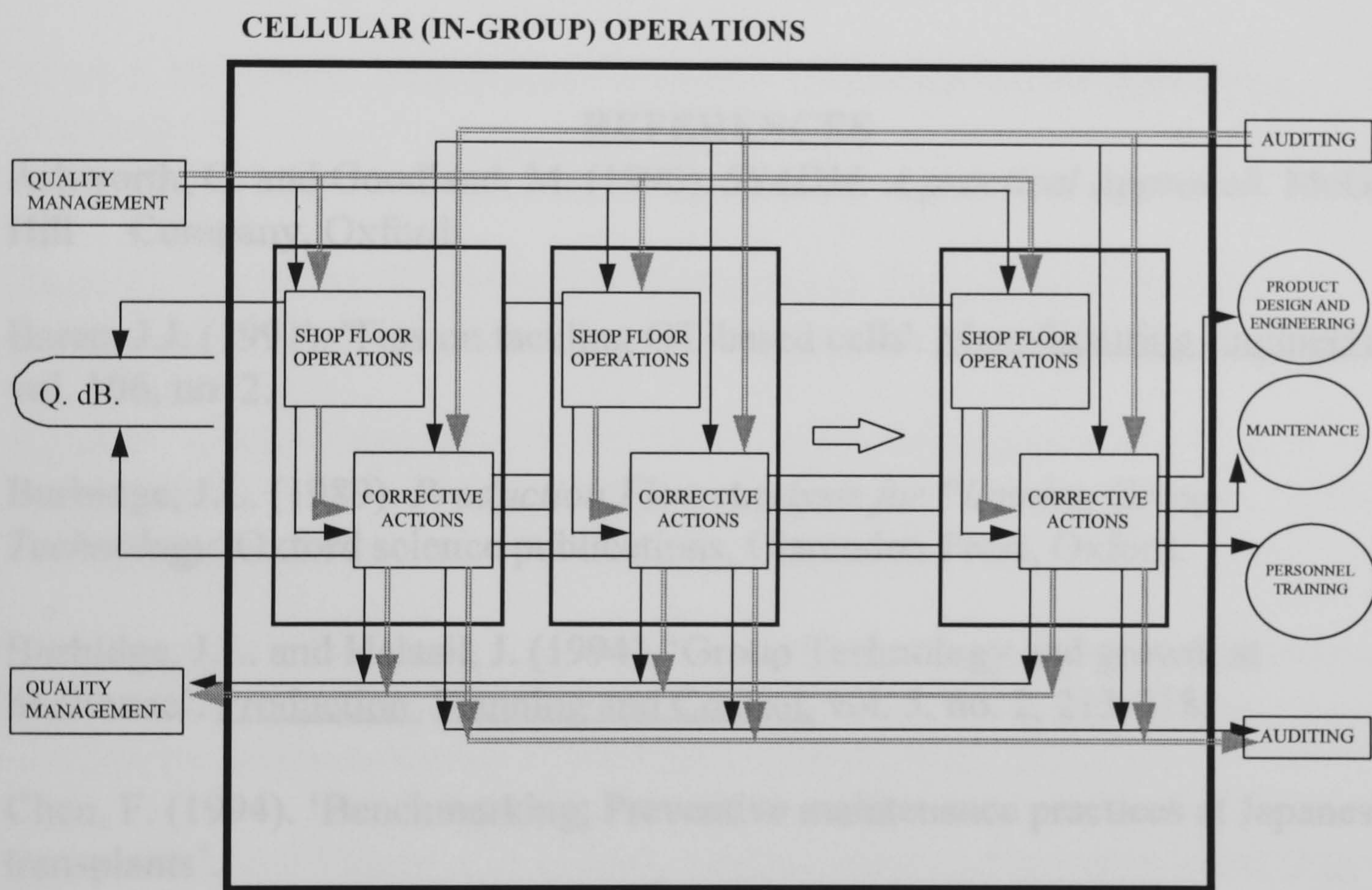


Figure 3: Cellular Operations in the Integrated Quality Management Information System

### CONCLUSIONS

Nowadays almost everywhere has become an international market. The competition, customer demand for greater precision, and shorter delivery times are day-by-day increasing. To challenge these growing pressures has become difficult with the conventional approaches.

The integrated quality management information system is designed to contemplate the problem as a whole starting from suppliers to the customers. It

has three major strengths in integration, flexibility and structuredness. These allow it to tackle the area and deal with contemporary problems in a simple way by breaking them into very small independent items isolated so as not to affect others.

Integration and circularity will allow further expansions in the same way. Better quality data management will substantially improve competitiveness and overall profitability. It will also create a harmony in other related activities by simply making them be aware of what is going on on the shop floor. At the edge of the move from the century of productivity to the century of quality (Juran, 1994) the types of schemes described here will be drives of this shift.

### REFERENCES

Ashworth, C. and Goodland, M. (1990). *SSADM; A practical Approach*. McGraw Hill Company, Oxford.

Baran, J.J. (1991). 'Tips on tackling GT-based cells'. Manufacturing Engineering, vol. 106, no. 2.

Burbidge, J.L. (1989). *Production Flow Analysis for Planning Group Technology*. Oxford science publications, Clarendon Press, Oxford.

Burbidge, J.L. and Halsall, J. (1994). 'Group Technology and growth at Shalibane'. Production Planning and Control, vol. 5, no. 2, 213-218.

Chen, F. (1994). 'Benchmarking; Preventive maintenance practices at Japanese transplants'.

International Journal of Quality and Reliability Management, vol. 11, no. 8, 19-26.

Cummings, G. (1993) 'Beyond most modern-day maintenance strategies: Strategy indicators'.

Industrial Engineering, (August), vol. 25, no.8, 22-23.

Dahlgaard, J.J. and Kristensen, K. and Kanji, K.G. (1994). 'The quality journey'. Total Quality Management Journal Supplement, Carfax Publishing Co., Oxfordshire.

Deeming, T. (1993). 'Cell mates'. Manufacturing Engineer, vol. 72, no. 3.

Gandoff, M. (1989). System Analysis and Design. Heinemann Professional Publishing Ltd., Oxford.

Irfanoglu, O. (1994). Method Engineer. MSc., TUSAS Aerospace Industries Inc., Ankara, Turkey.

Johnson, P. (1992). 'Unlocking the rewards of cellular manufacture'. Machinery and Production Engineering, 21th February.

Juran, J. M. (1993) 'Made in USA: Renaissance in quality'. Harvard Business Review. July-August, vol. 71, no. 4, 42-50

Juran, J. M. (1994). 'The century of quality'. Manufacturing Engineering. (September), vol. 113, no. 3, 10-11.

Kanji, G. K. (1990). 'Total Quality Management: The second industrial revolution'. Total Quality Management Journal, vol. 1, no. 1, 3-12.

Kanji, G. K. and Asher, M. (1993). 'Total Quality Management Process, A Systematic Approach'. Total Quality Management Journal Supplement, Carfax Publishing Company, Oxfordshire.

Kerr, R. (1991). *Knowledge-Based Manufacturing Management Applications of artificial intelligence to the effective management of the manufacturing companies*. Addison-Wesley Publishing Company, Inc., Singapore.

Knorr, R.O. and Thiede, E.F. (1991). 'Making New Technologies work'. The Journal of Business Strategy, (Jan/Feb), 46-49.

Kumar, K.R. and Hadjinicola, G.C. (1993). 'Cellular manufacturing and Champion Irrigation Products'. Int. J. of Operations and Production Management, vol. 13, no. 9, 53-61.

Menon, H.G. (1992). *TQM in new product manufacturing*. McGraw Hill Inc., USA.

Mills, A. (1989). CAMMS the way forward, a personal view. Project Report. Edinburgh University.

Oakland, J. S. (1989). *Total Quality Management*. Heinemann Professional Publishing Ltd., Oxford.

Oakland, J. S. (1993). *Total Quality Management: The route to improving performance*. Heinemann Professional Publishing Ltd., 2nd Ed., Oxford.

Rogerson, J.H. (1992). 'Total Quality Management in the Fabrication Industry'. Welding and Metal Fabrication, (October), vol. 60, no. 8, 375-377.

Sprague, R.H. and McNurlin, B.C. (1993). *Information Systems Management in Practice*. Prentice Hall International Inc., NJ.

Valenti, M. (1991). 'Maintenance software keeps machines up and running'. Mechanical Engineering, (November), vol. 113, no. 11, 63-65.

Welke, H.A. and Overbeeke, J. (1988). 'Cellular manufacturing: A good technique for implementing just in time and total quality control'. Industrial Engineering, (November), 36-41.

Winter, P.J. and Gilbert, J.P. (1987). 'Flexible manufacturing systems: resistance and trends'.

Production and Inventory Management, First Quarter, vol. 28, no. 1, 10-14.

Zairi, M. (1991). *Total Quality Management for Engineers*. Woodhead Publishing Ltd., Cambridge, England.



# TOTAL QUALITY MANAGEMENT PHILOSOPHY WITHIN THE GROUP TECHNOLOGY CELLS

METE GÜNDOĞAN

PROFESSOR JOHN M. KAY

## **ABSTRACT**

Today's highly competitive manufacturing environments force companies to work smart, rather than work hard, not only in isolated areas of operation but in all areas of operations, starting with suppliers and ending with customers. Information is again one of the key factors throughout these operations. It should be defined and recognised as a key resource for each level of management and operators and should be organised accordingly. This competition in general requires firms to improve market responsiveness, product quality, use computerised information systems for production planning & control, have more rapid changeovers, reductions in set-up times, work in progress reduction and hence throughput times reduction.

In order to achieve these objectives an Integrated Quality Management Information System is proposed for cellular manufacturing environments. This proposed structured management system integrating the Total Quality Management philosophy with the cellular manufacturing (i.e. group technology) technique is expected to produce a benefit by complementing each others strengths and minimising each others deficiencies. Better quality management data, with the help of the proposed management information system, will substantially improve competitiveness and overall productivity.

## **Introduction**

Manufacturers have now focused on quality as a contemporary competitive advantage in the international market and the emphasis has shifted to quality as defined by the customer. This customer satisfaction has focused management's attention on the key business processes in the organisation. Within this context Sprague and McNurlin (1993) are two of many researchers considering information systems as a primary resource for examining and reengineering these key business processes to improve organisational performance. As is described by Kerr (1991), information is an input to manufacturing subsystems interacting with each other. This interaction should be established in a way to support total management philosophy in the competitive manufacturing world. This competition in general requires firms to improve market responsiveness, product quality, use computerised information systems for operations planning & control.

have more rapid changeovers, reductions in set-up times, work in progress (WIP) reduction and hence throughput times reduction (Winter and Gilbert, 1987).

To achieve these objectives, however, it is required to combine the latest advances in information and knowledge engineering technology with completely new forms of manufacturing management philosophy and organisational design. Neither approach on its own is likely to be sufficient to make a significant difference to today's levels of overall productivity. Each technique or philosophy has its advantages and disadvantages in certain manufacturing surroundings. A well established structured management system integrating some of the techniques/philosophies would certainly produce a benefit by complementing each others strengths and minimising each others deficiencies. This study looks at the total quality management applications within the cellular manufacturing (i.e. Group Technology) environments.

### **The Total Quality Management (TQM)**

The definition of total quality management (TQM) that is given by the British Quality Association is: *Total Quality Management is a corporate business management philosophy which recognises that customer needs and business goals are inseparable. It is applicable within both industry and commerce. It ensures maximum effectiveness and efficiency within a business and secures commercial leadership by putting in place processes and systems which will promote excellence, prevent errors and ensure that every aspect of business is aligned to customer needs and the advancement of business goals without duplication or waste of effort.*

There a number of definitions for TQM. The most common definitions are reflected in the following two sets of definitions. British quality guru Oakland (1993) defines TQM as an approach to improving the competitiveness, effectiveness and flexibility of a whole organisation. It is essentially a way of planning, organising and understanding each activity, and depends on each individual at each level. TQM is also a way of ridding people's lives of wasted effort by bringing everyone into the processes of improvement, so that results are achieved in less time.

Kanji and Asher (1993) think that the TQM is about continuous performance improvement of individuals, of groups and of organisations. What differentiates TQM from other management processes is the emphasis on continuous improvement. With the emphasis on the continuous improvement they also associate four general principles with the TQM provision namely delight the customer, management by fact, people based management, and continuous improvement.

These new approaches also lead many authors (e.g. Dahlgaard, Kristensen and Kanji, 1994) to criticise the prevalent management understanding in the West. It is believed that the traditional Western forms of management which are based on a philosophy which divides responsibility for decisions into strategic, tactical and operational levels, are totally inadequate for modern, complex companies, since they do not give the connection between top management and the main processes at the bottom responsible for customer satisfaction. Consequently the management becomes ignorant of the real problems on the operational level, and do not support and back the operational level needs for the creation of customer satisfaction

From these and other signals, it is clear that the factory of the future also requires the management of the future by the year 2000. In practical terms it is generally accepted that there are three aspects of TQM relating to the manufacturing industry as is described by Rogerson (1992). The Commitment; TQM's success or failure rather depends on the commitment of the staff to the concept and on the acceptance of the staff for the need for the resulting culture change. The Management System; Which is needed to ensure that the quality aims are followed consistently and that the company conducts its business in a controlled, systematic way. The Tools and Techniques; which are used to measure the achievement and enhancement of quality, various measurement methods which give quantitative information. Quality assurance is the method to demonstrate customers that their quality needs have been met. Quality control is the physical control actions. TQM embraces both quality assurance and quality control concepts but it is much broader in its scope to cover all aspects of a business.

Today, there are a number of models representing TQM as a philosophy reflecting modern competitiveness. However, implementation of them is not as clear as their definitions. Let us have a look at the few of them.

Kanji and Asher (1993) proposed a four stage model to develop TQM implementation in an organisation; Firstly, Identification and Preparation, identify and collect information in the prime areas where improvement will have most impact on the organisation's performance. Then, Management Understanding and Commitment, prepare and adopt continuously the objective and methodology of TQM for management. The third step is Scheme for Improvement which establishes a proper scheme of training and communication to resolve quality issues by involving all management and supervision. Lastly, New Initiative, New Target and Critical Examination, start the new initiatives with new targets, indicate supplier and customer links in the quality chain and obtain information about progress. Kanji and Asher (1993), however, state their reservations about the implementation and continue that without the data to make informed decisions, without total commitment from the top, without the strength

of a united and co-ordinated middle management the implementation is most likely to fail.

Another one of the prominent models is the Oakland model (1989,1993) which is characterised as a pyramid representing five distinct components: Management Commitment: it is identified that senior management commitment is a prerequisite for success. Customer Supplier Chains: This is seen at the heart of the pyramid and is considered as a propeller for process ownership, management and improvement. Systems: which is the documentation of procedures and standards of doing things right first time and every time. SPC Tools: To measure and control conformance to customer requirements and agreed standards. Team Work: A culture of continuous improvement. Oakland (1993) too reflected similar reservations in the implementation stage and thought that employees will not be motivated towards continual improvement in the absence of; commitment to quality from the top management, the organisational quality climate and a team approach to quality problems. For a successful implementation of TQM, Oakland (1992), on the other hand, proposes several things to be done by all concerned in order to avoid total quality disillusionment or paralysis as was described by Kanji (1990) and developed a procedure which contains a mixture of ideas supported by the various quality gurus.

As a last example, another researcher Zairi (1991), on the other hand, proposed a TQM model at three levels. The Top:, this resembles the roof of a building which is perhaps the most important part since it shields the organisation from adverse external factors and protects it all the time. The Pillars:, these are represented by various quality assurance tools (like SPC, SQC, BS5750), user supplier chain, management control systems (OPT, MRPII, JIT), process flexibility, (FMS, CNC, AMT, CIM, CAD/CAM) and workplace design like layout, methods, ergonomics, safety etc. The Foundation:, this consists of continuous improvement which involves introduction of change, flexibility and adaptability, employee involvement and added value management activities.

When it comes to the implementation phase, researchers are a little curious because of the structural change requirements of the TQM philosophy. For instance, this curiosity is shown by Zairi(1991) as there is no single implementation procedure valid for all. The implementation of TQM is a unique experience to individual organisations and the ideas of individual gurus will not necessarily be enough to solve all the problems. He then proposes the idea of adopting a strategy based on a mixture of ideas from the various quality gurus.

From the discussions of various quality management researchers and various implementations it can be concluded that in general the basic concepts of TQM were seen as customer satisfaction, continuous improvement, total quality

control, continuous education and training, and total employee involvement. The implementation of it generally requires structural changes and these changes are not easily made because of their effects on the other manufacturing management areas like organisational changes, cultural changes, behavioural changes, system changes etc. Any deficiency within one of these items is likely to be a cause for a failure. Furthermore the following major points are either being reasons for a probable failure or being difficulties (obstacles) throughout the implementation:

- Lack of top management commitment,
- Lack of reorganisation accordingly.
- Lack of continuous improvement (if not mechanised).
- Lack of total employee involvement,
- Lack of communication,
- Lack of new performance indicators/measurements.

As was mentioned earlier, these items have a relationship with not only quality management but also production planning and control systems. It would therefore be ideal if this new implementation model is compatible with a manufacturing management technique as well. For instance Group, Technology attacks most of these problems with a structural organisational change.

### **Cellular Manufacturing ( The Group Technology)**

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According to an Ingersoll Engineers' survey (Johnson, 1992), by 1990 over half of UK engineering companies had implemented Cell Manufacture in some part of their business and they have seen improvements in performance. Total employee participation in such a system is very high. CM is to give ownership and authority to the people running the cells and the machines in them. Johnson (1992), for instance, defines this participation as a trick which is to make a large business have little businesses inside it. So the control span inside it is smaller and the sense of ownership greater so that people take pride in driving their little units. Application of GT requires organisational and layout changes, hence, creating a big opportunity for a new management philosophy to be implemented within. The groups are, as is usual with GT (Burbidge, 1994), responsible for their own: inspection, operation, scheduling, dispatching, setting-up, tool storage, deliveries and progressing of customer orders. In addition to the measurable economic benefits, Burbidge (1994) states that there are other benefits which are difficult to qualify, and for which the generation of savings cannot be illustrated by a mathematical model. Among these are better accountability and then improved

morale and job satisfaction. So a suitable quality management system broken down to cells will already inherit some advantages which are mentioned earlier by some authors, which would otherwise be probable failure causes of a TQM application.

With the GT applications, companies have also challenged many accepted beliefs and have adopted new ways of thinking. For instance cellular manufacturing application at Champion Irrigation Products (Kumar and Hadjinicola, 1993) have challenged functional integration of the factory and age-old procedures. They later on realised that the integration of two functions could yield operational efficiency. Additionally quality had become a central issue. It had also been similar motives that made Watervliet Arsenal Co. ventured into GT (Baran, 1991). Among other advantages, with the GT application in their plant, Welke and Overbeeke (1988) realised that the cellular manufacturing is one of the best vehicles used to implement JIT manufacturing and total quality control. They concluded that a compact cellular environment with employees who have ownership over the operations will drastically reduce lead times and inventories and almost certainly increase quality.

Simplicity seems to be a major key for creating GT-based cells and it is the great deal of the factory of the future. The more simple it becomes the more integrated it is required to be. For instance Deeming (1993) was surprised by the simplicity of the methods of control and the total commitment by the operator and the supervision in his first visit to Japan.

These simple, integrated new approaches are making some new inroads in Europe as well with increasing emphasis on employee participation, concurrent designs and the rewarding of employee contributions to the manufacture of quality products at competitive costs. Besides simplicity, in manufacturing environments, Menon (1992) stresses the importance of flexibility. In order to achieve TQM and flexibility he thinks that cellular manufacturing is the key element in the factories of the future. System integration is another important requirements in the TQM process. Existing systems for manufacturing are not very flexible (excluding most of the Japanese companies), and do not attempt to go beyond the quality management philosophy where the customer satisfactions are met.

Hence, changing environments towards the factory of future requires integration as was also said by Kerr (1991) that the integration of design and manufacture is an objective that was being increasingly pursued world wide. A simple integrated implementation study needs to be undertaken on how to install the TQM philosophy in cellular manufacturing. These two concepts seem to complement each other. If these two techniques can be merged successfully the result would

substantially be a better technique to tackle the problems. If we look at the advantages of cellular manufacturing, we see that they might address some of the obstacles/difficulties of TQM implementations. Integration here is the major task. The management data within the system should be organised in a way which allows the integration at the highest possible level and should be structured to allow for any changes and future developments.

### **A New Implementation Approach**

For structural integration of these two techniques or in other words to seed the TQM philosophy within GT, a new approach needs to be developed, rather than using one of the generic approaches described earlier. Analysis of the implementations and models lead to three structural pillars for a simple integrated successful implementation model. These are integration, implementation flexibility (i.e. circularity), and structuredness.

Integration: Although there are a lot of programmes to implement TQM, there are also a lot of cross functional and cross departmental problems associated with them. These borders should be well-defined in order to minimise inter-departmental and inter-functional barriers.

Circularity, implementation flexibility: One of the major problems in TQM applications is to know how and where to start. There should be an implementation flexibility allowing users to start wherever they would like to start. It should not cause a total quality paralysis or disillusionment as mentioned earlier. Whichever way one choose to start the implementation, that point should lead him/her to a company-wide total implementation as if it is applied after a long analysis to find out where/how to start. Once you started it should not be a problem, as is stated by Irfanoglu (1994), if you used top down, bottom up or both approaches for the implementation. It should also gradually lead you to a perfect circle where all the requirements of TQM are met. In cellular environments, since each cell will be treated as a small business. it will be easier to start the implementation with any of them convenient.

Structuredness: this is to do with the specific requirements of TQM to be defined and described in a way so that each function consists of small well defined activities which are in a specific sequence and interacting to each other. These activities should be as precise as possible to let both users and developers understand them. This structuredness should let any model fit into any level of industry to be implemented. Ashworth and Goodland (1990) argue that structured systems easily adopt themselves to any changes in an organisation. Hence a structured model of implementation is expected not to be halted if a change occurs in process, product or organisation.

Having these three pillars placed we now come to a certain point that rather than having the generic approach, a new approach of implementation should be developed. For the moment this can simply be defined as activity based approach of implementation (or Activity Based Implementation, ABI). With this ABI approach rather than concentrating on the solution of 'whats' the concentrations will be on 'hows'. The ABI approach is to target data management activities to integrate to each other, to develop and to control smoothly. So it is the information which flows through these activities which must be simplified, integrated and controlled. It will be possible to deal with each independent small activity in its own context. Any problem appearing will be within one of these activities managed and will easily be isolated not to affect others.

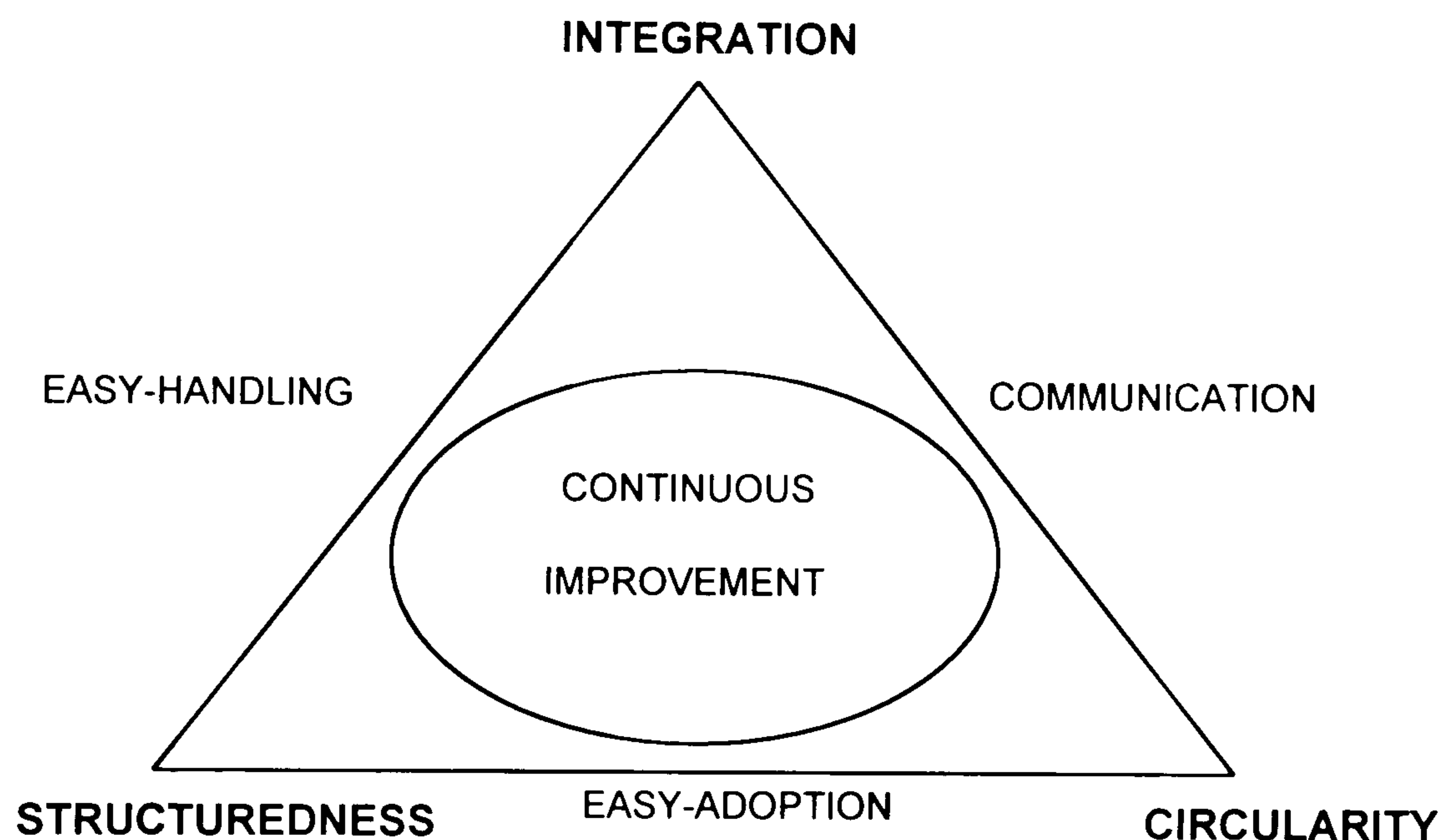


Figure 1: The dynamic elements of the ABI approach

To tie these three main pillars to each other we need further three convention namely easy handling, communication and easy adoption. These three main pillars associated with three supporting ties constitute the breakthrough triangle as depicted in Figure 1. Furthermore continuous improvement makes this triangle flow or work as smooth as required and planned. Strength of continuity comes from integration, circularity and structuredness together with their associates.

Wherever you start you should go through the similar steps and at every cycle the ABI approach should force people to achieve continuous improvement and to understand re-organisation and/or re-engineering/re-design through the circularity and integration. In many current applications we come across many pieces of information scattered around the company and they should be accommodated within the organisation with a convenient communication system. An integrated model should also be easily handled and adoptable to have the flexibility and to let the implementation start anywhere.



To develop this new implementation model, one of the business modelling techniques, Manufacturing Systems Analysis and Design, seems to be useful in three aspects; it analyses and simplifies the data, integrates the functions, and makes the functions as flexible as possible for any application (Ashworth and Goodland, 1990; Gandoff, 1989).

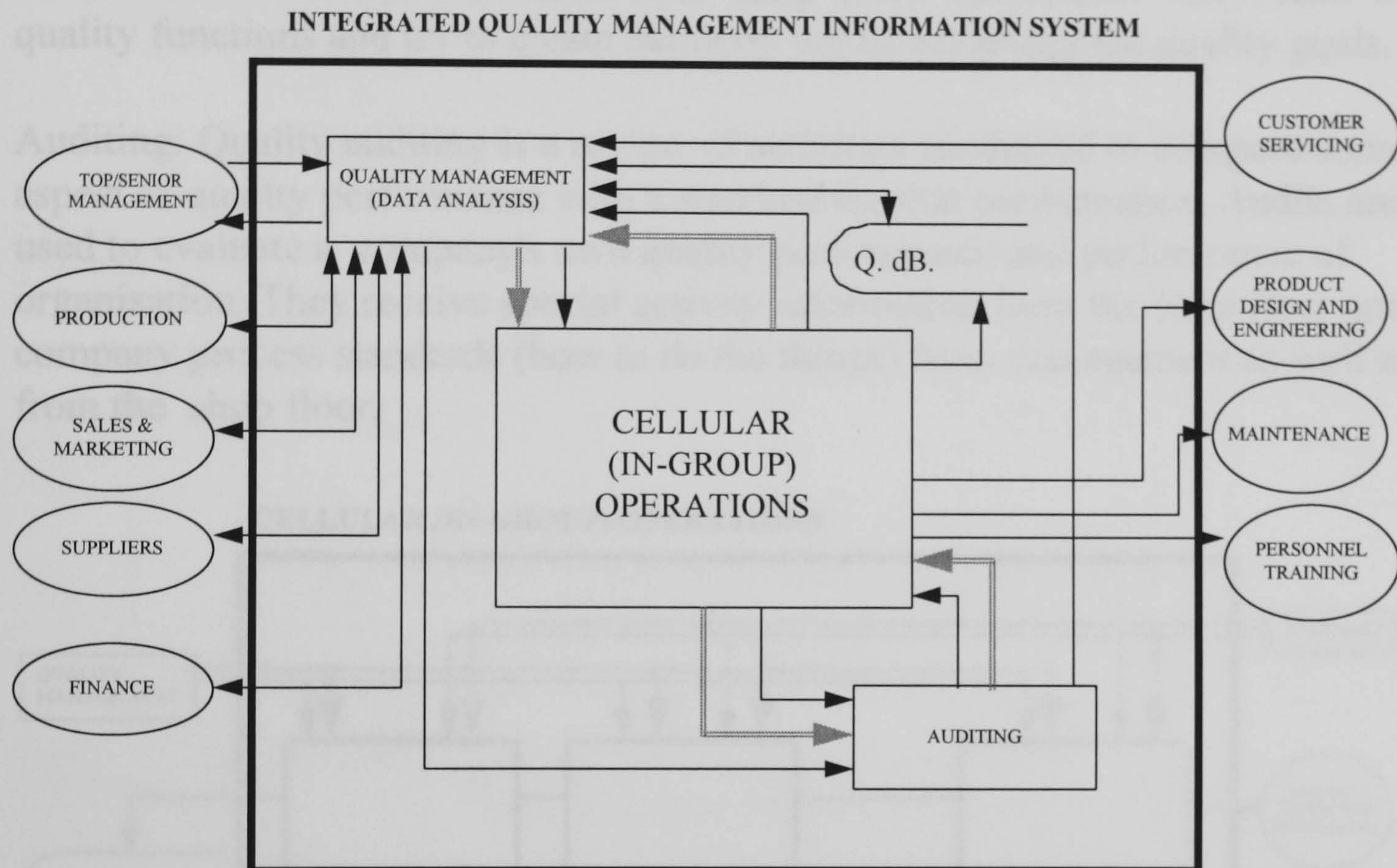


Figure 2: First level activities in the Integrated Quality Management System

### **Integrated Quality Management Information System**

At the first stage, the proposed model is seen in Figures 2 in detail. There are three main activities within the system as Quality Management, Cellular Operations, Auditing and a common Quality dataBase (Q.dB.) which holds all the quality management information.

The following departments (functions) should be related to the quality management system; Production, Sales and Marketing, Suppliers, Finance, Customer Servicing, Product Design and Engineering, Maintenance, Personnel / Training. As is seen in Figure 2, IQM System has a mutual relationship with production, sales and marketing, suppliers, and finance. It has feedback from customer servicing about the product and services being delivered (customer satisfaction). It informs product design and engineering, maintenance and personnel/training about the necessary developments through its operations.

Quality Management (Data Analysis): This is where all data analysis, reporting, system works (i.e. all office works) are carried out. They receive quality policy or commitment from top/senior management, they work on it to satisfy and then report back. This is the main input/output of an IQM model. They communicate with the other processes such as production, sales and marketing (field performance), supplying operations and finance. They receive input from customers and many feed back from shop floor operations. They feed other quality functions and try to create harmony whilst achieving the quality goals.

Auditing: Quality auditing is a review of activities conducted to compare some aspect of quality performance with a standard for that performance. Audits are used to evaluate a company's own quality performance and performance of organisation. They receive special activity information from the shop floor and company process standards (how to do the things) from management as well as from the shop floor.

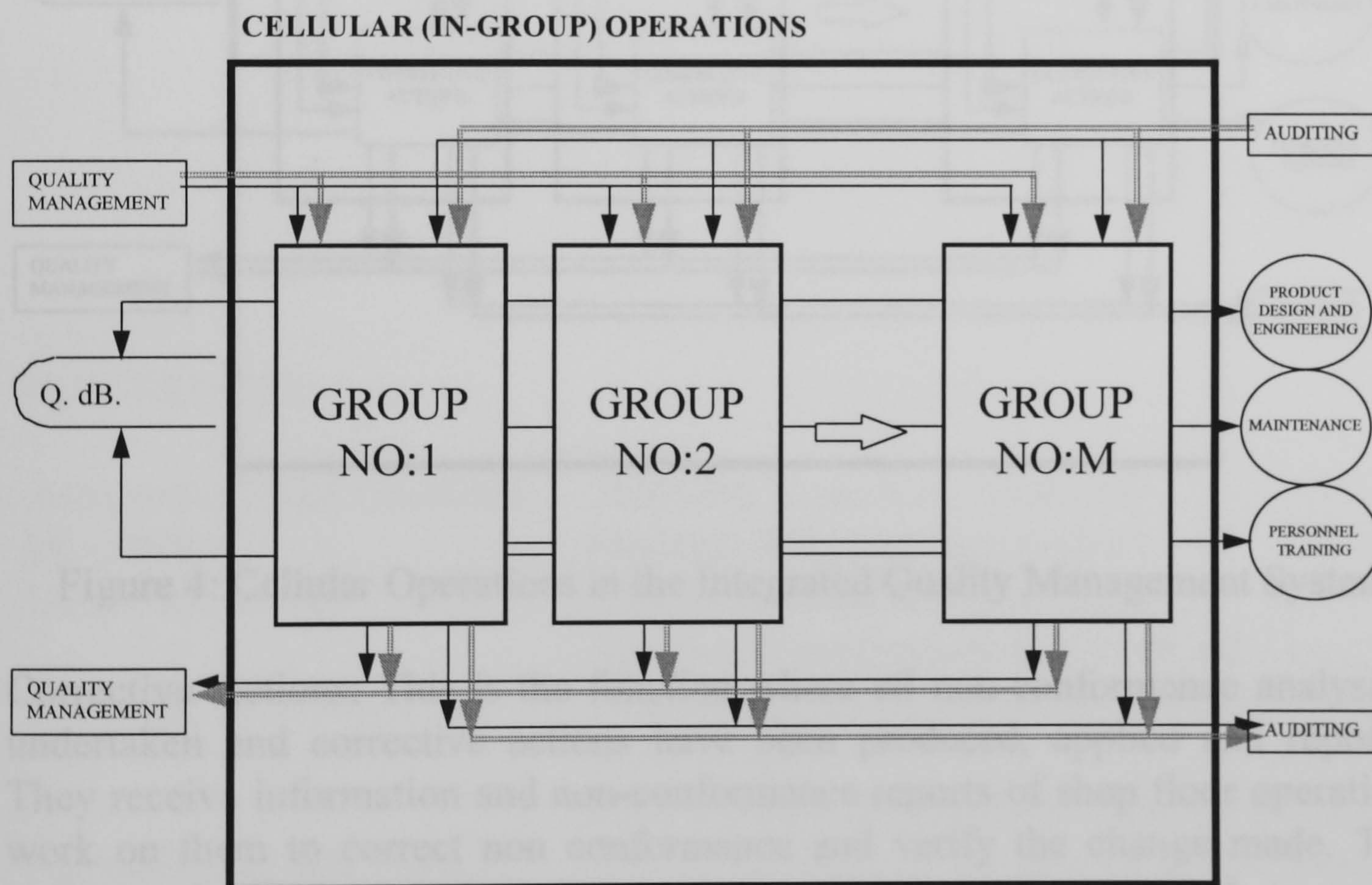


Figure 3: Boundaries of Cellular Operations

### Cellular (In-Groups) Operations

As is seen in Figure 3, each cell within the Cellular Operations boundary context is treated as a small business and the information flow is also set-up accordingly. Each cell is fed by information and materials in the similar way. Figure 4 shows activity boundaries of shop floor operations and corrective actions.

Shop Floor Operations: This function employs all quality control shop floor operations. Inspections, tests, calibration of measurement equipment, quality preventive activities are all within this functional area. They receive information, orders, work schedules, tasks, etc., together with materials (including information papers, forms, etc.). They process all orders/tasks and key-in the necessary preliminary results/information to a common Q.dB., and also pass the results with the paperwork to corrective action functions.

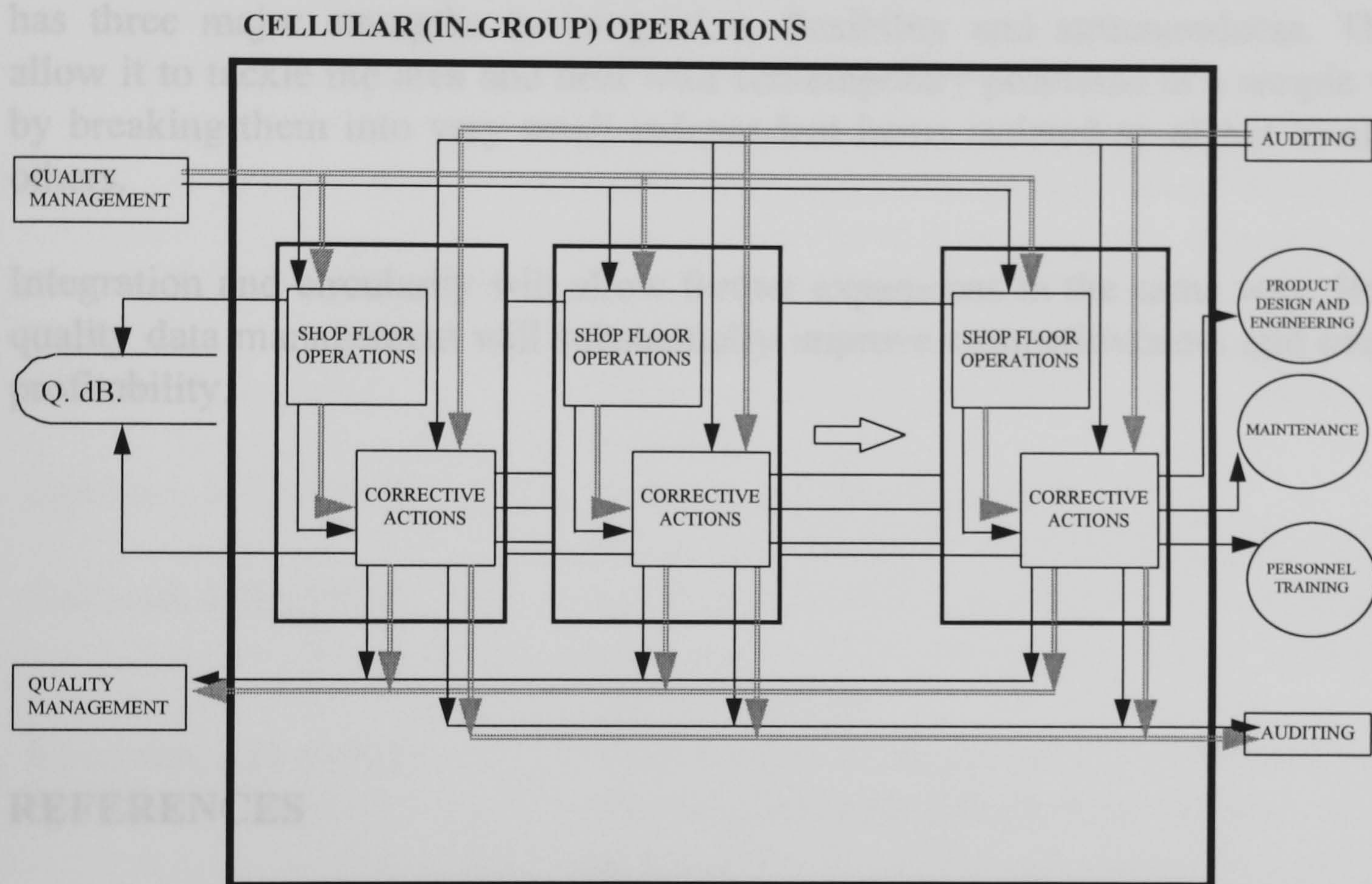


Figure 4: Cellular Operations in the Integrated Quality Management System

Corrective Actions: This is the function where all non-conformance analysis is undertaken and corrective actions have been produced, applied and reported. They receive information and non-conformance reports of shop floor operations, work on them to correct non conformance and verify the change made. They build up the data of the common quality database and report back to quality management for further analysis. According to the outcome of analysis and operations, they report to related bodies such as Product Design and Engineering, Maintenance and Personnel Training. They send information to the Auditing function as well. Within this area of activities a multi-skilled team called Material Review Board analysis inspection failure parts / materials to make a decision whether to scrap, repair or use as is. If a decision is taken, then the procedure for it also be written by MRB.

## Conclusions

Nowadays almost everywhere has become an international market. The competition, customer demand for greater precision, and shorter delivery times are day by day increasing. To challenge these growing pressures has become difficult with the conventional approaches.

The integrated quality management information system is designed to contemplate the problem as a whole starting from suppliers to the customers. It has three major strengths in integration, flexibility and structuredness. These allow it to tackle the area and deal with contemporary problems in a simple way by breaking them into very small independent items isolated so as not to affect others.

Integration and circularity will allow further expansions in the same way. Better quality data management will substantially improve competitiveness and overall profitability.

## REFERENCES

- Ashworth, C. and Goodland, M. (1990) 'SSADM; A practical Approach' McGraw Hill Company, Oxford
- Baran, J.J. (1991) 'Tips on tackling GT-based cells' Manufacturing Engineering, v106, n2
- Burbidge, J.L. (1989) Production Flow Analysis for Planning Group Technology Oxford science publications, Clarendon Press Oxford
- Burbidge, J.L. and Halsall, J.(1994) 'Group Technology and growth at Shalibane' Production Planning and Control, v5. n2, 213-218
- Dahlgaard, J.J. and Kristensen, K. and Kanji, K.G. (1994) 'The quality journey' Total Quality Management Journal Supplement, Carfax Publishing Co. Oxfordshire
- Deeming, T. (1993) 'Cell mates' Manufacturing Engineer, v72. n3
- Gandoff, M. (1989) 'System Analysis and Design' Heinemann Professional Publishing Ltd., Oxford
- Irfanoglu, O. (1994) Method Engineer. Msc., TUSAS Aerospace Industries Inc.

- Johnson, P. (1992) 'Unlocking the rewards of cellular manufacture' Machinery and Production Engineering, 21 February
- Kanji, G. K. (1990) 'Total Quality Management: The second industrial revolution' Total Quality Management Journal, nl, vl, 3-12
- Kanji, G. K.; Asher, M. (1993) 'Total Quality Management Process, A Systematic Approach' Total Quality Management Journal Supplement  
Carfax Publishing Company, Oxfordshire
- Kerr, R. (1991) 'Knowledge-Based Manufacturing Management Applications of artificial intelligence to the effective management of the manufacturing companies' Addison-Wesley Publishing Company, Inc. Printed in Singapore
- Knorr, R.O. and Thiede, E.F. (1991) 'Making New Technologies work' The Journal of Business Strategy, jan/feb 1991, pp46-49
- Menon, H.G. (1992) 'TQM in new product manufacturing' McGraw Hill Inc.USA
- Oakland, J. S. (1989) 'Total Quality Management' Heinemann Professional Publishing Ltd.,Oxford
- Oakland, J. S. (1993) 'Total Quality Management:The route to improving performance' Heinemann Professional Publishing Ltd., 2nd Ed. Oxford
- Rogerson, J.H. (1992) 'Total Quality Management in the Fabrication Industry' Welding and Metal Fabrication, October, v6O n8 pp375-377
- Sprague, R.H. and McNurlin, B.C. (1993) 'Information Systems Management in Practice' Prentice Hall Intentional, Inc. NJ
- Welke, H.A. and Overbeeke, J. (1988) 'Cellular manufacturing: A good technique for implementing just in time and total quality control' Industrial Engineering November, pp36-41
- Winter, P.J. and Gilbert, J.P. (1987) 'Flexible manufacturing systems: resistance and trends' Production and Inventory Management, First Quarter, v28 n1 p10-14
- Zairi, M. (1991) 'Total Quality Management for engineers' Woodhead Publishing Ltd. Cambridge, England

# TQM; A WAY TOWARDS TOTAL INTEGRATION

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## **Abstract**

This paper describes the result of a survey carried out in manufacturing environments to find out future trends and current implementation difficulties of quality management schemes. There is some evidence from the survey that the future of manufacturing systems lies within total information integration. Some of the companies have already achieved partial integration and many are considering establishing a totally integrated understanding of management. A total quality management philosophy can play a major role towards such total integration, which would probably result in new forms of management. Currently, it is also interesting to find that the required quality data is gathered on the shop-floor and then processed by middle management but does not influence top management quality policies as much as might be expected. However, total quality management based on continuous improvement is seen as a competitive advantage, although many companies and industries interpret it differently. It seems the new highway towards the factory of the future is illuminated by quality management.

## **Introduction**

Nowadays, in many cases a good quality management scheme can be a survival factor and can even be the key to prosperity. Manufacturers now concentrate on quality as a contemporary competitive advantage in the international market. Using this advantage in the right way broadens the frontiers of a company. It requires companies to be careful about certain things when it comes to the implementation of Total Quality Management (TQM). For instance, as is identified by Bertram (1991) and many other researchers (see for example Kanji and Asher 1993, and Oakland 1993) it is very difficult to implement TQM if top management fails to recognise its importance. Bertram said that the lack of top level commitment is the main reason for the upwards of 80 % failure rate on TQM programmes. Another important factor in implementing a TQM

programme is communication. Quimby et al (1991) define communication as encompassing all the ways and functions to support quality improvement. They say quality is about change, change is about behaviour and behaviour is about communication. Thus they use communication to mean any interaction that increases the probability of changed behaviour.

Furthermore Gundogan and Kay (1995) have summarised that in general the basic concepts of TQM are seen as customer satisfaction, continuous improvement, total quality control, continuous education and training, and total employee involvement. They state that structural changes are required to be made in the implementation of TQM and these changes are not easy because of their effects on other manufacturing management areas such as production planning and control, maintenance, product design and engineering.

### **Quality Management System Survey 1995**

Wilkinson et al (1994) pointed out from their survey that 71 % of their respondents claimed to have a formal quality management campaign, and a further 11 % were planning to introduce one. Our survey of Quality Management Systems carried out in March 1995 suggests that quality management systems are becoming more and more important and widespread.

This survey was carried out to assess the current quality management implementations from a systems analysis and design point of view, and to draw conclusions about their successes, integration with the other production management schemes, and their effects on future developments in manufacturing. Respondents were asked to select all of those choices that apply to them or their companies in each set of questions.

For this postal survey to be more effective, specific contacts were found at each of the sites surveyed. These contacts were individuals who are involved in the company's quality, manufacturing, production or system analysis programmes. They had mainly engineering backgrounds but all had a higher education or training in manufacturing management systems. With some of them, a face to face in-depth interview was also undertaken.

A total of 110 questionnaires were sent out to specific organisations. Thirty two questionnaires were returned resulting in an overall response rate of 29.1 %. As is seen in Figure 1, these manufacturing companies vary in size. Of the 32 questionnaires returned, 29 (26.4%) were used in the data interpretation.

## Implementation And Expectations

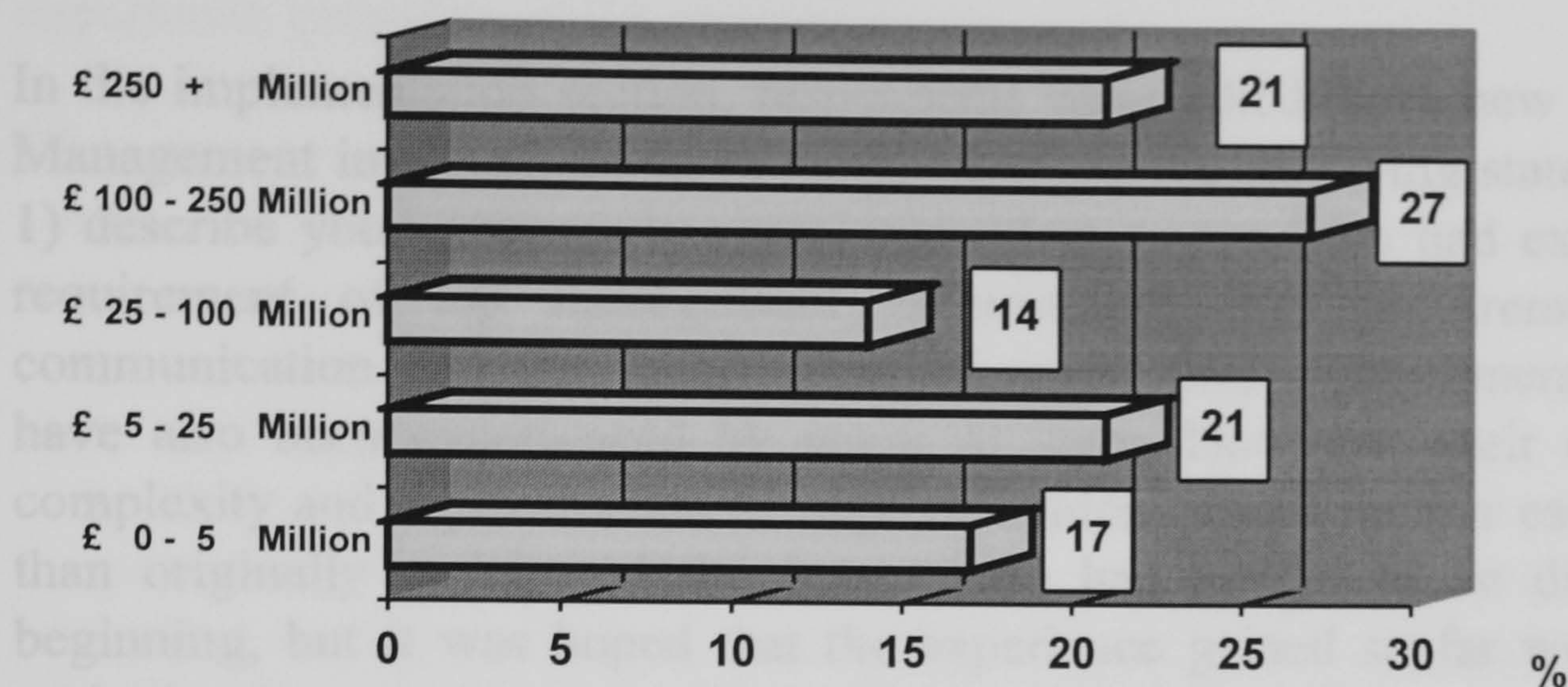


Figure 1. Turnover band of the respondent companies

### Structured Quality Policies

The first question was “do you or will you have a planned or structured quality policy?”. The great majority (86 %) of the 29 companies which responded either have, or are expecting to have, a planned or structured quality policy in the near future. The reasons for requiring a planned or structured quality policy are as follows:

Involved major departmental	
Involved	An internally determined need for improvement 88 %
Required	The need to keep pace with competitors 80 %
Required	Pressure from customers 68 %
Took	Need for departmental integration 28 %

These contributory factors illustrate the demands of competitors and customers. They result in the necessary motivation for companies to implement a planned or structured quality policy, to improve competitiveness and fulfil customer satisfaction.

In the second question, they were asked to assess the success of their quality management strategy in terms of various points such as profit, growth, integration, ease of adoption, implementation, communication, reporting and customer satisfaction. In terms of communication, profit, integration, growth and reporting there were many respondents who thought that their quality management strategy was weak. For the remaining factors, respondents considered that they had had a moderate, or high, success.



## Implementation And Expectations

In the implementation section, respondents were asked "in a new Total Quality Management implementation strategy, which of the following statements (Table 1) describe your company's experience. Most respondents had experienced the requirement of top management commitment. The requirement of good communication and the involvement of major time commitment respectively have also been experienced by many of them. However, their experience of complexity and sophistication of implementation proved neither easier nor faster than originally anticipated. Implementation had proved to be difficult in the beginning, but it was hoped that the experience gained so far would facilitate easier implementation in the future. In this section one of the cross-reference type questions was "implementation requires only management involvement". The response to this question, as was expected, was zero. Table 1 shows the requirements that had been experienced by respondents, in a new implementation strategy.

Table 1. Experienced requirements in a TQM implementation strategy

	Experience
Involved top management commitment	69 %
Required good communication	59%
Involved major time commitment	55%
Involved entire workforce	45%
Required personnel re-training	41%
Required change in the organisation structure	41%
Took longer than anticipated	38%
Harder than anticipated	35%
Required total change	35%
Required change in the data	35%
Required change in the work patterns	31%
Need external assistance to management change	21%
Involved major financial commitment	21%
Complex and sophisticated	7 %
Quicker than anticipated	3 %
Easier than anticipated	0 %
Involved of management only	0 %

In the implementation they experienced a need for total change (35% ). There is also a requirement of 35% for a change of data. They experienced the need for

entire workforce involvement (45%) but in the long term it is hoped that the experience gained would shrink this requirement.

With the implementation of a TQM philosophy, companies have also experienced a major beneficial change to their organisation (35%) and they expect this benefit to be increased to 38 % in the future.

### Data And Integration

Respondents were also asked to name the functions (or departments) that are integrated or they think should be integrated with quality (Figure 2.). There is a considerable tendency towards total integration. Currently production (79%), supplier information (66%), and product design and engineering (59%) seem to be somehow integrated with quality. In the future, however, maintenance (55%), sales and marketing (45%), personnel training (35%), and production design and engineering (31%) seem to be on the top of the integration agenda. It is also notable that finance is currently least integrated (14%) and only 38% expected it to be integrated with the quality management scheme in the future. There are also a number of respondents (10%) who think that finance should not be integrated with the quality management.

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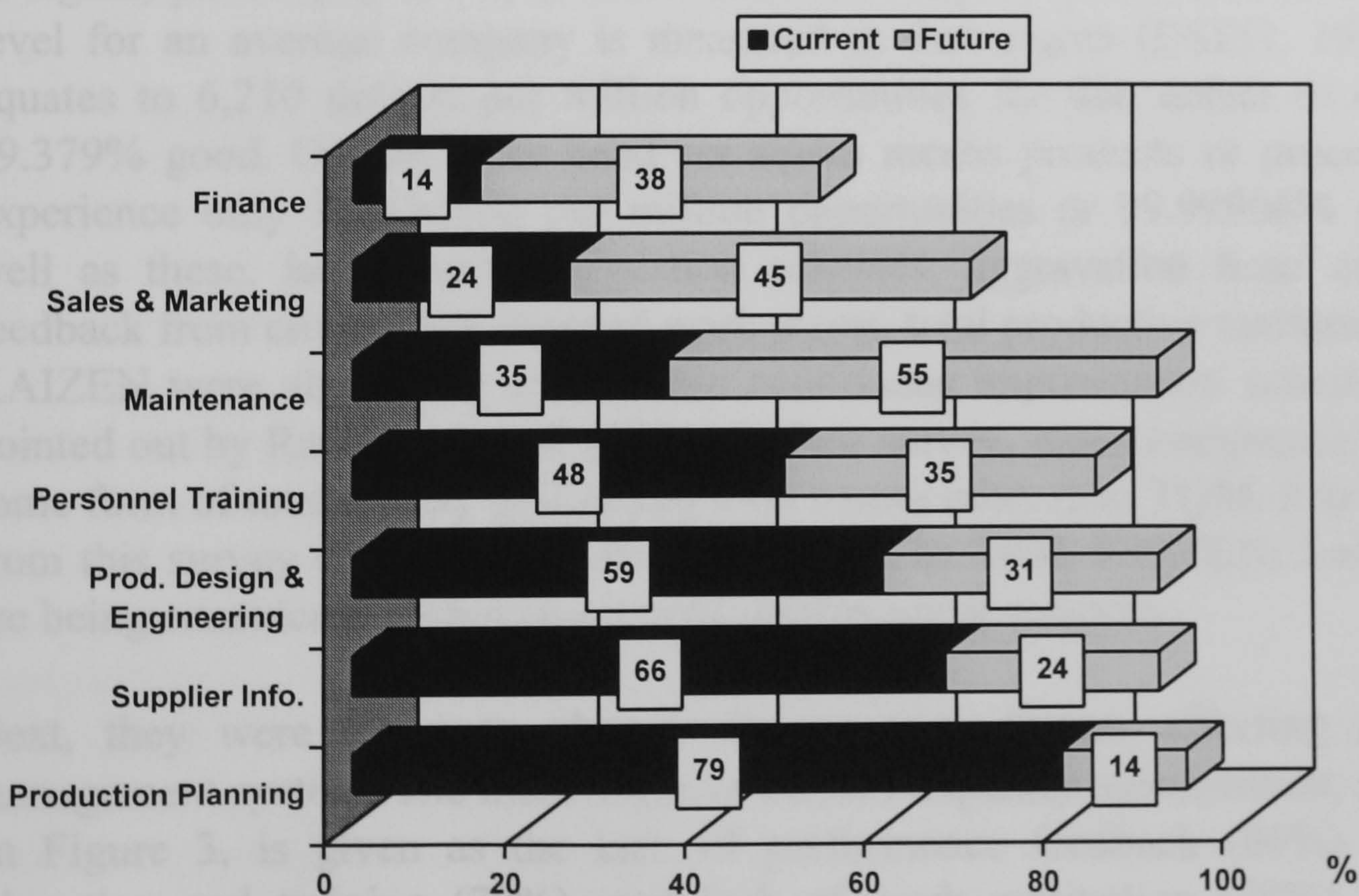


Figure 2. Current situation and future expectation with respect to the integration

In the questions which relate to data processing, respondents were asked to select the sentences which apply to their company. Many respondents think that the required quality management data is gathered on the shop floor (66%). Then the data gathered is best processed by the supervision or middle management (69%). However, most of them think that the results of this analysis do not affect the top management and quality policies. It affects the top management and quality policies in only 41% of companies. This may be for many reasons but could be because of a lack of communication between top management and supervision, lack of organisational change etc. There were also a considerable number of respondents who implied that the data collection was incomplete and that therefore the data processing was unsatisfactory. The root cause for this might be the lack of feedback from top management.

### **Quality Improvement Resources and Customer Satisfaction**

Respondents were asked if they have a continuous improvement scheme or not. The greater majority of the sites (79%) have some sort of a continuous improvement scheme. Most of the respondent companies carry out quality improvement projects (72%) and have regular meetings (55%) for the continuous improvement process. Communication schemes (48%), SPC tools (48%) and benchmarking (41%) were also commonly used for the continuous improvement. There were also a considerable number of companies which used the zero defect (6 sigma) philosophy (24%) as their continuous improvement scheme. The sigma level for an average company is measured at four sigma (DSEG, 1992). This equates to 6,210 defects per million opportunities for that defect to occur i.e. 99.379% good. On the other hand six sigma means products or processes will experience only 3.4 defects per million opportunities or 99.99966% good. As well as these, lean teams, suggestion schemes, aggravation from customers, feedback from clients, self directed work teams, total productive maintenance and KAIZEN were also being used within continuous improvement schemes. As is pointed out by Randhawa et al. (1994) in their survey, many companies are using some form of total quality philosophy with names other than TQM. It is also seen from this survey that mature philosophies such as TPM, KAIZEN, Lean Teams are being considered within continuous improvement schemes.

Next, they were asked to identify the negative factors affecting a quality management system. The most negative effect on quality management, as is seen on Figure 3, is given as the lack of performance feedback (86%). Lack of education and training (79%), and lack of work motivation (79%) are other important factors creating negative effects on quality management. If the span of control is too small only 24% thought it had a negative effect on the quality management. So within this context it could be very useful to break a management scheme into small well defined integrated activities. However, if the

span of control is going to be too large we would see some negative effects in quality management. This case is also seen in the overlapping responsibilities. More than half of the respondents think that overlapping responsibilities create negative effects on quality management.

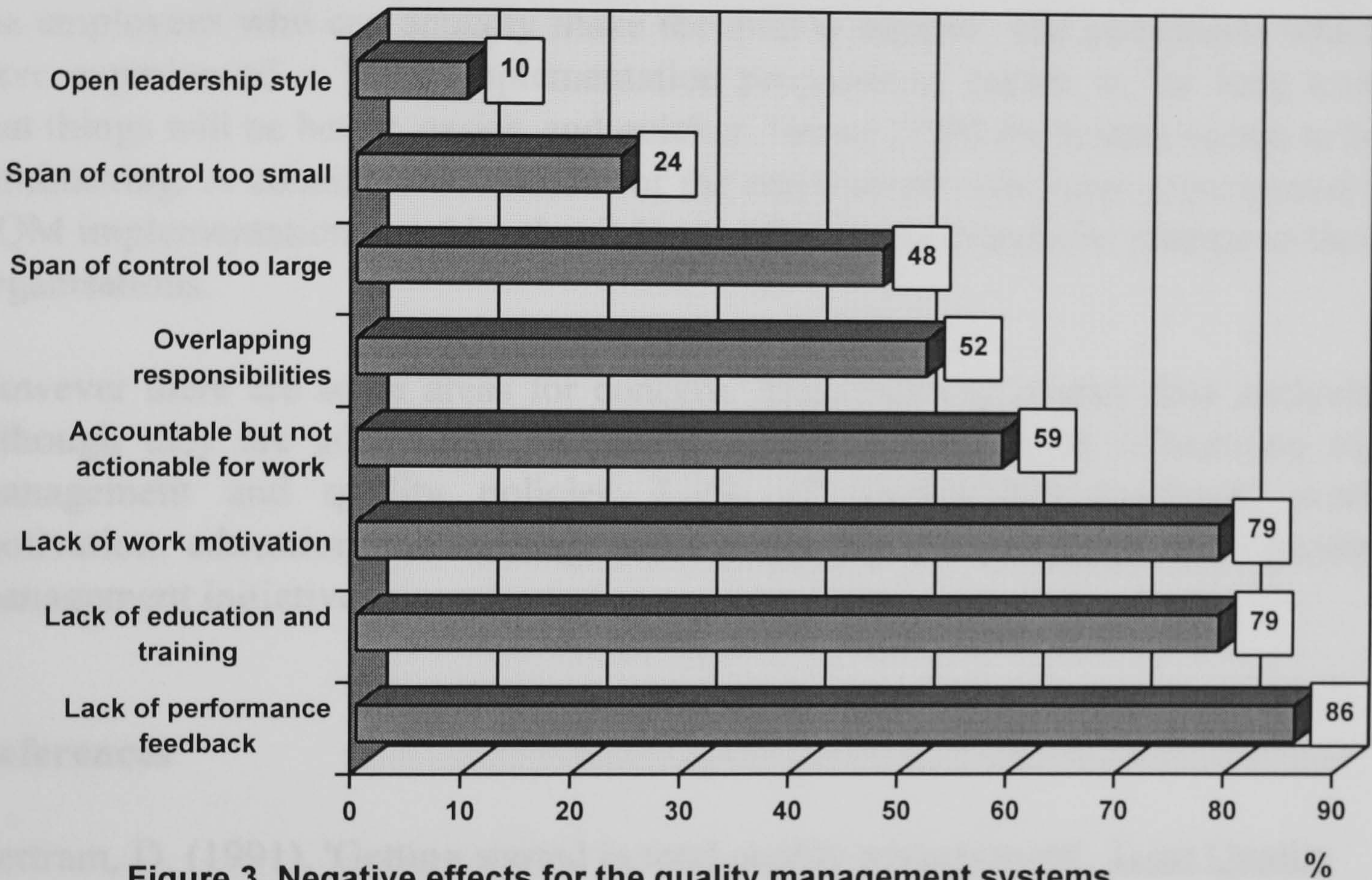


Figure 3. Negative effects for the quality management systems

Finally, respondents were asked if they do measure customer satisfaction and how. The most important thing for customer satisfaction seems to be monitoring customer complaints (86%). Analysing product returns and warranties (59%) is the second most important tool for customer satisfaction. Keeping up with the competition is also an important factor for customer satisfaction. Sending out audit forms to be filled in i.e. doing post-pack audits (24%) and asking customers to complete an installation record or service card (7%) are the least important measurements to be used to measure customer satisfaction.

## Conclusions

Overall, the results of the survey gave some interesting and encouraging signals. The message of quality as a strategic weapon for contemporary competitiveness seemed to be getting through the manufacturing environment. Companies have started thinking of systematisation of quality management and introducing it to non-production departments with an integrated approach. It seems it is well-established that it is not only managers who are responsible for quality, but also the employees who can actually make the quality happen. The companies which have experienced a TQM implementation programme, expect in the long term that things will be better, easier, and quicker. Hence TQM frustration seems to be diminishing. A considerable number of the respondents who have experienced a TQM implementation consider that it has made a major beneficial change to their organisations.

However there are some areas for concern. The results of quality data analysis, although they are adequately processed, do not appear to be influencing top management and quality policies. Lack of performance feedback, work motivation, education and training could jeopardise the commitment to quality management initiatives.

## References

Bertram, D. (1991). 'Getting started in total quality management'. Total Quality Management, vol.2, no.3.

DSEG. (1992). *What is six sigma?*. Texas Instruments, TI-29077, F21110, The USA.

Gundogan, M. and Kay, J.M. (1995). An integrated total quality management philosophy within group technology cells. In: *International conference proceedings on planned maintenance reliability and quality assurance*, 6th-7th April 1995, Cambridge, 59-64.

Kanji, G. K. and Asher, M. (1993). *Total Quality Management Process, A Systematic Approach*. Total Quality Management Journal Supplement Carfax Publishing Company, Oxfordshire.

Oakland, J. S. (1993). *Total Quality Management: The route to improving performance*. Heinemann Professional Publishing Ltd., 2nd Ed., Oxford.

Quimby, C., Parker, L. and Weimerskirch, A. M. (1991). 'How, exactly, do you communicate quality?'. Quality Progress, (June). vol.24. no.6.

Randhawa, S.U. and McDowell, E.D. and Tabaka, P.J. and Howard, N.L. (1994). 'TQM practices: A survey of companies in the pacific Northwest'. Industrial Engineering, vol.26, no.10, 28-30.

Wilkinson, A., Redman, T. and Snape, E. (1994). 'What is happening in quality management?:Findings from an IM Survey'. The TQM Magazine, vol. 6. no.1.