An Investigation into the Need and Implementation of Total Productive Maintenance (TPM) in Libyan Cement Industry

Mustafa Mohamed Graisa

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بسْمِ اللهِ الرَّحْمنِ الرَّحِيمِ

"يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ و اللَّهُ بِمَا تَعْمَلُونَ خَبيرٌ" سورة المجادلة الآية 11.

بِسْمِ اللهِ الرَّحْمنِ الرَّحِيمِ

الأهداء

"الى روح أبى الطاهره ....والى التى بدعائها وصلت الى هذه الدرجة من العلم ... أمى "

أهديهما هذه الرسالة

أبنكم

مصطفى قريصة

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ABSTRACT

The international competition and the demand to increase productivity of manufacturing and production lines have attracted the management of industrial organisations from a wide spectrum to implement Total Productive Maintenance (TPM) as a tool for improving productivity and system's output.

Some Libyan companies are still facing many problems concerning maintenance activities of assets. Inadequate maintenance can have cost impact on the maintenance performance and production. Following the privatisation of the Cement industry in Libya, companies are now interested in improving productivity, reducing cost, improving maintenance procedures and reducing the negative effect on the environment.

To address the above issues within the Libyan industry, this research presents an investigation into the need for implementation of Total Productive Maintenance (TPM) in Libyan cement industry. TPM is a generic maintenance philosophy that transforms maintenance activities from what is considered to be the 'necessary evil' into an essential part of the business. In TPM, maintenance and downtime is integrated within the production system and scheduled as an essential part of the manufacturing process.

This thesis investigates the problems facing four cement factories in Libya. Following a comprehensive literature review around the research problem; case studies, statistical data, semi-structured interviews, detailed questionnaires and site visits are utilised to evaluate and understand the problems within the four factories. Based on the analysis, this thesis suggests a new Framework and associated models for implementing Total Productive Maintenance (TPM) and identifying the key Factors to improve the overall maintenance performance.

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Abbreviations

Abbreviations and key words used in this thesis are as follow:

NCC …….. National Cement Company.

MCF ……. Mergeb Cement Factory .

LCF …….. Libda Cement Factory.

ZCF …….. Zeleten Cement Factory.

SCF …….. Souq al-Kames cement Factory.

DM ……...daily maintenance.

KPIs ………Key performance indicators **.**

MQFD…….. Maintenance quality function deployment.

MDT …….. Main down time.

MTTR ….... Mean time to repair.

MTBF ……. Mean time between failures.

NOC …….. National Oil Corporation.

OEE …….. Overall equipment effectiveness.

OP.Time…Optimum time **.**

QFD ………Quality function deployment **.**

PM ………. Preventive maintenance.

RTF………. Run-To- Failure.

RCA………Root cause analysis.

TQM………Total quality management.

TPM ………Total productive maintenance **.**

JIT ………. Just-In-Time.

CPMS…….. Comprehensive Productivity Maintenance Strategy.

CBP……….. Centre of Best Practice.

R&M………..research and Maintenance.

MMP………. Modern Maintenance Productivity.

Tri (X,Y,Z)…Triangular distribution of minimum of x, model of y and maximum of z.

Nor (X,Y,Z)….Normal distribution of average x and standard deviation y.

CHAPTER 1: INTRODUCTION

This chapter introduces the research domain. It presents the main aims and objectives of this research work. It outlines the basic background information, regarding the Libyan industry and cement production which leads into introducing the research problems, methodology and the structure of this thesis.

1.1 Background

As industry becomes increasingly capital intensive, and the relative cost of assets increases, so does the importance of maintaining these assets. This tendency is particularly true for industries with continuous processes. Here, the economic, safety, and the environmental consequences of equipment failure can be enormous. The increasing complexity of the equipment also has a profound influence on its maintenance. The maintenance function has become more specialised and costly.

Many researchers have elaborated on some of the aspects of maintenance. Husband, (1976) defined maintenance as the combination of all technical and associated actions intended to preserve an equipment item or restore it to a state in which it can perform its assigned function.
Many organisations in the UK, Middle East and North Africa have realised that significant savings can be made by managing maintenance in an effective way. Some of the advantages are increased production uptime, lower maintenance costs, and decreased safety and environmental risks.

The National Cement Company (NCC) is the largest cement company in Libya. It is continuously trying to improve its productivity and reduce costs to become more profitable. As part of this mission, this research work attempts to address the current problems within the company, and to advance the knowledge and the required skills by developing a comprehensive maintenance strategy that could optimise their maintenance and production activities and outcomes.

In general, maintenance strategies in Libya are based on assumptions built on experience from previous work and related theories, which most of the time have been extracted from other companies. This could cause some dissatisfaction with the measures and indicators that are used to perform and monitor maintenance work. In many cases, unsuitable key performance indicators (KPIs) are used for statistical evaluation of performance. To select appropriate statistical or key performance indicators, it is important for the maintenance strategy to take into consideration the circumstances in the company, and address the particular aspects within its environment.

This led NCC to give special attention to the importance of the maintenance management system to maintain good record keeping, such as equipment historical data and cost information. To create a general awareness of relevant management systems and maintenance topics among the section and departments of NCC, there is a desire to develop some techniques to enhance the performance of maintenance tasks. One of these techniques is Total Productive Maintenance (TPM), which will enhance employees' participation. TPM is a generic maintenance philosophy that transforms maintenance activities from what is considered to be the 'necessary evil' into an essential part of the business. In TPM, maintenance and downtime is integrated within the production system and scheduled as an essential part of the manufacturing process.

Despite the company's effort to introduce Total Productive Maintenance and other relevant strategies, there are still many general issues and parameters that should be addressed, in the following area:

1. Understanding and evaluating current production problems and practice in the National Cement Company and its four factories;
2. The current technical and cultural problems within the factories, and the actual availability of their machines;
3. Lack of knowledge and information regarding skills and the training requirements of their employees;

4. Lack of a suitable model or framework to address the problems in the factories;
5. Evaluation of the effect of the factories on the environment;
6. Lack of a methodology for decision-making regarding technical, maintenance and production issues;
7. The selection of key factors that could be used for developing and evaluating suitable maintenance strategies; and
8. Lack of information on the effect of each process on the overall productivity of the factory.

The majority of the above issues have been addressed in research and literature for different companies. However, Libya has a unique political, social and economic system which makes addressing strategic issues in large companies a complex task due to the possibility of misuse of the social and political system by the employees. Similar to the challenges some companies in the West face with trade unions, companies in Libya face with its employees. Central government in Libya is made up of General People's Committees (GPCs) that cover the core national issues, including finance, justice, economy and trade, workforce and training, planning and tourism, energy, etc. Secretaries of the GPCs hold the equivalent of Ministerial rank and act as a link between the People's Committees and the Executive, see Figure 1-1.

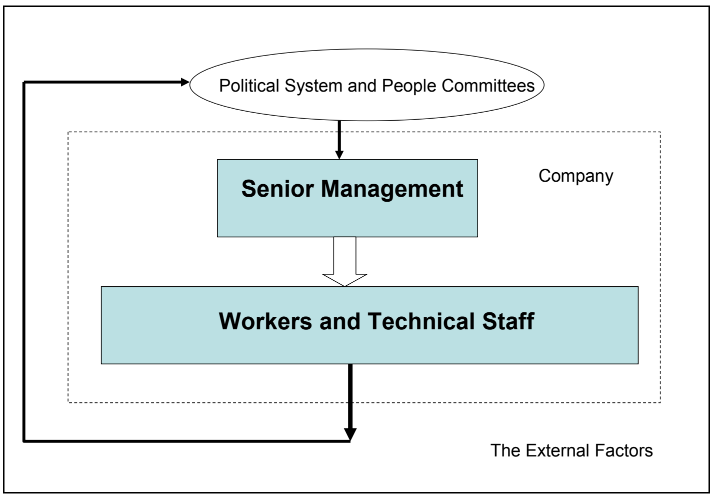


Figure 1-1: The unique influence of the political system and the external factors on the management process of the company and the factories(Author).

As presented in Figure 1-1, this means that companies are controlled by the employees and they have the authority, via their local People's Committees to change the head of departments and chief executives, which makes it challenging in two ways:

1. People with no management or technical experience could take a leading role; and
2. Changes of management and operational systems could be seen as undesirable actions and hence the people's committees could misuse their authorities.

This means that, there are many challenges to developing new strategies, whilst keeping employees happy and involved in the process.
In addition to the above, the political situation and embargo "between 1990 to 2003" on Libya by the United Nations has caused a negative effect on the availability of modern industrial technologies and technical training, which made it extremely difficult to maintain and sustain a productive and efficient culture within factories.

It is generally recognised that actual planning work must be done by a project team, but in NCC the initiative comes directly from the top management, and in some cases they play a direct part in the planning process (Al-Hassan et al 2002). Maintenance planning, of course, should be based on research and the more comprehensive and long term the planning is, the more important research becomes. Production, marketing, even personnel and social factors must be investigated (Fridrich, 1974) yet, at NCC, research efforts are generally rated relatively low.

As stated by Moubray (1997), British factories spend about £2 billion annually on equipment maintenance or maintenance related work. This may appear to be a large Figure but it could offer scope for considerable saving. Even a 1% saving would recover to £20 million (M) .

1.2 Research Problem

Some Libyan companies are still facing many problems concerning maintenance activities of assets. Inadequate maintenance can cause cost impact on the maintenance performance and the production process. Following the privatisation of the cement industry in Libya, companies are now interested in improving productivity, reducing costs, improving maintenance procedures, and reducing the damage to the environment.

Some maintenance managers in Libya assume that by adding standby equipment or systems, the equipment availability can be improved. On other situations, operate until failure is considered to be the most practical maintenance strategy in many of the companies in Libya. But this situation could lead to more resource, spare parts and manpower requirements. Other companies believe that automation will reduce depending on manpower and hence improve productivity; however, automation would require more skilled personnel and more investment in training. There are clear maintenance and production problems at the moment in Libyan cement factories caused by the non-standardisation of equipment, the lack of well-defined maintenance strategies, and systematic implementation of technical methodologies and evaluation techniques of systems' performance. The non-standardisation indicates that more training is needed for each machine or production line. National Cement Company (NCC) is one of the main cement companies in Libya and it has 4 cement factories near Tripoli, two in *Alkhums* (*Libda* (LCF) and *Merqeb* (MCF), one in *Zeleten* City (ZCF) and one in *Suq Al-Khames* (SCF). The company is interested in developing its knowledge and services in TPM and maintenance management. It is looking for new framework for its maintenance strategies and their implementation. These include definition of problems, identifying key factors and developing a suitable TPM model. This becomes of great importance, given the social structure and the local people's committees influence on any strategic decisions.

1.3 The Research Question

The National Cement Company (NCC) is one of the largest companies in Libya and one of the largest producers in North Africa. NCC is located in the North-west region of Libya. It has a cement production target of 3,330,000 tonnes per annum. NCC also has additional manufacturing facilities to produce gypsum, lime, factory bags, factory block, marble, concrete plant and Cement mixes. The company comprises four cement factories: Alkhumes/Margeb (MCF), Souq Alkames (SCF), Alkhumes/Libda (LCF) and Zeleten (ZSF). Cement produced from the four factories is for internal consumption due to the fact that the total production is required for the infrastructure of Libya. NCC produces cement according to specific Libyan specifications, which are similar to those of British Portland cement. It uses a dry process method in all of the factories. This cement is used for many construction purposes, particularly for building houses, bridges, roads, and ports. The author has worked in the company for about ten years. This has led to developing the research ideas, and identifying the following research questions that need to be answered in this thesis:

1. What are the problems facing the Libyan industry and the cement sector in particular and what are the key factors influencing the cement industry in Libya?
2. What are the limitations in the current practice in the production of cement in the NCC and what are the human-factor aspects that should be addressed in implementing TPM (including training and personal development)?
3. What are the cultural issues that should be addressed when designing a maintenance strategy and a TPM model?
4. What is the main effect of the current industry on the environment?
5. What is the effect of the political history and current local People's Committees on the cement industry in Libya, including the availability of spare parts and maintenance expertise?
6. What are the main aspects to be considered in a TPM model for the Libyan industry?
7. How can the TPM model be implemented in Libya, taking in to consideration all the issues that have been addressed in the previous research questions?

1.4 Research Aim and Objectives

This thesis aims to perform a performance evaluation of maintenance related functions within the Libyan cement production industry. As a continuous process, maintenance in cement production becomes the critical factor that influences productivity. The purpose of the study is to investigate the current problems and practice in the production of cement at NCC. This study evaluates the steps needed to implement Total Productive Maintenance (TPM), based on how it is defined by *Nakajima (1988)* and other Western authors *Charles & Andrew* (1995). It will take into account the culture of Libyan companies. The proposed solution or strategy should be supported by a suitable maintenance management system, a decision making process, and a staff development framework. Selecting key factors or statistical analysis that could influence maintenance performance is the other element proposed by this research, together with investigating the use and implementation of suitable tools or strategies to understand and control the production and maintenance activities.

1.4.1 Research Aim

The main aim of this study is to investigate the need and possibility of implement of Total Productive Maintenance (TPM) in the Libyan cement industry. It will investigate the effect of maintenance functions/activities on productivity, competitiveness, and the profitability of the four factories.

This thesis will investigate the problems facing four cement factories at the National Cement Company (NCC). Based on the findings, it may suggest a new framework for implementing Total Productive Maintenance (TPM), supported by a computerised simulation system, and identifying the key factors to improve the overall maintenance performance.

1.4.2 Objectives

The main objectives of the thesis are to answer the research questions described previously. The main objectives can be summarised as follows:

1. To Evaluate the performance and problems of the Libyan industry in general and the cement industry in particular.

2. To identify key factors influencing the cement factories.
3. To compare the productivity and performance of Libyan cement industry with other countries to establish a suitable benchmark.
4. To proposing a suitable implementation model and framework of TPM for the cement factories in Libya, taking into account the local organisational behaviour.

TPM is a generic maintenance philosophy that transforms maintenance activities from what is considered to be the 'necessary evil' into an essential part of the business. In TPM, maintenance and downtime is integrated within the production system and scheduled as an essential part of the manufacturing process.

This thesis will investigate some of the problems which the Libyan industry is facing, assess the need for TPM, and suggest a model for the cement factories in consideration.

1.4.3 Research Methodology

It is essential to have a clear and suitable methodology to achieve the objectives of this study. The selected methodology influences the validity, reliability and generalisability of the research results. Many different research methods have been described by various authors. Research methods including action research, case studies, experiments and surveys have been described by Gill and Johnson (1991), Bryman (1989), Mandy, (2004). Each method has advantages and disadvantages, and the reliability and validity of the data collected is different one from method to another. This work was initiated by the author as a result of facing productivity and maintenance problems during his work in the LCF. This was developed to this current research work in order to investigate the current problems and possible solutions. A literature review is conducted within the domain of this research work to investigate the general aspects within this work. This is followed by collecting statistical data from the factories, field observations, case studies, questionnaires and semi-structured interviews. Figure 1-2 presents the methodology used in this research work.

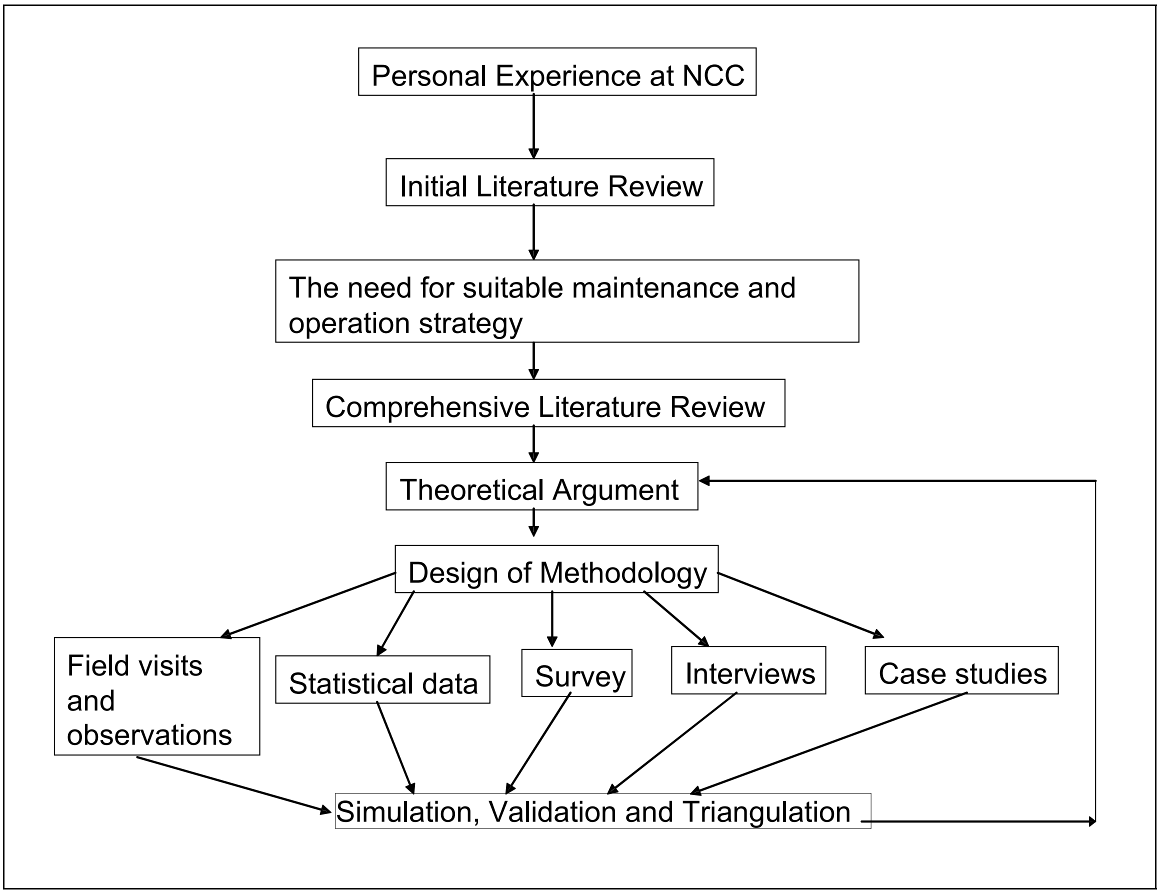


Figure 1-2: The research approach and methodologies that are implemented in this research work(Author).

Both quantitative and qualitative research methods are used in this thesis. This research is carefully designed in order to meet the time scale of a PhD thesis. The researcher decided to use four factories within the same company to collect data and perform the required analysis. National Cement Company (NCC) is the largest cement company in Libya. It has four cement factories: two in *Alkhums* (*Libda* (LCF) and *Merqeb* (MCF), one in *Zeleten* City (ZCF) and one in *Suq Al-Khames* (SCF). The author has worked in one of the factories for more than 10 years. This has led to the development of the research idea and to collaborate with the company in addressing its problems to improve productivity and reduce maintenance costs. The theoretical production of the four factories could reach 3350 thousand tonnes per annum based on company's data as will be discussed later in Chapter 5. However, the current production level for the four factories is about 60% to 70% of this theoretical level. This is the main reason for the author working with the company to address such issues. The author used his experience, combined with the initial literature review to develop the process, and to conduct the necessary literature review and state-of-the-art in the field of research. Based on this, the research problems have been identified, and the definition of the research aims and objectives were constructed in relation to the need and implementation of maintenance strategies in the four factories, combined with the initial theoretical argument regarding TPM implementation at NCC. The methodology used to conduct this work, as will be described in detail in Chapter 3, started with field work and observation in the four factories. According to Alan and Naikan (1989) it is essential for gaining first-hand knowledge, primarily during observation of employees as they go about their normal work activities. In addition to observing their behaviour, the author monitored the overall environment, and took photographs and collected evidence related to the condition of the production system. The author listened to what people said to each other, engaged in conversations, and used some people as informants about what was going on. This allowed the author to see behind the formal aspects of company settings, and revealed a rich, and possibly concealed issues and production problems.

During the field work, statistical production and maintenance data was collected to evaluate the general performance of the factories and to identify any current limitations or observations that could feed into future stages of the study. The field work and statistical data helped in developing and investigating the initial concepts, using questionnaires/survey in order to evaluate staff responses and ideas. According to Geoff (2005) surveys are used to collect data through questioning. In this research the author explored relationships between variables through structured questioning, and compared the extracted analytical data with data retrieved from other methods. The surveys were given to company employees and the results of the questionnaire are validated in comparison with statistical data, case studies, and interviews with company managers and chief engineers.

Interviews allowed the author to acquire more details and greater insight of the problem and issues concerned. Interviews are used in this work to discuss with middle and top managers and engineers all of the issues covered in the fieldwork, and observations and questionnaires to uncover specific information that might not have been obvious and also to allow the validation process through triangulation and comparison between different techniques. Semi-structured interviews are used in this research work where the interviewer started with a group of questions, but, based on the response of the interviewee, further discussion was generated on-line to investigate the subject further, which added high flexibility to the process.

The author in this research work has utilised several case studies from the maintenance department at NCC. Through those case studies, the author attempted to understand the overall situation in the company in order to implement a suitable strategy for Total Productive Maintenance (TPM), including methods and procedures that could be applied in the company with some supportive tools. The case studies implemented in this work are based on a mix of quantitative and qualitative evidence, combined with direct detailed observations. Both quantitative and qualitative approaches were used in this thesis. The case study is based upon evaluating the maintenance performance and criteria applied in NCC by analysing the maintenance performance and discussing the possibility to implement the TPM.

Geoff (2005 p76) stated that “case studies are concerned with measuring and looking at what is there and how to get there. It can enable the researcher to explore, and understand problems, issues, and relationships in a particular situation”. However, “the purpose of the case study method is to obtain information from one or a few situations that are similar to the researcher’s problem situation”.

The results collected from the different methods are discussed and compared in order to validate the outcomes and the conclusions Paul and Lynne, (2001). Simulation is also used to model the system on a micro scale in order to fully understand the system using quantitative data. Based on the findings from all methods, a new framework for implementing TPM is suggested. The framework is then evaluated using a final survey and its validity is discussed in detail.

1.5 Research Design and Thesis Structure

The purpose of this chapter is to determine the main aims and objectives of this research work. The following chapters in this thesis will be presented as shown in Figure 1-3 as follows:

Chapter 1: Introduction.
Chapter 2: Provides a summarised review of maintenance strategies and practices. The chapter presents a literature review in this area, and current problems that could face the developers of generic maintenance strategies. The chapter also introduces the main concept of Total Productive Maintenance (TPM). It describes the main issues and pillars that are needed to develop a successful TPM system.
Chapter 3: Provides details regarding the methodology implemented in this research work.
Chapter 4: This chapter presents and describes the context of the problem. It introduces the NCC and its factories, its operations and cement production processes. It identifies the generic problem that is facing the four factories and discusses the methodology that will be used during the rest of the thesis.
Chapter 5: This chapter describes the statistical data obtained from the company to identify key indicators and identify some of the key problems that face the company.
Chapter 6: This chapter presents the field visits related to productivity and the environment. It will describe comparative results between cement factories in the UK in comparison to the NCC factories. It will also discuss and identify the effect the factories have on the environment.
Chapter 7: This is the main quantitative chapter, using a questionnaire to investigate and identify problems in current practice, and future issues that should be taken into consideration for the implementation of TPM.

Chapter 8: This chapter includes the qualitative and quantitative analysis of the semi-structured interviews with managers. The chapter includes comparison between the previous findings and the opinion of managers about their findings and the implementation of TPM.

Chapter 9: Presents simulation of the production system using Simprocess software to evaluate the capability of the system and compare, the statistical data and the data captured by other methods.

Chapter 10: Introducing the application of the findings and understanding of the research domain into a new Framework to help implementing TPM in the Libya industry to improve productivity.

Chapter 11: Includes validation of the suggested framework and its associated models and includes further details to the suggested Framework.

Chapter 12: Conclusion of the generic findings, and discussion of the limitations of the research. The chapter will contribute to the knowledge and offer the proposition for future work.

1.6 Summary

The chapter introduced the research domain and problems for addressing current practice and the investigation of the need and the implementation of TPM in four Libyan Cement factories. It presented the main aim and objectives of this research work. It outlined basic background information, which leads into introducing the research problems and methodology. Figure 1-3 presented another of the structure of the thesis.

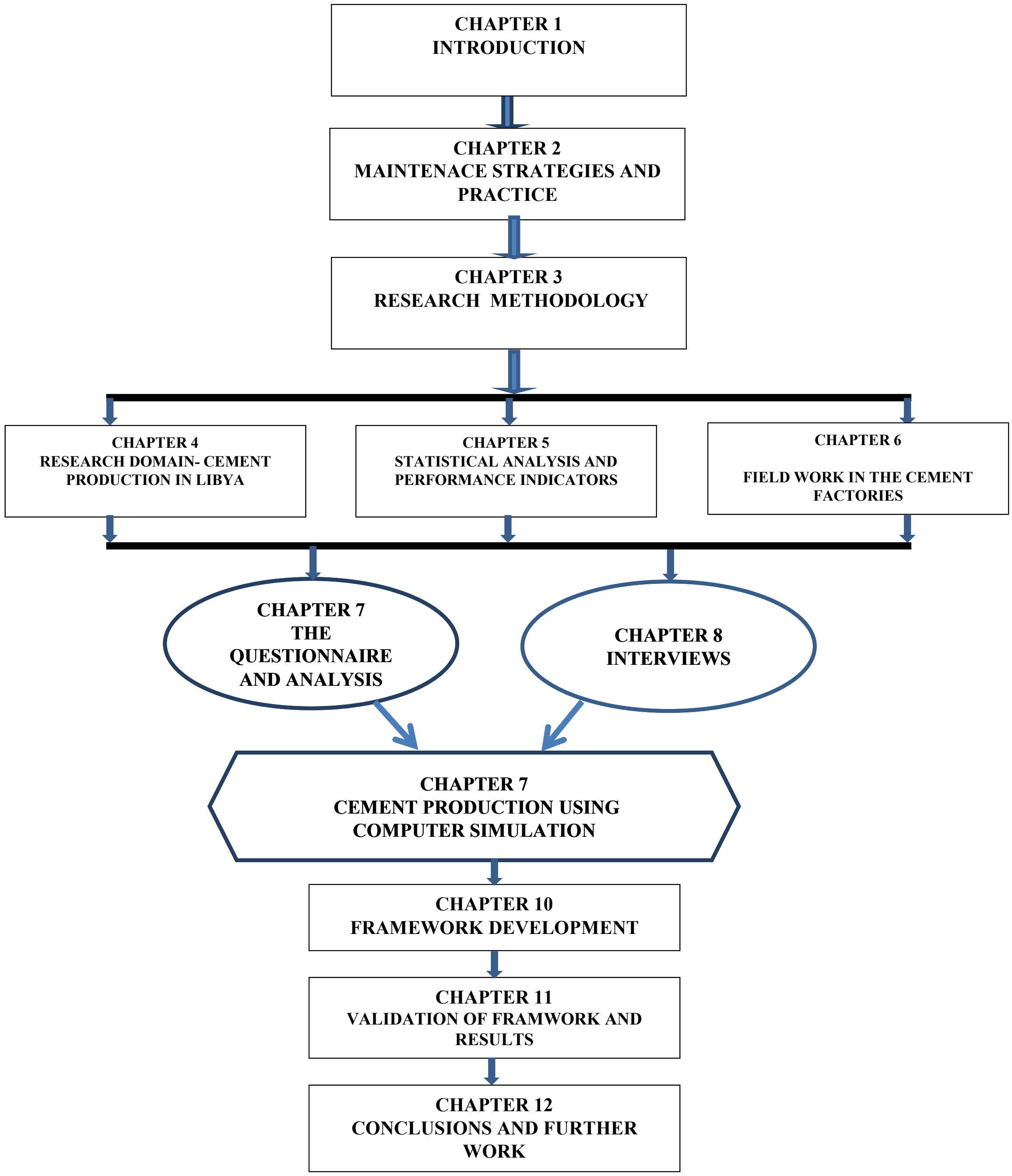


Figure 1-3: The chapter also included the structure and the research design(Author).

CHAPTER 2: Literature Review: Maintenance Strategies and Practice

Abstract

This chapter describes maintenance strategies and practice. It presents a comprehensive literature review in this area and current problems that could face the developers of maintenance strategies. This chapter also outlines the concept of Total Productive Maintenance (TPM) and the problems in implementing TPM strategies, particularly in Middle East and Africa. The chapter provides the reader of background regarding maintenance strategies and practice and outlines some of the industrial problems and previous research work in this area.

2.1 Introduction

For far too long, failures of machines have been thought of as inevitable events within any production system and engineers used to consider maintenance as repair operations and it was normally named as Breakdown or Reactive Maintenance.

According to (Murty and Naikan, 1989), Manufacturing in UK spends 14 Billion pounds on maintenance, one –fifth of the total value of all plant equipment. To which must be added the cost of maintenance breakdowns, usually downtime following breakdowns and quality failures because equipment was not properly set up. According to a study reported by CarlosManuel et al., (2008), 15-40% (with an average of 28%) of the final cost of finished goods can be attributed to maintenance activities in the plant. The integration of maintenance activities into manufacture is an efficient way of enhancing a company’s capability to handle manufacture losses and quality defects. This can get better competitiveness and extend the work content for production employees.

In 1950 some groups of Japanese engineering started new concept in maintenance that should be taken in the operation of the maintenance. That new trend was called “Preventive Maintenance”. As a result plant managers were encouraged to have their supervisors, machines, electricians and other specialists, develop programs for lubricating and making key observation to prevent damage of the equipment (Husband, 1976), (Mohammad et al, 2002).

In 1960 new concept was established “Productive Maintenance” as new trend, which determined a more professional approach (Raouf and Ben-Daya, 1995). The change was so profound that the term maintenance was changed to Plant Engineering, trend that includes a higher understanding of the equipment reliability and installation. Just a decade later, the globalisation of the marketplace has created the concept of world class, and a dynamic system which named Total Productive Maintenance (TPM). TPM is a continuous improvement concept that has proven to be effective. It is about the involvement and participation of each and everyone in the organisation towards optimising the outcome of the plant. As many modern techniques employed to develop performance and reduce cost, Total Productive Maintenance (TPM) has become one of the most importance techniques used to optimise equipment effectiveness, eliminate breakdowns, and promotes autonomous operator maintenance through day-to-day activities involving the total workforce.

As discussed previously in Chapter 1, the problems in cement production in Libya has been identified by the author as part of his experience at the factories. As presented in Figure 2-1, this research work attempts to link the factory problems to the existing TPM and other maintenance strategies available in literature . The research will evaluated the most suitable techniques and strategies and its suitability for implementation the Libyan cement industry. Therefore, this literature review chapter is not about identifying gaps in current research domain but to survey the maintenance systems that could be evaluated and assessed for the cement industry in Libya as described in Figure2-1.

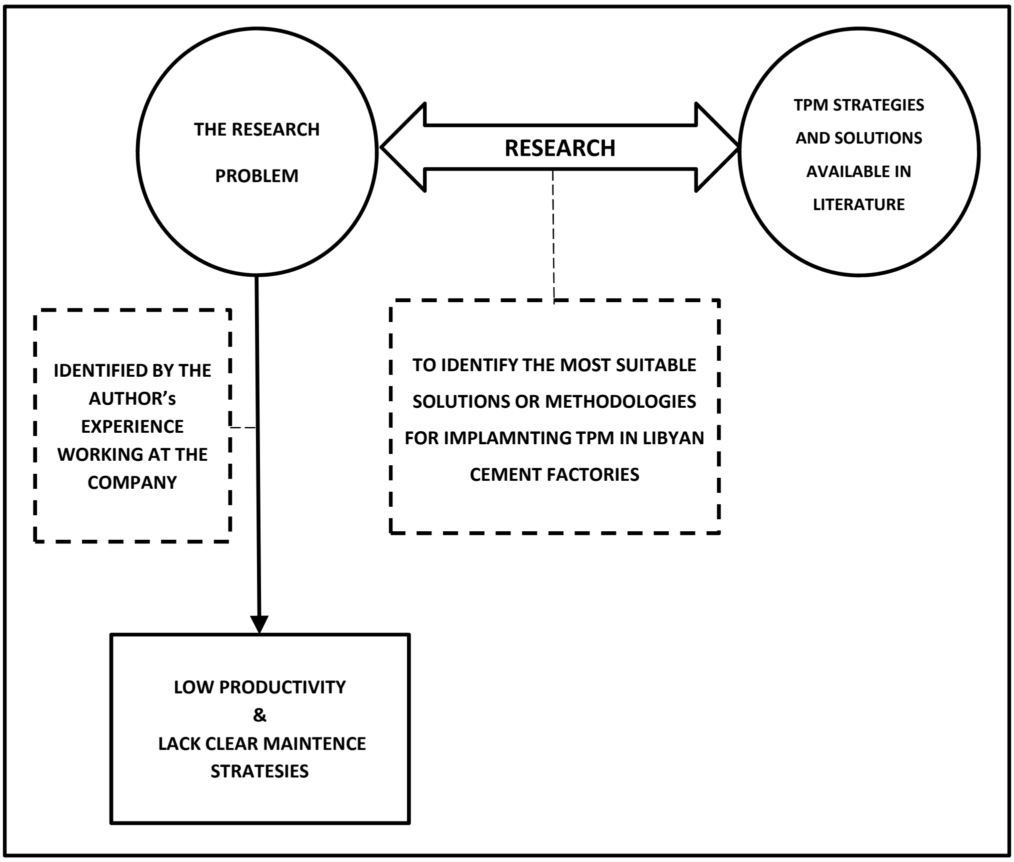


Figure 2-1: The domain of the research work (Author).

2.2 Definition of Maintenance

The phrase maintained, according to the Concise Oxford Dictionary (1995) is "the process of maintenance or being maintained, or the provision of the means to support by work". According to the UK's Department of Trade and Industry DTI (1991), maintenance can be defined as "the management, organisation, execution and quality of those activities which will make sure that optimum levels of availability and overall performance of plant are achieved". Imai (1997 p85) supplied a definition that is more in line with the strategic aim of maintenance: *"Maintenance refers to activities directed toward maintaining current technological, managerial and operating standards and upholding such standards through training and discipline".*

Maintenance is seen as an important part of any plant or system that is necessary to operate effectively. The way in which maintenance is carried out has a strategic effect on the real life of the equipment or component. In practice, there are many approaches to maintenance management, where managers will formulate a perception of how the above definitions should be applied within their company. In the majority of companies, it is usual to find that maintenance activities are carried out a “Quick fix” solution, it is also reasonable to suspect that maintenance activities are not aligned to the commercial strategy because the impact of maintenance on system or business performance has not been recognised (Murthy and Atrens, 2002), (Alan and Brit, 2009).

In this condition, maintenance management teams usually will not have a mechanism to formulate a maintenance strategy that can be aligned to their business strategy. As a replacement maintenance management will usually base their maintenance policies on cost or available resources without examining the prevailing conditions within the production environment.

Maintenance managers should be considering the necessary levels of maintenance for their particular production situation, allowing the development of a maintenance objective that is in accordance with their manufacture strategies. The cost of not developing an appropriate maintenance strategy can result in a costly non-competitive situation. According to the Department of Trade and Industry (DTI; 1988) “most companies do not know the cost of downtime and what the overall financial effect of unusable machinery is on their business”. The report concluded by stating that management attitudes towards maintenance must change, and that maintenance must be integrated into the manufacturing strategy.

2.3 Maintenance Practices

The stoppage of equipment can be mitigated by variety of maintenance policies whose rationale depends, mainly, on the failure characteristics of the equipment. Over the last 30 years, there have been many different approaches to improving maintenance efficiency; these have been called Modern Maintenance Practices (MMP) (Sherwin 2000; waeyenbergh and pintelon 2002). Table (2-2) illustrates the development of maintenance practices. In this section, definitions of MMP, total Productive Maintenance (TPM) Condition Based Maintenance (CBM) are presented.

Table 2-1:Development of Maintenance Philosophies Extracted from (Sherwin 2000; waeyenbergh and pintelon 2002).

Period Between 1900 – Present	Characteristics of equipment	Maintenance Philosophy
First generation maintenance (1900-1939)	•Equipment is simple and easy to repair	•Basic and routine maintenance •Reactive maintenance, "Only repair when broke"
Second generation maintenance (1945 – 1979)	•Equipment is more complex, greater dependence of industry on equipment •Maintenance costs are higher in relation to other operating costs	•Planned preventive maintenance •Time based approach •Total Productive maintenance (TPM) 'Total' employee participation. •Team based approach to maintenance, examine "Culture and people" not systems.
Third generation maintenance (1980s – Present)	•Equipment complexity increasing •Accelerated use of automation •Downtime very expensive •Increasing use of Just-In-Time •Customers now demanding higher quality goods •Tightening legislation on safety	•Condition monitoring (CM), hazard studies, failure modes and effect analysis •Reliability centered maintenance (RCM) examines "machine or system" •Computer aided maintenance management •Multi-skilled workforce •Emphasis on equipment reliability and availability •Maintenance is now proactive and strategic.

Shortly after the First World War, equipment was generally simple and robust. When equipment failed, it was easily maintained and in many cases; equipment failure was an acceptable reason for reducing production and maintenance was mostly reactive (Tolliday, 1998).

After the Second World War equipment was used until it failed, this was called Run-To-Failure (RTF). This approach to maintenance is corrective in nature. Reactive maintenance is not performed until equipment performance is unacceptable. RTF has the potential for a greater up time because equipment is in no way taken offline for maintenance. RTF allows for a lower skill set as the failures are usually well defined. On the other hand, failures may occur at the worst times and may severely affect production. Reactive maintenance is simplicity itself, it requires no forethought and, at least up to the point of machinery failure, requires the least amount of hold up from the operators and maintenance engineers (Ranky ,1990 ;Carlos Manuel et al., 2008).

Chan et al (2003) states that an organisation that practices reactive maintenance, slight if any concentration is paid to ensuring that the operating conditions are within the design specifications. As a result, the actual service performance and life span of the equipment are substantially below the estimates of the manufacturer. Equipment became more automated thus replacing the need for normal manual intervention and reducing work force requirements. Fail of production during equipment failure was also becoming unacceptable; this led to work on prevention before equipment lost. Particular attention was paid to the development of techniques, which not only enhanced equipment efficiency, but also improved the skill level of the employee. Modern equipment management began with preventive maintenance and evolved into productive maintenance.

Preventive Maintenance (PM) is the art of periodically inspecting the performance and /or material condition of a piece of equipment to determine if the operating conditions and resulting degradation rate are within the probable limits (Ollila and Malmipuro, 1999; Mohammad and Nader, 2002). If the degradation rate is not within the limits, a search for the reason for the further rapid degradation must be sough so that the problem can be corrected before the machine breakdown.

Failure statistics allow the test interval to be optimised although failures are still likely to happen. A well-developed preventive maintenance strategy can be cost –effective when the life span of the equipment is well understood and consistent. According to Swanson (2001) the benefits of preventive maintenance are “shutdown probability or equipment breakdowns and extensions of equipment life”.

This methodology helps organisations understand the importance of equipment effectives, one of the principles of Total Productive Maintenance (TPM).

2.4 The Importance of Maintenance in Production Systems

Today's global companies, large and small factories are characterised by larger emphasis on productivity, delivery performance and quality, which represent the business strategy for many companies to be the best in the market in their fields. To respond to these requirements, manufactures are using high-tech equipment. They are also adopting new material control methods such as the just-in-time (JIT) philosophy, which calls for non-stop production systems working without inventory-set-up and adjustment times are also reduced to a lowest. All these factors are shifting the focus to maintenance, since unplanned unavailability of machines will result in serious problems (Hayes and Pisano, 1996; Christian et al., 2009).

AS Blanchard (1997) confirmed that actual trends indicate that in general, systems are rising in complexity with the introduction of new technologies, however are not meeting customer expectations in term of performance and effectiveness. Further, systems are becoming more costly relative to their process and support. As a result , it is not only the cost of the maintenance that makes it more essential than before, even though the cost can be high, but it is also the necessity of controlling the equipment to serve the need of the production line to be competitive in the market. According to (Cecille and Gunaskeran, 1998) equipment maintenance and reliability management are essential in the effective running of business enterprises at present. By means of the growing dependence on technologies for the majority business operations, it is an aim to develop appropriate maintainability and reliability strategies to ensure that these organisations are able to transport high quality and dependable services to their customers.

Maintenance of equipment and machines is an important piece of the operation's function and an effective maintenance strategy can significantly contribute in adding value to the production activities. Maintenance should be seen and measured as a world class principal for manufacturers. Manufacturing organisations determined for world-class performance have shown that the contribution of an effective maintenance strategy can be important in providing a competitive improvement (Bamber et al., 1999; Al-Najar, 1996). The most important output of production is the desired product. However, the need for maintenance is secondary output, which is in turn an input for the maintenance function. Maintenance produces secondary input to product in the form of production capacity. While production manufactures the product, maintenance produces the capacity for manufacture. Therefore, maintenance affects production by increasing production capacity and controlling the quality and quantity of output. This relationship can be shown in Figure (2-2) (Ben-Daya & Duffuaa,1995):

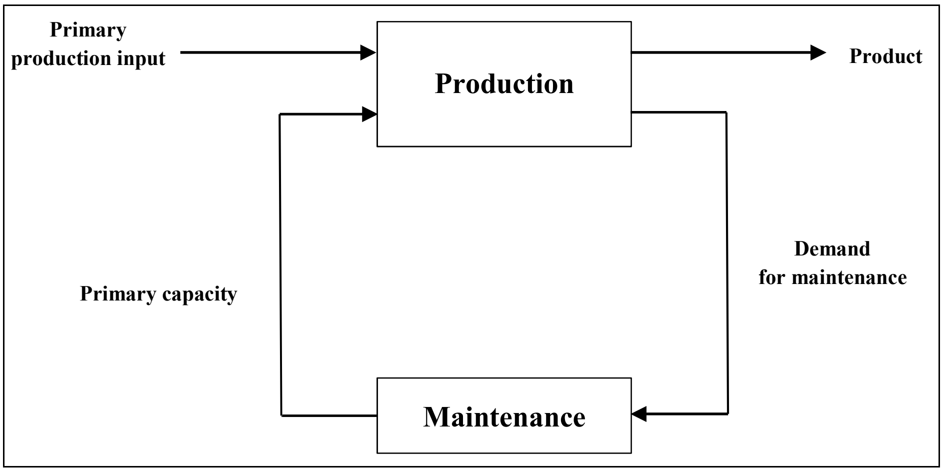


Figure 2-2: The Role of Maintenance in Production (Ben-Daya &Duffuaa,1995).

Maintenance is a very important function in an organisation that operates in conjunction with production to ensure the production flow. To receive a continuous production from machinery and equipment, manufacturers should consider maintenance as a heart function that needs to be planned in a strategic way.

Ollila and Malmipuro,(1999); Yamashina, (1995) stated that the increasing competitive power of the company depends on the making of advanced manufacture engineering to establish an appropriate production process , that demands brilliant maintenance practice in such a way that machines, and processes are available whenever wanted, and produce required products with a needs quality level. The role of maintenance in the long-term should be seen as an important function in an organisation’s strategy. Maintenance should be planned with awareness and realistically according to the organisation's ability and resources.

The clear development of maintenance and application will help to get better equipment's reliability and availability by reducing unplanned breakdowns and defects, and this will help in providing the marketplace with products that have high quality and lower cost.

2.5 Aims of maintenance

Maintenance and maintenance management are considered by many researchers to be the most important factors to improve manufacturing productivity and effectiveness, see for example (Murthy and Atrens, 2002), (Alan and Brit, 2009). It is important to develop or select the right maintenance strategy and functions for the plant even during the design phase (Maggard, 1992). Planned and unplanned maintenance must be clearly defined to avoid confusion between two different kinds of work to achieve the planned objectives. Unplanned maintenance work means either corrective or emergency work. Whereas planned maintenance work can involve either preventive or corrective activities (Husband, 1976; Juan, 2009).

The main aim of maintenance as discussed earlier is to support the production process objectives and operational goals. It is of great importance to realise that the maintenance function adds value to manufacturing processes and is crucial in linking different departments in the organisation. However, it can be argued that maintenance contributes to profitability through:

- Improvement of effectiveness ;
- Improvement of reliability and availability;
- Elimination of machine breakdowns;
- Accurate planning of maintenance requirements;
- Extending life of assets;
- Continuity of production and supplies, and
- Quick response and repair time (Davis and Greenough, 2002).

Maintenance systems include labour, materials, spare parts, tools, information, money, and external services. Those elements should be fully identified and utilised in order to achieve the planned outcome of maintenance activity, hence to ensure that other organisational systems will achieve their goals. Production systems are supported by maintenance tasks to secure the required production capacity and to improve equipment's availability. As a result, enterprise profit is expected to increase. The relationship between maintenance system and other organisational systems is shown in Fig 2-3.

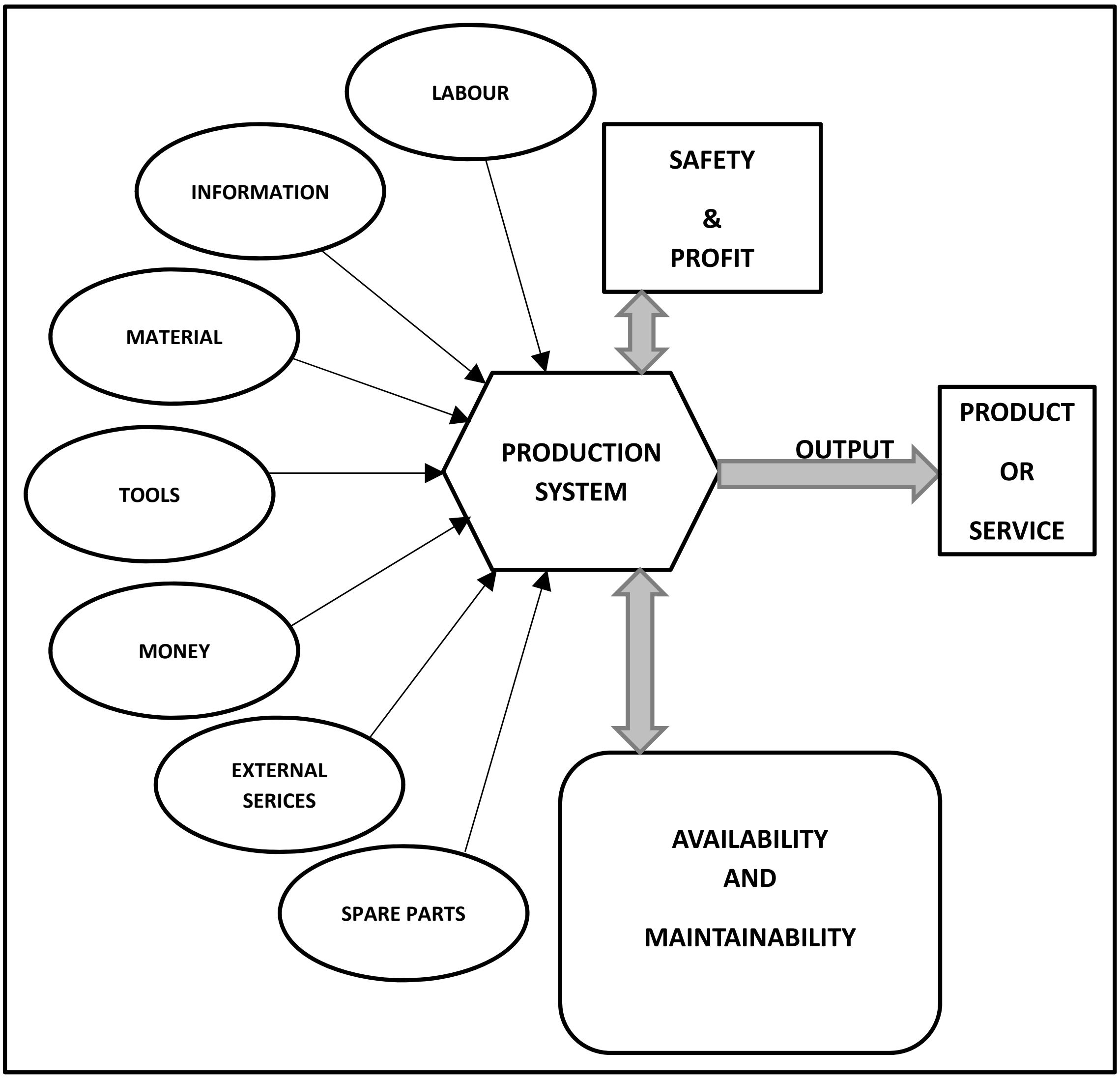


Figure 2-3: Maintenance system in relation with other organisation's system (Author).

Safety of equipment and personnel is an important objective of the maintenance function to keep the production processes run satisfactorily in normal operations and in emergency cases (Chan et al., 2005). Reducing maintenance cost, as part of the total operating cost, is one of the most important objectives to whome. To achieve the lowest maintenance cost, it could be necessary to employ an optimisation technique to determine the optimal associated costs. Often, the cost of failure is a significant portion of the maintenance cost. Moreover, in some situations, catastrophic failure of a piece of equipment can result in damage to the overall system and may cause injuries to personnel (Michael and Gerald, 1993). If maintenance procedure has been created and defined properly many of plant failures can be prevented. Maintenance procedure should be reviewed from time to time to ensure that the equipment reliability and availability are maintained in line with the operational needs.

2.6 Types of Maintenance

There are mainly three types of machine maintenance as defined by Al-Najjar (1996), Graisa and Al-Habaibeh (2007) and Albert (2002), unplanned breakdown maintenance, planned schedules maintenance and Condition monitoring Based Maintenance (CBM). Unplanned maintenance and unpredictable failure of machines have a crucial effect on the efficiency of the production system. Low reliability of machines increases downtime, consequently causing unnecessary and unexpected costs. The planned scheduled maintenance is normally based on the statistical analysis of the machine failure history and maintenance recommendation of machines/spare parts manufacturers that normally include unnecessarily high factor of safety. The third type of maintenance strategies is the condition monitoring based strategy. It is a planned maintenance based upon measuring the conditions of the critical elements of the machine during operation. The analysis of the condition monitoring data can be done to predict the failure time and thus allow maintenance to be planned Qin and Tang (2005), Juan (2009) and Rosqvist et al (2009).

Condition monitoring can reduce breakdown costs by enhancing preventive maintenance scheduling and effectiveness of maintenance operations. Figure 2-4 presents a general structure of maintenance strategies.

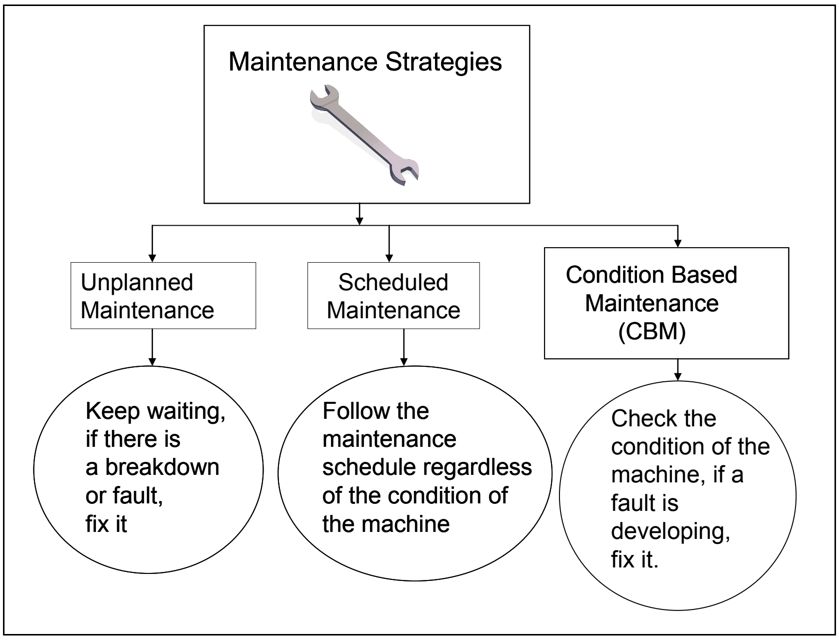


Figure 2-4: The main three types of maintenance strategies (Author).

CBM is an evolving area of condition monitoring. In terms of the future of CBM, researchers believe that the future of technical development is heading towards prognostication and calculations of remaining useful life (Robert, 2006). Some other Authors, such as (Baglee et al., 2003; Anish et al., 2008; Roberts, 1997) divide maintenance into two main types, Breakdown Maintenance and Preventive Maintenance; other types are considered sub-types of these two types. Figure 2-4 shows categories of maintenance types.

2.7 Reliability, Availability, and Maintainability

System effectiveness is a measure of the system ability to achieve a set of specific requirement; it is a function of availability, where availability can be enhanced by reliability, maintainability and maintenance performance. System effectiveness can be measured by an excellent tool of the equipment history records. It is of great importance to define Reliability, Availability, and Maintainability to identify their contribution and enhance maintenance strategy (Anish et al., 2008).

2.7.1 Reliability

Reliability is defined as a measure of the ability of a machine to perform a required function for a given time and continue to operate according to its specification. There are many actions suggested to increase reliability such as:

- Parallel redundancy where more than one equipment operate in parallel (hot spare), in case of one failed and the other still working.
- Preventive maintenance, periodical maintenance components replacement by new spare parts before failure of machine (Mann and Kehoe, 1995; Carlos Manuel et al., 2008).

2.7.2 Availability

Availability is defined as the percentage of the year where the plant is producing its designed output adequately. At the design stage the designer should consider reliability and maintainability, while the availability concept is focusing on the plant after commissioning or when the production state is reached (Alan and Naikan, 1989). There are several responsibilities have to be stated by maintenance department during the operation which are:

- Data collection and data analysis of historical data which considered very important for failure diagnosis and its consequence.
- Training of maintenance staff
- Maintenance documentation.
- Availability of spare parts and materials required for repair or replace of damaged parts (Mckone, 1999).

2.7.3 Maintainability

Maintainability is defined as the probability that a particular repair can be performed within a given time in order to retain the system in, or system restored (Murthy and Atrens, 2002). All components eventually fail, given a sufficient time and means must be found to keep the system operating in the presence of such failures. One way to achieve this can be done by maintenance.

2.7.4 OEE Overall Equipment Effectiveness

According to Kennedy (1998) OEE measures all losses caused by equipment faults, and many organisations recognise the importance of OEE in determining effectiveness or the efficiency of equipment. OEE is defined as the ratio of Fully Productive Time to Planned Production Time.

Most researches agree that the objective of all production improvement activities is to improve productivity by maximising the output for a given input (i.e. the ration of the output to the input). TPM is unique in that it allows the company to recognise the problems caused by inappropriate maintenance by examining and eliminating what Nakajima (1988) called the six big losses (i.e. equipment stoppage, setup time, interruption in production, defects and losses due to transient behaviour of the process, Bulent et al, 2000). An advantage of OEE is that it provides a benchmark to initiate a maintenance strategy by providing one simple figure from three different areas, namely performance, availability and quality.

2.8 Maintenance resources

Maintenance resources include manpower, staff training, and financial support for activities. High utilisation of maintenance resources by quick response to breakdown will lead to high plant availability; reduce equipment down time and consequently reducing maintenance cost. Providing a clear framework of responsibility and authority assignment is used to ensure that the best utilisation of maintenance manpower is employed. In developing a strategy to handle the management of production and maintenance function of the plant, it must satisfy the particular requirement of the company. Maintenance mangers that have the line of authority and responsibility to determine the maintenance needs should directly represent the maintenance function at high level of organisation to achieve the desired objectives (Moore and Rath, 2000).

2.8.1 Maintenance manpower

To perform the maintenance tasks and to reach the intended maintenance objectives, the manpower including skilled, semi-skilled and maintenance operators, directed with a proper management tools are required. It is of great importance to describe maintenance activities, planned or unplanned. Job description should be available in written form in order to identify and highlight key areas to be performed. Responsibility for preparing job description normally lies with management service department aimed to make a little sense to operate a personnel policy for maintenance separated from the production and other company functions (Husband, 1976; Mohammad and Nader, 2002). In addition to management tools and job description, a utilisation of maintenance manpower should include a good training program to ensure that maintenance organisation members have the knowledge and skills they need to perform their jobs effectively, taking a new responsibilities and adaptable to changing conditions.

2.8.2 Training

Training primary focuses on teaching maintenance staff how to perform their current jobs and helping them acquires the knowledge and skills they need to be effective performers. Development focuses on building the knowledge and skills of maintenance members so that they will be prepared to take on new responsibilities and challenges. The on job training and experience is one of the main factors used in staff promotion to higher position in the hierarchy of the operation and maintenance organisation (Penny, 2006; Christian et al., 2009).

2.9 Maintenance cost

Successful maintenance function must be economically justifiable in addition to its technical success. Therefore cost control should be incorporated in the maintenance system. Cost or resources, cost of breakdowns, cost of training personnel, effective charging of different expenditures among users and total cost of production are other related and have great influence on each other and define the overall picture of the plant operation. The cost can be divided according to work type and further can be divided according to resources used, e.g. Labour cost, cost of materials and spare parts, and cost of production losses. Figure 2-5 shows a different types of the cost of maintenance (Imai, 1997; Peter et al., 2010; Carlos Manuel et al., 2008; Gotoh and Tajire, 1992):

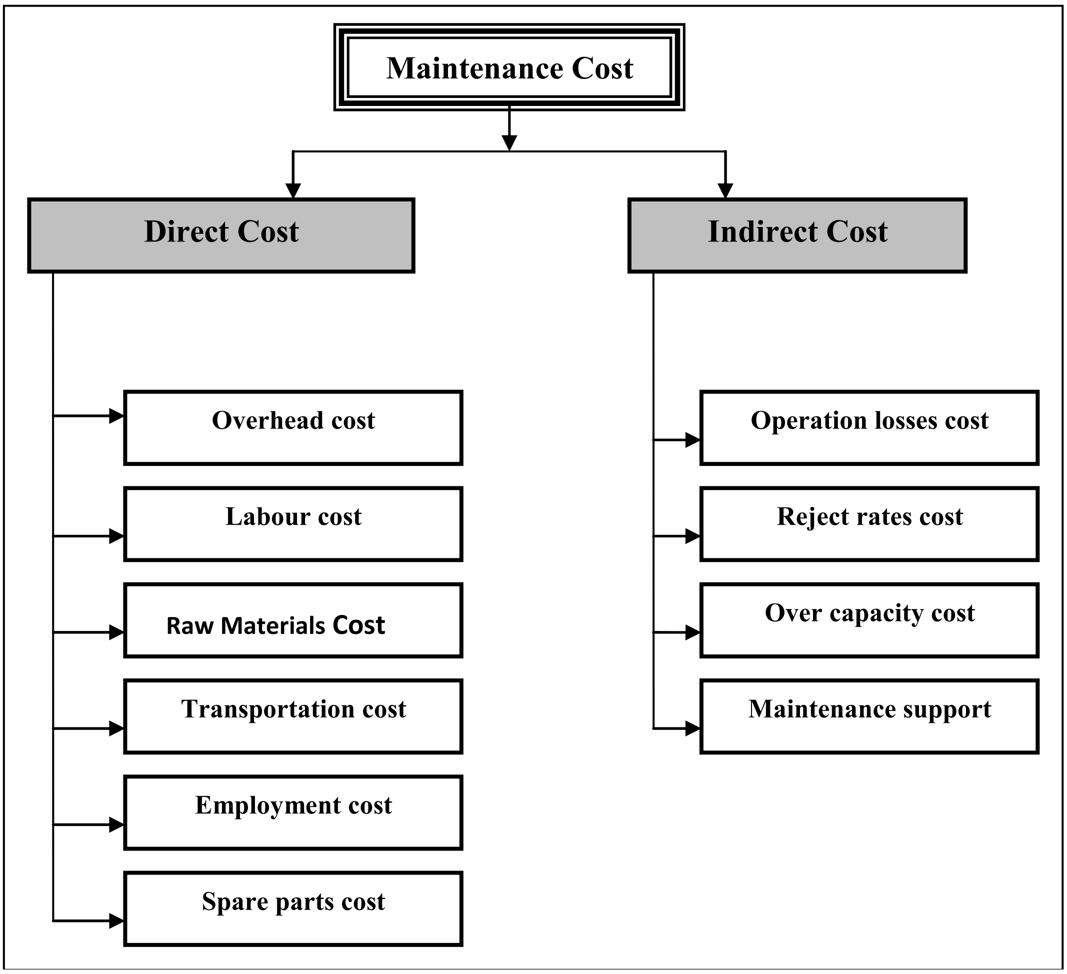


Figure 2-5: Maintenance cost (Imai, 1997; Gotoh and Tajire, 1992)

The objective of maintenance cost control can be defined as obtained specific degree of production efficiency at the lowest possible cost. In order to reduce maintenance costs it is necessary to adopt a strategy aimed to:

- Reducing the time of maintenance by advanced planning to maintenance resources;
- Training of maintenance staff;
- Good controlling procedure;
- Good information system; and
- Involving all employees (Imai, 1997).

Once the amount of maintenance to be performed is decided, the next step is to establish controls and procedures to ensure performance at the lowest possible cost. When we achieve the optimum amount of maintenance at the lowest cost, we achieve maximum cost effectiveness (El-Haram and Horner, 2002).

2.10 Maintenance and quality

Quality is a business strategy which is defined as the ability of product or service to meet the customer needs (Al-Najjar 1996; Panagiotis 2009). Whereas maintenance as defined in this literature as keeping plant under good operating conditions, can be modelled together to enhance the position of the organisation in the market to enjoy significant competitive advantages. Maintaining equipment in good operating conditions with running effectively is the basic of this new environment to succeed and get continuous improvement. While production manufactures the product, maintenance produces the capacity for production. Therefore maintenance is directly affects the production by producing the capacity for production and controlling the quality and quantity of output. It is of great importance to consider the quality of maintenance activities and highlight the relationship between maintenance and quality. Quality improvement means:

- Elimination of waste such as scrap and rework;
- Move the final control inspection to the adequate process level techniques;
- Eliminate defects and variations;
- Identifying machine performance problems earlier;
- Running equipment in ideal operating conditions; and
- The link between maintenance and quality has been identified by Total Productive Maintenance (TPM) (Alan and Naikan, 1989).

The link aimed to provide a good equipment management, based on quality, because quality is a key factor in measuring equipment effectiveness. One of six big losses of any equipment is directly related to quality as identified by (Nakajima, 1989) the father of TPM (Albert, 2002), (Christian et al, 2009) who pioneered the approach in Japan and exerted a major influence over the economic progress made by Japanese manufacturers from the late 1970s.

2.11 Total Productive Maintenance(TPM)

Total Productive maintenance (or Total Productive Manufacturing) is often defined as "Productive Maintenance involving total participation". (Takahashi et al., 1990; Ahuja and Pankaj, 2009). TPM is aimed at continuous improvement that embraces all aspects of an organisation. A complete definition of TPM includes the following five TPM objectives according to the above references:

1. TPM aims to maximise Overall Equipment Effectiveness (OEE);
2. TPM establishes a thorough system of preventive maintenance for the equipment's entire life span;
3. TPM is implemented by various departments (engineering, operation and maintenance);
4. TPM involves every single employee, from top management to workers; and
5. TPM is based on the promotion of preventive maintenance through motivation management.

The objective of TPM programme is to significantly increase production while, at the same time, increasing employee morale and job satisfaction, this is done by focusing on the employee as part of the maintenance and production strategy.

Total productive maintenance (TPM) according to Maggard (1992) is predominantly used because it integrates production and maintenance functions but more importantly redefines the roles of the operators and maintainers, hence empowering the workforce, something that should be at the heart of any change in maintenance actives. Pintelon (1999) claimed that TPM implementation is impractical within a short time because it wants through planning and sufficient management support including the approval of funds.

Figure 2-6 presents a general definition of Total Productive Maintenance. TPM includes employees and eliminates all machine problems and encompasses all departments. Maintenance is integrated within production and problems are eliminated or minimised. Machines are kept at excellent working conditions and preventive maintenance and Condition-Based Maintenance (CBM) are used.

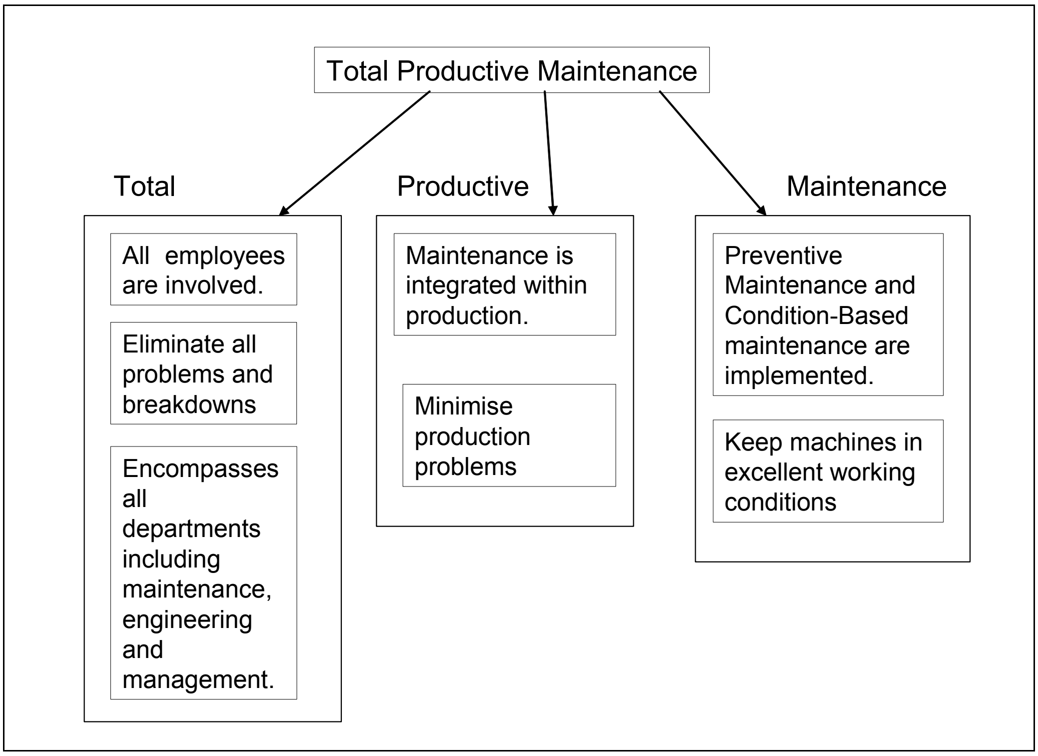


Figure 2-6: The definition of Total Productive Maintenance (Author).

Maggard and Rhyne (1992, cited by Lawrence 1999) claimed that TPM is essentially an integration of production and maintenance function with the goal of optimising equipment reliability and reducing downtime and waste. Example of TPM effectiveness have claimed to reduce downtime by up to 80%, reduce the waste and rework by 75% and increase labor efficiency by 100% (Labib 2000; Tsang 1998; Cooke 2005 and Shad 2008).

2.11.1 History of Total Productive Maintenance (TPM)

According to (Roberts, 1995) in the 1970s with the growing complexity of equipment and high degree of automation, expectations from maintenance were growing. TPM was introduced as an organisation-wide initiative. This new approach to maintenance was termed Total Productive Maintenance (TPM). The history of Total Productive Maintenance (TPM) can be traced to

Nippondenso Company, a supplier of electrical parts to the Toyota motorcar company. Nippondenso soon realised Toyota has already improved their working practices by incorporating and developing the Toyota Production System (TPS). A system, according to (Ohno, 1978) was developing for “the absolute elimination of waste”. Production increased at Toyota as did their requirement for spare parts, soon demand exceeded supply. The senior management at Nippon decided to measure a mixture of factors such as output per hour, lost time due to machine breakdowns and defect rates (Yamashina 1995; Anish et al., 2008).

TPM achieves this by placing a high value on group work, consensus building and continuous enhancement (Moore and Rath, 2000). Companies in Japan started adopting this approach as a basic maintenance philosophy and between the 1970s and 1980s, TPM gradually developed as an organisation–wide initiative, as its remarkable advantages and benefits became recognised with the concepts of tools upkeep underwent a paradigm shift from ‘I operate you fixit’ to ‘it is my machine, I operate and maintain it’ (Hokoma et al., 2008).

According to Cooke (2000) TPM is intended to carry both functions (production and maintenance) together by a combination of good working practices, group working and continuous improvement.
Labib (2000) stated that the idea of TPM is to transport maintenance and production together, during small groups, to exchanges skills and take specific actions.

This action helps to identify maintenance problems and suggest methods to overcome them. TPM is derived from Total Quality Management (TQM) concept of zero defects. Applying it to equipment will help to decrease the number of breakdowns and minimal production loss (Goto, 1991; Ahuja and Pankaj, 2009).

The premise of TPM was to maintain equipment in optimal working condition, extend its practical life, eliminate breakdown and reduce, if not eliminate, unplanned stoppages. On the other hand, this can only be achieved if the commitment from senior management is visible to all workers.

TPM is not a quick fix; it must be seen as an ongoing process allowing maintenance activity to be brought into focus as a required and important operation within a business.

Organisations can plan downtime for maintenance, which will become part of the manufacturing day. TPM has now been recognised as a maintenance programme that involves a recently defined concept, the introduction of operation to perform maintenance on equipment. Nakajima (1988) often regarded as the father of TPM, defines the target of TPM as to improve equipment effectiveness and maximise equipment output. It achieves this by the determination to attain and maintain optimal equipment conditions in order to prevent unexpected shutdowns, speed losses and quality defects in process. During TPM, it should also be possible to increase employee morale and job satisfaction by allowing the employees to be involved with every aspect of TPM. Nakajima (1988) developed five pillars, namely life cycle of equipment, training, improving maintenance, involving production and improving equipment, that originally guided TPM. According to Kennedy (1998 p44), in the 1980s “opportunities were being lost because of poor production scheduling, hence the development of the second generation of TPM which focused on the production process”.

Recently TPM’s issues relating to quality and safety have been identified as ‘necessary pillars’ of TPM. Consequently, according to Kennedy (1998) this now adds two extra pillars to TPM and creates a third generation.

Most of the universally established definitions of TPM by authors such as Bamber et al (1999), Rich (1999), Cooke (2000), Blanchard (1997), Davis (1995) and Willmott (1997) build upon the basic five pillars outlined by Nakajima (1988). They state that in order for TPM to be doing well all of the five original pillars must be used to eliminate equipment losses in a sustainable manner.

2.12 The basic pillars of Total Productive Maintenance

The most accepted a definition of TPM is built on basic five pillars created by the Japan Institute for Plant Maintenance Figure 2-7. For TPM to be successful all of the pillars, or key elements, must be implemented to eliminate equipment losses in a sustainable manner.

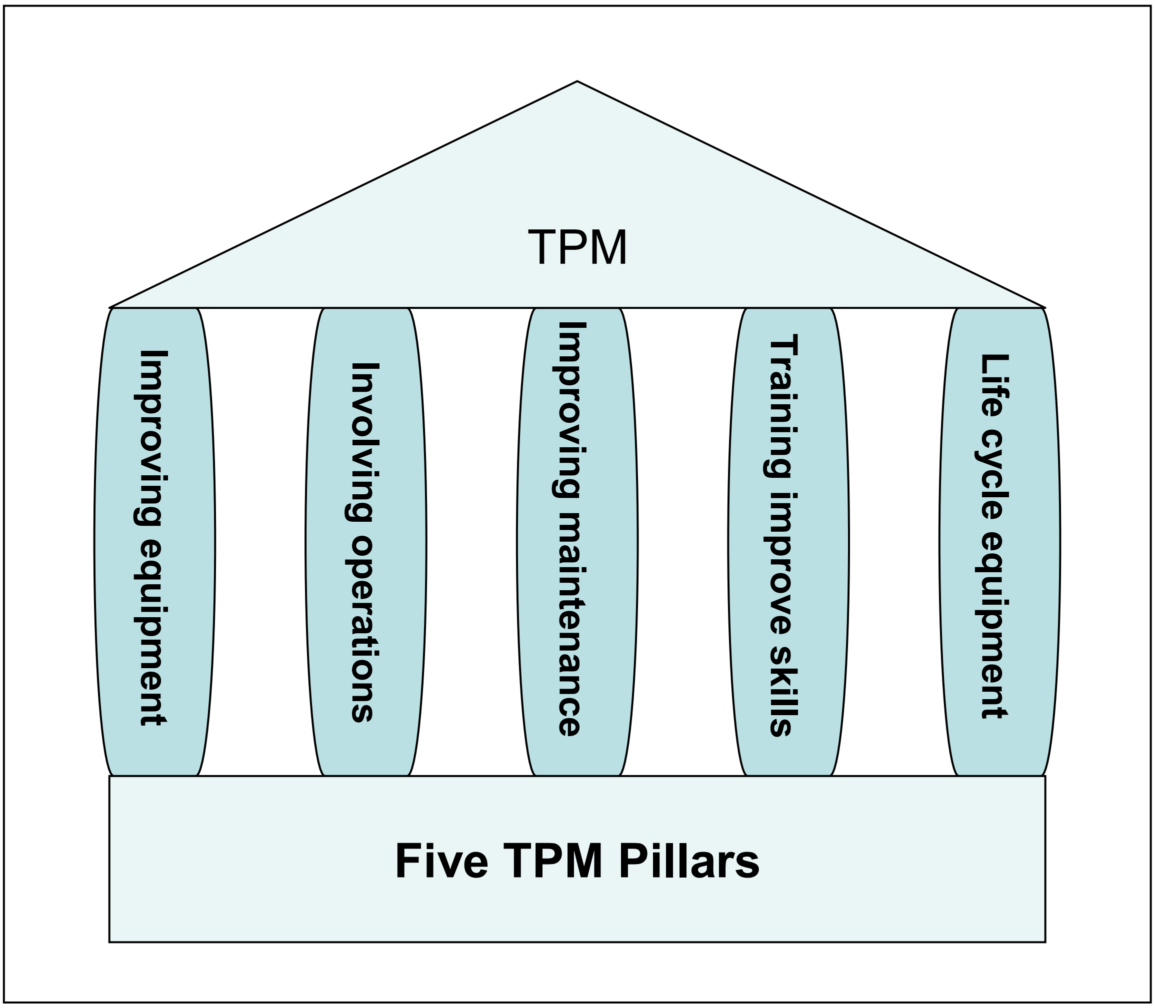


Figure 2-7: Five TPM Pillars Nakajima (1989).

As discussed earlier, TPM activities should focus on process and as TPM seeks to eliminate the major non-value added activities, it considers Overall Equipment Effectiveness (OEE) as one of the fundamental measures used to eliminate them. Improving maintenance efficiency and effectiveness can be achieved by adopting strategy looking to improve (Shirose, 1992):

- Spare parts
- Computerized maintenance management system
- Preventive maintenance
- Predictive maintenance
- Maintenance tools
- Work order system
- Equipment histories

Regarding the involvement of operators in daily maintenance of their equipment, this activity should be integrated with the culture of the factory and production. TPM concentrates on some tasks that can be performed by operators such as cleaning, lubrication and inspection of equipment. However, in order to achieve this, operators should be trained.

Training could include different types and fields including maintenance training, operation training, leadership training, cause-effect analysis of faults and reliability training (Martyn, 1999). Training should start with addressing the basic needs of people and equipment targeted for TPM. This should discuss how to help the employees involved to understand what TPM is and its importance. Finally life-cycle equipment management and maintenance prevention design should take into consideration the design or installation of new equipment. Involving operators in maintenance tasks is discussed by many people under Autonomous Maintenance (MACI, 1995).

2.12.1 Issues to be considered in the Implementation of TPM in Libya

In order to apply TPM concept to factory maintenance activities, the entire staff must firstly be convinced that senior management is committed to the programme (Hayes and Pisano, 1996). Moreover, all staff should be convinced of the importance of TPM program and that they understand it and its implications. Teams should be formed to employ TPM concept, these teams are usually created from employees who directly have an impact on the problem being addressed. Operators, maintenance technicians, shift supervisors, and senior management should all be included on a team. Every employee is required to do his/her best to contribute to the success of the team effort. In well-run TPM strategy, team members often visit co-operating plants to observe and compare TPM methods, techniques, and to observe work in progress. This comparative process is part of an overall benchmarking technique which is one of the greatest assets of the TPM program.

Implementing TPM might not be an easy task in Libya. However, success has been limited for various reasons in literature anther countries, with negative effects. Some of those reasons are (Cooke, 2000):

1. Lack of senior management support
2. Lack of budget or investment.
3. Pressure of workload
4. Confliction of management initiatives
5. Inefficient use of maintenance staff
6. Senior management's tolerance of poor performance

To avoid the above barriers, successful implementation of TPM requires top management support and commitment, a greater sense of ownership and responsibility from work-shop staff, co-operation and involvement of both the production and the maintenance staff, and importantly an attitude change from everybody. Shirose and Kaneda (1995) confirmed that the pillars of TPM must be introduced in parallel. For example, autonomous maintenance is introduced together with training, and training is introduced with early equipment management. Based upon the definitions supplied by Nakajima (1988) and Shirose and Kaneda (1995) TPM can be considered as an interrelated and multi-layered methodology that provides organisations with an overlapping cross-functional structure to bear maintenance development. Bamber et al (2000p76) suggests, "TPM implementation strategies may vary and emphasis or concentration on each pillar is often presented with differing approaches". Roberts (1995, cited in Bamber et al, 1999) mentioned that in practice concentration and implementation of TPM tends to focus on the single autonomous maintenance pillar. In adding up, TPM implementation is centered on people is membership and is not necessarily concerted with performance measurement and maintenance strategy development.

Organisations wishing to develop and implement a maintenance strategy based upon TPM should examine the pillars that carry and guide the process of change and decide which pillars are appropriate to their situation. Davis (1995) states that for the successful implementation of TPM within any company there is a need to take into consideration not only the practices and techniques but also the philosophy of TPM.

TPM can be defined in various ways to suit the unique requirements of a company, although the greater parts of accepted definitions build upon the original basic five pillars supplied by Nakajima (1989).

To begin with the first pillar, “Improve Equipment Effectiveness” is used to target the major losses associated with poor maintenance practices. The maintenance performance indictors used within TPM are the measure of equipment availability, performance rate and quality rate. The purpose of TPM according to Chan et al (2005) is to make best use of equipment effectiveness and Overall Equipment Effectiveness (OEE) is used as the measure.

The achievement of TPM depends on the collection and analysing of relevant and accurate data. The factors, which affect OEE, are not equally recognised in all organisations and therefore, a bespoke OEE in different organisations is sometimes required. But, the start of any TPM implementation, according to Chan et al, (2005) should include OEE that is a fundamental measurement method for equipment performance.

The second pillar of TPM is “Autonomous Maintenance by Operators” involves the equipment operators performing some of the routine and basic maintenance tasks. These tasks include the daily cleaning, inspecting, tightening, and lubricating as the equipment requires. Since the operators are more aware of their equipment than anyone else is, they are able to notice quickly any problems. ” According to Ben-Daya (2000), the involvement of the operators in the success of TPM is essential. The use of autonomous maintenance has many advantages including that the operators learn to recognise equipment problems and understand the equipment function and structure. This process allows the operators to identify and understand the relationship between equipment states and quality, and to to have the right skills to undertake equipment maintenance. Nakajima (1988 p83) states that autonomous maintenance “brings production and maintenance people together to stabilise conditions and halt equipment deterioration”.

The third pillar, “Planned Maintenance” must be combined with autonomous maintenance (Nakajima, 1989). The aim is to allow machine operators to analyse the cause of equipment failures and to develop a planned maintenance system to repair or modify the equipment to improve maintainability. According to Cooke (2000) and Alsyouf (2009), planned maintenance is responsible for supporting autonomous maintenance to improve OEE. Planned maintenance typically involves the work conducted by skilled maintenance technicians/engineers, but the aim is to transfer the tasks to the equipment operators. According to McKOne (1999), organizations should involve operators and maintenance technicians to develop a well organised planning process for maintenance activities. (Shad 2008, cited by McKone 1999) argues that strong maintenance planning enables the company to capture equipment information to identify trends for completing maintenance tasks within a scheduled period. However, developing planned maintenance system can be difficult because the consequence of the failure is often ignored in favour of quickly completing the maintenance operations (Pintelon 1999). In addition, planned maintenance sometimes is determined by calendar days rather than by equipment usage or need. Performing too much maintenance can be as costly as not performing enough maintenance can influence productivity; there should be a balance by critically performing analysis of the equipment repairs, and allow this maintenance to be accomplished as a priority (Anish et al., 2008).

According to Nakajima (1988) the forth pillar is "training" to Improve operator and maintenance skills for TPM implantation to be successful. Cahn (2005) suggests that, "a specific guideline for training was one of the key factors for TPM implementation". Nakajima (1988), states that the skills of the operators and maintenance technicians/engineers must be improved for autonomous maintenance and maintainability improvements of TPM, are to become successful.

The training that is needed to make autonomous maintenance would need to achieved in several ways. Firstly, the manufacturing and maintenance technicians and their management are educated in the concepts of TPM and benefits of autonomous maintenance. Secondly, the maintenance technicians/engineers should educate equipment's operators on how to clean and lubricate the equipment; and thirdly, health and safety awareness training is provided to address the new tasks performed by the machine operators (Maggard 1992; Blanchard 1997 and Shad 2008). Davis (1995) states that staff must obtain training in how to structure an approach to problem solving and implementation. Training can be expensive and time consuming. For that reason, a training programme must address the basic needs of people and equipment targeted for TPM.

The fifth pillar is "Equipment Management" which examines the process of maintenance prevention. Nakajima (1988 p85) states: "During the operation – maintenance stage, on the basis of regularly scheduled inspection, equipment is restored, modified or replaced. The data gathered in this process provides the basis for three types of improvement: (a) Improve maintainability, (b) improve maintenance work systems, and (c) facilitate maintenance free design in new equipment".

The main objective is to develop a maintenance system that is focused on reducing the amount of maintenance that is required. Researchers such as Blanchard (1997); Maggard and Rhyne (1990); Davis (1995) and Shirose and Kaneda (1995) state that by collaborating with equipment suppliers, the knowledge that is gained from maintaining equipment can be integrated into the future generation of equipment design. This Design for Maintenance (DFM) approach results in equipment that is easier to maintain. Moreover, the equipment supplier may be able to provide data on their components that will help to determine the necessary frequency of inspections and scheduled maintenance. The equipment management pillar is one of the important components of TPM, which helps in capturing organisational learning, which can be utilised for future equipment purchases. However, the strength of this pillar lies within the communication between the organisation and the equipment supplier. It is important that the implementation of TPM developed to suit the organisational demand. This is essential for the implementation of TPM in the Libyan cement industry. The direct implementation of strategies in literature might not be as effective. For example, case studies by Chan et al (2005) have shown that the implementation of the five original pillars of TPM within an Electronics organisation created an effective equipment management strategy. The reported benefits were an 83% improvement in equipment productivity and a drop in equipment stoppages from 517 to 89 hours. However, this was not the second attempt by the organisation to implement TPM. A structured organisational change to lead and handle the TPM implementation was required to achieve the change. This suggests that the implementation was not developed in the first attempt to suit the organisational demand, and that each of the five pillars was developed in isolation and not as one overlapping methodology. An organisation, such as NCC in Libya, wishing to develop maintenance utilising TPM, must examine their culture, determine their maintenance requirements and align the required pillars of TPM with the available resources.

Western devotees of TPM such as Hartmann (1992); Willmott (1997) acknowledge that the original five pillars have been developed for Japanese traditions that is built on teamwork and do not allow one person to be the driving force. The definition supplied by Hartmann (1992 p61) stated, “TPM improves the overall effectiveness of the equipment with the active involvement of operators”. Hartmann (1992) cited by Bamber et al (1999) suggested that TPM, to become successful, must include all human resources in the organisation from top management to line operators. This is another findings to support that the implementation of TPM in Libyan cement industry might not be a direct implementation of the existing knowledge in literature.

Harmann (1992); Willmott (1997) and Ahuja and Pankaj, (2009) argued that a small team of workers from different departments is a pre-requisite to the successful implantation of TPM. Many companies who have successfully introduced TPM within the UK or the USA have not followed the original five pillars of TPM. Through trial and error, many of the companies needed to modify each pillar to suit their needs. However, the literature in relation to the implementation failed TPM strategies is limited. Many companies in the USA such as Ford and Kodak have successfully adopted TPM (Maggard 1992). However, these TPM systems had to be customised to be suitable the American culture and market. According to authors such as Maggard and Rhyne (1992), Hartmann (1992), Steinbacher (1993) and Shad (2008) routine maintenance in America is the task of the maintenance staff, and is not considered a task of operators, which is completely different from the Japanse culture. Hartmann (1992) states that 50% of TPM initiatives introduced in America fail, because of the failure of the management to examine the necessary elements of TPM in a way that can link the maintenance strategy with the business and culture. In general, many authors such as Tsang (1998), Waeyenburgh (2002) have also stressed the necessity for a customised maintenance concept of using TPM.

Although there is a commitment to TPM by practitioners and academia, the development and implementation of TPM is still poor. During the author’s discussion with senior engineers and managers in the four factories, they have admitted that it is difficult to implement TPM with limited resources.

2.13 Automation & TPM

Through the early 1980s, the interest in TPM in Europe and the USA was limited. With the rising complexity an automation of equipment and the high expenses of maintenance, European and American production managers believed that the inclusion of monitoring techniques on critical a costly equipment could reduce the amount of maintenance needed. The goal was to optimize the maintenance –monitoring approach to achieve the lowest possible operational and maintenance cost. Hence, management examined a maintenance approach that attempts to detect the degradation prior to the deterioration in the component or machine. This approach is known as Condition Based Maintenance (CBM) as described in chapter two.

As automation and labour saving operations drove production tasks away from humans, this affected output, quality, cost, health and safety, and staff morale. Ignored equipment can result in excessive losses and time wasted on finding and fixing the fault. Both the operations and maintenance departments should be responsible for keeping equipment in good condition (Chan et al., 2005). So fat, this technology is extremely limited in the Libyan cement factories and the most common approach, from the author's experience, is ' if there is a problem, fix it'.

To reduce the losses hidden in a typical factory, the role of staff in managing production process must be appreciated. No matter how thoroughly factories are automated, staff are ultimately responsible for machine operation and maintenance. Every aspect of a machine's performance, whether positive or negative, can be traced back to a human effect and influence. Therefore, no matter how advanced the technology is, staff play the most important role in keeping the optimised performance of the equipment. When factory staff accept this argument, the advantage of building quality into machines will be recognised. This company- wide team-based effort is at the heart of TPM. It represents a significant change from the traditional views that so often divides staff in factories. During TPM, member of staff co-operates to maintain the equipment with which the company depends on for production and profitability **Moore and Rath** (2000). This research work will address the human aspect as part of this research and as part of implementing a suitable TPM strategy.

2.14 Staff Involvement

Margaret and Harry (1997) states that Employee Involvement (EI) is a participative process in which, employees are encouraged to align their commitments towards the organisational success. It has also been defined by Mann and Kehoe (1995) as a method of participation by all employees at all levels in the thinking process of the company. Margaret and Harry (1997) states that EI has a positive effect on the productivity of the organisation, which could be an outcome of creating an organisation in which staff feel responsible for and are fully involved in the productivity of their organisation. Supporting this, Hokoma and Khan (2008) concluded that the concept of total people involvement alongside the techniques such as JIT and TQM were critical to the successes of TPM implementation. Staff involvement will be investigated and discuss as part of this research work for the Libyan cement factories.

2.15 Education and Training

Geoff, (2005) stated that the behaviour of people is affected by education and training programmes, which is considered as a very important factor for the successful TPM implementation. In line with this, Roberts (1995) argued that training programmes should be applied for all the involved workers with TPM to make them aware of their benefits. Moreover, education creates a pleasant working environment for employees within the organisation, and reduces internal conflicts by creating more positive working relations. These programmes should consider the different learning needs for the involved employees at different operational and managerial levels within the manufacturing environment. These aspects will be discussed and investigated for the implementation of TPM for the Libyan cement industry. Training programmes have been strongly recommended for the Libyan industry by Hokoma and Khan (2006) as they affect the behaviour of people. Different training programmes should be designed in a proper suitable way for different individuals and teams, depending on their working responsibilities.

2.16 Commitments

Pramod et al., (2006) stated TPM needs people with leadership who should take initiatives for setting clear aims and objectives, and forming the required strategic plans and policies to reach the goals of such policies. It was presented by Roberts, (1997) that implementing TPM successfully mainly depended on senior management commitment as their commitment plays a very significant role towards implementing TPM programmes within any organisation. This commitment will be investigated during this research work. Also, the top management involvement and commitment are essential for creating and deploying clear quality values and objectives in line with the mission and vision of the organisation. This participation is also required in initiating and creating well-defined methods, system, and measuring the performance of these aims. These methods and system guide all the quality activities and encourage all the workers to participate in implementing TPM programmes (Hartmann, 1992).

2.17 TPM and Benchmarking

Benchmarking is considered one of the most popular business-management tools of the last decade. It has been promoted as a technique that, when implemented, brings improvements in quality, productivity and efficiency to an organisation's business processes by learning from other organisations and the application of better practices Penny, (2006).

Many companies had interest to get information on how their competitor's manage their manufacturing plants, benchmarking techniques are found useful to achieve this. There are numerous definitions of benchmarking. One of them is defined as "continuous improvement process based on measuring performance and practices against those competitors who recognised as industry leaders (best in class)" (Charles and Andrew, 1995).

Three types of benchmarking can be identified according to (McQueen, 1999):

(1) Internal benchmarking, where multiple-plant companies such as NCC establish a company- wide standards for each of the sites to follow, then

monitor how standards are met. This will be performed in this study through statistical data.

(2) Industry benchmarking, where company performance is measured against other companies in the same industry. This will be performed by filed visits in the UK to compare the factories with the ones in Libya.

(3) Best-practice benchmarking, where performance is measured against other companies considered to be industry leaders, regardless of business as stated by Al-Muhaisen and Santarisi (2002).

As the NCC in Libya needs to implement a suitable TPM strategy, the best way to do this is by benchmarking the TPM practice and results achieved at other organisations. Implementing TPM could include dramatic and continuous changes that could start by reaching out to other companies, including literature, to learn how they had improved their businesses. Avoiding common mistakes and selecting suitable strategies can be achieved by studying in the experience of others as stated by Charles and Andrew (1995). In order to achieve benchmarking, several indicators could be implemented (Menda and Dilts, 1997). Due to the lack of quantitative indicators from other factories, qualitative indicators will be used in this work. However, if data is available quantitative indicators can be used.

Quantitative indicators should be performed by maintenance and store department practices, and there are some common practices that used for comparison or benchmarking such as (Herbert and Irene, 2005):

- scheduling of maintenance
- Computerising management system for maintenance
- Training courses and programmes
- Technologies and techniques
- Strategy adopted for improvement such as lean manufacturing
- Employees performance
- Procedure of problem solving and attitude
- Supplier collaborative performance
- Management tools

Establishing network relationship between factories to evaluate increasing of practice and improvement should include involvement of staff in this network and motivation should be generated lead to the development of organisation (Sakakibara et al., 1993).

2.18 Case Studies of the Implantation of TPM in Middle East and Africa

A study that investigates the ways in which the Nigerian manufacturing industries can implement TPM as a strategy and culture for improving its performances and suggests has been desribed by Eti, M.,Ogaji, S. and Probert, S. (2004).

It has been found that the quality of maintenance significantly influences business profitability. Many factors have been investigated including safety and customer service, not just plant costs and availability. Reducing operating costs as well as the strategic importance of employing better and optimal maintenance strategies need to be implemented. (Eti, M.,Ogaji, S. and Probert, S. ,2004).

According to Twati, J. and Gammack, J. (2006), Libyan organisations should address many negative issues for the implementation of information systems and information technologies, including:

- lack of organisational readiness
- inadequate support for the needed change
- lack of alignment with company's strategy
- limited support and staff involvement
- unrealistic or exaggerated expectations

The same reference has concluded that Libya is not yet ready to accept and adopt Information Systems because of a lack of infrastructure. Moreover, top management are not keen to be involved in adopting IS projects due to the lack of education, skills, and avoiding anything which is new and uncertain. However, the new generation is interested in the new technology including the internet.

In Egypt, a study to identify management attitudes towards management systems such as 9001:2000 has been performed by Magd and Curry (2003). A sample consisting of 38 managing directors (MD) in Egypt was analysed. Results indicated that Egyptian organisations have a high level of understanding of the purpose of ISO certification. It has been found that the main drive behind the implementation of certified quality system in Egypt is to improve the efficiency of the quality system, and to complete competitors. The benefits of ISO 9001: 2000 for Egyptian organisations have been found to include improved documentation, improved efficiency of the quality system and more effective supplier selection.

2.19 Conclusion

The international competition and the demand to increase productivity of manufacturing and production lines have attracted the management of industrial organisations from a wide spectrum to implement Total Productive Maintenance (TPM) as a tool for improving productivity and system's output.

Total Productive Maintenance (TPM) is a maintenance program philosophy which is similar in nature to Total Quality Management (TQM) in several aspects, including the total commitment of upper level management to the TPM programme, employees must be empowered to take initiatives and corrective actions, and continuity and long term strategy is needed as TPM is a continuous process. The implementation of the available technology and cultural change of employees and management are also necessary to achieve the objectives of the process.

With the implementation of TPM, maintenance is no longer the necessary evil, but it is a vitally important part of the business. The general vision of TPM eliminates any 'conflict of interest' between production and maintenance departments. If the objective is to optimise the performance of the production line, it is important to integrate both activities in a comprehensive strategy. Down-time for maintenance should be scheduled as an integral part of the manufacturing process. Total Productive Maintenance is often defined as

"Productive Maintenance involving total participation". The objective of TPM is the continuous improvement that embraces all aspects of an organisation.

This research work will utilise the concepts of TPM discussed in this chapter to investigate a suitable strategy for the implementation of TPM in the Libyan cement factories.

CHAPTER 3: Research Methodology

Abstract

This chapter presents the research methodology selected and implemented in this thesis. Research methods in the field of engineering management are often divided into quantitative and qualitative methods. This chapter will discuss both types, outline the advantage and disadvantage of each type and explain the justification for using the selected types in this research work.

3.1 Introduction

Research methodology is normally defined as the study of methods and it invites several philosophical questions regarding the possibility for researchers to reach knowledge in particular field and how valid their claims to knowledge might be. According to Larbsh (2010), methods are concerned with which data can be collected to reach knowledge and what is the suitable way to do it.
Fisher (2007) stated that the most commonly used methods are: interviews, questionnaires, panels, observation, documents and databases.
During this research work, research methods will be adopted to allow the author to collect significant amounts of comparable data and compare the findings derived from the study with literature. Hence, the research is realist using both quantitative and qualitative methods.

Research methods in engineering management (and the other related business and social sciences) are often divided into main types : quantitative and qualitative methods. This thesis will discuss both main types: quantitative methods and what distinguishes quantitative from qualitative methods

Qualitative and quantitative methods also differ in their strength on what is the crucial approach to gaining knowledge (Muijs,2011). Qualitative researchers normally see their aim in achieving deep understanding of a phenomenon, usually by investigating a small number of participants/observations. The research could possibly evolved in generating new theory. Quantitative researchers, however, are often more concerned about testing theories with specific statistical confidence (Barkham et al, 2010).

Similar to the approach suggested by Larbsh (2010), the author has considered the following generic points in preparation for the methodology used in this research work:

- The investigation of the main type of data collection techniques such as interviews, questionnaires, data analysis, simulation and observational techniques.
- The way of approaching the organisation under investigation and the respondents, including stated purpose of the research, length questionnaire, the type of questions in the interviews, confidentiality and anonymity, etc.
- The design of modules or categories of questions within the questionnaire or the interview in order to develop a comprehensive approach in solving the problem.

The rest of this chapter will outline the main research strategies, the research methodologies implemented in this research work and their justification and other research aspects and statistical methods that should be considered for reaching the aims of this research work with confidence.

3.2 Research strategies

Research strategies should be selected based on the research situation as indicated by Yin (1994). Each research strategy has its own identifiable approach to collect and analyse information, and therefore each strategy has its own advantages and disadvantages. Although each strategy has its own unique features, there are overlapping areas, which could bring some level of complexity to the selection of the most suitable strategy. In order to avoid significant misalignment between the desired outcome and the chosen strategy, Amaratunga et al (2002) indicates that the type of question put forward, the control over actual behavioural elements and the level of focus on historical or up-to-date events are the main conditions that should provide the grounds for selection of the most suitable strategy.

In the following sub-sections, the most general research strategies are presented with comments on their relation to this research work. Further details of the implemented strategies will be covered in the following sections of this chapter.

3.2.1 The experimental strategy

The experimental strategy aims to identify links or connections between variables. For example, investigating the relationship between the voltage through a resistor and the current passing through the same resistor is an experimental strategy which will lead to the conclusion that the current will increase linearly with the increase in voltage. It is simply used to investigate the relationship between two variables. Normally, one of these is the independent variable which is under the control of the investigator while the other variable , the dependent variable, is not.

In this research work, experimental strategy has been found to be difficult in the context described above. However, the relationship between production/productivity levels and some variables has been investigated in this thesis using historical production data and simulation.

3.2.2 The survey Strategy

This is one of the most important strategies utilised in this research work. The survey strategy seeks to produce general conclusions about populations by collecting information from samples or respondents Collis and Hussey(2003). Survey may intend to describe the characteristics of the population or may aim to test explanatory theories by using correlation analyses that follow the same logic as the experiment strategy. In general, Survey strategies could include questionnaires, interviews and analysis of official reports or statistics. It has been found that this strategy could be on of the most important for this research work, further analysis will be described in future sections of this chapter.

3.2.3 The case- study strategy

The case-study strategy aims to examine a single instance of some more generic class of phenomena in order to generate a rich and complex understanding Fellow (1997) and Chambers (2003).

Based on its aims; using this strategy often means engaging in a diversity of research methods such as interviews, questionnaire, observation and the analysis of official records. Both quantitative and qualitative analytical methods are likely to be required. In this research work, several case studies have been used in order present the problems that the factories of the NCC face and guide the development of the other research methodologies in identifying the exact problems and possible solutions.

3.2.4 The ethnography strategy

Sometimes is also called ‘field study’, the ethnography strategy aims to shed light on social behaviour of participants who are studied Lancaster (2005). Ethnography aims to achieve an understanding of human behaviour by direct observation of the participants and in some cases interviews and questionnaires cane be used for this purpose. Most commonly long-term participant observation, informal interviewing and qualitative analyses are the most common methods to be used in this strategy. In this research work, the author has worked in one of the factories where the ethnography strategy was used as the initial method to evaluate the situation in the company particularly in relation to identifying some of the organisational behaviour and cultural issues that could influence the productivity within the company.

3.2.5 The action research strategy

The aim of the action research strategy is to introduce changes in organised social practices, such as production environments, and to develop knowledge from the modified processes and practices Yin (1994).It therefore requires normally strong collaboration between the researcher and the organisation in order to introduce the change and monitor the effect of this change.

Live action projects are implemented on immediate, live problems in a series of steps that involve diagnosing problems, introducing solutions, and assessing their effects (Thomas, 2004). The drawback of this strategy in the authors opinion is the need of high level of commitment from the organisation where research to be conducted and the need to monitor progress over significant period of time for research conclusions to be viable. Action research strategy has been found to be difficult to implement in this research work for the following reasons:

1. Identifying the real problems and the suggestion of viable solutions are the most important objectives for this research work.
2. The need for significant time for monitoring progress following the introduction of new solutions. This is not possible within the time scale of a PhD thesis.
3. The need for immediate financial contribution and investment from NCC for implementing any ideas or developing any possible training courses or technical solutions.
4. The commitment of the majority of staff at all levels within a short period of time.
5. Cement production is a continuous process, and any introduced changes will take significant time for the results to be reliable for reporting.
6. The use of statistical simulation to study the production process.

3.2.6 Simulation Strategy

Statistical or stochastic simulation could be considered part in some cases of action strategy. Simulation of production system, from the author’s point of view, is a combination of action research and experimental strategy. Experimenting in real production or manufacturing environment is expensive, time consuming, disruptive or unpractical process. Computer simulation can use current statistical data of the production system to create a ‘what if’ scenario and compare the results to the real production system without the risk of disrupting the real manufacturing process. Simulation is used in this research work to investigate the current non-productive time in one of the cement factories and study the transient state results from a breakdown in the kiln.

In the following section, further details will be presented in relation to the research methods used in this research work.

3.3 The Implemented Research Methods

Figure 3-1 presents the methodologies used in this research work. The personal experience used ethnography strategy to observe the production environment, culture and the organisational behaviour in LCF at NCC. This has initiated this research work when it became clear that there is a production problem combined with lack-of-interest culture from some of the staff at the factories.

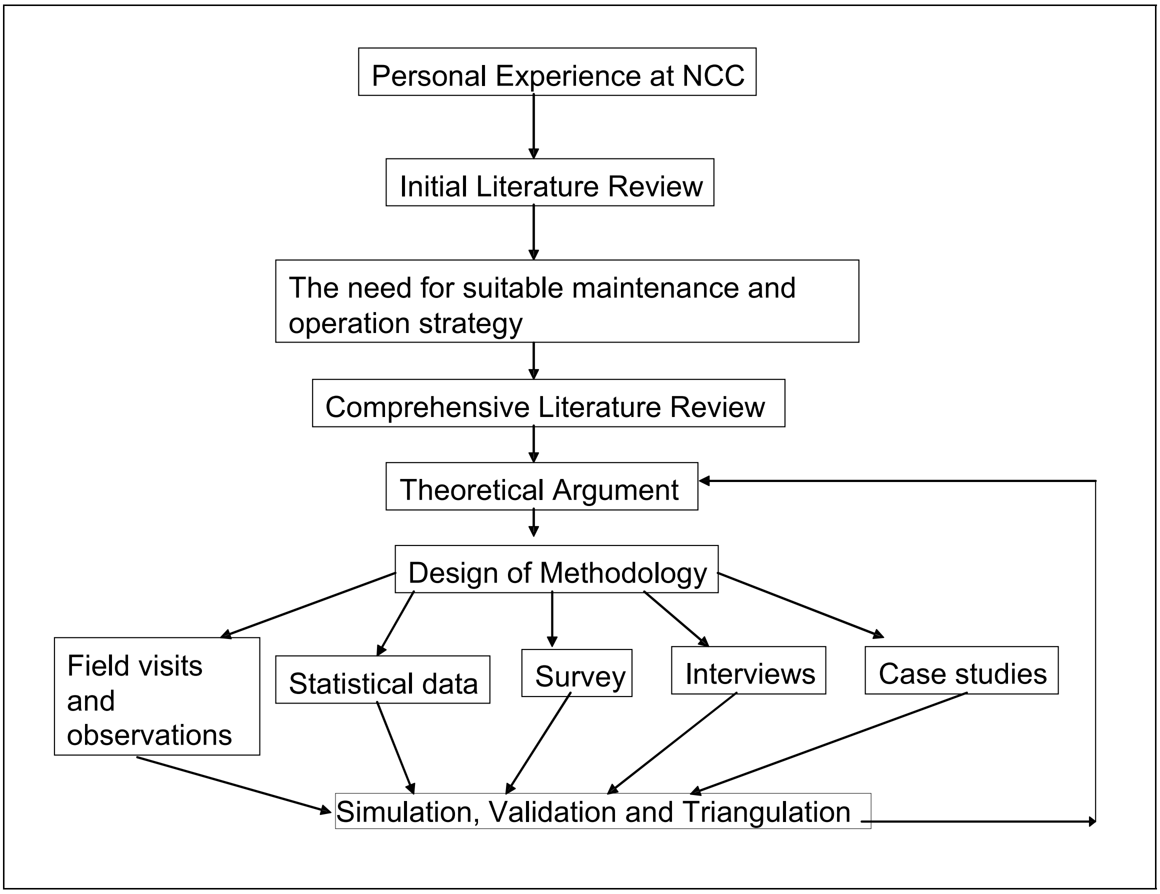


Figure 3-1: The research methods that have been implemented in this research work (Author).

The initial literature review work that has been performed provided further evidence and understanding of the drawbacks in the NCC and the four cement factories. Based on that, the aims and objectives of this research work has been formulated. A further detailed literature review has been conducted to identify modern research in this area and outline further drawbacks and the areas that should be addressed in this research work. The theoretical arguments and framework is then developed to be investigated in detail in the suggested research methodologies, namely field studies, analysis of data from factories, questionnaires, interviews, case studies and simulations. The results have been validated using triangulation between different methods combined with a validation survey. The findings have helped to formulate a novel framework to address the problems in the NCC and its four factories. Further details will be provided in the following chapters in relation to each research method and the findings.

3.3.1 Field visits and observations

Filed visits and observations have been used by many researchers, see for example Baglee(2005) and Singh et al (2010). In this research work field visits have been used to observe and qualitatively compare between different production environments. Observations from visits to the four cement factories in Libya have been compared to the findings in visits to two factories in the UK. This allowed better understanding in the culture and the organisational behaviour. The findings have been documented in this thesis using images and qualitative analysis/comments. Furthermore, the field visits have been an opportunity to have informal conversations and interviews with many members of staff to develop the questionnaires and the semi-structures interviews.

The participant observations have been an effective technique to observe how each factory planned and carried out certain maintenance tasks. This method developed a basis for creating a triangulation allowing the results to be compared against UK factories and also against the other factories and to provide a more complete understanding of the behaviour of the factories. Initially, for this research, the role of the author is that of direct observer. The direct observational researcher must attempt to maintain a non-judgmental bias throughout the study.

Therefore, the aim is not to become involved in the daily activities of the staff. The researcher's goal is to observe and describe similarities and differences as they occur. While absolute objectivity is impossible, it is paramount that the researcher keeps, as much as possible, an open mind while observing the Groups. According to Alan and Naikan (1989) this is essential for gaining first-hand knowledge, primarily during observation of employees as they go about their normal work activities. In addition to observing their behaviour, the author monitored the overall environment, and took photographs and collected evidence related to the condition of the production system. The author listened to what people said to each other, engaged in conversations, and used some people as informants about what was going on. This allowed the author to see behind the formal aspects of company settings, and revealed a rich, and possibly concealed issues and production problems.

The author has been allowed to stand near to the maintenance groups and a machine operates while carrying maintenance tasks that were either reactive or planned. The author has visited all factories at NCC in Libya and Two factories in the UK. Were taken photograph pictures for all side in factory, many pictures shown in section 6.2 chapter 6.

During the field work, statistical production and maintenance data was collected to evaluate the general performance of the factories and to identify any current limitations or observations that could feed into future stages of the study. The field work and statistical data helped in developing and investigating the initial concepts, using questionnaires/survey in order to evaluate staff responses and ideas.

3.3.2 Statistical Data Survey

Statistical data analysis has been used by many researchers including Johnson and Bhattacharyya (2010); Bryman and Bell (2007). Company production data has been statistically analysed to identify current productivity problems and availability of machines. The information collected from NCC included capacity, downtime and failures, target production, actual production, technical reasons of downtime and schedule maintenance. Also data in relation to the workforce has been analysed. Chapter 5 includes further details regarding the data and the results found.

3.3.3 Questionnaire Survey

Questionnaire has been used in this research to capture information, vision and believe of members of staff. Questionnaires have been used in the past by many researchers in the area of productivity improvement Lancaster (2005).
In general and according to Oppenheim (1992), the questionnaire survey has the following advantages:

- Avoidance of interviewer bias error, since it gives respondents the opportunity to think freely before answering any question.
- Low cost of data collection and analysis.
- Ability to reach respondents remotely by mail, telephone and the internet.
- Anonymity of respondents for sensitive issues.

However, in some cases questionnaires survey could suffer from low response rate, and consequent bias through the returning sample's interest in the topic; unsuitability for respondents of poor literacy and no opportunity to correct misunderstandings or offer explanations to participants Thomes (2004). Telephone questionnaires are more popular with the availability of mobile and smart phones, especially in developed countries.

In this research work, the author has done group distribution since the questionnaires have been conducted in four locations. The author has been able to assemble groups of respondents in the same place and, therefore, is able to explain the questionnaire to them. This method is characterised by simplicity, low cost and a high response rate of 81% in this case. This argument is supported by research by (Collis and Hussey, 2003 and Larbsh, 2010).

3.3.3.1 Questions Type

According to Muijs (2011) there is number of different question type we can include in a survey or questionnaire: open–ended and closed questions.

The **closed (or pre-coded) questions** are the most common type of question and they are the most common ones used in this research work. They are suitable for questions structured answers for simplified coding and analysis. They are typically easy and quick to answer; but could be superficial in some cases. However, the authors in this research work has based his questions based on previously discussed methods with comprehensive questions to cover most of production areas. The author has also included **Open questions** since they are more suitable for open-ended and flexible enquiries including an interview context. It is a good idea to put a small number of open questions in survey (Lancaster, 2005). Open questions can provide rich information and new ideas and thoughts. However, they might be difficult to easily summarised and analysed.

Closed questionnaires could be coded and analysed in quantitative way. Quantitative analysis is often assumed to be more objective and scientific than qualitative techniques. Because quantitative data is in the form of numbers, it can often be analysed using standard statistical techniques including reliability tests. Qualitative analysis relates to data that cannot be quantified and numerically analysed. Some researchers argue that qualitative and quantitative analysis include different types of data as well as different perspectives or approaches with regard to data and research methodology (Lancaster, 2005). Hokoma (2007) has represented an investigation into the application of Just-In-Time (JIT), manufacturing resource planning (MRPII) and total quality management (TQM) within ten key manufacturing industries in Libya using a closed questions questionnaire. In addition, (Singh et al, 2010) tried to improve productivity of SMEs using TPM by implementing a questionnaire survey.

3.3.3.2 The Design of Questionnaires

The questionnaire's questions need to be designed to provide accurate information from every member of the sample. Therefore, the questionnaire should be unbiased, clear, and should maintain the respondent's interest and motivation Henn et al (2006).

Clear objectives should be decided in line with the research questions including the information to be secured, and how the results will be presented. It has been suggested by my researchers, see for example Baglee (2005) and Hokoma (2007), that it is important to write a draft of the questionnaire and to evaluate a pilot study before finalising the main survey. The author has done this during his first filed study to get the feedback needed to finalise the questionnaire.

According to Lancaster (2005), the questionnaire should be as short as possible; have a logical structure with clear section for each topic. The reference also indicates that it is a good idea to start with factual and background information, and then explores the main area of interest with simple questions.
The author has taken this in consideration and develops clear structure for the questionnaire, see appendix C4.
Questionnaires and interviews were designed to answer four main research questions have been developed for this research work.

- What are the factors affecting Productivity from Operational perspective.
- What are the factors affecting Productivity from Maintenance perspective.
- What are the factors affecting Productivity from a combined Operation and Maintenance perspective.
- What is the awareness level in terms of (Healthy, Safety and Environment) HSE.

A clear flowchart and structure for the question is described in detail in Chapter 7. It has been decided to translate all the contents of the developed questionnaires and interviews into the Arabic language, making it easier for all the respondents to understand clearly the precise and deep meaning of all the questions.

A pilot study is an important stage in producing a good level questionnaire. This stage helps the researcher to improve the questionnaire through finding out any drawbacks such as ambiguous and unnecessary questions and sometimes the weaknesses of the questionnaire design. Collis and Hussey (2003) indicated that it is essential to pilot the questionnaire as fully as possible before distributing it. At the very least, one should use colleagues to read through it and play the role of respondents.

Therefore, in this study, there has been a number of stages before final distribution of the questionnaires. In the first stage, a draft of the questionnaire was produced by writing down and grouping all questions and issues which had resulted from the literature review. The first discussion of the questionnaire draft was with the supervisors at Nottingham Trent University to elicit their comments on the wording and structure of the questionnaire.
After that the questionnaire was translated from English into Arabic with, professional help to avoid any bias and to confirm the meaning in Arabic language. In addition, a draft of the questionnaire was checked for grammar and meaning in the Arabic language to ensure high accuracy..

Considerable research in this thesis involves asking and obtaining answers to questions through conducting surveys for engineers, technical staff and management using questionnaires and interviews. According to Thomas (1996), before choosing the sample, it is necessary to clearly define the population being surveyed, also to ensure that the sample selected provides an accurate representation of the population. The main aim of this study is to investigate into need and the implementation TPM in Libyan Cement Industries; therefore, engineers and technical staff from the Libyan Cement factories who work directly or in relation to the questions asked.

As documented in this thesis, responses are compared with hard data, such as official factory report for evaluation and analysis of results. According to Amararunga et al., (2002), the expected cost of a survey will be very large if the population is substantial, however, in this project the author managed to collect the questionnaire from the respondents in groups within each factory which made the cost and time much less than expected.

The author’s experience of National Cement Company NCC and the Knowledge throughout the intensive reading and reviewing of the literature were used for designing and developing the questionnaires as a research methodology. For wanted quantitative and qualitative data from cement factories in Libya that mean comprehensive information needed.

The questionnaire was designed to investigate many aspects; management, maintenance, raw materials, operation, training and participation towards the TPM techniques throughout the strategic level. The TPM questionnaire focuses on investigating in detail the implementation levels of TPM philosophy within the National Cement Company through the targeted organisations.

The questionnaire has a total of 47 key questions. They provide a detailed picture of the status of TPM implementation and situation in the factories. The details of the questionnaire will be covered in the chapter seven; the full questionnaire is given in Appendix C4.

3.3.3.3 Reliability and Validity of Data

Reliability is the extent to which a test or procedure produces similar results under constant conditions on all occasions (Yin, 1994). The goal of reliability is to minimise the errors and biases in a study. Therefore, a test is reliable if a later investigator followed exactly the same procedures, similar findings and conclusions would be obtained.

In convention of the quantitative research paradigm, the basic difference between reliability and internal validity is that reliability deals with the data collection process to guarantee consistency of results, while internal validity focuses more on the way such results support conclusions (Amaratunga et al, 2002).

Although early qualitative researchers felt constrained to relate traditional notions of validity and reliability to procedures in qualitative research, later researchers (Miles and Huberman, 1994; Yin, 1994) developed their own language or terminology to describe the quality criteria in a qualitative research paradigm. Miles and Huberman (1994) concentrated on improved and rigorous techniques for analysis as the best way to enhance credibility and acceptance.

According to Hokoma (2007), Cronbach's Alpha can be used to estimate the reliability of a questionnaire. Cronbach's alpha simply splits all the questions in the questionnaire every possible way and computes correlation values for them all, normally using SPSS software. The software will generate one number for Cronbach's alpha. Similar to the correlation coefficient, the closer it is to one, the higher the reliability estimate of the questionnaire. Cronbach's alpha is a less conservative estimate of reliability than test/retest which would require two groups of questionnaires to evaluate the reliability, whereas the internal consistency method of Cronbach's Alpha involves only one administration of that questionnaire. According to pallant (2005), the ideal value of Cronbach's Alpha Coefficient should be above 0.7, which implies that the scale is reliable with the used sample. Author used SPSS software in chapter seven to investigate the reliability for questionnaire.

Mathematically, Cronbach's Alpha (α) can be expressed as:

$$\alpha = \left(\frac{k}{k-1}\right)\left[1 - \frac{\sum s_i^2}{s_{sum}^2}\right] \qquad (1)$$

In this formula, the s_i^2 denote the variances for the k individual items; s_{sum}^2 denotes the variance for the sum of all items. Therefore, for uncorrelated coefficient *alpha* will be equal to zero if the variance of the sum will be the same as the sum of the variances. If all items are perfectly reliable and), then coefficient alpha is equal to 1.

In addition, Cronbach's alpha is utilised to assess with 0.60 value indicating adequate reliability (Taj and Morosan, 2011).

The author has used SPSS and MS Excel software to data analysis. Other researchers have examined SPSS, according to Das et al (2011) used the same statistically to found the reliability coefficient (Cronbach's alpha) for the role of leadership competencies construct is 0.968, which is highly acceptable.

3.3.3.4 Variance and X^2 Chi Square Test

A deviation about the average or mean of a population is the basis for most of the statistical analysis. It measures how widely a set of scores is dispersed about the average. The deviation about the average is expressed as variance or standard deviation. The variance measures variability within a distribution. Standard deviation is a number that indicates how much, on average, each of the values in the distribution deviates from the mean (or average) of the distribution. The variance is the square of the standard deviation.

The Chi Square X^2 test is one of the most important and most applied members of the nonparametric family of statistical tests. Chi Square is used to test the difference between an actual sample and another hypothetical or previously established distribution such as that which may be expected due to chance or probability. Chi Square can also be used to test differences between two or more actual samples. Equation (2) presents the chi-square mathematically.

$$X^2 = \sum \frac{(Observed\ frequency - Expected\ frequency)}{Expected\ frequency} \qquad (2)$$

Chi-square is used as a test of significance when the analysis involves one or two nominal variable. The observed variables (frequencies) are compared with the expected population frequencies which are either known (one-sample chi-square) or estimated by combining the samples where the researcher has data from more than one sample (Howitt and Cramer, 2008); (Johson, 2010).

3.3.3.5 Non-respondent Bias

The prediction of the direction of non-respondent bias is useful for assessing uncertainty in results. In this work, the response rate is 81%. This indicate 19% of the respondent (all population in the four factories) did not return the questionnaire. This could have some influence on the results and the statistical analysis. However, the lack of response as observed during the factory visits is mainly related to ‘don’t know’ response or a negative response that engineers or technical staff are not willing to share for the sensitivity of the matter.

3.3.4 Interview Survey

An interview is a survey that would involve personal contact between the interviewer and the respondent, and it is a method of collecting data in which selected participants are asked questions in order to find out what they do, think or feel (Collis and Hussey, 2003).

Interviews have selected in this study because they allow the author to acquire more details and obtain greater depth of knowledge about what is under investigation that questionnaires might not be able to cover, particularly for qualitative analysis.

The interview process depends on main three issues: sampling control, information control, and administrative control (Fletcher, 1973).

Sampling control depends on the researcher’s ability to direct questions to the interviewee and to get the desired co-operation. Personal interviews usually involve face to face communication between interviewers and interviewees. The advantages of personal interviews include the ability to allow the interviewer to see the interviewee allowing the interviewer to spend more time with his or her interviewees as opposed to phone calls or written documents. Interviews could be conducted face-to-face or over the phone. The author has selected face-to-face option because it is expected to give a much better response and provide opportunities to discuss complex questions and pick up nonverbal cues from the respondent. However, face-to-face interviews are more expensive and they are usually more time-consuming. However, in this thesis the author had the opportunity to visit the factory three times to interview participants and collect the required data. The author travelled to Libya and visited all of the factories mentioned above. Interviews were then conducted with 15 top, middle managers and senior engineers. These interviews sought to uncover specific information from participants who know or have access to the information being investigated.

Information control depends on the ability of the researcher to design and develop questions for a particular interview and to continuously modify them when necessary. The questions developed for this research are drawn from a preliminary review of the literature, field work, case studies and the survey questionnaire. According to Bill (2000), interviewees should be informed about the aim of the investigation and should be granted confidentiality. Moreover, the interviewer must be able to direct questions to every interviewee while avoiding possible bias. Administrative control depends on suitable documentation and presentation of the data collected. For further information regarding interviews design, the reader could refer to (Robert, 1996).

The author has designed a semi-structured interview for this research work. Semi-structures interviews refer to a context in which the interviewer has a series of questions that are in the general form of an interview schedule but he or she is able to vary the sequence of questions. The questions are more general than in a structured interview. In addition, the interviewer has some latitude to ask further questions in response to what are seen as significant replies (Bryman and Bell, 2007). The most difficult task of an interview, perhaps, is to be aware of an organisation's 'political culture', and to try to persuade the interviewees that information disclosed during a particular interview will be handled with utmost confidentially. Confidentiality is an important issue since without it interviewees may simply find it difficult to express their opinion in a frank and clear way. For instance, many workers are too afraid to openly criticize top managers. For reasons of confidentiality in this research, every interview was given a code in order to keep the interviewee's identity confidential.

The information gathered from the interviews was analysed in two ways: quantitatively (using a coding system for the answers, i.e. similar to questionnaires) and qualitatively. Qualitative analysis is not about mere counting or providing numeric summaries. The aim is to discover variation, to portray shades of meaning, and to examine complexities. The primary objective of the analysis is to reflect complexity of human interaction by describing it in the words of the interviewees and through actual events and to make that complexity understandable to others (Leslie, 1988; Herbert and Irene, 2005).

The interviewer used a similar data collection strategy to that which was described in the previous Questionnaire. Questions were, thus, asked to the interviewees whose answers were then categorised into different codes depending on the type of obtained answers. A semi-structured interview approach has been utilised which allowed the dialogue to be unrestrictive, conversational, and exploratory. Moreover, every time a new question emerged, it was also coded and utilised in order to obtain a more in-depth insight into the subject under study.

3.3.5 Case Studies

This thesis presented several case studies from the data collected from the four factories in order to attempt the 'normal' production levels and to understand the causes behind low productivity and the reason for breakdown.
Graphs of changes in data have been presented and discussed, the results have been compared with the results obtained with the field work observations, questionnaires and interviews.

3.3.6 Simprocess Simulation

In this thesis, Simprocess simulation software has been used to simulate the production system of LCF using real statistical data captured during the field visits. Simulation intends to accurately represent, through a computer model, a "real" or "imaginary" system. There are a number of discrete-event simulation packages available in the market today, but based on the manufacturing process that was to be simulated and after an evaluation of several software packages, Simprocess was selected. Simprocess is an object-oriented software environment used to develop, model, simulate, visualise and monitor dynamic flow process activities and systems (Nordgren, 2003). The simulation can be interrupted at any stage and a comprehensive reporting system can be viewed, either in graphical or tabular form.

The reliability in the results generated by a simulation model is an important aspect of any successful simulation study. Therefore, any model must be verified and validated to ensure that it behaves as expected (Garza-Reyes, 2010). This has been done in this thesis by ensuring the output of the factory matches the real values of the production system.

3.4 Summary

It is essential to have a clear and suitable methodology to achieve the objectives of this study. The selected methodology influences the validity, reliability and research results. Many different research methods have been described by various authors. Research methods including action research, case studies, experiments and surveys have been described by Gill and Johnson (1991), Bryman (1989), Mandy, (2004). Each method has its own advantages and disadvantages, and the reliability and validity of the data collected is different one from method to another. This work has been initiated by the author as a result of facing productivity and maintenance problems during his work in the LCF. This was developed to this current research work in order to investigate the current problems and possible solutions. A literature review is conducted within the domain of this research work to investigate the general aspects within this work. This is followed by collecting statistical data from the factories, field observations, case studies, questionnaires and semi-structured interviews. Both quantitative and qualitative research methods are used in this thesis. The research methodology is carefully designed in order to meet the time scale of a PhD thesis.

CHAPTER 4: RESEARCH DOMAIN- CEMENT PRODUCTION IN LIBYA

Abstract

This chapter introduces the cement production in Libya as the research domain within the National Cement Factory. It presents the background information about the company and its cement factories. It outlines the stages of cement production and introduces some key production trends that will be used to identify the main problems in the cement production in Libya. The chapter concludes with the current challenges facing the factories and an outline of the methodology to be used within this research work to solve such problems.

4.1 Introduction

Cement is used to make concrete and mortar, which is a type of 'glue' holding blocks and other building materials together. The first building glue in history was wet clay which sets hard as it dries and holds the stone in place. The Egyptians and Romans discovered how to make stronger building glue than clay by using limestone, which they burnt and mixed with gypsum. The pyramids are some of the oldest examples of blocks held together by a cement-like material (Lafargecement 2007).

In 1824, Joseph Aspdin, a British stone mason, obtained a patent for cement which he produced in his small workshop. The inventor heated a mixture of finely ground limestone and clay on a kitchen stove and ground the mixture into a powder, thus creating cement which hardens with the addition of water. Aspdin named the product "Portland cement" by analogy with the Portland stone, an oolitic limestone that is quarried on the channel coast of England, on the Isle of Portland in Dorset. With this invention, Aspdin laid the foundation for today's Portland cement industry. Materials that include appropriate amounts of calcium compounds, silica, alumina and iron oxide are crushed and placed in a rotating cement kiln. Ingredients used in this processes are typically materials such as limestone, marl, shale, iron ore, clay, and fly ash (Cement 2009).

The heater is called a kiln, which produces very high temperatures. This high heat removes the chemically combined water and carbon dioxide from the raw materials and forms new compounds (tribalism silicate, dicalcium silicate, tricalcium aluminates and tetracalcium aluminoferrite). The material that leaves the kiln called clinker. This clinker is in the form of marble sized pellets. The clinker is very finely ground to produce Portland cement. A small amount of gypsum is added during the grinding process to control the cements set or rate of hardening see(Cement 2009); (Cementindustry 2007). Cement has so many applications. It is a key element of modern construction, from our homes, through to schools, hospitals, offices, roads, railways and airports. We also rely on it for building reservoirs for our water, and for other vital utilities. This chapter will include cement production stages in more detail within the context of the National Cement Company in Libya.

4.2 The National Cement Company

The National Cement Company (NCC) is one of the largest companies in Libya, and one of the largest producers in North Africa. NCC is one of the companies owned by the Libyan Government, and it is located in the north-west region of Libya. It has a cement production target of 3,330,000 tonnes per annum. NCC also has additional manufacturing facilities, for example, it also produces gypsum, lime, factory bags, factory block, marble, bums concrete plant and cement mixes. The company comprises four cement factories. The first was built in 1968 near *Alkhumes city, Margeb* (MCF), which is 80 miles west of Tripoli, (see Figure 4-1). It was designed for a production capacity of 330,000 Tonnes per annum. The second factory was built in 1977, 25 miles north of *Souq Alkames*, a town near Tripoli, and has a target production of 1,000,000 Tonnes per annum (SCF). The third factory was built in 1979 at *Alkhumes, Libda* (LCF) which is 90 miles west of Tripoli. This factory has also been designed for a production capacity of 1,000,000 Tonnes per year. The fourth factory was built in 1984 at Zeleten city (ZCF), which is about 103 miles from Tripoli. This factory is designed for a production capacity of 1,000,000 Tonnes per annum. The cement produced from the four factories is for internal consumption, due to the fact that the total production is required for the infrastructure of Libya.

NCC produces cement according to Libyan specifications, which are similar to those of British Portland cement. It uses a dry process method in all factories. This cement is used for many construction purposes, particularly for building houses, bridges, roads, and ports.

The management structure of NCC, (see Figure 4-2 and 4-3) has a centralised management system (i.e. Head quarter) to control all factories and plants which is located at Alkhumes city, due to its central geographical position. Figure 4-4 presents a factory organisation within the company.

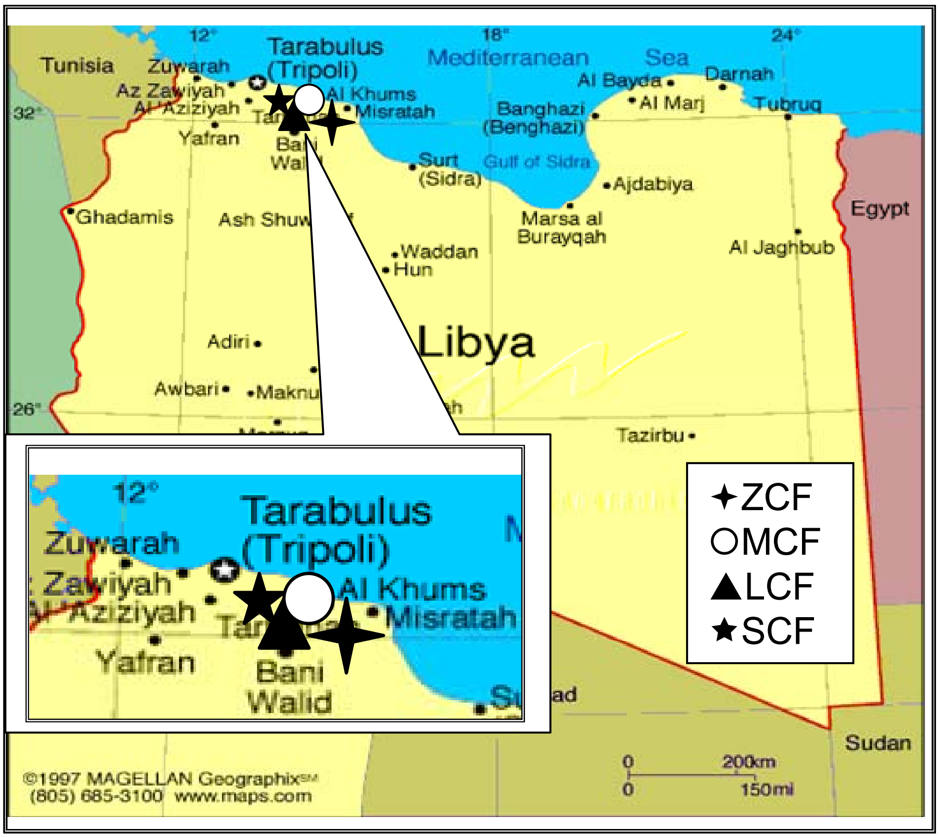


Figure 4-1: Map of Libya which shows Tripoli in the North West (Map of Libya 2007).

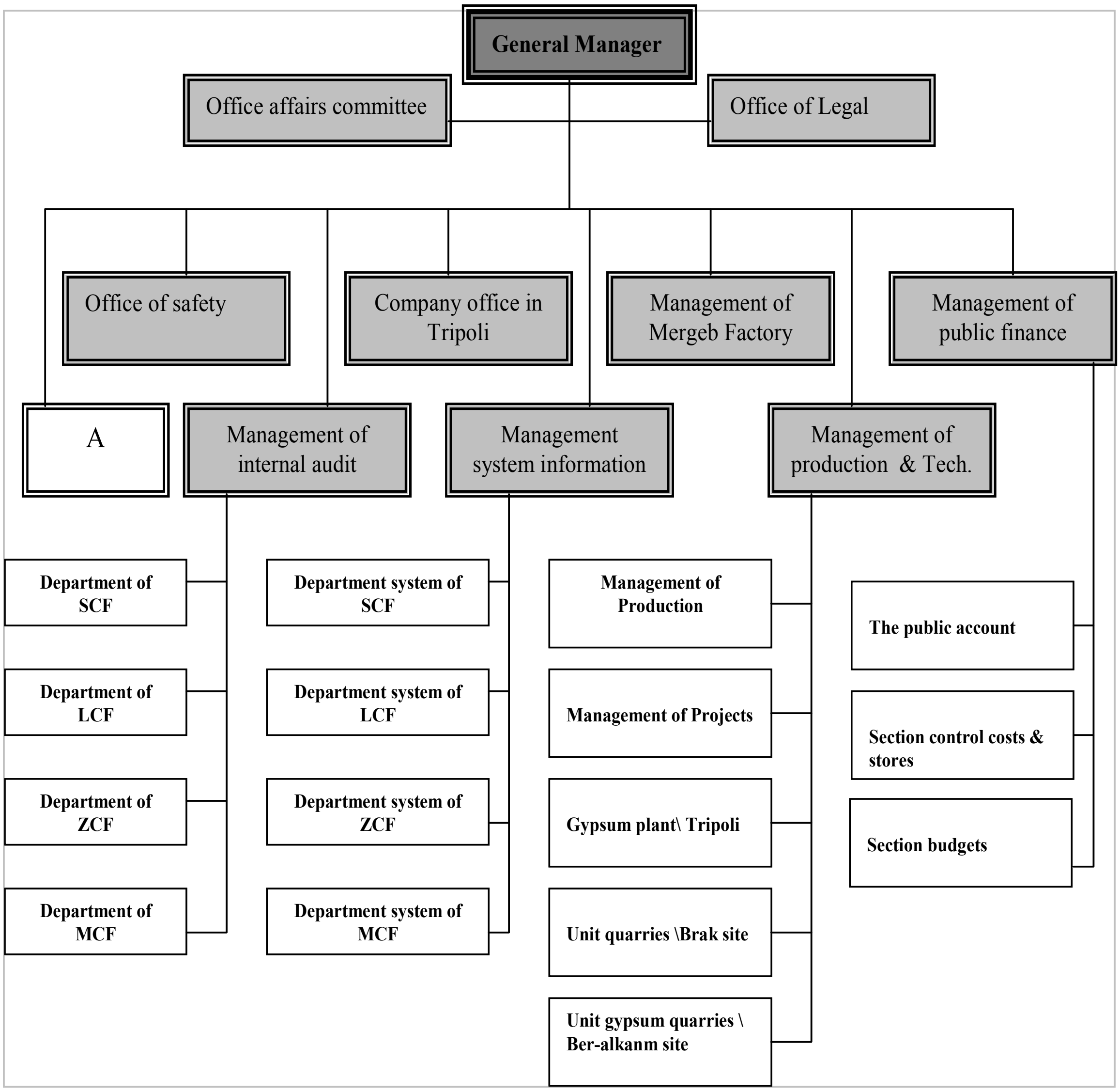


Figure 4-2: The organisational structure of National Cement Company(RPA, 2006)

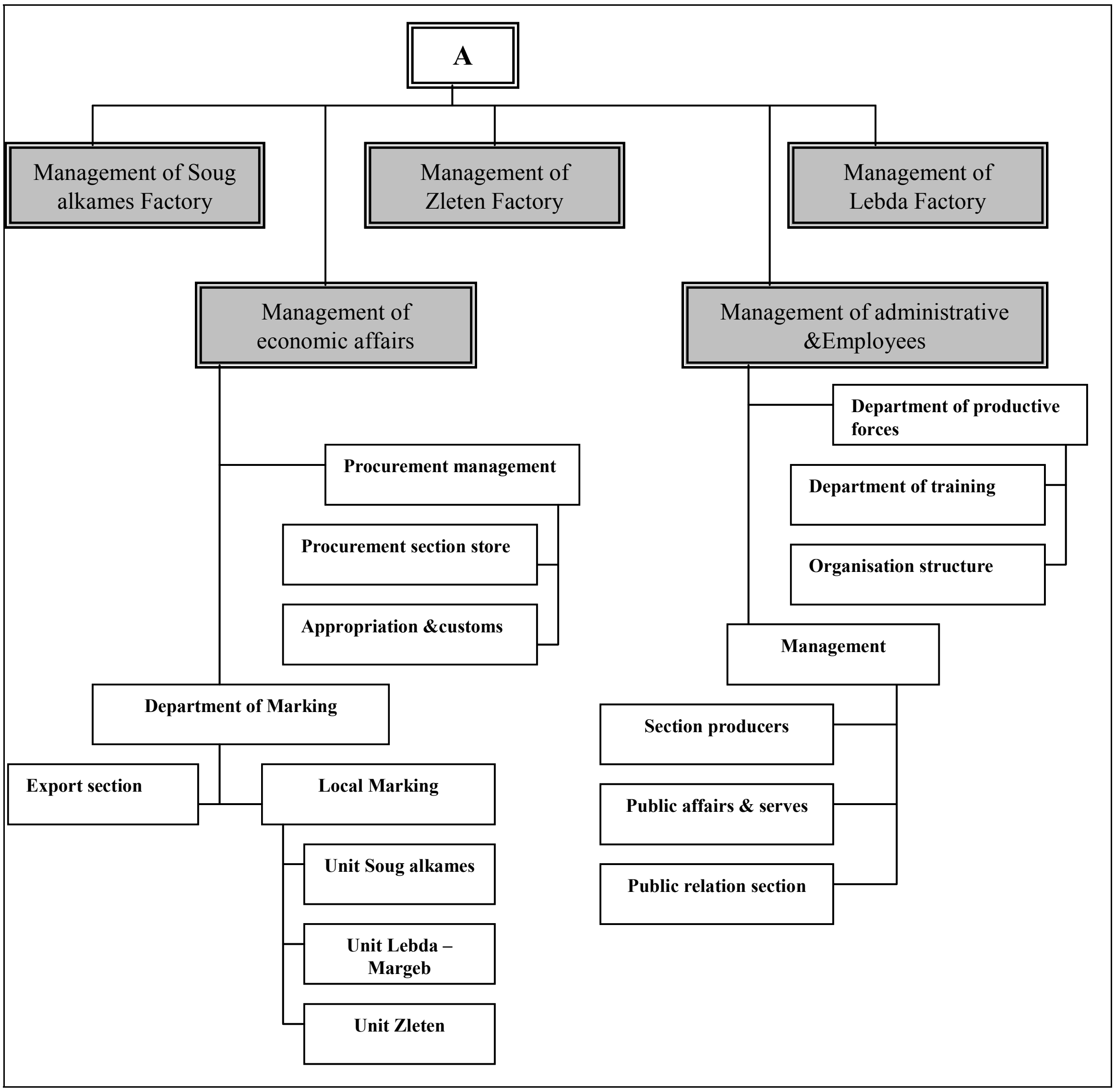


Figure 4-3: Continues the organisational structure of National Cement Company(RPA, 2006)

The company structure seems similar to other organisations of similar nature. However, the Production Management department seems too far separated from Project Management & Research and Development. Hence, the maintenance activities are split between both departments with no clear responsibility. In most modern companies, (see Chapter 3) this is normally more integrated within one unit of operation; this is true particularly if TPM is implemented. Another problem that could be indicated from the structure is that the four factory structures are separate units from the main departments. Hence, it could be argued that the HQ departments are mainly for data collection. However, this could increase the complexity of the operational aspects of the factories and reduce their autonomy.

Figure 4-4 presents the structure of Libdah's cement factory, which is almost identical to the other three factories. From the structure, it is clear that the Management of Production is separated from the Management of maintenance, which contradicts with modern production systems, and generates a conflict of interest between production and maintenance. Moreover, the separation of the maintenance systems into studies (research), electrical, mechanical, and construction generates more disconnection in the maintenance process.

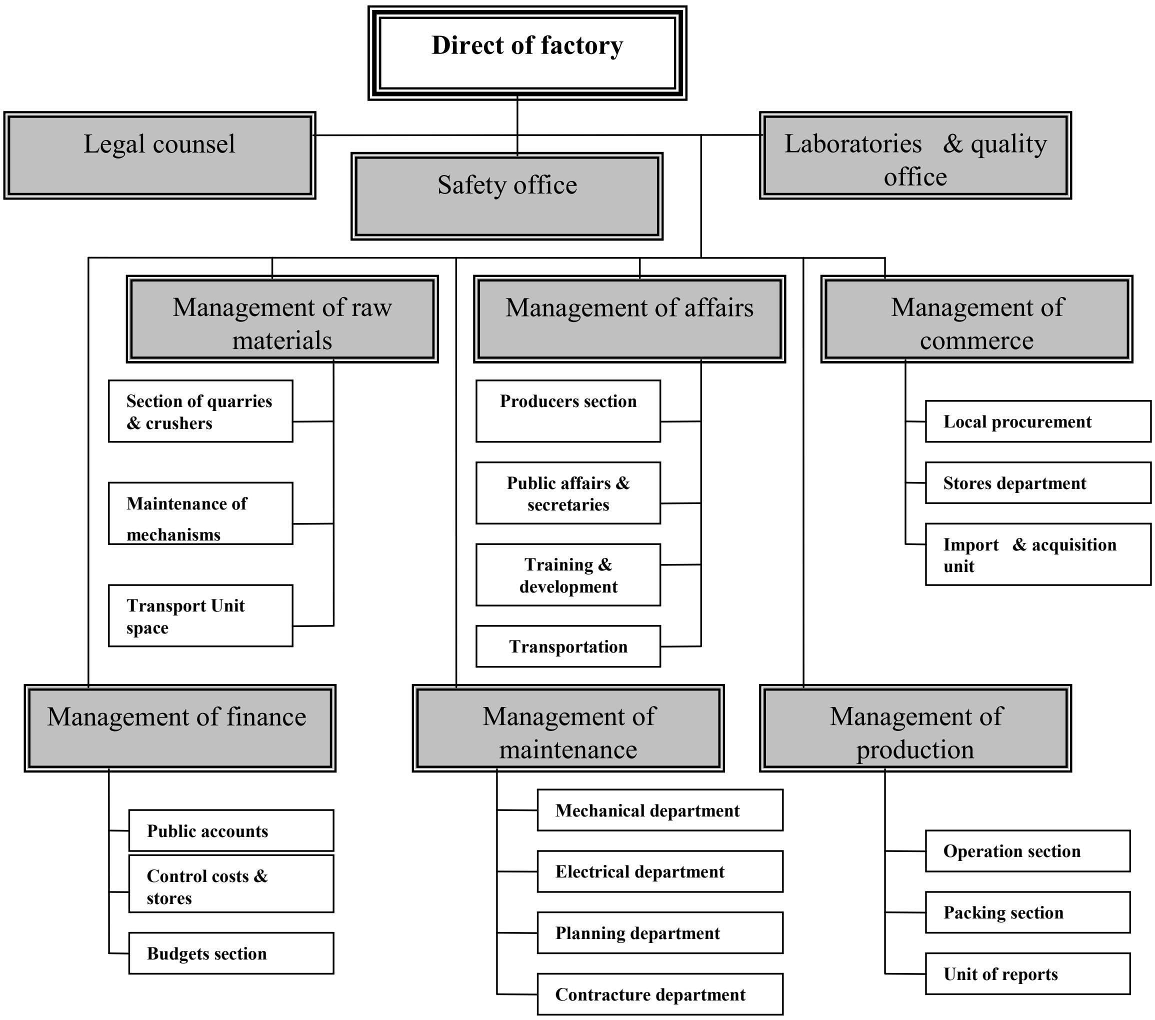


Figure 4-4: The organisational structure of Libda Cement Factory (LCF) (RPA, 2006)

For simplicity, the following abbreviations will be used to describe the four factories: *Margeb Cement Factory:* MCF, *Libda Cement Factory:* LCF, *Zeleten Cement Factory:* ZCF and *Souq Alkames Cement Factory:* SCF.

4.3 Production of Cement in Libya at NCC

Portland cement, the fundamental ingredient in concrete, is calcium silicate cement made with a combination of calcium, silicon, aluminium, and iron. Producing cement that meets specific chemical and physical specifications requires careful control of the manufacturing process. Figure 4-5presents the main step of cement production and Figure 4-6 presents the detailed structure of producing cement as within LCF as an example to the other three factories at NCC. The first step in the Portland cement manufacturing process is obtaining raw materials. Generally, raw materials consisting of combinations of limestone, shells or chalk, and shale, clay, sand, or iron ore are mined from a quarry near the plant. Figure 4-7 presents photographs of one of the quarries at Libda cement factory.

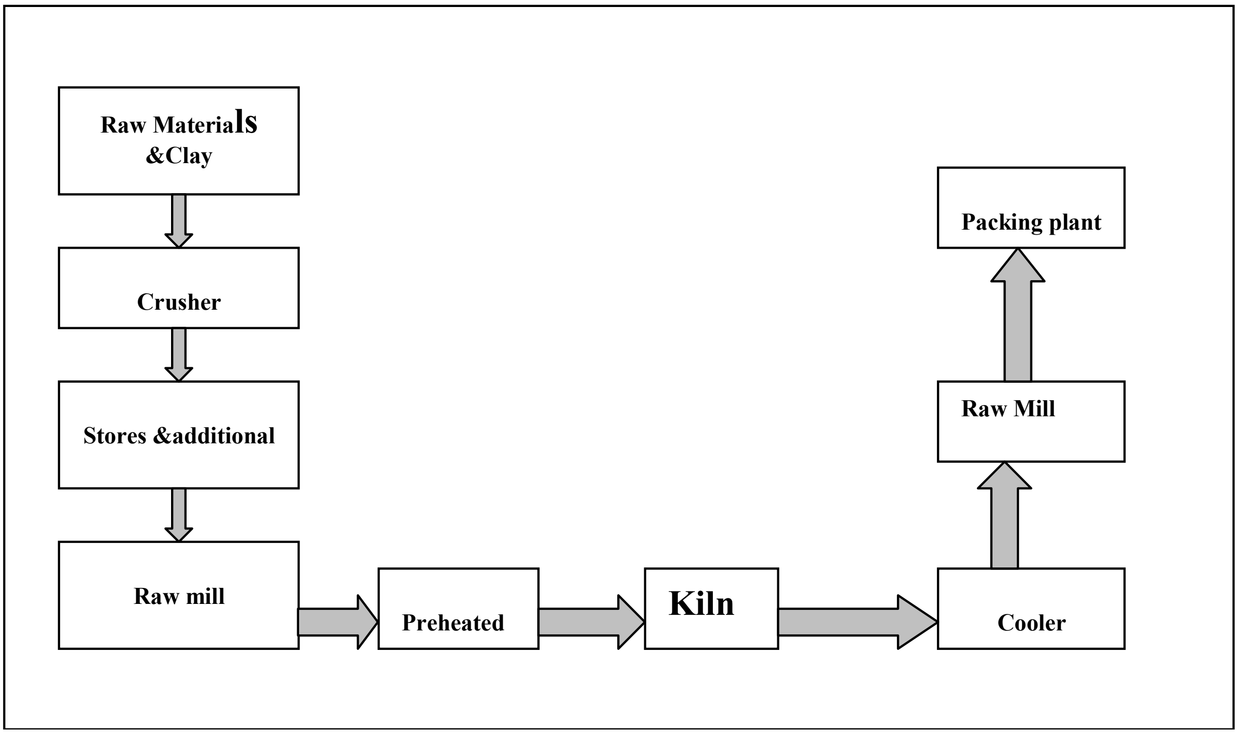


Figure 4-5: Outline of the main steps of cement production (Author).

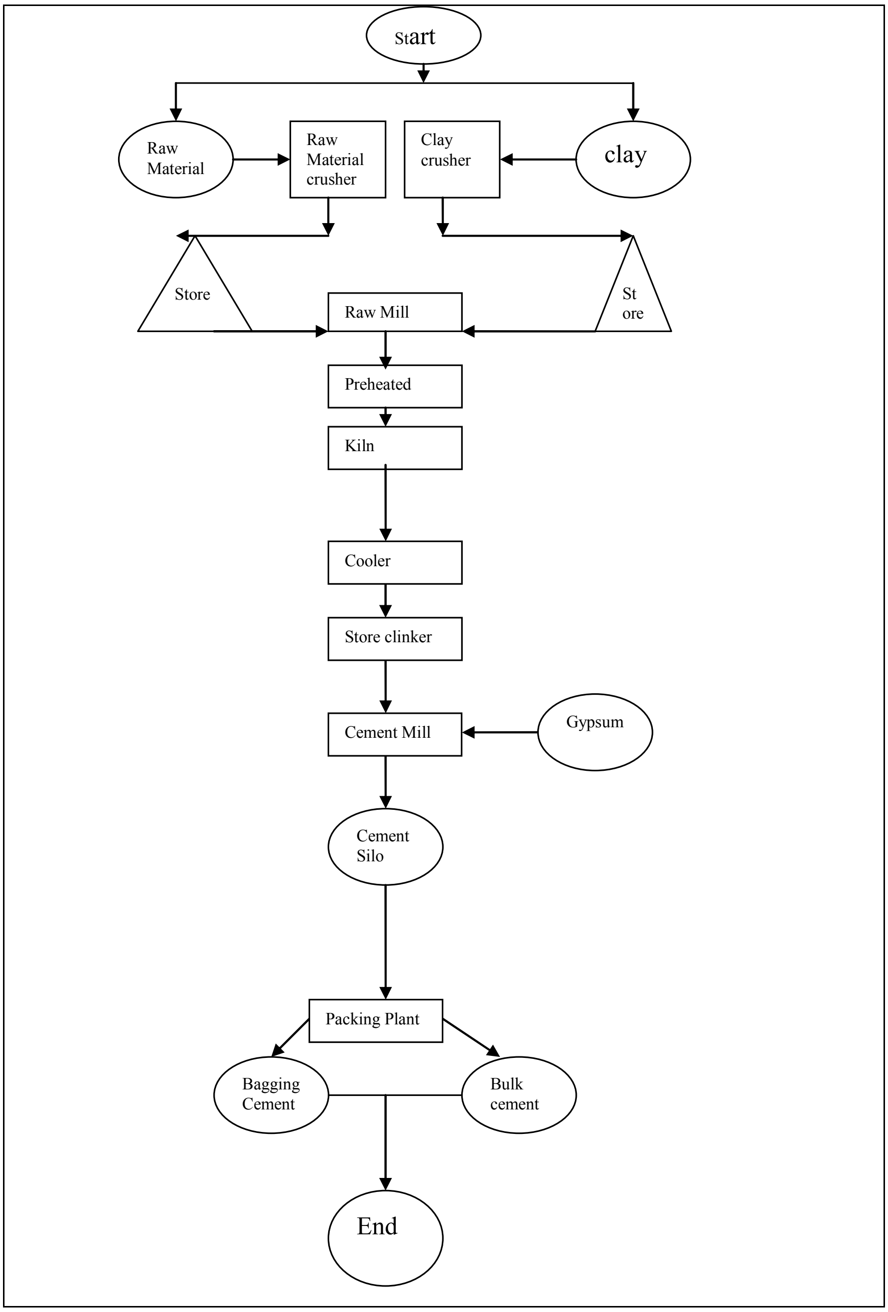


Figure 4-6: Production of cement flow chart (Author).

Figure 4-7: Quarry for retrieving raw material at Libda Cement Factory (2007)(Author).

At the quarry, the raw materials are reduced by primary and secondary crushers. Stones are first reduced to about 125-mm in size, then to 19 mm. Figure 4-8 is a photograph of the crusher at Libda Cement Factory (LCF).

Figure 4-8: Raw materials at crusher of Libda cement plant (Author).

In general, two different methods, dry and wet, are used to manufacture Portland cement. In the dry process, dry raw materials are proportioned, ground to a powder, and blended together. The dry method is the one which is used at the four factories in Libya.

The raw materials may contain a sulphur compound as either sulphide or sulphate. High SO_2 emissions by the rotary kiln systems of the cement industry might be attributable to the sulphides contained in the raw material.

Figure 4-9: Raw materials, clays and additional (Iron) silo of Libda cement plant (Author).

Figure 4-9 shows the mixing and storage of raw materials, clay and iron to produce the right quality of cement.

The materials are dried and finely ground in a" Raw Mill" to form an intermediate product, called "raw mill". The grinding provides an increased surface area to enhance the heat exchange in the downstream heating process,
(see Figure 4-10).

Figure 4-10: The Raw-Mill at Zeleten Cement Factory (Author).

The “raw-mill” is then stored in a homogenising silo, (see Figure 4-11) in which the chemical variation is reduced. This homogenising process is important to stabilise the downstream entering process as well as to provide a uniform quality product. The “raw-mill” is then transferred to the Preheating Tower.

Figure 4-11: Materials are homogenised and stored in silos before entering the heating process at Zeleten Cement Factory (Author).

The heating process consists of two stages: a preheating process and then the kiln heating process (see Figure 4-12). Before entering the kiln, the raw-mill undergoes a series of concurrent heat exchanges with the hot exhaust gas from the kiln system. The gas and material streams are separated by cyclones after each heat exchange process. The raw-mill temperature increases from 80^{o}C to 1000^{o}C within 40 seconds. The first chemical reaction also takes place in the Precalciner of the Preheating tower, where limestone $CaCO_3$ is decomposed into lime (CaO), and fed into the kiln in a dry state (Cement Manufacture process 2009) .

Figure 4-12: The Kiln and the pre-heater at Zeleten Cement Factory(Author).

As presented in Figure 4-12, the kiln resembles a large horizontal pipe with a diameter of 3 to 4 meters and a length of 90 meters or more. One end is raised slightly. The material is placed in the higher end and as the kiln rotates the materials move slowly toward the lower end. Flame jets are positioned at the lower end and all the materials in the kiln are heated to high temperatures (Mohammad and Nader 2002).

The material following the kiln is called 'clinker'. The clinker burning process is a high temperature process resulting in the formation of nitrogen oxides (NOx).

Nitrogen monoxide (NO) accounts for 95% and nitrogen dioxide (NO2) for some 5% of this compound present in the exhaust gas of rotary kiln plants. As most of the NO is converted to NO2 in the atmosphere, emissions are given as NO2 per m^3 exhaust gas.

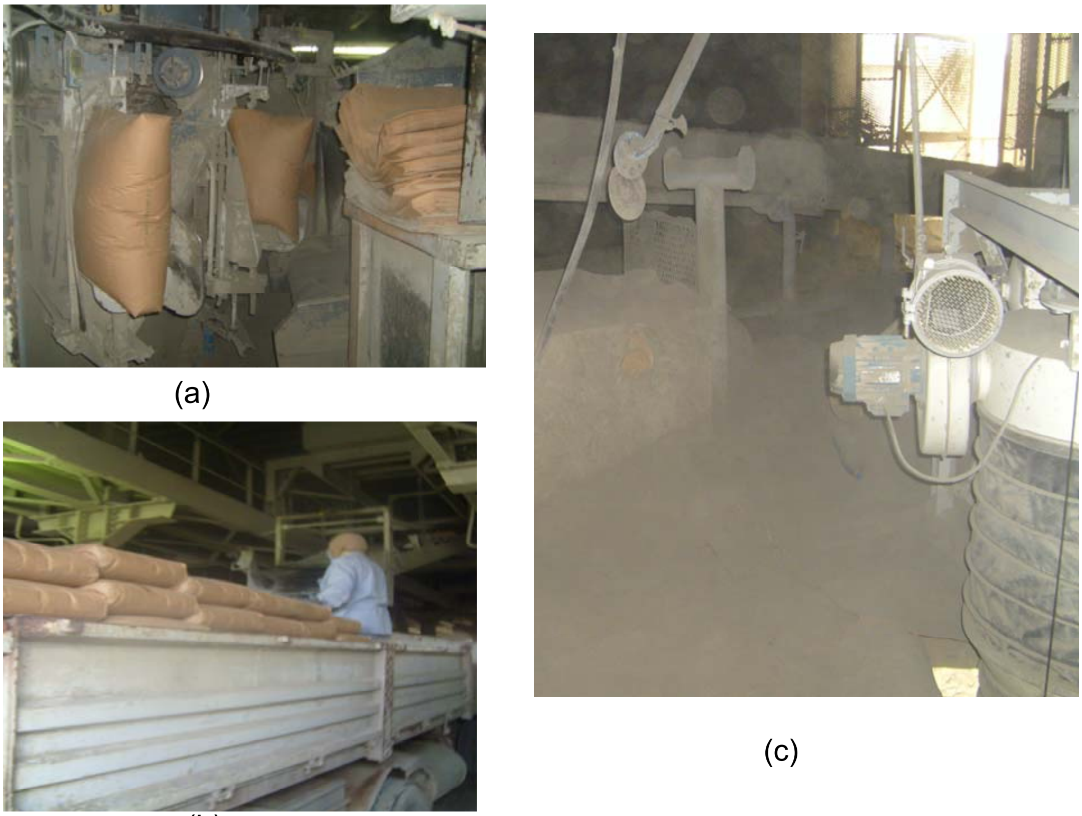
The residual heat from the clinker leaving the kiln is recovered by a large cooler as shown in Figure 4-13. Cooling air is injected from the bottom of the cooler, and is forced into the clinker, which is travelling slowly on the grate. The heated air is then recycled as secondary air for combustion in the kiln, or in the precalciner.

Figure 4-13: Clinker cooler at Libdah Cement Factory (Author).

Cooled clinker is combined with gypsum and ground into a fine grey powder. The clinker is ground so fine that nearly all of it passes through a 75 micron sieve.

Figure 4-14: Cement Mill which mixes clinker with gypsum at Libda Cement Factory (Author).

The clinker with a controlled amount of gypsum is fed into a finish mill, see Figure 4-14. Typically, a finish mill is a horizontal steel tube filled with steel balls. As the tube rotates, the steel balls are lifted, tumble and crush the clinker into a super-fine powder. The particle size is controlled by a high efficiency air separator. At the packing stage, Figure 4-15, the cement under goes its last steps at the plant, there are two processes one of the first bagging, and another for bulk despatch direct to the Lorries.



(a) (b) (c)

Figure 4-15: Packing facilities at Libda Cement Factory, bags of cement are filled (a) , transported to customers (b) and bulk filling equipment (C) (Author).

4.4 The Problem in Context

In order to present the current problems in the NCC, the production of each of the four factories is investigated over a significant number of years (between 1993 and 2006). This discussion will investigate the trends in the factory production and highlight the main problems and limitation in the current production and maintenance strategies.

The production of the Margeb Cement Factory (MCF) can be seen in Figure 4-16, It can be observed that in 1993 the factory had a very low production, which improved the following year, after which the production showed a high fluctuation, and the fluctuation level has increased in recent years with the lowest production in 2003, but with some improvement between 2004 and 2006.

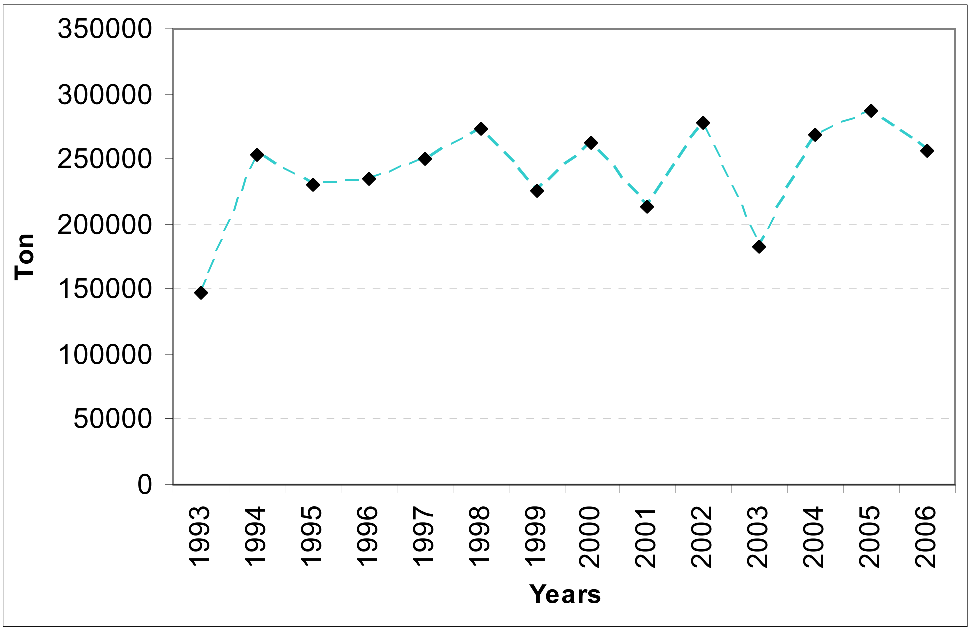


Figure 4-16: MCF production from 1993 to 2006.

When examining the production of Libda Cement Factory (LCF) as presented in Figure 4-17, it is clear that in 1993 the factory had a very high production level which decreased between 1994 and 1998. Then some improvement occurred between 1999 and 2001, after which the production showed some decrease but with stability between 2002 and 2006. However, the production is about 60% of the design capacity of the factory.

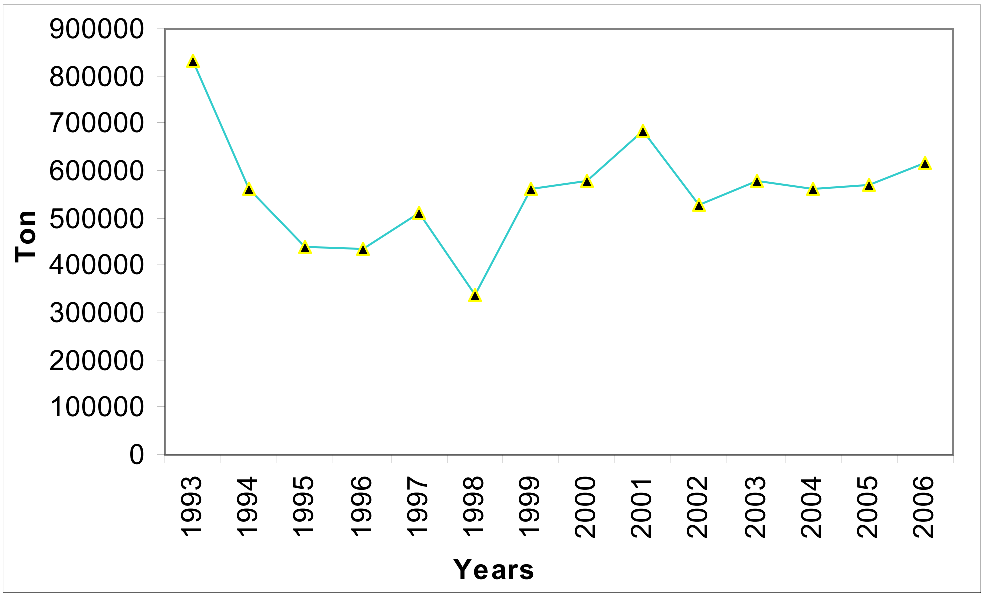


Figure 4-17: Libda factory production from 1993 to 2006.

Zeleten Cement Factory (ZCF), see Figure 4-18, has a trend similar to Libda's factory. The production has reached 40% of the design capacity in 1997. It has improved over the years, but there are still significant fluctuations and the recent maximum production was only 80% of the design capacity.

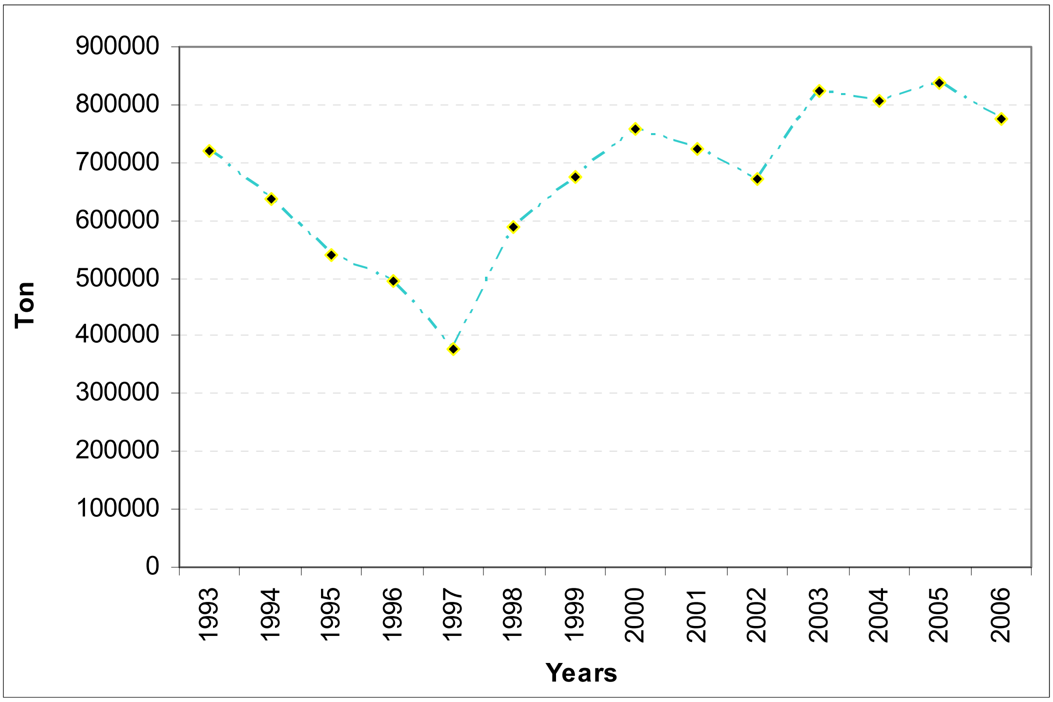


Figure 4-18: Zeleten factory production from 1993 to 2006.

Souq-Alkames Cement Factory (SCF) production is illustrated in Figure 4-19. It is observed that the production started at about 90% of the design capacity. But it went down during the following years to almost 50% of the design capacity. The production level rose during the last three years in the graph but production is still within only 80% of the design capacity.

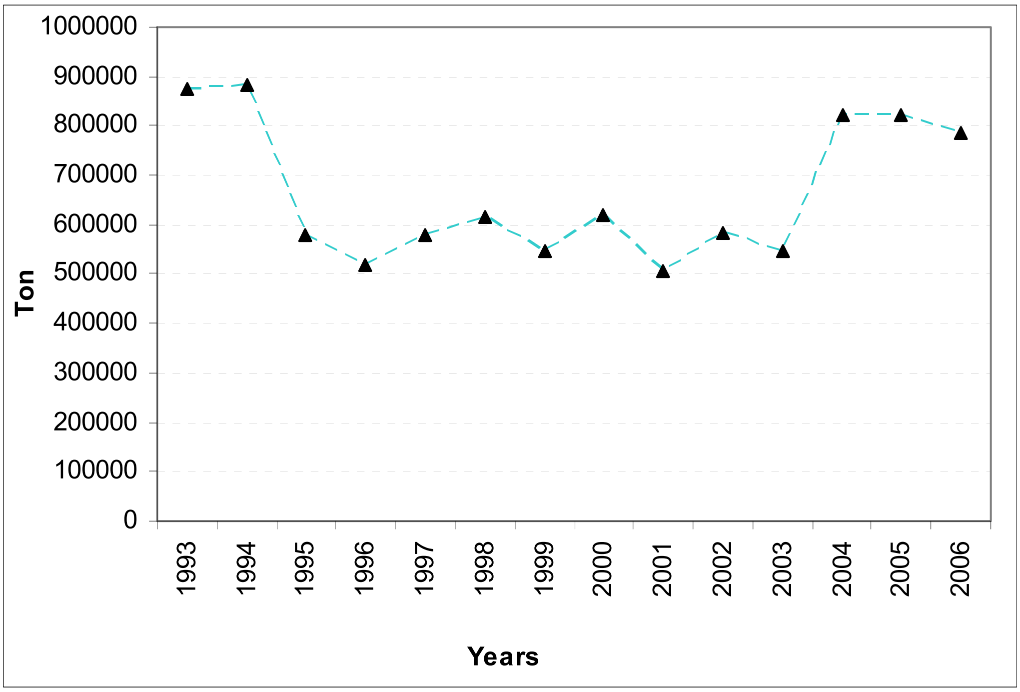


Figure 4-19: Souq-Alkames factory production from 1993 to 2006.

4.5 Conclusion - Problem definition

This chapter has introduced the NCC and its four factories. It also explained the process of producing cement. Production data from the four factories is presented and discussed. This information in this chapter leads to the following questions:

a) Why have the four factories much less production than the designed capacity?

b) Why have some of the factories (e.g. LCF) less productivity than others?

c) Why are there some trends and significant fluctuations in the production of the factories between 1993 and 2006?

Based on the above three questions, the author has developed the following detailed questions that he will try to answer in the following chapters of this thesis:

1. What are the problems facing the Libyan industry and the cement sector in particular?
2. What are the limitations in the current practice, in the production and maintenance activities, of the cement factories at the NCC?

3. What are the cultural issues that should be addressed when designing a maintenance strategy and a TPM model?
4. What are the most important key factors for the cement industry in Libya?
5. What are the human-factor aspects that should be addressed in implementing TPM (including training and personal development)?
6. What is the main effect of the current industry on the environment?
7. What is the effect of the political history and current local people's committees on the cement industry in Libya, including the availability of spare parts and maintenance expertise?
8. What are the main aspects to be considered in a TPM model for the Libyan industry?
9. How can the TPM model be implemented in Libya taking in to consideration all the issues that have been address in the previous research questions?

The above questions will be addressed by comprehensive statistical analysis of data, field work, questionnaires, interviews and simulation analysis in an attempt to answer them and provide comprehensive understanding of the conditions in the four factories.

Figure 4-20 includes a general Framework to provide an initial and conceptual framework to be addressed in this thesis. It highlights the main issues to be understood and addressed to provide a TPM model.

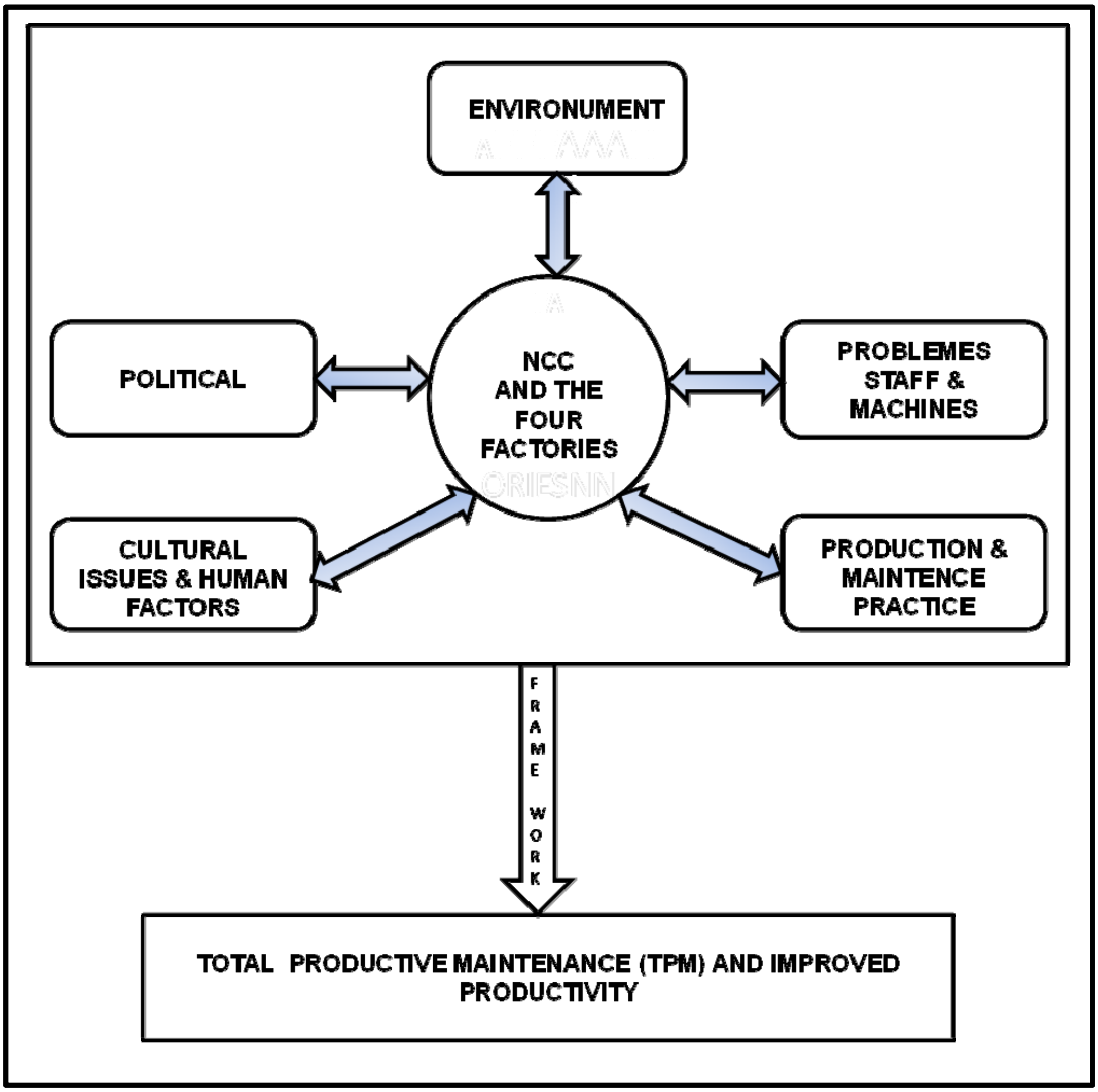


Figure 4-20: General Framework to provide an initial and conceptual framework (Author).

CHAPTER 5: STATISTICAL ANALYSIS AND PERFORMANCE INDICATORS

Abstract

The previous chapter introduced the fluctuation in the production levels in the four factories. This chapter will present further statistical analysis of the production data and downtime from the four factories at NCC. The chapter will attempt to fully understand the production situation and identify the problems in order to address them in the field work, questionnaires and interviews in the rest of this thesis.

5.1 Productive and Non-Productive Time

In order to understand and evaluate the actual problems facing the company, detailed statistical data was collected from the company, which was then compiled and analysed. The data represents production between 2004 and 2008. Table 5-1 presents the downtime of the four factories and its type as collected by the company from (01/01/2004) to (31/12/2004) (RPA, 2006).

Table 5-1: **Statistical data of downtime and failure between (01/01/2004) and(31/12/2004).(RPA, 2006).**

NCC	Working Hours target	Reasons for down time per hour					Total hours of down time	Total actual working hours	The proportion of hours down time/the total working hours target
		Lack of Materials & Supplies	The shortage of Spare Parts	Technical failure	Electricity failure	schedule maintenance			
MCF	8784	0	0	245	13	1358	1616	7141	18%
LCF	8784	0	0	917	10	1178	2106	5717	24%
ZCF	8784	0	0	432	3	1247	1683	7101	19%
SCF	8784	0	0	866	0	2088	2955	7306	33%
Total	35136	0	0	2460	26	5871	8360	27265	23%

It is clear from the table that the downtime in 2004 was between 18% and 33% . The electricity failure was when the supply of electricity failed which was mainly caused by a problem in the grid and it was outside of is Control Company in most cases and it was still a very limited number of hours. The majority of non-productive time, see Figure 5-1, is mainly caused by 'Scheduled Maintenance'. This could be a result of unnecessary scheduled maintenance procedures and more focus on condition-based maintenance could be implemented.

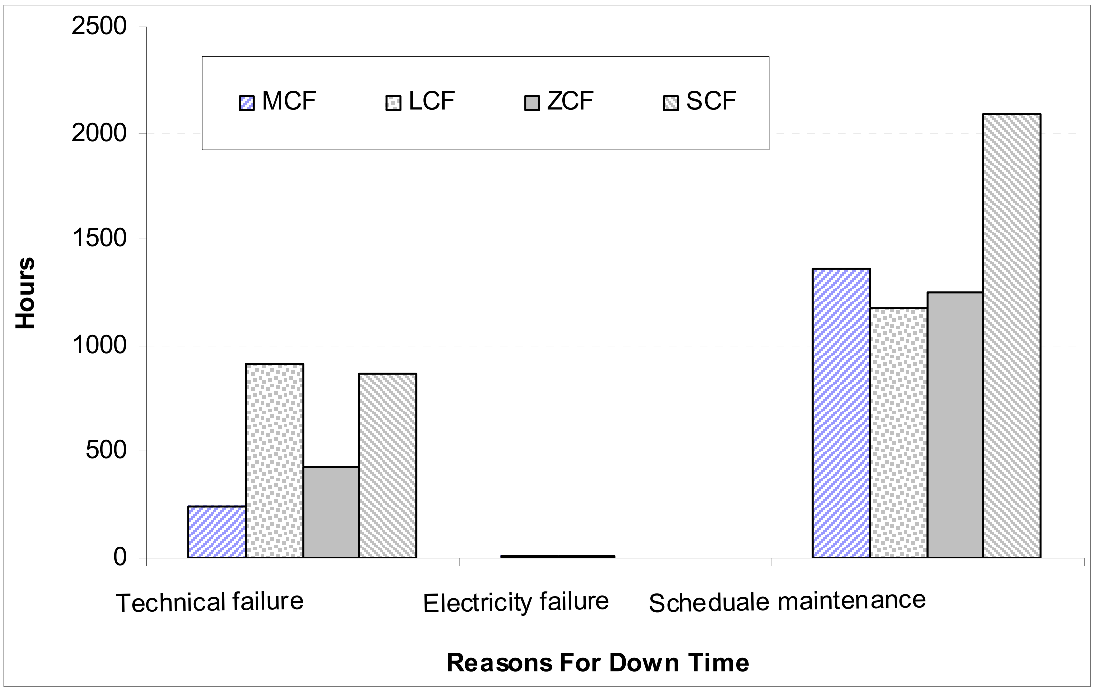


Figure 5-1: Reasons For down time from 01/01/2004 to 31/12/2004

During the period observed, material and supplies suffered no lack of availability and did not contribute to downtime values. Procurement and supply of spare parts was reported to be fully efficient, and this again had no effect on downtime. There appears to be a considerable variation in the distribution of technical failure in the four factories. However, it should be noted that the Figures relating to *souq al-Kames* (SCF) do in fact refer to two separate production lines operating at the same site. Therefore, it may be regarded as two factories, as each has its own quarry, processing plant and kiln. Thus, one might consider the average downtime to be 33/2%.

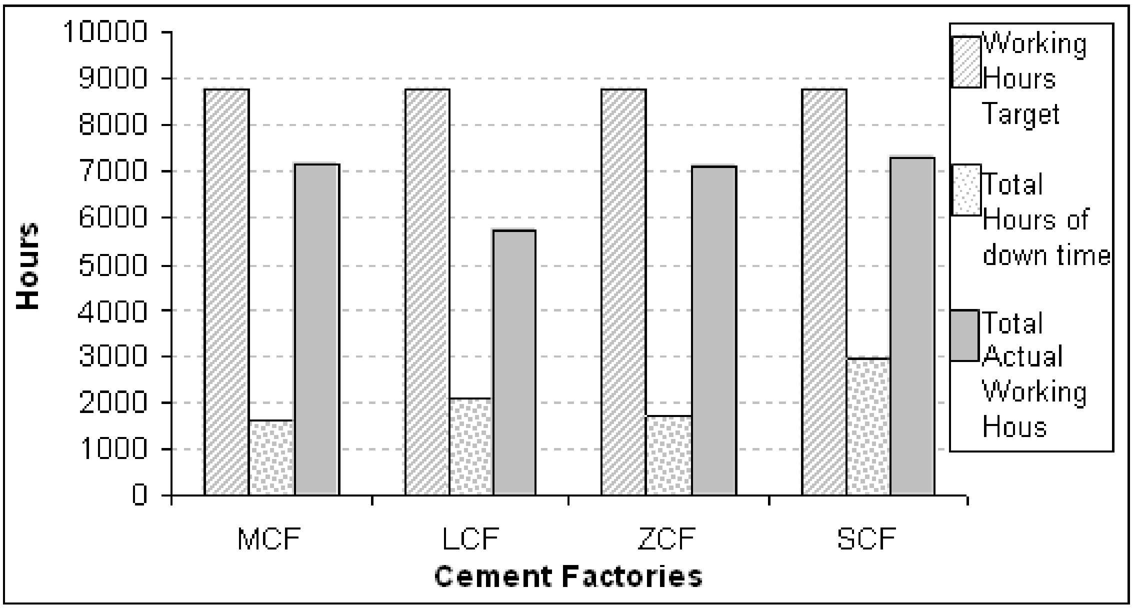


Figure 5-2: The relationship between target hours and actual hours and downtime as in Table 5-1.

Figure 5-2 illustrates the target working hours, the total hours of downtime and the total actual working hours in 2004 for MCF, LCF, ZCF and SCF. There was a considerable increase in the number of hours at SCF, 3000 hours. Additionally, there was also an increase in downtime hours at LCF, which reached a total of 2106 hours.

Similarly, for 2005, Table 5-2 presents statistical data of downtime and failure between (01/01/2005) and (31/12/2005).

Table 5-2: Statistical data of downtime and failure between (01/01/2005) and 31/12/2005)(RPA,2006).

NCC	Working Hours target	Reasons for down time per hour					Total hours of down time	Total actual working hours	The proportion of hours down time/the total working hours target
		Lack of Materials & Supplies	The shortage of Spare Parts	Technical failure	Electricity failure	schedule maintenance			
MCF	8760	0	0	0	0	1296	1296	7464	14%
LCF	8760	25	0	503	3	3045	3577	5182	40%
ZCF	8760	22	0	745	11	902	1680	7079	19%
SCF	8760	25	0	539	0	1519	3084	5675	35%
Total	35040	72	0	1788	14	6763	9638	2540	27%

From the data, and as presented in Figure 5-3, there is a similar trend as scheduled maintenance is the most significant non-productive time.

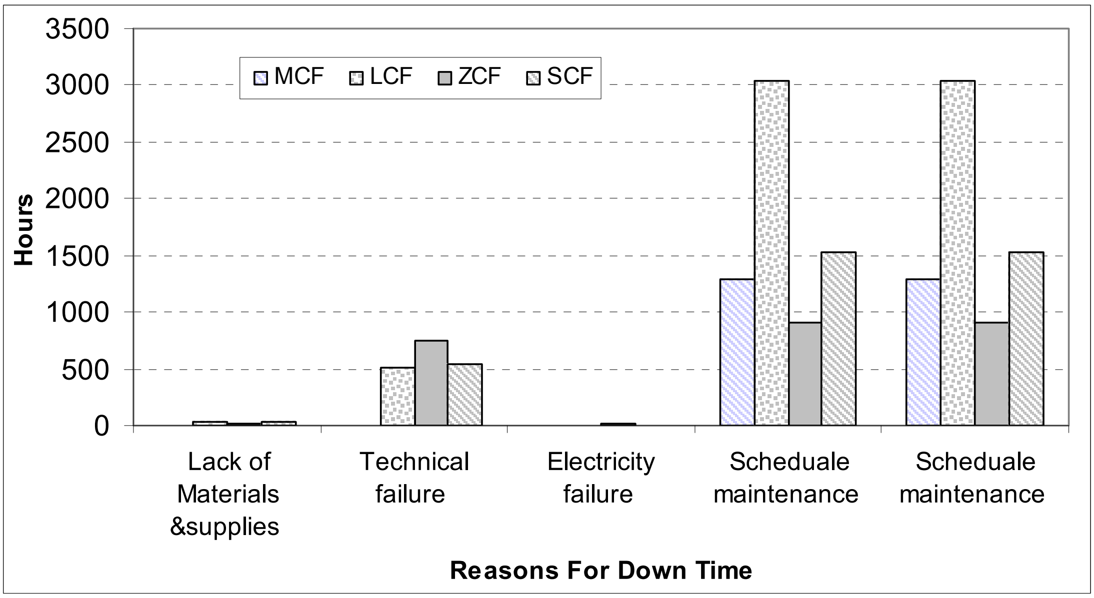


Figure 5-3: Non-productive downtime from 01/01/2005 to 31/12/2005.

The three factories LCF, ZCF and SCF experienced an almost negligible amount of downtime due to a lack of materials and supplies, and similarly the procurement of spare parts did not contribute to the total downtime.

However technical failures did create unpredicted downtime at LCF, ZCF and SCF, although this was not the case at MCF. The impact of scheduled maintenance was the major contributor to downtime, and this reached a peak at LCF where 3045 hours (127 days) were lost in 2005, as presented in Figure 5-4.

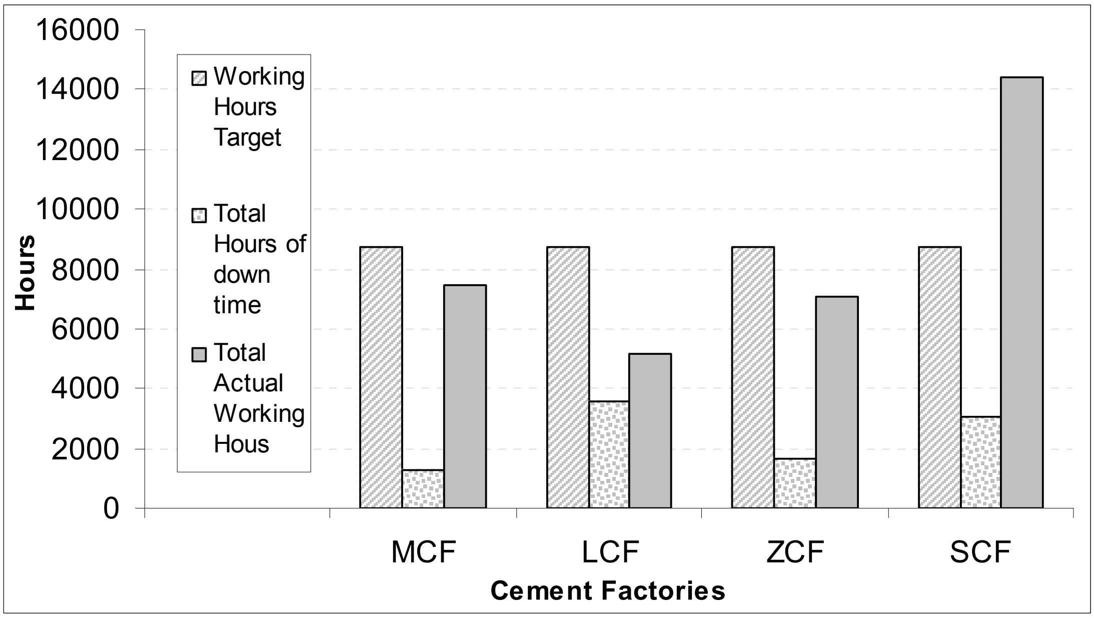


Figure 5-4: Target working hours , total hours of downtime and total actual working hours (2005).

Figure 5-4 illustrates clearly that LCF suffered the highest number of downtime hours, at 3577, which is the equivalent to 150 working days. The number of hours lost at SCF was also significant, at 3084. Table 5-3, Figure 5-5 and Figure 5-6 present a similar analysis for the year 2006.

Table 5-3: Statistical data of downtime and failure between (01/01/2006) and (31/12/2006). (RPA, 2006)

NCC	Working Hours target	Reasons for down time per hour					Total hours of down time	Total actual working hours	The proportion of hours down time/the total working hours target
		Lack of Materials & Supplies	The shortage of Spare Parts	Technical failure	Electricity failure	schedule maintenance			
MCF	8760	0	0	73	3	1967	2043	6717	23%
LCF	8760	147	0	246	15	2570	3008	5752	34%
ZCF	8760	5	0	598	2	1141	1746	7014	20%
SCF	8760	19	0	228	4	1233	1484	7276	17%
Total	35040	171	0	1175	24	6911	8281	26759	23.60%

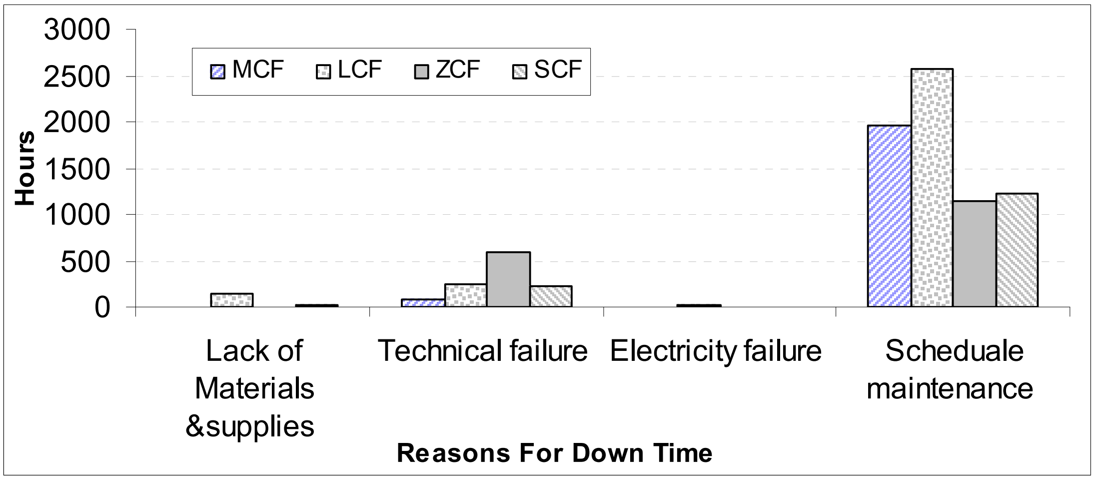


Figure 5-5: Reasons for non-productive time from 01/01/2006 to 31/12/2006.

It can be seen that downtime in 2006 at LCF decreased slightly from 2005 due to a fall in the scheduled maintenance hours of 3008 hours in 2006, compared with 3577 in 2005. However, this downtime is still significant and represents 126 days. Figure 5-6 shows the target working hours, total hours of downtime and total actual working hours from 01/01/2006 to 31/12/2006. It can be observed that LCF has the largest downtime hours, with total hours reaching 3008.

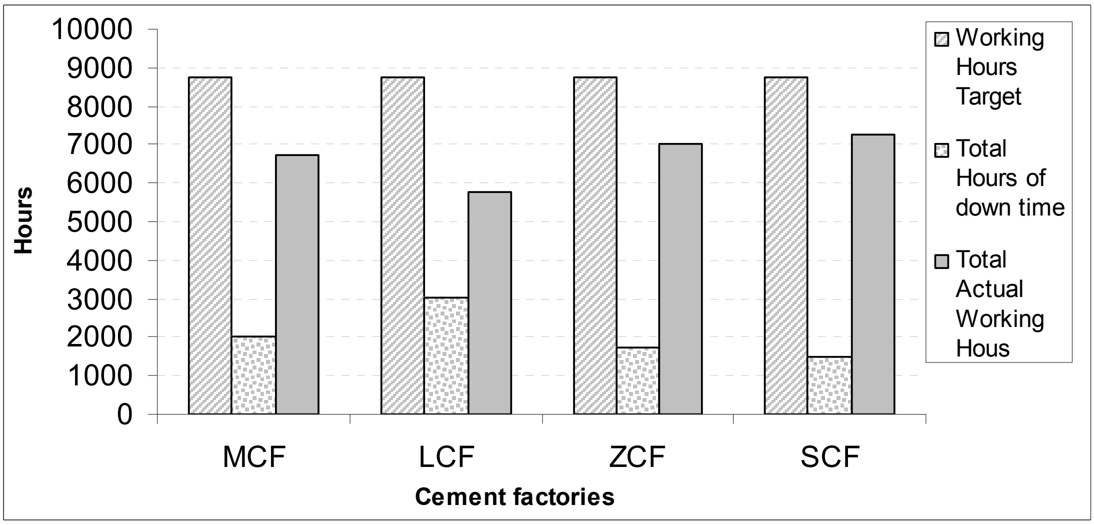


Figure 5-6: Working hours target &Total hours of downtime &Total actual working hours in (2006).

It is apparent from the above discussion that, between 2004 and 2006; the non-productive time is significant and could be measured in tens of days. This could be considered extremely low compared with UK and other cement factories. LCF and SCF are the worst in terms of their productive hours.

5.2 Capacity and Production Data

Table 5-4 presents actual and target production levels (value in tons) between (01/01/2004) and (31/12/2004) (RPA, 2006). The Design capacity and actual production is summarised in Figure 5-7. It is clear from the data that MCF has a much lower design capacity of 33k tons than the other three factories (about 1M tons).

Table 5-4: Production from 01/01/2004 to 31/12/2004. (RPA,2006) Notes: value in pounds.

NCC	Unit	Design		Production				Ratios & Indicators	
				Target		Actual		Preparation of the Actual	
		Quantity	Value	Quantity	Value	Quantity	Value	Design %	Target %
MCF	Ton	333,000	6,336,000	330,000	6,336,000	268,741	5,159,827	81	81
LCF	Ton	999,996	19,200,000	999,996	19,200,000	576,800	11,070,567	57	57
ZCF	Ton	999,996	19,200,000	999,996	19,200,000	807,436	15,502,771	80	80
SCF	Ton	999,996	19,200,000	999,996	19,200,000	830,961	15,954,451	83	83
Total	Ton	3,329,994	63,936,600	3,329,994	36,936,600	2,474,000	47,691,609	74	74

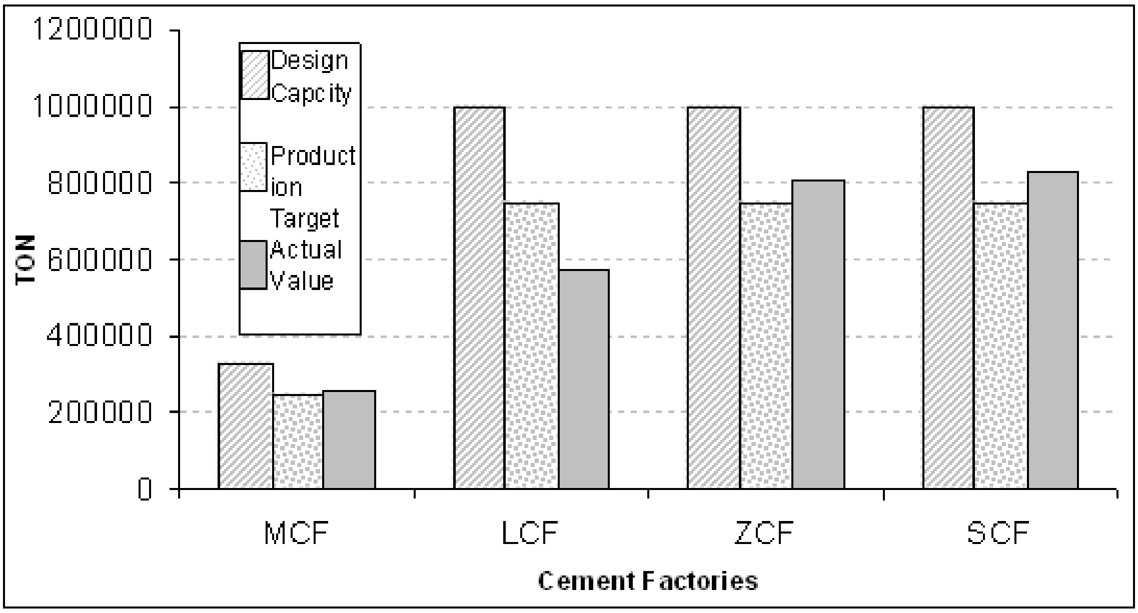


Figure 5-7: Production from 01/012004 to 31/12/2004

Figure 5-7 presents production from 01/01/2004 to 31/12/2004. It can be seen that the target production is intended to be similar to the design capacity. However, none of the factories managed to achieve that capacity.

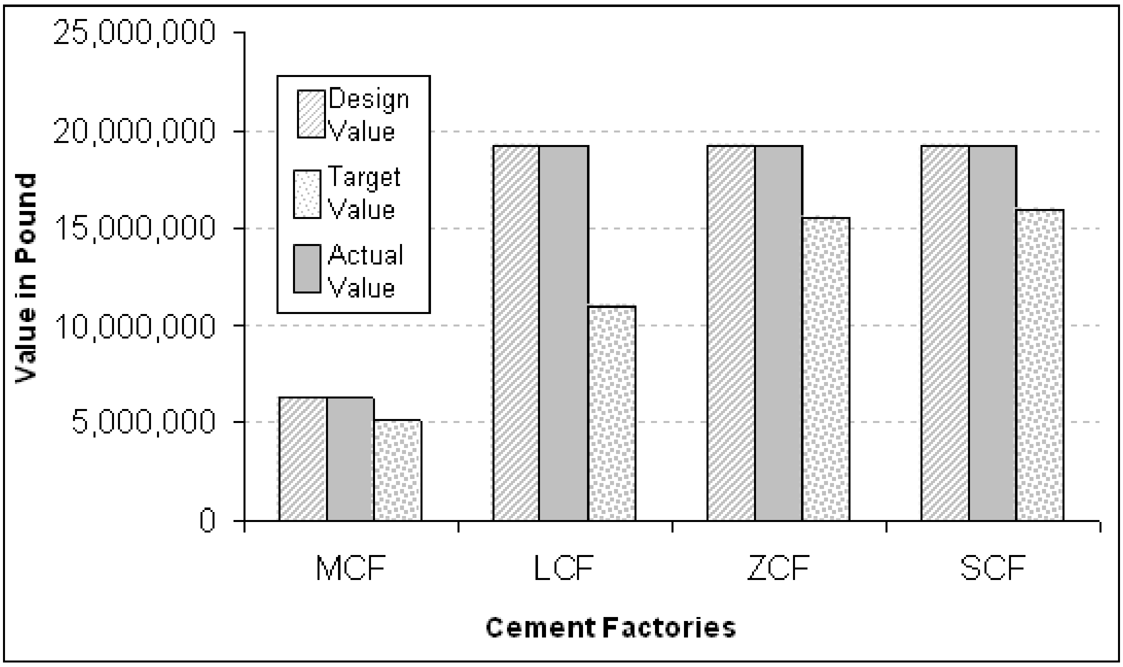


Figure 5-8: Design Value, Target Value &Actual Value by Pound for 2004.

Figure 5-8: presents the design value, target value and actual value calculated in UK sterling pounds at the 2004 rate. Rate (1 British Pound = 1.99492 Libyan Dinar 1 Libyan Dinar (LYD) = 0.50127 British Pound (GBP)). It can be observed that LCF generated the lowest value at 11,074,560 sterling pounds. This represents a shortfall of 8,125,440 against the projected target of 19,200,000 sterling pounds.

Similar to the above discussion, the production for the year 2005 is summarised in Table 5-5 and graphically obtainable in Figure 5-9 and Figure 5-10.

Table 6-5 presents actual and target production levels (value in Tons) between (01/01/2005) and (31/12/2005) (RPA, 2006).

Table 5-5: Production from 01/01/2005 to 31/12/2005. (RPA, 2006) Notes: value in Pound.

NCC	Unit	Design		Production				Ratios & Indicators	
				Target		Actual		Preparation of the Actual	
		Quantity	Value	Quantity	Value	Quantity	Value	Design %	Target %
MCF	Ton	333,000	6,336,000	330,000	6,336,000	268,854	5,507,520	87	87
LCF	Ton	999,996	19,200,000	749,996	14,400,000	570,505	10,953,696	57	76
ZCF	Ton	999,996	19,200,000	749,996	14,400,000	839,276	16,114,099	84	112
SCF	Ton	999,996	19,200,000	749,996	14,400,000	823,041	15,802,387	82	110
Total	Ton	3,329,994	63,936,600	2,579,997	49,536,000	2,519,672	48,377,702	76	98

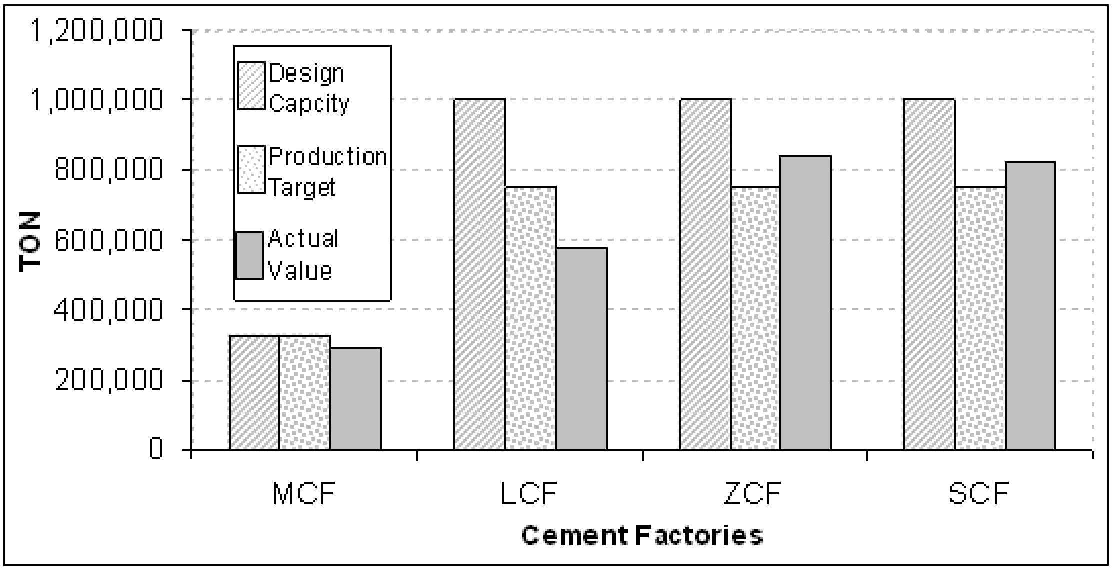


Figure 5-9: Production from 01/012005 to 31/12/2005

Figure 5-9 indicates that LCF continued to have the lowest production figure, as in the previous year. However, one of the interesting issues in 2005 was that the target level was reduced much less than the capacity of the factory. ZCF and SCF managed to produce above the production target. However, the production of LCF was less than the reduced target. The reduction of the target level, given the high demand of cement in Libya, is an unusual decision and this will be discussed in detail in this thesis in the following chapters.

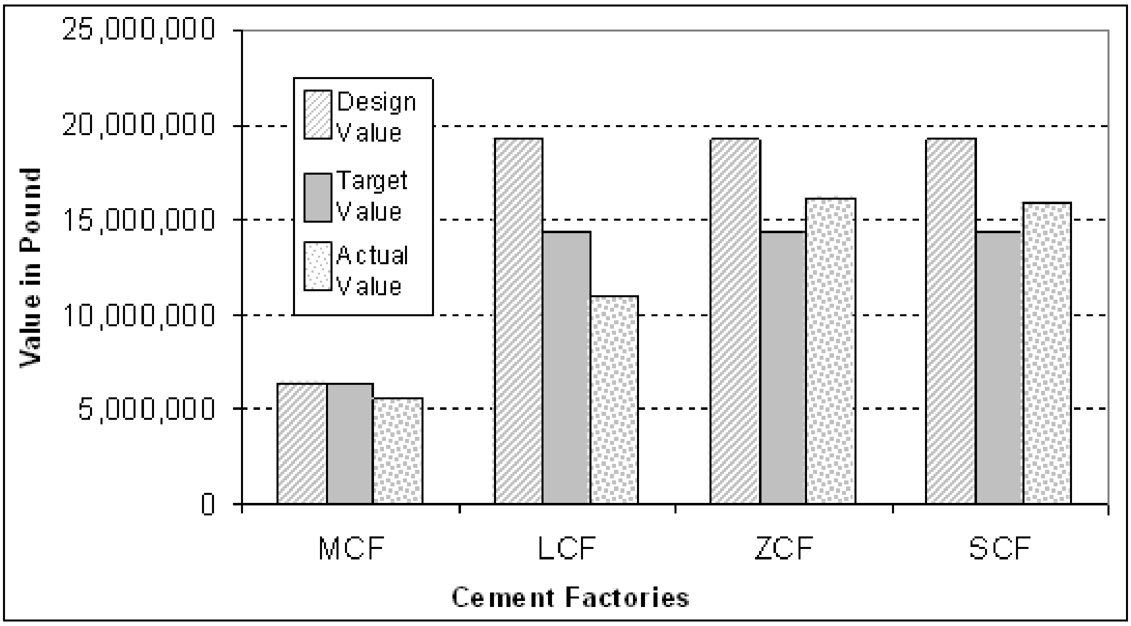


Figure 5-10: Design value, target value and actual value in Pounds sterling (2005).

Figure 5-10 presents the design value, target value and actual value (all the value in £ pound) in the year 2005. It can be seen that LCF has the lowest actual value of £10,953,696. On the other hand, the most productive factory, MCF reached a total of £5,507,520 pound which was very close to the set target value. Table 5-6 presents actual and target production levels (value in Tons) between (01/01/2006) and (31/12/2006) (RPA, 2006).

Table 5-6: Production from 01/01/2006 to 31/12/2006. (GPC, 2007) (Value in Pound).

NCC	Unit	Design		Production				Ratios & Indicators	
				Target		Actual		Preparation of the Actual	
		Quantity	Value	Quantity	Value	Quantity	Value	Design %	Target %
MCF	Ton	333,000	6,336,000	247,500	4,752,000	255,608	4,907,673	77	103
LCF	Ton	999,996	19,200,000	750,000	14,400,000	615,000	11,808,000	62	82
ZCF	Ton	999,996	19,200,000	750,000	14,400,000	776,302	14,904,998	78	104
SCF	Ton	999,996	19,200,000	750,000	14,400,000	785,143	15,074,745	79	105
Total	Ton	3,329,994	63,936,600	2,497,500	47,952,000	2,432,053	46,695,416	73	97

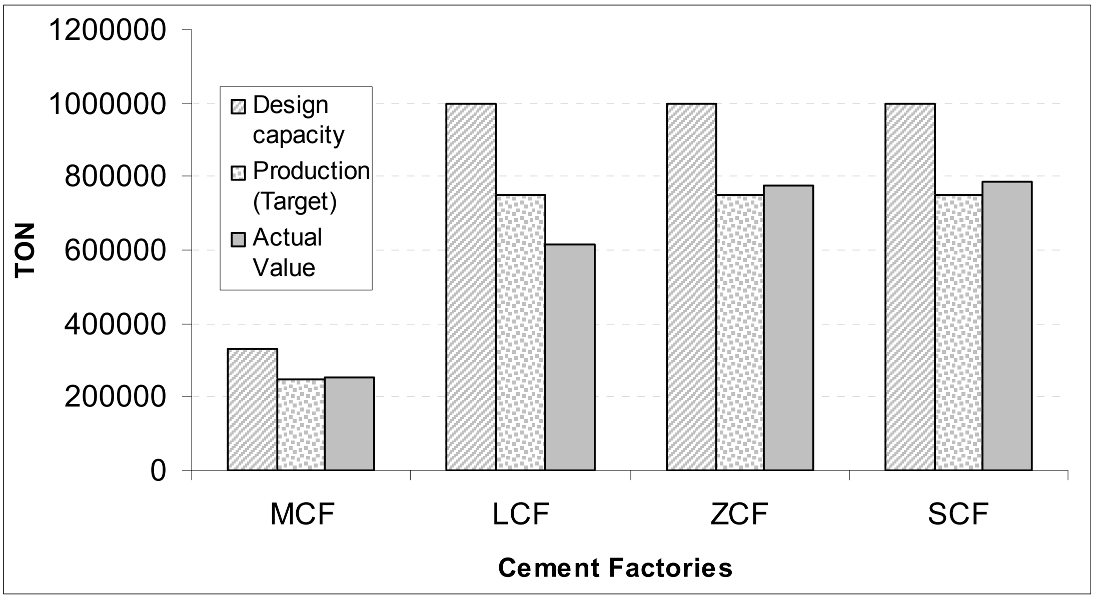


Figure 5-11: Production from 01/012006 to 31/12/2006.

Figure 5-11 presents the production from 01/01/2006 to 31/12/2006. Here, we see a slightly increased production at LCF; but LCF remains the lowest producer of all of the factories. At LCF production reached 615000 Tonnes cement.

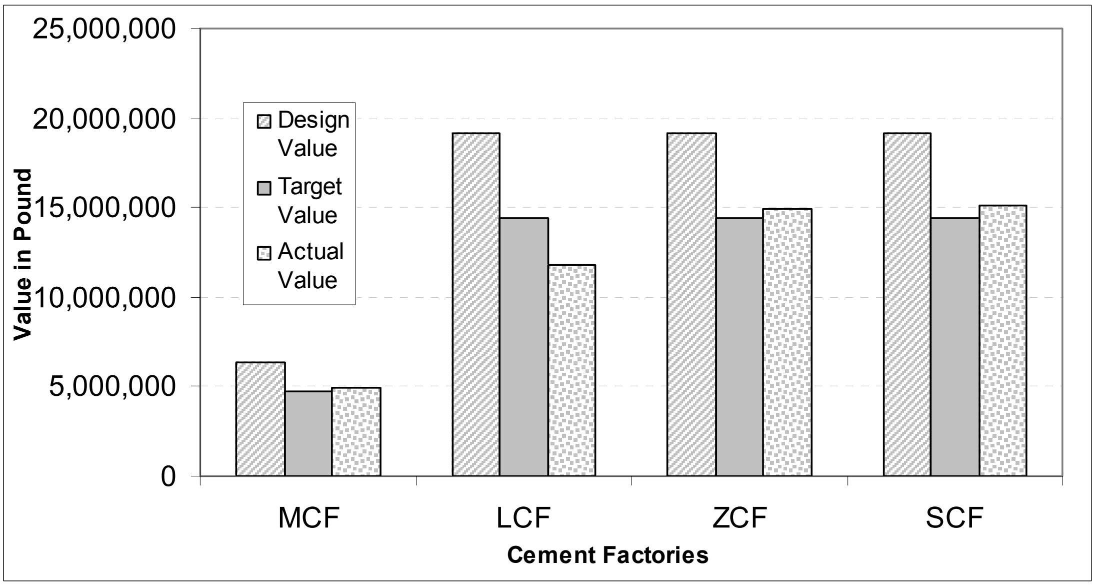


Figure 5-12: Design Value, Target Value &Actual Value in Pound 2006.

Figure 5-12 presents the design value, target value and actual value in £ is in 2006.It can be seen that LCF was the only factory that did not exceed the target value in 2006. Also in this year, 2006, the MCF reduced its target production below the capacity of the factory.

In the above section, it has been noticed that none of the factories reached their capacity values and the target production level was reduced despite the fact that there was a high demand for cement production between 2004 and 2006. Because cement production is a continuous process, the main effect on productivity would be that machine unavailability due to breakdown and hence lack of efficient maintenance procedure.

5.3 Workforce in the Cement Factories.

This section will discuss the workforce within the four factories during the same years. This is an attempt to find out if the size of the work force has changed or has any influence on productivity. Table 5-7 includes the main statistical data in relation to personnel in 2004. The number of employees in 2004 is summarised in Figure 5-13.

Table 5-7: The position employees during the period from 1/1/2004 to 31/12/2004.(RPA,2006).

NCC	Number of Employees		National Employees			Non-National Employees				
	Active	Vaccancy	Male	Female	Total	Seasonal Contract	Local contract	Contract Expatriate	Technical Assistancec	Total
Management	384	36	367	16	383	0	0	0	1	1
MCF	355	38	333	5	338	0	0	0	17	17
LCF	681	67	626	8	634	2	3	0	42	47
ZCF	694	62	640	1	641	0	1	0	52	53
SCF	882	73	777	11	788	0	2	4	88	94
TOtal	2996	276	2643	41	2784	2	6	4	200	212

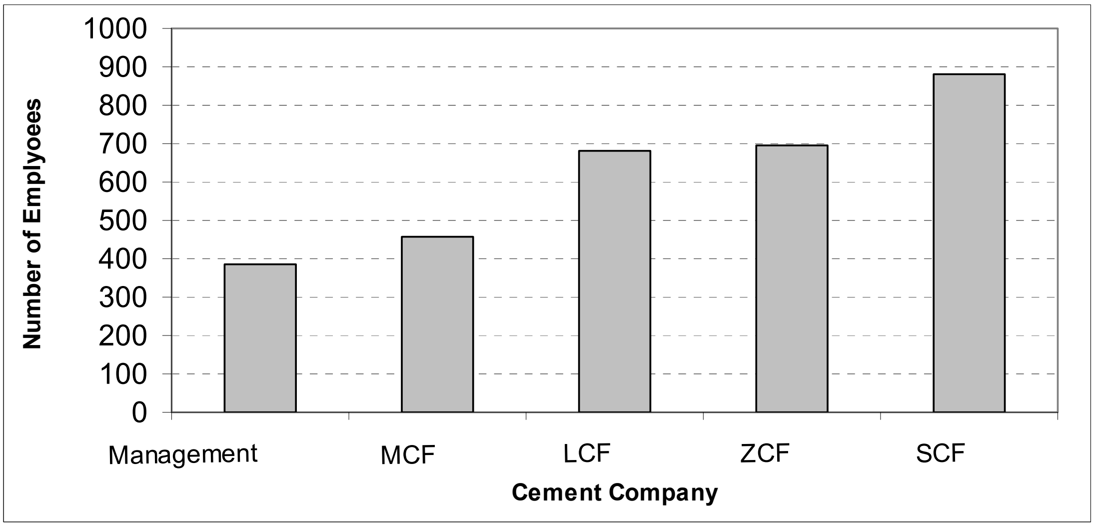


Figure 5-13: The number of employees in 2004.

Figure 5-13 presents the number of employees in 2004 at NCC and the four cement factories. The total number reached 3000. There is a significant difference in the number of employees between the factories given that three of them have similar capacities. This issue will be discussed in future chapters. The number of female employees is limited compared with the total number of employees. This could be due to the difficult nature of cement factories and the type of work requiring significant physical abilities that might not be acceptable.

The number of employees for 2005 is presented in Table 5-8 and summarised in Figure 5-14.

Table 5-8: The position of employees during the period from 1/1/2005 to 31/12/2005. (RPA, 2006).

NCC	Number of Employees		National Employees			Non-National Employees				
	Active	Vaccancy	Male	Female	Total	Seasonal Contract	Local contract	Contract Expatriate	Technical Assistancec	Total
Management	384	36	367	16	383	0	0	0	1	1
MCF	355	38	333	5	338	0	0	0	17	17
LCF	681	67	626	8	634	2	3	0	42	47
ZCF	694	62	640	1	641	0	1	0	52	53
SCF	882	73	777	11	788	0	2	4	88	94
TOtal	2996	276	2643	41	2784	2	6	4	200	212

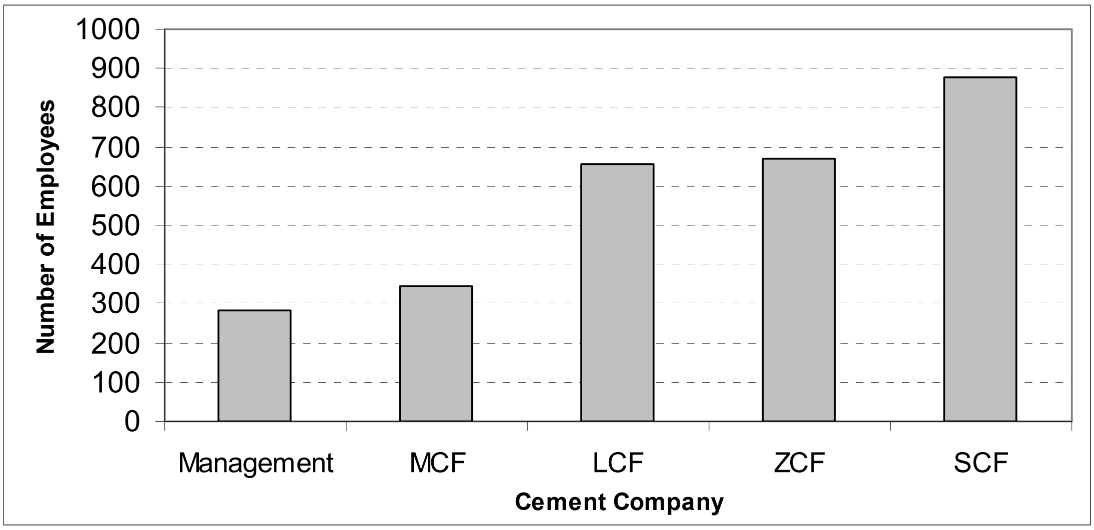


Figure 5-14: The number of employees in 2005.

Table 5-9 presents some statistical analysis of employees in 2006.

Table 5-9: presents some statistical analysis of employees. 1/1/2006 to 31/12/2006(RPA, 2006).

NCC	Number of Employees		National Employees			Non-National Employees				
	Active	Vaccancy	Male	Female	Total	Seasonal Contract	Local contract	Contract Expatriate	Technical Assistancec	Total
Management	281	57	259	21	280	0	0	0	1	1
MCF	346	38	333	5	328	0	0	0	18	18
LCF	658	19	586	7	593	0	2	0	63	65
ZCF	668	70	611	1	612	0	1	0	55	56
SCF	878	73	781	11	792	0	4	3	79	86
TOtal	2831	257	2560	45	2831	0	7	3	216	226

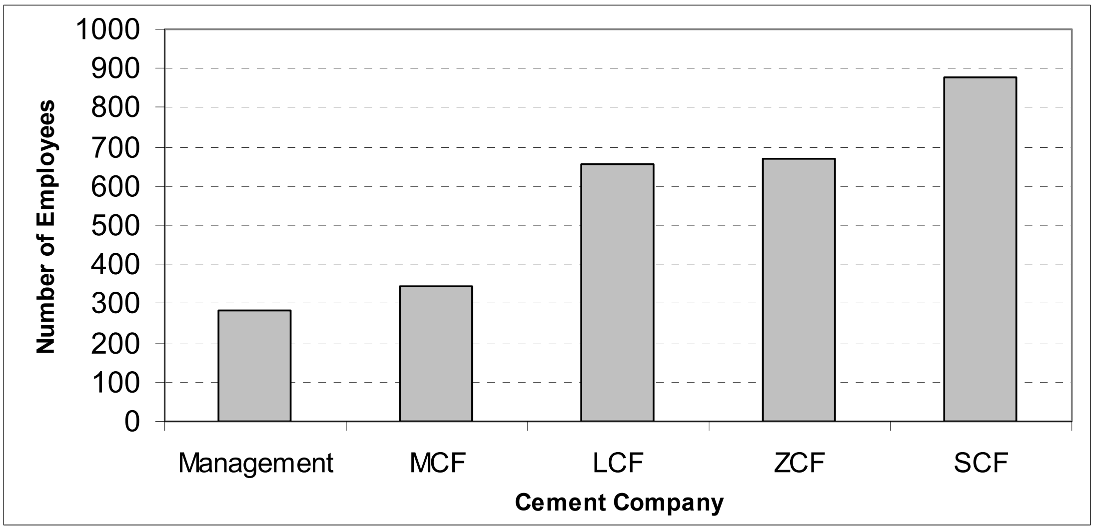


Figure 5-15: The number of employees in 2006.

Figure 5-15 presents the number of employees in 2006 in the four factories. According to the data, the number of employees decreased from 2004. The major reduction was in the management system at HQ, with minor changes in the factory workforce. The number of employees will be assumed (on average) to be constant in the factory for productivity analysis. This is due to the fact that the change, if any, was insignificant in comparison to change in productivity.

5.4 Productivity and Efficiency levels

Productivity is a relative measure that can be used to compare different factories or the same factory as a function of time. Productivity, in general, is defined as in equation 5.1.

$$productivity = \frac{output}{input} \qquad \text{Eq. (5.1)}$$

The output in Equation 5.1 can be in measures such as production, deliverables. The input can be any of the input aspects, such as people, time, resources, raw material. Based on the previous data, some productivity measures will be discussed and analysed.

$$productivity = \frac{output}{input} = \frac{Actual\,production}{Actual\,Working\,Hours} \quad Tons/\,per\,hour$$ Eq. (5.2)

Based on equation (5.2), the productivity for 2004 of the four factories is described in Table 5-10 and Figure 6-16.

Table 5-10: **Productivity in 2004 based on equation (5.2).**

National Cement company	Production in 2004 (ton)	Total Actual Working hours	Productivity (Tons/hour)
MCF	268741	7141	37
LCF	576800	5717	100
ZCF	807436	7101	113
SCF	830961	7306	113

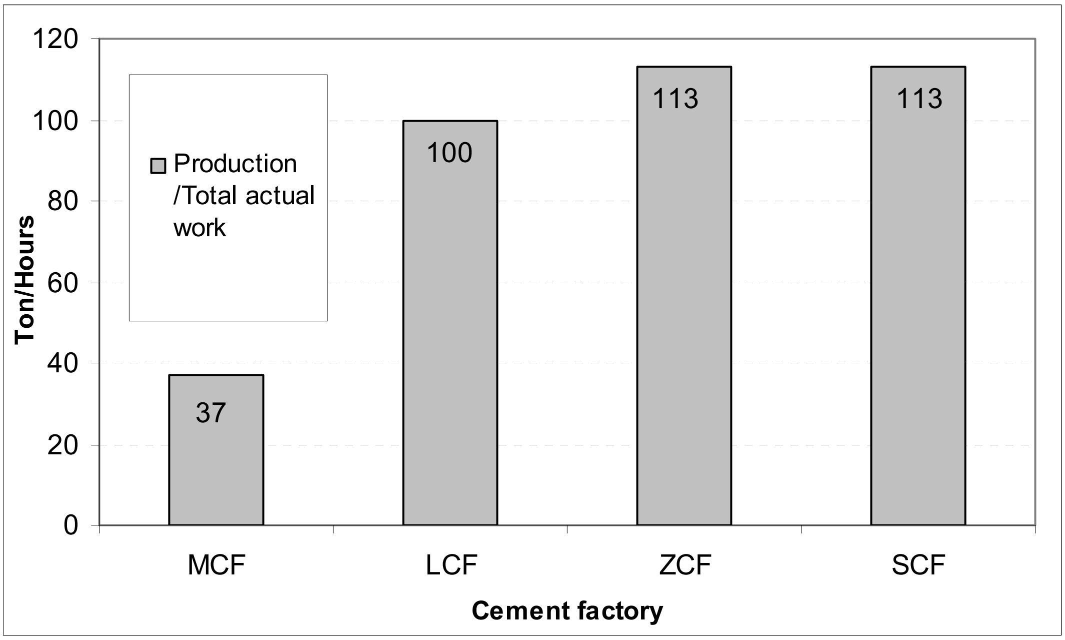


Figure 5-16: Productivity (Tons/hour) for 2004.

Similarly, for 2005, the productivity Figures can be summarised in Figure 5-17 and 5-18 for 2005 and 2006 respectively.

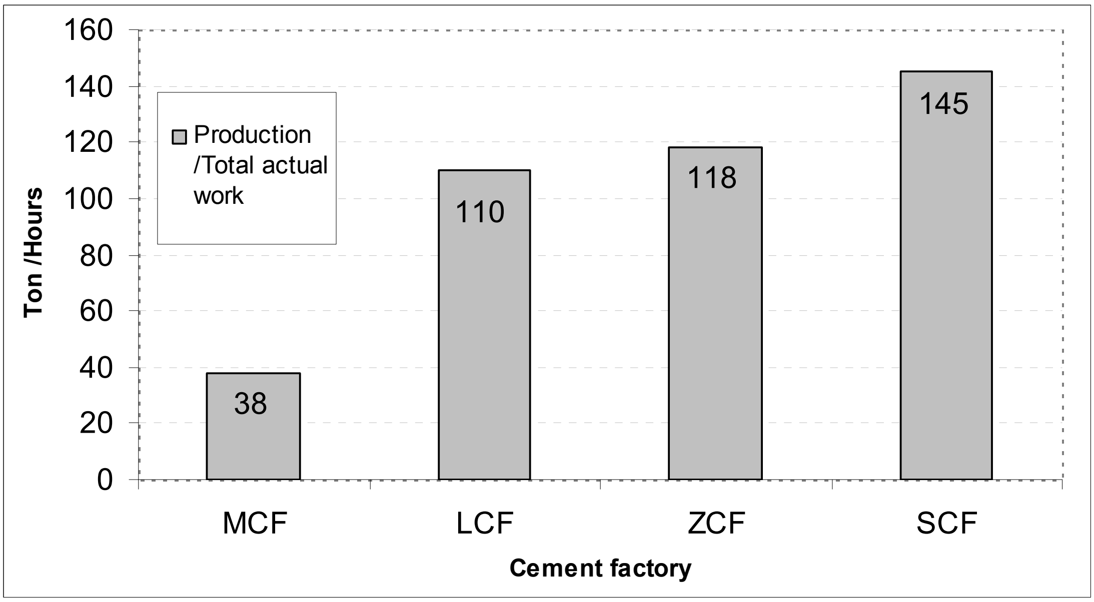


Figure 5-17: Productivity (Tons/hour) for 2005.

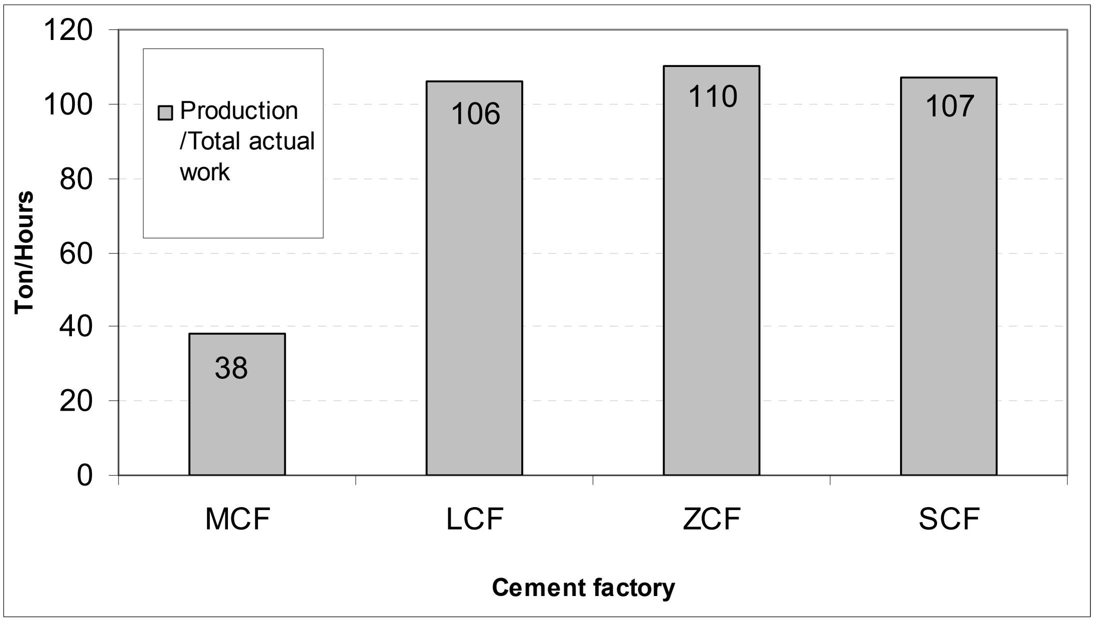


Figure 5-18: Productivity (Tons/hour) for 2006.

The above three Figures present the real production per hour from each of the factories. In order to increase productivity, the above values could be helpful to improve productivity from two angles: to increase the working hours of the factory and to increase the output during the operational hours.

However, since the capacity of MCF is different from the rest, for comparison purposes the following productivity equation is used:

$$productivity = \frac{output}{input} = \frac{production}{Capacity} \quad Tons/Tons \qquad \text{Eq. (5.3)}$$

Based on equation 5.3, the productivity of the four factories for the years 2004, 2005 and 2006 is presented in Figures 5-19, 5-20 and 5-21 respectively.

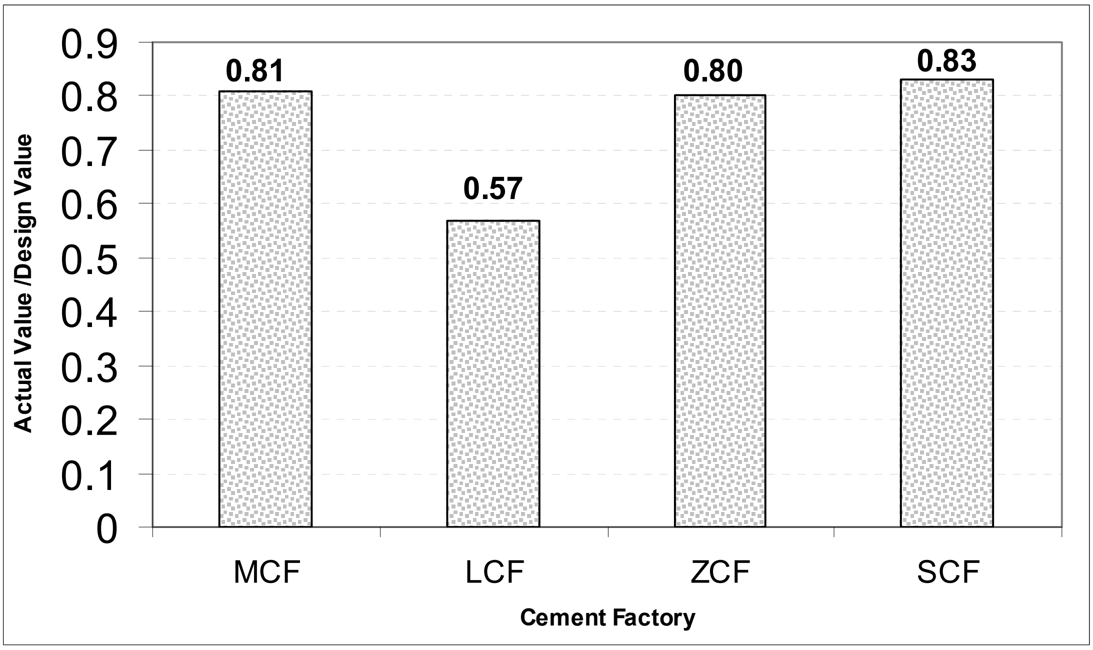


Figure 5-19: Productivity as production/capacity for 2004.

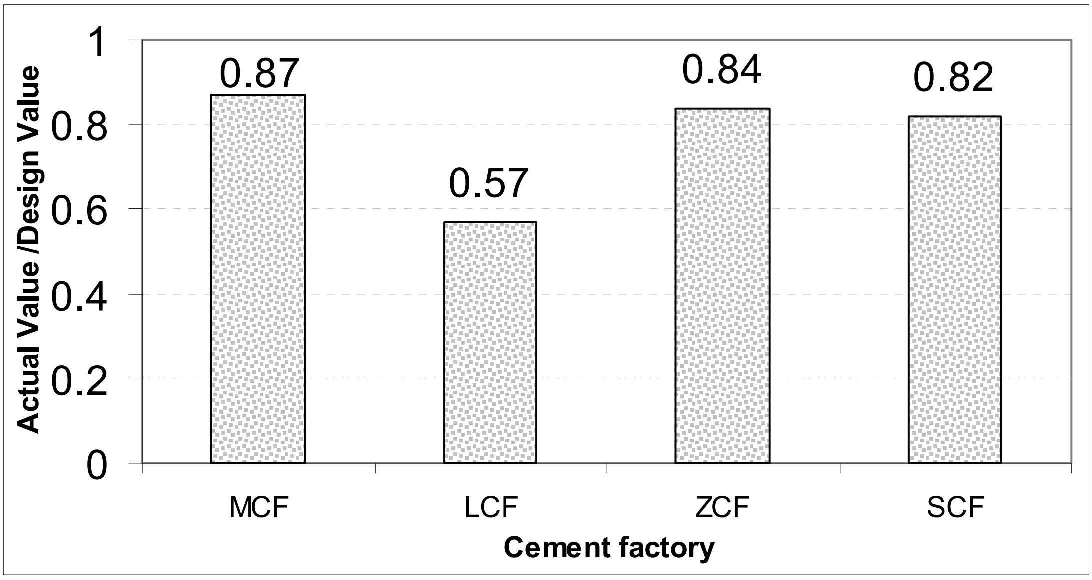


Figure 5-20: Productivity as production/capacity for 2005.

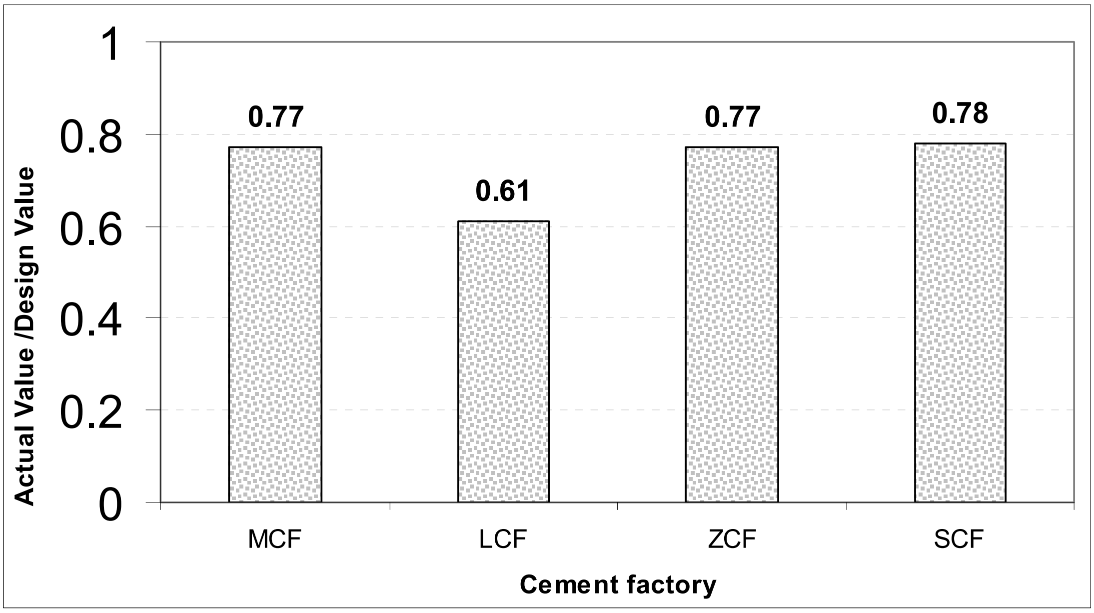


Figure 5-21: Productivity as production/capacity for 2006.

From the above Figures, it is clear that LCF has the lowest productivity. The others have similar productivity but still much less than the typical productivity of more productive factories. This issue will be investigated during the course of this research work.

In order to understand the output of each employee (£/employee), a new productivity is defined as:

$$productivity = \frac{output}{input} = \frac{production\_in\_pounds}{number\_of\_employees} \quad Tons/person \qquad \text{Eq. (5.4)}$$

Based on equation (5.4), the productivity of the four factories for the years 2004, 2005 and 2006 is presented in Figurers 5-22, 5-23, and 5-24 respectively.

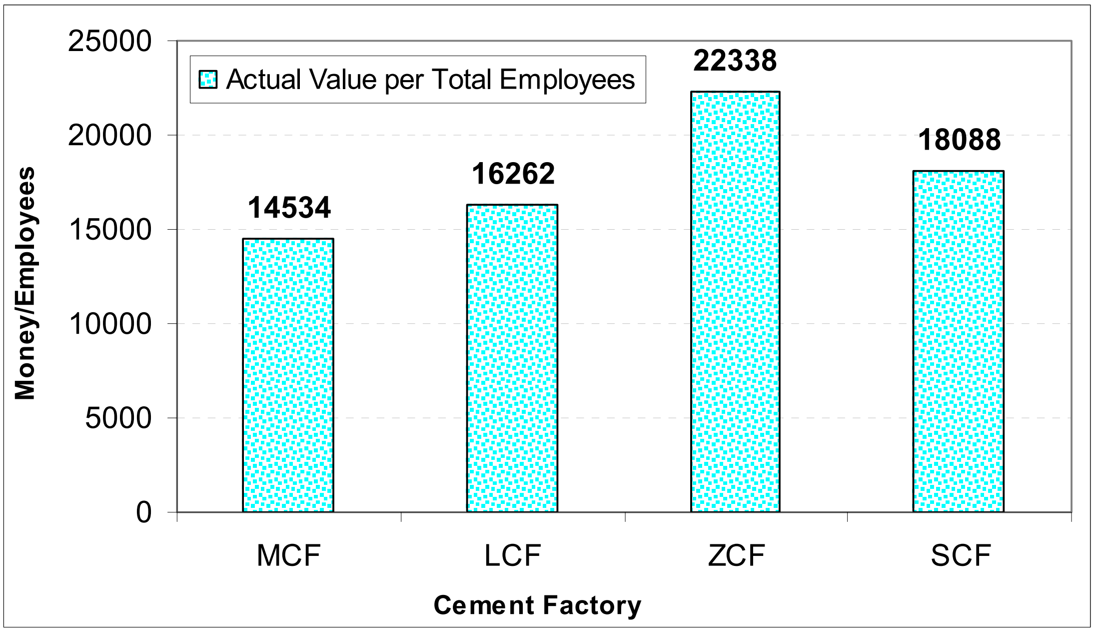


Figure 5-22: Productivity as production/employee for 2004.

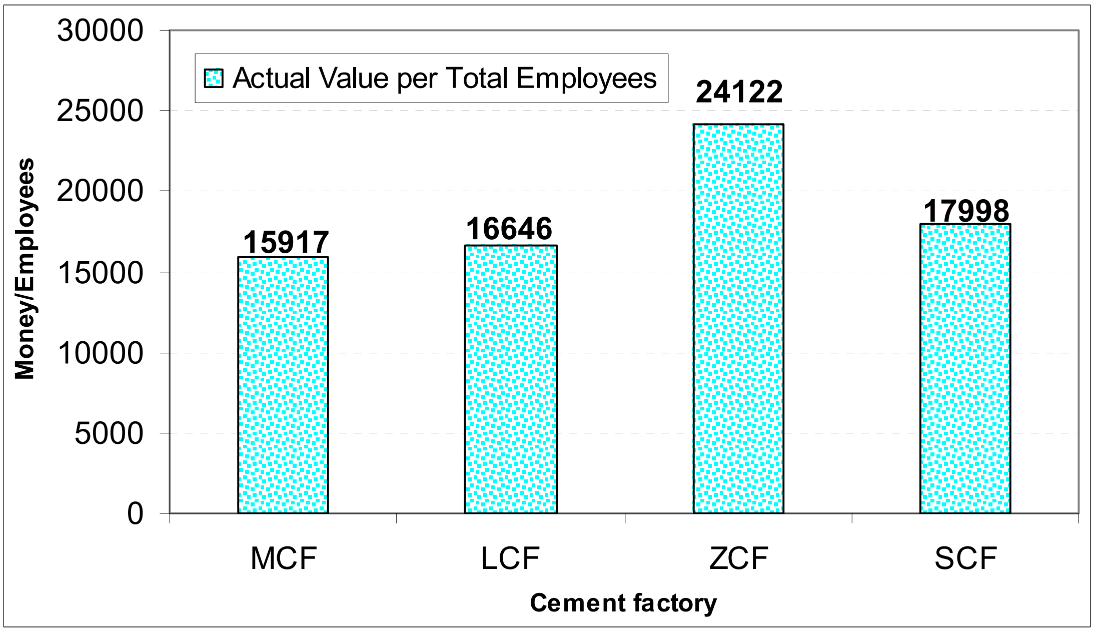


Figure 5-23: Productivity as production/employee for 2005

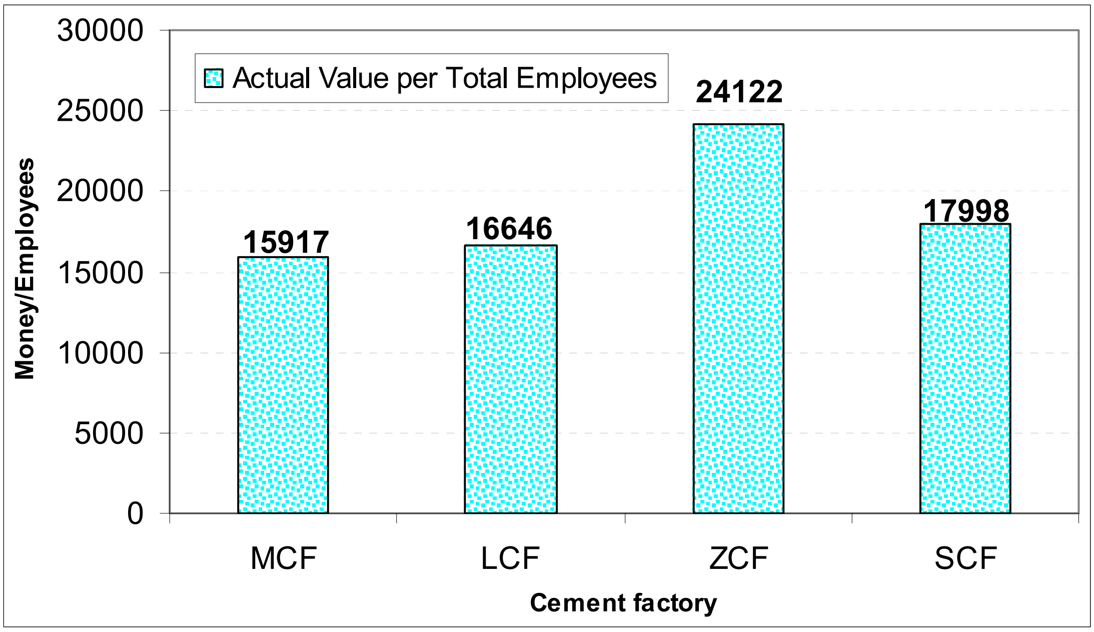


Figure 5-24: Productivity as production/employee for 2006

From the above Figures it can be seen that ZCF is the most productive in terms of number of employees.

In order to understand the percentage of non-productive time in comparison to the operation time, the equation (5.5) is used:

$$non\_productivity = \frac{\text{non\_productive\_time}}{productive\_time} \quad hour/hour \qquad \text{Eq. (5.5)}$$

Based on equation (5.5), the productivity of the four factories for the years 2004, 2005 and 2006 is presented in Figures 5-25, 5-26 and 5-27 respectively.

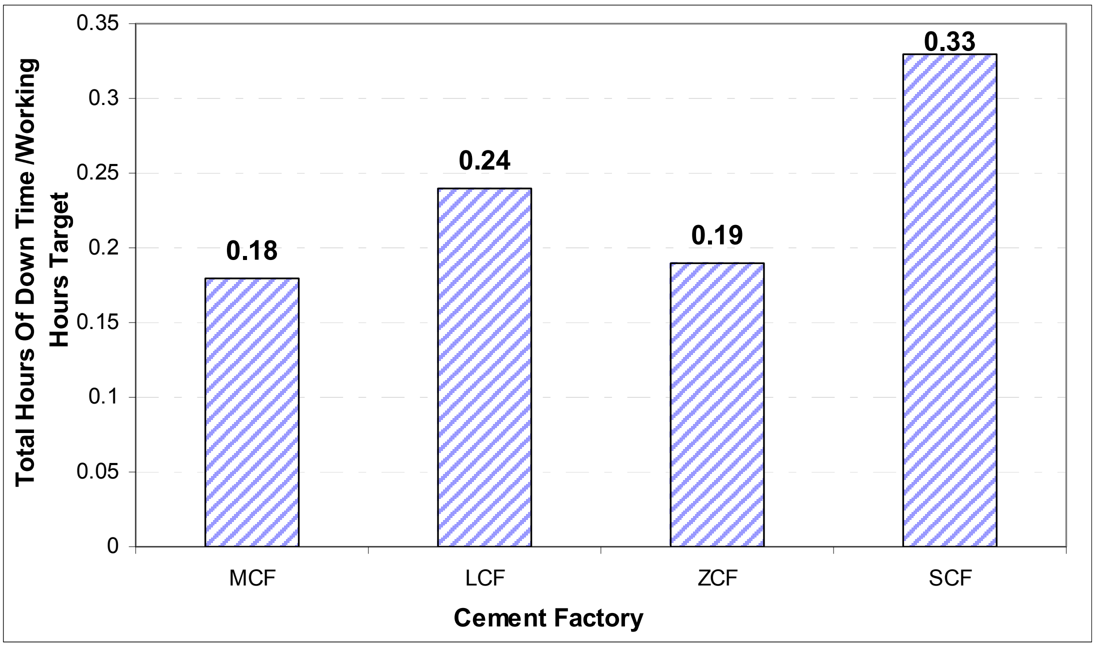


Figure 5-25: Non-productivity for 2004.

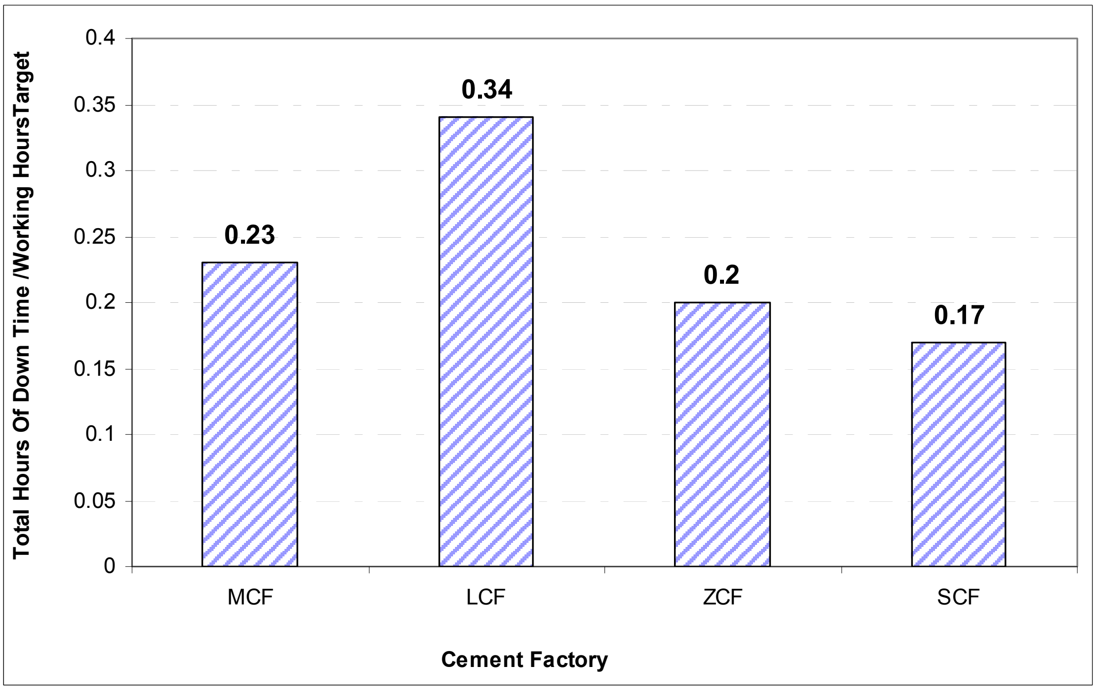


Figure 5-26: Non-productivity for 2005.

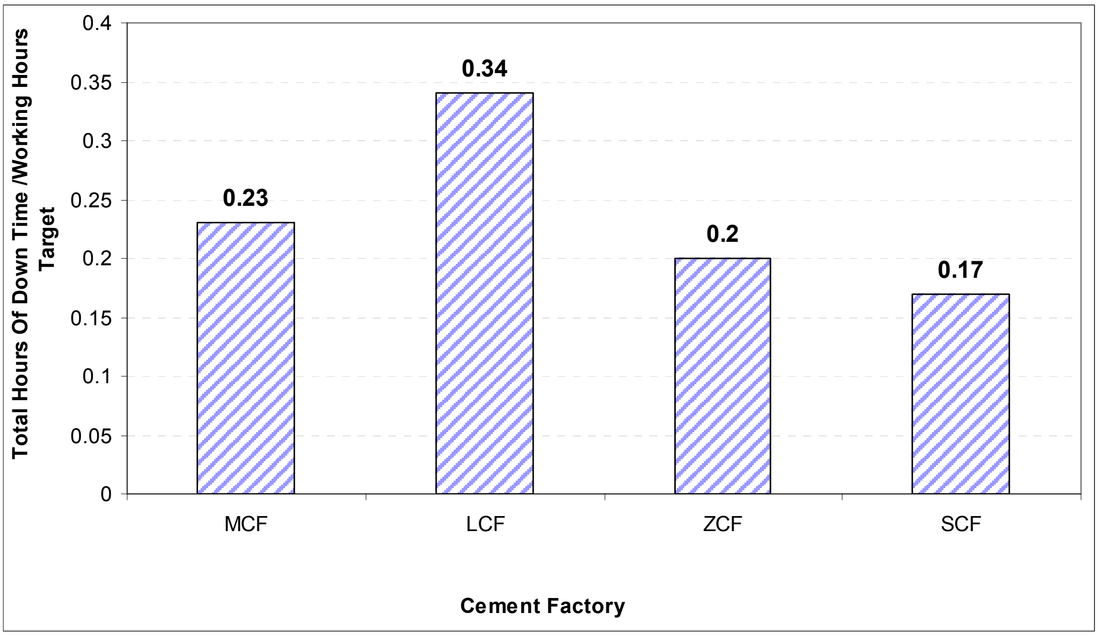


Figure 5-27: **Non-productivity for 2006.**

From the above Figures it can be concluded that SCF and LCF are the two factories with worst downtime, while ZCF is one of the best in this area.

5.5 Conclusions

This Chapter has provided some production data and productivity analysis for the four factories which was available between 2004 and 2006. Productivity is a relative measure that can be used to compare different factories or the same factory as a function of time. The chapter includes production levels, downtime and number of employees. The findings indicate that the factories have low productivity and there is a significant difference between the factories. The findings from the statistical-data in those chapters will be used for the design of the questionnaire and interviews to investigate the reasons behind the findings. The situation, based on field visits, did not change. However, data following 2006 was not available with the same details for further analysis.

CHAPTER 6: Field work in the Cement Factories

Abstract

The previous chapter, Chapter 5, has highlighted the variation in productivity between the four factories and the change in production of the same factory over three years. In order to be able to clarify the reason for this, this Chapter includes field visits to the Libyan Cement factories in order to observe the general culture, environment and attitude of employees in the factories. The chapter also includes a comparison between the Libyan factories and a cement factory in the UK. The chapter also describes the environmental factors and the effect of the factories on the environment.

6.1 Initial field comparison between Libyan and UK Cement factories

In order to establish an initial benchmark, field visits to the four cement factories in Libya and a similar factory in the UK were conducted. The difference in standard between the four factories in Libya and the UK has been clear. Figure 6-1 presents a comparison between different aspects of the UK and Libyan factories. The factory visited was Rugby Cement works in addition to a second factory for vehicle manufacturing. The difference between the pollution levels, as emitted from the chimney, in the UK; (which is less than the minimum standards) and the Libyan pollution levels is clearly noticeable, as shown in Figure 6-1.

UK **Libya**

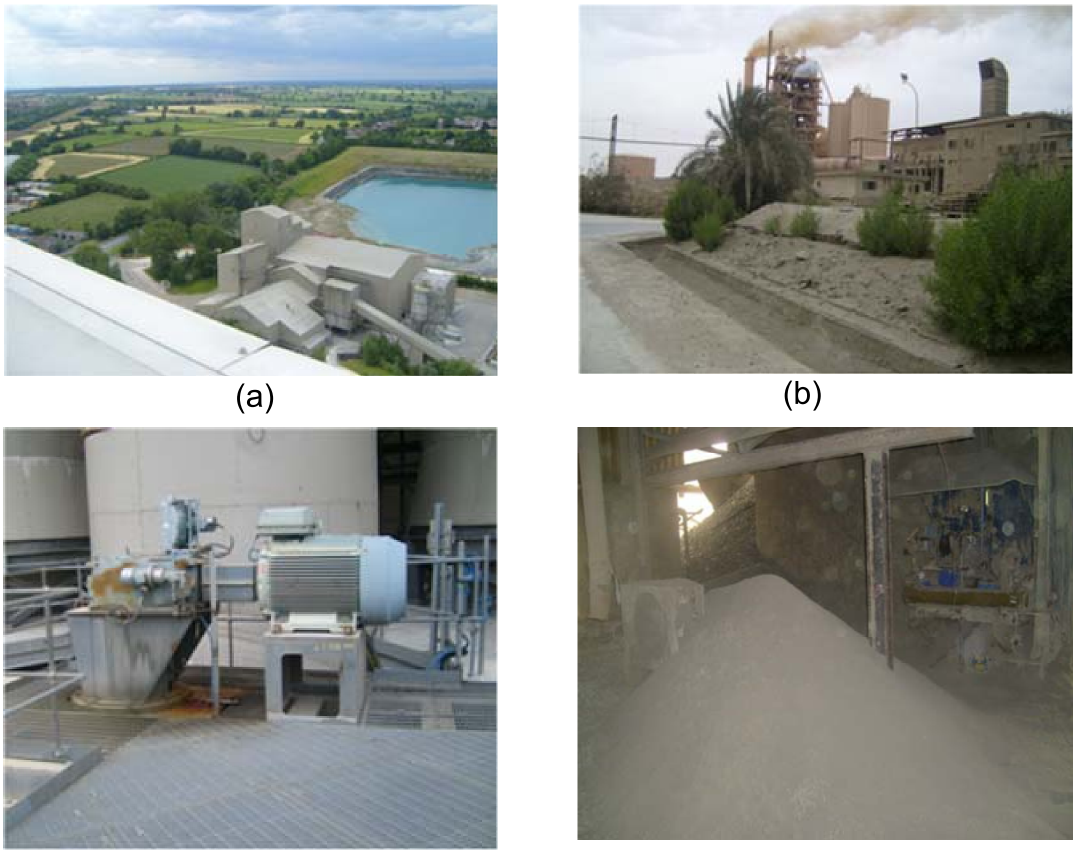


Figure 6-1: Comparison between UK and Libyan Cement factories. The effect on the environment in the UK (a) and Libya (b); Conditions of equipment in UK (c) and Libya (d) (Author).

Also the differences in the condition of equipment are very clear. In the UK the equipment and machinery are well maintained and clean; while in Libya the machinery is covered with dust and oil, see Figure 6-2 (c and d).

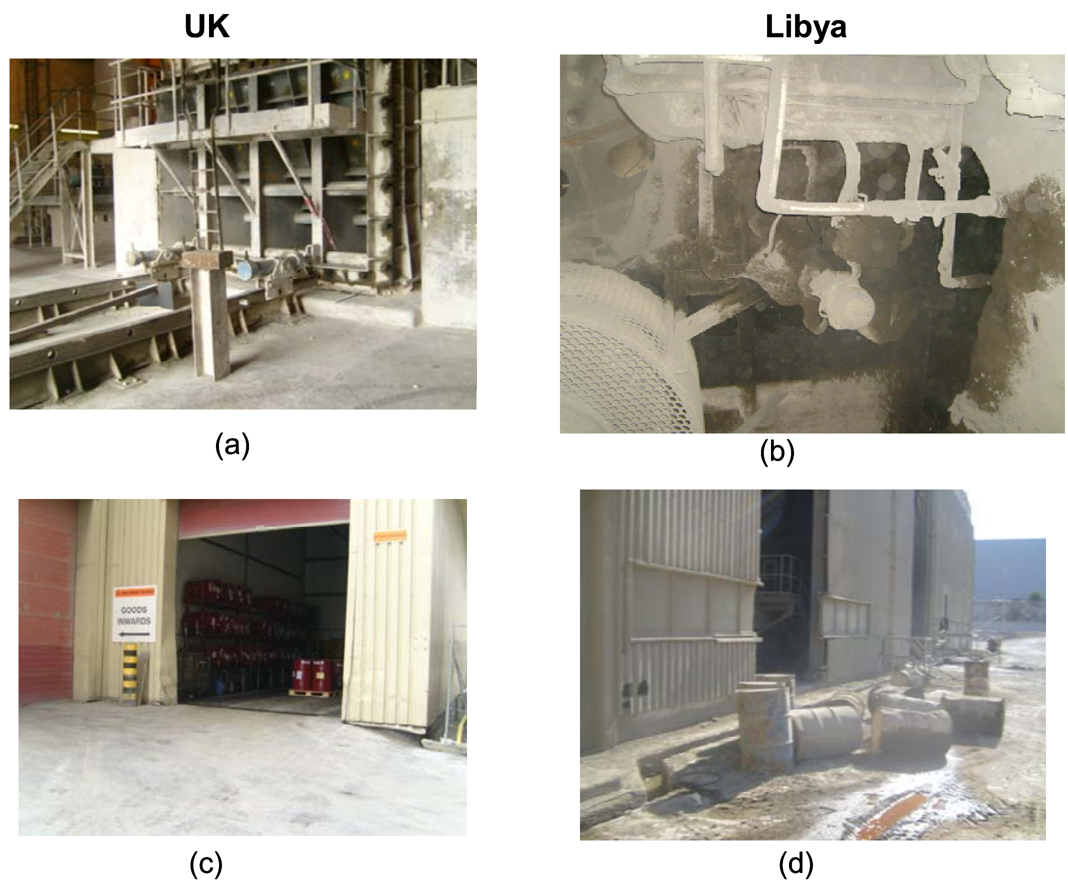


Figure 6-2: Comparison between UK and Libyan Cement factories. The condition of the equipment and dust levels in the UK (a) and Libya (b); Storage of materials in the UK (c) and Libya (d).

Figure 6-2 demonstrates another comparison between a UK cement factory and a Libyan cement factory. Notice the condition of the UK equipment (a) and Libyan equipment (c) which is full of dust. Also notice the clean and tidy storage spaces in the UK factory (c) when compared with the Libyan cement factories (d).

UK Libya

(a) (b)

(c) (d)

Figure 6-3: Comparison between UK and Libyan Cement factories. The condition of the kiln in the UK (a) and Libya (b); Condition of equipment in the UK (c) and Libya (d) (Author).

Figure 6-3 shows a comparison between the conditions of the kiln in the UK and Libya. Notice oil leakage from the kiln in Libya. Similar situations are found in various equipment around the other factories. Figure 6-4 presents the overall environment in the factory and the health and safety practice. Notice that the UK employee wears a safety helmet and yellow reflective jacket, while the technician in Libya wears dark colours which might not be obvious to vehicles, there is also no helmet. Also the effect of the dust and pollution is very clear at the Libyan factory (Figure 6-4.d), where the land around the factory is covered with cement. Notice the difference when compared with the UK factory (Figure 6-4.c).

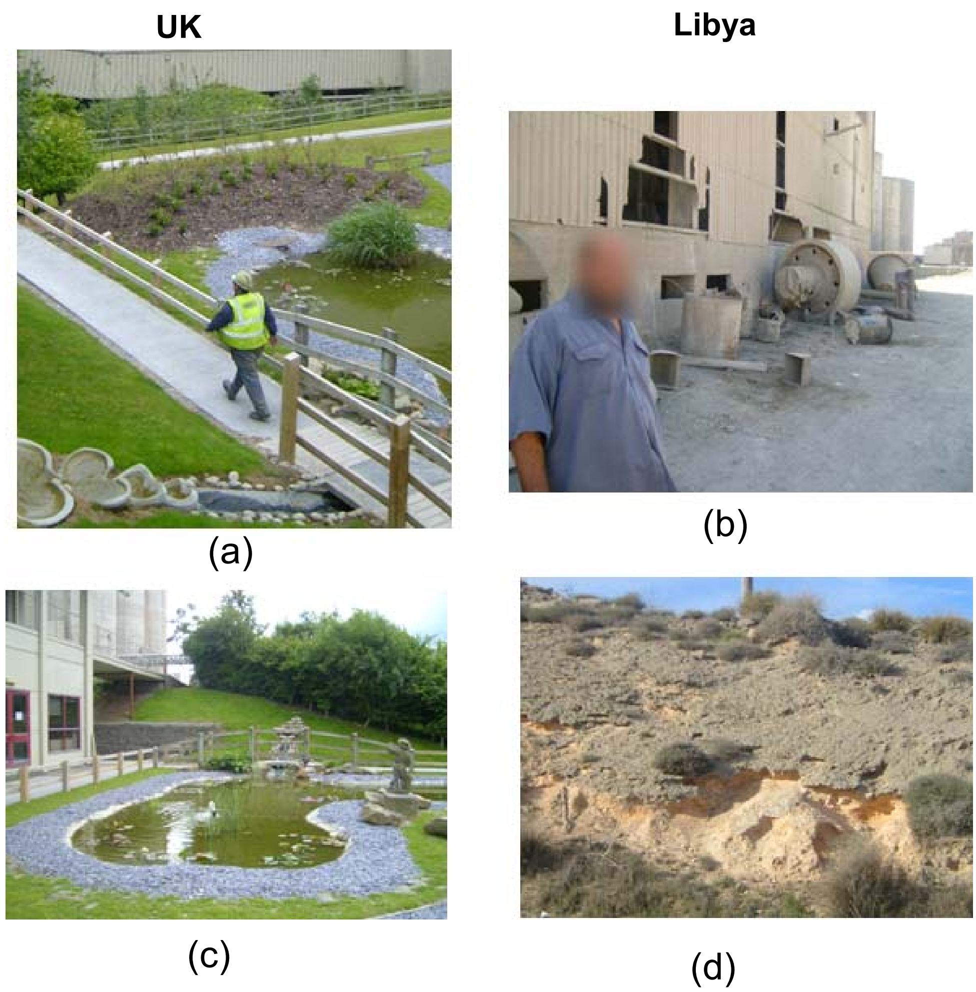


Figure 6-4: Comparison between UK and Libyan Cement factories. The health and safety in the UK (a) and Libya (b). The effect on the environment in the UK (c) and Libya (d) (Author).

UK Libya

Figure 6-5: The control room at the cement factory in the UK (left) and Libya (right) (Author).

It is evident from the field work that the control room in the UK is fully computerised and includes comprehensive information in relation to the old systems in Libya that include only part of the information about the process, see Figure 6-5

UK Libya

Figure 6-6: Locating equipment and tools in specific location is part of the UK manufacturing culture (right). This culture is still not implemented in the Libyan industry (right) (Author).

Figure 6-6 presents a direct comparison between UK factories and one of the Libyan cement factories in relation to the application of 5's. It is clear that UK industry implements most of the lean manufacturing and TPM principles; however, from the field work it is evident that the Libyan factories are still not implementing such strategies.

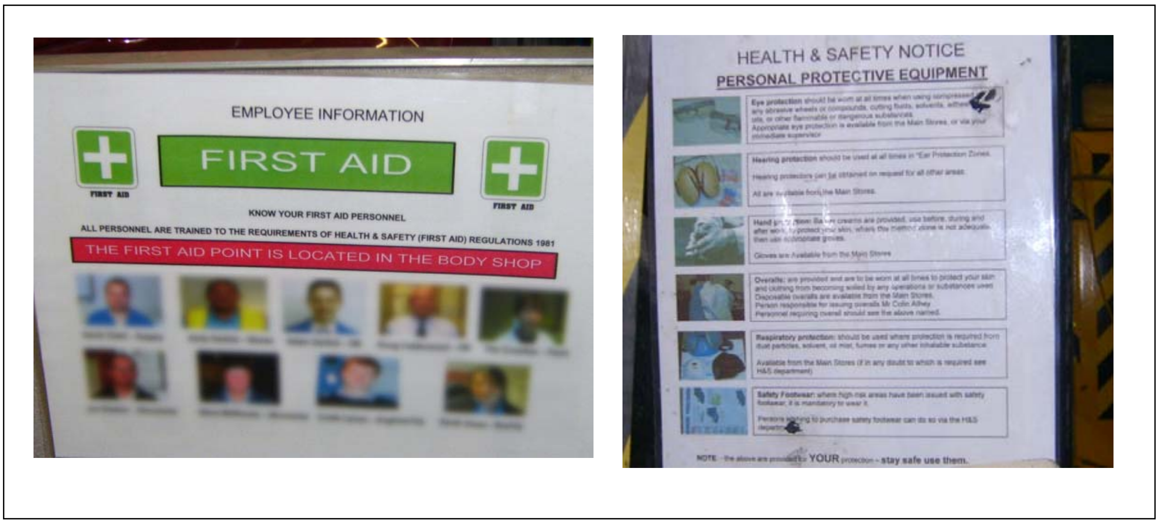


Figure 6-7: Health and safety is an important part of the UK manufacturing culture (Author).

When visiting UK factories, it was evident that health and safety is the focus of the factories. This might be due to the general culture combined with the legal obligations of employers. Figure 6-7 presents some of the posters found in different locations within UK factories.

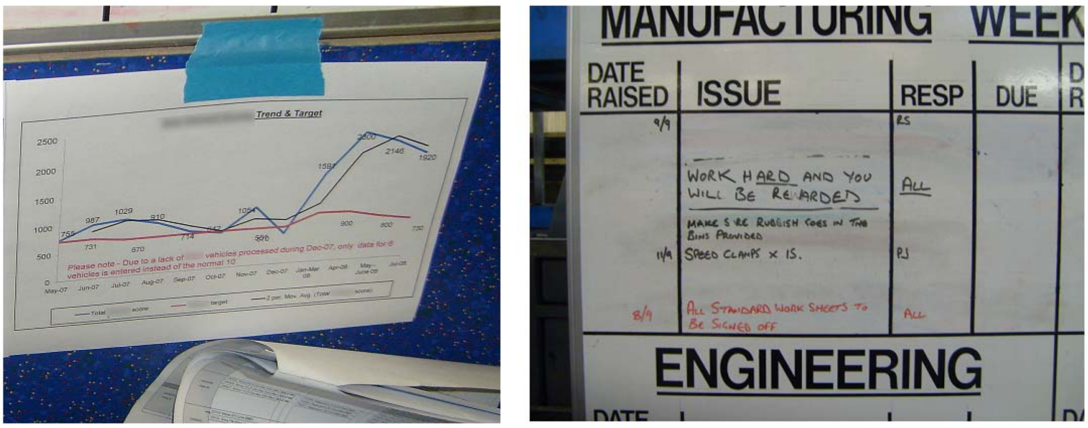


Figure 6-8: Productivity figures are clearly communicated to staff in UK industry. Notice the statement "Work hard and you will be rewarded" (Author).

Communication and team work are both essential for improving productivity. Figure 6-8 presents how productivity Figures and production problems are dealt with in UK manufacturing environment. Figure 6-8 presents how productivity data is presented on daily basis for employees to inform them about their performance. Figure 6-8 presents production problems and how it is communicated to the production team. Notice the statement “Work hard and you will be rewarded” which could indicate a relationship between quality and the rewarding system. None of the above examples has been found in Libyan factories.

The comparison has been found important because it highlights the problems in the Libyan cement factories that could be observed during the visits in comparison to UK factories.

6.2 Pollution and the Environment

The problems in a factory could go beyond the walls of the factory to have negative effect on the health and the environment. Pollution could be the most important external effect of the factory that could be linked directly to lack of maintenance. The high levels of pollution in the four Libyan cement factories are very clear, even when viewed from space. Figures 6-9, 6-10 and 6-11 presents a Satellite image from Google Earth which clearly indicates the high level of pollution in the local area. In comparison, the satellite image of the Rugby cement factory in the UK is shown in Figure 6-12. Notice that in Rugby, the residential area is very close to the factory in Rugby and the area is very clear and green. In comparison, observe the smoke and dust coming out of the chimney in Libya. Notice the red colour on the roof (Figure 6-9) and ground which is caused by iron dust. In this chapter the author will discuss the type of pollution that is emitted and some facts and Figures in relation to production of cement.

Figure 6-9: Satellite image of SCF in Libya (Google Earth).

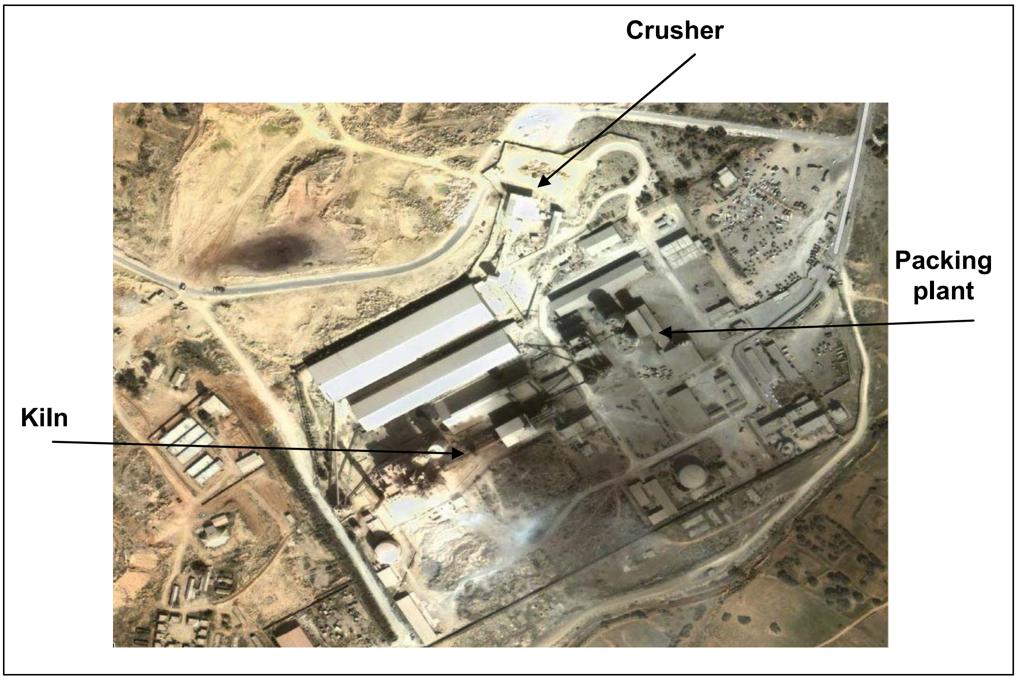


Figure 6-10: Satellite image of LCF in Libya (Google Earth).

Figure 6-11: Satellite image of MCF in Libya (Google Earth).

Figure 6-12: Satellite image of Rugby Cement Works in UK (Google Earth).

Figure 6-13 presents a comparison between the two chimneys, one in the UK (a) and one in Libya (b). Notice the significant level of pollution which could be seen from space as described previously.

UK **Libya**

(a) (b)

Figure 6-13: Comparison between chimney pollution in UK (a) and Libya (b)

The most significant stage of pollution in any cement factory is the kiln. Emissions from cement works can be determined both by continuous and discontinuous measuring methods, which are described in corresponding national guidelines and standards. Continuous measurement is primarily used for dust, NO_x and SO_2, while the remaining parameters relevant to the of ambient pollution legislation are usually determined discontinuously by individual measurements. The following explanation on emissions refer to modern kiln plants based on dry process technology Nitrogen Oxides –Dust-Carbon Monoxide (CO) –Carbon Dioxide (CO2) – Sulphur Dioxide (SO2) ;
To produce one ton of Portland cement, about 1.5 to 1.7 tons of raw materials, 0.1 ton of coal and 1 ton of clinker must be ground to fine dust during production. In this process, the steps of raw materials preparatory processing, fuel preparation, clinker burning and cement grinding constitute major emission sources for particulate components. In the West, dust emissions of up to 3,000mg/m³ were measured at the stack of cement rotary kiln plants in the 1950s; these can be less than 30 mg/m³ in current days(The Atmosphere, Climate & Environment 2009). The main pollutant gases that are produced by cement factories will be described in the following sub-sections to provide the reader with some information about them and their negative effect.

6.2.1 Nitrogen oxides (NOx)

The clinker burning process is a high temperature process resulting in the formation of nitrogen oxides (NOx). Nitrogen monoxide (NO) accounts for about 95% and nitrogen dioxide (NO2) for about 5% of this compound present in the exhaust gas of rotary kiln factories. As most of the NO is converted to NO2 in the atmosphere, emissions are given as NO2 per m³ exhaust gas.
Without reduction measures, process related Nox contents in the exhaust gas of rotary kiln plants would in most cases considerably exceed the specifications of e.g. European legislation for waste burning plants (0.50 g/m³ for new plants and 0.80 g/m³ for existing plants) (Shahgedanova et al ,1999);(Household Hazardous Waste Collections 2009).

Reduction measures are aimed at smoothing and optimising plant operation. Technically, staged combustion and Selective Non Catalytic No Reduction (SNCR) are applied to cope with the emission limit values.

High process temperatures are required to convert the raw material mix to Portland cement clinker. Kiln temperatures in the entering zone of the rotary kiln, range at around 1,450 °C. To reach these, flame temperatures of about 2,000 °C are necessary. For reasons of clinker quality, the burning process takes place under oxidising conditions, under which the partial oxidation of the molecular nitrogen in the combustion air results in the formation of nitrogen monoxide which dominates. This reaction is also called the Thermal No Formation. At the lower temperatures prevailing in a secondary firing unit, however, thermal No formation is negligible: here, the nitrogen bound in the fuel can result in the formation of what is known as fuel related Hokoma et al, (2008).

6.2.2 Carbon Monoxide (CO)

Is a colourless, fragrance-free gas produced by the inefficient burning of carbon-based fuels It has direct implications on people. Once inhaled, it inhibits the delivery of oxygen throughout the body. Low amounts of CO can cause dizziness, headaches and fatigue. High concentrations can be fatal, especially for children and the elderly (Shahgedanova et al, 1999), (Talaat, 1994).

6.2.3 Carbon Dioxide (CO2)

In a balanced environment, vegetation takes in this gas and, in turn, produces oxygen for animals and people to breathe. But the balance has shifted, and CO2 is now the principle contributor to the Greenhouse effect which is the primary cause of global warming. All excesses of CO2 can be traced back to human sources. It is primarily caused by burning natural resources such as coal, gas and oil. Power plants and cars are primary sources. CO2 can be toxic in high concentrations. It can cause increased breathing rates, unconsciousness and even death (Sten et al, 1981).

6.2.4 Sulphur Dioxide (SO2)

Is a gas which is related to sulphuric acid. At low concentrations, it is odourless. However, it has a penetrating odour and can irritate the eyes and air-passages at moderate to high concentrations. The exposure for asthmatics is significantly more damaging than for people in normal health. However, moderate concentrations may result in a fall in lung function in asthmatics. Tightness in the chest and coughing occur at high levels, and the lung function of asthmatics could be impaired to the extent that medical help is required (Bounicore and Davis 1992); (Sulphur- Dioxide 2009).

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6.3 The effect of cement factories on the environment in Libya

The lack of maintenance and its effect on the environment and agriculture has been found clear during the visits to the local areas around the factories. During the field visit, the author visited olive tree farms near the cement factories (within 5 km radius). The farmers have stated that the production of their olive trees is much less than the norm (about 25% of the expected level). This is caused by the high level of dusts and pollutants, a direct indication of poor maintenance to filters and other associated parts within the factories. The farmers have also pointed out that the production of olive oil from trees near the factory is significantly reduced in quantity and quality. When visiting another farm about 100 km from the cement factory, it appears that the production levels of olive trees are within the normal level. Figure 6-14 presents a comparison between the two farms.

(a) (b)

Figure 6-14: The effect of cement factories on olive trees. Olive trees within 5 km distance of the factory (a) and olive trees within 100 km distance from the factory (b).

Plants and vegetation around the factory are damaged by the cement dust and as clearly presented in Figure 6-15; the land is covered by layers of cement.

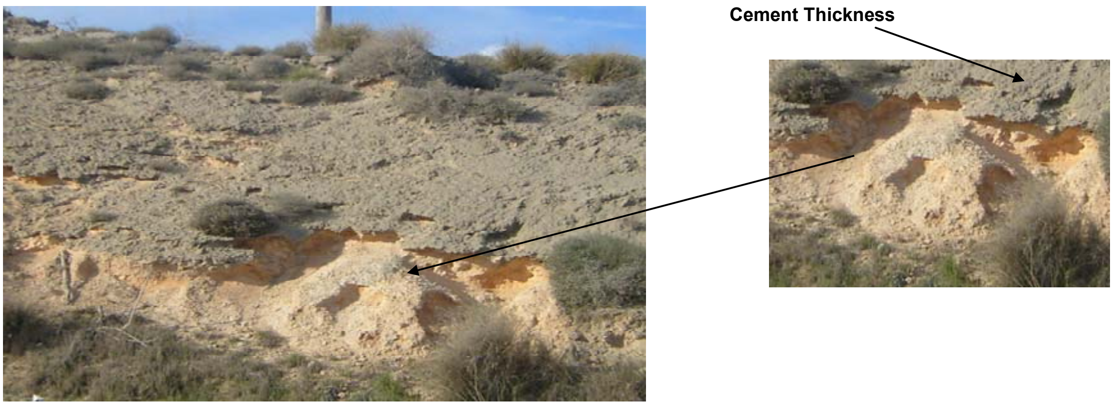


Figure 6-15: The negative effect of cement on plants and vegetation in Libya.

6.4 Summary

This chapter has presented field visits to cement factories Libya and in the UK. The chapter has given comparison case studies between a UK cement factory and the Libyan cement factories. There is a clear difference in the level of maintenance from visual perspective, health and safety and the effect on environment. The UK factory is found to have pollution levels less than the minimum legal requirements with almost no effect on the residential area near the factory. On the other hand, the Libyan factory clearly has a negative effect on the environment. Cement factories are considered to be one of the most dangerous resources of pollution, especially when not appropriately maintained. The most significant pollutants produced by cement factories in Libya are dust and fuel combustion outputs. From the field work it has been found that a high level of pollution negatively influences the environment and plants in an area of over 5 km around the factories.

CHAPTER 7: THE QUESTIONNAIRE

The previous chapters have discussed the productivity and environmental issues within the four cement factories. This chapter attempts to understand the culture, practise and systems within the factories by collecting data through questionnaires in the four factories. This chapter will introduce the design of the questionnaire and the results obtained. It also includes a discussion regarding the results found.

7.1 Introduction – Developing the Survey and the design of the questionnaire

Based on the findings from the literature review and the information learnt from field visits, and the research conceptual framework, the author initiated his methodology by designing a survey. However, it is worth noting that the author wished to expand the study of TPM to investigate technical as well as the human side of it. This is important because, without evidence that managers are taking their role and responsibilities from the human aspect, it might be difficult for the technology to succeed.

The first step in any survey is deciding what you want to learn Ariene (1995). The objectives of the research will determine the questions that will be asked and to what type of employees. If the goals were unclear, the results will probably be unclear

Therefore, following the design of the research conceptual framework, a survey was designed to answer different areas within TPM Brace (2004).

Four main research questions have been developed for this research work.

- What are the factors affecting productivity from operational perspective.
- What are the factors affecting productivity from maintenance perspective.
- What are the factors affecting productivity from a combined operation and maintenance perspective.
- What is the awareness level in terms of (Healthy, Safety and Environment) HSE.

The main four questions have been translated to four different diagrams that will highlight main points. There is some overlap between these issues. However, they have been separated in the following discussion to simplify the presentation. The issues and factors in the diagrams are selected based mainly on the author's industrial experience combined with knowledge from literature.

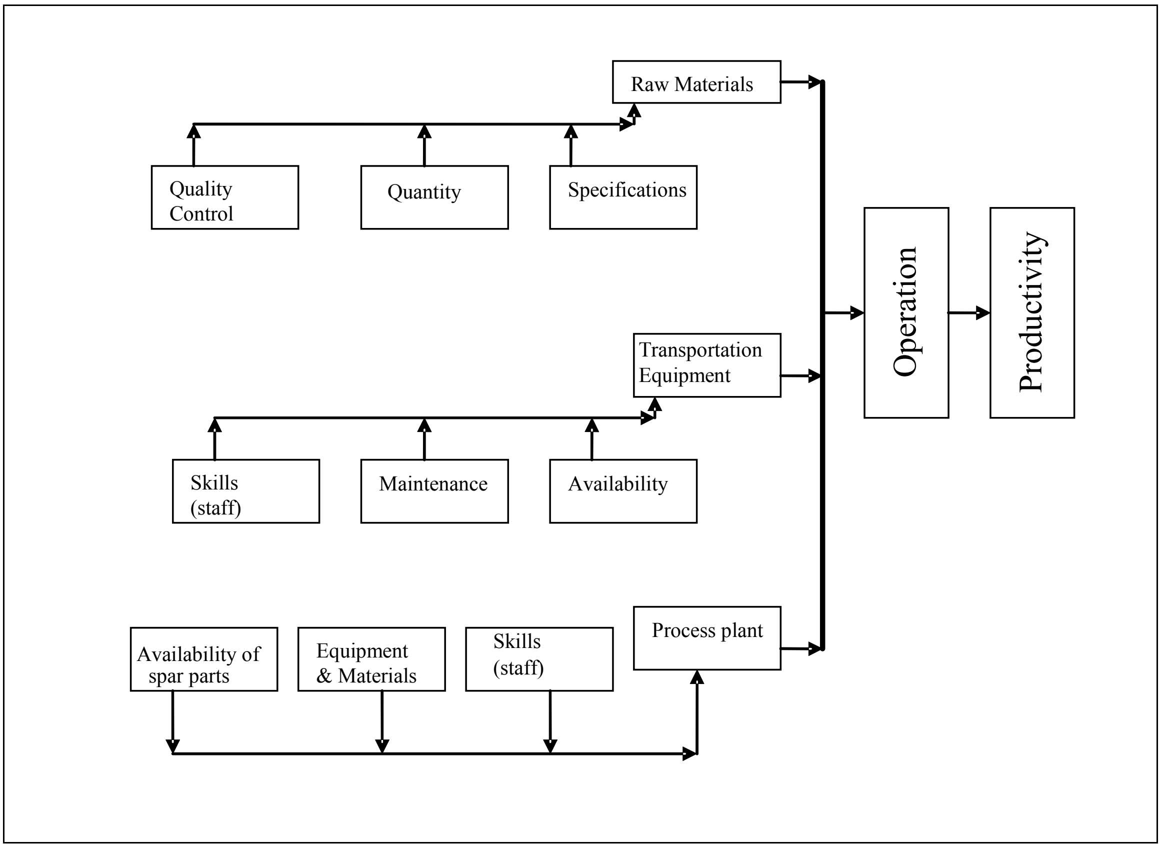


Figure 7-1: Issues that might influence the operation within the four factories (Author).

From literature and field visits, it has been found that the main issues that might affect the operation within the factory are

1. Availability of raw materials.
2. Availability of transportation equipment.
3. Availability of the process plant.

The availability of raw materials could be associated with quality control, availability in terms of quantity and the existence of specifications, or the lack of them.

In terms of transportation, e.g. Lorries and bulldozers, their numbers, maintenance, the availability of staff able to operate such equipment could influence the operation of the factory.
The efficiency of the processing plant, in terms of the skills of the staff, availability of equipment and the availability of spare parts, have also a significant influence on the operation of the factory.

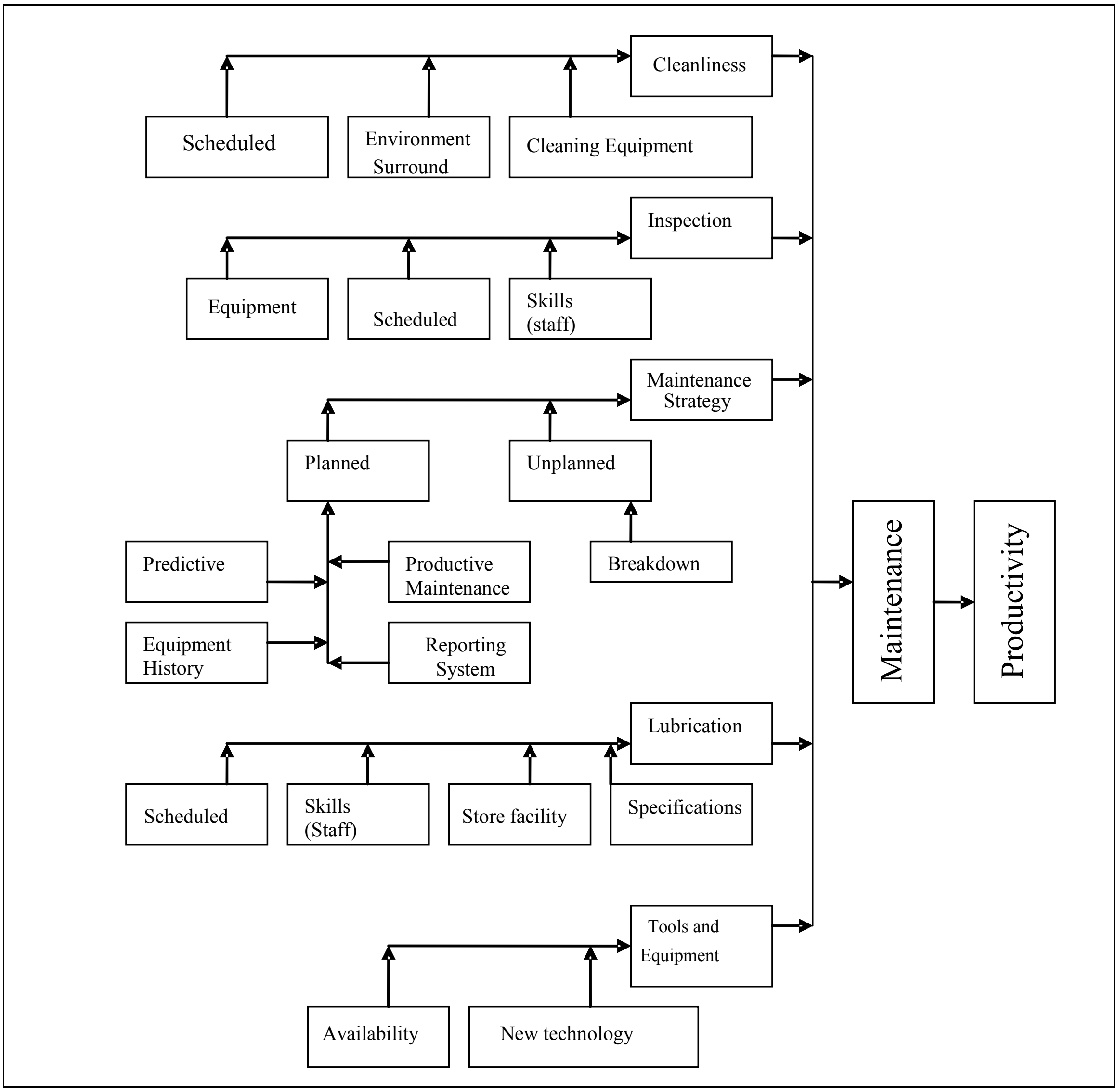


Figure 7-2: Maintenance activities and its effect on productivity (Author).

In terms of maintenance, five main issues should be considered based on field observations: cleanliness, inspection, maintenance strategy of equipment, lubrication procedures and the availability of tools and equipment. Each category is divided to sub-categories and factors based on the main possible issues that might influence the performance and the decision making as shown in Figure 7-2. Figure 7-2 presents the main tasks or activities related to maintenance including cleanliness, inspection, maintenance strategy selection, lubrication of equipment and the use of tools and equipment.

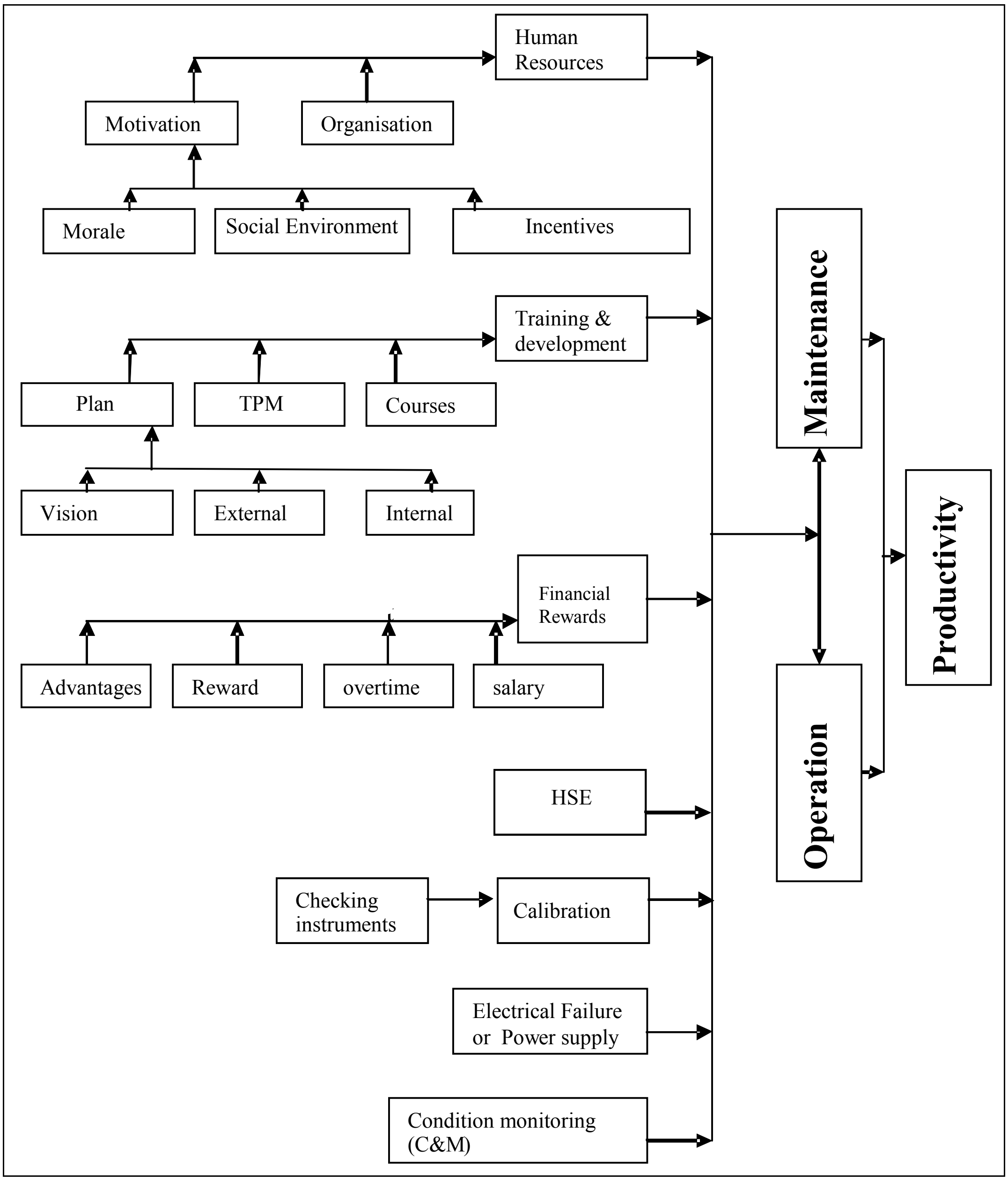


Figure 7-3: Factors affecting Productivity from a combined Operation and Maintenance perspective (Author).

The issues which could influence the combined production and maintenance activities can be categorised into two aspects: human and technologies. From the human aspect: issues such as human resources, incentives, training, health and safety and financial rewarding system can be included From the technology side, calibration, electric failures and condition monitoring can also influence both sides of activities. Figure 7-3 presents the issues that could have an effect on the above categories.

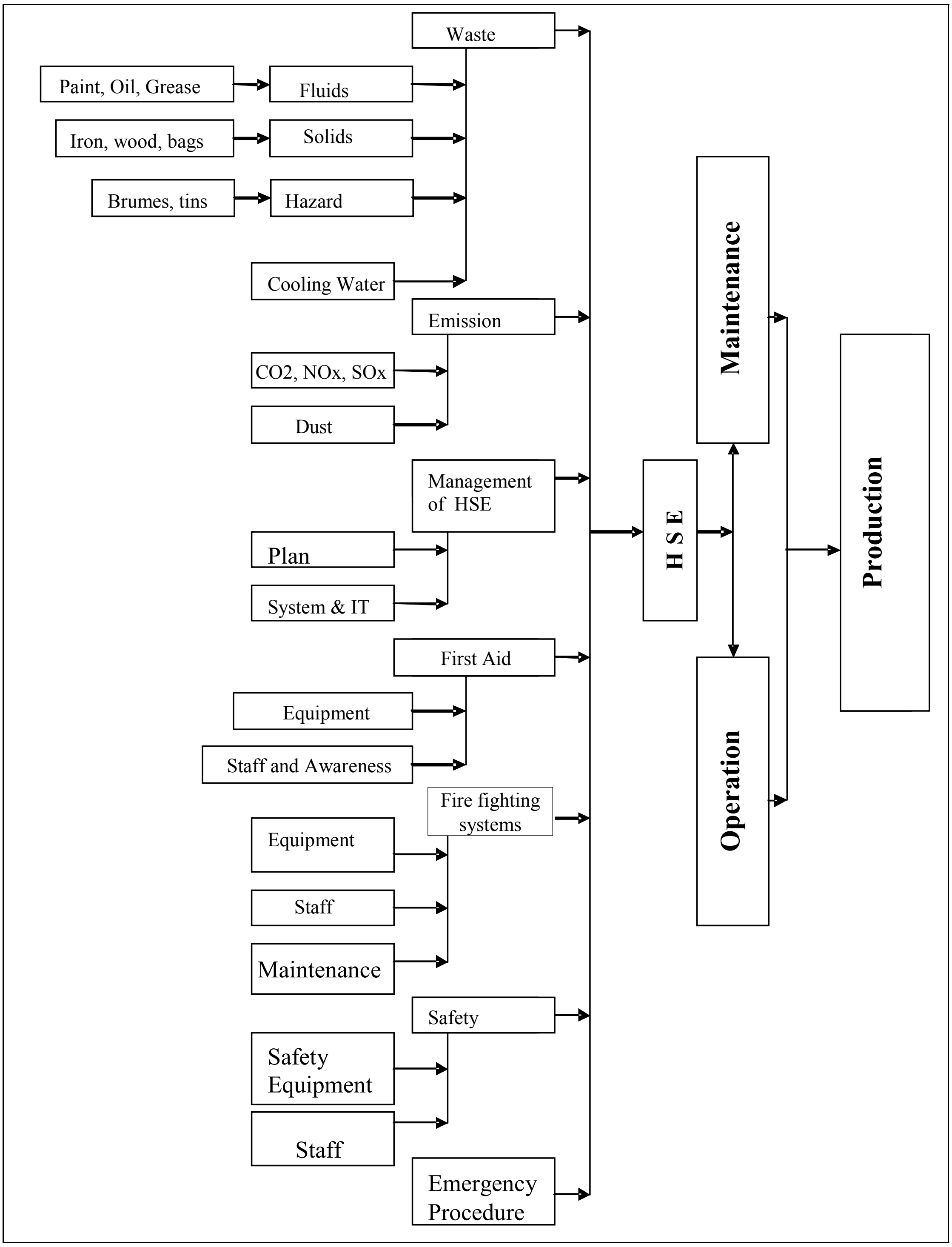


Figure 7-4: Systems and awareness level in terms of Healthy, Safety and Environment (HSE)(Author).

Health, Safety and Environment (HSE) are very important issues. The company, on a strategically level, is interested in providing a very safe working environment and reducing any negative effects on the environment. HSE is categorised in this research work into seven categories: waste disposal, emissions, management, first aid, fire- fighting systems, general industrial safety and emergency procedures. Figure 7-4 presents HSE categories and aspects that might influence its outcomes. The categories were identified mainly based on the author's industrial experience.

This survey has targeted engineers on the shop floor. Based on, the table of Krejcie and Morgan (1970) sample size for a population of 160 with confidence level of 95% and a margin of error (Degree of accuracy) of 5% would be 130 Engineers. A total of 160 questionnaires were distributed and 130 engineers responded which makes the response rate to be about 81%. This indicates that the majority of engineers are interested in participating in any studies to improve the working environment enhancing the productivity of the factory. This chapter will outline the main observations. Future chapters will discuss the findings in relation to interviews and field visits. Cronbach's Alpha, as discussed in Chapter 3, is found to be 91.0% which proves the reliability and consistency of the questionnaire.

In the following sections, the main four questions, see page 177 will be discussed and the results will be analysed.

7.2 Productivity

This section will present some of the questions related to productivity and the response of engineers in each factory.

Q1: Have you ever noticed a shortage of raw materials in the factory?

Table 7-1: Response to shortage of raw materials

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	1	4	8	20	7
SCF	1	1	4	18	3
ZCF	0	5	9	15	5
LCF	0	4	7	10	8
All	**2**	**14**	**28**	**63**	**23**

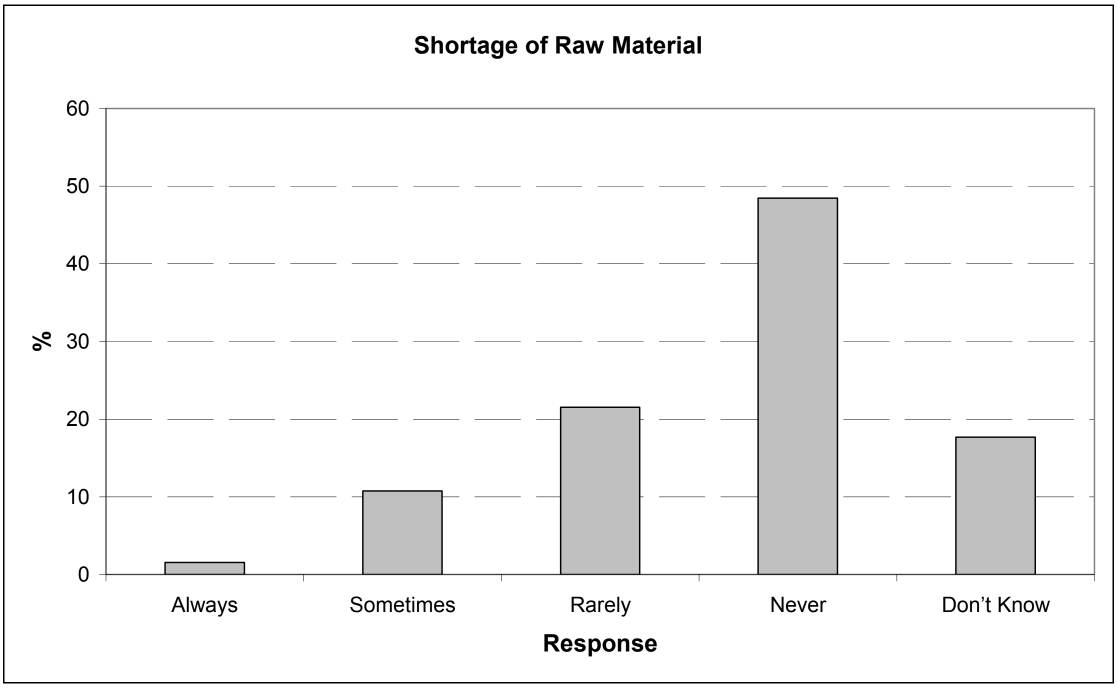


Figure 7-5: Response to shortage of raw materials, based on Table 7-1.

It can be observed in both Tables 7-1 and Figure 7-5 that raw materials are available in general. The above results are in-line with company's production reports.

Figure 7-5 indicates that about 12% of respondents noted shortage of raw materials as 'always' or 'sometimes'. About 18% of respondents did not know whether there was a shortage of raw materials or not. This lack of knowledge (i.e. 'don't know') can mainly be associated with lack of training and communication. As will be seen later in this chapter, many respondents indicated that there is a problem in communication within the factories and there is a need for training courses and newsletters to keep staff updated about production data and other production related issues. According to Nakajima (1988) training is very important for all workers from top management to the shop floor. For example maintenance training helps staff to perform their jobs more effectively and also to acquire the knowledge and skills they need to be more efficiency. (As documented in chapter two sections 2.8.2).

Q2: Does the standard of raw materials meet the specifications required for the manufacture of cement?

Table 7-2: Specifications of raw materials meet requirements

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	19	11	4	1	5
SCF	15	6	2	1	3
ZCF	15	8	5	0	6
LCF	11	6	6	0	6
All	**60**	**31**	**17**	**2**	**20**

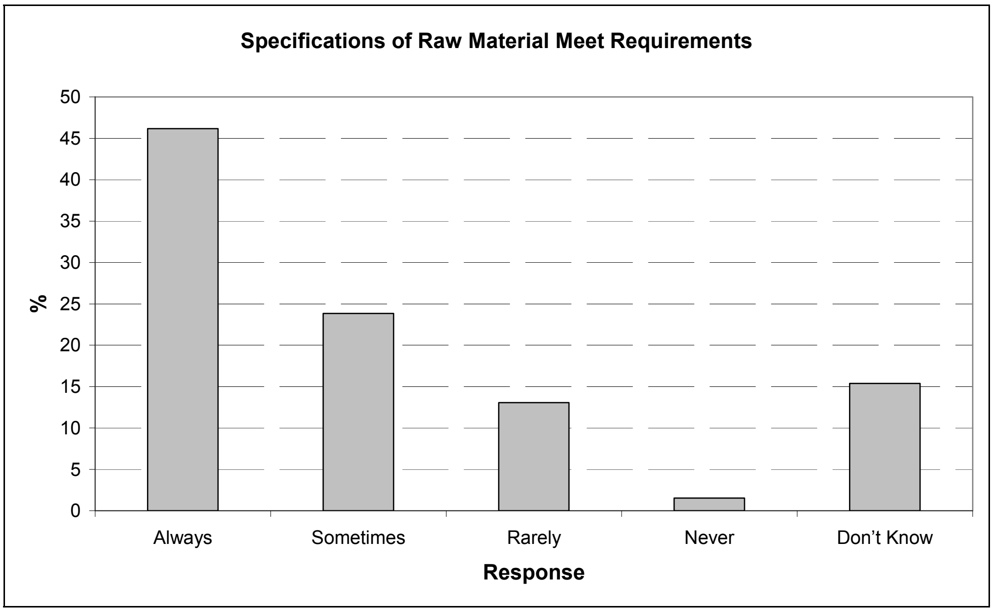


Figure 7-6: Response to raw material specifications, based on Table 7-2.

The responses to the second question indicate that respondents consider that 69% of raw materials meet the Libyan specifications for Portland cement (identical to British standards).

This high percentage decreases production problems during the kiln and burning process at the kiln area. Because raw materials directly affect bricks in the kiln, damage to bricks may occur if the raw materials contain silica. EA and EH (2007) agrees that in the past many raw materials contained silica because all factories were short of bulldozers. However, these problems have now been resolved, and bulldozers have been acquired.

About 15% of engineers did not know about material specifications and standards. This indicates the lack of communication and training courses across these factories.

Q3: Do you have a suitable process in place to test the raw material

Table 7-3: Suitable process in place to test the raw material.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	19	11	5	1	4
SCF	12	8	2	0	5
ZCF	12	8	2	0	5
LCF	11	7	6	2	3
All	**44**	**37**	**18**	**5**	**16**

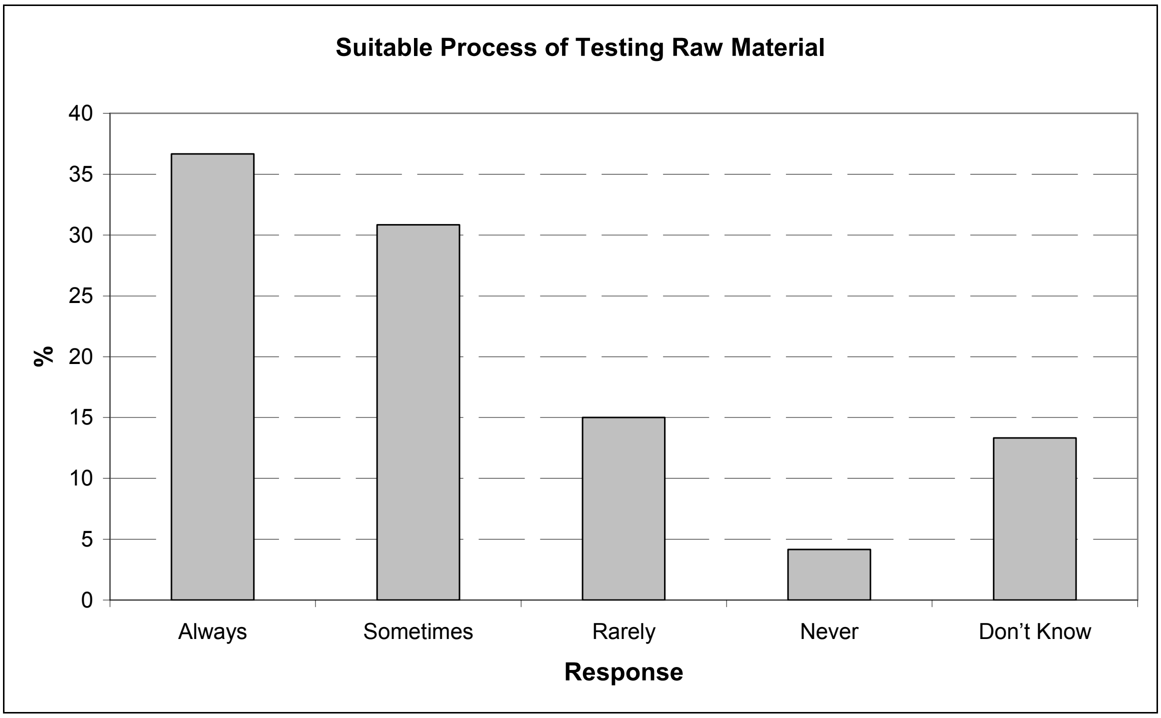


Figure 7-7: Suitable process in place to test the raw material, based on Table 7-3.

About 36% of respondents believes that there is an adequate process for examining the raw material during production. However, about 31% engineers indicates that the process is available only 'sometimes'. This could lead to inconsistency in testing the materials.

Another group of respondents (13%) did not know if there is a suitable process for testing the raw material. This shows their strong need for further intensive training in operations and maintenance jobs. This also indicates the need to improve communication across the various members of companies' staff. In a production environment, simple and basic facts of work should always be known by the majority of staff from an induction course or other training courses during their work in the factories.

Q4: Have you undertaken a training course to enhance your understanding regarding raw materials and their testing?

Table 7-4: Undertaken a training course.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	1	3	15	17	4
SCF	1	2	8	10	6
ZCF	2	4	8	12	8
LCF	1	5	7	12	4
All	5	14	38	51	22

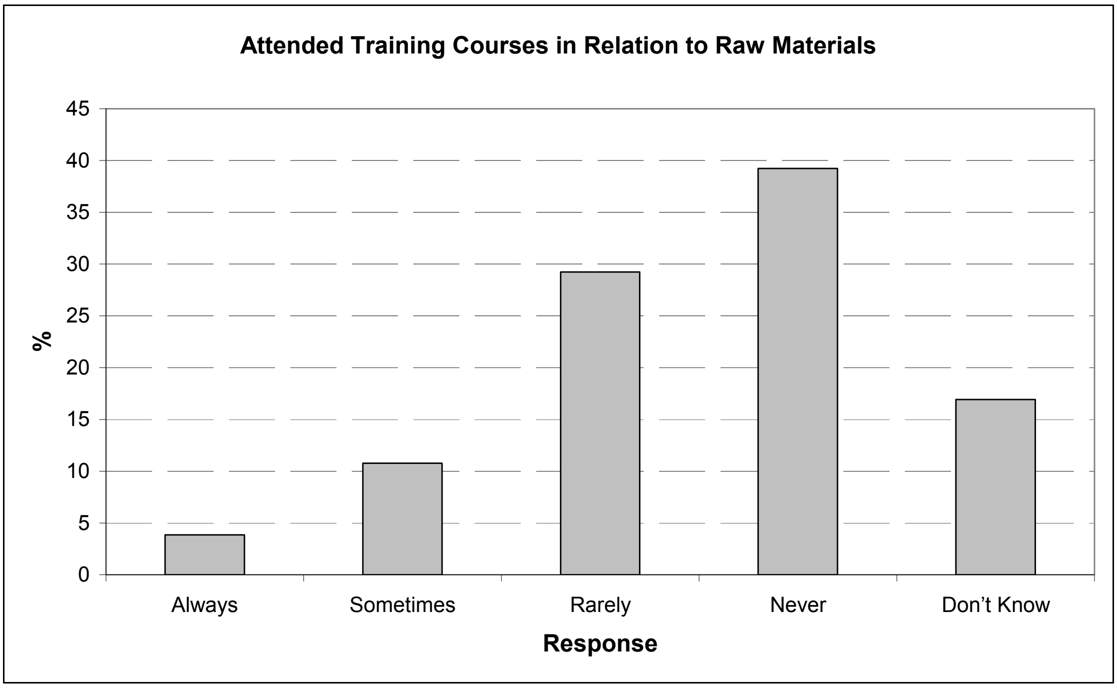


Figure 7-8: Undertaken a training course, based on Table 7-4.

This question, which is one the most important, deals with the importance of training in the company. From the results (see Figure 7-8) it is clear that almost more than 85% lack training courses. This again shows that further training of engineers and other employees is required. 19% did not know I they had training courses, this group of people might have chosen the 'politically safe' option to avoid any assumed potential conflict with management.

Q5: Is there sufficient transportation to maintain the right level of raw materials in production?

Table 7-5: Sufficient transportation.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	1	12	18	5	4
SCF	1	8	11	2	5
ZCF	2	8	10	9	6
LCF	1	7	9	8	4
All	**5**	**35**	**48**	**24**	**19**

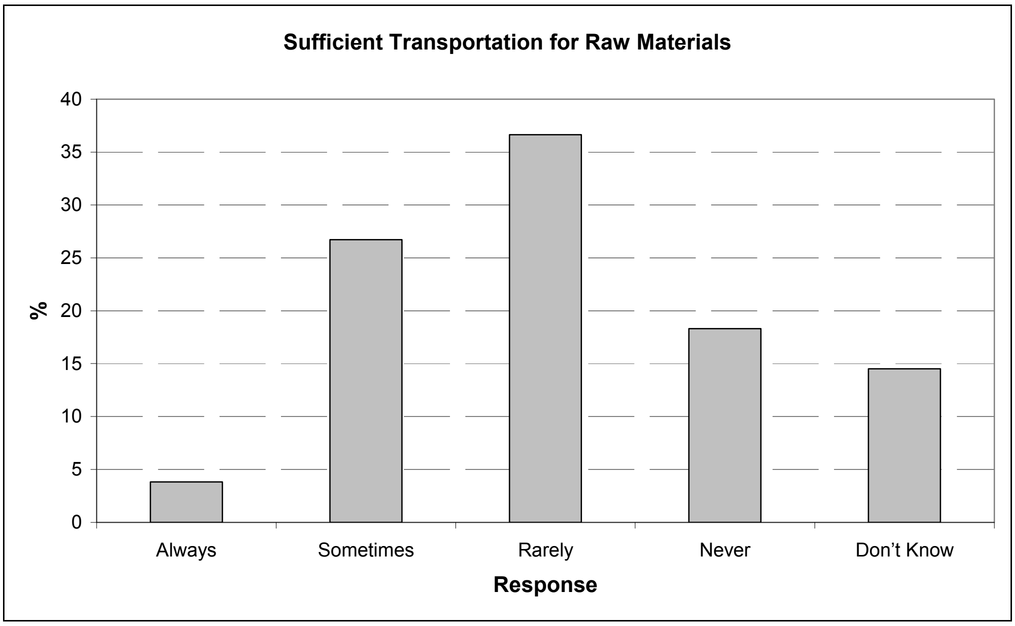


Figure 7-9: Sufficient transportation, based on Table 7-5.

Figure 7-9 indicates that about 55% of engineers in the survey believe that there is a lack of sufficient transportation to transfer raw materials from quarries to the factory. A manager of production management in NCC agreed with this finding, especially during the embargo between 1990 and 2003 and also with of the fact that workers did not have/use vehicles, in addition lack of clear cut answers with regard to maintenance and spare parts.

Other surveyed respondents (14%) group in total do not know which again points to lack of communication and training courses. Figure 7-9 shows that only 4% of engineers are of the opinion that there is sufficient transportation for raw materials. As mentioned earlier (See chapter 3 section 3.6) educational programmes need to be applied which are available for all personnel involved with TPM to make them aware of their benefits.

Q6: Is there a shortage of spare parts for the transportation system

Table 7-6: Shortage of spare parts.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	4	16	12	0	8
SCF	2	11	7	1	6
ZCF	6	12	9	0	7
LCF	5	10	8	0	6
All	**17**	**49**	**36**	**1**	**27**

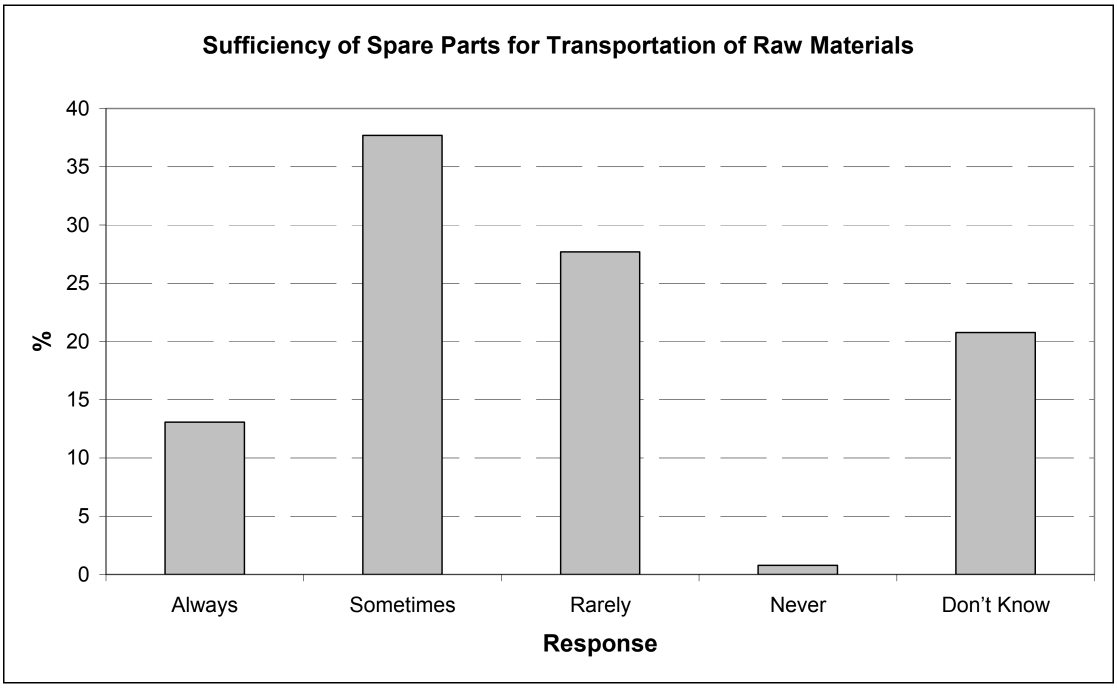


Figure 7-10: Shortage of spare parts, based on Table 7-6.

From Figure 7-10 it can be seen that there could be a significant lack of spare parts for transportation equipment (e.g. bulldozers and Lorries). The Figure above shows that only 13% of engineers believe that spare parts are always available. 20% of engineers do not know if there is a sufficient amount of spare parts for the transportation of raw materials. Hence in the majority of cases, parts, materials are not available. This is probably due to a lack of communication and /or training courses. A month to month publication about production and maintenance along with weekly meetings amongst staff can help to make every-one up to date with all factory issues, including raw materials, shortages, and spare parts. This is further explained in chapter 10, which also relates to the need for training.

Q7: Is the number of skilled engineers and workers in the production area sufficient?

Table 7-7: Number of skilled engineers.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	8	16	10	1	5
SCF	5	10	7	1	4
ZCF	7	12	7	0	8
LCF	5	11	6	0	7
All	**25**	**49**	**30**	**2**	**24**

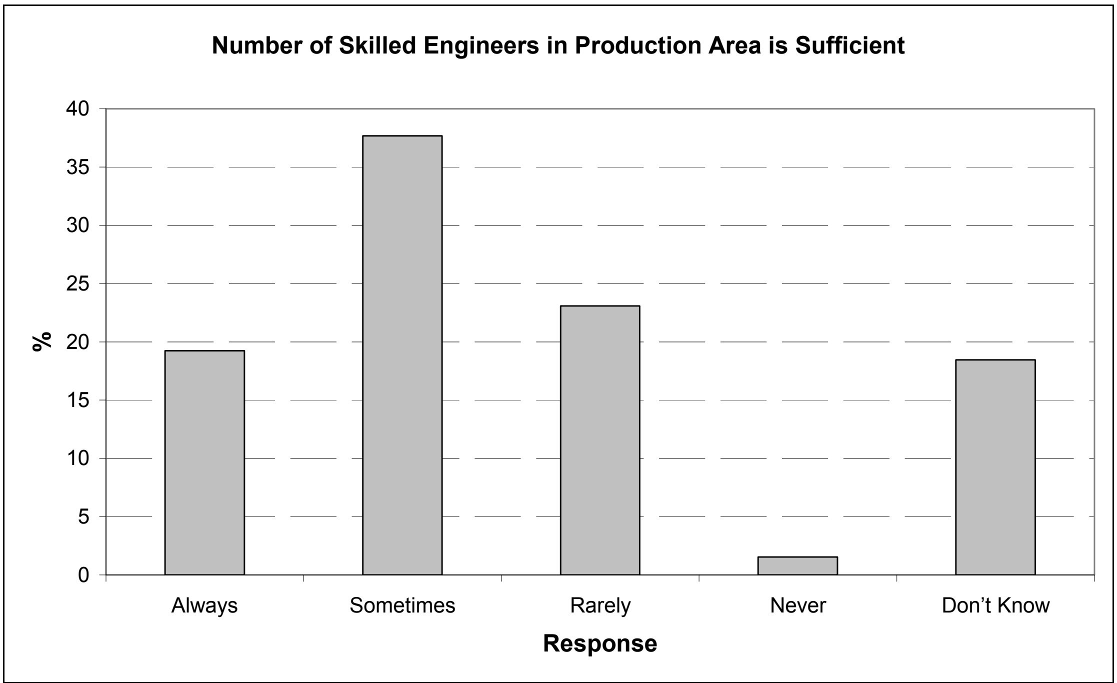


Figure 7-11: Number of skilled engineers, based on Table 7-7.

About 23% of engineers thought that there is a need for more skilled engineers in the team to work in the production area. However, about 18% do not have a clear opinion which points to lack of communication. As mentioned before, (chapter 3) training consists of different types including maintenance, operations, and leadership, the aim of which is to improve worker's skills.

Q8: Do you have shortage of spare parts in the production area?

Table 7-8: Shortage of spare parts in Production.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	0	5	8	10	17
SCF	0	3	4	10	11
ZCF	0	5	8	8	13
LCF	0	6	9	8	6
All	**0**	**18**	**29**	**36**	**46**

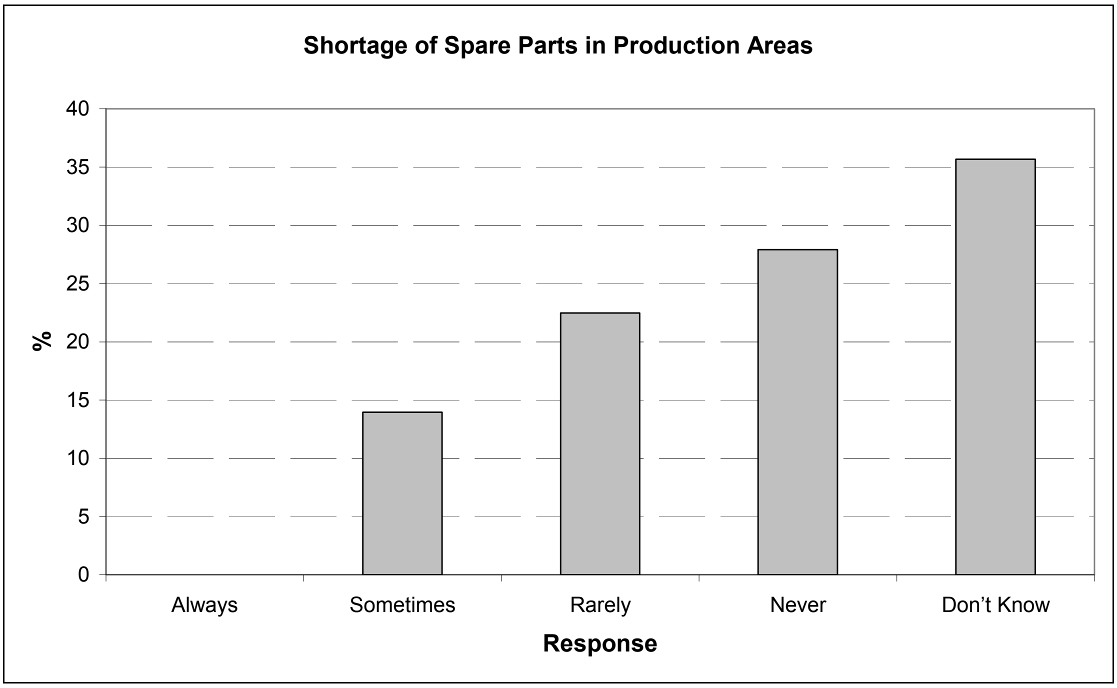


Figure 7-12: Shortage of spare parts in Production, based on Table 7-8.

About 36% of engineers did not know if there is a shortage of spare parts in the production area. This is arguably due to a lack of communication between production and maintenance engineers. It also indicates that there is a shortage of training courses. Documented in (chapter 3) training should focus on addressing the basic needs of people and the equipment targeted for TPM, to help employees involved understand what TPM is it and its importance.

Q 9: Are spare parts for the operation area available locally?

Table 7-9: Spare parts available locally.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	1	13	17	4	5
SCF	1	7	12	2	5
ZCF	1	11	13	5	4
LCF	0	7	10	6	6
All	**3**	**38**	**52**	**17**	**20**

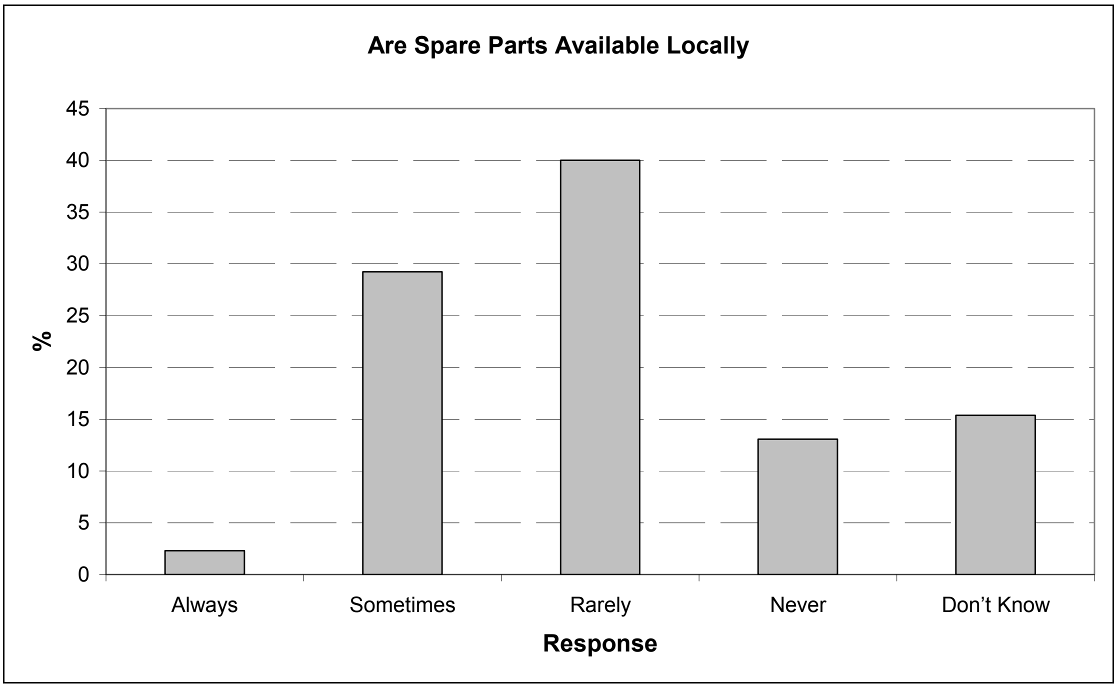


Figure 7-13: Spare parts available locally, based on Table 7-9.

From Figure 7-13 it can be observed that 53% of engineers indicated that spare parts are never, or rarely available locally in Libya. This means that there could be a delay in importing spare parts for the factory.

Q10: Does production operate on a regular schedule?

Table 7-10: Production operates at regular schedule.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	9	17	6	2	6
SCF	8	11	5	1	2
ZCF	8	13	6	3	4
LCF	8	10	5	1	5
All	**33**	**51**	**22**	**7**	**17**

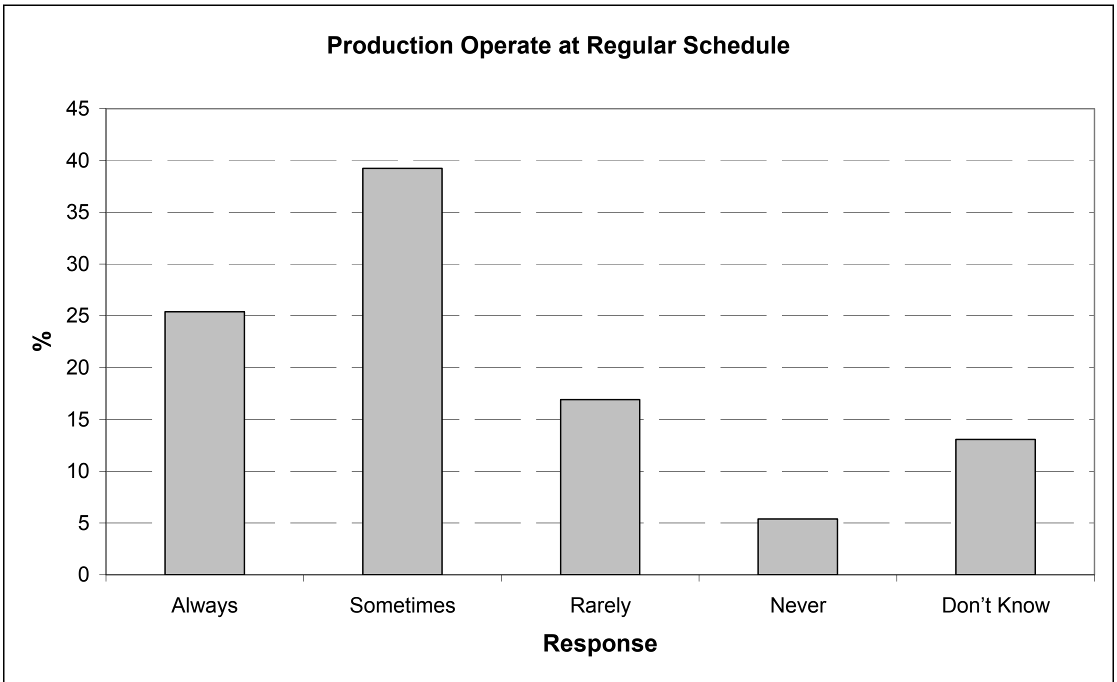


Figure 7-14: Production operates on a regular schedule, based on Table 7-10.

From Figure 7-14 it can be said that 25% of engineers believe that production operates on a regular schedule. Only 15% are of the view that production is not regular. On the other hand, about 40% of surveyed engineers are saying that initial production schedules did not remain constant and changed from time to time. Based on earlier Figures, the level of production can improve. (More information mentioned at chapter 3) McMullen et al., (2000) stated that within production scheduling, a decision should be taken at department levels concerning the assignment of machine tools to accomplish each operation on scheduled parts and tasks.

Q11: Do you modernise your production equipment and facilities when needed?

Table 7-11: Modernise equipment and facilities.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	6	16	9	1	8
SCF	3	11	7	1	5
ZCF	5	13	7	2	7
LCF	4	10	8	1	6
All	**18**	**50**	**31**	**5**	**26**

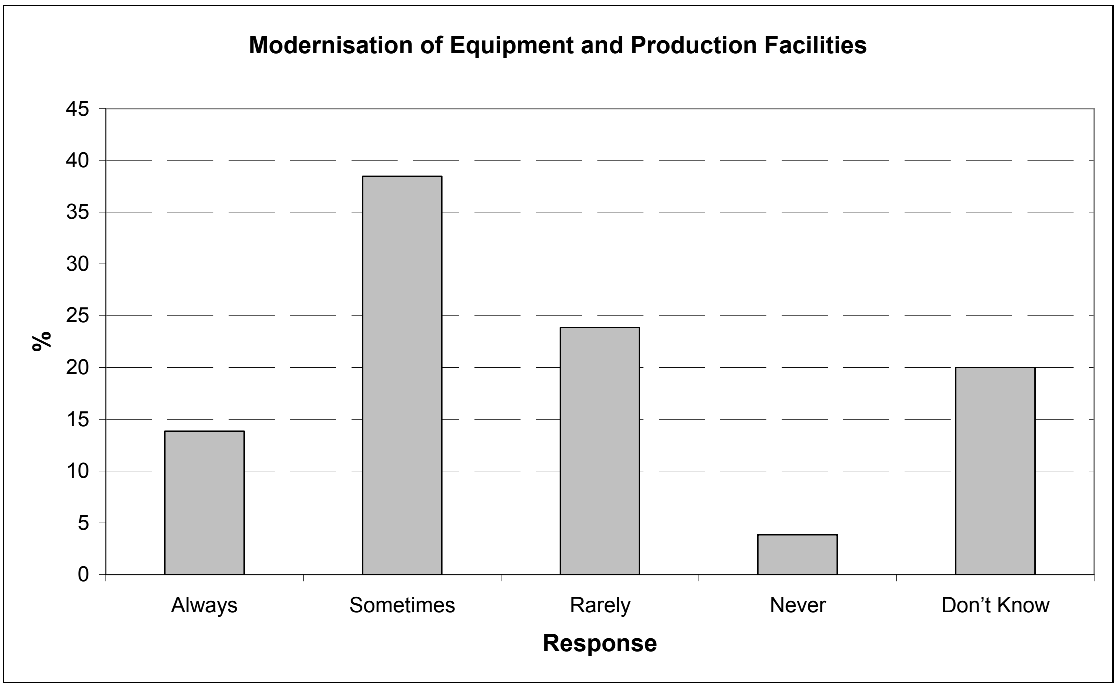


Figure 7-15: Modernise equipment and facilities, based on Table 7-11.

From Figure 7-15 above, it is clear that the modernisation of equipment occurs sometimes only. This is the view of the majority of respondents, nearly (40%). However, another group about 25% believe that modernisation of equipment rarely happens. Therefore, it is clear that top management does not always invest in new machinery. This however, can have an adverse impact on productivity and can also prevent workers from acquiring new skills. Nakajima (1988) states that the fourth pillar, i.e. training to improve operator and maintenance skills, is vital if the TPM implantation is to be successful. Also, as the author documented earlier (Chapter 2 section 2.3) over the past years, there have been many different approaches to improving maintenance efficiency; these have been called Modern Maintenance Practices (MMP).

Q12: Is the number of skilled technicians and engineers who work in maintenance sufficient?

Table 7-12: Number of skilled technicians and engineers.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	18	17	2	1	2
SCF	11	9	2	1	4
ZCF	12	8	2	2	10
LCF	10	7	3	0	9
All	**51**	**41**	**9**	**4**	**25**

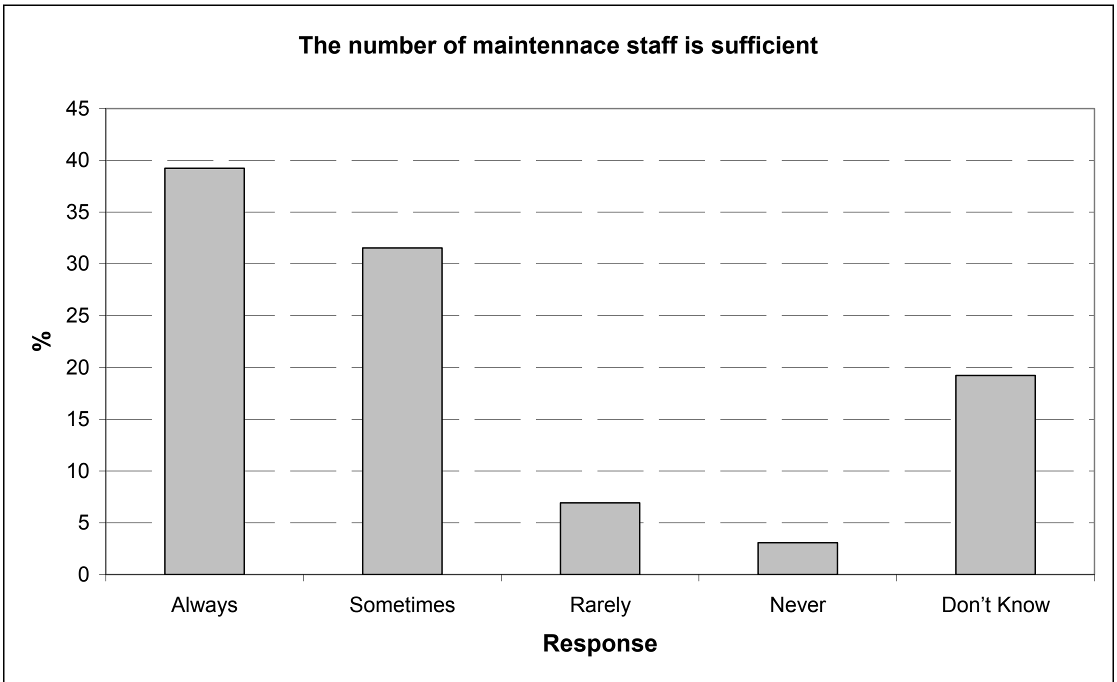


Figure 7-16: Number of skilled technicians and engineers, based on Table 7-12.

Figure 7-16 shows that a high number of skilled professionals work in maintenance (70.76%). The question arises though: why is it that there has been a low level of productivity over so many years? For example, it has been documented (in chapter 4) that production is almost always below 70% per year. The head of production management at NCC states as will be described in the next chapter, that within these factories the reason why there is no increase in productivity is that there is hardly any team work even though the workers they employ are very skilled and very talented. Again, it can be stated that people maybe need more training and education in team work and general modern technical skills.

Q13: Is the process of reporting and communicating regarding factory equipment efficient?

Table 7-13: Process of reporting and communicating.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	9	16	7	0	8
SCF	7	10	6	0	4
ZCF	9	14	6	0	5
LCF	7	11	6	0	5
All	**32**	**51**	**26**	**0**	**22**

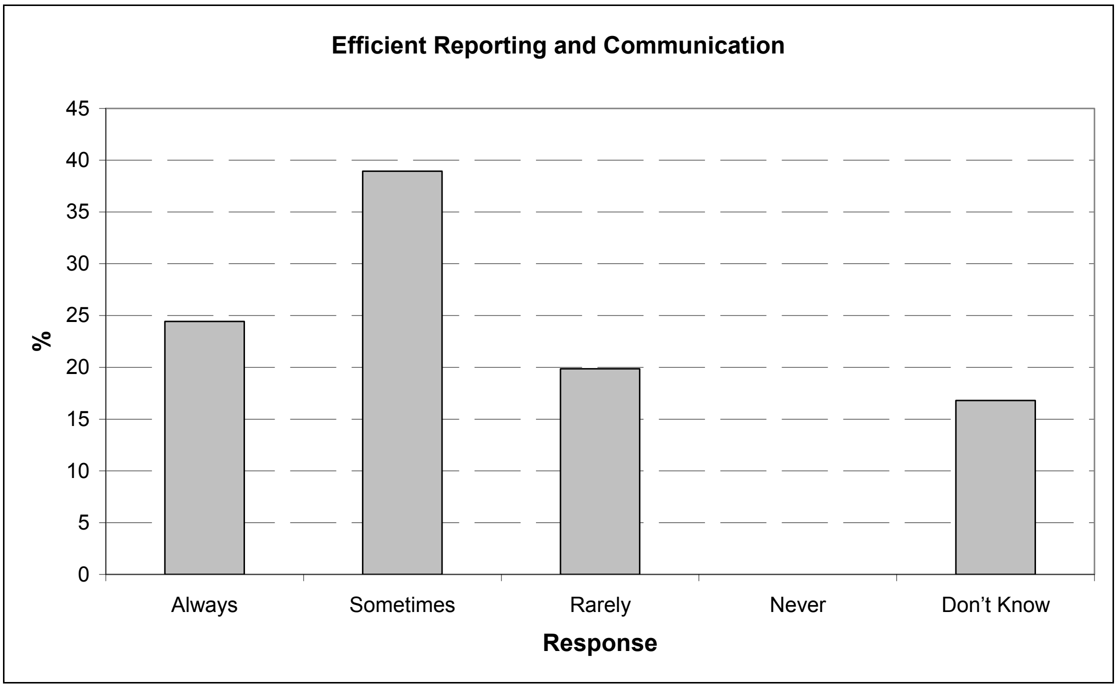


Figure 7-17: Process of reporting and communicating, based on Table 7-13.

More than 64% (Figure 7-17 above) agreed that communication and reporting processes are efficient. However, there are no regular reports and the communicated information is poor. Perhaps, communication is a very important business aspect. Some reports for instance, help make critical decisions especially when 'red spots' appear on the kiln. Figure 7-17 reveals that almost 20% of respondents do not have a clear view about that status of communication and reporting processes within their factories.

Q14: Are the control devices and equipment inspected regularly and to schedule?

Table 7-14: Control devices and equipment inspected.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	18	9	5	1	7
SCF	11	7	5	1	3
ZCF	11	9	6	1	7
LCF	9	8	7	2	3
All	**49**	**33**	**23**	**5**	**20**

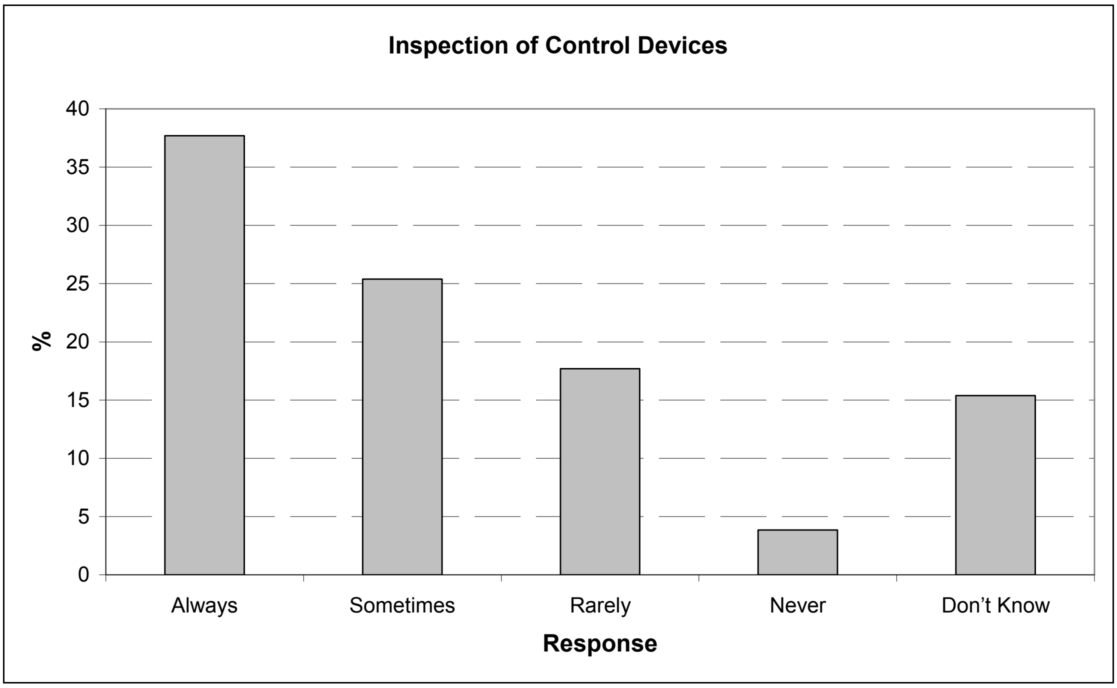


Figure 7-18: Control devices and equipment inspected, based on Table 7-14.

From Figure 7-18 above, it is clear that the majority of respondents are of the view that control devices are inspected on a regular basis. More than 37% state that this inspection happens more frequently. About 16% of respondents, on the other hand, do not know if inspection is performed or not. Another group of respondents, 20%, believe that an inspection never or rarely happens.

Q15: Are spare kiln bricks readily available?

Table 7-15: Spare Kiln Bricks available.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	16	9	4	3	8
SCf	11	8	4	1	3
ZCF	13	10	3	0	8
LCF	10	8	6	0	5
All	**50**	**35**	**17**	**4**	**24**

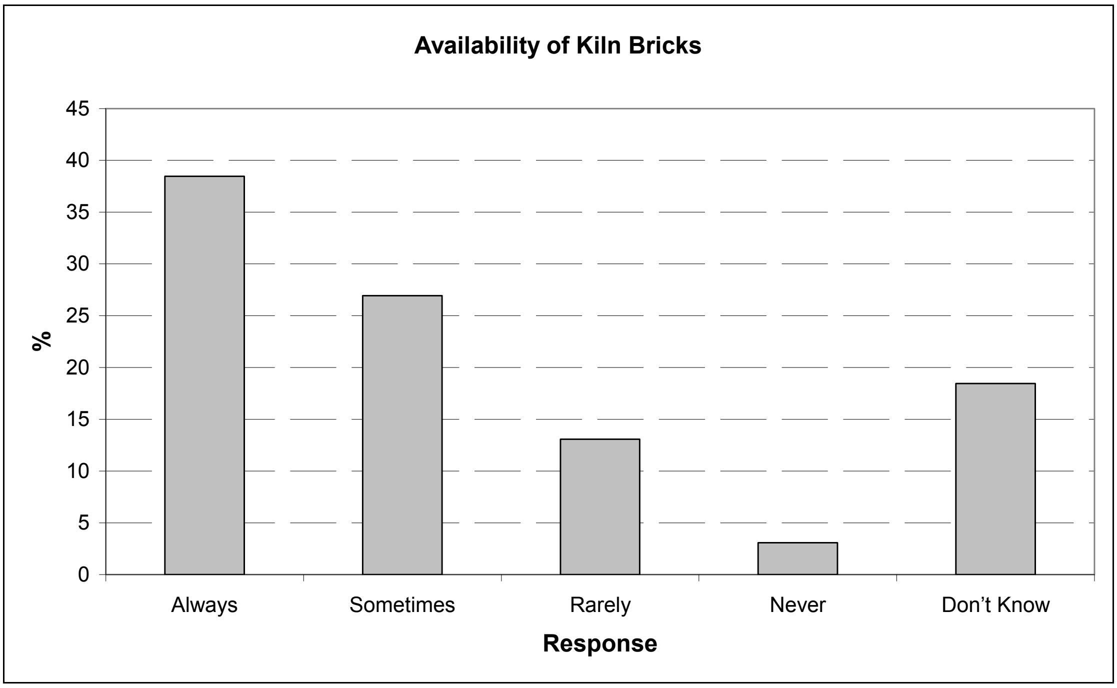


Figure 7-19: Availability of Spare Kiln Bricks, based on Table 7-15.

More than 65% of surveyed staff stated that Kiln Bricks were available always and/or sometimes (see Figure 7-19). Kiln bricks are not manufactured in Libya which means that this building material may become unavailable locally. The other risk facing Libyan factories is the potential delay in receiving the necessary numbers.

On the other hand, Libyan cement factories consume large amounts of bricks each year. This is mainly because the raw materials that come from the local quarry are not pure and have many unneeded elements.

Q 16: Do the brick ovens meet thermal specifications to produce good quality?

Table 7-16: Brick ovens meet thermal specifications.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	17	8	4	1	10
SCF	10	8	3	1	5
ZCF	13	9	3	1	8
LCF	11	7	6	0	6
All	**51**	**32**	**16**	**3**	**29**

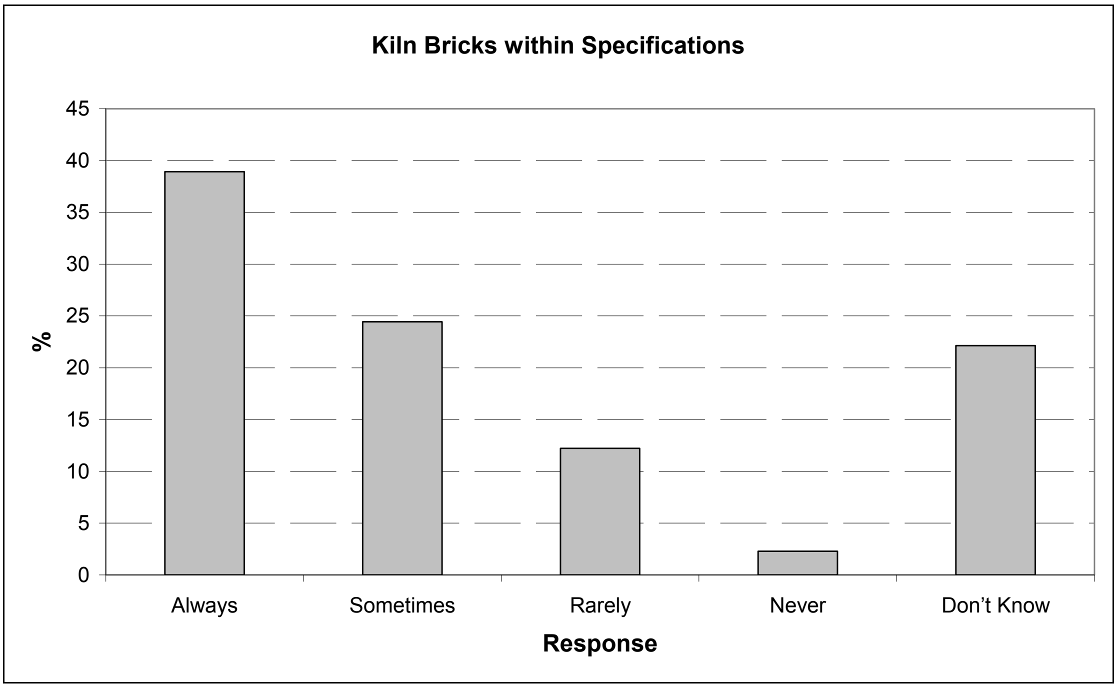


Figure 7-20: Brick ovens meeting thermal specifications, based on Table 7-16.

Figure 7-20 shows that more than half of the participants (63%) believe that Kiln bricks meet thermal specifications to product quality. Disintegration of bricks in the kiln, therefore, may be caused by the quality of raw materials or the design (i.e. dimension or speed) of the Kiln. This point will be further elaborated upon in the following chapter.

Q17: Is equipment and machinery cleaned regularly?

Table 7-17: Equipment and machinery cleaned.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	4	16	11	2	7
SCF	3	11	7	2	5
ZCF	5	13	9	4	3
LCF	6	11	7	0	5
All	**18**	**51**	**34**	**8**	**20**

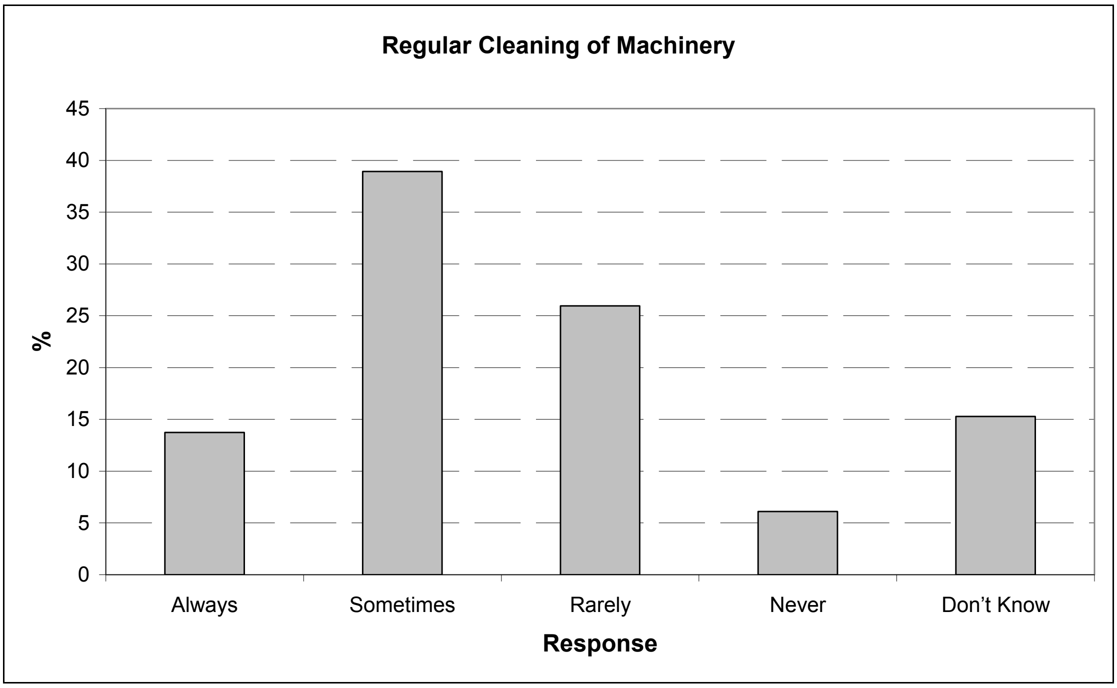


Figure 7-21: Equipment and machinery cleaned, based on Table 7-17.

According to the majority of technicians (more than 60%, see Figure 7-21 above) the cleaning of machines and other production equipment occurs sometimes or rarely. Less than 15% of engineers believed that the cleaning process happens on a regular basis. These Figures are in no contradiction to the reality. Indeed, the author's field visit in September 2007 discovered significant amounts of dust on manufacturing equipment in many places.

As discussed earlier (Chapter 3), an important pillar of TPM is a regular check and maintenance, including daily cleaning of all machinery.

Q18: Are cleaning materials and tools available?

Table 7-18: Cleaning materials and tools available.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	8	10	15	2	5
SCF	3	7	12	2	3
ZCF	6	10	11	4	3
LCF	6	11	8	2	2
All	**23**	**38**	**46**	**10**	**13**

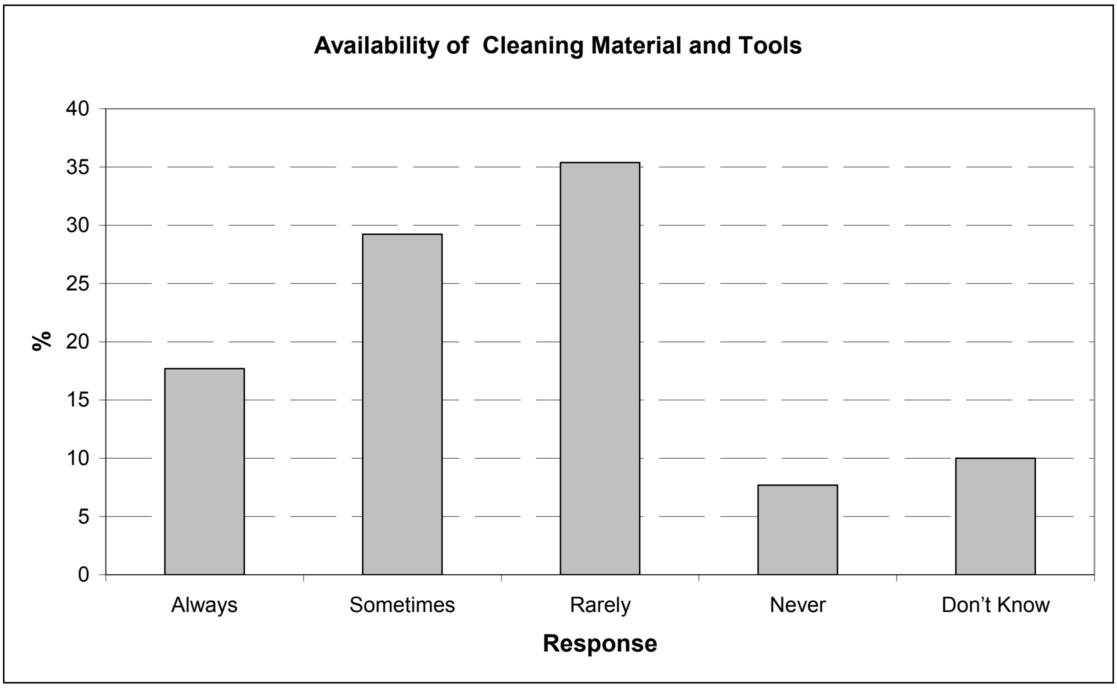


Figure 7-22: Cleaning materials and tools available, based on Table 7-18.

As Figure 7-22 above shows that less than the 20% of surveyed engineers believed that there was continuous availability of cleaning products. Thus, according to the majority of respondents, cleaning materials were not always available. This could well be the reason why in all factories the cleaning of manufacturing equipment did not occur daily.

The author mentioned in (Chapter 3) that according to Mckone (1999) autonomous maintenance can help to develop shared responsibility for daily maintenance tasks. This encourages a company to start of implementation TPM and make intensive training.

Q19: Is there a high level of dust in the factory?

Table 7-19: High level of dust.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	12	12	8	1	7
SCF	8	9	4	3	3
ZCF	11	11	7	0	5
LCF	2	9	9	1	8
All	**33**	**41**	**28**	**5**	**23**

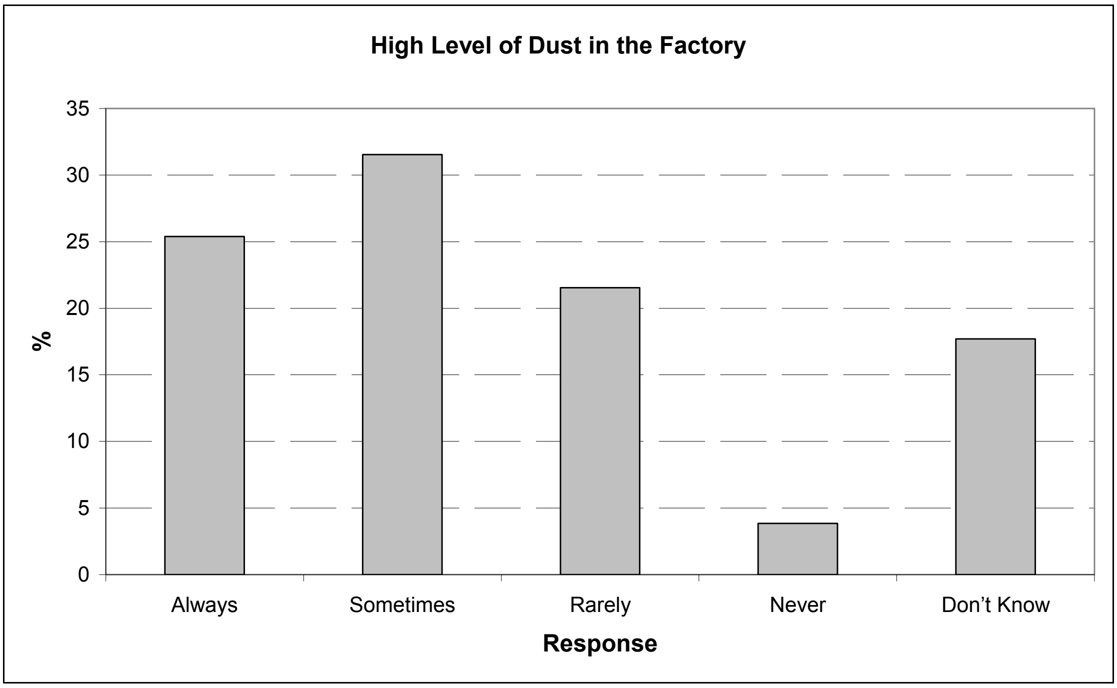


Figure 7-23: High level of dust, based on Table 7-19.

From Figure 7-23 it is clear that more than 50% of staff believes that there is a high level of dust in the factory. However, up to 17% of engineers do not have any knowledge in this regard. This proves the initial concept which is discussed earlier of trying to be 'politically correct' and avoiding criticism of the senior management. This could be due to the lack of maintenance of dust filters inside the factory. Another explanation is the absence of modern sophisticated machinery to clean up the dust. A third reason is the shortage in the number of cleaners. Indeed, most of these factories do not employ a sufficient number of cleaners. Nonetheless, improving equipment efficiency requires the development of an effective preventive maintenance programme that keeps the equipment at a high level of overall effectiveness (Ben-Daya, 2000) ;(Mitchell et al, 2002).

Q 20: Is there a program for the inspection of machinery and equipment?

Table 7-20: Program for inspection.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	6	10	15	2	7
SCF	4	8	10	1	4
ZCF	6	8	10	2	8
LCF	6	8	9	0	6
All	**22**	**34**	**44**	**5**	**25**

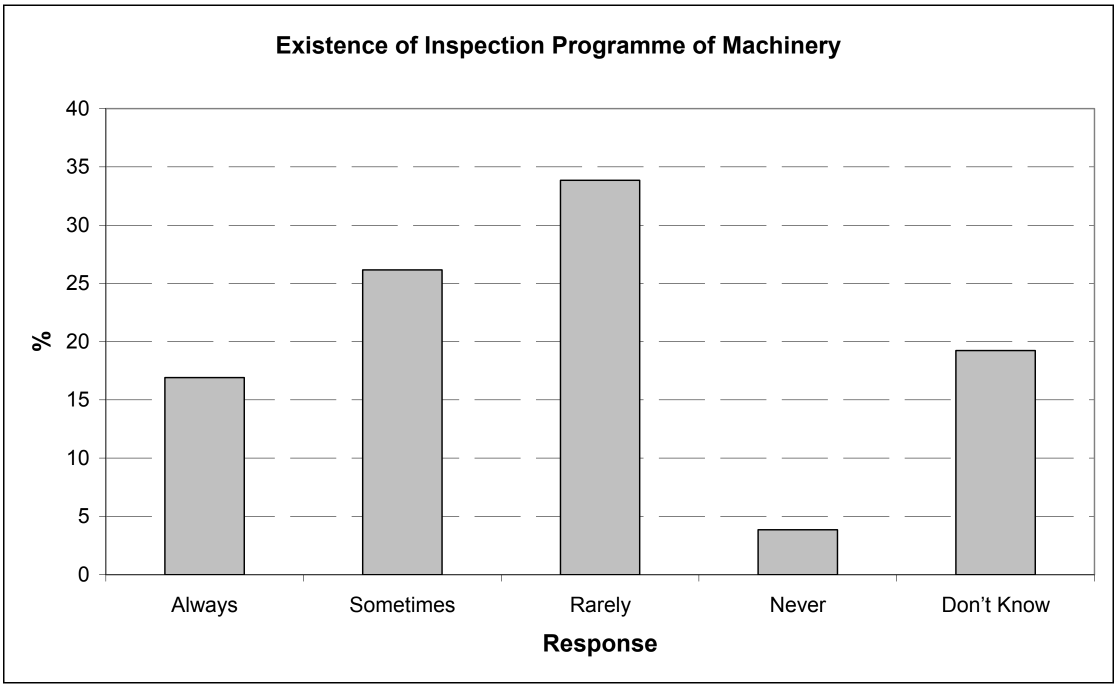


Figure 7-24: Program for inspection, based on Table 7-20.

Figure 7-24 shows nearly 40% of staff stating that their factory does not have any programme in place for inspection of equipment. Hence, there is a significant weakness in the maintenance strategy within these factories.

The author mentioned in chapter 3 that the second pillar of TPM "autonomous maintenance by operators" involves the equipment operators performing some of the routine maintenance tasks. These tasks include inspecting, monitoring, measurement and lubrication.

Q 21: Is there a process in place to inspect equipment and machinery regularly based on the inspection programme?

Table 7-21: Process in place to inspect equipment and machinery.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	16	11	8	2	3
SCF	11	7	5	1	3
ZCF	14	9	6	1	4
LCF	11	7	6	0	6
All	**52**	**34**	**25**	**4**	**16**

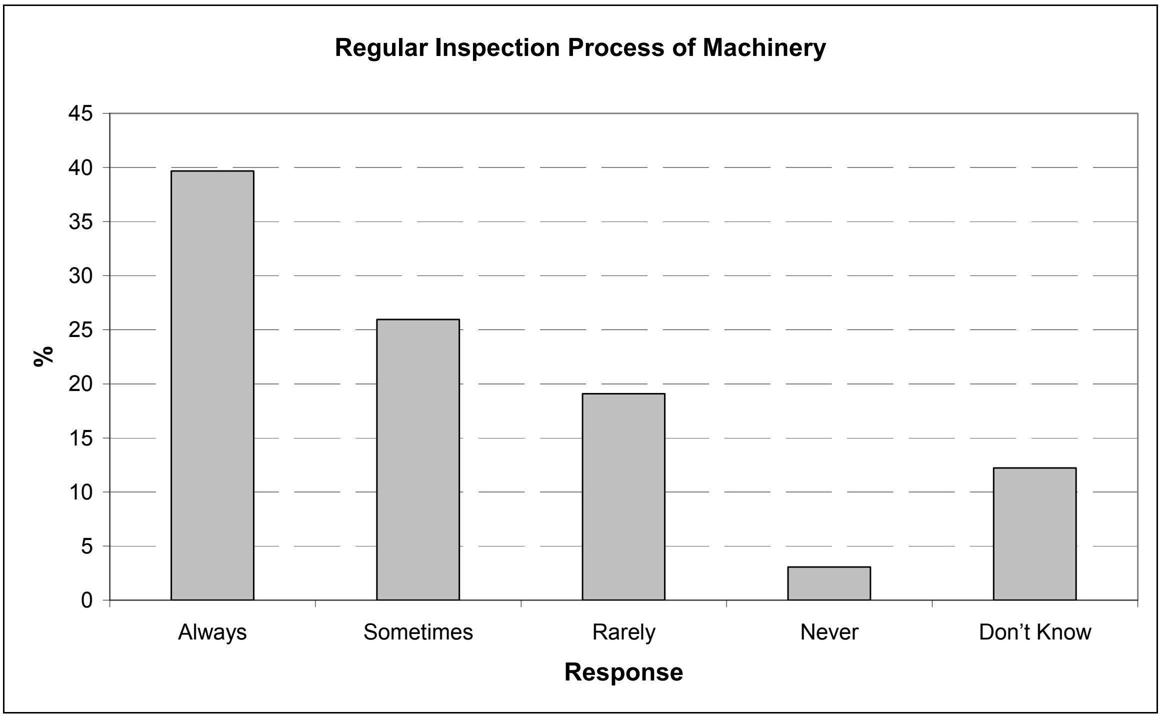


Figure 7-25: Process in place to inspect equipment and machinery, based on Table 7-21.

Inspection is undoubtedly one of the most important factors of a highly successful TPM. Up to 25% of engineers believe that the level of regular inspection of machinery is not sufficient. About 40% of staff, on the other hand, believe that the inspection process is always satisfactory and adequate. As discussed in the literature review (see Chapter 2) the third pillar of TPM is "Planned Maintenance. Planned maintenance according to Cooke (2000) is responsible for supporting autonomous maintenance to improve OEE.

Furthermore, planned maintenance includes inspection of equipment and machinery.

Q 22: Do you have a preventive maintenance programme?

Table 7-22: Preventive maintenance programme.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	2	7	14	11	6
SCF	2	3	11	8	3
ZCF	1	6	13	10	4
LCF	1	5	10	8	5
All	**6**	**21**	**48**	**37**	**18**

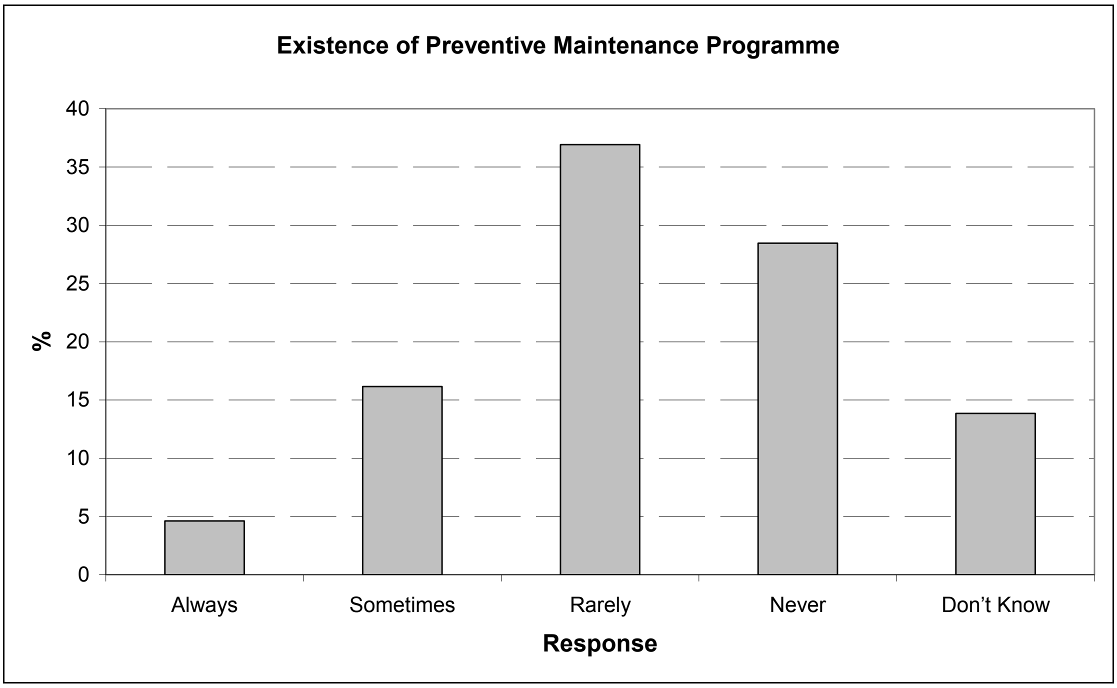


Figure 7-26: Preventive maintenance programme, based on Table 7-22.

Although preventive maintenance is a relatively old and well known system, more than 65% of the technical staff states that their respective factories do not have a preventive maintenance programme. This is arguably one of the reasons for the considerable decline in production. It can be argued that the main reason for the lack of preventive maintenance programmes within these factories lies in the absence of cultural awareness, knowledge, communication and training in the Libyan society. As the author documented earlier (Chapter 2), the primary goal of preventive maintenance is to prevent the failure of equipment before it actually occurs.

Q23: Is the number of skilled staff to conduct the maintenance sufficient in every shift?

Table 7-23: Availability of skills in the technical staff responsible for maintenance activities.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	2	16	12	3	7
SCF	0	11	8	3	5
ZCF	5	14	6	3	6
LCF	6	11	8	2	2
All	**13**	**52**	**34**	**11**	**20**

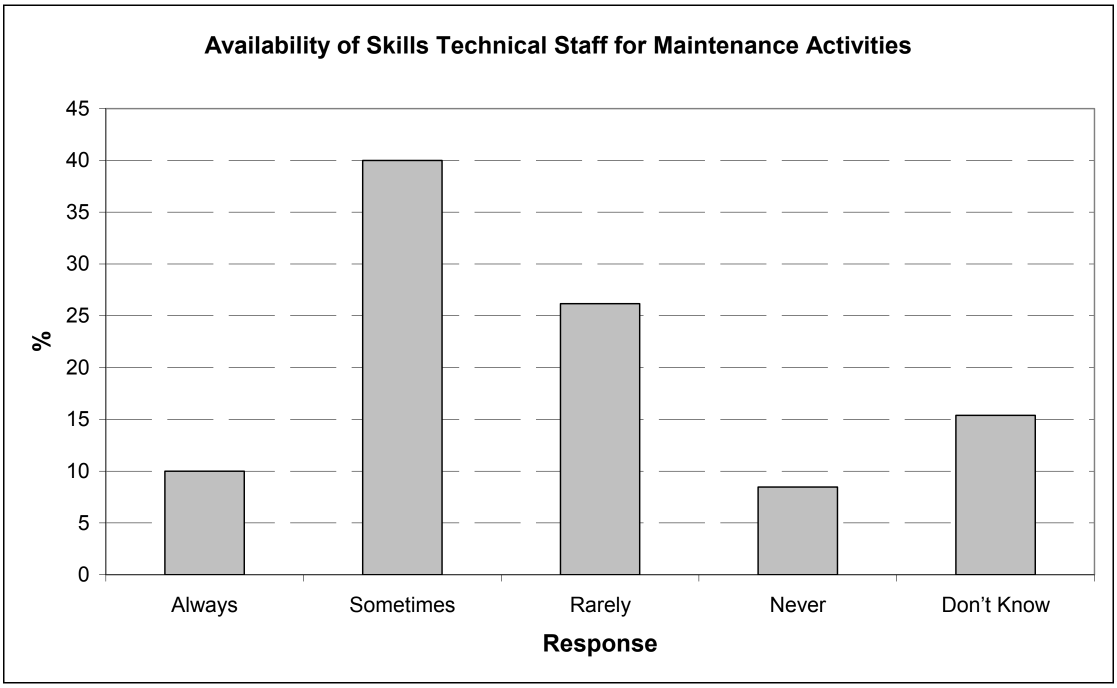


Figure 7-27: Availability of skills in the technical staff responsible for maintenance activities, based on Table 7-23.

Figure 7-27 reveals that only 10% of engineers believe that the factory always has a durable access to technical stuff responsible for maintenance. Up to 30% of respondents however, think it is the opposite, i.e. the factory does not always utilise skilled technical stuff.

This could be related to operating long shifts, and during weekends. This has been investigated further during the interviews.

Q 24: Is there a system for recording maintenance data or information?

Table 7-24: System recording maintenance data.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	1	15	12	4	8
SCF	0	12	9	2	4
ZCF	3	12	9	3	7
LCF	4	10	8	1	6
All	**8**	**49**	**38**	**15**	**20**

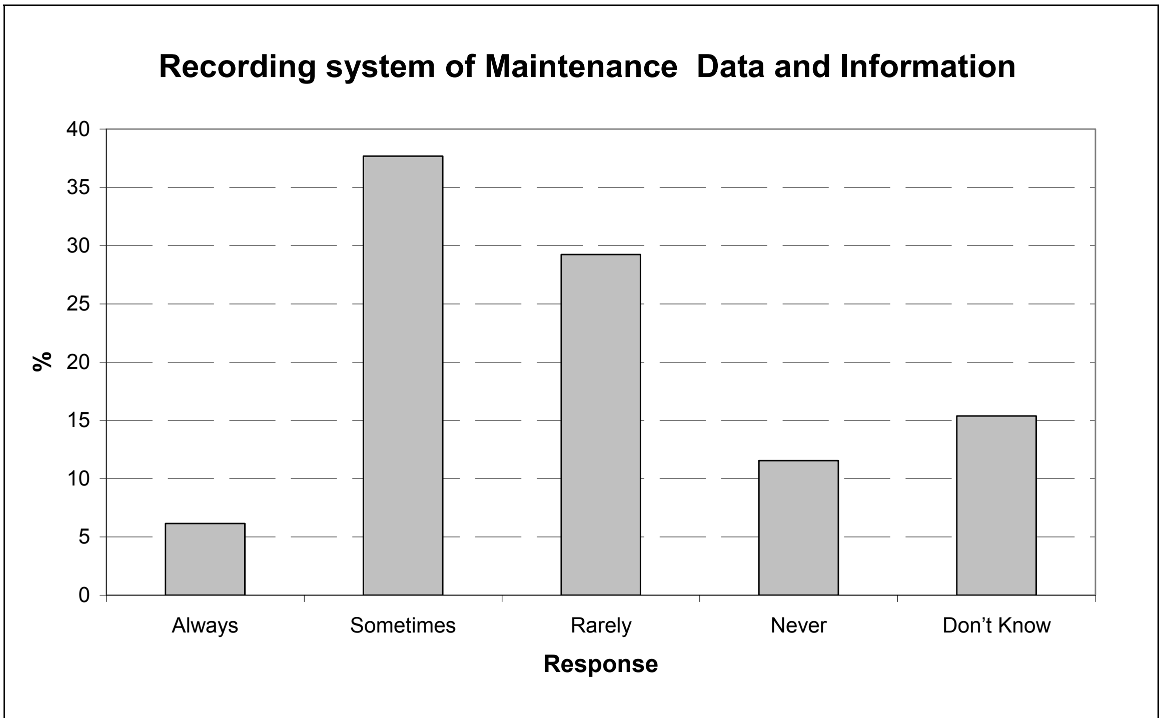


Figure 7-28: System recording maintenance data, based on Table 7-24.

From Figure 7-28 it is clear that the cement factories under investigation lack a maintenance data recording system (archive is not available). Without a recording system of maintenance activities, the factories may not be able to have a better R&M strategy in the future. The absence of recording R&M activities within these factories may be due to the lack of knowledge and information, and also to an adequate training policy of employed stuff. There is lack of a maintenance data recording system in spite of the fact that the four factories have a large number of computers.

Q25: Do you have some ideas for improving productivity or reliability of some of the machines or equipment in the factory?

Table 7-25: Ideas for improving productivity.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	7	15	9	3	6
SCF	3	11	8	2	3
ZCF	7	11	9	3	4
LCF	4	10	8	1	6
All	**21**	**47**	**34**	**9**	**19**

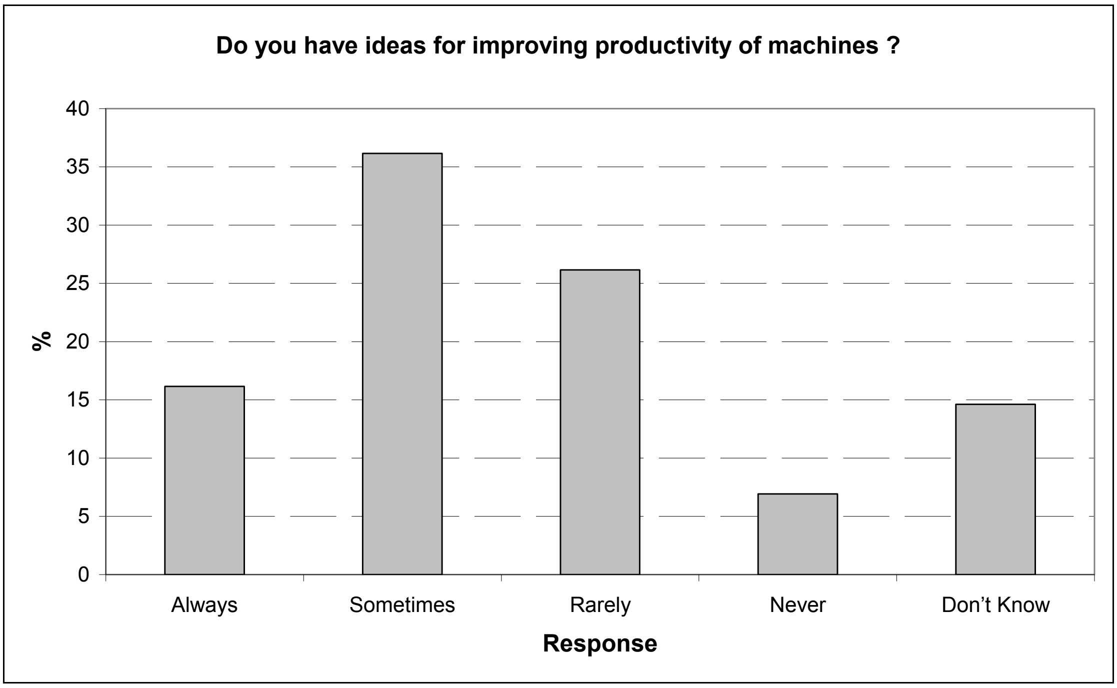


Figure 7-29: Ideas for improving productivity, based on Table 7-25.

Figure 7-29 above shows that almost half of the surveyed staff knows how to improve the productivity of cement production. This indicates that even shop floor workers are willing to develop the performance of their respective factory. More than 30% of engineers, on the other hand, state that they have a lack of knowledge with regards to improving productivity. As documented earlier (Chapter 2) autonomous maintenance “brings production and maintenance people together to stabilise conditions and halt equipment deterioration”. Some top management in NCC, as discussed in chapter 8,did not recall any workers state that they had some ideas about how to improve or solve problems.

Consequently, to increase productivity, all employees must go through intensive training and continue to develop regularly.

Q26: Is plant's non-productive time due to technical malfunctions?

Table 7-26: Plant non-productive time is due.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	12	14	8	3	3
SCF	9	11	3	1	3
ZCF	8	10	6	3	7
LCF	7	9	6	1	6
All	**36**	**44**	**23**	**8**	**19**

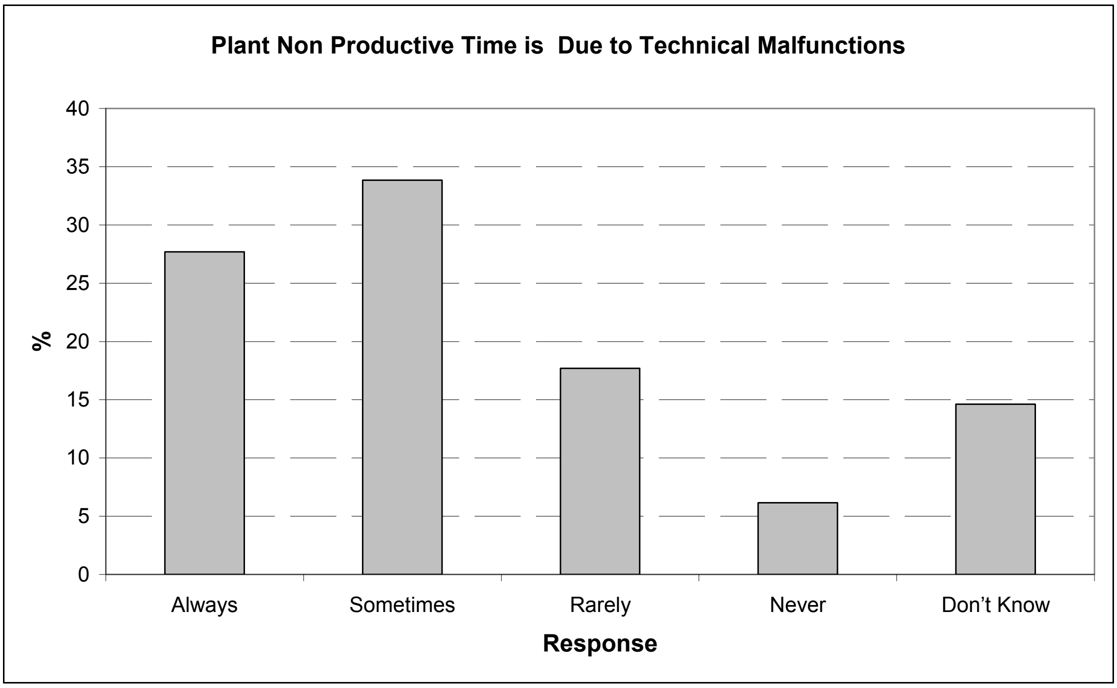


Figure 7-30: Plant's non-productive time due to technical faults , based on Table 7-26.

About 60% of staff state that non-productive time in the factory is due to technical faults and breakdowns. One of the conclusions that can be drawn here is that the managerial staff of these factories does not seem to understand the importance of maintenance programmes. Without planning maintenance programmes, the continuous running of operations and the continued existence of these cement factories (and all businesses in general) is maybe at risk. As discussed in the literature review (Chapter 2) the third element of TPM is to develop a planned maintenance system to repair or modify equipment in order to improve maintainability.

Q27: Do you want to move to another job role?

Table 7-27: Move to another job role.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	4	15	13	2	6
SCF	2	11	8	2	4
ZCF	4	12	10	2	6
LCF	2	10	8	1	8
All	**12**	**48**	**39**	**7**	**24**

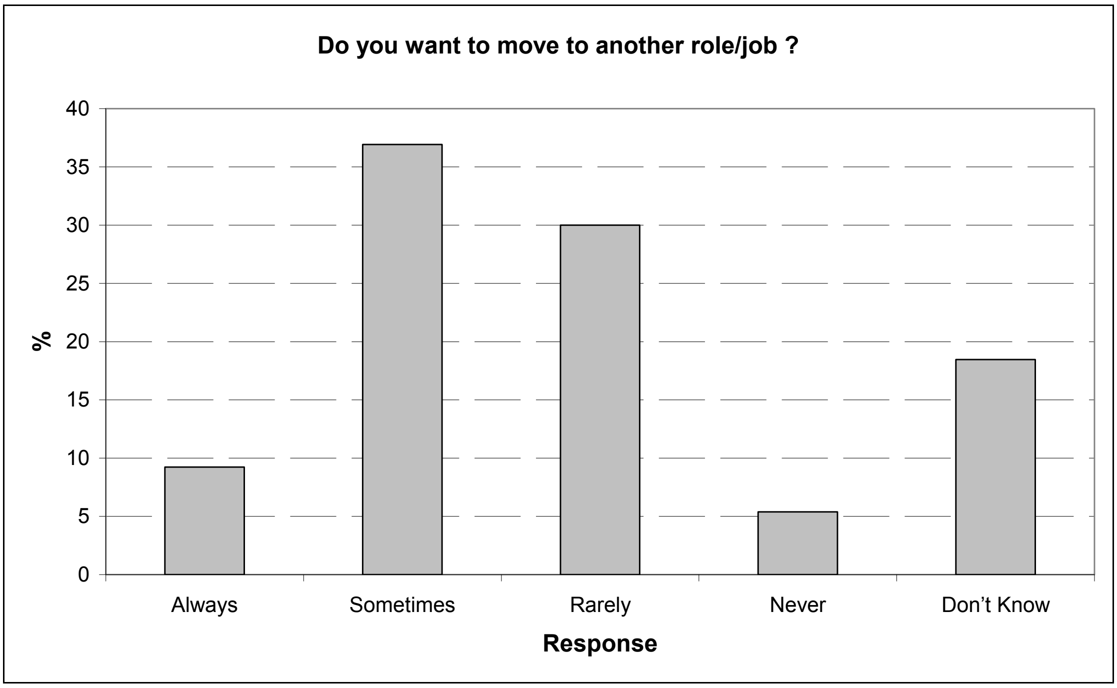


Figure 7-31: Move to another job role, based on Table 7-27.

Figure 7-31 shows that more than 40% of engineers would like to switch to another job role. This is negative news for the top management in the factories under investigation. It shows that the majority of hired engineers are not happy about their job situation. Many managers do not pay sufficient attention to the needs of their workers, and this could lead to a decline in commitment and the desire to excel at one's job on the part of the employees.

Q28: Are you well treated by senior management?

Table 7-28: Well treated by senior management.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	16	11	7	0	6
SCF	12	8	3	0	4
ZCF	14	12	4	0	4
LCF	10	8	5	0	6
All	**52**	**39**	**19**	**0**	**20**

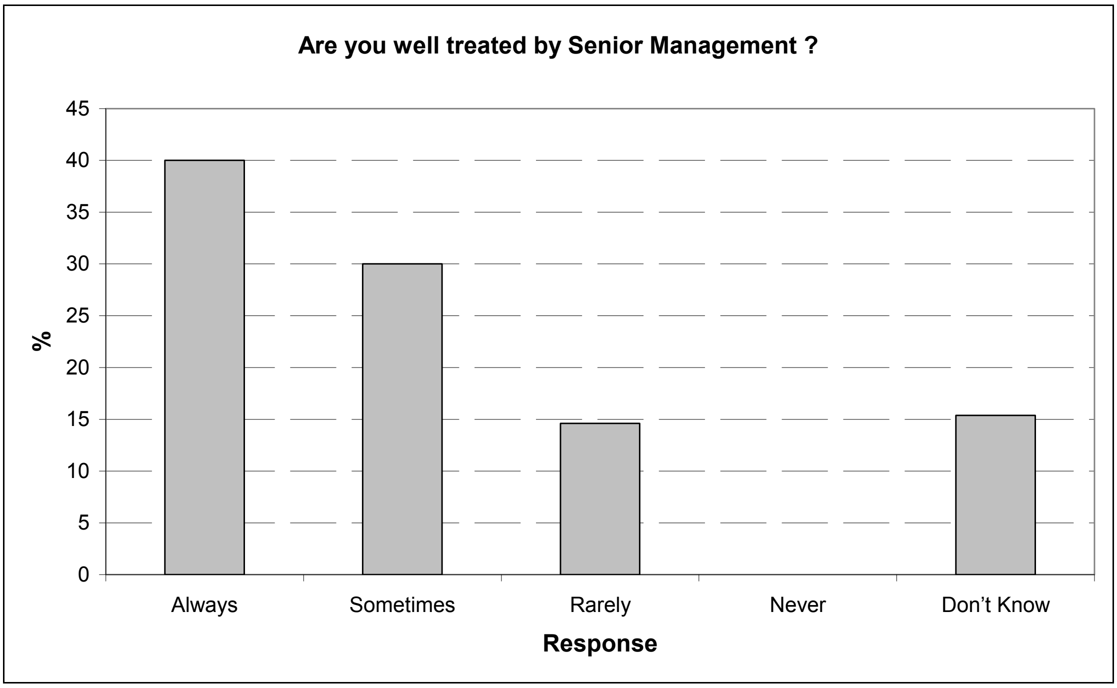


Figure 7-32: Well treated by senior management, based on Table 7-28.

Figure 7-32 shows that the majority of engineers (almost 70%) are satisfied about senior management's behaviour and attitudes towards them. However, a small group of respondents (about 15%, see graph) did not state their exact attitudes towards senior management. This could be due to the lack of the culture of criticism and feedback.

Q29: Are there recreational programme/trips organised by the factory?

Table 7-29: Recreational programme /trips.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	0	4	12	16	8
SCF	0	4	8	10	5
ZCF	0	2	10	18	4
LCF	0	1	8	12	8
All	**0**	**11**	**38**	**56**	**25**

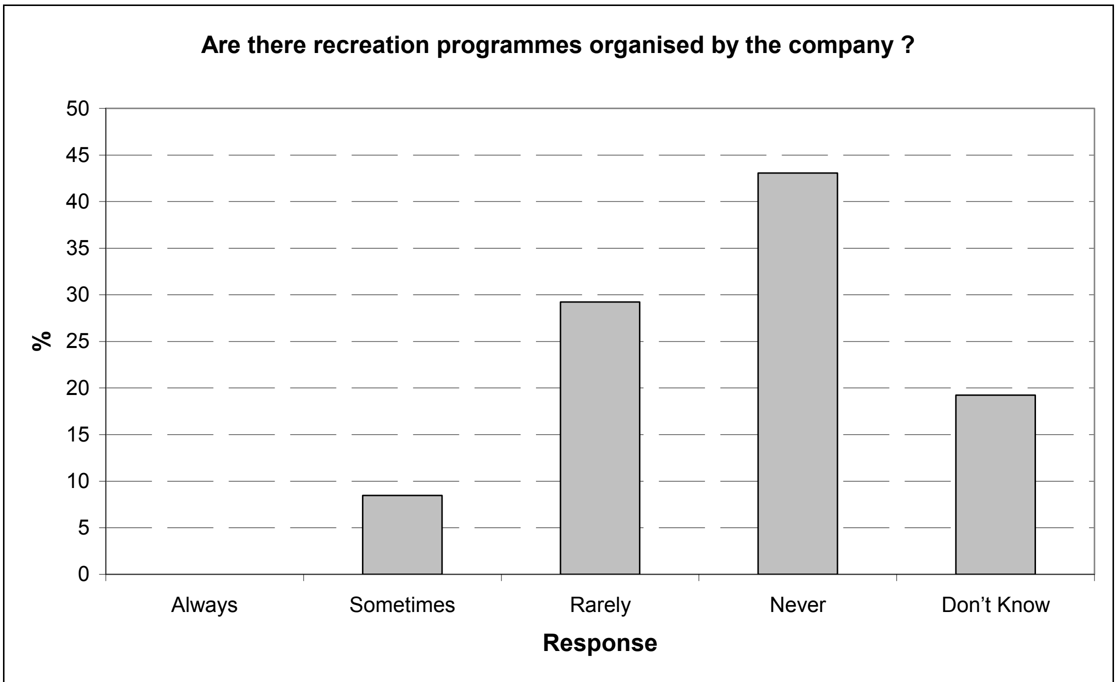


Figure 7-33: Recreational programme /trips, based on Table 7-29.

Figure 7-33 shows that more than 70% of engineers stated that hardly any recreational programmes are organised by their respective companies. Hence, there are hardly any sports, trips, lectures, contests (competitions), and other recreations within the factories, and this, could lead to a considerable drop in work productivity, and could also lead to a lesser degree of team work amongst factory staff.

Q30: Have you received any certificate of appreciation during the period of your work?

Table 7-30: Received any certificate.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	1	11	16	4	8
SCF	1	8	11	2	5
ZCF	1	11	14	3	5
LCF	1	9	11	2	6
All	**4**	**39**	**52**	**11**	**24**

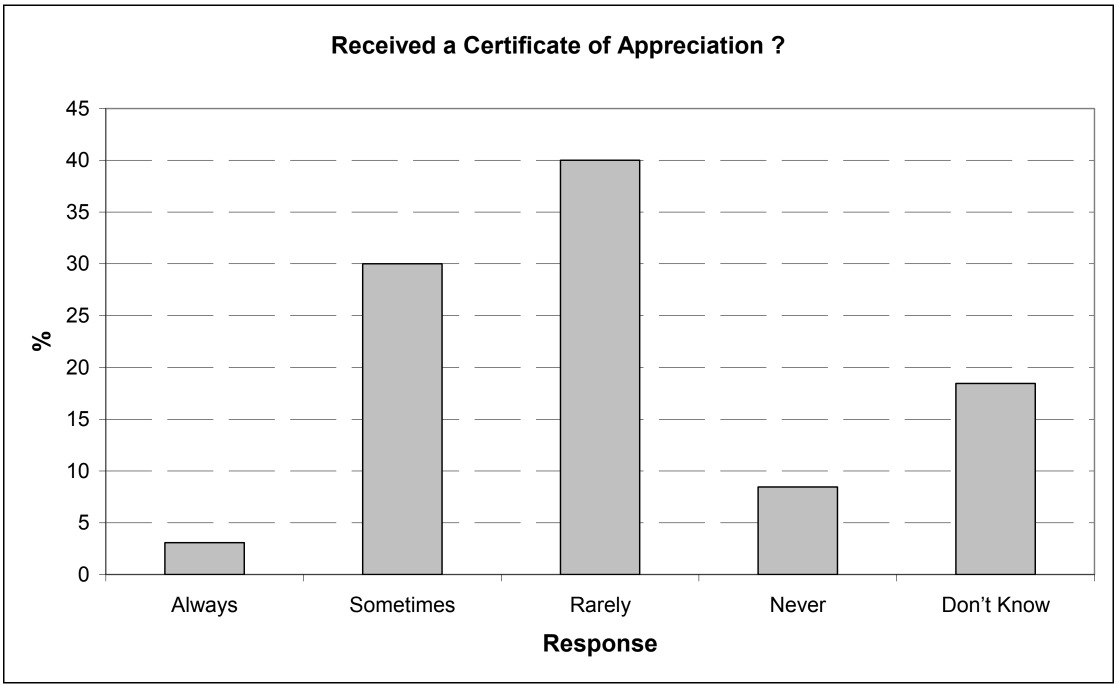


Figure 7-34: Received any certificate, based on Table 7-30.

From Figure 7-34 above it is clear that factory staff rarely receive a certificate of appreciation. Only a small proportion of engineers (about 15%) state that they do not know whether or not they have been awarded a certificate of appreciation, which is rather strange. The lack of appreciation towards staff in these factories is not surprising. Indeed, none of these factories has an incentive strategy that would motivate incumbent stuff to work harder. This aspect will be further discussed in later chapters.

Q31: Did you have any training courses in the past?

Table 7-31: Training courses.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	0	7	14	11	8
SCF	2	11	7	3	5
ZCF	2	8	11	9	4
LCF	2	12	7	3	5
All	**6**	**38**	**39**	**26**	**22**

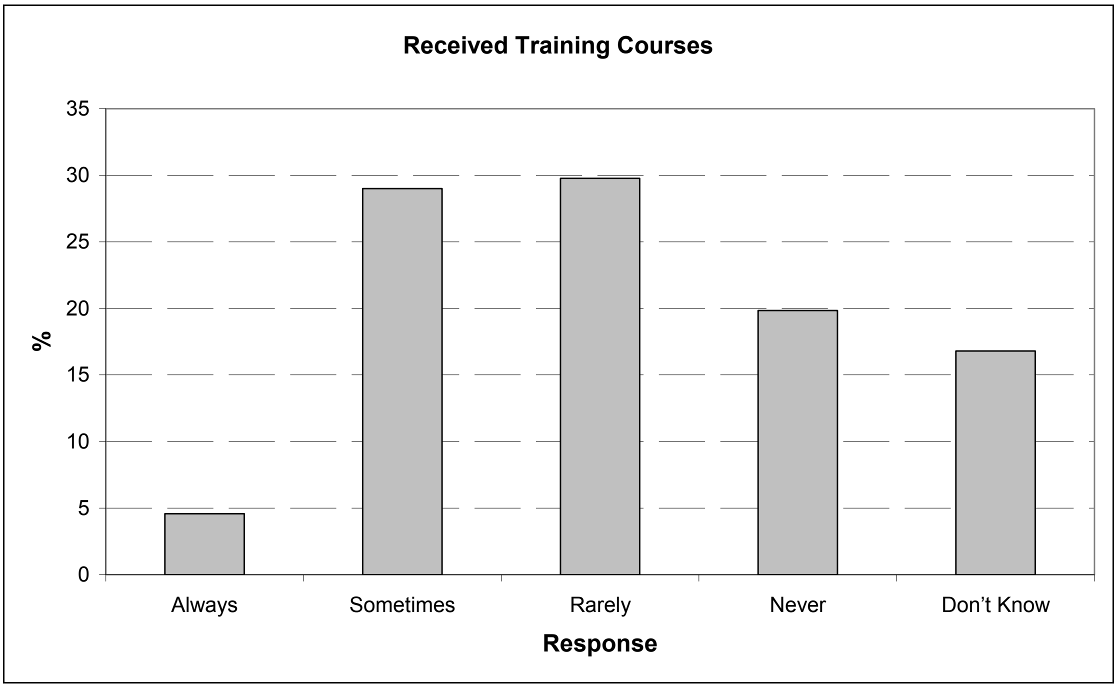


Figure 7-35: Training courses, based on Table 7-31.

About 65% of the staff rarely or never goes on training courses. This points out to a lack of personal development programmes within the factory. Obviously, this will lead to a decline in productivity, and also to a shortage of skills that are necessary to the company's future development plans.

Q32: Do you need training courses to fulfil your role?

Table 7-32: Need training courses.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	14	16	3	0	7
SCF	7	10	3	0	7
ZCF	12	13	2	0	7
LCF	7	11	5	1	5
All	**40**	**50**	**13**	**1**	**26**

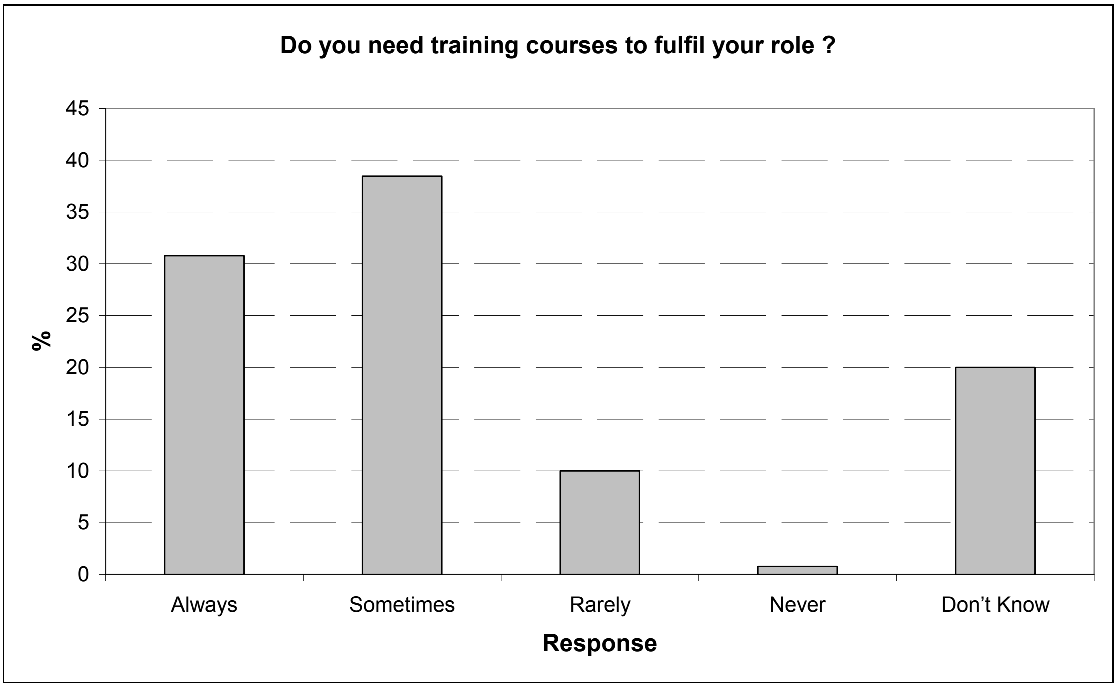


Figure 7-36: Need training courses, based on Table 7-32.

Only 1% of the staff does not need training courses to conduct their job duties. This is a very significant finding and must be taken into consideration during the development of the TPM strategy.

Q33: Do you have any knowledge of TPM strategies?

Table 7-33: Knowledge of TPM.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	2	3	16	14	5
SCF	1	1	10	9	6
ZCF	2	6	12	8	6
LCF	2	2	11	8	6
All	**7**	**12**	**49**	**39**	**23**

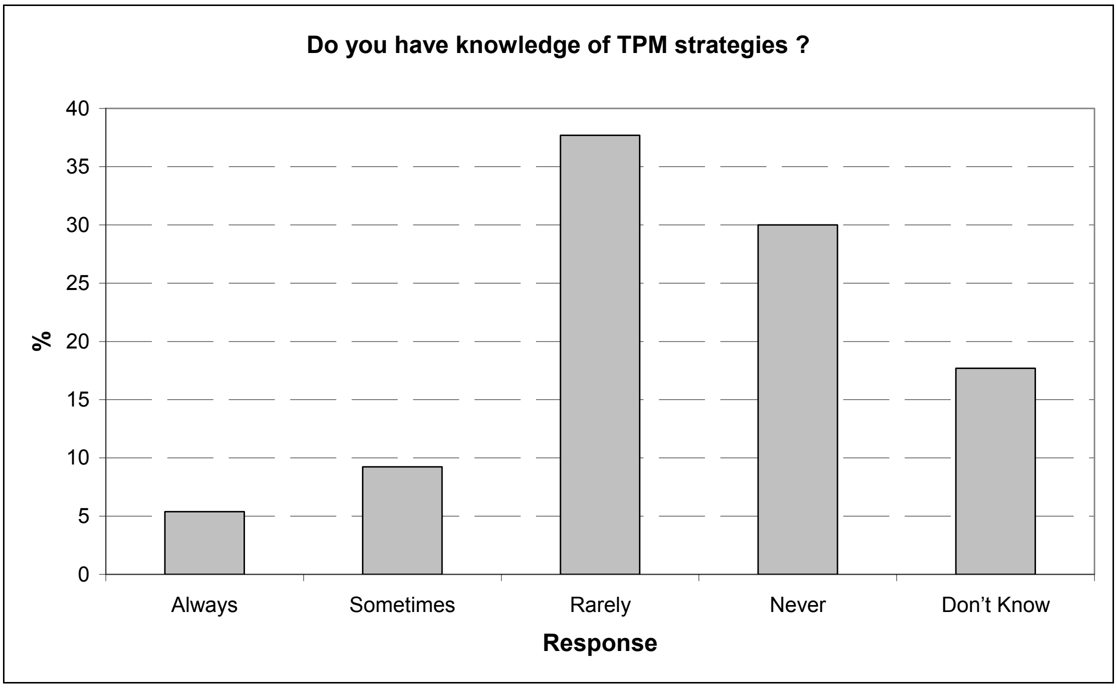


Figure 7-37: Knowledge of TPM strategies, based on Table 7-33.

Only about 14% of the staff is aware of TPM strategies. This is indicative of the lack of training courses for staff, and the lack of maintenance strategies within the factory.

Q 34: Does your salary include a performance related incentive?

Table 7-34: Salary includes a performance related incentive.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	1	4	17	15	3
SCF	1	3	10	8	5
ZCF	0	4	14	10	6
LCF	0	4	11	8	6
All	**2**	**15**	**52**	**41**	**20**

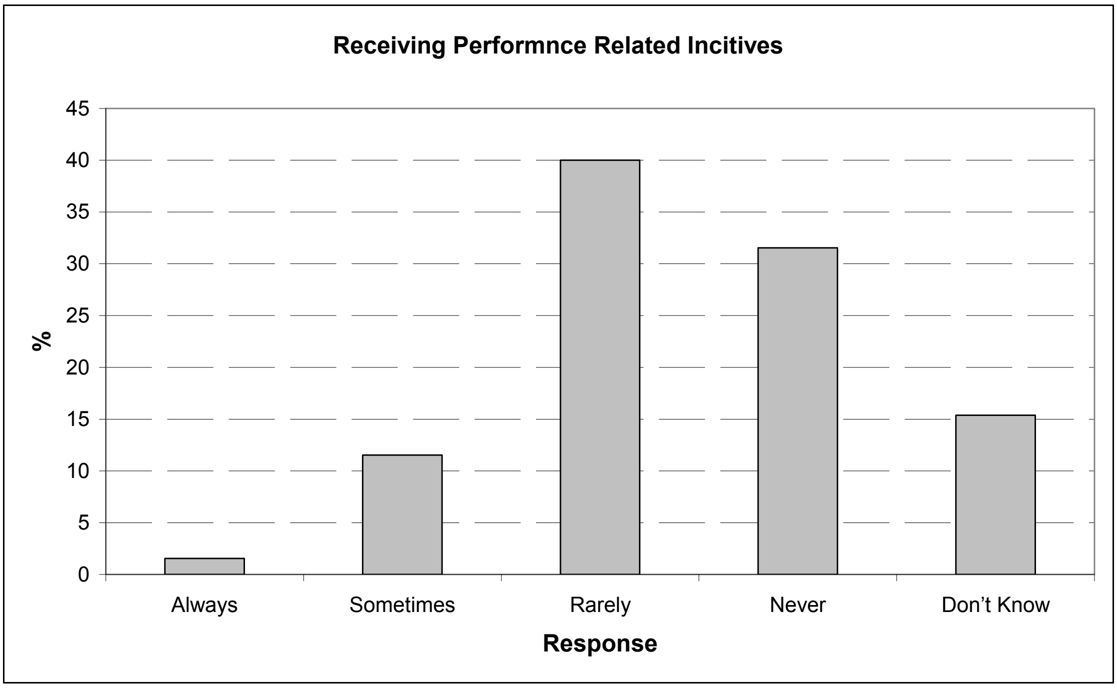


Figure 7-38: Salary includes a performance related incentive, based on Table 7-34.

We note here that the number of workers who receive a performance related incentive is very small, at just 1.53%. However, the vast majority of employees do not receive performance related incentives, and this could lead to lower motivation and disappointment at work. About 15% of workers do not know if they receive a performance related salary, which is indicative of a conservative and polite culture of not responding with a negative answer.

Q35: Do you undertake external work to meet your financial needs?

Table 7-35: Undertake external work.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	12	15	6	3	4
SCF	8	11	4	1	3
ZCF	8	12	7	3	4
LCF	8	10	5	1	5
All	**36**	**48**	**22**	**8**	**16**

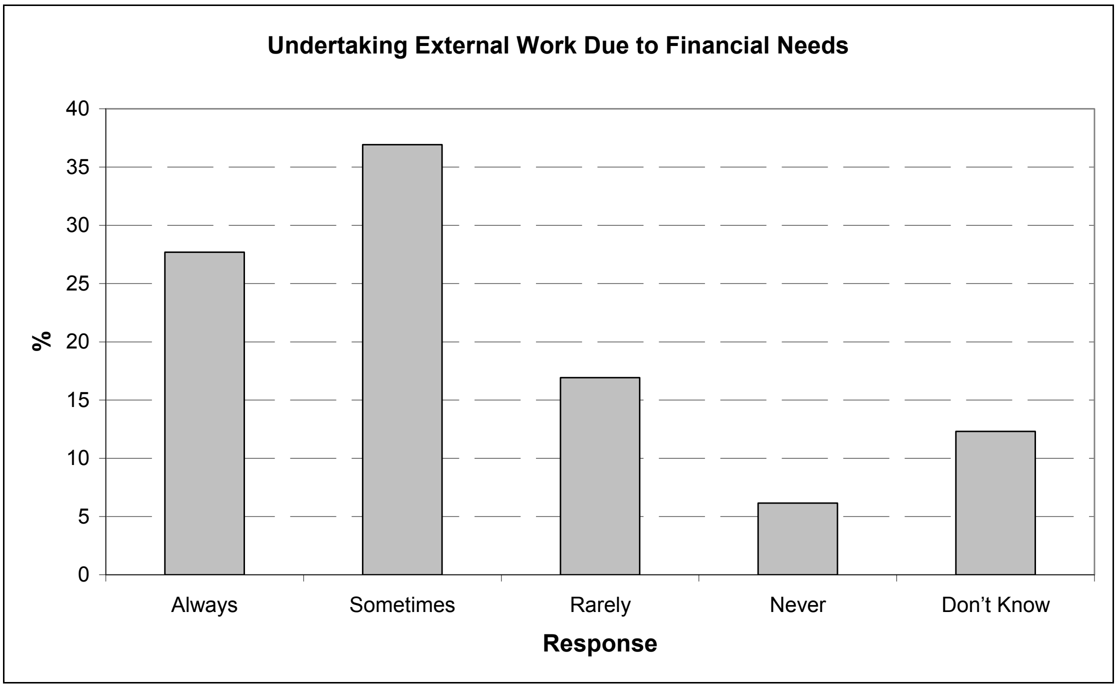


Figure 7-39: Undertake external work, based on Table 7-35.

Only 6% of staff does not undertake any other employment or work. This clearly indicates that the salary of the vast majority of employees is insufficient, which could in turn bring about lower motivation to work towards a better factory performance, particularly with the absence of financial incentives.

Q37: Do you have a program for calibration of monitoring devices?

Table 7-36: Program for calibration.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	1	12	18	5	4
SCF	2	11	7	3	5
ZCF	5	13	9	4	3
LCF	6	1	5	8	9
All	**14**	**37**	**39**	**20**	**21**

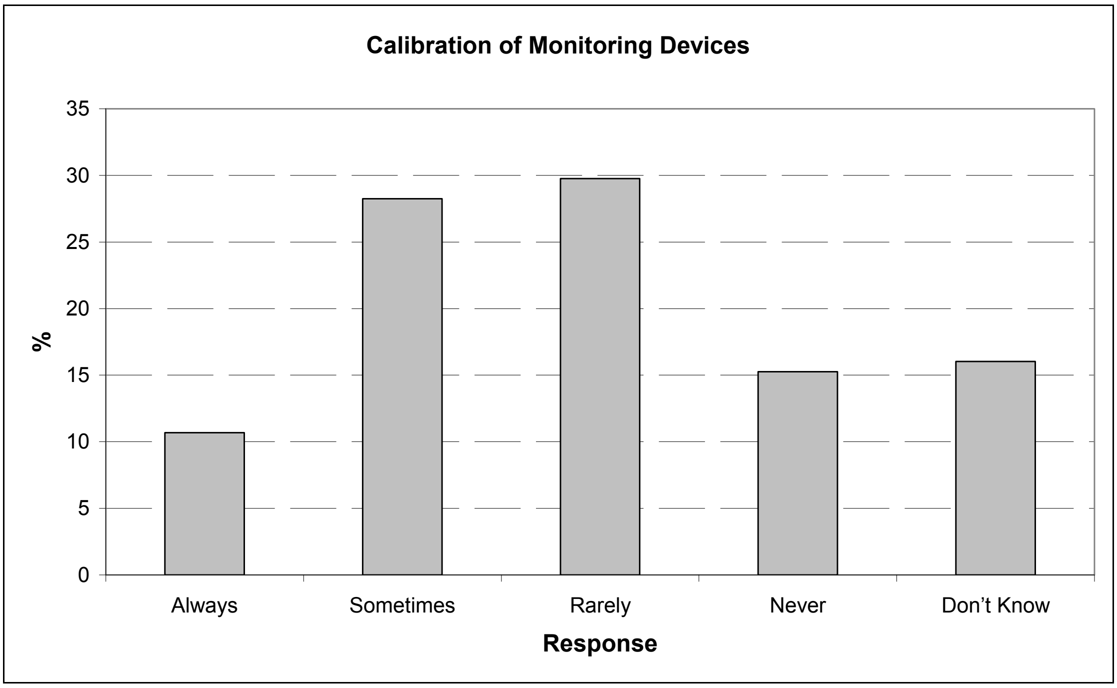


Figure 7-40: Program for calibration, based on Table 7-36.

Only 11% of staff believes that calibration of monitoring devices (e.g. temperature, pressures.) within the factory is performed on a continuous basis. The lack of calibration ultimately will affect the device measurements across the factory. Eventually, this could lead to errors in the diagnosis of warning indicators, which could have negative effects on productivity as well as health and safety.

Q38: Is there a policy for re-using or recycling of material such as iron, cardboard, wood and empty cement bags?

Table 7-37: Re-using or Recycling Materials.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	11	16	4	4	6
SCF	8	9	6	0	4
ZCF	8	12	6	4	4
LCF	8	9	6	6	5
All	**35**	**46**	**22**	**17**	**19**

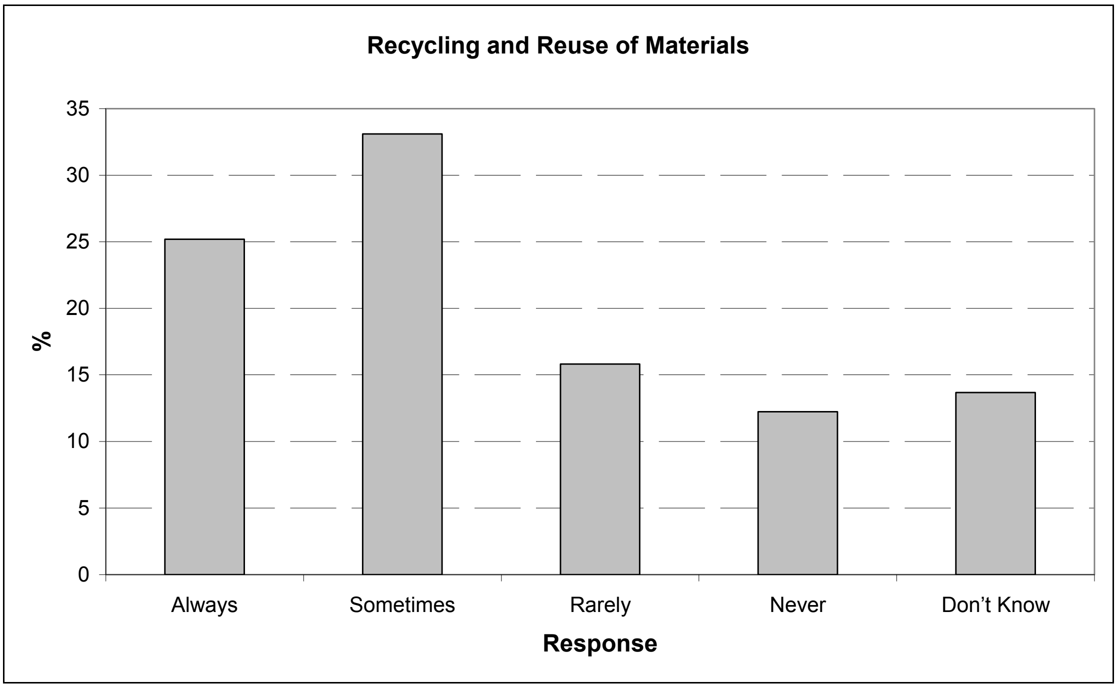


Figure 7-41: Re-using or Recycling Materials, based on Table 7-37.

There is a positive indication over the reuse and recycling of materials within the factory. The incentive to recycle, as the field visit in September 2007 revealed, does not have anything to do with the environment as one would naturally think. Rather, the recycling relates to a number of financial factors.

Q39: Is waste (e.g. Lubrication oil) used and disposed of in an environmentally appropriate manner?

Table 7-38: Waste used and disposed.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	13	15	5	2	5
SCF	7	11	4	1	4
ZCF	10	12	6	4	2
LCF	8	11	6	6	2
All	**38**	**49**	**21**	**13**	**13**

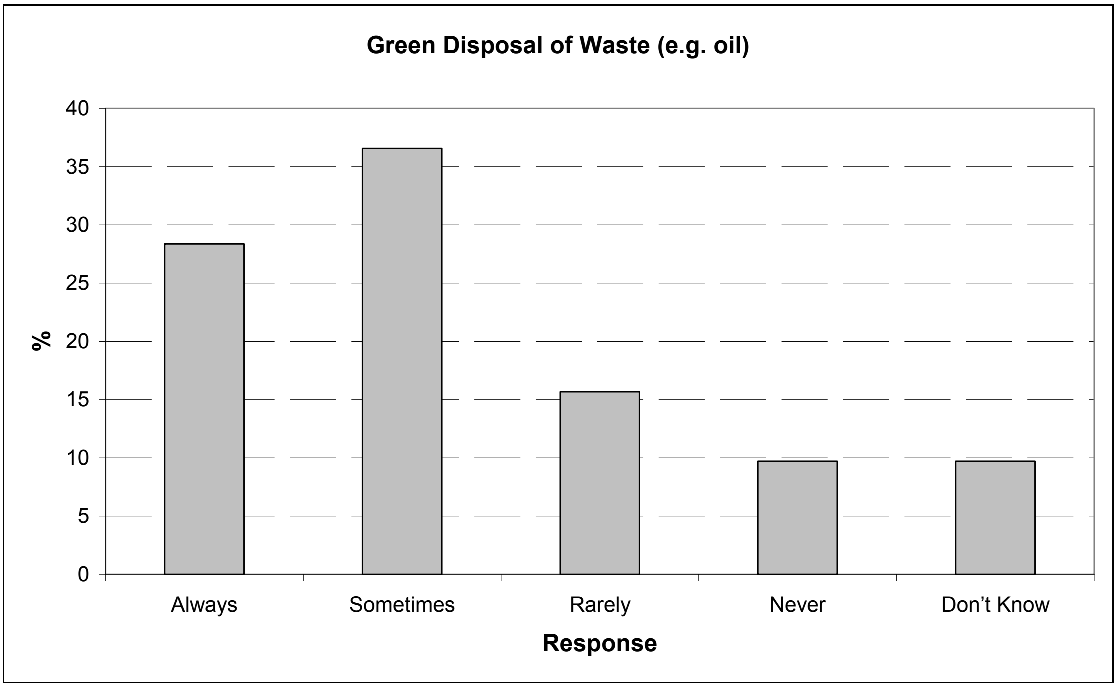


Figure 7-42: Waste used and disposed in environmental friendly way, based on Table 7-38.

According to 50% of the respondents, waste material is used and disposed of in an environmentally friendly manner (Figure 7-42 above). As the Sept 2007 visit revealed, however, this is not done to protect the environment but rather to achieve further financial benefits (e.g. selling the oil in the commercial market).

Q 40: Do you measure the waste gases and pollution level emerging from the chimney?

Table 7-39: Measure the waste gases and pollution.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	0	0	13	15	12
SCF	0	1	9	11	6
ZCF	0	0	12	13	9
LCF	0	0	11	12	6
All	**0**	**1**	**45**	**51**	**33**

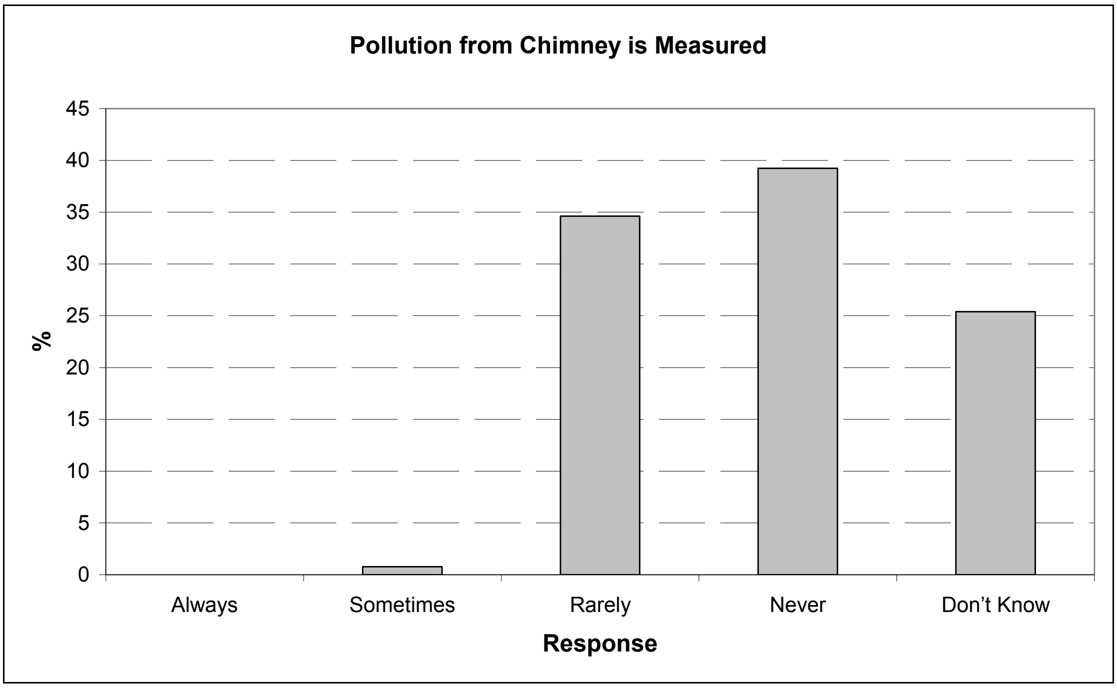


Figure 7-43: Measure the waste gases and pollution, based on Table 7-39.

The survey shows that there is no measurement and control over pollution levels emitted from chimneys. This could be one of the most significant findings of this research. The above survey results are in line with the field visits and satellite images which point to high levels of pollution in this geographical location.

Q41: Are gases and dust emitted from the chimney be treated to prevent environmental damage?

Table 7-40: Gases and dust prevent environmental.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	0	0	13	15	12
SCF	0	1	9	11	6
ZCF	0	0	10	15	9
LCF	0	1	12	13	3
All	**0**	**2**	**44**	**54**	**30**

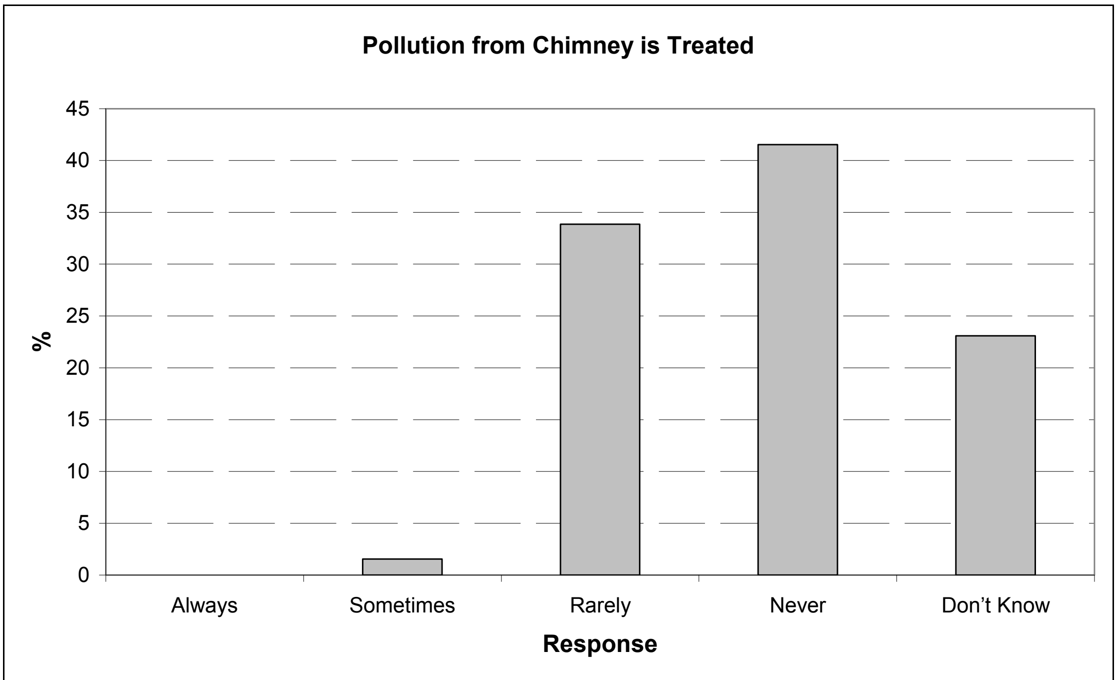


Figure 7-44: Gases and dust are treated to prevent environmental damage, based on Table 7-40.

The previous question was about whether or not waste gases and pollution levels emerging from the chimney were subject to measurement. As Figure 7-44 indicates, respondents are now asked about the treatment process of gases and dust emitted from the chimney.

As Figure 7-44 shows, the majority of engineers, up to 70%, believe that there are never any real repairs or maintenance of Filters. Moreover, pollution is not effectively treated before leaving the chimney which could put staff and people who live in the neighbourhood under high risk of health problems.

Q42: Do the filters operate to a high standard?

Table 7-41: Filters operate to a high standard.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	2	8	11	14	5
SCF	0	8	6	10	3
ZCF	1	10	9	11	3
LCF	0	9	6	11	3
All	**3**	**35**	**32**	**46**	**14**

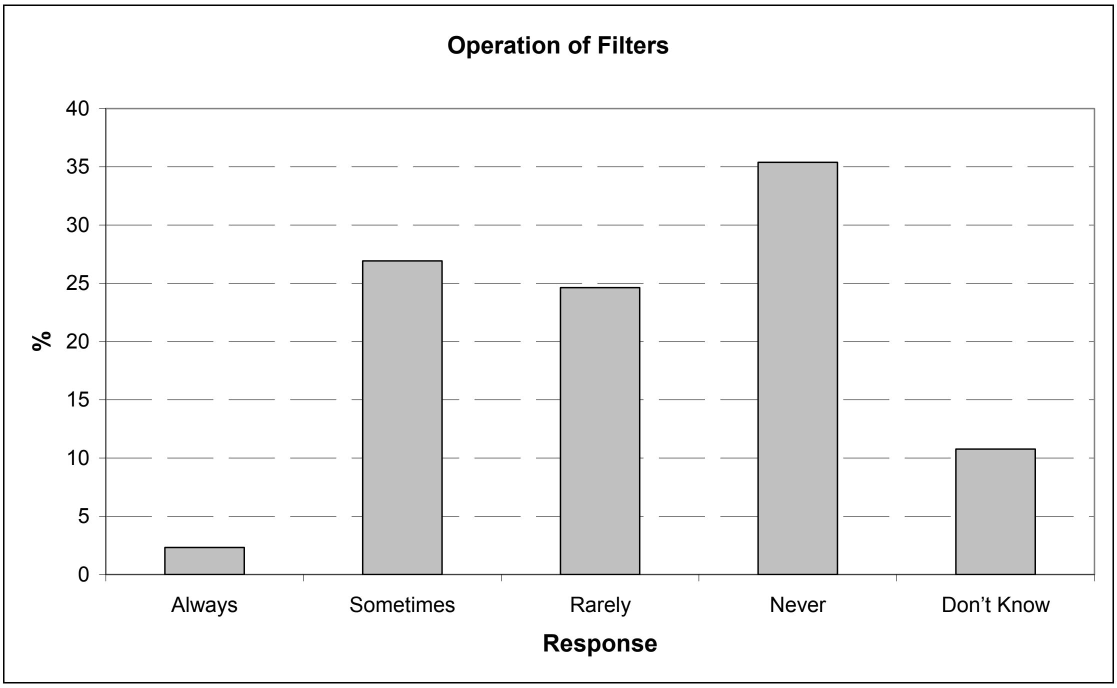


Figure 7-45: Filters operate to a high standard, based on Table 7-41.

The data above indicates that there is a considerable lack of maintenance in the filters (above 55%). This is evident from the high emission of dust in the surrounding areas, as the researcher discovered during the field visits in September 2007.

Q 43: Are there any penalties for the failure of wearing protective equipment?

Table 7-42: Penalties for the failure of wearing protective equipment.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	0	6	14	12	8
SCF	1	1	13	11	1
ZCF	0	2	14	11	7
LCF	0	2	12	10	5
All	**1**	**11**	**53**	**44**	**21**

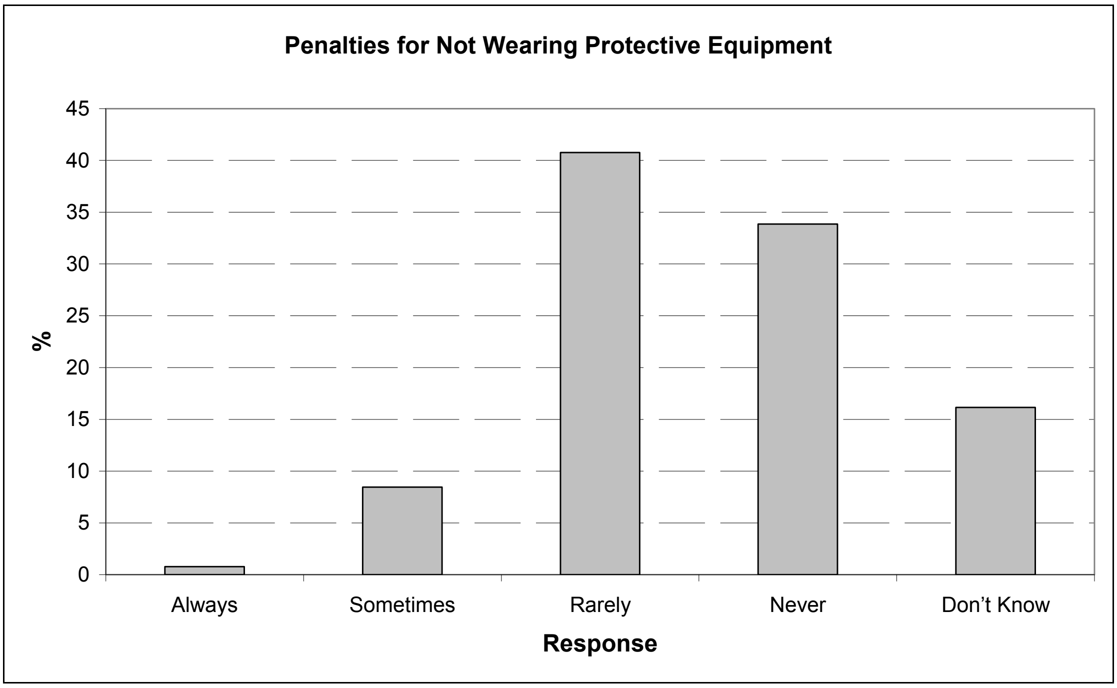


Figure 7-46: Penalties for the failure of wearing protective equipment, based on Table 7-42.

As can be seen from Figure 7-46, more than 90.75% of staff states that there are no penalties for not wearing the right protective equipment. This clearly indicates the lack of health and safety standards within the factories.

Q44: Is an emergency system in the factory ready for action in case of fire or any other incident?

Table 7-43: Emergency system in the factory.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	16	12	0	3	9
SCF	12	11	0	0	4
ZCF	13	12	0	1	8
LCF	13	12	0	0	4
All	**54**	**47**	**0**	**4**	**25**

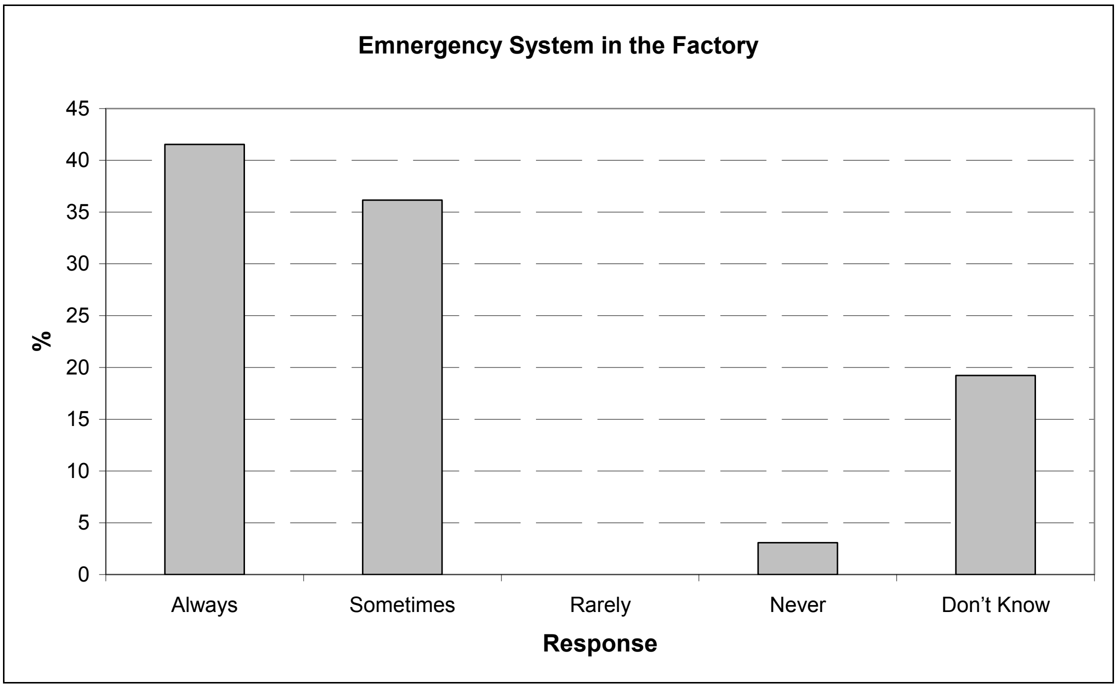


Figure 7-47: Emergency system in the factory, based on Table 7-43.

The vast majority of staff believes that there is an emergency system in place in case of a fire breaking out or any other emergency occurs. Indeed, in every factory there is a fire brigade. This was evident during the researcher's field visits.

Q45: Did you have training to deal with an emergency situation (health and safety training)?

Table 7-44: Training to deal with an emergency situation.

Factory	Always	Sometimes	Rarely	Never	Don't Know
MCF	0	4	12	16	8
SCF	0	3	8	10	6
ZCF	0	5	11	12	6
LCF	0	6	8	9	6
All	**0**	**18**	**39**	**47**	**26**

Figure 7-48: Training to deal with an emergency situation, based on Table 7-44.

There is clearly no continuous training with regards to health and safety, and emergency procedures. Furthermore, about 36% of workers state that they do not go to any training courses (see above). This may be considered to be a very significant finding of the present investigation.

7.3 Conclusion

This chapter has introduced the design and analysis of the questionnaire. Maintenance, operation and health and safety aspects have been used to design the questionnaire. Cronbach's Alpha is found to be 91.0% using SPSS software which indicates the reliability and consistency of the questionnaire.

The results of the above questionnaire can be summarised as follows:

Negative issues to be addressed:

1. Lack of a maintenance strategy within the four factories.

2. High levels of non-productive time due to technical faults.

3. Insufficient training courses for staff within the factory.

4. Lack of performance-related incentives and inadequate salary.

5. Pollution within the factory is not monitored.

6. Lack of health and safety programmes or measures.

7. Lack of social programmes within the factories.

8. Lack of transportation of raw materials to the factory.

9. Lack of calibration of instrumentation.

10. Lack of job-satisfaction amongst the personnel.

11. Maintenance data and information is not sufficiently recorded or documented.

Positive issues:

1. Availability of raw materials.

2. Recycling and reuse of waste materials.

3. The existence of fire brigades within the factories for emergency purposes.

4. A large number of staff accepts that not every single employee possesses the required skills and knowledge. This is positive because employees admit and realise their own problems and drawbacks.

5. Spare parts relatively available.

CHAPTER 8: INTERVIEWS

Abstract

The previous chapter has discussed the questionnaire and its findings. The questionnaire was developed for engineers and technicians on the shop-floor. This chapter presents the interviews that have been conducted with middle managers and senior engineers in order to validate part of the findings and provide in depth analysis.

8.1 Introduction

Interviews allow researchers to acquire more details and obtain greater depth of knowledge about what is under investigation. The quality of an interview depends on several issues, including: sampling control, information control, and administrative control (Fletcher, 1973). Sampling control depends on the researcher's ability to direct questions to the interviewee and to get the desired co-operation. Personal interviews normally involve face to face communication between interviewers and interviewees. Personal interviews within organisations must always proceed in this manner.

Some of the advantages of personal interviews include: the ability to allow the interviewer to see the interviewee. Furthermore, personal interviews allow the interviewer to spend more time with his or her interviewees as opposed to phone calls or written documents. With reference to face-to-face interviews, the interviews are more expensive and they are usually more time-consuming.

The author travelled to Libya and visited all of the factories mentioned above. Interviews were then conducted with 15 top, and middle managers and senior engineers. These interviews sought to uncover specific information from participants who know or have access to the information being investigated.

Information control depends on the ability of the researcher to design and develop questions for a particular interview and to continuously modify and revise them if necessary. Questions developed should be evaluated thematically and dynamically. Thematically means that questions should have relevance to the research theme. The questions developed for this research were drawn from a preliminary review of the literature, field work, case studies and the survey questionnaire.

Interviewees should be informed about the aim of the investigation and should be granted confidentiality. Moreover, the interviewer must be able to direct questions to every interviewee while avoiding possible bias Bill (2000).
Administrative control depends on suitable documentation and presentation of the data collected. For further information regarding interviews design, the reader could refer to (Robert, 1996).

8.2 The Interview process

An interview regularly starts with a few minutes of casual chat between interviewer(s) and their interviewee(s). The chat can be about almost anything including shopping, food and sports events. Sometimes, a mild joke might be included to relax interviewers and interviewees alike Herbert and Irene (2005). This could lead to a more successful and more fruitful interview, since some interviewees may lack confidence and feel nervous about speaking about their jobs to strangers. Furthermore, in this inaugural but crucial part of the interview, interviewers may have to spend a little time tactfully reassuring their respective subjects. Individuals who agree to be interviewed must always be treated on the basis that they are competent at their jobs, and that whatever they may say about their professions is of great interest to the interviewers. Furthermore, if all colleagues agree that a particular individual is the most suitable person for the interview; then it would be more appropriate for interviewers to inform that individual if he or she happens to be the person selected for the interview (Herbert and Irene, 2005), (Leslie,1988).

Some interviewees may begin to fear that the interviewer is judging them on their ability to answer questions correctly. It is important, therefore, to remind all interviewees that there is no right or wrong approach in how they tackle questions in an interview. Furthermore, what must matter for interviewers are the interviewees' experiences (i.e. how they feel and what they think about their jobs) (Leslie, 1988).

In the course of this research, the researcher's various personal experiences and the reasons behind the decision to undertake the research were presented in detail at the beginning of each interview that was conducted. It was felt that it would be more helpful for the interviewees to have some background (i.e. preliminary) information about the research and the researcher. Several authors (e.g., Herbert and Irene, 2005; Leslie, 1988; Margaret and Harry, 1997) support the idea that the interviewer must first describe the aim of the research to his or her subjects as this could lead to a more productive interview.

Interviewees often want to know how the interviewer happens to be interested in them and why he particularly wants to have an interview with them. In this study, questions related to the choices of individuals selected for the interviews did not require much consideration, since the four cement factories operate under the same company.

The most difficult task of an interview, perhaps, is to be aware of an organisation's 'political culture', and to try to persuade the interviewees that information disclosed during a particular interview will be handled with utmost confidentially. Confidentiality is an important issue since without it interviewees may simply find it difficult to express their opinion in a frank and clear way. For instance, many workers are too afraid to openly criticize top managers. For reasons of confidentiality in this research, every interview was given a code in order to keep the interviewee's identity confidential.

The information gathered from the interviews was analysed in two ways: quantitatively (using a coding system for the answers, i.e. similar to questionnaires) and qualitatively. Qualitative analysis is not about mere counting or providing numeric summaries. The aim is to discover variation, to portray shades of meaning, and to examine complexities. The primary objective of the analysis is to reflect complexity of human interaction by describing it in the words of the interviewees and through actual events and to make that complexity understandable to others (Leslie, 1988; Herbert and Irene, 2005).

Fifteen interviews were conducted with representatives from the four Libyan cement factories, including top and middle managers and senior engineers. The results were coded (as will be shown in subsequent sections) to ease the quantitative analysis of their opinions.

The quantitative analysis of obtained interview data is presented below. The qualitative analysis, on the other hand, will be introduced in chapter 10.

8.3 Coding of Interviews

The interviewer used a similar data collection strategy to that which was described in the previous chapter. Questions were, thus, asked to the interviewees whose answers were then categorised into different codes depending on the type of obtained answers.

A semi-structured interview approach was utilised which allowed the dialogue to be unrestrictive, conversational, and exploratory. Moreover, every time a new question emerged, it was also coded and utilised in order to obtain a more in-depth insight into the subject under study.

Similar to the previous chapter, four research issues are addressed including:

- What factors are likely to affect productivity from an operational perspective?
- What factors are likely to affect productivity from a maintenance perspective?
- What factors are likely to affect productivity from a combined operations and maintenance perspective?
- What is the awareness level in terms of Health, Safety and Environment (HSE)?

Open questions were asked and the results were coded (as can be seen in Figure: 8-1A to Figure: 8-24Z). Each question was assigned a single letter alphabetic code, while every answer was given a unique number code.

The results from the interviews, using the coding system prove the following issues:

1. Raw materials are available but contain some impurities. Yet, none of the factories had in place a strategy whereby all raw materials can be tested.
2. The majority of employees need personal development training. However, the four factories do not invest enough resources in training. In fact, none of the four factories had in place a suitable training strategy.
3. Paid salaries are not sufficient which forces some employees to look for a second job in order to compensate the deficit.
4. Lack of training in the area of maintenance and inspection procedures and programmes.
5. Insufficient investment in cleaning and cleaning products which inevitably lead to inspection and maintenance problems.
6. The four factories lacked a clear training strategy amongst employees on the lubrication of equipment.
7. Machines were not cleaned and/or maintained on a regular basis.
8. Waste bins were not available at all times.
9. There was no system in place for emergency procedures.
10. A significant amount of training was needed in order to ensure that preventive maintenance strategy was in place.
11. Lack of communication between managers/supervisors and shop floor workers. Moreover, the four factories lacked a unique and universal organisational culture.
12. Maintenance data was not properly recorded. Hence, the recruitment policy adopted by the four factories is not very efficient.
13. Employees did not receive any performance -related incentives.
14. The majority of staff considered leaving the factory if nothing was done by senior managers to improve their situation in terms of salary, incentives.
15. Lack of social, recreational and entertainment activities. This could potentially have a substantial negative impact on the performance of the employee. Unfortunately, the four factories did not have any major investment plans in the area of entertainment activities.

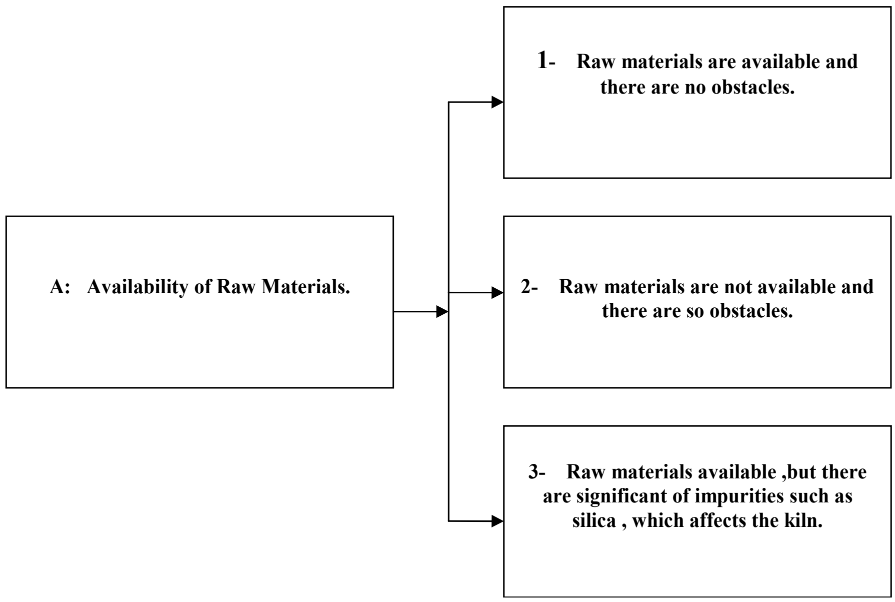
16. Very few workers attended training courses about maintenance and total productive maintenance (TPM) issues. Moreover, there was no clear personal development system in place.

17. There was no system in place to measure pollution levels. Health-related monitoring programmes for staff, on the other hand, were not very frequent.

In this chapter, abbreviations have been used to describe some interviewees as indicated in Appendix A.

QA: Are the raw materials available in the factories of good quality?

Table 8-1: Availability of Raw Materials.



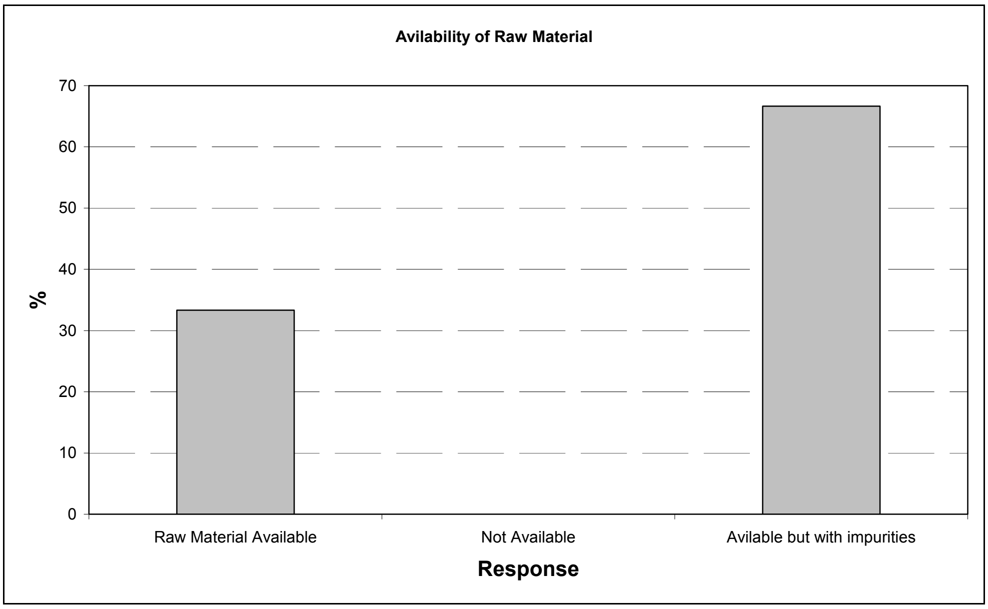


Figure 8-1: Availability of Raw materials.

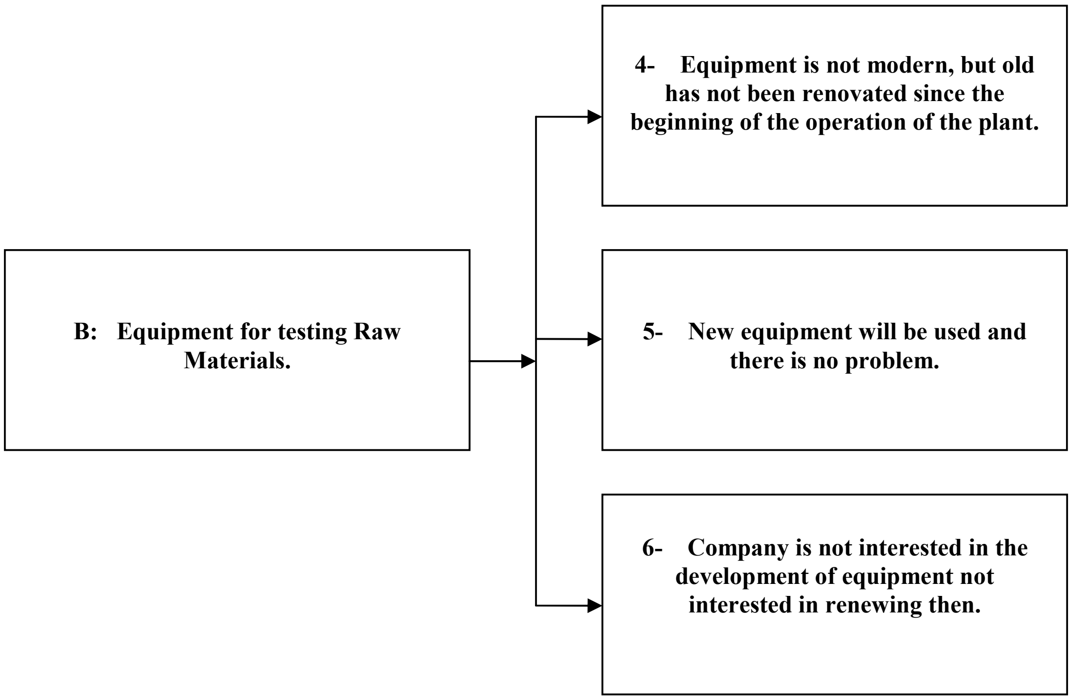
Figure 8-1 indicates that raw materials are available. The same Figure, however, shows that not all of the stored materials meet quality standards. This is mainly because some materials in stock are not one hundred percent pure. An example of this is the silica ingredient, which can have an adverse impact on the kiln.

The above issue of raw materials' defective nature is in accordance with the results of the survey questionnaire (consult chapter 7 for details).

According to (EA) "*raw materials are available. However, they contain some unwanted materials, which affect Kiln operations. The problem is further aggravated by the fact that the company has no equipment that removes materials' impurities*".

Q B: Do you use equipment's for testing raw materials?

Table 8-2: Equipment for testing Raw Materials.



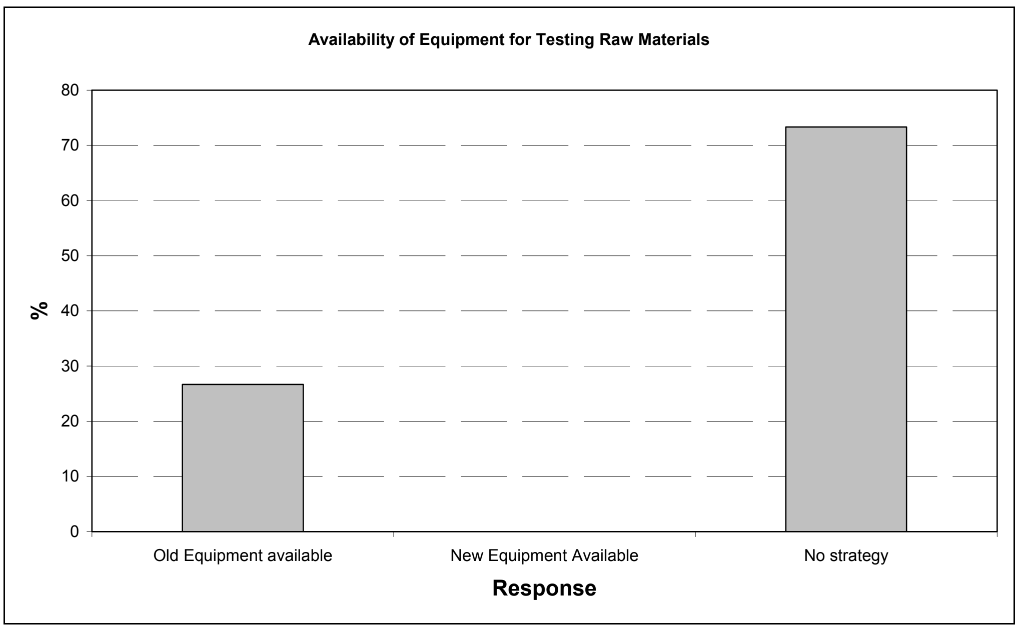
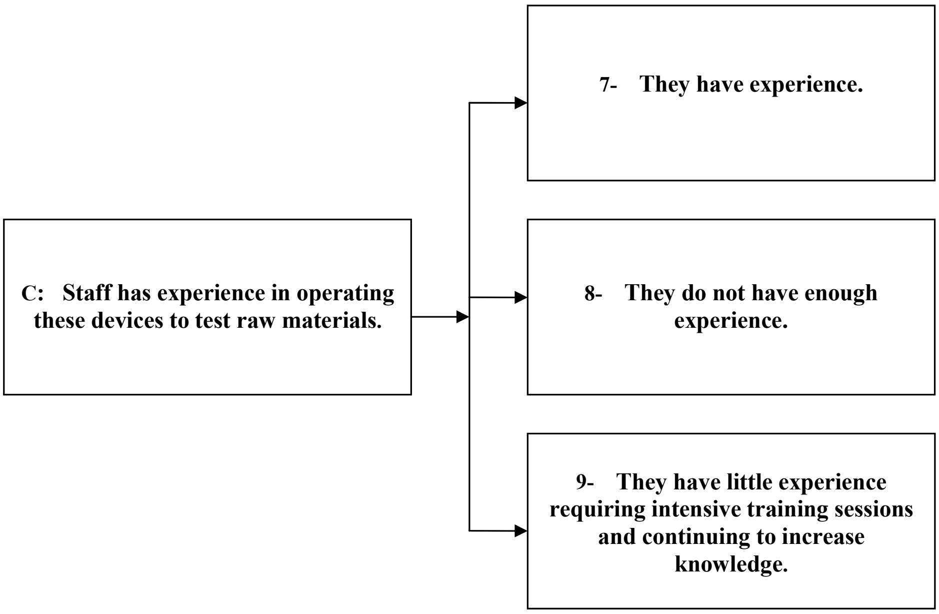


Figure 8-2: Equipment for testing Raw Materials

Figure 8-2 shows clearly that up to 70% of the majority of Middle managers and engineers agree that the company is not interested in the development and renewing the equipment. (EG) maintains that, "*top managers do not want to improve equipment in the plant and there is no future strategy*". This result agrees with the surveyed questionnaire (see question 3). Therefore, it will be lead to increased problems in the factory in future.

Q C: Have staff has experience in operating these devices to test raw materials?

Table 8-3: Staff has experience in operating these devices to test raw materials.



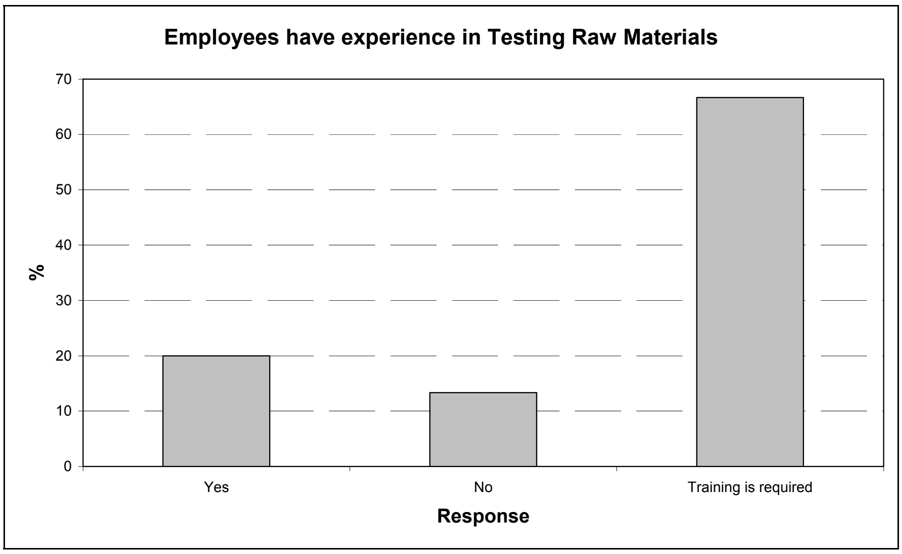
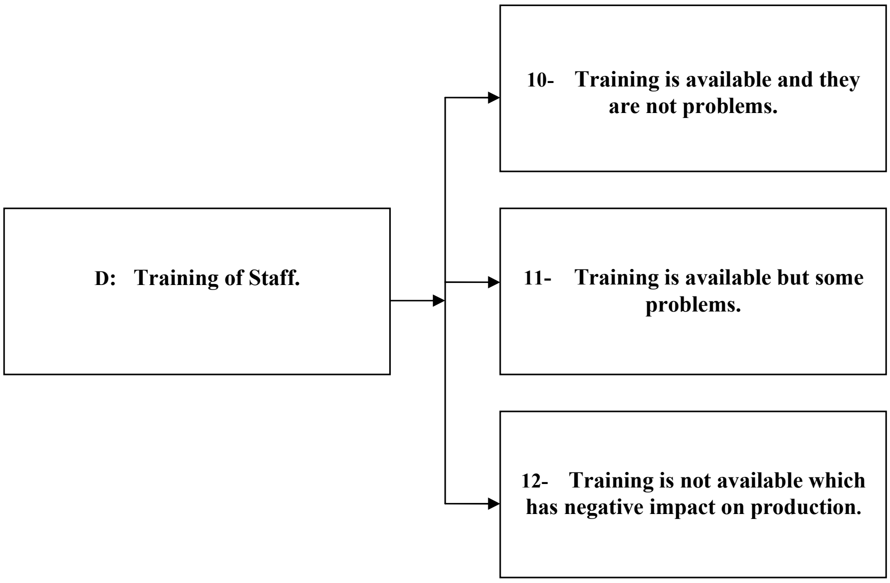


Figure 8-3: Staff has experience in operating these devices to test raw materials.

Figure 8-3 illustrates that more than 60% of Middle manager and engineers believe they have little experience and require intensive training sessions to increase their knowledge of the industry. Chapter 3 explained the importance of training and these results agree with the previous chapter. (EA) states "*the top managers are not concentrating on training; there are no future plans for* *training*". Consequently, from the above results the majority of workers still wait training.

Q D: Are there any training courses for staff?

Table 8-4: Training of staff.



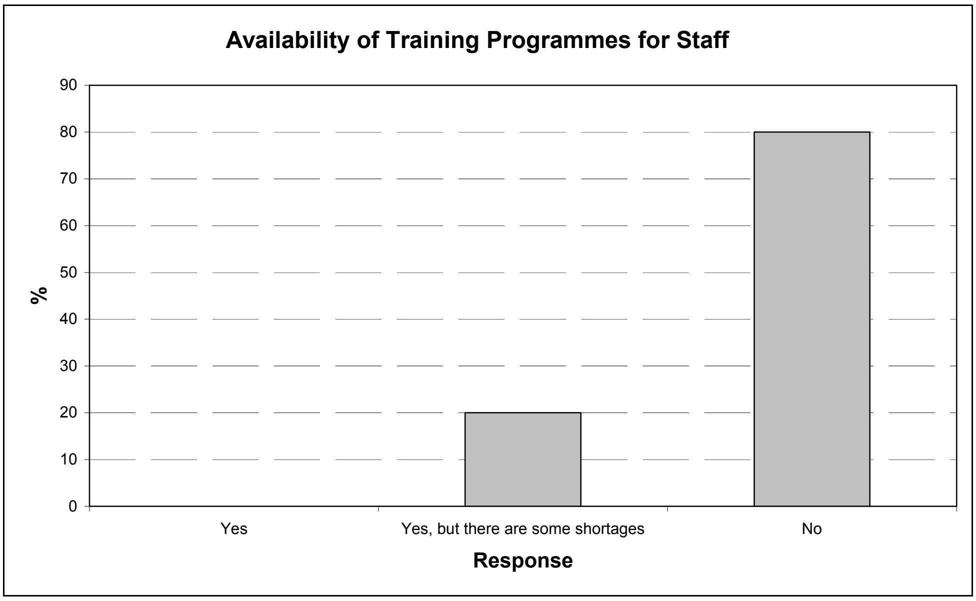


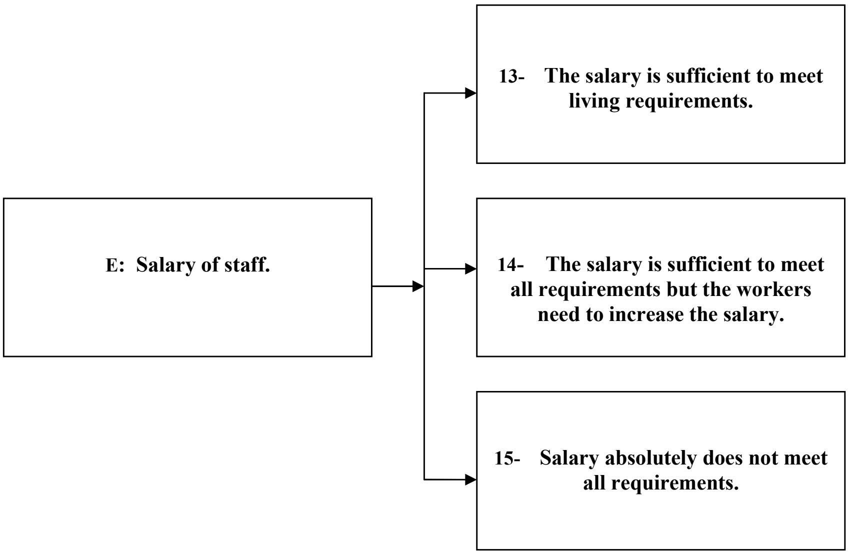
Figure 8-4: Training of staff.

Figure 8-4 shows that more than 80% of staff believes training programmes for staff is not available which has negative effect on production levels. According to (EL) "*the main problem in factories is that there are unavailable planning strategies for training*".

As mentioned earlier in chapter 3; training is very important form top management through to the shop floor, which is one of the main pillars of TPM (see chapter 3). Furthermore, the above graph has the same opinion with surveyed questionnaires (See chapter 7).

Q E: Do you receive a good salary?

Table 8-5: Salary of staff.



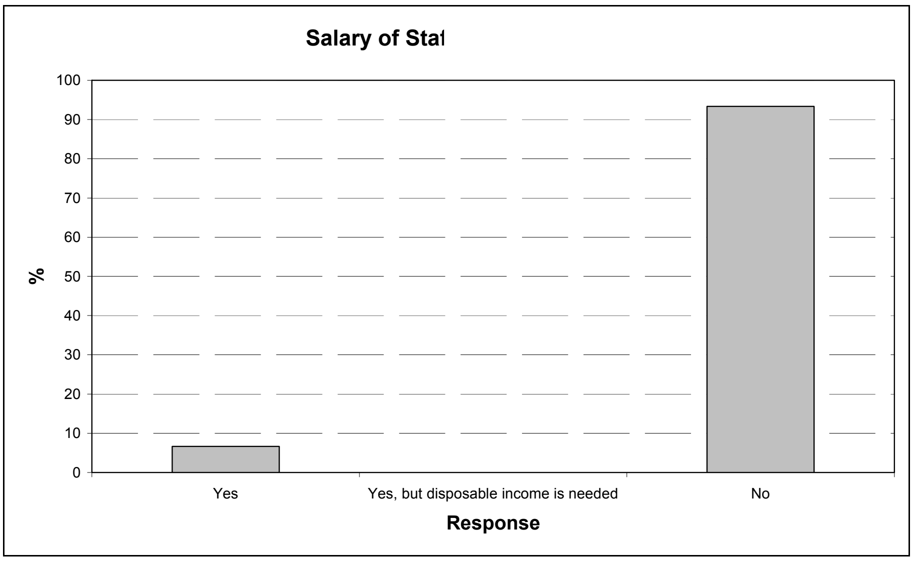
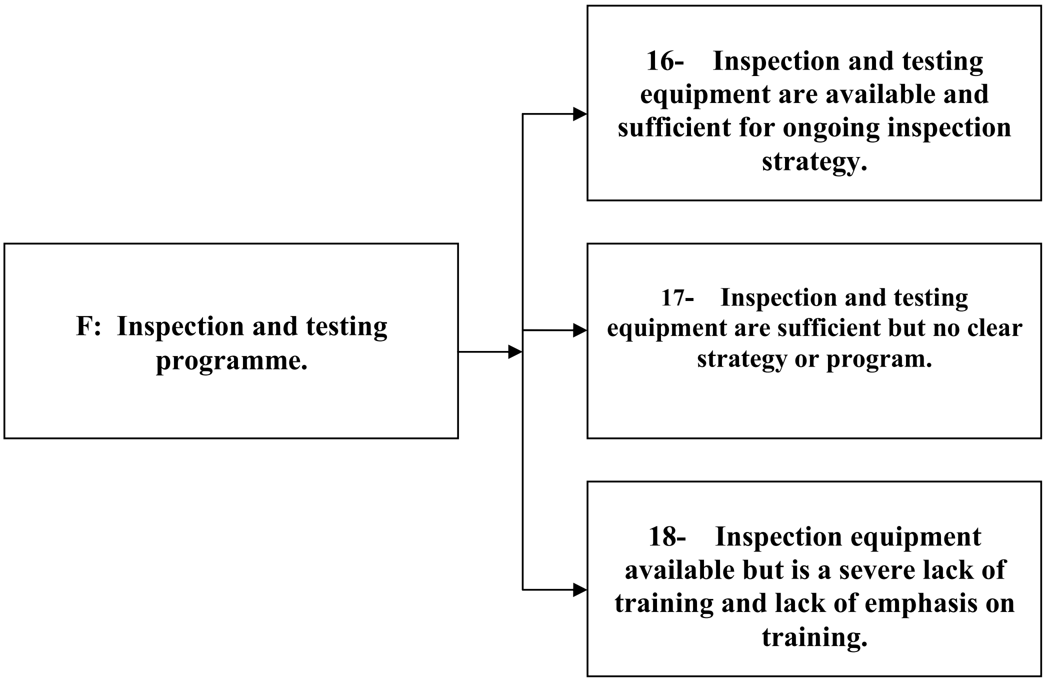


Figure 8-5: Salary of staff

Figure 8-5 shows that up to 90% of managers and engineers are dissatisfied with their salary. Therefore, the salary absolutely does not meet all their requirements. This result agrees with the previous chapter (see surveyed questionnaire question number 34). In addition, (EE) said "*we usually work* *overtime to improve our salary*". All the information indicators are given from the above Figure. The salaries are not sufficient.

Q F: Is there a program for the inspection of machinery and equipment?

Table 8-6: Inspection and testing programme.



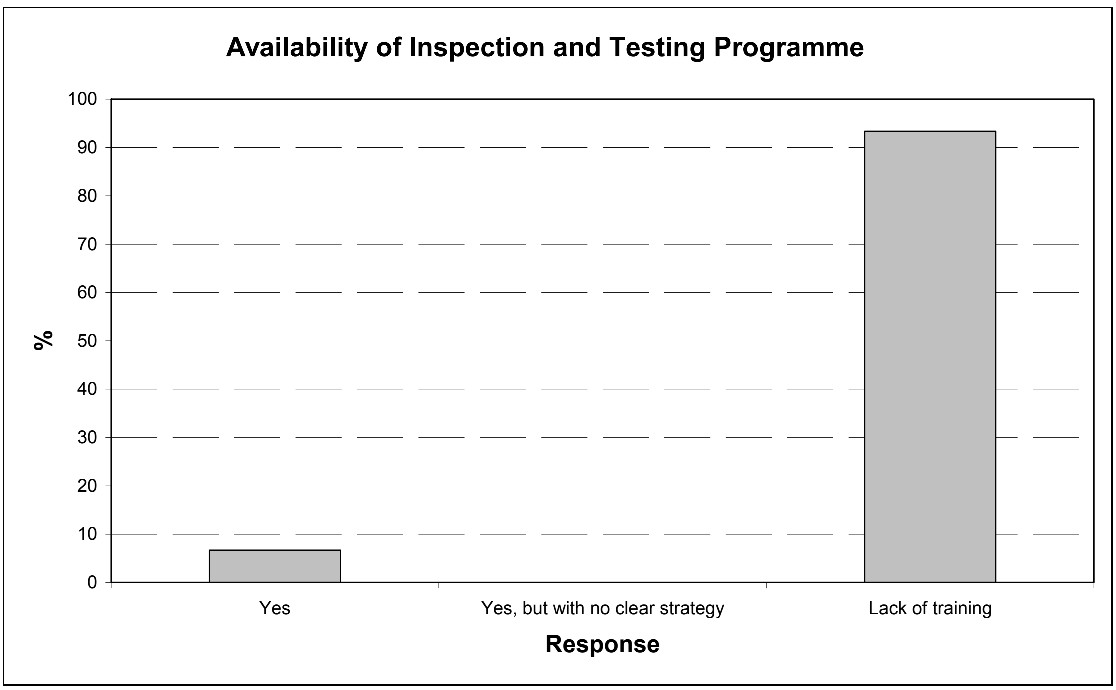
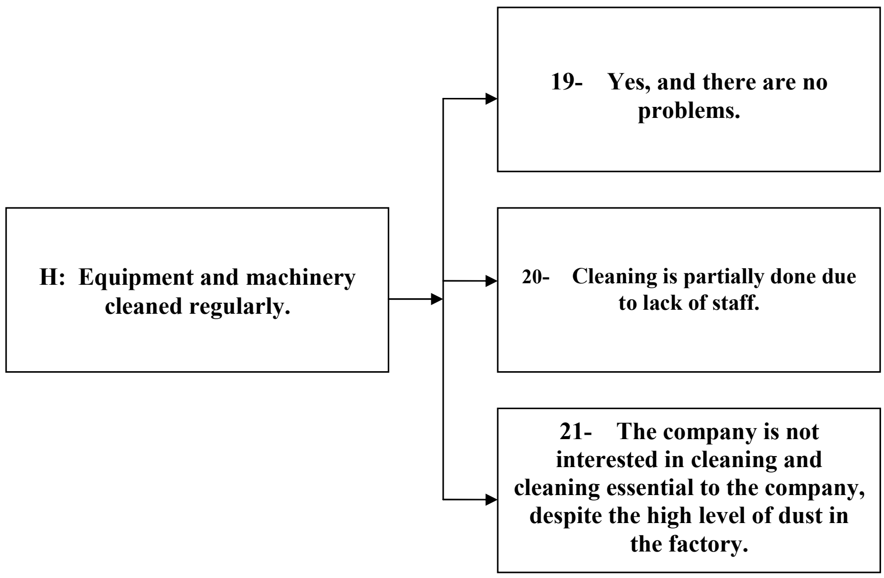


Figure 8-6: Inspection and testing programme.

Figure 8-6 shows that more than 90% of middle managers and engineers believe that inspection equipment is available, but that there is a severe lack of training and lack of emphasis on training. However, TPM in chapter 2 recommended and advised to use inspection; it is one of the most important elements. (EK) suggests that" *we do not concentrate too much on inspection, because actually we do not have a good enough people to use it*". This result agrees with the previous chapter 7 (surveyed questionnaire question number 20).

Q H: Is equipment and machinery cleaned regularly?

Table 8-7: Equipment and machinery cleaned regularly.



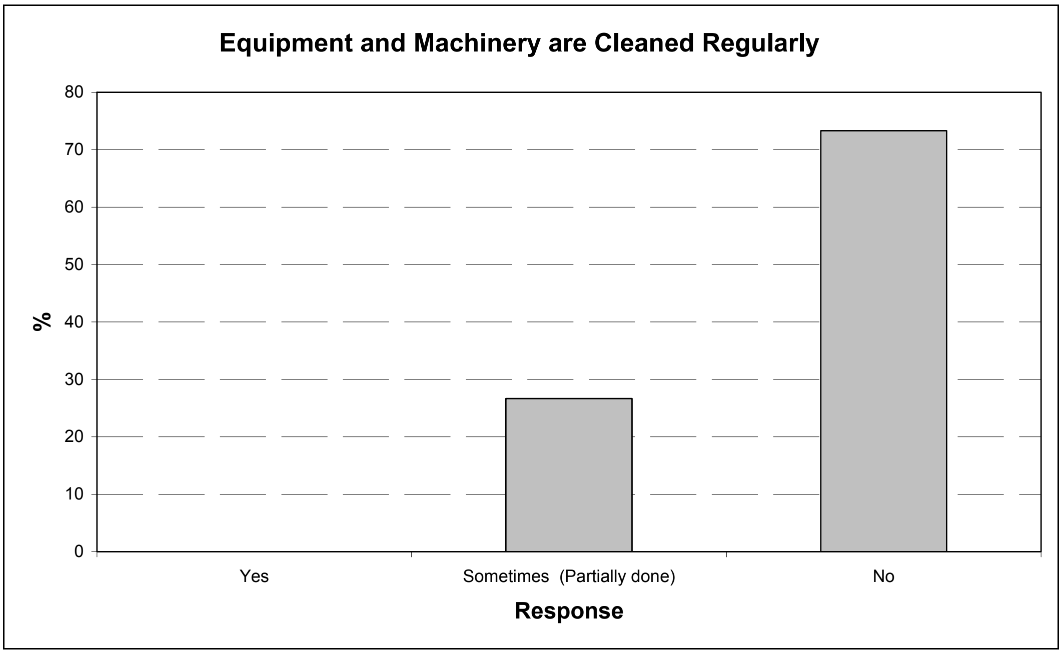


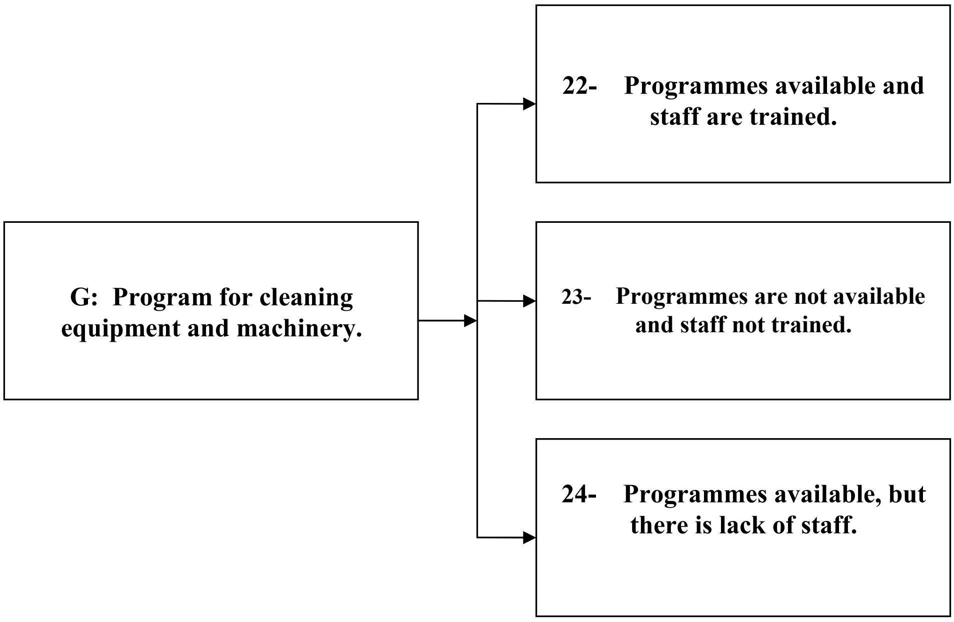
Figure 8-7: Equipment and machinery cleaned regularly.

Although, cleaning is one of the most important items of TPM, as mentioned in (chapter 3) the majority of managers and engineers (up to 70%) do not believe in cleaning in the factories. Thus the company believes that cleaning is not essential in the factories, despite the high level of dust in them.

According to (ED) "*we cannot control dust, because stopping it needs cleaning equipment and more workers*". Furthermore, the above Figure agrees with the previous chapter 7 (surveyed questionnaire question 17).

Q G: Do you have a programme for cleaning equipment and machinery?

Table 8-8: Programme for cleaning equipment and machinery.



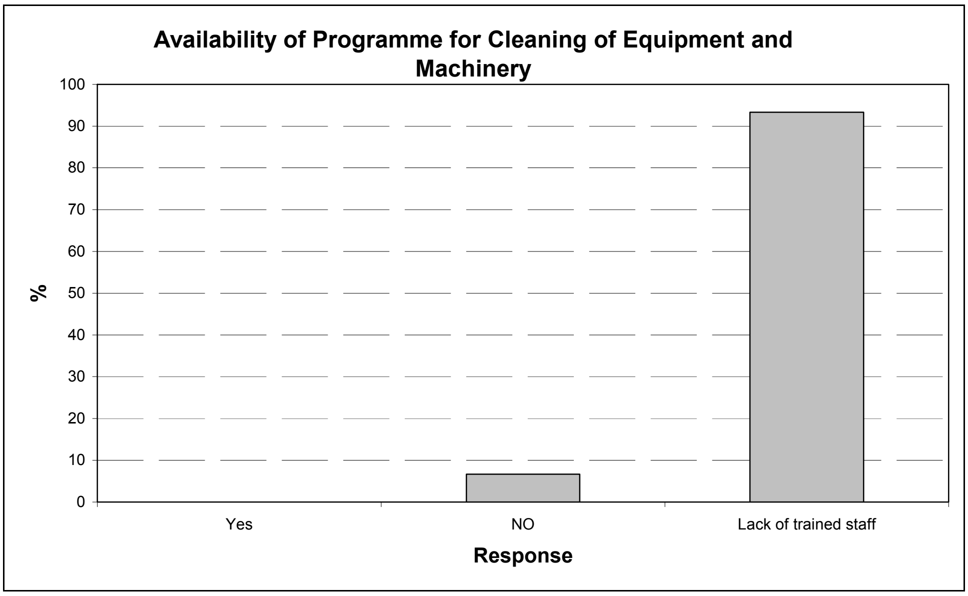
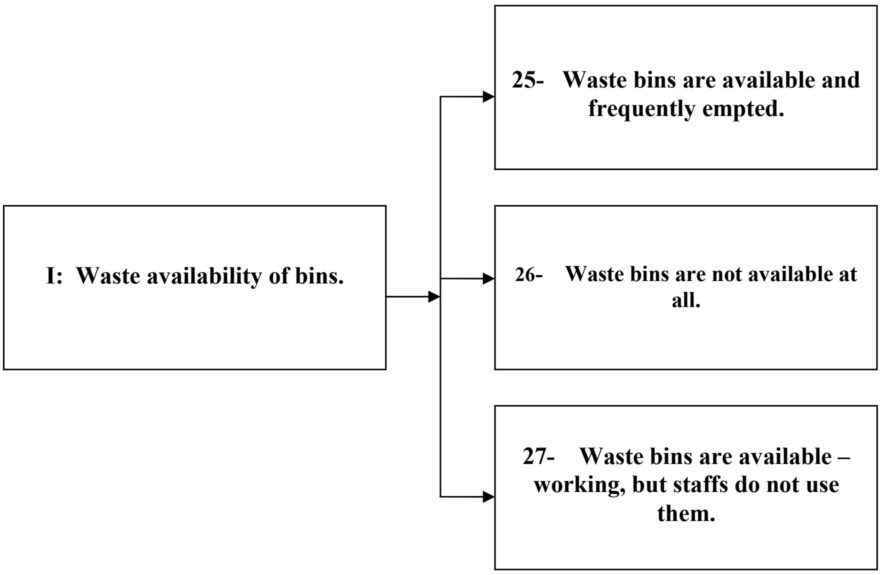


Figure 8-8: Programme for cleaning equipment and machinery.

According to the majority of managers and engineers (More than 90%, see Figure 8-8) there are programmes available for cleaning, but there is a lack of staff and cleaning equipment. This agrees with previous chapter 7 (surveyed questionnaire question number 17and 18). (EI) said "*the programme is always available but there is a lack of staff and cleaning equipment*".

Q I: Is waste used and what is the availability of bins?

Table 8-9: Availability of waste bins.



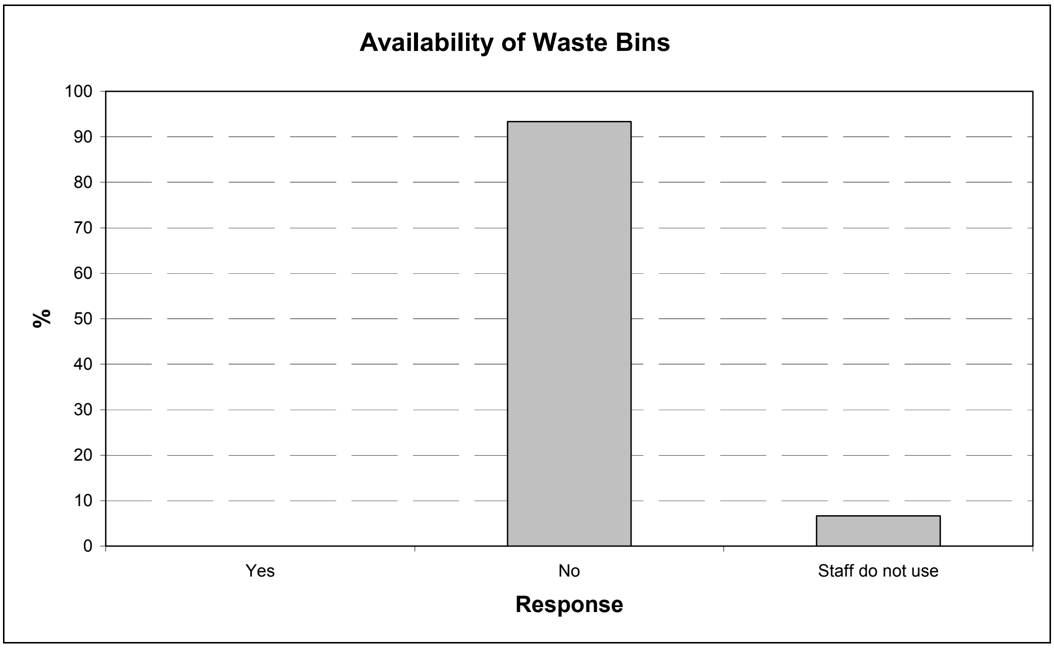


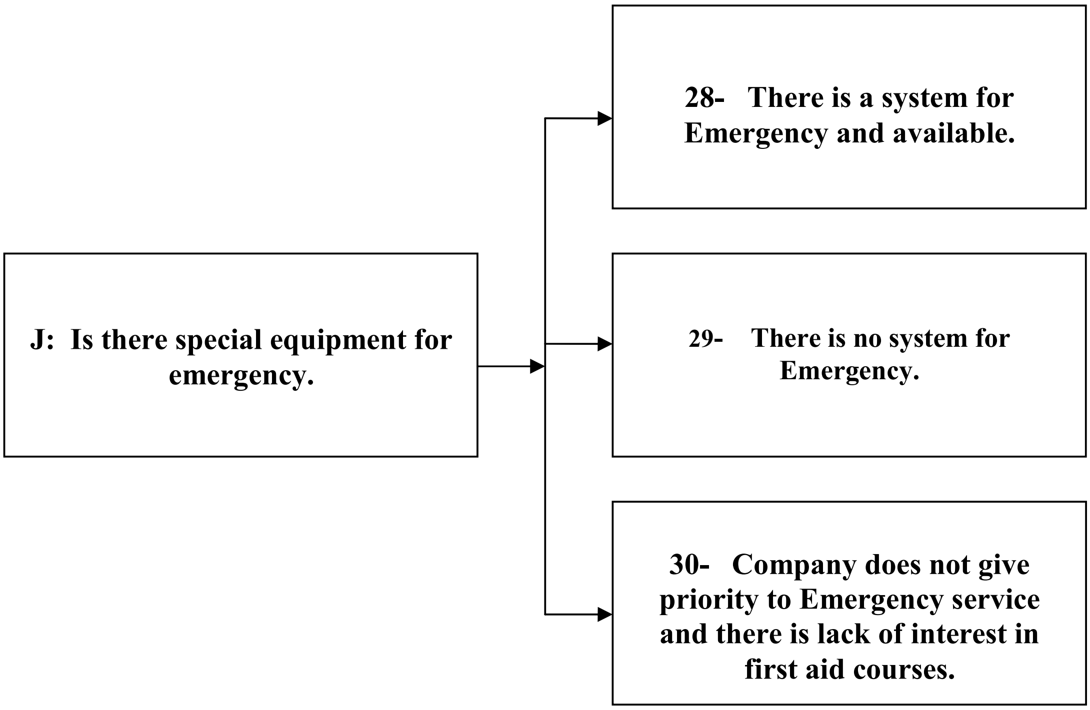
Figure 8-9: Availability of waste bins.

From Figure 8-9 it can be said that nearly 100% of managers and engineers believe that waste bins are not available at all. (ED), suggests that "*the top manager of NCC are not aware of availability of waste bins*"

According to the author as the September 2007 visit revealed, there is much rubbish everywhere in the factory. Although there are workshops in the factories the top managers do not discuss whether to make or design waste boxes to use. Therefore, this is a negative point that should be addressed.

Q J: Is there an emergency system in the factory ready for action in case of fire or any other incident?

Table 8-10: Is there special equipment for an emergency.



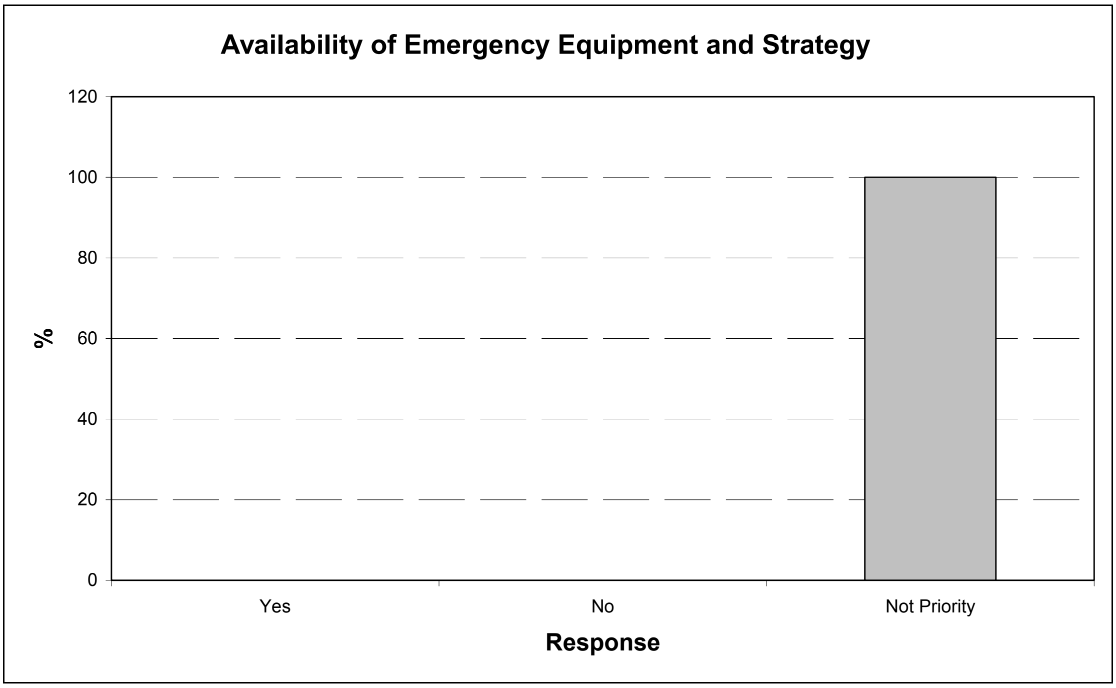


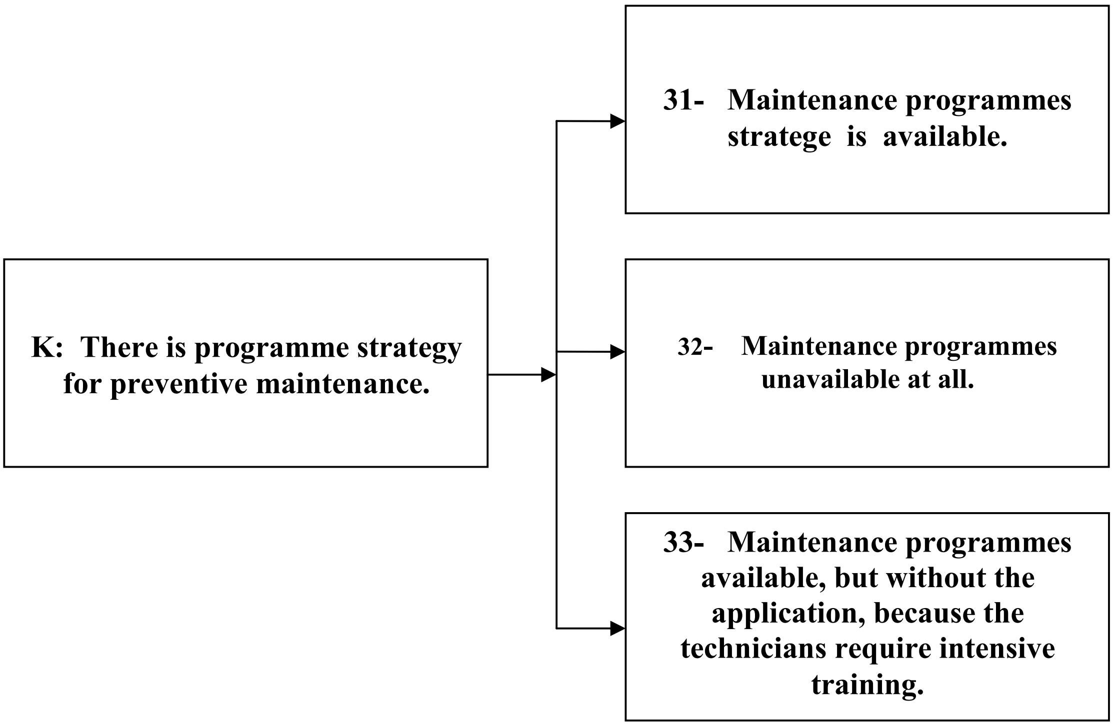
Figure 8-10: Is there special equipment for emergency.

Figure 8-10 shows that 100% of the engineers and managers believe that the company does not give priority to an emergency service, and there is a lack of interest in first aid courses.
According to (EN) "*NCC does not really concentrate on emergency equipment and training (courses)*".

Actually, this question disagrees with the previous chapter 7, (questionnaire surveyed question 44), and where the workers believe that there is available equipment and training courses in the factories. However, as the author visited the factories the equipment was available but was not regularly checked.

Q K: Do you have a preventive maintenance programme?

Table 8-11: There is a programme strategy for preventive maintenance.



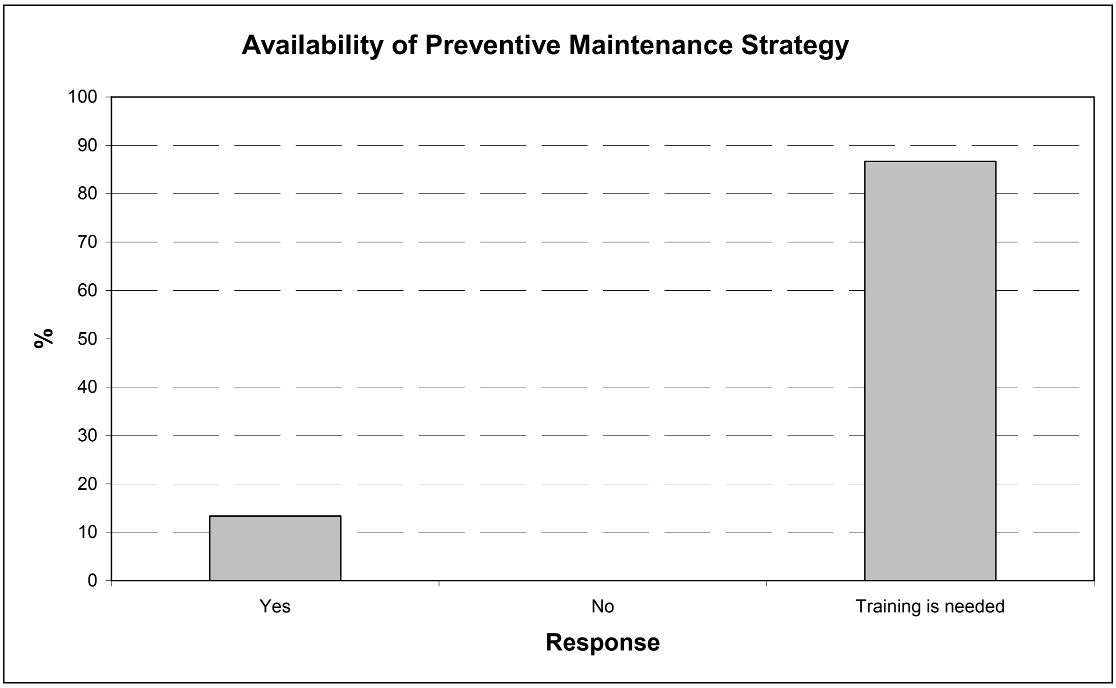


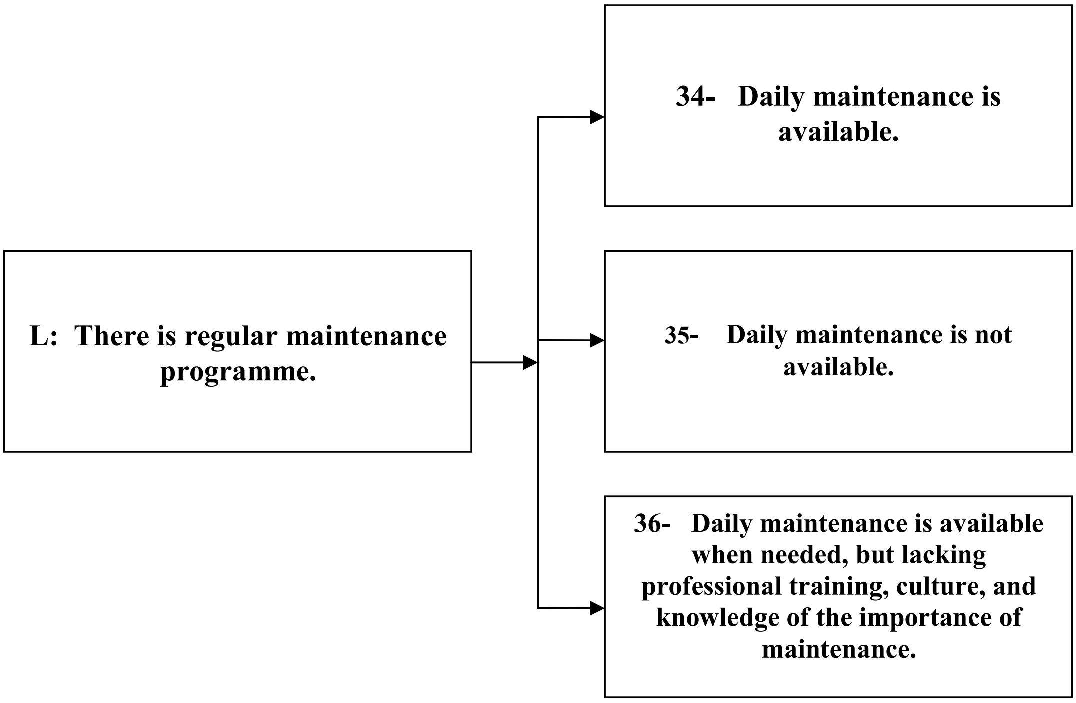
Figure 8-11: There is programme strategy for preventive maintenance.

From Figure 8-11 clearly the majority, up to 80%, of managers and engineers believe that there is programme strategy for preventive maintenance. However, the workers need more training and knowledge of the industries. Maintenance programmes are available, but without the application, because the technicians require intensive training, which is not given.

The result of this question disagrees with the previous chapter 7 (surveyed questionnaires question number 22). Where workers believe preventive maintenance is available but other problems such as knowledge, communication and training need solving. (EJ) suggests that "*the programme strategy for preventive maintenance is available but we need more training and lectures to improve our skills*".

Q L: Do you have a regular maintenance programme?

Table 8-12: There is a regular maintenance programme.



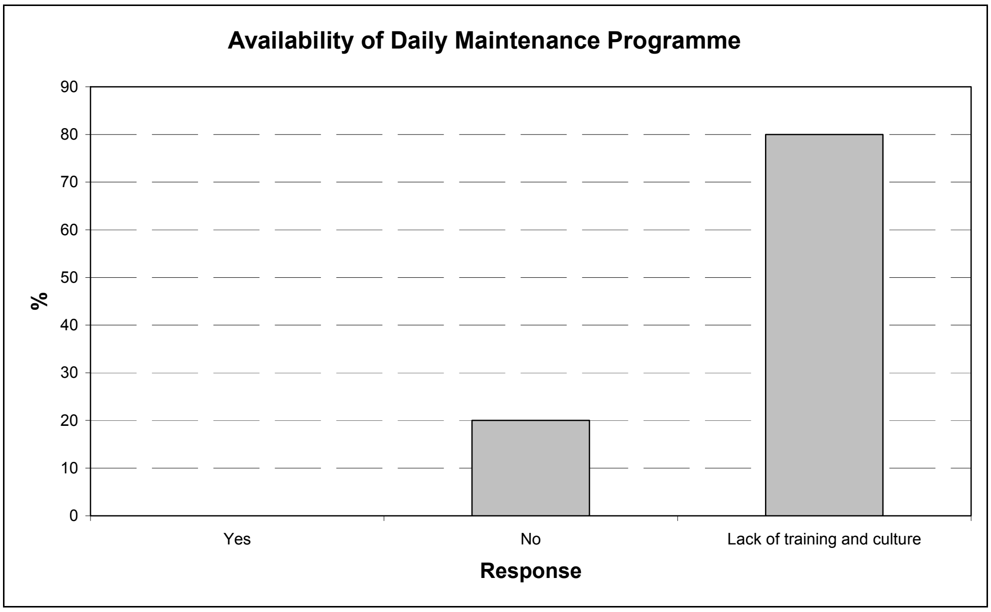
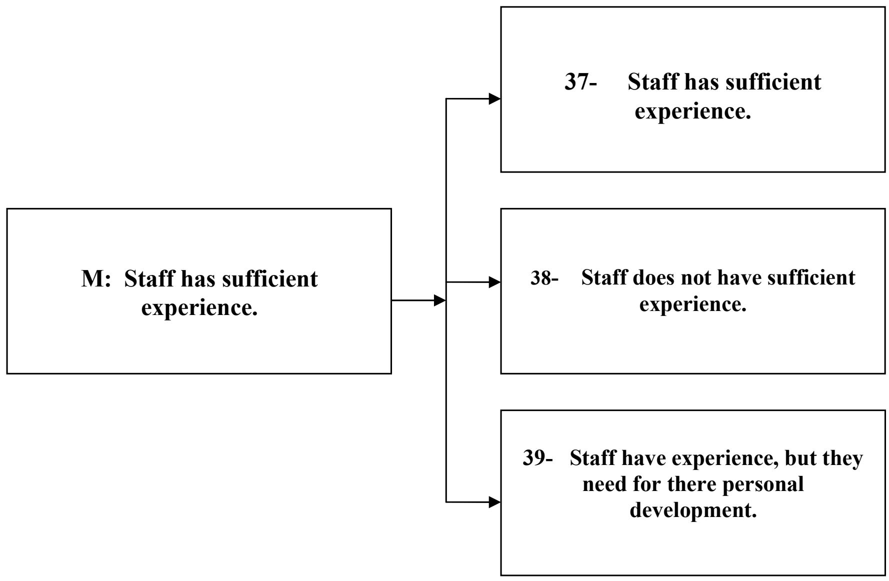


Figure 8-12: There is a regular maintenance programme.

From Figure 8-12 above, it is clear that the regular maintenance programme is not available at all. This is the view of the majority of respondents, nearly 80%. (EM) states that "*daily maintenance is available when needed, but there is a lack of professional training, culture, and knowledge of the importance of* *maintenance*". Furthermore, the author mentioned early in (chapter 2) that maintenance is important.

M: Does staff have sufficient experience?

Table 8-13: Staff has sufficient experience.



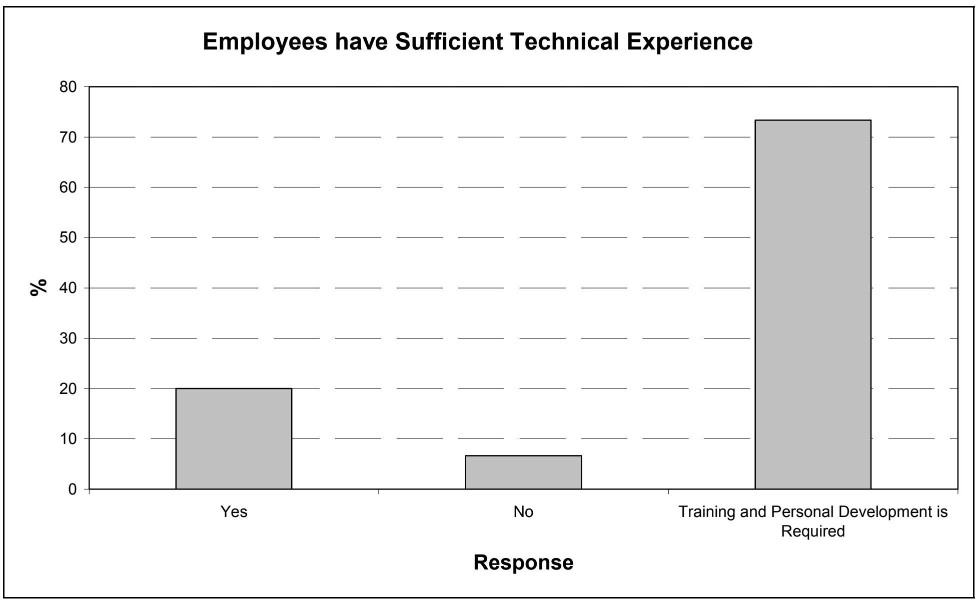


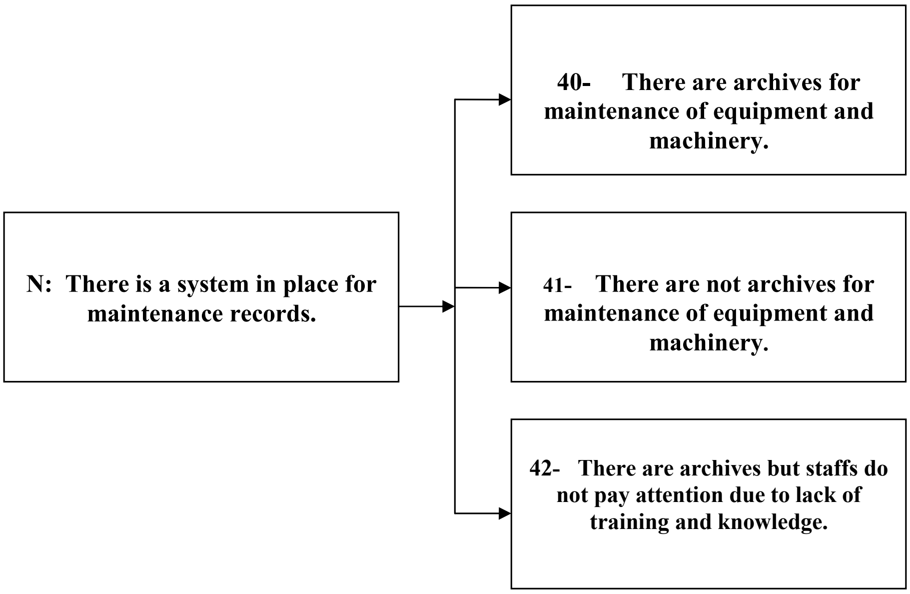
Figure 8-13: Staff has sufficient experience.

Figure 8-13 indicates that about 70% of managers and engineers in the interviews believe that there is a lack of sufficient experience. This result agrees with the previous chapter 7 (questionnaire surveyed question number 7).

(EK) argues "*staff have experience, but more upgrade of personal development and training is required*".

Q N: Is there a system for recording maintenance data or information?

Table 8-14: There is a system in place for maintenance records.



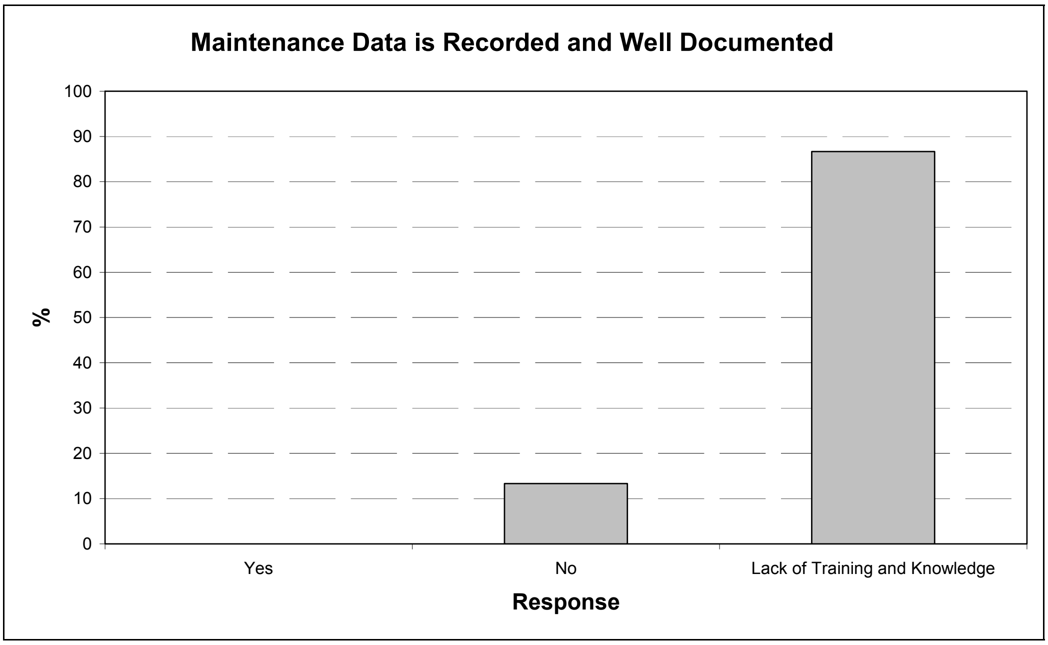
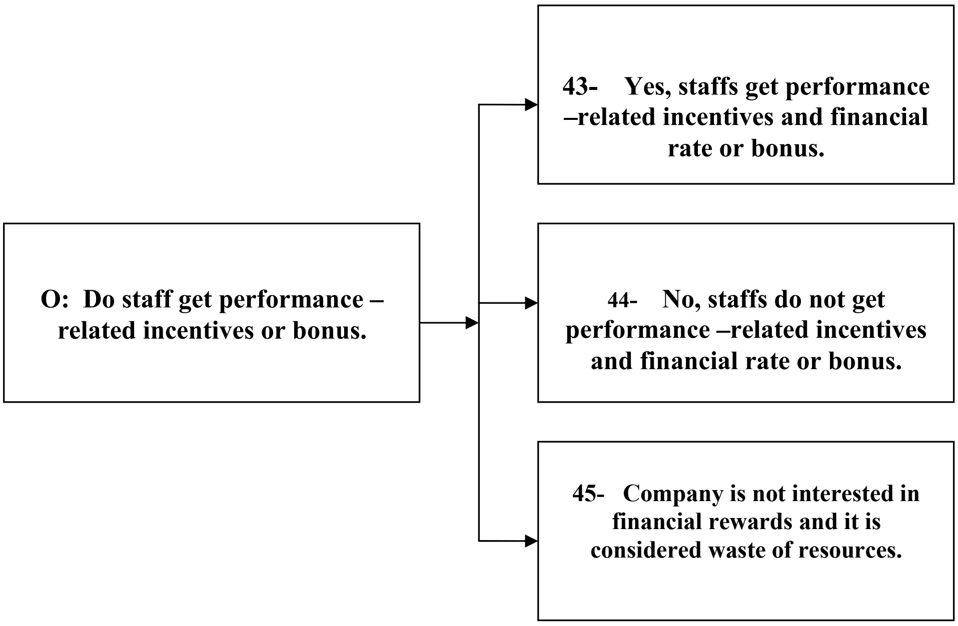


Figure 8-14: There is a system in place for maintenance records.

Figure 8-14 shows that the majority of middle management engineers (almost 80%) believe that there is a system in place for maintenance records. However, staff need to understand how to use them, and there are a lack of knowledge and training. According to (EE) "*There are archives but staff do not use them due to a lack of training and knowledge*". As mentioned early in the previous, chapter 7, (question 24) the factories may not be able to have a better TPM strategy in the future.

Q O: Does your salary include a performance related incentive?

Table 8-15: Do staff get performance related incentives or bonuses?



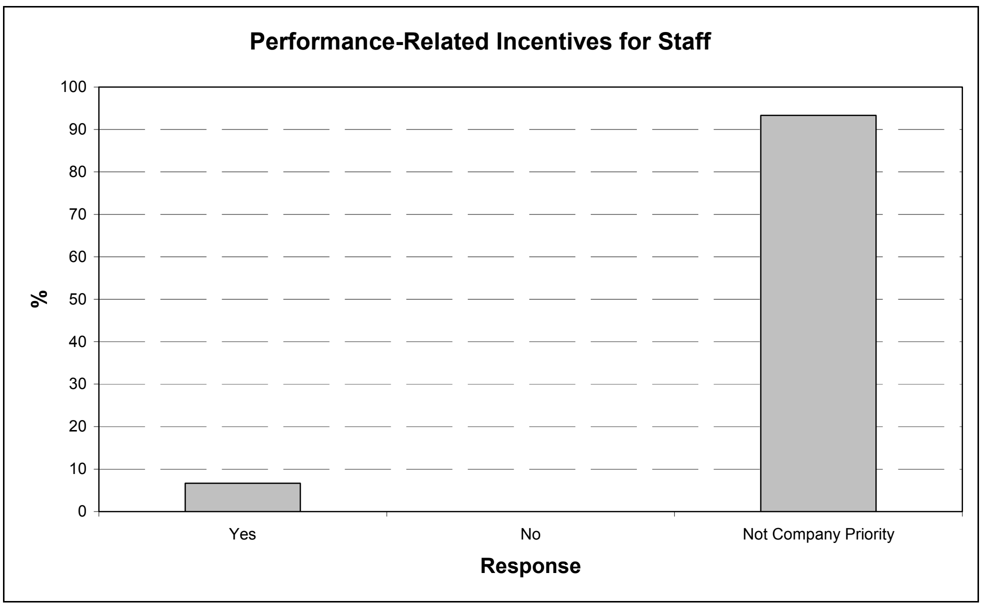
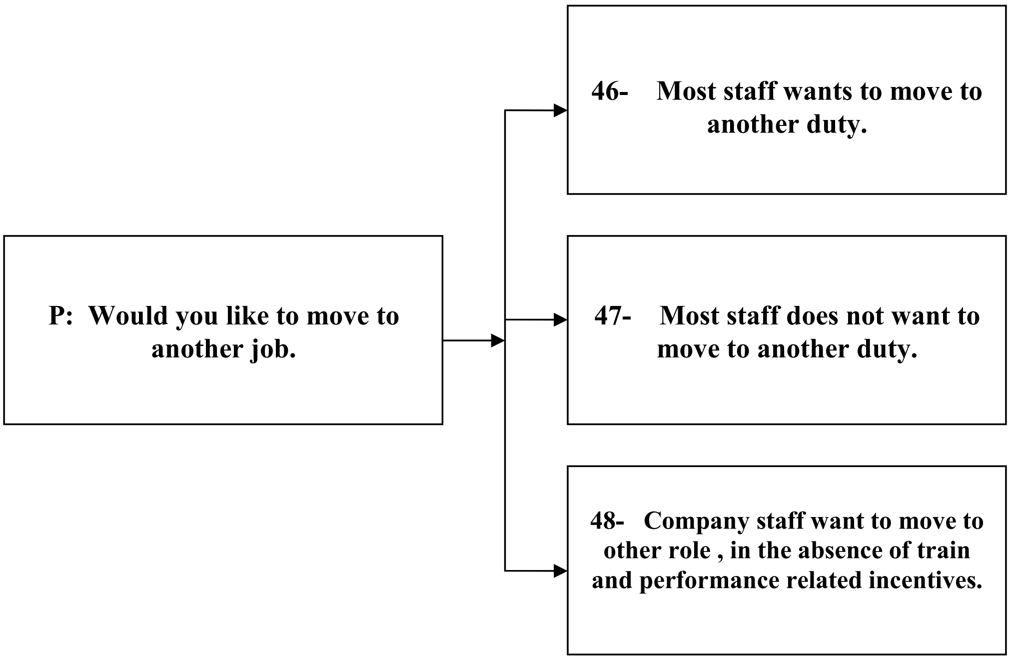


Figure 8-15: Do staff get performance related incentives or bonuses?

Figure 8-15 illustrates that up to 90% of the managers and engineers believe that they do not receive any performance-related incentives. Therefore, this agrees with the previous chapter 7 (questionnaire surveyed question number 34). (EH) states that "*the top manager in NCC is not interested in financial rewards and it is considered a waste of resources*".

Q P: Do you want to move to another job role?

Table 8-16: Would you like to move to another job.



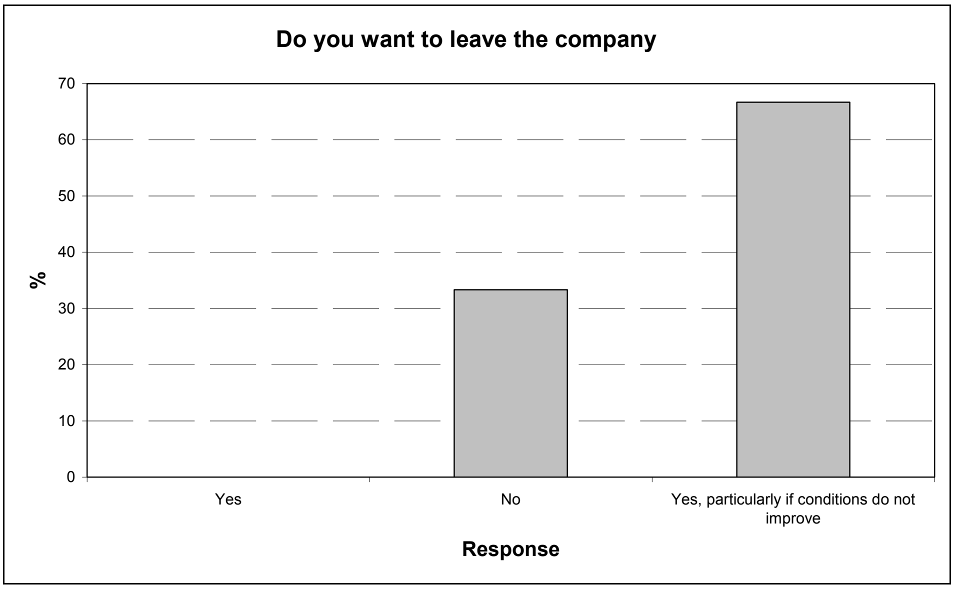
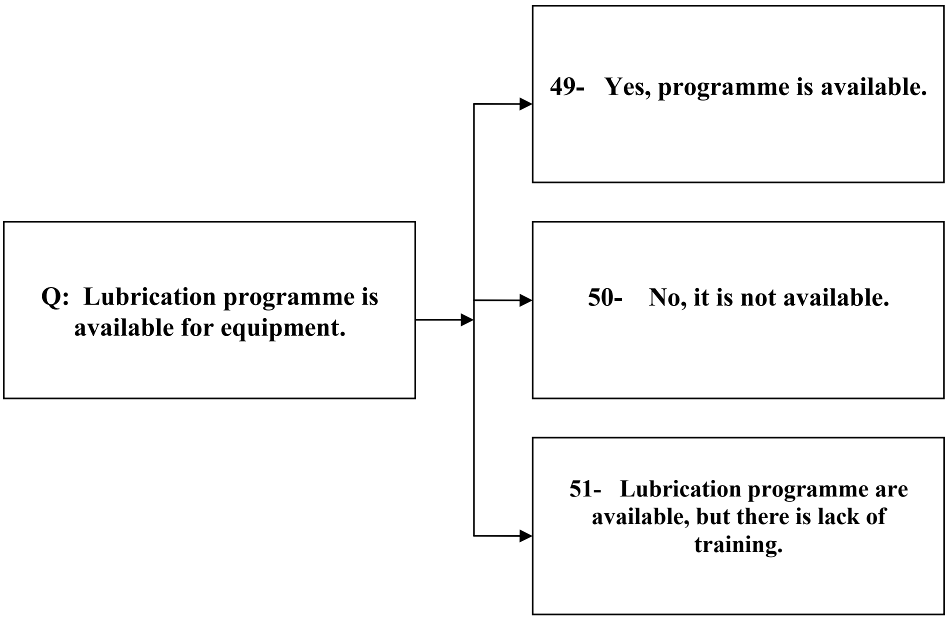


Figure 8-16: Would you like to move to another job?

As Figure 8-16 above shows, more than 60% of the total number of surveyed managers and engineers believed that there is a need to move to another occupation. Thus the majority of engineers are not happy with their job situation. The author suggested this early in chapter 7 (see questionnaire surveyed question number 27). (EF) defines that "*many managers do not pay sufficient attention to the need of their workers*".

Q q: Is a lubrication programme available for the equipment?

Table 8-17: Lubrication programme is available for the equipment.



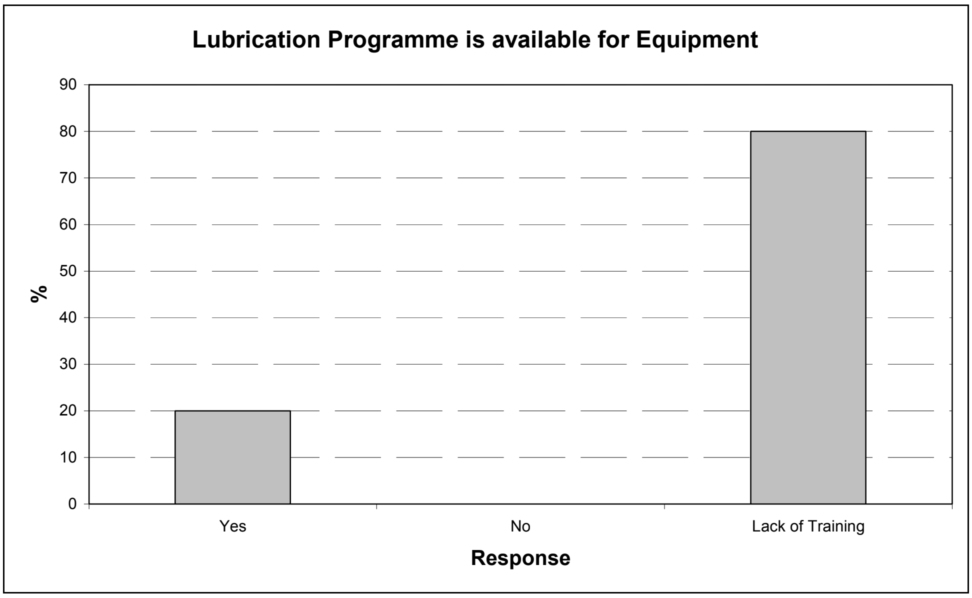
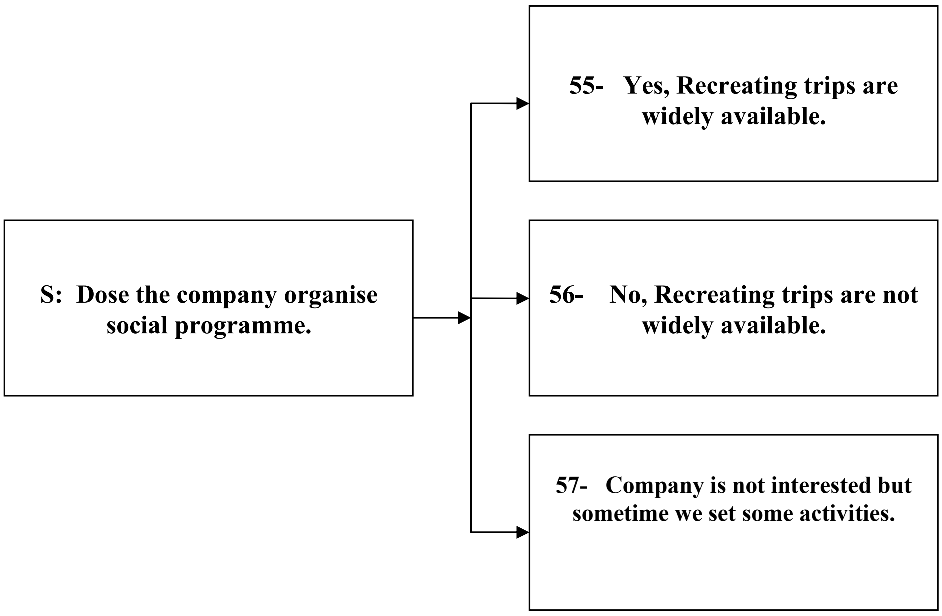


Figure 8-17: Lubrication programme is available for the equipment.

From Figure 8-17 It can see clearly that the majority (up to 80%) of the managers and engineers consider that the programme is available, however there is a lack of trained staff. According to (EA) "*the lubrication programmes are available, but there is a lack of training*".

Q S: Are there recreational programme/trips organised by the factory?

Table 8-18: Does the company organise a social programme?



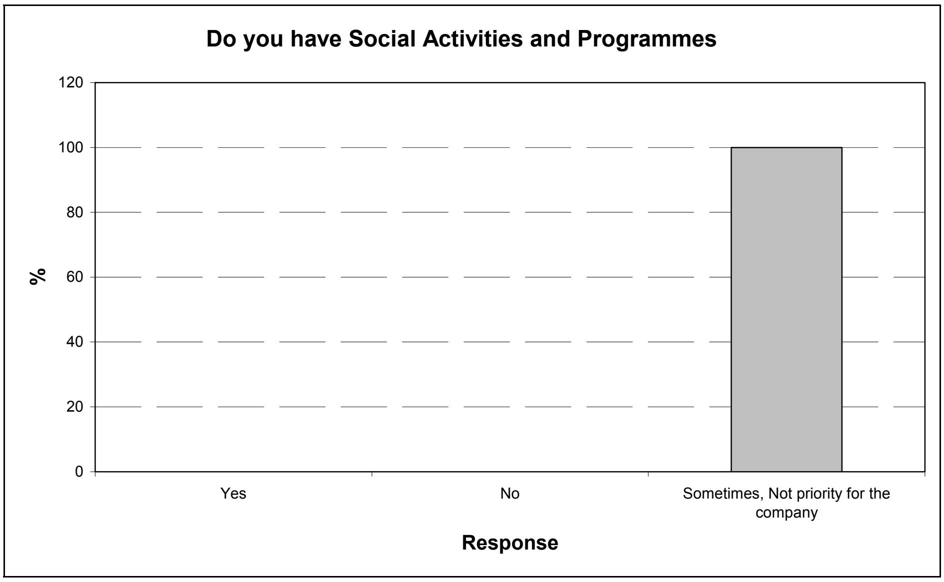


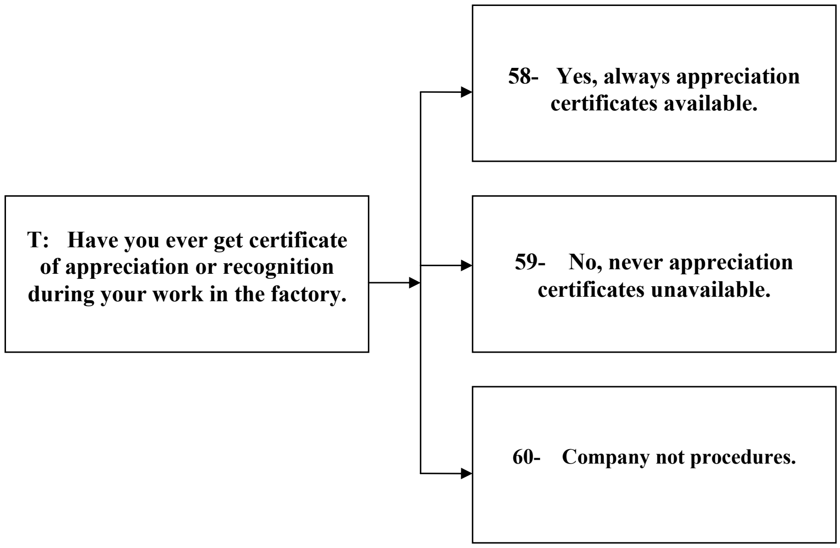
Figure 8-18: Does the company organise a social programme?

All of the middle management and engineers (100%) believe that there is no entertainment at all in the factories. However; this indication led to a decrease in the productivity of the factories, result shown in the previous chapter 7 (Questionnaire surveyed question number 29).

(EI) suggests that "*the top managers in NCC are not interested, but sometimes we set some activities, but the workers are not happy*". It can be stated that the top management need more training and education in social programmes in general.

Q T: Have you received any certificate of appreciation during the period of your work?

Table 8-19: Have you ever received a certificate of appreciation or recognition during your work in the factory?



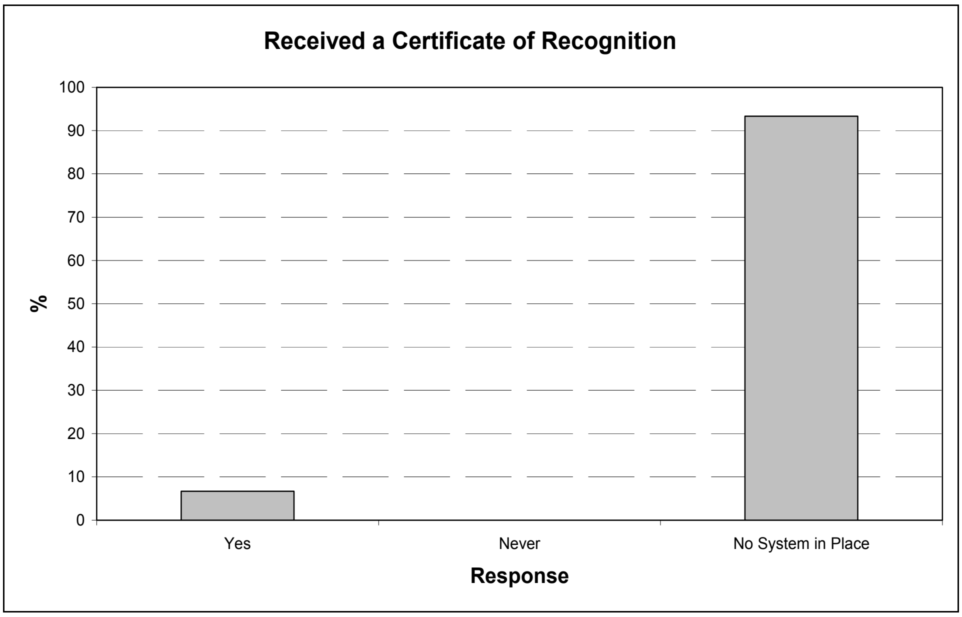


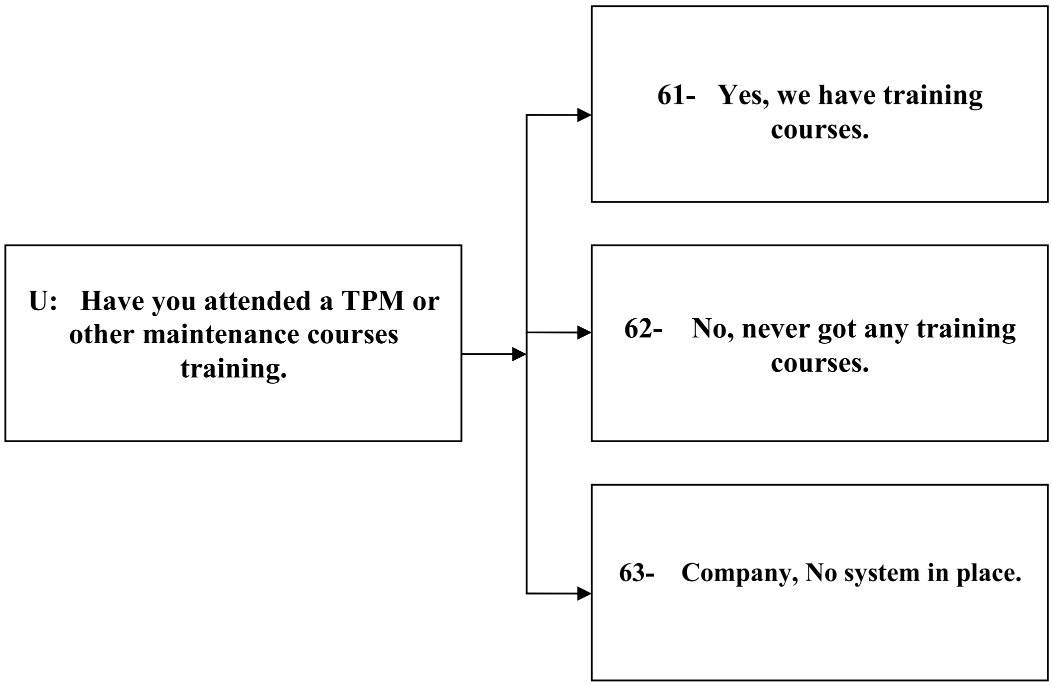
Figure 8-19: Have you ever received a certificate of appreciation or recognition during your work in the factory?

Figure 8-19 shows that the majority of middle management and engineers (almost 90%) is unsatisfied about NCC not producing any motivation such as a certificate.

As seen in the previous chapter 7(see Questionnaire surveyed question number 30), the company does not produce anything like this. (EO) argues that “many *people* who have *worked in NCC for more than 20 years unfortunately do not receive any certificates of thanks .This could lead the factories to drop productivity*”. Many managers do not pay sufficient attention to the needs of their employees and this has maybe led to a productivity decline.

Q U: Do you have any knowledge of TPM strategies?

Table 8-20: Have you attended a TPM or other maintenance course training?



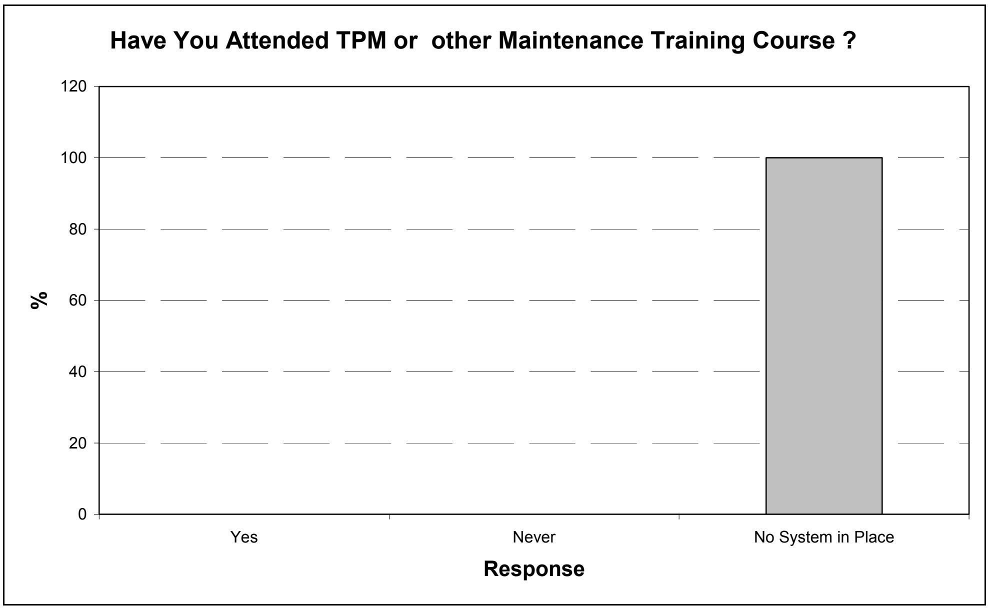


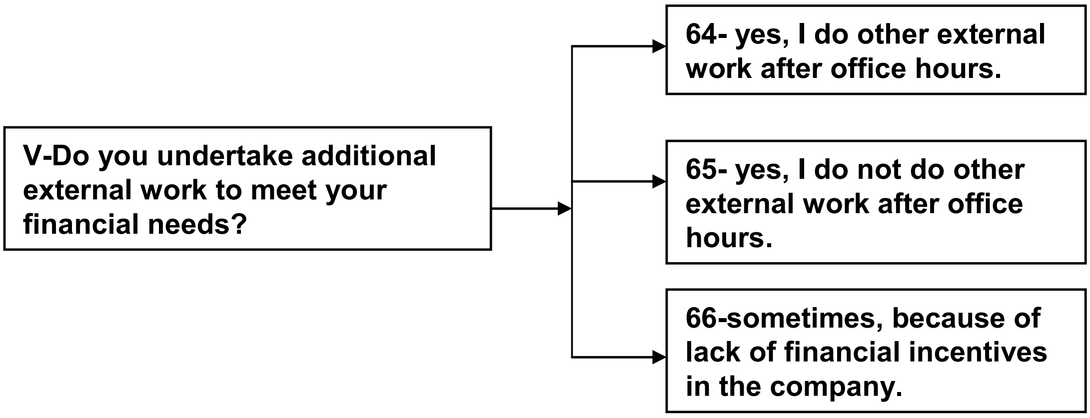
Figure 8-20: Have you attended a TPM or other maintenance course training?

As shown in Figure 8-20, almost 100% of middle management and engineers in NCC do not have any idea or information about TPM strategies. Also we can see that all of the workers in the previous chapter 7(Questionnaire surveyed question number 33) agree with this result.

The author mentioned this early in chapter 3 (see this for more details about how important it is to use in the factories). On other hand (EK) states "*that actually none of the engineers have any idea about TPM because there is a lack of training, education and knowledge*".

Q V: Do you undertake external work to meet your financial needs?

Table 8-21: Do you undertake additional external work to meet your financial needs?



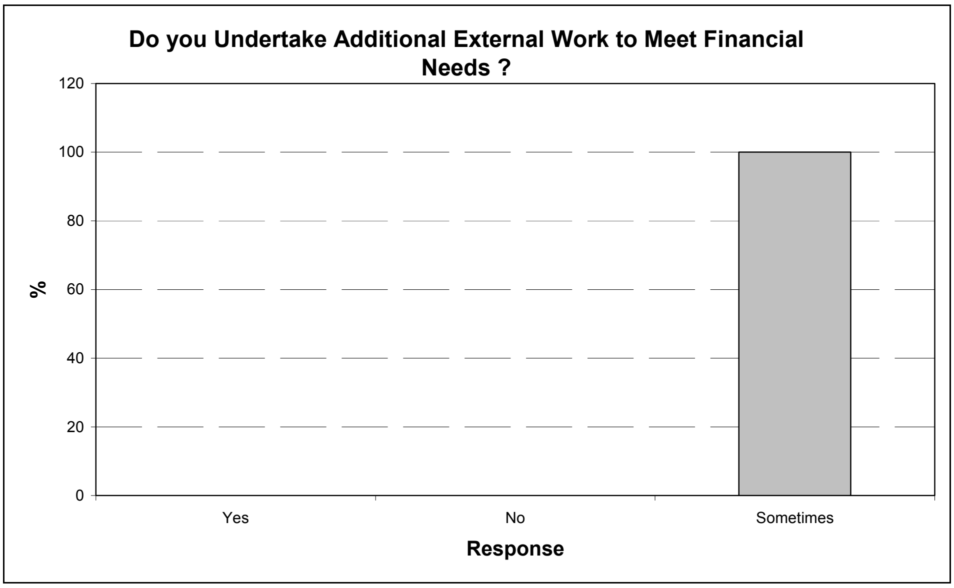
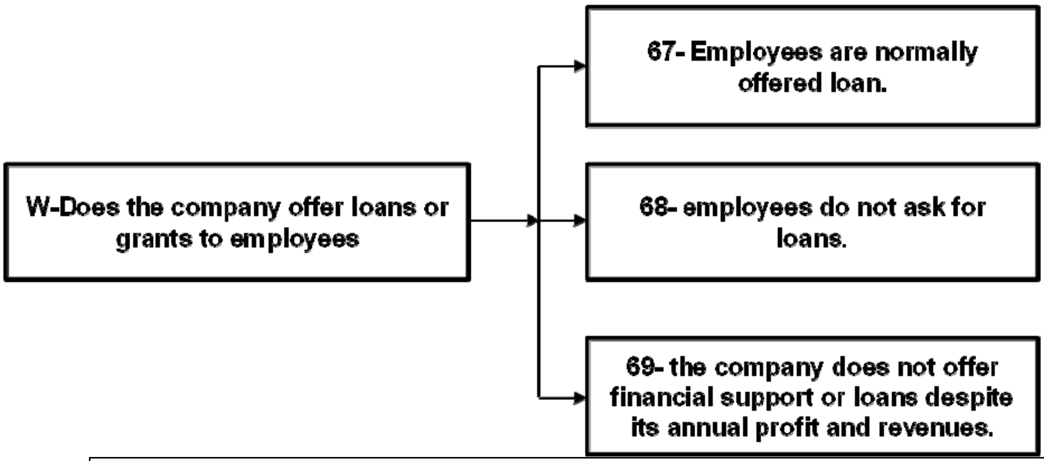


Figure 8-21: Do you undertake additional external work to meet your financial needs.

From Figure 8-21 above, it is clear that all (100%) of middle management and engineers in NCC believe that the salary is very low. This consequence agrees with the previous chapter 7(questionnaire surveyed question number 35). In addition (EC) maintains that" *the salary of the vast majority of employees is insufficient*".

Q W: Does the company offer loans or grants to employees?

Table 8-22: Does the company offer loans or grants to employees?



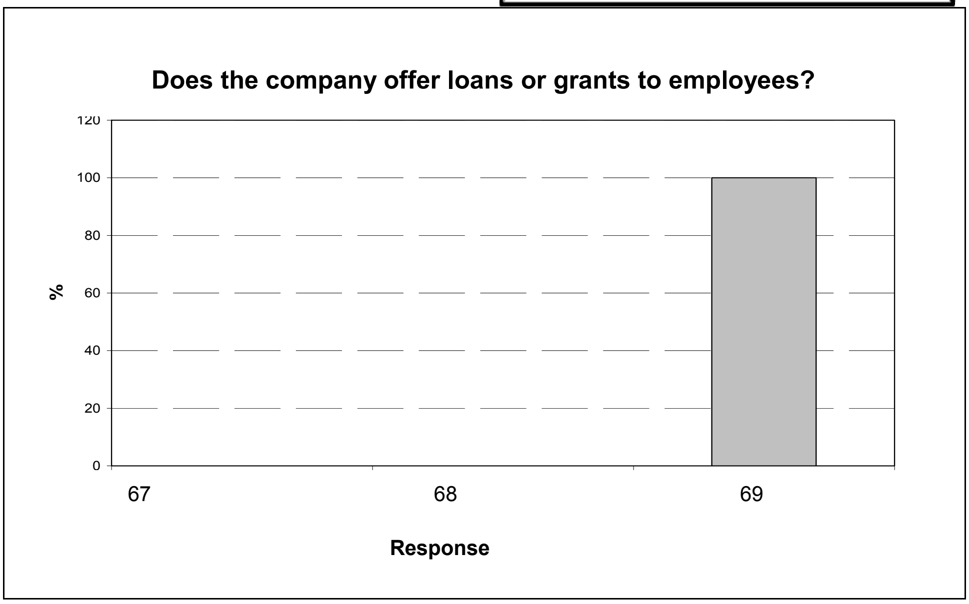
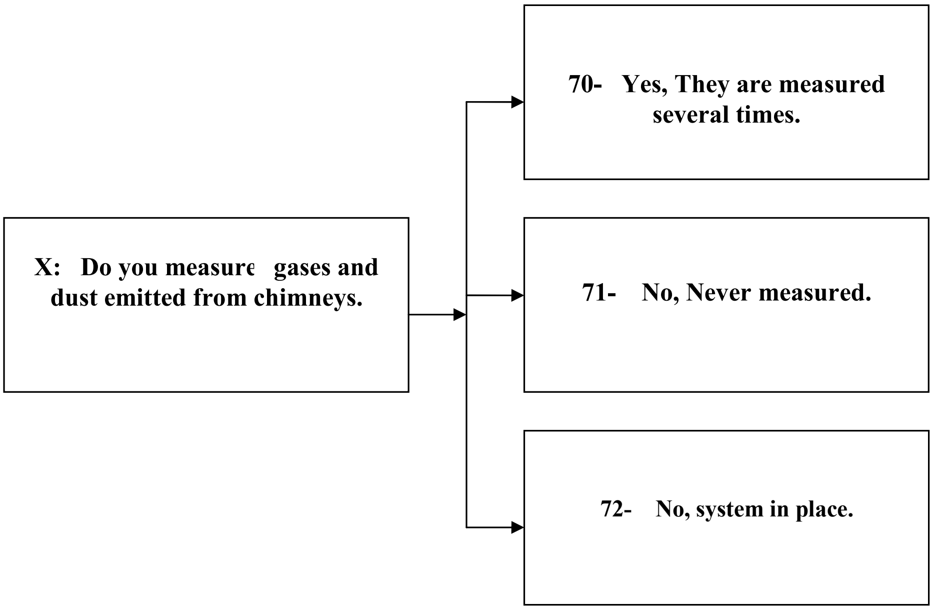


Figure 8-22 : Does the company offer loans or grants to employees?

From Figure 8-22 it is clear that among all interviewees, they argued that the company does not provide loans or financial support.

Q X: Do you measure the waste gases and pollution levels emerging from the chimney?

Table 8-23: Do you measures gases and dust emitted from chimneys?



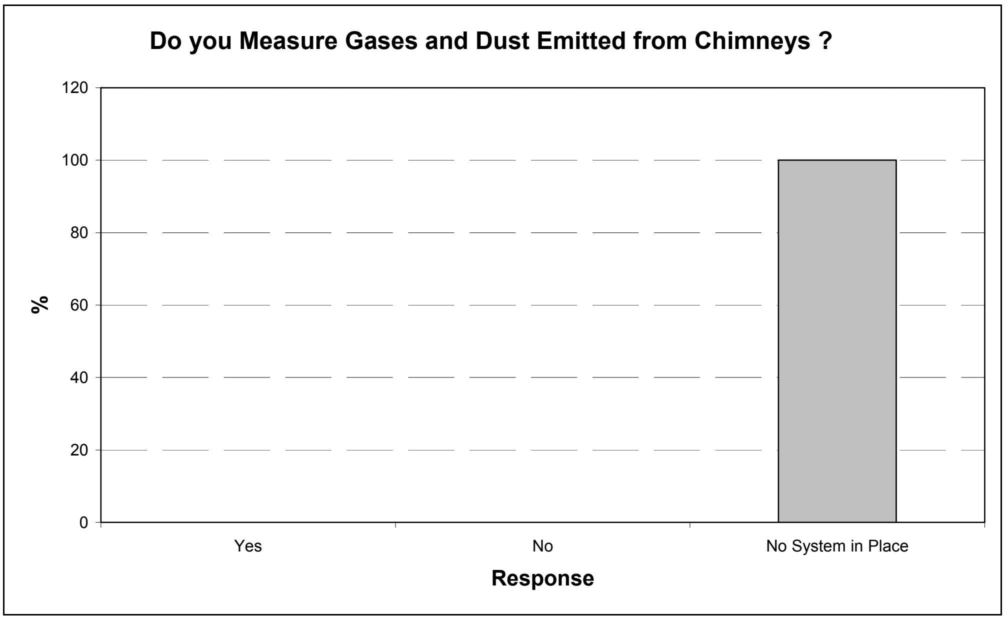


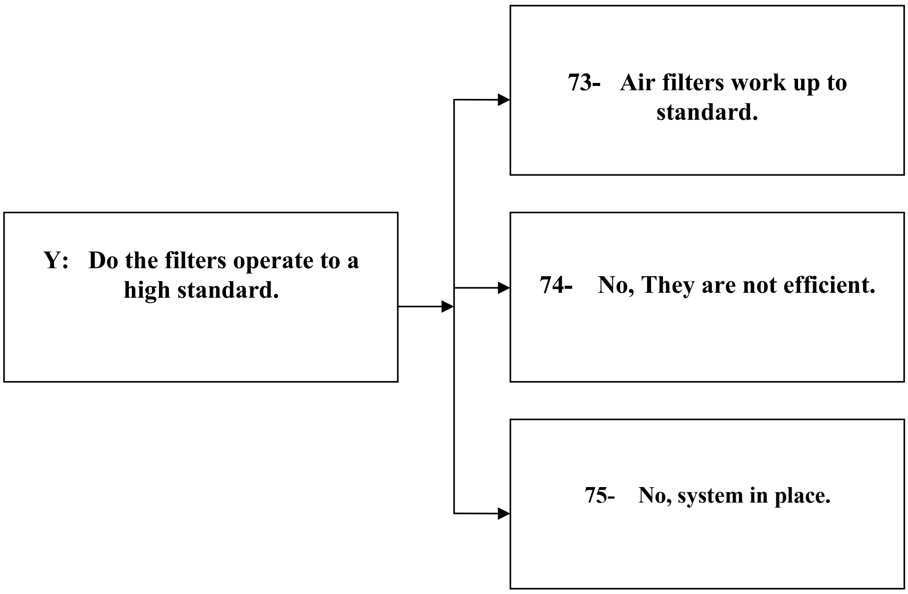
Figure 8-23: Do you measure gases and dust emitted from chimneys?

Figure 8-23 demonstrated the measurement of gases and dust emitted from chimneys. 100% of the middle management and engineers believe that no gases are measured by gauges or instruments. This result agrees with previous chapter 7 (questionnaire surveyed question number 40).

According to (EB) "*every time we asked about gauges or instruments to use in the factories we get no reply*".

Q Y: Do the filters operate to a high standard?

Table 8-24: Do the filters operate to a high standard?



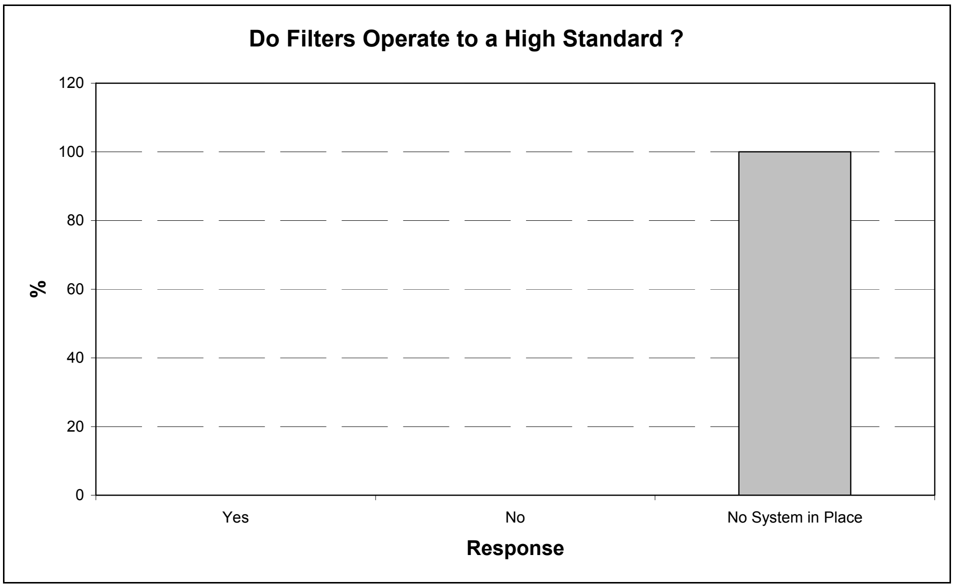


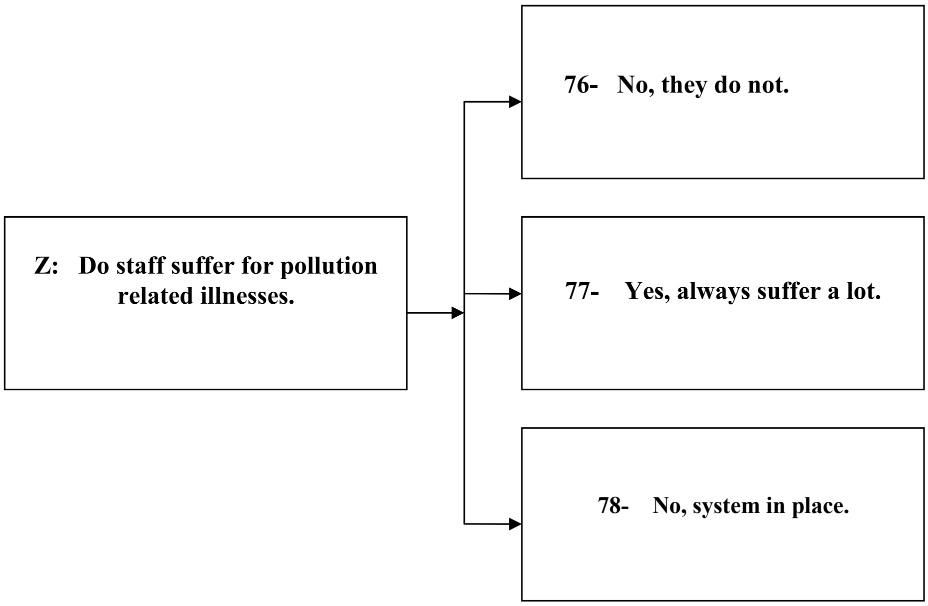
Figure 8-24: Do the filters operate a high standard?

Figure 8-24 shows that all of the middle management and engineers in NCC believe that there is a large amount of dust throughout the factories. This means that all filters do not operate at a high standard. Therefore, this agrees with the previous chapter 7 (questionnaire surveyed question number 42).

Moreover, (EJ) said *"for many years we have not repaired or made any maintenance to the filters".* As the researcher discovered during the field visits in (September 2007) there is much dust everywhere which is affecting the environment and natural life.

Q Z: Did you have any training to deal with an emergency situation (health and safety training)?

Table 8-25: Do staff suffer from pollution related illnesses?



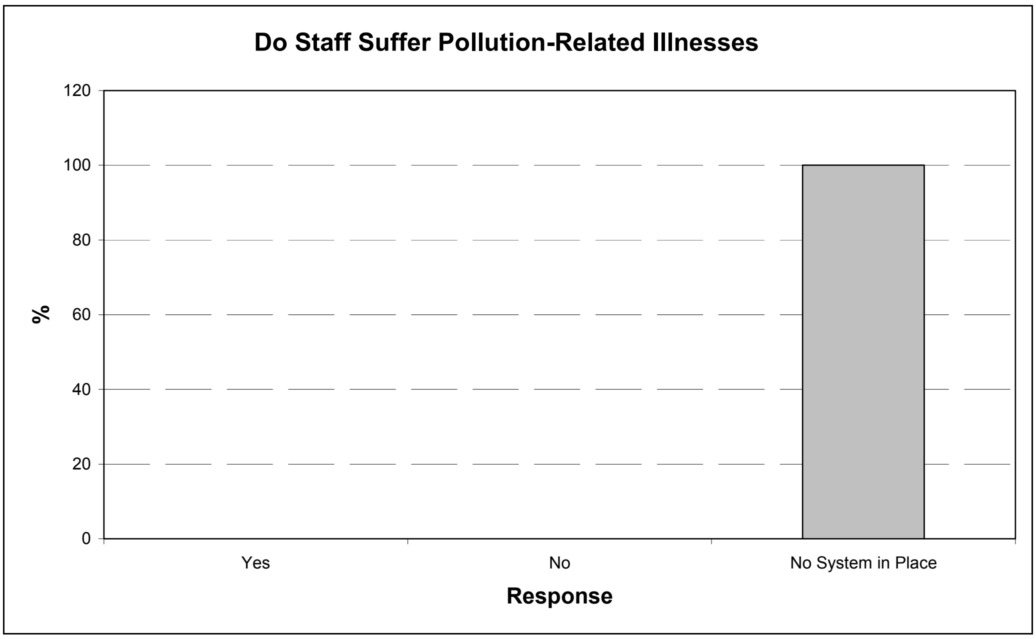


Figure 8-25: Do staff suffer from pollution related illnesses?

As shown in Figure 8-25, 100% of the respondents believe that the environment surrounding the factories contains very bad conditions. This result agrees with previous chapter 7 (see Questionnaire surveyed question 40), that gives a negative factor of NCC. The survey shows that there are many pollution related illnesses. (EK) states *"that there is a high level of pollution in the geographical location around the factories*".

The results of the interviews are summarised based on the options of the above Figures and the results of the interviews are summarised in Tables 8-26 and 8-27.

Table 8-26: Questions A to M.

Interviewee Number	Questions A to M												
	A	B	C	D	E	F	H	G	I	J	K	L	M
1	3	6	9	12	13	18	20	23	27	30	31	35	38
2	3	6	9	12	15	18	21	24	26	30	33	36	39
3	3	4	9	12	15	18	21	24	26	30	33	36	39
4	3	6	9	12	15	18	21	24	26	30	33	36	39
5	1	4	7	11	15	16	20	24	26	30	33	35	37
6	3	6	8	12	15	18	21	24	26	30	33	36	39
7	1	6	9	12	15	18	21	24	26	30	33	36	39
8	3	6	9	12	15	18	21	24	26	30	33	35	39
9	1	4	7	11	15	16	20	24	26	30	33	36	37
10	3	6	9	12	15	16	21	24	26	30	33	36	39
11	3	6	9	12	15	18	21	24	26	30	33	36	39
12	1	6	8	12	15	18	21	24	26	30	33	36	39
13	1	4	7	11	15	16	20	24	26	30	33	35	37
14	3	6	9	12	15	18	21	24	26	30	33	36	39
15	3	6	9	12	15	18	21	24	26	30	31	36	39

Table 8-27: Questions N to Z

Interviewee Number	Questions N to Z												
	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	41	43	47	51	54	57	58	63	66	69	72	75	78
2	42	45	48	51	54	57	60	63	66	69	72	75	78
3	42	45	48	51	54	57	60	63	66	69	72	75	78
4	42	45	48	51	54	57	60	63	66	69	72	75	78
5	42	45	47	49	54	57	60	63	66	69	72	75	78
6	42	45	48	51	54	57	60	63	66	69	72	75	78
7	42	45	48	51	54	57	60	63	66	69	72	75	78
8	42	45	47	51	54	57	60	63	66	69	72	75	78
9	42	45	47	49	54	57	60	63	66	69	72	75	78
10	42	45	48	51	54	57	60	63	66	69	72	75	78
11	42	45	48	51	54	57	60	63	66	69	72	75	78
12	42	45	48	51	54	57	60	63	66	69	72	75	78
13	42	45	48	49	54	57	60	63	66	69	72	75	78
14	42	45	47	51	54	57	60	63	66	69	72	75	78
15	41	45	48	51	54	57	60	63	66	69	72	75	78

8.4 Conclusion

This chapter has outlined the interviews with fifteen middle managers and senior engineers from the four factories. The results are in-line with those from questionnaires given to the shop-floor staff. There is lack of clear strategy in production, maintenance, environment, health and safety, and the personal development of staff.

CHAPTER 9: The Assessment of the Dynamic Nature of Cement Production Using Computer Simulation

Abstract

This Chapter investigates the dynamic nature of cement production using discrete-event simulation. It investigates the use of computer simulation for evaluating the performance of Cement Production in *Libda* Cement Factory (LCF) as a case study, and evaluates non-productive time within the factory. The author, during two field visits, monitored the production process and collected statistical data regarding the complete production line, which is used in this chapter to simulate the complete production line. The purpose of this chapter is to compare the results of simulation with statistical data presented in previous chapters to estimate the non-productive time of the factory using actual data and the simulated model and to study the transient response of the kiln as a key and critical stage within the factory.

9.1 Introduction- Productivity and the Need for Simulation

Because of the natural changes in material type, the statistical nature of the time needed for each process and the probability of breakdown, it became important to use a suitable tool to model the factory. This was done in order to understand the criticality of each stage and the most suitable tool to improve it and to address any major problems including identifying bottle-necks within the production system. It has been found difficult to study the complete cement production using mathematical models or simple spread sheets due to the probabilistic nature of the problem. In order to understand the current cement factory condition in Libya, Simprocess software has been implemented for process mapping and to simulate the workflow in every stage of the factory, including the transportation process. Simulation is important with the increasing of randomness and interdependencies between different activities within the factory. Using simulation allows the author to estimate the output of the complete factory and to determine the non-productive time associated with specific production levels.

Computer simulation has gained popularity in recent years for evaluating production systems; this is partly due to the availability of computers and improvements in simulation programming languages. According to Roger (1991), the process of describing complex realistic manufacturing systems using only analytical or mathematical models can be difficult. This is mainly due to the probabilistic nature of real systems and interconnectivity between stages. Ruzela et al (2009) stated that simulation is a technique for experimenting models of actual or imaginary systems. It allows researchers to manipulate parameters and to observe the impact of any modification on the model. The most significant advantage of using simulation is the saving of money and time Andrew (2004). It can also find complex relationships between different factors that could influence the system. In this chapter, Simprocess software is used to simulate the ideal operation of the factory using actual statistical data collected by the author it is also used to study the transient response of the kiln following a breakdown. Then a non-productive time is introduced to evaluate the effect of the changes on the system and to note any bottlenecks that could be produced. In general, simulation is carried out using three main stages:

1. Building the model using realistic data.
2. Running the model and comparing the simulated results with the actual system to analyse the performance measures.
3. Evaluating alternative scenarios and analysing similar performance measures.

Process simulation allows the representation of complex, random and dependent processes and activities in a dynamic computer model. Manufacturing processes are much too complex and dynamic, (as a function of time and dependency of activities) to be understood and assessed using flowcharts or spreadsheets.

9.2 Simprocess Software

Simprocess is integrated process simulation software that is used for process modelling and analysis. SIMPROCESS software provides building blocks for constructing dynamic manufacturing models, with the capability to introduce expression language to add more complicated business scenarios and logic. It has high capabilities to simulate different types of systems. It has been selected in this research work because it is simple to learn, easy to use, affordable, easy to implement and includes flexible output formats. It also has high capabilities to simulate different types of systems.

The most critical step in simulation is building the model to represent real life scenarios. The basic modelling system of Simprocess is shown in Figure 9-1.

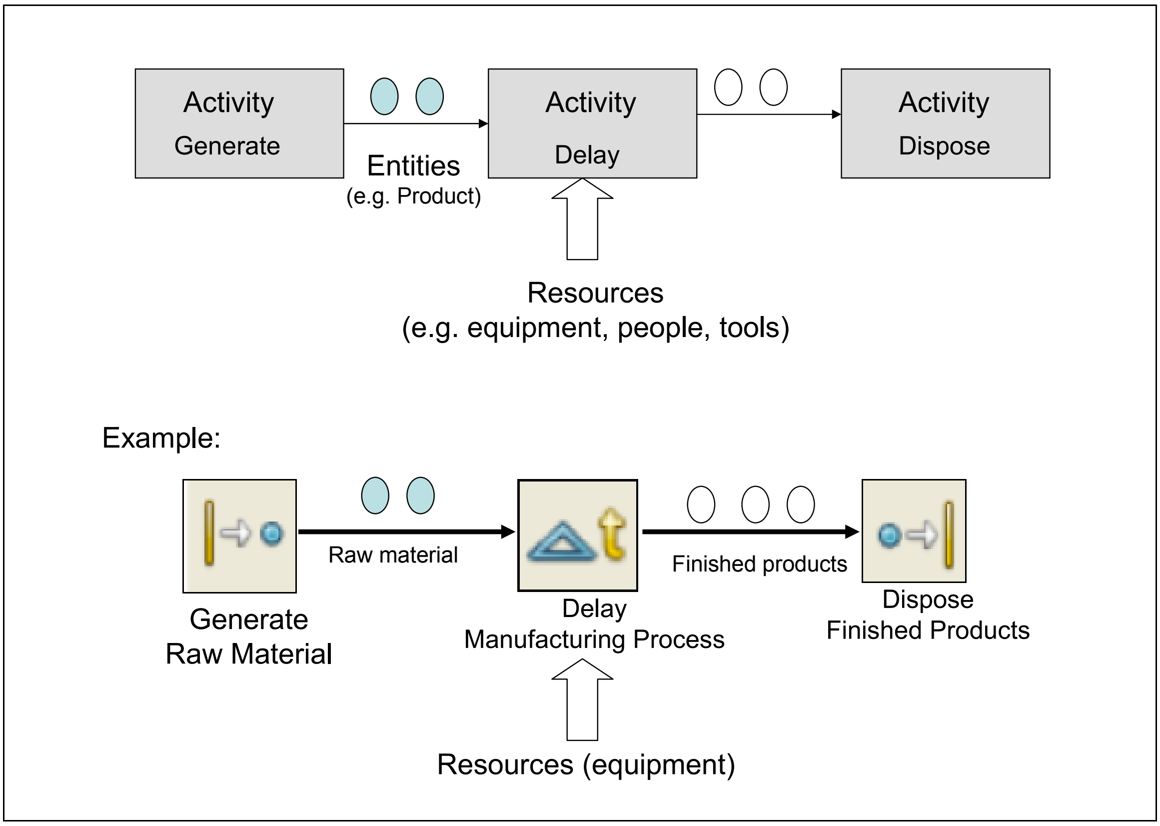


Figure 9-1: Simprocess basic modelling construct and the way they could be used in a simple manufacturing example.

Activities are the objects at the lowest level of the Simprocess hierarchy and they are used for modelling the behaviour of a process. *Entities* represent objects flowing through system such as products. *Resources* are used to define costs, capacity and interdependency associated with limited resources. Simprocess can also calculate costs using Activity Based Costing (ABS). Figure 9-2 presents the main activities that could be used to construct a Simprocess model. The activities that are used in this thesis will be described in this chapter as part of system description.

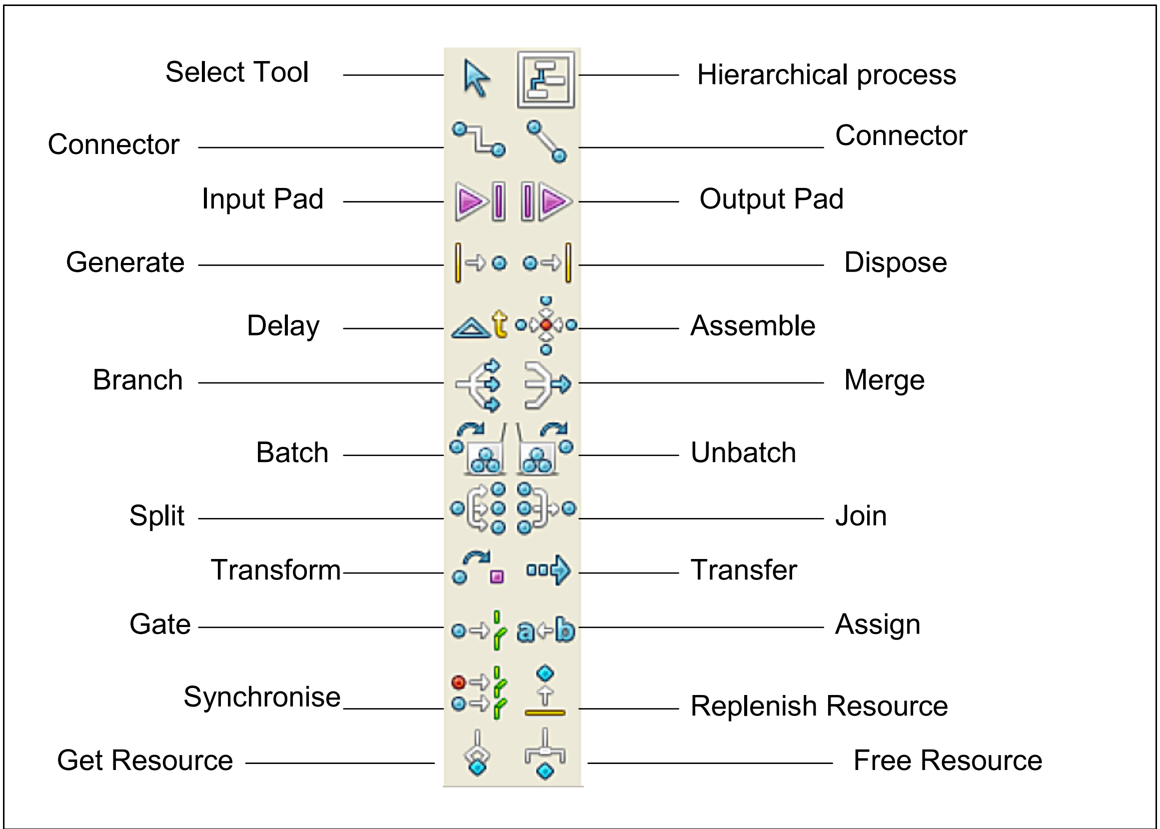


Figure 9-2: The main activities that could be used to construct Simprocess model.

Simprocess has been selected to simulate cement production for the following reasons:

1. The dynamic simulation and animation of entities enables the analyser to see how the cement (in Tonnes) moves with time. This will allow deeper understanding and appreciation of the dynamic nature of the problem.
2. The graphical interface is easier to follow and visualise than a spread-sheet.
3. The dependency between the activities can be simulated. For example, when a process has to wait for an entity to arrive from another process.

4. The Capacity aspect of the resources can be easily simulated by Simprocess and are more difficult to be simulated when using a spread sheet.
5. Analysis of the dynamic performance and transient response.

9.3 Cement Production and its Simulation

In Chapter 4 of this thesis the author has presented the main processes of cement production. Figure 9-3 gives a similar presentation of the overall production of cement and Figure 9-4 shows the complete hierarchical model of the cement factory.

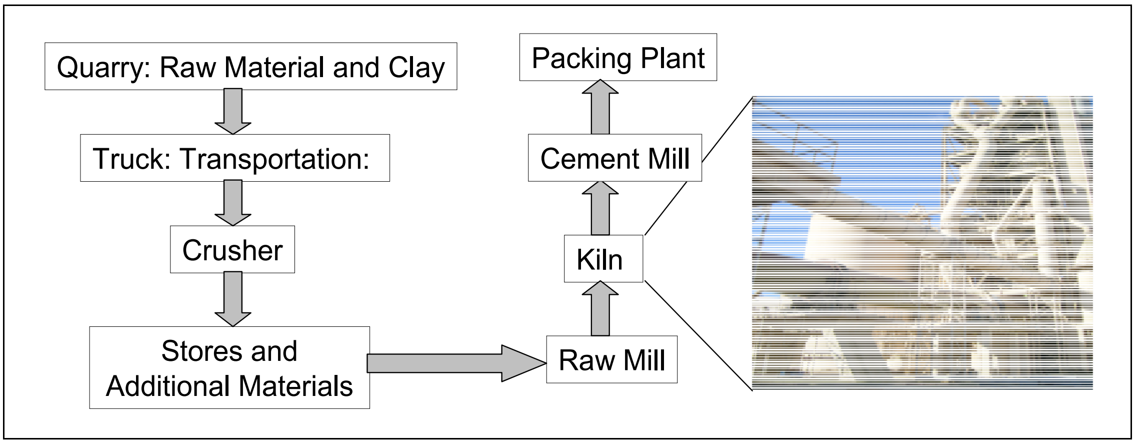


Figure 9-3: Outline of the main stages of cement production.

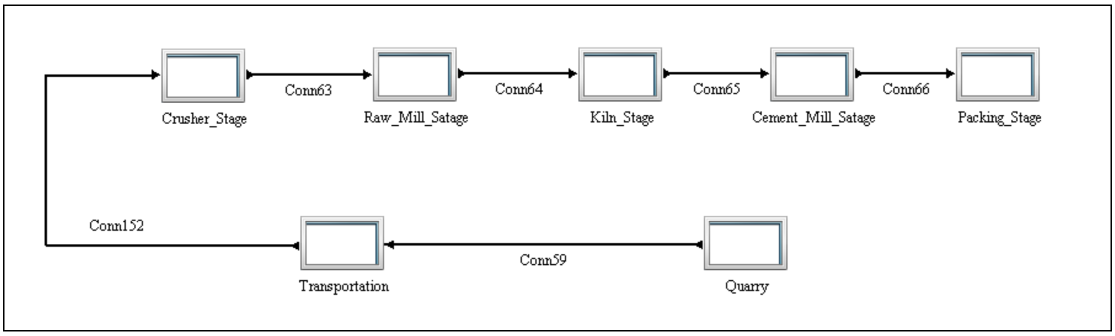


Figure 9-4: The complete Simprocess simulation of the Cement factory.

The first step in the Portland cement manufacturing process is obtaining raw materials which are mined from a quarry near the plant. The raw materials are then transported to the factory and reduced by primary and secondary crushers. Stones are first reduced to about 125-mm in size, then to 19 mm. The materials are dried and finely ground in a Raw Mill to form an intermediate product, called “raw mill”. The grinding provides an increased surface area to enhance the heat exchange in the downstream heating process. The “raw-mill” is then stored in a homogenising silo in which the chemical variation is reduced. This homogenising process is important to stabilise the downstream entering process as well as to provide a uniform quality product. The raw-mill is then transferred to the Preheating Tower. As presented in Figure 9-3, the kiln resembles a large horizontal pipe with a diameter of 3 to 4 meters and a length of 90 meters or more. One end is raised slightly. The material is placed in the higher end and as the kiln rotates the materials move slowly toward the lower end. Flame jets are positioned at the lower end and all the materials in the kiln are heated to high temperatures. The material following the Kiln is named ‘clinker’. The clinker burning process is a high temperature process. Clinker is then cooled and combined with gypsum and ground into a fine grey powder. The clinker is ground so finely that nearly all of it passes through a (75 micron) sieve. Quantity with a controlled amount of gypsum is fed into a finish mill. Typically, a finish mill is a horizontal steel tube filled with steel balls. As the tube rotates, the steel balls are lifted and they tumble and crush the clinker into a super-fine powder. The particle size is controlled by a high-efficiency air separator. At the packing stage where the cement under-goes its last steps at the plant, there are two processes the first is bagging and the other is for bulk despatch direct to the lorries.

The first attempt to simulate the process was to use code writing rather than resources approach to simulate the transient response of the kiln following a breakdown. In this case, the capacity of the activity was assigned as variable, and the variable value changes depending on the entities in or out of the system. Figure 9-5 presents an example of the implemented methodology to simulate the kiln using Simprocess with capacity variables. The Kiln processes and storage have been used as an example to present the innovation in this work. To speed the simulation processes the entity used throughout the system is ‘Truck’ capacity which is equivalent to 40 Tons. The entities will be transformed through the systems from Lime-Stones to Raw-Material, to Clinker and finally to Cement. When the entities (Truck) go through each activity, a delay process will be activated which is statistically modelled for each process based on the real data and information within the factory. Every activity is assigned to one or more resource. The software enables a code-writing facility to develop complex analysis, and in this work the author has developed a special code to direct each entity by using 'Branch' activity to continue through the production system, or to exit when the process is full or overloaded. In this case, the system will allow very accurate measurements of the activities in order to be able to estimate the capability of each system and to balance the lines as needed. Figure 9-5 presents the Kiln and the Clinker storage system simulation. As shown in Figure 9-6, it takes more than 15 hours for the Kiln to reach steady state value when all processes have stopped. Figure 9-7 shows the average quantity and the observed quantities within the system. Figure 9-7 presents the excessive quantities that are rejected from the system which proves that the Kiln is actually a bottle neck within the factory even with 100% availability. Figure 9-7 indicates that there are 70 trucks (2800 Tons) beyond the capacity of the Kiln in a 5 hour period. It is clearly indicated that the Kiln is a bottleneck within the factory. However, the average flow using this method was not realistic for the complete factory because of the lack of dependency between the flow lines and their capacity. However, the capacity variable system and the overflow were found useful in simulating parts of the system.

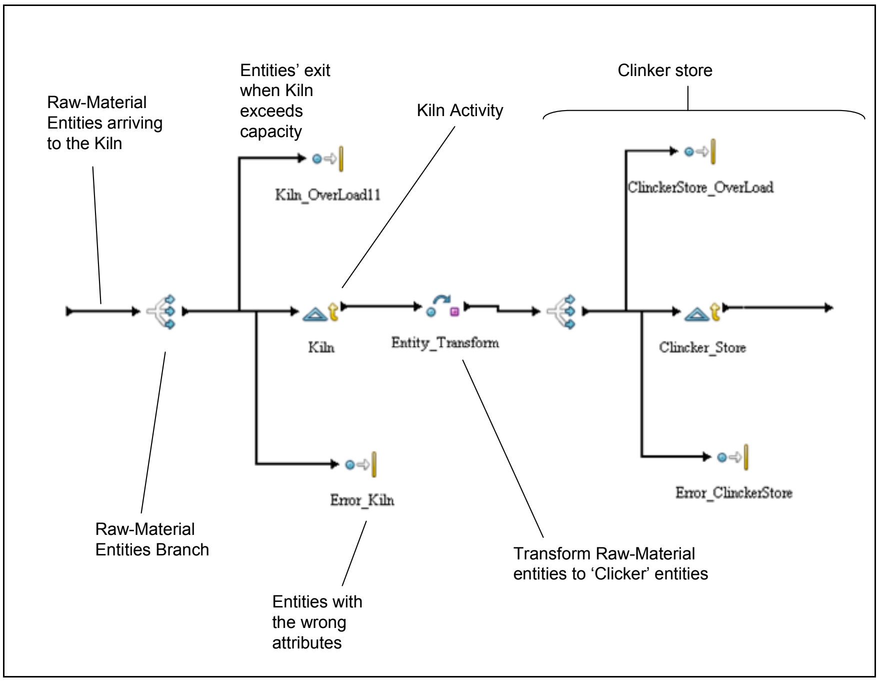


Figure 9-5: Simulation of the Kiln and the Clinker store activities.

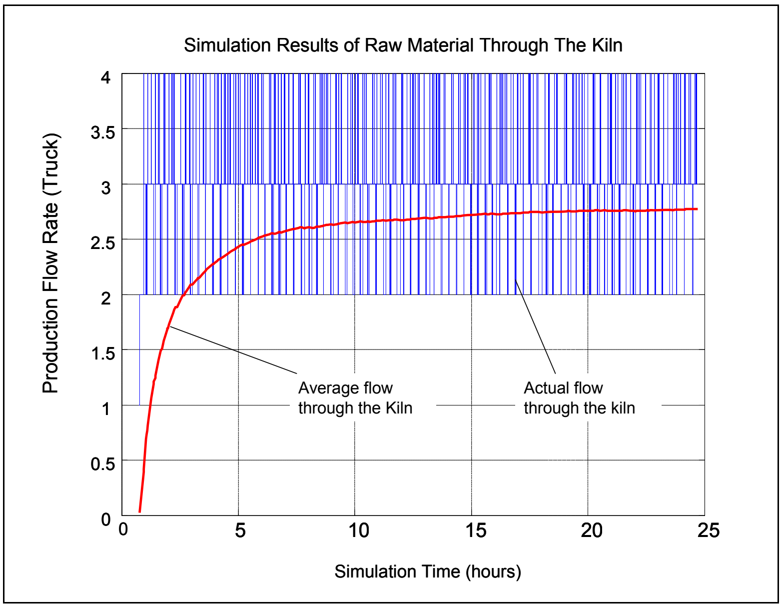


Figure 9-6: Simulation results of the Kiln

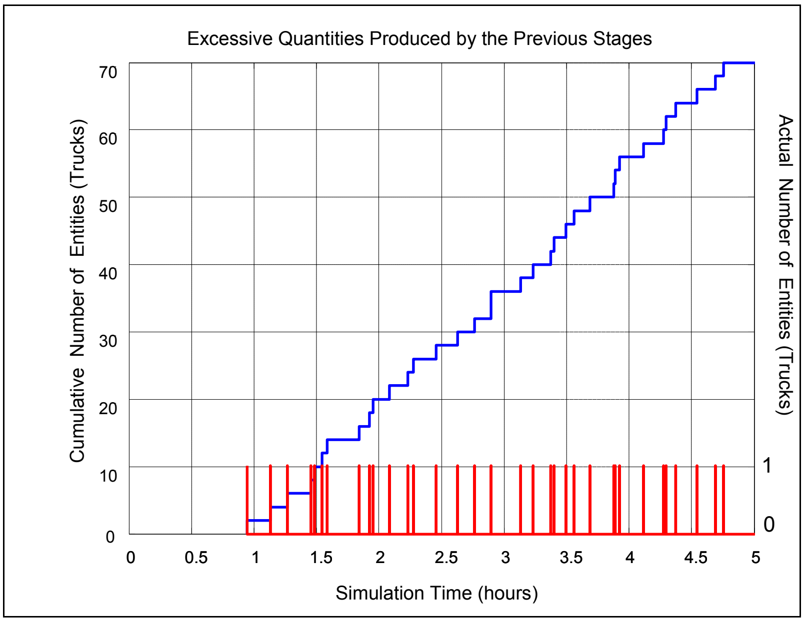


Figure 9-7: Excessive Production prior to the Kiln Stage which proves that the Kiln is a bottle-neck in the process.

But, it was found not efficient enough to simulate the complete system.

9.4 Simulation of the complete factory using resources-approach

For this purpose, a 'resource' was introduced for each activity which represents the equipment and the machine used with a capacity/quantity value related to the capacity of the machine.

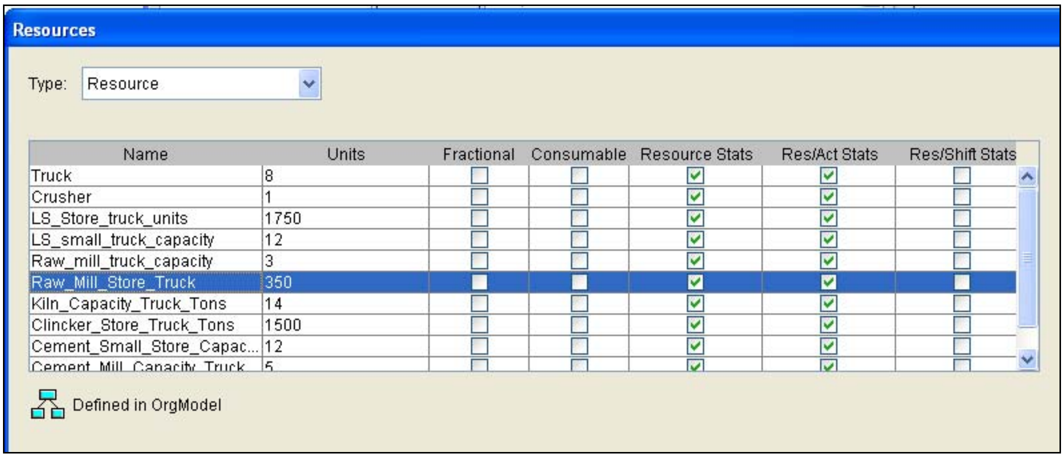


Figure 9-8: The Resource and capacity of the activities.

Figure 9-8 presents example of the resources using for each activity to simulate the production system. This has provided an improved version of the simulation methodology; it is more accurate in presenting the factory. Based on statistical data collected during the visits to LCF, the model was designed for an ideal capacity of about 1 M tonnes per annum. The design data and capacity has been used to simulate the ideal system. Simprocess software was used to simulate 1.1 M tonnes per annum output.

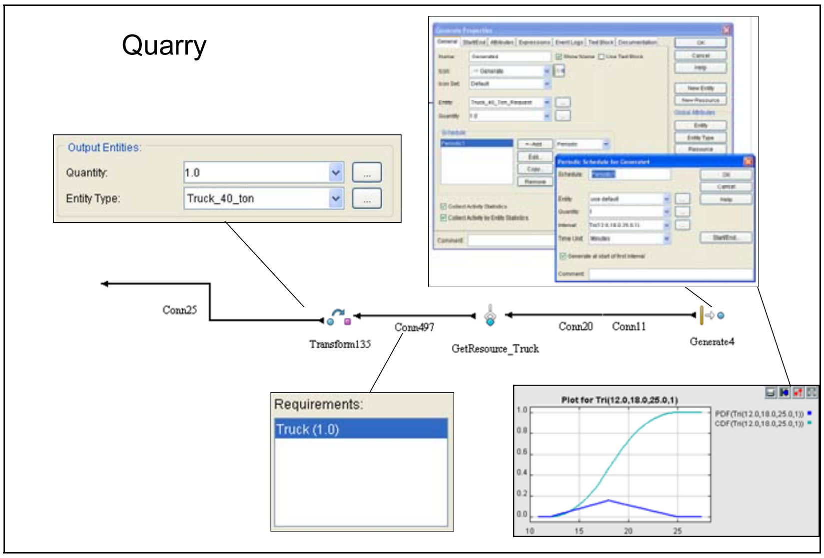


Figure 9-9: The Simulation of the Quarry stage

As shown in Figure 9-9, the Quarry stage starts with the 'Generate' activity with Tri(12.0, 18.0,25.0,1). This indicates a Triangular Distribution with minimum of 12 minutes, maximum of 25 minutes and a mode of 18 minutes. This generate command simulate the frequency at which trucks are able to leave the quarry with the raw data. There are eight trucks in total available in the factory. Each time a 40-tonne-truck leaves the quarry; its resource (truck) is removed from the resources available using (Get Resource) command until the truck goes back to the Quarry. The Generate command generates requests that are transformed into Truck_40_Ton entity using the 'Transform' command. The trucks work for 12 hours per day to carry the raw material to the cement factory. When the Trucks stop the crushers of the raw material also stops. However, the other parts of the factory continue to work.

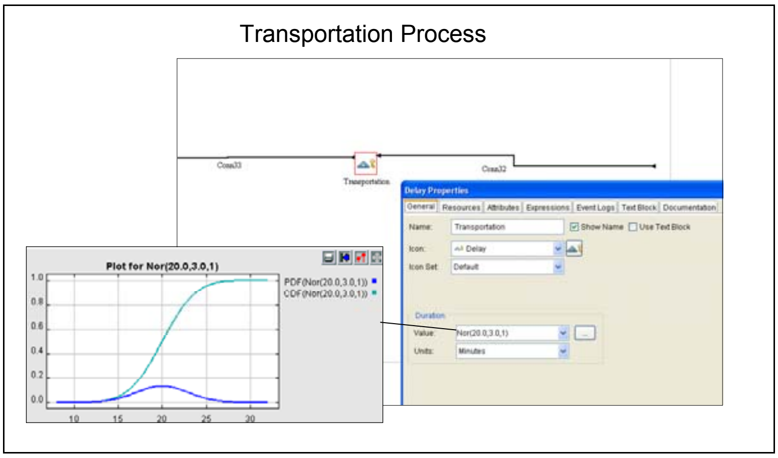


Figure 9-10: The Simulation of the transportation stage from the quarry to the factory

The transportation process is found to be a normal distribution of a an average of 20 minutes and a standard deviation of 3 minutes as shown in Figure 9-10. The Transportation activity is simply a delay activity with resources 'truck' which is already reserved from the previous stage.

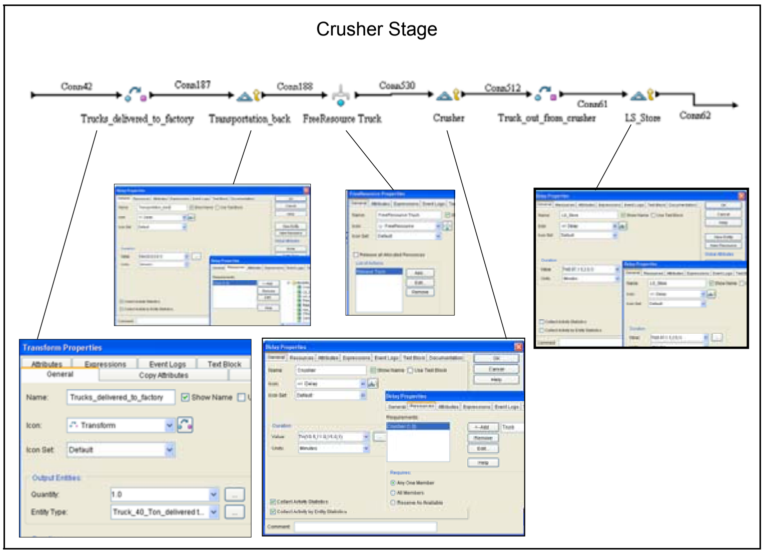


Figure 9-11: The Simulation of the Crusher stage.

Figure 9-11 presents the simulation of the Crusher stage. When the trucks arrive to the factory, their entity changes to 'Trucks_Delivered_to_Factory', this is to improve the understanding of the production line and trace the trucks effectively. In order to simulate the return trip of the truck back to the quarry, a delay process is introduced with normal distribution of an average of 20 minutes and a standard deviation of 3 minutes before the resource (Truck) is released from the system using 'Free Resource' command. The Crusher is then needs Tri(10.5,11.0,15.0,1) in order to process the raw material delivered (i.e. Triangular distribution of 10.5 minimum, Mode of 11 minutes and a maximum of 15 minutes). Then the entity is transformed to 'Truck_out_of_crusher' before transforming it to the Lime Stone Store 'LS_Store' delay activity with delay of Tri(0.87,1.5,2.0,1).

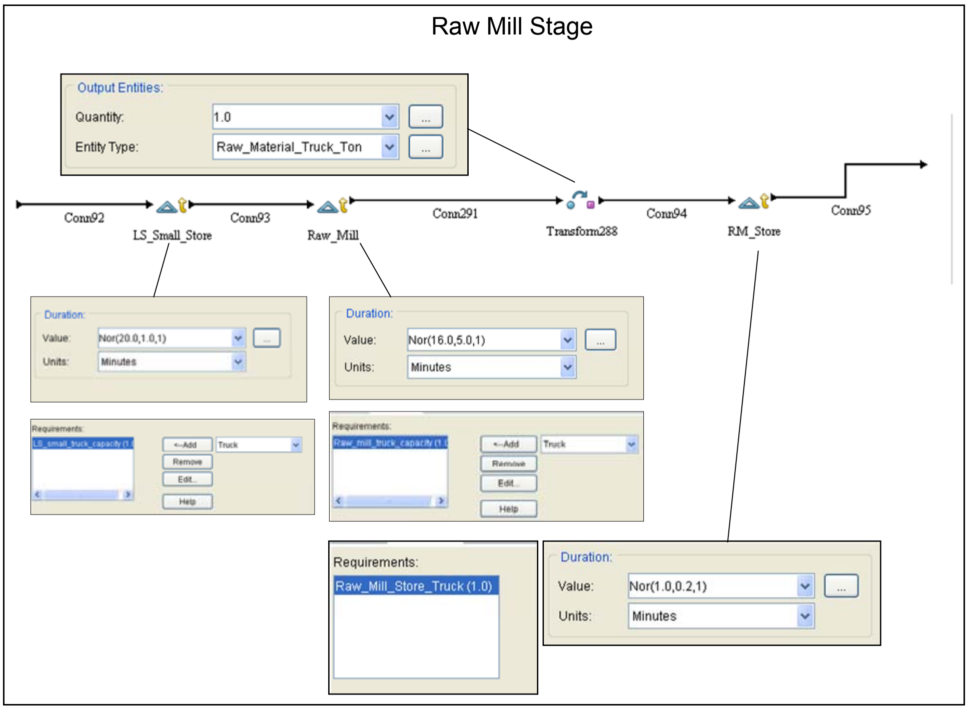


Figure 9-12: The Simulation of the Raw Mill Stage.

Figure 9-12 presents the Raw Mill Stage. The entities then moves into the small Lime Stone Store with Nor(20.0,1.0,1), Normal distribution of an average of 20 minutes and a standard deviation of one minute before moving the entities (40-Ton-Truck) material to the Raw Mill. Each 40-Ton Truck will need Nor(16.0,5.0,1) in order to process the raw material to fine powder. Then the default entity is changes to 'Raw_Material_Truck_Ton' before moving to the Raw Mill Store with takes Nor(1.0,0.2,1) to process each entity.

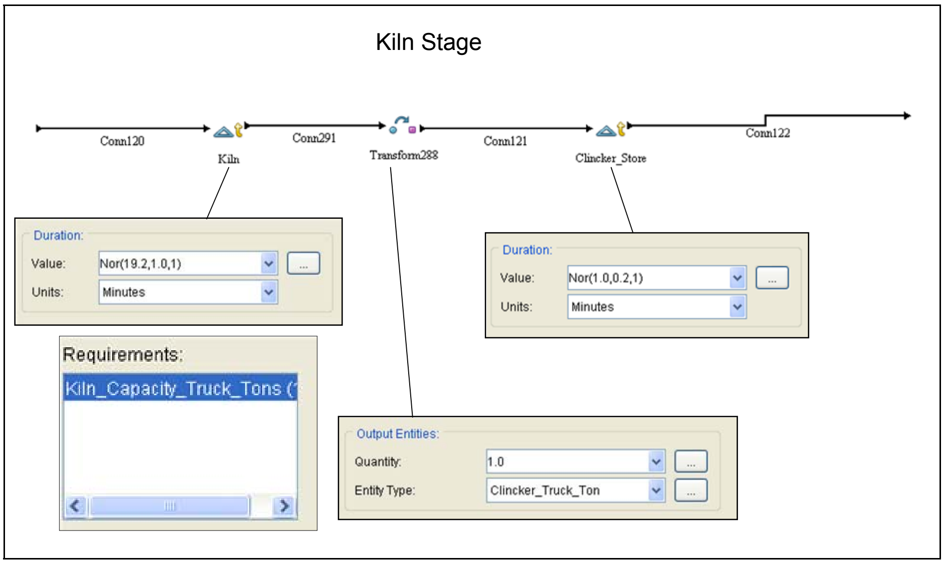


Figure 9-13: The Simulation of the Kiln Stage.

Figure 9-13 presents the Kiln Stage. The process starts with the Kiln delay process of Nor(19.2,1.0,1) minutes (Normal distribution with an average of 19.2 minutes and a standard deviation of one minute). The process uses the Kiln as a resource. After the kiln, the entities are transformed into ‘Clincker_Truck_Ton’ entity which is fed then to the Clincker Store with a processing delay of Nor(1.0,0.2,1).

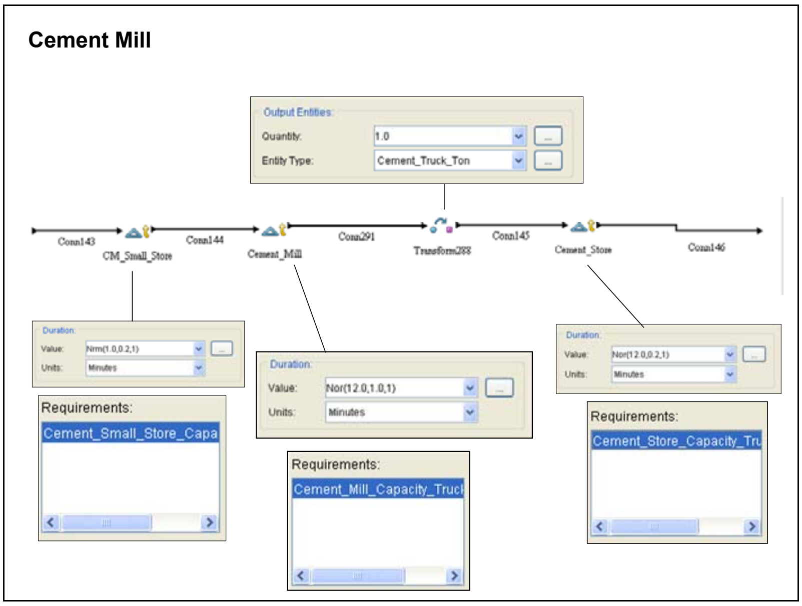


Figure 9-14: The Simulation of the Kiln Stage.

Figure 9-14 presents the Cement Mill Stage of the factory. The process starts with Cement Mill Small Store with delay of Nor(1.0,0.2,1). Following that the entities go to the Cement Mill with delay of Nor(12.0,1.0,1). Then the entities through the system are transformed into 'Cement_Truck_Ton' before transferred to the Dement Store with Nor(12.0,0.2,1).

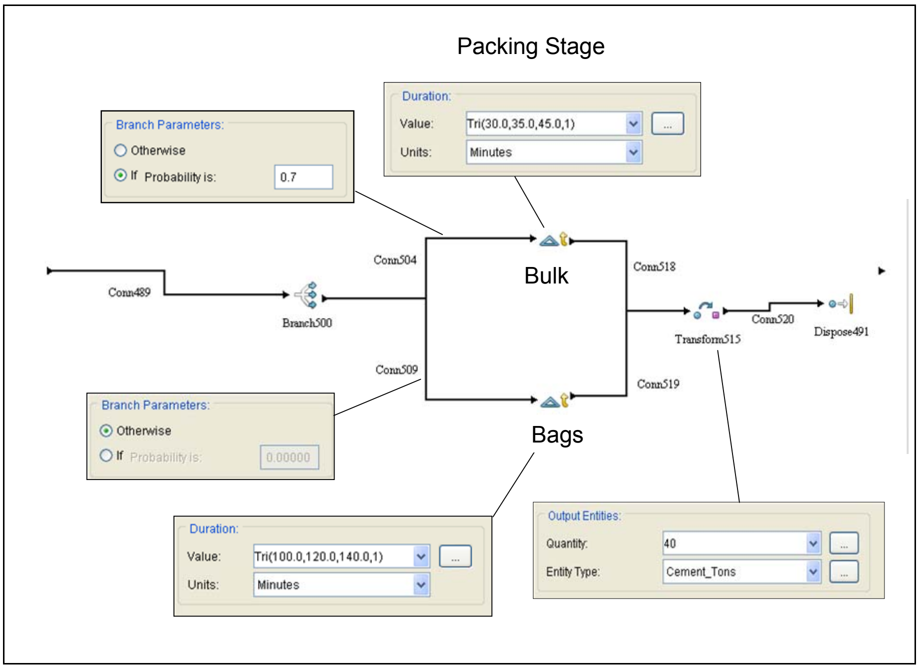


Figure 9-15: The Simulation of the Packing Stage.

Figure 9-15 presents the Packing Stage in the factory. The last stage of the factory is the Packing stage. 70% of the cement is processed using 'Bulk' packing system while 30% is processed using 'Bag' stage. The simulation is done using the 'Branch' command for this purpose. The Cement_Truck_Ton entity is then multiplied by 40 to get the quantity of production in Tonnes.

The system simulated a 1.1M tonnes per annum system. Figures 9-16 and 9-17 represent the 40-Tonnes truck count through the Kiln and the average flow. Notice the dynamic nature of the flow based on the arrival of raw material and the delivery of the products to the system. This dynamic behaviour is also evident from the Kiln cycle time for 40-Tonnes Truck value as shown in Figure 9-18. Also this is evident from the number of trucks out of crusher and the average number through the first 40 hours of operation as shown in Figure 9-19.

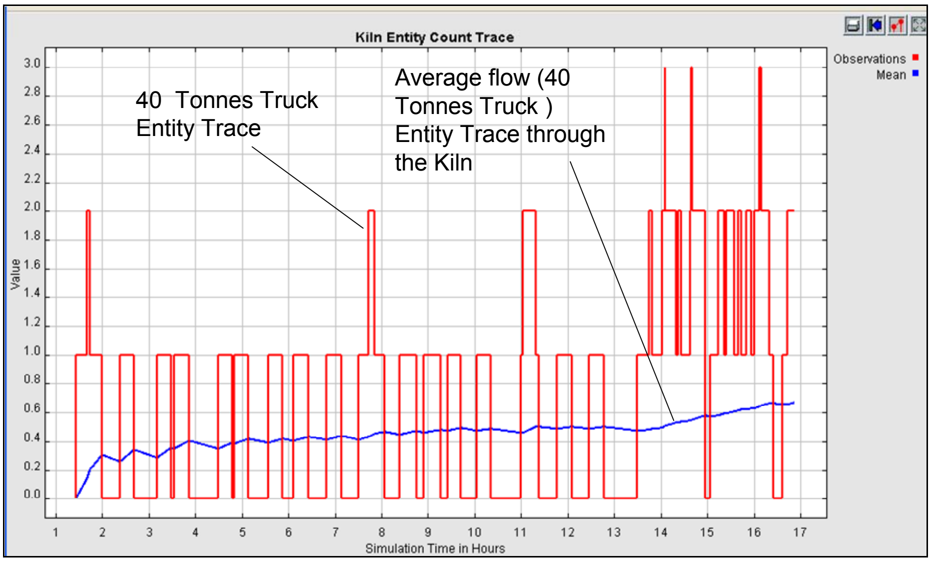


Figure 9-16: The 40-Tonnes truck count through the Kiln and the average flow.

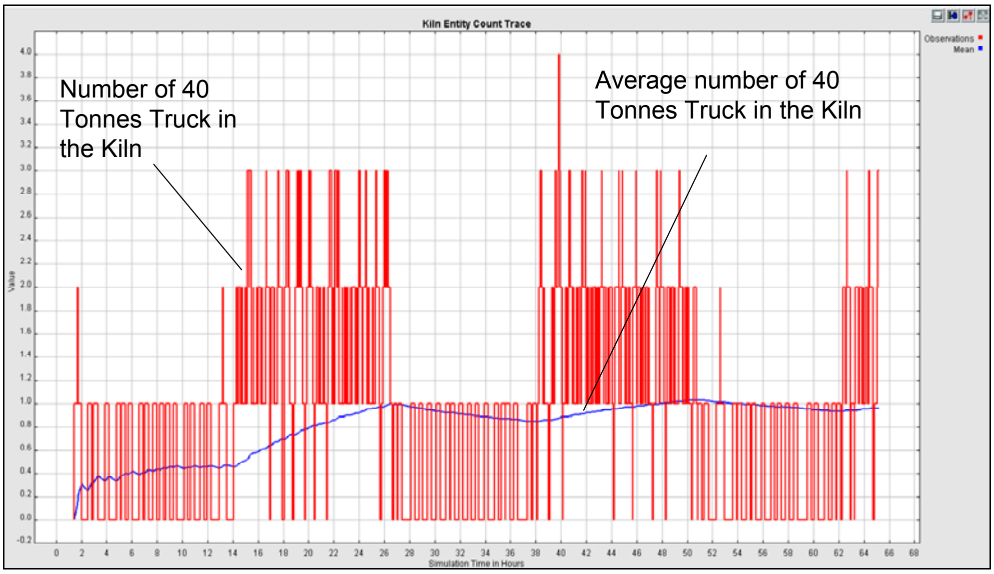


Figure 9-17: The 40-Tonnes truck count through the Kiln and the average flow.

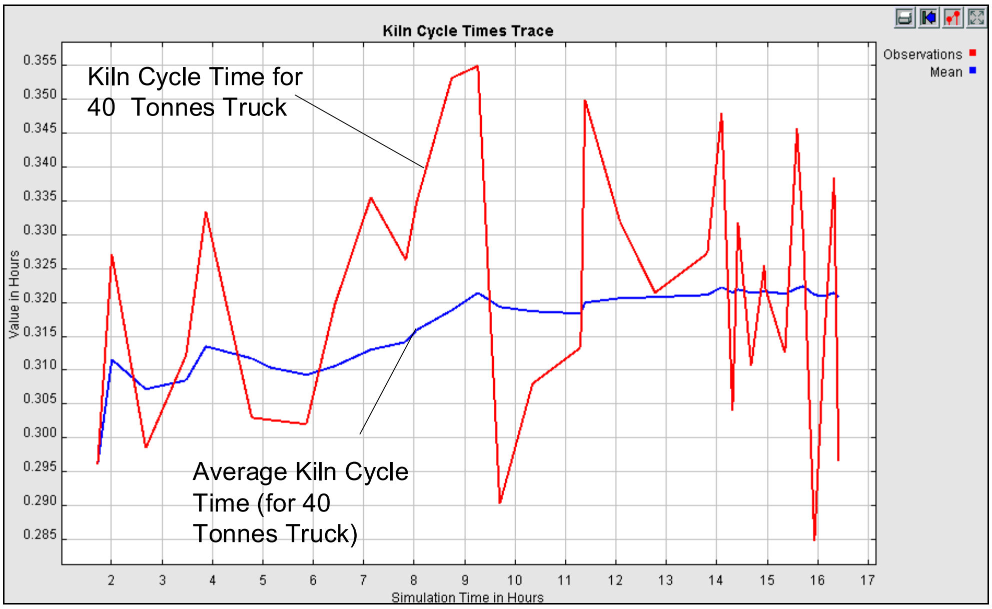


Figure 9-18: The Kiln Cycle Time for 40 Tonnes Truck

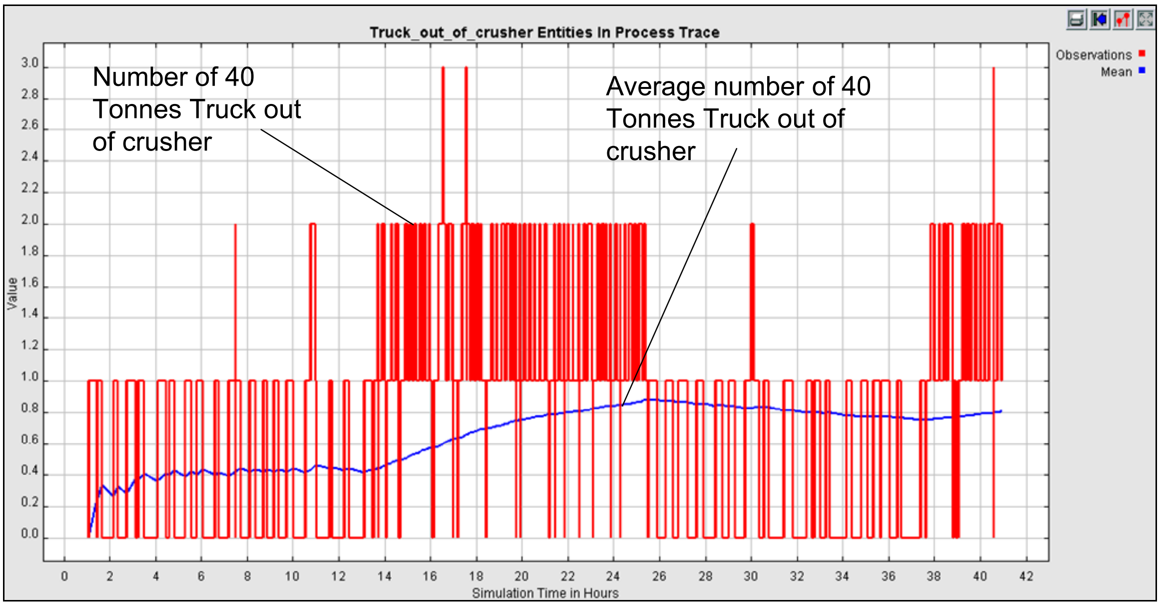


Figure 9-19: The Number of trucks out of crusher and the average number through the first 40 hours of operation.

When a non-productive time was introduced to the system, the 96 days stoppage resulted in an out-put of 0.7 M Tonnes. This clearly indicates that the overall stoppage or non-productive time of the factory is equivalent to 96 days.

9.5 Conclusion

This chapter has provided an analysis of the factory using simulation. The author, during his field visits, has collected statistical data on every part of the process. The statistical nature of the processes was simulated. The results presented the dynamic behaviour of the system, despite the fact that it is a continuous process. It has been found from the model that current production level of the factory is associated with 96 numbers of days of non-productive time. However, the model has its own limitations, including the difficulty of quantifying the cost for each process (people, energy) due to lack of information within the factory. The transient response of the kiln has been studied and it takes about 15 hours for production to reach steady state. Also the kiln has been identified as a bottle neck within the factory.

CHAPTER 10: Framework Development

Abstract
In the previous chapters, the problems in the four cement factories have been identified using field visits, questionnaires, interviews and computer simulation. This chapter builds on the findings of the previous chapters and presents a novel Framework for improving the productivity and maintenance activities in the four factories in Libya and for introducing TPM based on the local constraints.

10.1 Introduction
The outcomes of the statistical analysis, field surveys, questionnaires and interviews all agree on the fact that there are many drawbacks in the current situation in the factory in terms of productivity, maintenance, health and safety, and environmental issues.

From the statistical analysis, it has been found that the four factories have much less production than the designed capacity, given that there is high need in the market for cement and Libya is currently importing cement from abroad. Moreover, there are high levels of fluctuation in the production of the factories over the years. From the questionnaires, it has been found that:

- There is lack of maintenance strategy within the four factories.
- High level of non-productive time due to technical faults.
- There is insufficient training for staff within the factory.
- There is lack of performance related incentives and sufficient salary.
- Pollution is not monitored within the factory.
- Lack of health and safety programmes.
- Lack of social programmes within the factories.
- Lack of transportation of raw materials to factory.
- Lack of calibration of instrumentation.
- Lack of staff self-satisfaction.

- Maintenance data and information is not sufficiently recorded or documented.

And from the interviews, the problems can be summarised as lack of systematic approach to most problems and the majority of the work is done without any strategic plan and clear vision. Employees, particularly workers and technical staff, lack clear guidance and direction in the work culture. For example, when comparing productivity and internal culture of cement factories in the UK to the factories in Libya, we can conclude that the Libyan factories need development beyond technology applications and more into the human and cultural side of the process to start with. Libya has been for significant time isolated from the developed world and there is a need to improve the situation from different aspects including the utilisation of technology, modern management techniques, cultural aspects and many other factors.

10.2 Discussion: Steps of Improvement

There could be many issues and steps that could be taken to improve this negative situation. In terms of the environmental aspects, much legislation could be put in place to force the company to take positive measures regarding pollution and health and safety. However, the roles and regulations, which could theoretically be already in place, might not be sufficient to improve the situation on practical basis and more positive attitude from the company is required including Cooperative Social Responsibility.

In terms of productivity, the system productivity could be increased by investing more heavily into modern equipment whether this involves complete systems or more for maintenance and monitoring equipment. However, as we have seen from the past statistical data, this might not guarantee a high productivity if the human aspect is not taken into consideration. The lack of training, motivation and the possible resistance attitude of staff can drastically restrain productivity.

The maintenance aspect of the business is still poor and based on ‘fire-fighting’ scenarios rather than building a clear strategy. However, it is believed that lack of training and motivation could be the main reason for poor maintenance practice and the negative attitude of the majority of the technical staff, particularly when considering the lack of performance-related payments and the insufficient salary they receive. Many of technical staff have answered ‘don’t know’ for basic and obvious question, which could also indicate some carelessness or lack of trust between them and senior management. This could be a cultural issue that should be addressed to improve the situation in the cement factories.

From the above discussion, it is believed that the main aspect in order to improve productivity is to focus on the human aspect of the business. This could be in terms of the internal side of the company or the external side of the business (i.e. with the society, government departments and other organisations). It can be argued that improving the human aspect, not only by ensuring that employees understand what is expected of them, but also to give them the freedom to become proactive within the company. It is believed that the lack of self-satisfaction and the carelessness could be the main drawbacks to the system.

In relation to training and when looking at history of industry following the 2nd world war, in 1960s major companies set up training departments which gradually grew into large units. Training was comprehensive and intensive, since the career and qualifications of every trainee depended on it. There was a culture of quality and productivity which became at the end of the last century as the ‘standard’ practice. The most important training was the training of newly recruited production workers and office employees and also the further education of middle managers. Continuous and further education outside the company was also made possible. Establishing an effective link between training and strategic planning is one of the most important challenges facing companies. The importance of human resource planning itself is underlined by Martyn (1999), clear fit and alignment of human resource activities with company’s strategy.

From the finding of previous chapters, it seems that there is a lack of strategic planning on different levels within the factories, and hence it has been difficult to do any long term planning. Most important is personal contact between senior management and workers either informally or through conferences/workshops. Emphasis could be placed on group development, section leaders being called upon to improve communications within their sections.

General principles can be advanced to develop an effective model/framework that can be developed to address the problems in the four factories. Strategic planning and the management of the organisation's culture are the two key elements that should be addressed when developing the solution for the current problems. Figure 10-1 presents a novel approach to address the problems in the four factories. As discussed in previous chapters, the social and political system in Libya is unique when compared to other countries, and hence you need a complete novel strategy to address these issues.

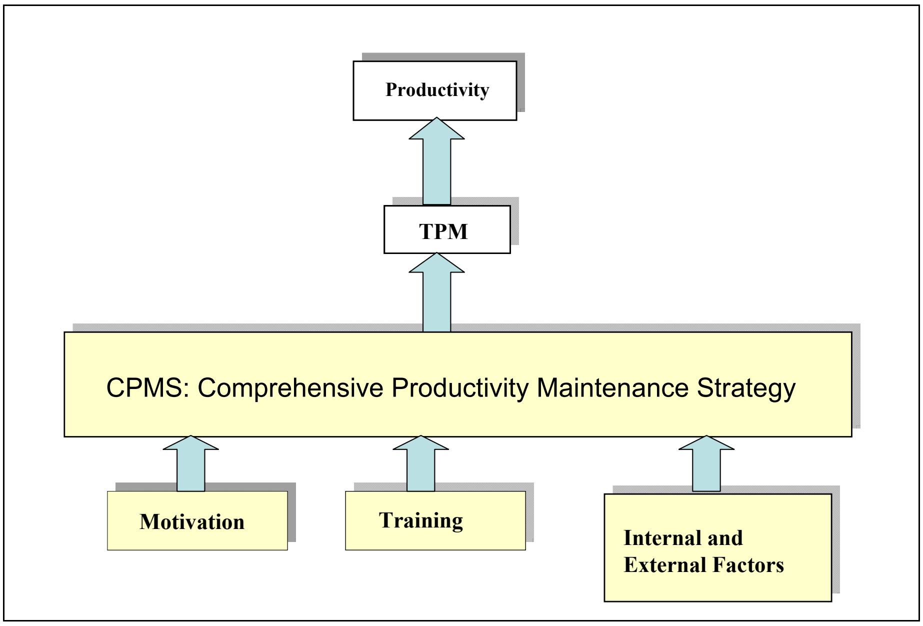


Figure 10-1: The novel Framework that is developed to solve the cement factories problems(Author).

Before implementing TPM to improve productivity, it is important to develop Comprehensive Productivity Maintenance Strategy (CPMS). This new strategy is an overall framework which addresses the main factors that influence the factory. The new system builds on three main aspects which have been identified from the previous chapters and discussion: staff training, staff motivation and the internal and external Factors. This leads to the Comprehensive Productivity and Maintenance Strategy that will feed into TPM Strategy which will lead into improving productivity and profitability enhancement. The justification for this Framework is that the situation in the Libyan factory does not allow the direct implementation of the standard TPM principles. Therefore, before being able to implement the TPM principles, training, motivation and the internal and external environmental factors should be addressed and improved to a minimum level that allows the experience and procedures/technologies of other factories to be implemented. CPMS is a people-driven framework which should create the right culture and work environment for the improvement of productivity measures.

10.3 Motivation

There is lack of motivation culture in the cement factories. People are normally motivated to satisfy important personal needs. Among the theories available in motivation are equity theory which assumes that staff are motivated to obtain equitable rewards and expectancy theory which assumes that for motivation to occur a person must believe he or she can in fact obtain a valued reward Gary (1979).

Motivating is both one of the simplest and most complex of management jobs. It is simple because people are basically motivated or driven to behave in a way that they feel leads to rewards. However, people look at motivation in different and personal perspective. For example, what one person considers an important reward, another person might consider useless. Gary (1979) The question becomes: what is the right approach to motivate staff in the Libyan cement factories?

There are two basic requirements to motivate people: the incentive or reward must be important to the person; and he/she must feel that effort will probably lead to obtaining the reward. Workers need be envisioned in a hierarchy. Each succeeding higher level does not become aroused until the next lower level need is fairly well satisfied. In general, factors that lead to job dissatisfaction could include supervision, working conditions, and salary. The factors leading to satisfaction and motivation (if they are present) include intrinsic job factors such as achievement and recognition.

10.4 The Effect of Motivation on Productivity – A case Study

The historical data found included significant information in relation to the motivation and productivity improvement in one of the Libyan cement factories. The case study which is presented in this study describes the effect of the human aspect on productivity and total productive maintenance at Libdah cement factory. As discussed in previous chapters, the Libdah factory is designed to produce 1M tonnes annually (based on 24 hours a day operation of the kiln), in order to satisfy some of the local consumption of cement in Libya. Figure 10-2 presents the production of the Libdah factory from 1981 to 2006. The actual production in the factory started in 1981 with a production of 0.47M Tonnes, which was less than 50% of the design capacity of the factory. This could be related mainly to the need for experienced workers and training of employees. There was lack of focus on maintenance strategies or maintenance training at the start of production. Between 1982 and 1983 the production increased to about 0.7 M Tonnes (point A on Figure 10-2). However, the production dropped down between 1984 and 1986 reaching its lowest level of about 0.22 M Tonnes (point B). This drop was mainly caused by the need for maintenance experience and strategies which were needed to maintain the factory to the right standard. As a results of the problem, new group of maintenance and production engineers where employed to improve the factory's performance. There was steady increase in the production of the factory between 1986 and 1993 (between points B and C). During 1993 (point C), the factory had reached its maximum production level of about 0.84 M Tonnes. This simply was the maximum capacity that theoretically could be achieved from the factory based on the actual 20 hours operation a day.

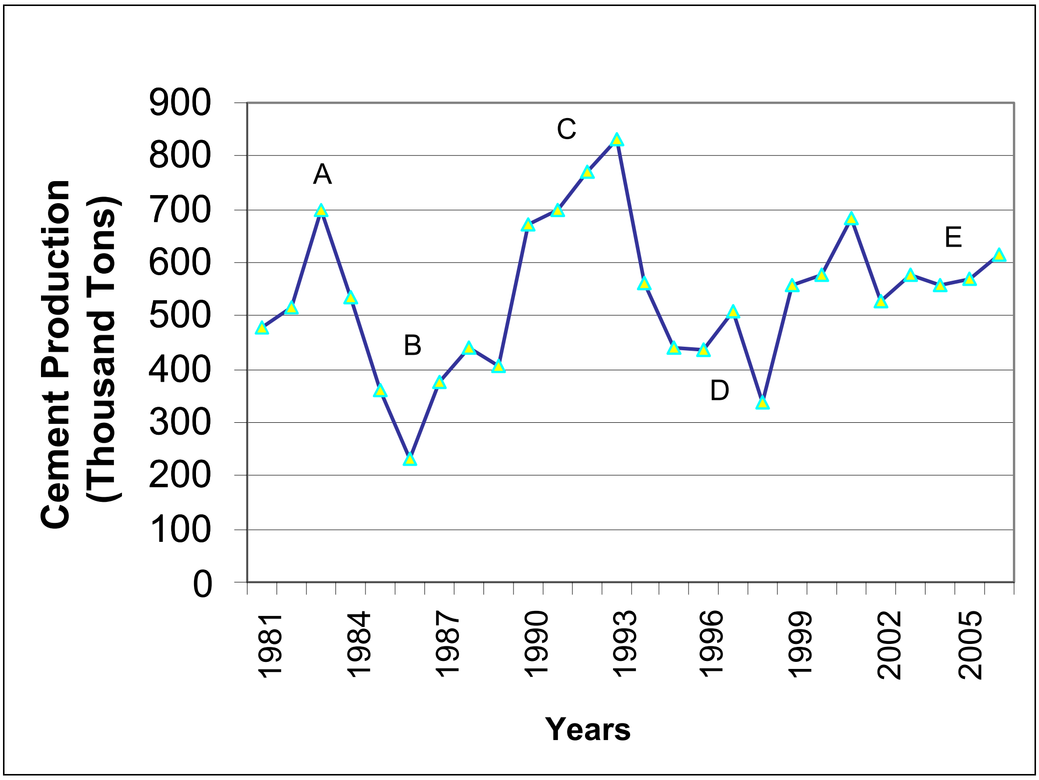


Figure 10-2: Cement production in thousand tons in Libdah factory.

The main reason of achieving this maximum productivity was the introduction at the end of 1992 to a new department to the factory, named (Maintenance Research and Development) which focused on the development of integrated production and maintenance strategies with Total Productive Maintenance as the main aspect of the strategy. The new department realised that the factory had two shifts only (8 hours each). The factory operated from 7 AM to 11PM. This meant that the factory had been working at a maximum production level of about 67%. (I.e. 0.67 M Tonnes annually). Each shift normally included one technician, 2 electrical engineers, 3 mechanical engineers and 4 general service workers. Without the use of any additional resources, the new management changed the culture of the factory by introducing three shifts and extending the working hours of the factory into 20 hours and raising the theoretical production capacity of the factory into about 84% (i.e. 0.84 M Tonnes Annually). The first shift started at 7 Am to 2PM, the second shift was between 2Pm and 9 PM and the third shift is between 9 PM and 4 AM. In order to create the motivation and incentives to the new shift culture, the production of each shift was monitored and displayed on a production sheet in the factory. The management awarded the shift with efficient and highest production a certificate of achievement which was displayed in the factory. Moreover, another certificate of achievement was given to the shift with maximum production on monthly basis. The staff of that shift were awarded an individual 'Champion Certificate'. Additional two days leave were given also to the Champions to reward them for their hard work. This created an innovative and dynamic environment where staff worked hard and enjoyed the rewards and incentives. Problems and bottlenecks were solved based on lean manufacturing and self-motivation.

This achievement was performed on local management level without the need for any additional resources. At the beginning of 1994, a new management structure came to place, which resulted in removing incentives, empowerment and self-motivating culture of weekly and monthly certificate of achievements and the additional holidays. This resulted in staff refusing to work overnight shifts and the factory went back to two shifts with 16 hours a day in total (67% maximum production). In addition to this, the new management did not have a clear production and maintenance strategy which resulted that technical staff were reassigned to do marginal tasks within the factory. This is lead to having the production going into steep decline between 1993 and 1998 (between points C and D on Figure 10-2). Naturally the management, in response to the decline in production, had managed to increase the productivity (point E) using the same two shifts system. However, the three shift culture and increasing the working hours has been difficult to achieve again due to the lack of staff incentives, empowerment and rewarding system.

10.5 Training

It is evident that training is needed in the four cement factories. Training could be related to the modern technology, management systems, procedures, work culture, health and safety, energy and sustainability, productivity awareness, etc. The isolation of Libya for some time due to the political and commercial situation, did not help in the cultural exchange and the development of people. Now, the government strategy is to compensate for that and develop the people and provide the necessary training and personal development. Any member of staff at any factory could be brought to a desired standard of efficiency, condition or behaviour by instruction and practice. Training can be divided into a number of different elements. Each element may be carried out at several levels, in different ways and at different stages in the employment relationship. These elements are:

- Identifying training needs in the light of the overall strategy of the organisation and the specific requirements of individuals.
- Planning and organising training to meet those needs.
- Designing and delivering it.
- Evaluating the effectiveness of training.

Working to these four elements lies at core of the training function whether that is carried out by one person or several, inside or outside the organisation. By approaching each step systematically, the process of learning can be made more efficient according to Penny, (2006).

The previous chapters indicated that the cement factories lack a clear training strategy and more emphasis should be given to address the training process. From the questionnaire and interviews it is evident that there is no systematic audit of the training needs or approaches required to achieve this. It is often that of the prime responsibilities of a manager is the training and development of his/her staff and workers. This can normally be done by developing relationships between shop-floor staff and managers which will assist the manager to achieve any aims of training and development calls for positive efforts on the part of the manger. The manager should become involved only in problems which nobody else can solve and as a result managerial skill is used when it is needed. The principal advantage of the training course is that it brings together a group of workers who can discuss mutual problems, learn as a group and cross- fertilise ideas and methods and, more than any other benefit, can practise their theoretical skills on each other, the above discussion is also in line with Leslie, (1988).

Appropriate human resources policies are now recognised as essential for the success of the modern organisation. Personnel /human resources programmes and activities contribute to the organisation in three ways Martyn (1999):

- By ensuring that employees possess the characteristics required for effective performance, achieved by appropriate recruitment, development and training.
- By promoting self-motivating through performance review or appraisal process.
- By creating an appropriate framework for the interaction between the individual and the senior management.

Training can be done through lectures, workshops, vocational qualifications, conferences, Based on the culture of the factory and the type of employees , as suitable level can be selected, see Gary (1979). In order to maintain a sustainable training and development, a novel Sustainable Development and Collaboration Framework (SDCF) is proposed in Figure 10-3.

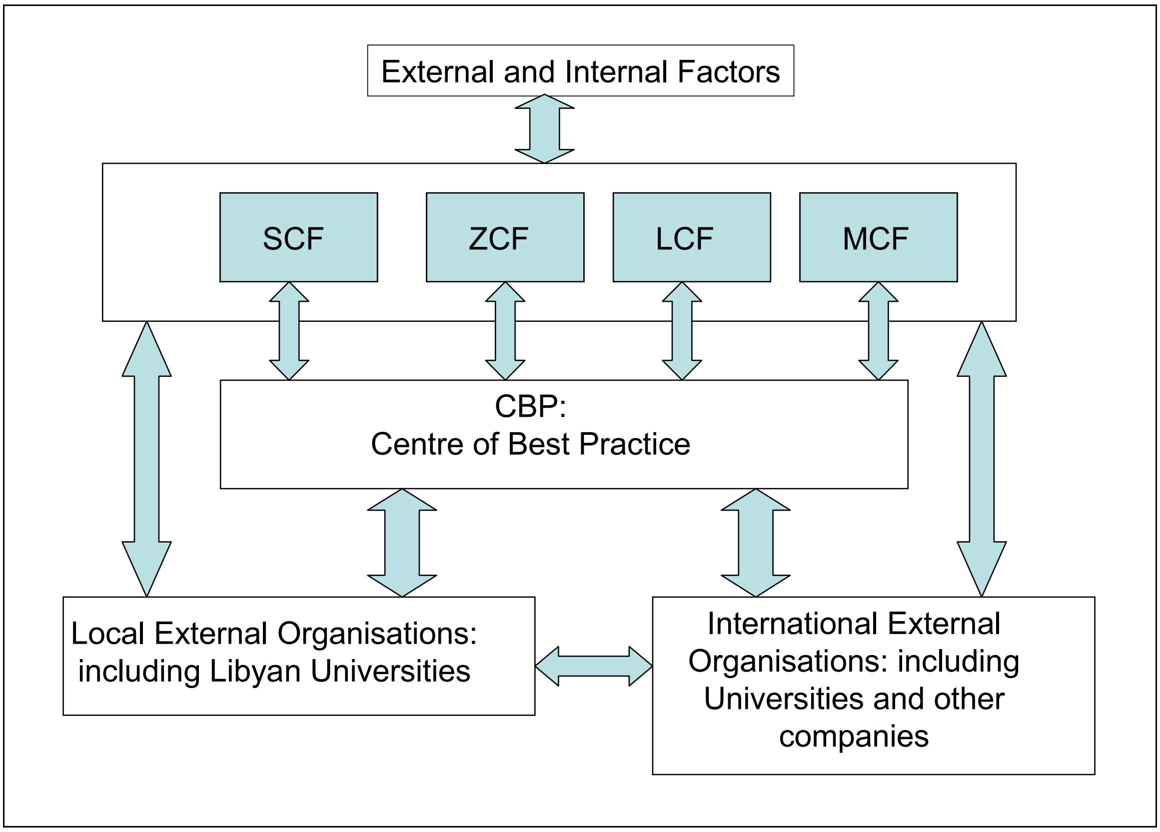


Figure 10-3: Sustainable Development and Collaboration Framework (SDCF)(Author).

This proposed framework will be based on establishing a Centre of Best Practice (CBP), this will be the gateway between the company's four factories and the outside environment to capture best practise and suitable training courses from national and international organisations including universities and other colleges. This will be performed with consideration to internal and external factors within the four factories. This will be discussed in the following section.

10.6 Internal and External Environmental factors

Libya has unique political and social system. The political system is given to people in their communities (similar to unions in Europe), which could lead to sudden refusal of any new framework or proposed system. Therefore, any change should take into consideration the internal and external environmental factors in the society.

There are several factors that could influence the progress and the development in the factory. For example, the tribal and family system in Libya could influence the high position in the factory. This means the votes and the selection of the top management could be easily influenced by the tribal system in the area around the factory. The relationship between colleagues sometime are badly managed which could lead to lack of team work. Also the collaboration with other organisations, including universities, is extremely limited. The collaboration with other cement factories to exchange experience is also limited. The internal and external factors are discussed as part of the validation process of the framework in the next chapter.

10.7 Conclusion

This chapter highlighted a new Framework for improving productivity in the Libyan cement factories. The Framework outlines that the most critical factor to improve productivity is the human aspect within the production environment. The model highlights three main areas for development in Comprehensive Productivity Maintenance Strategy (CPMS). The CPMS strategy is dependent on three main areas of development, namely: motivation, training and addressing the internal and external factors that influence the factory. In the following chapter, the model will be validated by the employees by comparing between the Framework and the workers' feedback on some of the ideas. The Framework will be enhanced based on the validation process.

CHAPTER 11: Validation of Framework and Results

Abstract

This chapter addresses the validation and assessment of the Frameworks and the models developed in the previous chapter. A questionnaire has been developed to assess some of the main points related to motivation, training and the internal and external factors.

11.1 Testing the Validity of the Suggested Model

A questionnaire has been developed with focused questions to assess and validate the developed framework. The questionnaire included eleven questions as shown in Table 11-0.

Table 11-0: The design of the validation questionnaire

Question Number	Framework Area	Description
1	Motivation	Salary and Financial reward
2	Training	International Training
3	Internal and External Factors	Pollution, Environment and Productivity
4	Training	Internal training
5	Motivation	Incentives
6	Internal and External Factors	Maintenance
7	Motivation	Social aspects and holidays
8	Internal and External Factors	Environmental contribution
9	Training and Motivation	Communication and fulfilment
10	Internal Factors	Productivity
11	External Factors	External factors that influence productivity

The purpose of this questionnaire is to validate the results obtained from the interviews and questionnaires in this research work. The questions are designed to test and validate some of the solutions suggested in this work.

The questionnaire was given to 60 engineers and technical staff, 45 questionnaires were returned. The result below presents the questions and the response of the technical team. SPSS software was used to develop the calculations and test the reliability of the questionnaire. Cronbach's Alpha is found to be 96.1% which proves the reliability and consistency of the questionnaire.

11.2 Results of the Questionnaire

The first question is on motivation and the salary received by the employees. It was evident from the field work that many workers had several jobs and they are not focused on their factory role. In Q1 employees are asked about their increase in salary, as shown in Table 11-1and Figure 11-1. The results indicate that a 300% increase in salary would be ideal for all employees and prevent them from seeking other work. This proves that insufficient salary is the main drive for not focusing on the factory's work.

Table 11-1

Letter	Q1 : Monthly Salary	yes	No	Do not know
A	Would a 100% increase in your monthly salary make your focus on your factory job and stop you from working outside the factory on a 2nd job ?	5	0	40
B	Would a 200% increase in your monthly salary make your focus on your factory job and stop you from working outside the factory on a 2nd job ?	10	0	35
C	Would a 300% increase in your monthly salary make your focus on your factory job and stop you from working outside the factory on a 2nd job ?	45	0	0

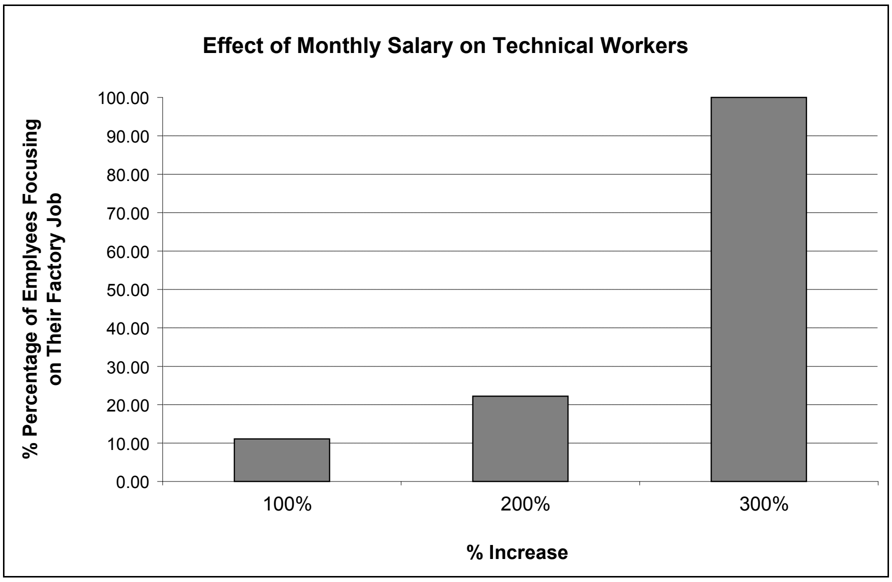


Figure 11-1: The Effect of Monthly Salary on Behaviour of Engineers and Technical Workers.

Question 2 is related to international training. It is evident that employees prefer long term international training courses as shown in Table 11-2 and Figure 11-2.

Table 11-2: Q2 International Training outside Libya.

Sub-question	Q2: International Training outside Libya.	Yes %	No %	Do not know %
A	Do you prefer training for short periods outside Libya in other countries for personal development?	11.2	0	88.9
B	Will international training courses outside Libya give you the desire to work harder and increase your productivity and dedication?	77.8	0	22.3
C	Will long international training courses outside Libya give you the desire to work harder and increase your productivity and dedication?	84.5	0	15.6

It has been found that employees prefer longer training courses and 77.7% believe that training courses outside Libya will give them higher motivation and dedication and improve their productivity.

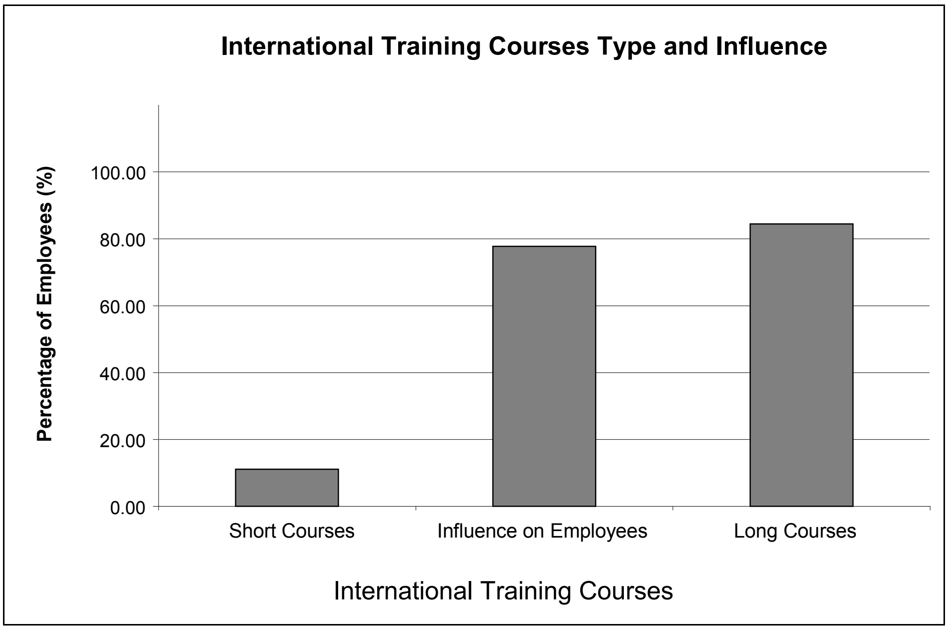


Figure 11-2: The Type of influence of the training courses.

Question 3, as presented in Table 11-3 and Figure 11-3, is related to pollution and the environment.

Table 11-3: Q3 Factory Pollution and the Environment.

Sub-question	Q3: Factory Pollution and the Environment.	Yes %	No %	Do not know %
A	Do you think focusing on the environmental aspects would reduce the pollution emitted by the factory?	77.8	0	22.3
B	Do you think the improving the quality of filters and spare parts would reduce the amount of pollution emitted by the factory?	77.8	0	22.3
C	Do you think using high quality filters and maintaining them according to specifications would reduce the pollution emitted by the factory?	77.8	0	22.3
D	Do you think that establishing a common engineering committee/panel between the company's factories would increase productivity?	66.7	0	33.4
E	Do you think workshops, seminars and the exchange of experiences between engineers in Libya and other international factories would be beneficial to address the problem of dust and pollution?	77.8	0	22.3
F	Do you think workshops, seminars and the exchange of experiences between engineers in the factory and Libyan universities would be beneficial to address the problem of dust and pollution?	73.4	0	26.7
G	Do you think using measurement and monitoring technology to monitor dust pollution will contribute in improving the environmental; performance of the factory?	77.8	0	22.3
H	Would you like to develop joint collaboration between the company's factories and international universities to solve some of the technical problems?	84.5	0	15.6
J	Would you like to develop joint collaboration between the company's factories and international factories to solve some of the technical problems?	77.8	0	22.3
K	Do you think the development of joint collaboration between the company's factories and Libyan universities to exchange ideas/information/lecture would solve some of the technical problems and improve productivity?	77.8	0	22.3
L	Do you think the development of joint collaboration between the company's factories and international universities to exchange ideas/information/lecture would solve some of the technical problems and improve productivity?	86.7	0	13.4
M	Do you think the development of joint collaboration between the company's factories and international companies/factories to exchange ideas/information/lecture would solve some of the technical problems and improve productivity?	82.3	0	17.8

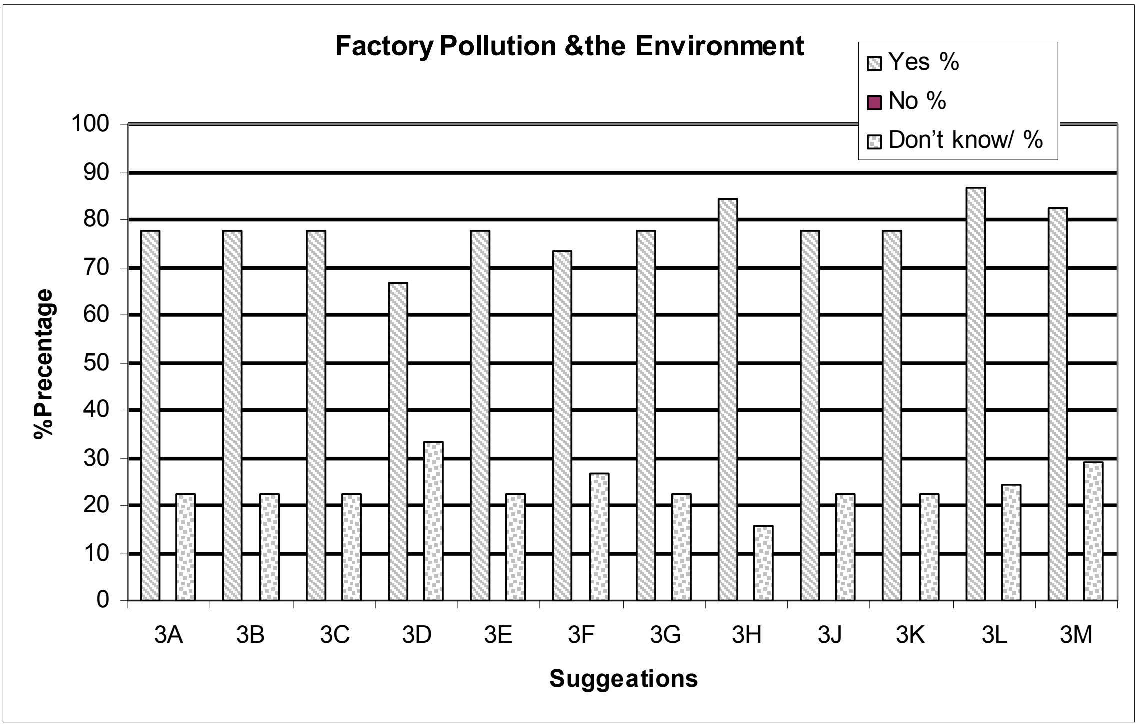


Figure 11-3: Factory Pollution and the Environment.

It is evident from Question 3 that the engineers prefer to work with international factories and universities in comparison with local ones. There is significant number of engineers who are not interested or do not have a specific opinion about this. There is believe that developing collaboration between the factory and other international companies and universities will improve productivity. In general employees are very supportive and no one had a negative opinion about this.

Question 4 is related to internal training in the factory related to first aid, health and safety, TPM and other specialised training. From Table 11-4 and Figure 11-4, it seems that all employees are interested in training and personal development in their areas of expertise but less interested in other types of training. It is evident that technical or specialised training is more important to them than other types of training as indicated in Q4-E where 100% of the employees would like to receive in their area of expertise.

Table 11-4: Q4 Training in the Factory.

Sub-question	Q4: Training in the factory	Yes %	No %	Do not know %
A	Would you like to receive training in First Aid?	66.7	22.3	11.2
B	Would you like to receive training in using Fire fighting appliances?	66.7	24.5	8.9
C	Would you like to receive training on emergency procedures and health and safety?	68.9	20	11.2
D	Would you like to receive training on TPM and other maintenance strategies/procedures?	80	11.2	8.9
E	Would you like to receive training in your area of expertise to improve your skills and knowledge to an international standard?	100	0	0

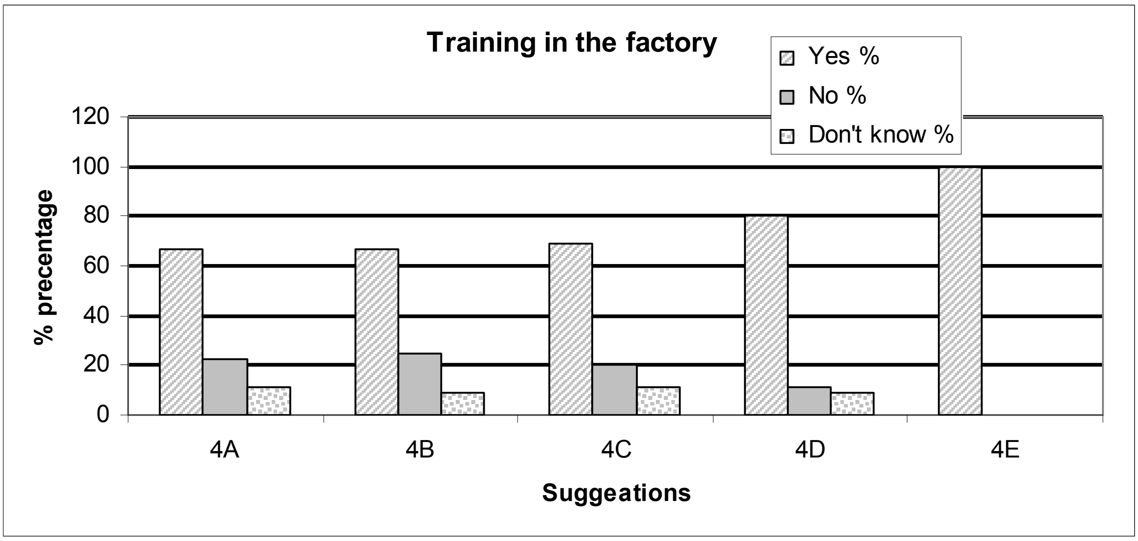


Figure 11-4: Training in the factory

Question 5 covers the incentives for employees. As indicated in Table 11-5 and Figure 11-5, the incentives appear to be extremely important to the employees. A combined financial incentive and a certificate of achievement are the most favourable one among employees with 100% support. In general, financial rewarding is found to be of more importance to the employees than other type of rewarding systems.

Table 11-5: Q5 Incentives.

Sub-question	Q5: Incentives	Yes %	No %	Do not know %
A	Do you think rewarding you with a performance certificate/award will enhance your motivation and productivity?	11.2	0	88.9
B	Do you think a financial prize/reward will enhance your motivation and productivity?	28.9	0	71.2
C	Do you think that offering you a special promotion or higher position will enhance your motivation and productivity?	66.7	0	33.4
D	Do you think that offering you a performance certificate and financial prize/award on annual basis will enhance your motivation and productivity?	100	0	0

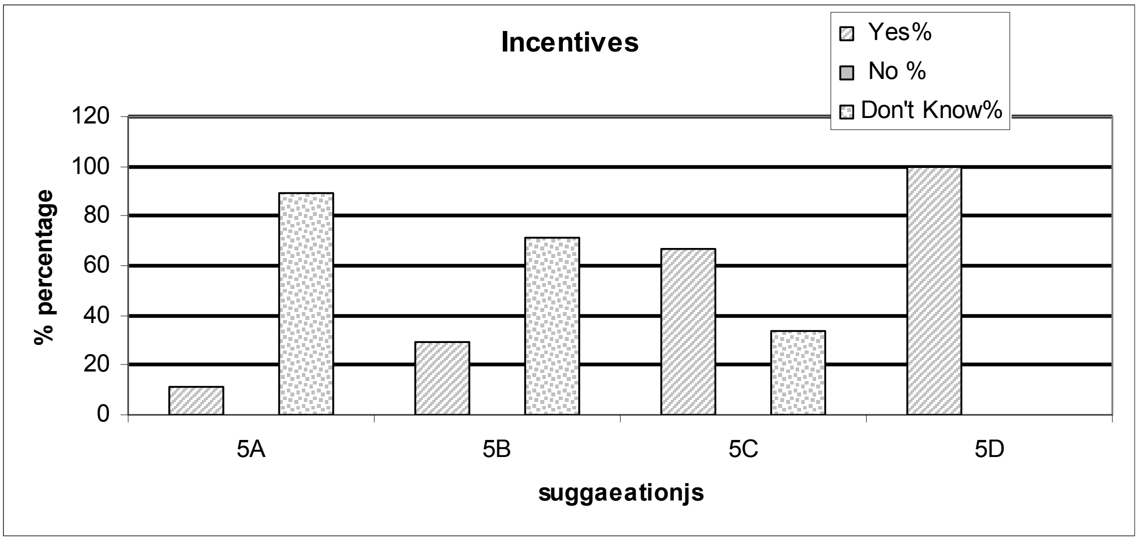


Figure 11-5: Incentives for employees.

Question 6, as indicated in Table 11-6 and Figure 11-6; indicate some main aspects supported by employees to improve productivity.

Table 11-6: Q6 Maintenance.

Sub-question	Q6: Maintenance	Yes %	No %	Do not know %
A	Do you think that carrying out routine maintenance would lead to productivity improvement?	91.2	0	8.9
B	Are do you think that scheduled maintenance would improve the management of maintenance activities?	93.4	0	6.7
C	Do you think the collaboration with international experts/consultants to assist you in maintenance activities will enhance your productivity and performance?	97.8	0	2.3
D	Do you think the existence of a computerised maintenance information system will help in organising maintenance and production activities and help in improving productivity and availability of spare parts ?	100	0	0
E	Do you think that the exchange of technicians and engineers between the company's factories contribute to increasing productivity?	82.3	0	17.8
F	Do you think lubrication programmes in the factory are sufficient?	88.9	0	11.2
G	Do you think that low maintenance of bulldozers contributed to the lack of raw material arriving to the factory?	66.7	0	33.4

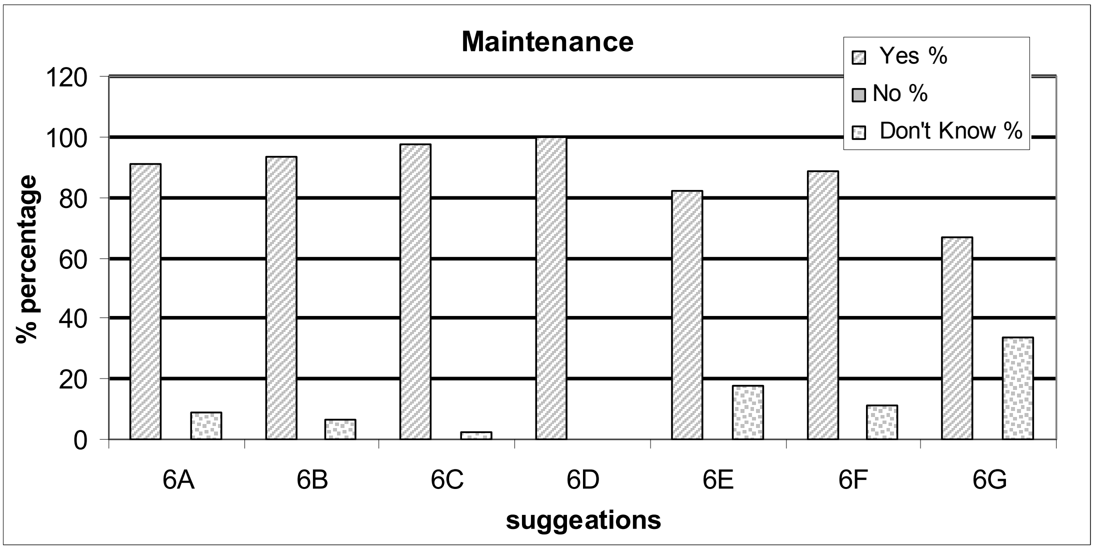


Figure 11-6: Maintenance.

The results from question 6 indicate that all employees agree that computerised information system is necessary to improve productivity. Routine maintenance and lubrication is also believed that it will enhance the productivity. It is also believed that scheduled maintenance will improve maintenance activities. However, there is lack of knowledge or information regarding the maintenance of bulldozers within the factories. About 82.3% of participants agree that exchange of technical staff between factories will have positive effect on productivity.

Question 7 covers the social aspects and holidays as shown in Table 11-7 and Figure 11-7.

Table 11-7: Q7 Social Aspects and holidays.

Sub-question	Q7: Social Aspects and holidays.	Yes %	No %	Do not know %
A	Do you prefer be paid in lieu instead of your annual holidays?	55.6	0	44.5
B	Do you think spending a holiday in one of Libyan resorts paid by the factory will enhance your productivity?	82.3	0	17.8
C	Do you think spending a holiday with your family outside Libya paid by the factory will enhance your productivity?	100	0	0

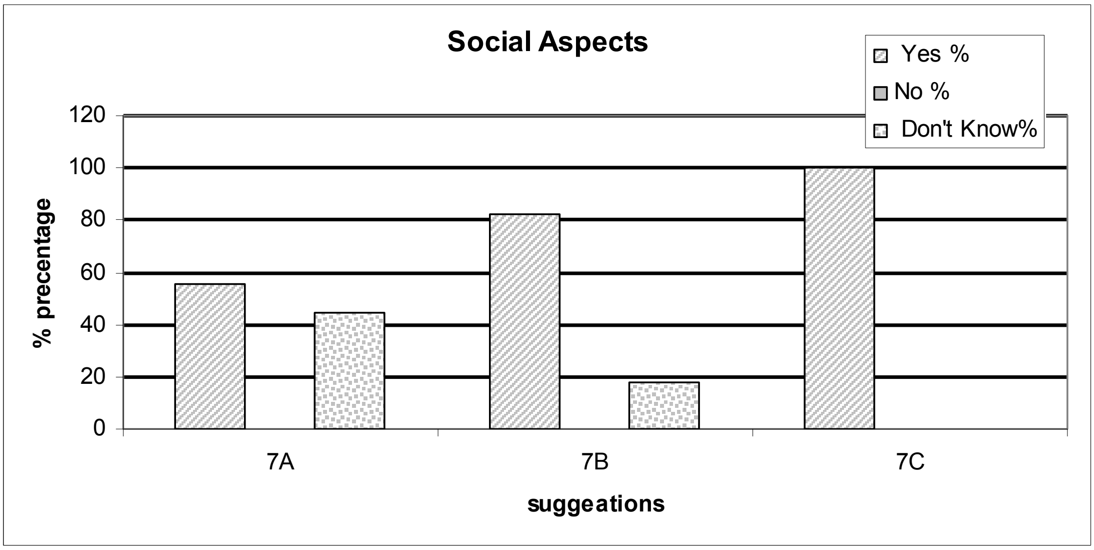


Figure 11-7: Social Aspects.

Question 7 indicates that all employees believe that spending a holiday with their families outside Libya paid by the factory will enhance their productivity. Only 82.3% support the holiday to be in Libya. More than 55% of the participants also prefer to be paid in lieu than taking annual holiday. Combining the two results indicate that there is need for financial reward and the employees are most supportive for holidays outside Libya paid by the company.

Question 8, as presented in Table 11-8 and Figure 11-8, is focused on the internal and external factors related to the environmental contribution.

Table 11-8: Q8 Environmental Issues.

Sub-question	Q8: Environmental Issues	Yes %	No %	Do not know %
A	Are you prepared to contribute and work towards a clean environment in the factory?	88.9	0	11.2
B	Are you prepared to participate in the planting the areas adjacent to the factory to improve the local environment?	88.9	0	11.2
C	Do you work with your colleagues to keep the place of your work tidy and clean?	82.3	0	17.8
D	Are you prepared to participate in a campaign to clean the factory to be free of dust?	77.8	0	22.3
E	Do you have the desire to work towards reducing pollution emitted by the factory?	84.5	0	15.6

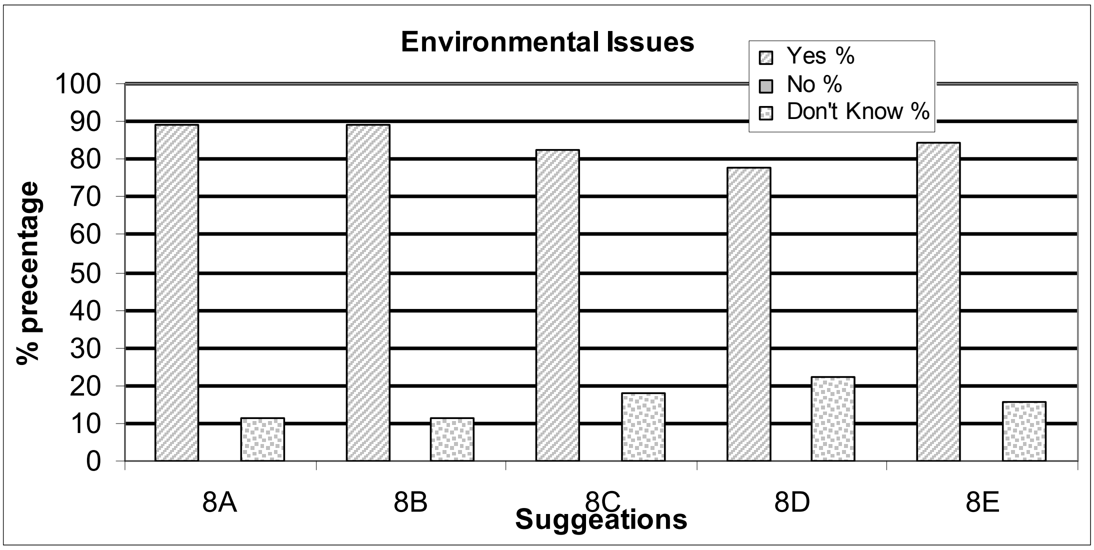


Figure 11-8: Environmental Issues.

Question 8 indicated that the majority of employees are prepared to contribute to the environmental measures within and a round the factory. More than 88% are happy to support the environmental drives which indicate that they have good awareness of the environment and sustainability issues. Table 11-9 and Figure 11-9 present different questions that cover communication and fulfilment.

Table 11-9: Q9 Communication and fulfilment.

Sub-question	Q9: Communication and fulfilment	Yes %	No %	Do not know %
A	Are you satisfied in your work at the cement industry?	88.9	0	11.2
B	Will you work toward improving productivity in the factory?	91.2	0	8.9
C	Would you like to receive periodicals and magazines related to cement production to improve your knowledge and skills?	84.5	0	15.6
D	Do you think that the stability of the management system will enhance the productivity?	86.7	0	13.4
E	Do you think improved relationship and communication between senior management team and the engineers/employees would enhance the productivity of the factory?	93.4	0	6.7
F	Have you attended any engineering conferences in the past in relation to cement production and/or improving productivity?	6.7	88.9	2.3

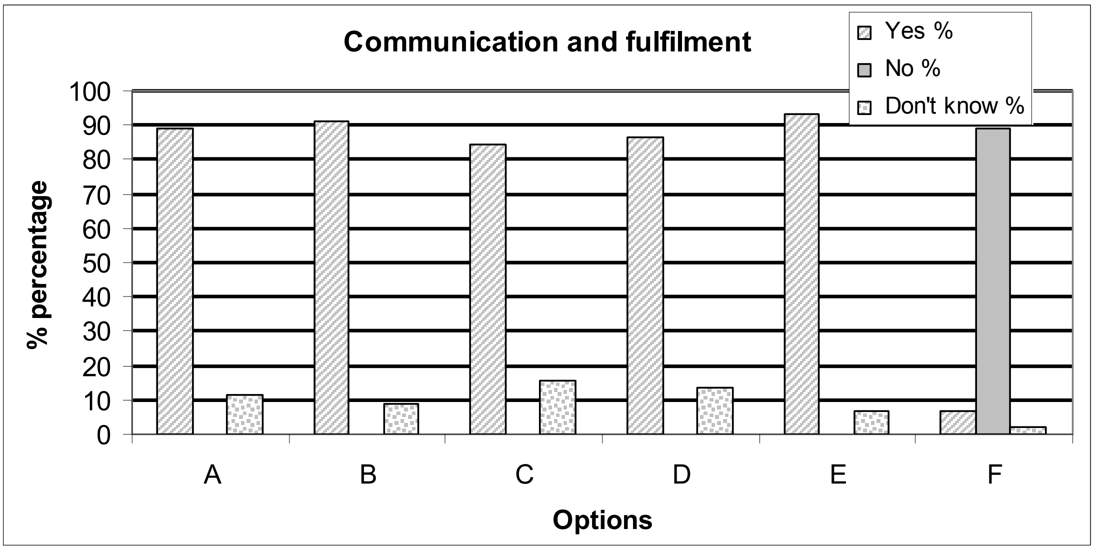


Figure 11-9: Communication and fulfilment.

Very limited number of employees has attended engineering conferences to communicate their work or receive suitable development. Most of employees seem to be positive about contributing to enhancing the productivity of the factory and they seem to be happy and satisfied in working in the factory. The majority also agree that improving the communication and relationship with the Senior Management Team will improve and enhance productivity (93.4%).

Question 10 is an open question which is phrased as: in your opinion what are the internal factors that affect production and productivity in the factory? The answers are collected and presented in Table 11-10 and Figure 11-10.

Table 11-10: What are the internal factors that affect production and productivity in the factory?

Category	Answers	Number of Answers	Percentage (%)
A	Appointing unqualified people in some important positions.	40	89
B	Lack of personal equipment and tools necessary to carry out maintenance procedures.	38	85
C	Tribal system and groups directly affect the work.	39	87
D	Lack of incentives (financial and others)	41	92
E	Deficiencies and lack of training	43	96
F	Lack of clean environment	42	94
G	Lack of team work	42	94
H	The lack of international scientific conferences and lack of support in personal development.	43	96
I	The lack of communication with academic and industrial experts in the field	40	89
J	Lack of clear maintenance programmes	41	92
K	The lack of social and recreational programs.	43	96

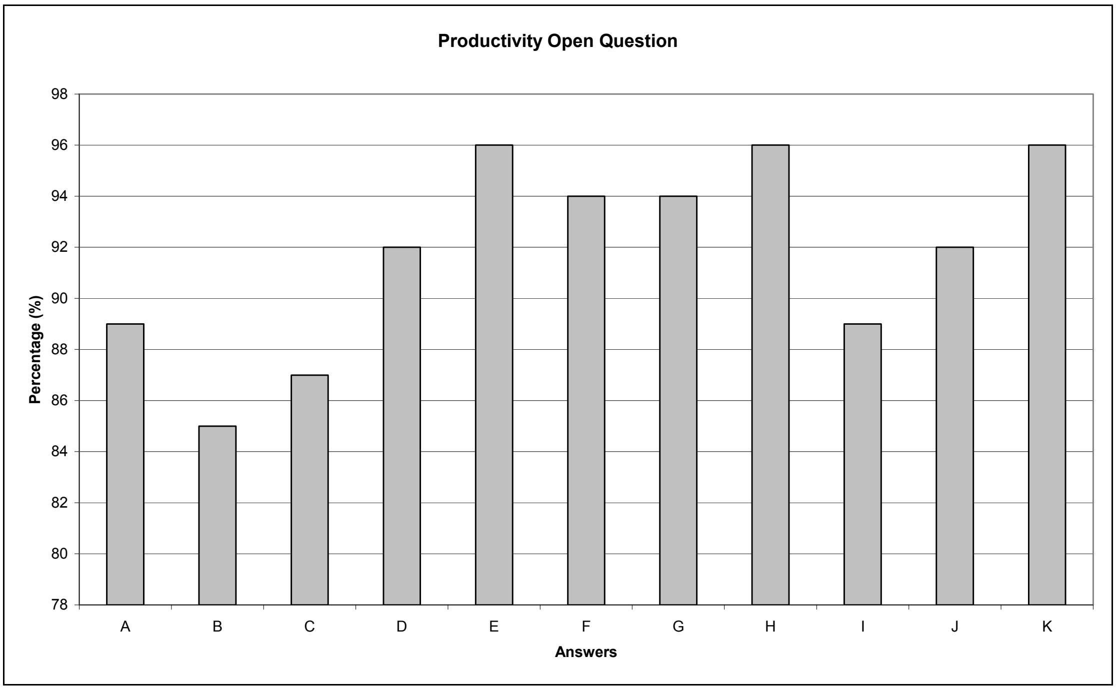


Figure 11-10: what are the internal factors that affect production and productivity in the factory?

This open question has identified the main factors the workers believe that has negative effect on productivity. The highest one is lack of training, lack of scientific conferences and lack of social and recreational programmes with 96% score. This is followed by lack of clean environment and lack of team work (94%). Lack of incentives (financial and others) and Lack of maintenance programmes are (92%) each. Appointing unqualified people in some important management positions and the lack of communication with academic and industrial experts in the field are both mentioned (89%). The lack of maintenance equipment and the existence of the tribal system are mentioned 87% and 85% respectively. The above points should be addressed in the Framework in order to improve the productivity of the factory. This will be discussed in detail in next sections.

Question 11 is an open question which is phrased as: in your opinion what are the external factors that affect production and productivity in the factory? The answers are collected and presented in Table 11-11 and Figure 11-11.

Table 11-11: What are the external factors that affect production and productivity in the factory?

Number	Answers	Number of Answers	%
1	Misunderstanding or misuse the existing political system in Libya.	45	100
2	Lack of external markets for cement products.	40	89
3	Lack of collaboration with the Libyan and international universities.	42	94
4	Lack of collaboration with international companies in the cement sector.	41	92
5	Interruption of electricity supply.	40	89

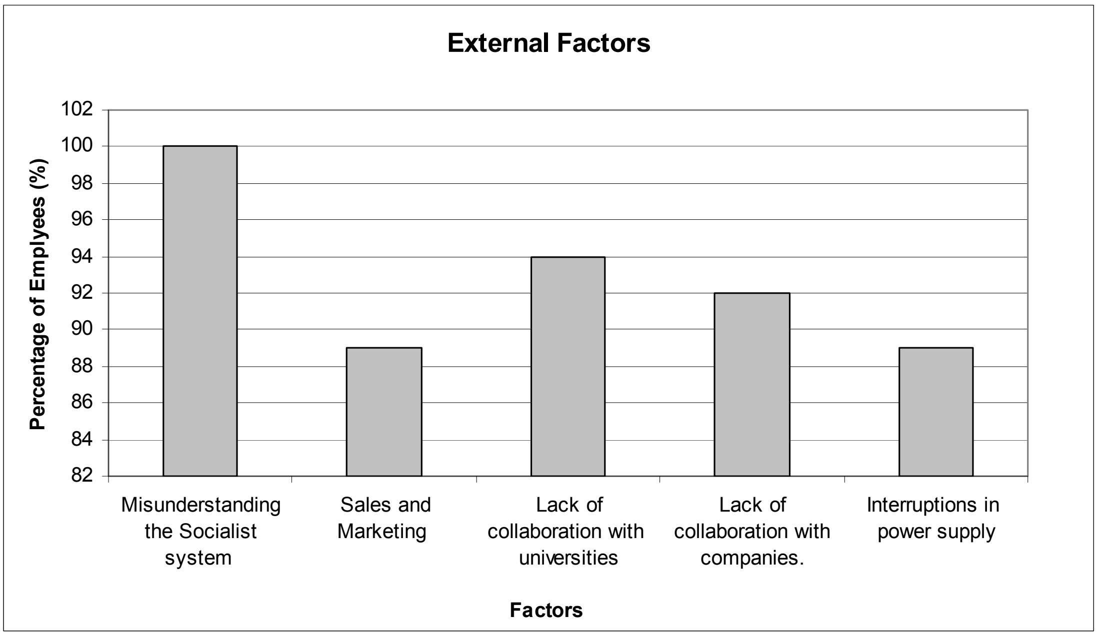


Figure 11-11: What are the external factors that affect production and productivity in the factory?

From the open question, the answers are found to be focused and the most significant one (100%) is the misunderstanding or misuse of the existing political system. This is followed by lack of collaboration with universities (94%) and companies (92). Interruption of power supply in the electricity grid and lack of international markets both have scored 89% score.

11.3 Discussion and Framework Presentation

From the results found in this chapter, the framework suggested in Chapter 10 can be expanded to include some of the validated details as sown in Figure 11-12.

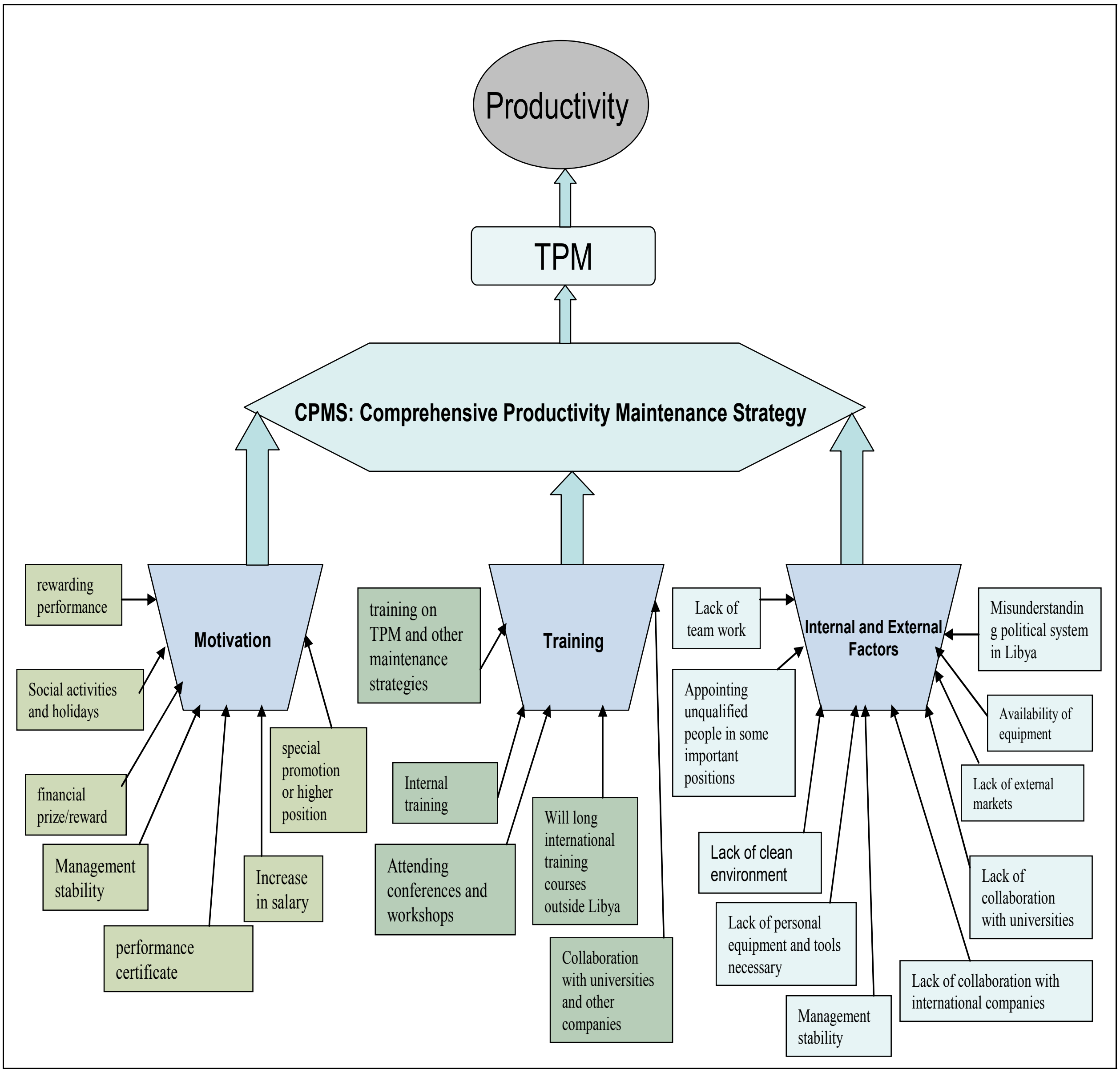


Figure 11-12: The influence parameters as identified by the validation study (Author).

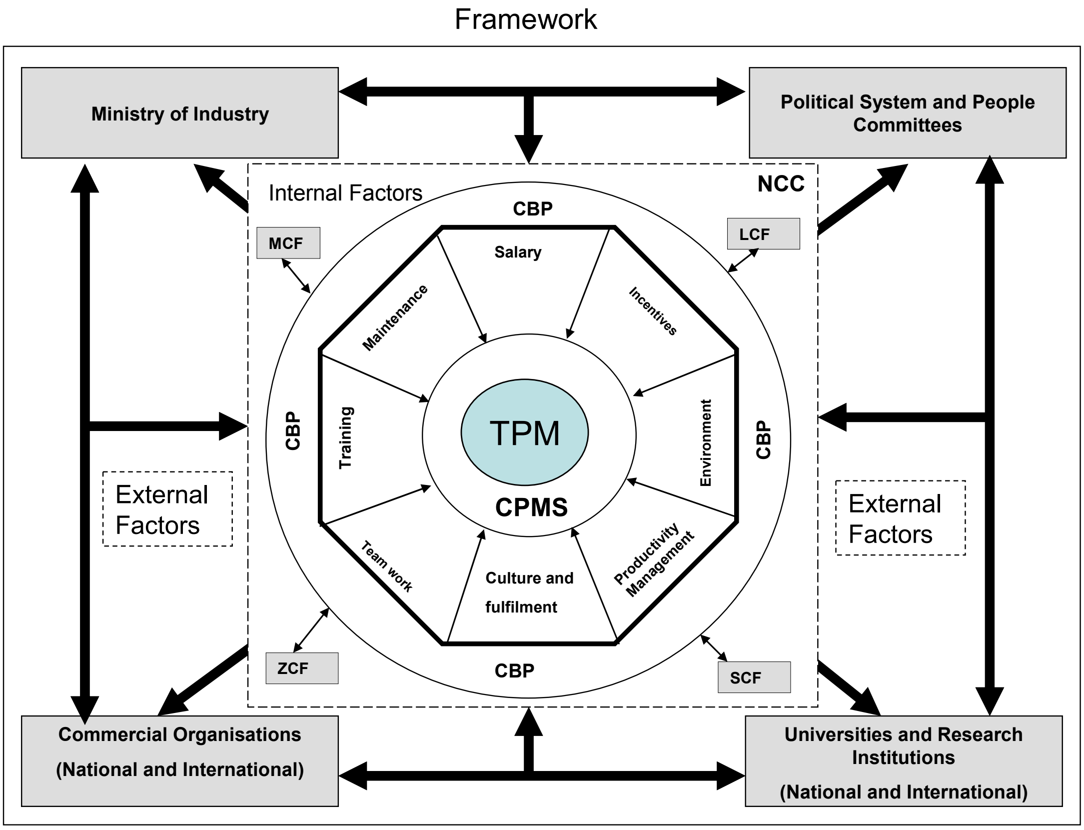


Figure 11-13: The complete Framework based on the results of validation (Author).

Figure 11-13 presents the overall framework for implementing TPM to improve productivity. The framework takes into consideration four types of external organisations, namely the Ministry of Industry, the Political System, Commercial Organisations and Academic/Research organisations. The external organisations communicate with NCC and the four factories through the Centre of Best Practice (CBP). The CBP takes the main three factors (motivation, training and the influence of internal and external factors) into consideration for an integrated approach of continuous improvement, named Comprehensive Productivity Maintenance Strategy, to allow the company and the four factories to implement TPM. The three main factors are expanded in Figure 11-13 to include maintenance, salary, incentives, environment, productivity management, team work and training. A three dimensional presentation of the central part is shown in Figure 11-14. The Centre of Best Practice continuously improve the situation and work practice within the company taking into consideration motivation, training and the internal and external factors and by utilising best practice in the external organisations and government initiatives.

All influencing parameters are integrated and improved through the CPMS into a level where TPM can be applicable.

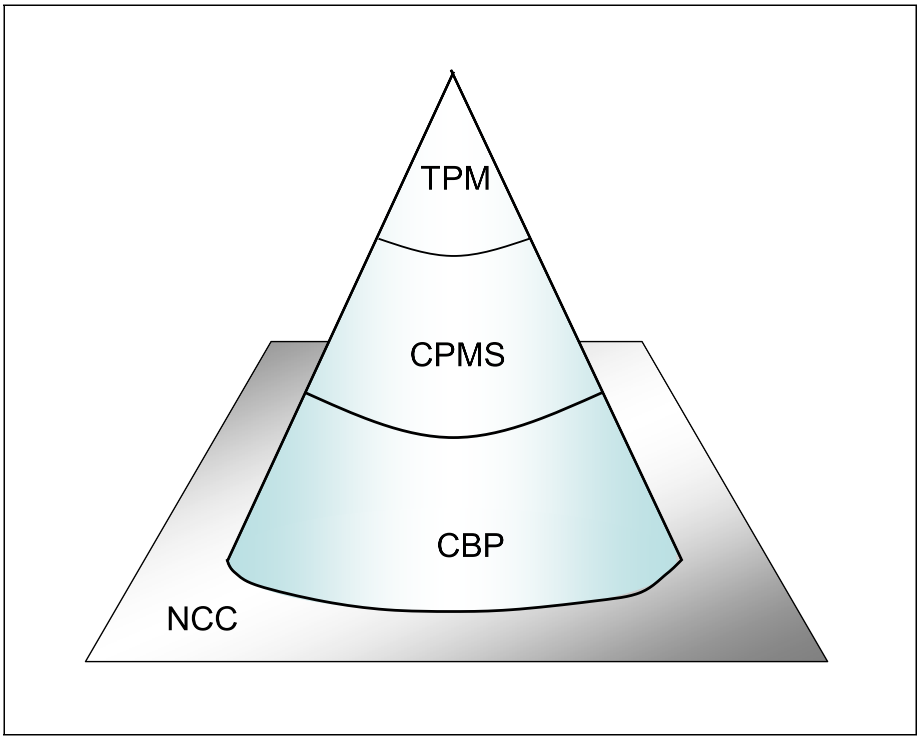


Figure 11-14 : A 3D schematic diagram to show the relationship between CBP, CPMS and TPM (Author).

Each influencing parameter should be addressed and investigated in a more comprehensive approach to find the most suitable solution. However, in this chapter, for example, the salary aspect was addressed in detail and it has been found that three times the current salary would be sufficient for employees to focus on their work.

11.4 Conclusion

This Chapter has highlighted the validation of the suggested framework in the previous chapter. A questionnaire has been designed to validate the motivation, training and the internal and external factors that influence the productivity and the implementation of TPM in the factory. The results have proved that the Framework and models developed in the previous chapter are accurate and reflect the current practice and limitations in the cement factories in Libya. There is clear lack of training and motivation. Also this chapter has highlighted the internal and external factors that influence the productivity of the factory.

CHAPTER 12: Conclusions and Further Work

Abstract
This chapter outlines the main findings of this thesis. These are discussed against the research aims and objectives identified in earlier chapters. The key findings of this research work are summarised, and the research contribution to knowledge and implications of this research work are presented. The research's strengths and limitations are discussed and recommendations of future research are outlined.

12.1 Thesis overview
This research work has been done in order to assist the Libyan National Cement Company (NCC) is driving the improvement within its four factories, namely Alkhumes/Margeb (MCF), Souq Alkames (SCF), Alkhumes/Libda (LCF) and Zeleten (ZSF) in order to enhance its productivity. The author has identified the main research questions during his work at the company. It has been obvious when compared with other cement companies, European ones in particular, that the productivity of the NCC is extremely low. It has been difficult to identify the most suitable methodologies to improve productivity. Because cement production is a continuous process, maintenance strategies have been identified as the potential key issue to improve productivity. In such production environment, maintenance and its management is considered to be the most important approach to improve productivity. Planned and unplanned maintenance work should be clearly identified and managed for the benefit of the production environment. The author also identified TPM (Total Productive Maintenance) as a key maintenance management strategy that has the potential to improve maintenance and productivity as has been found in the literature. However, it has been difficult to identify the exact methods that could be used to implement TPM in the NCC and it has been found essential to understand the most important problems and develop comprehensive understanding of the Libyan manufacturing environment, when compared with

the European industry, before attempting to develop a strategy for implementing the TPM.

Before starting the research work, there have been many unknowns and questions that needed to be answered before developing any maintenance or TPM strategy. The main questions have been identified in Chapter 1, section 1.3. The research questions were mainly related to identify clearly the problems facing the industry from all aspects and the ways to help in supporting the improvement of productivity using modern systems such as TPM.

Libya has suffered isolation from the Western World in the recent past, and this has influenced the education and the industrial systems in Libya. One of the key issues is that the current research on TPM in other parts of the world might not be directly applicable to Libya due to its recent history and unique culture and political, social, and economic systems. The research questions described in Chapter 1 have been used to formulate the research aim and objectives.

The main aim of this study has been formulated to investigate current practice and the need and implementation of Total Productive Maintenance (TPM) in Libyan cement industry. It investigated the effect of maintenance functions on productivity, competitiveness, and the profitability of the four factories. Based on the findings, it suggested a new Framework for implementing Total Productive Maintenance (TPM) supported by computerised simulation system and identifying the key factors to improve the overall maintenance performance.

Diversity of methodologies has been used to achieve the objectives of this study and provide suitable level of validity, reliability and research results. This work has been initiated by the author as a result of facing productivity and maintenance problems during his work in the LCF. This has been developed to this current research work in order to investigate the current problems and possible solutions. A literature review is conducted within the domain of this research work. This followed by collecting statistical data from the factories to understand the production problems and trends. The statistical data also provided comparison between the two factories within the same company. This work has utilised field observations, case studies, questionnaires and semi-structured interviews to understand the problems and develop a solution framework. Figure 1.2 presented summary of the methodology implemented in this research work.

Both quantitative and qualitative research methods are used in this thesis. This research is carefully designed in order to meet the time scale of a PhD thesis. The methodology used to conduct this work started by field work and observation in the four factories. This has been essential for gaining general knowledge on the four factories. In addition to observing the internal processes within the factories, the author monitored the overall environment around the factories and took photographs and collected evidence. The analysis for the field work has been supported in this thesis by visits to two UK factories to develop a suitable benchmark for comparison. During the field work, statistical production and maintenance data has been collected to evaluate the general performance of the factories and to identify any current limitations or observations that can be fed into future stages of the study. The field work and statistical data helped in developing and investigating the initial concepts using questionnaires/survey in order to evaluate staff response and ideas. Interviews, conducted with middle and top managers and senior engineers, allowed the author to acquire more details and greater insight of the problem and issues concerned. During interviews, the author has discussed all issues covered in the fieldwork, observations and questionnaires to uncover specific information that might not have been obvious and also to allow the validation process via cross-check between the findings from different methods. Semi-structured interviews are used in this research work where the interviewer started with a group of questions, but based on the response of the interviewee, further discussion was generated on-line to investigate the subject further which added high flexibility to the process. The results of the interviews have been coded in this research thesis to develop, in addition to the qualitative analysis, quantitative analysis to evaluate the results and information obtained from the interviewees.

Case studies have also been presented in an attempt to understand the overall situation in the company. The case studies covered in this work are based on a mix of quantitative and qualitative evidence combined with direct detailed observations. The case studies have been based upon evaluating the maintenance and production performance.

The results collected from different methods are discussed and compared in order to validate the outcomes. Simulation is also used to model the system to evaluate the transient behaviour of the Kiln as a critical stage in cement production and estimate the yearly breakdown time based on the stochastic simulation of the processes within the factory.
Following the development of the framework, a validation questionnaire has been used to validate the findings and refine the suggested framework.

12.2 Key Findings of the research

In Chapter 2 of the literature review, the author has described, in general terms, maintenance strategies and practice. It has outlined different maintenance strategies and its importance to production systems. It has been found that maintenance is a critical function for continuous production systems, such as cement production. It has been also found that it is essential to integrate production activities with maintenance plans in order to achieve the most out of it and enhance productivity. Maintenance is considered to be part of the business and not a ‘necessary evil’ that is only performed with machine breakage. Maintenance cost is also discussed and direct and direct costs are presented. It has been outlined that indirect costs (such as reject rates costs and over capacity costs) could have significant negative effect on the factory and profitability as much as direct costs (such as spare parts costs and employment costs).

Chapter 3 has introduced Total Productive Maintenance (TPM) as one of the strategies that could provide a suitable solution for the cement factories in Libya. The advantage of TPM has been found to be the continuous improvement that embraces all aspects of an organisation. It has been found to involve all employees, attempt to eliminate all breakdown problems and encompasses all departments including production, management and maintenance. It is one of the key strategies that integrate maintenance with production activities to minimise production problems. It is an inclusive strategy that could utilise preventive maintenance and condition-based maintenance to keep machines at excellent working conditions. TPM employs five pillars to achieve its objectives which are: improving equipment effectiveness by targeting major losses, involving operators in daily maintenance of their equipment, improving the overall maintenance efficiency and effectiveness, focus on training to improve skills and life-cycle equipment management and maintenance design. From the author's experience, it has been found that TPM could be the solution to the problems facing the cement production in Libya. However, one of the problems is the methodology that can be used to implement TPM. It has been found that the current culture and behaviour does not allow for TPM to be implemented directly and research is needed to address this problem and identify the most suitable techniques to introduce TPM and improve productivity.

Chapter 4 has introduced the context of the problem. It has outlined key information about the cement company and its four factories for the reader to be able to understand the context of the study.

Chapter 5 has presented statistical analysis and performance indicators of production data and downtime in the four factories. It has been found that the percentage of downtime-hours relative to the target operational hours is relatively high and could reach 40% in some cases. The minimum percentage between 2004 and 2008 is found to be 18% for MCF while the minimum average of all factories is found to be 23% which is significantly high. Technical failures and schedule maintenance are found the most significant in the overall downtime. However, the author, based on the field work, is not confident that the scheduled maintenance is a real 'planned' maintenance but could be a technical failure that is categorised as schedule maintenance since there was lack of strategic maintenance plan at the factory during the field work. The actual production has been found to reflect the downtime and is much lower than the target value. In some cases, as in 2006, it has been noticed an artificial reduction in the target value below the design capacity so that the actual production could exceed expectations (see Figure 5-12). This could be related to the cultural influence and statistical manipulation to show progress when compared to previous years. Productivity in relation to the output per employee is also found relatively low and fluctuates between factories and years. The key finding is that the productivity of the factories are relatively low and there is significant difference between the factories. The analysis of the statistical data has been used to design the questionnaire and the interviews in order to study the reason behind this behaviour.

Chapter 6 has included field visits to UK factories and Libyan cement factories. The visits provided observations and outlined some drawbacks in Libyan factories when compared with UK factories. Photographic evidence has been used to show the difference so that UK production system could act as a benchmark to the Libyan counterparts. Several problems have been identified including pollution, cleanliness, condition of equipment, maintenance procedures, health and safety, age of equipment, technology involved and team work and communication with employees. The negative effect of the Libyan factories on the environment could easily be seen from space by Google Earth photos. The field visit also has outlined problems with agricultural production as a result of this pollution during some discussion with farmers and observations during field visits. The high level of pollution is found to be a direct result of poor maintenance of filters and other equipment within the factories that causes emission of dust and other harmful gases.

Chapter 7 presented a design of a questionnaire to understand the culture, practice and management systems within the four factories. The survey has covered the operational, maintenance and health & safety aspects in an attempt to provide a comprehensive understanding to problems and current practice in the four factories including the technology and the human aspects. In total, 130 employees have responded to the survey from the original 160 questionnaires that have been distributed. The results have presented several negative issues including the lack of maintenance strategies, high level of non-productive time, lack of performance related incentives, insufficient training and personal development, insufficient monitoring of pollution, insufficient social programmes, lack of transportation equipment for raw materials, lack of job satisfaction and unavailability of documentation and data management. Despite the long list of negative issues, the survey has identified several positive aspects including the availability of raw materials, recycling of materials, availability of fire stations and the relative availability of spare parts.

Following the survey, a semi-structured interview in chapter 8, has been designed and conducted for top and middle managers in the company and the four factories. The interviews have been analysed using a coding quantitative approach and qualitative analysis. The results have been found to be in-line with the findings from the survey. Simprocess software, presented in chapter 9, has been utilised as a stochastic modelling tool to simulate LCF. The simulation has been used to study the transient repose of the Kiln and to simulate the complete output of the factory. A field visit has been utilised to collect the statistical data in order to develop the stochastic statistical modelling to construct the simulation. Simprocess was used with design availability to simulate the complete system. Then a breakdown was introduced to evaluate the output of the system. It has been found that LCF with its average output has the equivalent of non-productive time of 96 days. This is more than 3 months of complete shutdown of the factory every year. The simulation results also highlighted that it takes about 15 hours for the Kiln to reach its steady state production level. From the results, it has been found that the current low production of the factory is a direct result for stoppage time and low availability of equipment due to technical faults and poor maintenance.

From the results of the first nine chapters, Chapter 10 introduced a novel framework for the implementation of TPM. The main idea is the integration of the three parameters, namely: motivation, training and consideration of the internal and external factors within the factories. These three parameters are integrated in one dimension using Comprehensive Productivity Maintenance Strategy (CPMS) model. The CPMS combines the parameters and integrate the processes within the factories to suitable level where TPM can be implemented. A model of Sustainable Development and Collaboration Model have been presented which suggests a collaboration system between the factories and the national and international organisations through a Centre of Best Practice (CBP) which acts as the focal point between all partners to encourage continuous improvement and collaboration.

Chapter 11 has presented different parameters that could be categories under motivation, training and internal and external factors. The validation included salary and financial award, international training, environmental issues, internal training, incentives, maintenance, social aspects, environmental contribution, communication and fulfilment, productivity and the type of factors that influence productivity. The results prove that the above issues have significant influence on productivity and should be included in the framework as sub-factors and should be addressed as part of the CPMS model. A general and comprehensive outline of the suggested framework is presented in Chapter 11 to suggest all aspects that should be taken in order to improve productivity in the cement industry at NCC.

12.3 The Answers to the Research questions

This section summarises the research questions and the answers found as a result of conducting this research.

- What are the problems facing the Libyan industry and the cement sector in particular and what are the key factors influencing the cement industry in Libya?

The author from his experience in the factory has identified several problems such as low productivity, fluctuation in production and the negative effect on the environment. However more detailed analysis was needed to able to understand the problems in detail.

Using statistical analysis, Chapter 4 highlighted some of the production problems over more than a decade (between 1993 and 2006), see Figures 4-16 to 4-19. The chapter investigated the trends in the factory production and highlight the main problems and limitation in the current production and maintenance strategies. It has been observed that the production has significant fluctuation and production reaches almost 50% of the design capacity in some years.

In chapter 5, factory reports were used highlight the investigate problems non-productive time and investigate the different between actual production and target production over several years, see Figures 5-7 to 5-12. The findings indicate that factories low productivity and the significant difference between the four factories.

Chapter 6 has highlighted field work visits to UK and Libya cement factories. It has been found that the condition of cement factories in Libya would need significant improvements in area such as cleanliness, environment, maintenance of machinery, oil leakage, prevention, using modern control rooms and the implementation of the 5S's techniques. It has found that the four factories had significant negative effect on the environment and on the farming community as a result of cement deposition on the ground and trees, see Figures 6-9 to 6-15 . Using simulation in Chapter 9, the author has evaluated the effect of downtime on the productivity of the system. It has been found that the non-produce time in Libda's factory is equivalent to 96 days.

- What are the limitations in the current practice in the production of cement in the NCC and what are the human-factor aspects that should be addressed in implementing TPM (including training and personal development)?

This question has been investigated as part of field visits in chapter 6, has been found there is lack of motivation and interest between staff. The Questionnaire in chapter 7 has investigated the effect of operation, maintenance, health,

safety and productivity. It has been found there is lack over a clear systematic approach towards managing tasks with the factory. For example there is lack of maintenance strategy within the four factories and there are insufficient training courses in the factories. There is lack of interest from staff in the work due to lack of performance related incentives and inadequate salary. Part 5 pillars of TPM are training and skills improvement, improvement equipment, and improving maintenance. The questionnaire highlighted many drawbacks and the current practise and the culture. It has been found there is lack social programme to motivate employees and the lack job satisfaction.
It has also been found that regular maintenance of equipment is not maintained such as calibration of instrumentation and recording of maintenance procedure. On the other hand, there are some positive issue such as availability of raw materials and spare parts.

Chapter 8 included interviews with middle managers and senior engineering. This chapter has outlined the interviews with fifteen middle managers and senior engineers from the four factories. The results are in-line with those from questionnaires given to the shop-floor staff. There is lack of clear strategy in production, maintenance, environment, health and safety, and personal development of staff.

- What are the cultural issues that should be addressed when designing a maintenance strategy and a TPM model?

TPM builds most of its strength on the development, motivation and training of employees' chapters 7 and 8 have highlighted many cultural issues that should be addressed in the Libyan factories including training, salary, incentives, team work and being proactive.

For example, in Chapter 7, more than 70% of engineers stated that there is hardly any recreational programme organised by their respective factories (e.g. sports, trips, lectures, contests, etc.).

It is clear that factory staff rarely receive training or a certificate of appreciation. None of the factories has an incentive strategy that would motivate incumbent stuff to work harder. About 65% of staff rarely or never goes on training courses. This points out to a lack of personal development programmes within the factory. Obviously, this will lead to a decline in productivity, and also to a shortage of skills that are necessary to the company's future development plans. The number of workers who receive a performance related incentive is very small, at just 1.53%. However, the vast majority of employees do not receive performance related incentives, and this could lead to lower motivation and disappointment at work.
In general, the engagement and development of employees should be addressed as part of the maintenance strategy. However, due to the low salary and lack of award this has resulted in lack of motivation and interest in the work. Hence this has resulted in low productivity in the factories.

- What is the main effect of the current industry on the environment?

Chapter 6 has highlighted that the problems in a factory could go beyond the walls of the factory to have negative effect on the health and the environment. Pollution could be the most important external effect of the factory that could be linked directly to lack of maintenance. The high levels of pollution in the four Libyan cement factories are very clear, even when viewed from space; see Figures 6-9, 6-10 and 6-11. The field work has highlighted effect of poor maintenance on the local farms and agriculture were olive trees have been found to have low productivity due to cement dust in the local area around the factories , see figure 6-14. Also there was clear effect of the deposition of cement layer on wild life in the local area, see Figure 6-15.

In Chapter 7**,** the survey shows that there is no measurement and control over pollution levels emitted from chimneys. This could be one of the most significant findings of this research. The above survey results are in line with the field visits and satellite images which point to high levels of pollution in this geographical location. Figure 7-44 showed that the majority of engineers, up to 70%, believe that there are never any real repairs or maintenance of Filters. Moreover, pollution is not effectively treated before leaving the chimney which could put staff and people who live in the neighbourhood under high risk of health problems.

- What is the effect of the political history and current local People’s Committees on the cement industry in Libya, including the availability of spare parts and maintenance expertise?

The UN embargo on Libya “Between” 1993 to 2003 had negative effect on importing of technology and spare parts. This had a direct effect on maintenance and productivity. In addition, Libya, before 17 February 2011, had a unique political, social and economic system which makes addressing strategic issues in large companies a complex task due to the possibility of misuse of the social and political system by the employees. Similar to the challenges some companies in the West face with trade unions, companies in Libya face with its employees. Central government in Libya is made up of General People’s Committees (GPCs) that cover the core national issues, including finance, justice, economy and trade, workforce and training, planning and tourism, energy and others. Secretaries of the GPCs hold the equivalent of Ministerial rank and act as a link between the People's Committees and the Executive. Moreover, the central bank of Libya had full control on foreign currencies and factories needed to get permission to be able to pay foreign currencies; this has been slow process that does not much the speed of response needed for modern industries.

- What are the main aspects to be considered in a TPM model for the Libyan industry?

Chapter 10 has highlighted the main aspects that could influence the TPM model, see Figures 10-1 and 10-3. The framework suggested in Chapter 10 has included motivation, training and other external/internal factors within the company. A sustainable Development and Collaboration Framework has been

suggest which utilises collaboration and training with other industrial and academic partners. Using an evaluation survey, Chapter 11, has improved and provided further details to the model. It has been found that motivation would include issues such as rewarding performance, social activities, financial prize\reward, management stability, performance certificate, and increase in salary, especial promotion or higher position, increase in salary.
Training has been found to involve the following:

1. Training TPM and other maintenance strategies.
2. Internal training.
3. Attending conferences and workshops
4. Will long international training courses outside Libya.
5. Collaboration with universities and other companies.

Internal and external factors include:

1. Lack of team work.
2. Appointing unqualified people in some important positions
3. Lack of clean environment.
4. Lack of personal equipment and tools necessary.
5. Management stability.
6. Lack of collaboration with international companies.
7. Lack of collaboration with universities.
8. Lack of external markets.
9. Availability of equipment.
10. Misunderstanding political system in Libya.

- How can the TPM model be implemented in Libya, taking in to consideration all the issues that have been addressed in the previous research questions?

Chapter 11, Figure 11-13, presented the overall framework for implementing TPM to improve productivity. As presented in the chapter, the framework takes into consideration four types of external organisations, namely the Ministry of Industry, the Political System, Commercial Organisations and Academic/Research organisations. The external organisations communicate with NCC and the four factories through the Centre of Best Practice (CBP). The CBP takes the main three factors (motivation, training and the influence of internal and external factors) into consideration for an integrated approach of continuous improvement, named Comprehensive Productivity Maintenance Strategy, to allow the company and the four factories to implement TPM.

All influencing parameters are integrated and improved through the integration between CBP, CPMS and TPM as discussed in Chapter 11. Figure 11-14.Each influencing parameter should be addressed and investigated in a more comprehensive approach to find the most suitable solution. However, in this chapter, for example, the salary aspect was addressed in detail and it has been found that three times the current salary would be sufficient for

12.4 Contribution to Knowledge

The main emphasis of this research work is to investigate the current practice and the implementation of TPM in Libyan Cement Industry. It has been found that TPM's application in literature is difficult to be implemented directly in the Libyan Industry due to many internal and external factors as discussed in this thesis. The main contribution to knowledge has been to develop a Framework that could help in placing the Libyan cement factories in a position where modern TPM methods and research could be implemented. The difference in culture, environment and work ethics makes it difficult to export modern TPM as known in the developed world directly to Libya.

In summary, this thesis has contributed to knowledge in the following areas:

1. The identification of the current problems in cement production in Libya, particularly when addressing a combination of internal and external factors combined with the identification of production and maintenance problems.

2. The comparison between UK and Libyan cement and manufacturing systems to benchmark the current drawbacks in the Libyan manufacturing environment, particularly in the cement production sector.
3. Clear description of the cement production processes at NCC combined with stochastic modelling of the transient response of the Kiln and complete simulation of LCF.
4. Identifying key environmental problems caused by lack of maintenance at some of the cement factories in Libya.
5. Critical evaluation of the historical production data to evaluate the drawbacks and the areas of potential improvement.
6. Developing a comprehensive approach towards evaluating the current productivity in the Libyan factories is combining Operation, Maintenance and Health & Safety factors.
7. Evaluating the problems in four cement factories within the same study to develop a generic and general framework for implementing TPM.
8. Critical design and analysis of the questionnaires and interviews in order to identify current problems in cement production and possible solutions for the implementation of TPM in Libya.
9. The implementation of a diverse methodology to address the productivity problems in Libyan cement factories that comprises literature review, field work, case studies, statistical analysis, simulation, questionnaires, interviews and a validation survey.
10. The development of a novel Framework and its associated models to help implementing TPM in the Libyan industry.
11. The methodology and the developed Framework could be used as a generic platform for the development and production improvement of manufacturing systems in less developed countries.
12. The validation of the model using a survey and the identification of the factors that could be included in the Framework in order to improve productivity and the implementation of TPM.

12.5 The Strength and Significance of the Research

Libya is moving towards significant development in the educational and manufacturing sector. However, most modern research is difficult to implement directly in Libya due to many internal factors (within the production system) and external factors (culture and society related).

The significance of this research work is in the development of the Framework to prepare the cement factories into the implementation of modern TPM via CPMS (Comprehensive Productivity and Maintenance System). The production systems need to be addressed and improved to be at minimum level or requirements to be able to apply modern methods and techniques. If you imagine, productivity research as a pyramid, as shown in Figure 12-2, most modern research in the 21st century is targeted towards the 'tip of the pyramid to achieve an optimised performance for an already existing high productivity production systems with modern technologies and management strategies. The less developed countries, such as Libya, will find it difficult to implement such modern techniques and strategies, because the production system could be described as being at the 'base of the pyramid'. The attempt to implement too advanced techniques and strategies for the existing systems could lead to an unstable system that is difficult to implement. The argument that less developed countries could use 1950's and 1960's strategies and technologies, might not be as simple as it seems. The 20th century strategies and technologies were implemented in different culture, technological environment and political system. Hence, the 20th century strategies could be described as a 'pyramid in a different dimension' as described in Figure 12-2. In simple terms it might be difficult to implement productivity strategies that were implemented in Japan in 1980's, for example, in Libya in 2010.

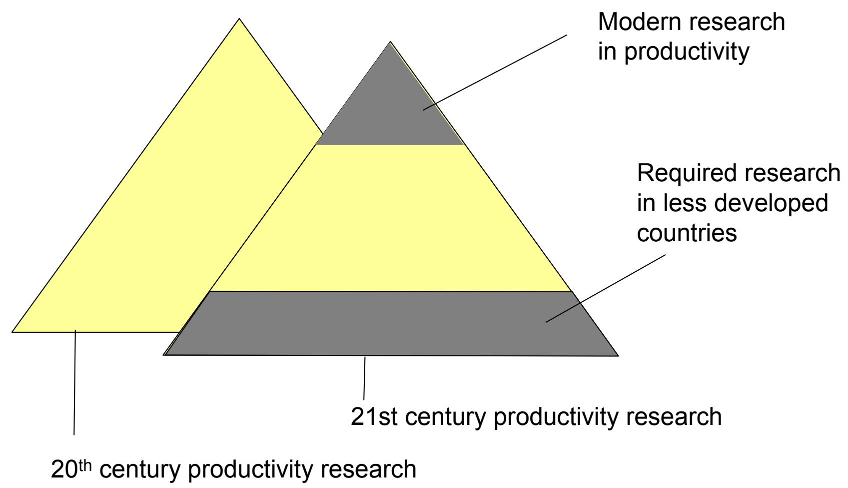


Figure 12-1: Comparison between modern research in productivity and the requirements of less developed countries such as Libya (Author).

The unique nature of Libya's political and culture could develop in complex management systems as described in previous chapters where average workers could have negative effect on the strategic development of the company similar to some trade union cases in Europe. This study has identified this problem and developed a Framework to address these internal and external factors for productivity improvement.

This research work has identified current problems that the Libyan manufacturing faces and potential solution to address such productivity problems. The methodology and the solution of this research work could act as a generic solution for other manufacturing sectors in Libya and other less developed countries. This research could act as demonstration for other sector and organisation who probably suffer from the same problems.

One of the findings of this research is that there exist a problem associated with the communication of problems and the sensitivity towards criticism. One of the solutions provided in this thesis and identified in the framework is the involvement of external organisations, such as universities, to act as a consultant in order to avoid any internal problems between employees and management. When the comparative study between UK's and Libya's factories was presented for the Libya factories, it acted as an ‘eye-opener’. The Libyan factories showed their interest to use the study as a training course for employees and management to show a positive benchmark that the Libyan factories could aspire to achieve. The comparison between Libya and the UK will be used as education material as an eye-opener. The identification of important internal and external factors that should be addressed to improve training and motivation is one of the important aspect of this thesis.

12.6 Limitations of the Research

Due to the time limitation and some other constraints in conducting this research work, there are several limitations that can be summarised as follows:

1. Simulation analysis could be more comprehensive in relation to the effect and availability of each stage on the complete system. However, the analysis was intended to be done on factory level rather than process level.
2. Validation included only shop-floor employees and top/middle management could be included in future research. However, the interviews the author had were sufficient to examine the relevance of the validation.
3. The interviews and questionnaires were conducted in Arabic language and translated into English. Although all effort has been made to ensure the accuracy of translation, there could be some minor differences between the languages in transferring the technical information.
4. The effect on the environment has been stare searched in qualitative method. Quantitative measurement could have been used to measure the level of pollution. However, other studies have been found to cover some aspects of this.
5. The study did not include questionnaires or interviews with people living near the factories to see if they suffer from any health problems as a result of their close proximity to a source of pollution.
6. The developed of the framework could have been applied in one of the factories. However, due to time limitation this has been found extremely difficult.

7. The study could have benefited from industrial visits to other cement factories in the Arab world to develop a second bench mark for the study.

12.7 Recommendations for Future Research

The author would like to propose some future recommendations for the research with regards to this domain:

1. Replicate the research on the same grounds but including other manufacturing sectors.
2. Performing an in-depth investigation with regards to availability of each machine and the effect of the simulation model.
3. Research to include the application of the author's framework in the cement industry and other type of organisations in Libya.
4. Investigating issues in relation to TPM in more detail following the implementation of the suggested framework.
5. Exploring evaluation process and application for TPM in the Libyan industry.

12.8 Summary

This thesis successfully provides answers to the research questions proposed at the beginning of this thesis. The research aim and objectives are achieved as follows:

1. The current practice and the need and implementation of Total Productive Maintenance (TPM) in Libyan cement industry have been investigated as the main aim of the thesis.
2. The current performance and problems of the Libyan industry in general and the cement industry in particular have been investigated and identified.
3. Productivity of the factories have been identified through statistical analysis, simulation and field visits.
4. A benchmark and a comparison study have been developed between the Libyan and UK cement industries.
5. A framework for implementing TPM for the cement factories in Libya has been suggested taking in the account the local organisational behaviour.

6. The study has provided a reasonable analysis of the cement manufacturing in Libya with future plan to improve the outcomes.
7. The research work also reflected on the problems and implementation of TPM and the internal and external factors that should be address to improve this.

Therefore, it could be confidently stated that this thesis provides significant information and knowledge on identifying current practice in the Libyan industry and the measures that should be taken to improve productivity and implement TPM.

Reference

Ahuja, I. and Pankaj, K. (2009), "*A case study of total productive maintenance implementation at precision tube mills*." Journal of Quality in Maintenance Engineering. Vol. 15 No. 3, pp: 241-258.

Aissani, N., Beldjilali, B., Trentesaux, D. (2009), "*Dynamic scheduling of maintenance tasks in the petroleum industry: A reinforcement approach.*" Engineering Applications of Artificial Intelligence. 22 (2009), pp: 1089–1103.

Akersten, P. and Backlund, F. (2003), *"RCM introduction: process and requirements management aspects*." Journal of Quality in Maintenance Engineering Vol. 9 (3), pp: 250-264.

Alan, M., Brit, K. (2009), *"Maintenance for historic buildings: a current perspective.*" Journal of Structural Survey. Vol. 27 No. 3, pp 210-229.

Alan, M., Naikan, A. (1989), "Availability *and maintenance cost optimization of a production plant.*" International Journal of Quality & Reliability Management Vol. 12, Issue: 2, pp: 28 – 35.

Albert, T. (2002), "*Strategic dimensions of maintenance management*." Journal of Quality in Maintenance Engineering Vol. 8, Issue: 1, pp: 7 – 39.

Al-Hassan, K., Swailes, D., Chan, J. and Metcalfe, A. (2002), "*Supporting Maintenance Strategies using Markov models.*" Journal of Management Mathematics Vol. 13, pp: 17-27

Al-Najjar, B. (1996), *"Total Quality Maintenance*." Journal of Quality in Maintenance Engineering Vol. 2(3), pp: 4-20.

Alsyouf, I. (2009), *"Maintenance practices in Swedish industries: Survey results."* Int. J. Production Economics 121 (2009) 212–223.

Andrew, G. (2004), "*Simulation modelling for Business*." England, Ashgate publishing limited.

Anish, S., Dinesh, K. and Pradeep, K. (2008), "*Planning and optimizing the maintenance of paper production systems in a paper plant*." Journal of Computers & Industrial Engineering 55, pp: 817-829

Arlene, F. (1995), *"How to Ask survey questions*." London, SAGE publications Ltd.

Baglee, D., Trimble, R. and MacIntyre, J. (2003), "*An investigation into the perceived barriers to Total Productive Maintenance in small medium enterprises."* International Conference on Manufacturing Research, University of Strathclyde, Professional Engineering Publishing.

REFERENCES

Bamber, C. J., Sharp, J. M. and Hides, M. T. (1999), "*Factors affecting successful implementation of TPM: A case study perspective*." Journal of Quality in maintenance Engineering Vol. 5(3), pp: 162-181.

Bamber, C. J., Sharp, J. M. and Hides, M. T. (2000), "*Developing management systems towards integrated manufacturing: a case study.*" Journal of Integrated manufacturing system Vol. 11 (7), pp: 454-461.

Ben-daya, M. (2000), "*You may need RCM to enhance TPM implementation.''* Journal of Quality in Maintenance Engineering Vol. 6 (2), pp:82-85.

Bill, G. (2000), "The Research Interview." Great Britain, TJ International, Padstow ,Gornwall .

Blanchard, B. (1997), "*An enhanced approach for implementing TPM in the manufacturing environment*." Journal of quality in Maintenance Engineering Vol. 3(2), pp: 69-80.

Bounicore, A. and Davis, T. (1992), *"Air Pollution Engineering Manual"*. New York: Van Nostrand Reinhold.

Brace, I. (2004), "*Questionnaire Design."* London, Kogan Page, limited.

Bryman, A. (1989), *"Research methods and organisation studies*." London, Billing and sons.

Bulent, D., Tugwell, P. and Greatbanks, R. (2000), *"Overall Equipment Effectiveness as a measure of operational improvement: A practical Analyses."* International Journal of Operations and Production Management Vol. 20(12), pp: 1488-1502.

Carlos Manuel, d., Carlos Manuel, C. and Joao carlos, M. (2008), "*Proactive reliability maintenance: a case study concerning maintenance service costs."* Journal of Quality in Maintenance Engineering Vol. 14 No. 4, pp: 343-355.

Catherine C, and Gillian S (2004), *"Essential Guide to Qualitative Methods in Organisational Research."* London , SAGE publications Ltd.

Cecille, P. and Gunaskeran, A. (1998), *"Implementation of productive improvement strategies in a small company."* Technovation Vol. 18 (5), pp: 311-320

Chan, F., Lau, F., Chan, S. and Kong, S. (2005), *"Implementation of Total Productive Maintenance: A case study."* International Journal of Production Economics Vol. 95 (1), pp: 71-94 .

Charles, J. and Andrew, P. (1995), "*Implementing TPM the North American Experience"* Productivity Press, Inc.

Christian, M., Ju¨ rgen, F., Alexander, B., Heiko, H., Jan, W., Alexander, O. and Matthias, S. (2009), *"Development and implementation of smart maintenance activities for machine tools."* CIRP Journal of Manufacturing Science and Technology 1 (2009) 237–246.

Company, H. M. (2000), *"The American Heritage Dictionary of the English Language."* Houghton Mifflin Company.

Concise Oxford Dictionary, Ninth Edition (1995), Clarendon press. Oxford.

Cooke, F. L. (2000), "*Implanting TPM in plant maintenance: some Organisational barriers."* International Journal of Quality & Reliability Management Vol. 17 (9), pp: 1003-1016.

Davis, C. and Greenough, R. M. (2002), "*Measuring the effectiveness of Lean Thinking Activities within Maintenance.''* Maintenance Journal: pp: 8-14.

Davis, R. K. (1995), "*Productivity Improvements through TPM, the philosophy and application of TPM."* New York. London, Prentice Hall.

Deming, E. (2009), *"The father of the quality Evolution."* (www.skymark.com). (2009-01-19).

DTI (1988), "*Effective Maintenance A Route to Increased Profitability*." DTI and Industry Publication managing into the 90's series.

Duffuaa, S., Ben-daya, M., Al-Sulatn, and Andijani, A. (2001), *"A generic conceptual simulation model for maintenance system."* Journal of Quality in Maintenance Engineering Vol. 7 (3): pp: 207-219.

El-Haram, M. and Horner, M. (2002), *"Factors affecting housing maintenance cost."* Journals of Quality in maintenance Engineering Vol. 8, Issue: 2, pp: 115-123.

ESOMAR/ Congress Amsterdam (1973), *"Fieldwork, Sampling and Questionnaire Design."*

Ferdows, K. and DeMeyer, A. (1990), *"Lasting improvements in manufacturing performance: in search of a new theory."* Journal of Operations Management 9(2), 168-184.

File, W. (1991), "*Cost Effective Maintenance: Design and Implementation."* Bodmin Cornwall, Butterworth Heinemenn.

Fletcher, J. (1973), *"The interview at work."* Liverpool UK, Unwin Brothers Ltd.

Fridrich, F. (1974), *"Why the Japanese have been so successful in business."* (Translation by George copeman). UK, W&J Mackay LTD, Chatham.

REFERENCES

Galbraith, J. R. (1977), *“Organisational Design Addison-Wesley.”* Reading, MA.

Gary, D. (1979), *“Human Behaviour Improving performance at work.”* .USA (Reston, Virginia), Reston publishing company, Inc. Aprentice-Hall Company.

Geoff, L. (2005), *“Research Methods in Management: A Concise Introduction to Research in Management and Business Consultancy.”* Published by Elsevier/ Butterworth Heinemann.

Gill, J. and Johnson, B. (1991), “*Research Methods for Managers.”* second edition. Paul Chapman Publishing Ltd, London.

Gotoh, F. and Tajire, M. (1992), *“TPM Implementation: A Japanese approach.”* New York, MCGrow Hill.

Goto, F. (1991), *“Equipment Planning for TPM.”* Maintenance Prevention Design. Cambridge .Mass, Productivity Press.

Graisa, M. and Al-Habaibeh, A. (2007), *“Total Productive Maintenance (TPM)-Case Studies from Human Factor and Technology Perspectives.”* ASME international Conference in Bahrain.

GPC (2007), The General People’s Committee for Industry and Minerals, Information and Documentation Centre Industrial Libya (10-01-2007).

Hartmann, E. H. (1992), “Successfully installing TPM in a non –Japanese plant.” Pittsburgh, PA, TPM Press.

Hayes, R. and Pisano, G. (1996), *“Manufacturing strategy : at the intersection of two paradigm shifts.”* Production and Operations Management 5 (1), 25-41.

Herbert, J. R. and Irene, S. R. (2005), *“Qualitative interviewing : the art of hearing data-2nd ed.”* USA ,Acid-free paper.

Hokoma, R. and Khan, M. (2006), *“Strategic impact of JIT technique for reducing the storage and eliminating the waste within petroleum industry.”* proceeding of the 9th Mediterranean Petroleum Conference and Exhibition, Tripoli, Libya, pp: 152-165.

Hokoma, R., Khan, M. and Hussain, K. (2008), “*Investigation into the implementation stages of manufacturing and quality techniques and philosophies within the Libyan cement industry.”* Journal of Manufacturing Technology Management. Vol. 19 (7).

Husband, T. (1976), “*Maintenance management and terotechnology first edition.”* Robert Maclehose & co.ltd. Saxon house.

REFERENCES

Imai, M. (1997), *"Gemba Kaizen A commonsense Low cost approach to management."* New York, McGraw-Hill.

James F, and Sabine, O. (1995), *"How to conduct interviews by telephone and in person."* London, SAGE publications Ltd.

Jennifer, A. F., Eileen, M., Toni, L. and June, W. (2009), *"Critical success factors for human resource outcomes in Kaizen events: An empirical study."* Journal of Int. J. Production Economics 117 pp: 42–65.

Johns, S. and Okland, (1993), "*Total Quality Management."* second edition.

Juan, F. A. (2009), *"Framework for implementation of maintenance management in distribution network service providers."* Reliability Engineering and System Safety 94 pp: 1639–1649.

Katayama, K. and Bennet, D. (1996), *"Lean Production in a changing competitive world : A Japanese perspective."* International Journal of Operations and Production Management Vol. 16 (2) pp: 8-23.

Kennedy, R. (1998), *"TPM: The Next Quality Frontier."* The Quality magazine Vol. 12, pp: 48-53.

Koelsh, J. R. (1993), *"A dose of TPM; downtime needn't be a bitter pill."* Manufacturing Engineering. 63-66, April.

Krejcie, R. and Morgan, D. (1970), *"Determining sample size for research activities ."* Educational and psychological measurement, vol. 30 pp: 607-610.

Krisztina, D. and Zsolt, M. (2010), "The impact of lean practices on inventory turnover." Int. J. Production economics.doi:10.1016/j.ijpe.

Labib, A. (2000), *"Framework for benchmarking appropriate productive maintenance."* Management Decision Vol. 10 (37),pp:792-799.

Lawrence, J. (1999), *"Use Mathematical Modelling to give your TPM implementation effort an extra boost."* Journal of Quality in Maintenance Engineering Vol. 5(1) pp: 62-69.

Leslie, R. (1988), *"The skills of interviewing: a guide for managers and trainers."* UK, Biddles Ltd, Guidford and King's Lynn.

Lewis, M. (2000), *"Lean Production and sustainable competitive advantage."* International Journal of Operations and Production Management Vol. 20(8), pp: 959-978.

REFERENCES

MACI (1995), "*Four phase approach to planned maintenance.*" In: Proceeding of the sixth Annual Total Productive Maintenance Conference and Exposition .Productivity Inc, Norwalk, CT, pp: 204-243.

Maggard, B. (1992), *"TPM That Works: The Theory and Design of Total Productive Maintenance."* Pittsburgh. TPM Press

Maggard, B. and Rhyne, D. (1992), *"Total Productive Maintenance: A Timely Integration of Production and Maintenance."* Production and Inventory Management Vol. 4 (4): pp: 6-10.

Mann, R. and Kehoe, D. (1995), *"Factors affecting the implementation and success of TQM."* International Journal of Quality &Reliability Management Vol. 12 (1). pp: 11-23.

Mandy, v. d. (2004), *"Guide to management Research Methods."* Published by Blackwell.

McKone, K. (1999), "*The impact of TPM practices on manufacturing performance ".* Journal of Operations Management Vol. 19 (19), pp: 39-58.

Mckone, K. E., Schroeder, R. G. and Cua, K. O. (1999), *"Total productive maintenance :a contextual view."* Journal of operations Management 17 (2), pp: 123-144.

Margaret, A. R. and Harry, A. B. (1997), *"Training interventions: Managing employee development –fifth ed."* UK, the Cromwell press, Wiltshire.

Martyn, S. (1999), *"Ahandbook for Training strategy-2nd ed."* Cambridge ,University press.

Menda, R. and Dilts, D. (1997), *"The manufacturing strategy formulation process: Linking multifunctional viewpoints."* Journal of operations management 15 (4), pp: 223-241.

Michael, P. C. and Gerald, M. K. (1993), *"Reducing preventive maintenance cost error caused by uncertainly."* Journal of quality in maintenance engineering, vol. 2, issue 3, pp: 21-36.

Miller, W. B. and Schenk, V. L. (1997), *"All I Need to Know about Manufacturing Learned at Joe's Garage: World Class Manufacturing Made Simple."* Bayrock Press, USA.

Mitchell, E., Robson, A. and Prabhu, V. (2002), "*The impact of maintenance practices on operational and business performance."* Managerial Auditing Journal Vol. 17, No. 5, pp: 234-240.

REFERENCES

Mohammad, A. and Nader, S. (2002), "*Auditing of the maintenance system of Fuhais plant/Jordan Cement factories Co.*" Journal of Quality in Maintenance. Vol. 8 No.1, pp: 62-76.

Moore, R. and Rath, R. (2000), *"TPM / RCM: Combining TPM and RCM, A case study."* Maintenance and Asset management Vol. 15(5), pp: 12-18.

Moubray, J. (1997), *"RCM II Reliability- centred maintenance."* Oxford, Butterworth –Heinemann.

Murthy, D. and Atrens, A. (2002), "*Strategic Maintenance Management."* Journal of Quality in Maintenance Engineering Vol. 8(4), pp:1355-2511.

Nakajima, S. (1988), *"Introduction to TPM first edition."* Productivity press, Inc.

Nakajima, S. (1989), *"Introduction to TPM first edition."* Productivity press, Inc

Neff, S. (1999), "Total Productive Maintenance." TMPonline.com Articles, USA.

Ohno, T. (1978). "*Toyota Production System: Beyond Large-Scale Production."*

Ollila, A. and Malmipuro, M. (1999), "Maintenance has a role in quality." The TQM Magazine. Vol. 11 pp: 19-21.

Panagiotis, H. T. (2009), *"Classification and calculation of primary failure modes in bread production line."* Journal of Reliability Engineering and System Safety. 94, pp: 551-557.

Patterson, W., Fredendall, L., Kennedy, W. and McGee, A. (1996), "Adaptting Total Productive Maintenance to Asten, Inc." Production and Inventory Management Journal, Fourth Quarter, pp: 32-36.

Paul, B. and Lynne, M. (2001), "*Organisational Research Methods."* London, SAGE publications Ltd.

Penny, H. (2006), *"Training practice."* UK, Cromwell press, Trowbridge, Wiltshire.

Peter, M. M., Frank, H. M. and Jurgen, H. (1991), *"Total productive maintenance: an international analysis of implementation and performance."* http:// www.bwl.uni-mannheim.de

Peter, M., Liliane, P. A., Ludo, G. A. and Harry, M. (2010), *"Development of maintenance function performance measurement framework and indicators."* International Journal of Production Economics, doi:10.1016/j.ijpe.2010.04.039.

Pintelon, L. (1999), *"Case Study: RCM-yes, no or maybe?''* Journal of Quality in Maintenance Engineering Vol. 5 (3) :pp:182-191.

Powell, T. C. (1995), *"Total quality management as competitive advantage: a review and empirical study."* Strategic Management Journal 16, pp: 15-37.

Pramod, V., Devadasan, S., Muthu, S., Jagathyraj, V. and Dhakshina, G. (2006), *"Integrating TPM and QFD for improving quality in maintenance engineering."* Journal of Quality in Maintenance Engineering, Vol. 12, Issue: 2, pp: 150 – 171

Qin, S. and Tang, B. (2005), *"Development of vi-based predictive maintenance system."* http:// www.library.witpress.com

Ranky, P. (1990), "*Total Quality Control and JIT Management in CIM."* Surrey, England, British Library.

Raouf, and Ben-Daya, M. (1995), *"Total maintenance management: a systematic approach."* Journal of Quality in Maintenance Engineering, Vol. 1 Issue: 1, Page: 6 – 14.

Rhyne, D. (1990), *"Total plant performance advantages through total productive maintenance.''* APICS Conference Proceeding Birmingham : pp: 683-686.

Rich, N. (1999), *"TPM: The Lean Approach."* Great Britain, Tudor Press.

Robert, A. (2006), *"Generate Corrective Maintenance Tasks."* http:// www.mt-online.com .(20/11/2007).

Robert, E. (1996, 1999), *"Effective interviewing."* London, Kogan page Ltd.

Roberts, J. (1995), "*TPM : Basic Implementation Process."* Texas University, 2001.

Roberts, J. (1997), *"Total productive maintenance (TPM)."* Department of Industrial and Engineering Technology, Texas A&M University-Commerce, et.nmsu.edu

Roger, M. (1991), *"A Practical Perspective."* United Kingdom Edition, by Academic press Limited.

Rosqvist, T., Laakso, K. and Reunanen, M. (2009), *"Value-driven maintenance planning for a production plant."* Journal of Reliability Engineering and System Safety 94 pp: 97-110.

Ruzela, K., Wolfgang, K. and Tim, B. (2009), *"Combining Simulation and Animation of Queuing Scenarios in a Flash –Based Discrete Event Simulator."* UNISCON, LNBIP 20, pp: 251.

RPA (2006), Report of the Public Authority for the ownership of companies and

Economic units, and investment management companies (The General People's Committee), 13-01-2006.

Sakakibara, S., Flynn, B. and Schroeder, R. (1993), *"A framework and measurement instrument for just–in-time manufacturing."* Production and Operation Management 2 (3), pp: 177-194.

Shad, D. (2008), "*The role of industrial maintenance in the maquiladora industry: An empirical analysis."* Journal of Int. J. Production Economics. 114 pp: 298-307.

Shahgedanova, M., Burt, T. and Davies, T. (1999), *"Carbon monoxide and Nitrogen Oxides pollution in Moscow."* Journal of Water, Air and Soil Pollution Vol. 112(1-2): pp: 107-131.

Sherwin, D. (2000), "*A review of overall models for maintenance management."* Journal of Quality in Maintenance Engineering Vol. 6 (3) : pp: 138-164.

Shirose, K. (1992), "*TPM for Workshop Leaders."* Productivity Press, Cambridge, MA.

Shirose, K. and Kaneda, Y. (1995), *"P-M analysis ,an advanced step in TPM implantation."* Portland Oregon, Productivity press.

Steinbacher, H. and Steinbacher, N. (1993), *"TPM for America-what it is and why you need it."* Productivity Press, Cambridge, MA.

Sten, L., Ann, O. and Dick, T. (1981), *"Carbon Dioxide Output in Spontaneously Breathing Infants During Anaesthsia and Surgery."* Br.f. Anaesth, 53,647.University Hospital Sweden.

Swanson, L. (2001), "*Linking maintenance strategies to performance."* International Journal of Production Economics Vol. 70 (3): pp: 237-244.

Takahashi, Y. and Osada, T. (1990), *"TPM, Asian."* Production Management organisation, Tokyo.

Talaat Alawaj (1994), "Air pollution and environment." Egypt.

Tolliday, S. (1998), "*The Rise and Fall of Mass Production."* Cheltenham, Edward Elgar Publishing.

Tsang, A. (1998), "A Strategic approach to managing maintenance performance." Journal of Quality in Maintenance Engineering Vol. 4(2) pp: 1355-2511.

Teresko, J. (1992), "Time Bomb or Profit Centre?." Industry Week 241, no. 5 March 2 pp: 52-57.

REFERENCES

Waeyenbergh, G. and Pintelon, L. (2002), *"A framework for maintenance concept development."* International Journal of Production Economics Vol. 77, pp: 299-313.

Willmott, P. (1997), "*TPM the Western Way."* Oxford, Butterworth- Heinemann.

Yamashina, H. (1995), *"Japanese manufacturing strategy and the role of total productive maintenance."* Journal of Quality in Maintenance Engineering Vol. 1 (1) pp: 27-38.

Web. Site :

All about Cement(2007)[online] . Available from :
http://www.lafarge.co.uk/wps/portal/uk/2_2_3-History.
[Accessed : 01 February 2007].

Cement Manufacture (2009) [online] from:
http://www.cement.org/manufacture/
[Accessed: 15 January 2009].

Cementindustry (2007)[online] from:
http://www.cementindustry.co.uk.
[Accessed: 07 February 2007].

Cement manufacture Process (2009)[online]from:
http://www.gich.com.hk/Facilities/f_manflow.htm
[Accessed: 05 March 2009].

Household Hazardous Waste Collections(2009)[online]from:
http://www.epa.state.il.us/land/hazardous-waste/household-haz-waste/index.html
[Accessed: 20 January 2009].

Map of Libya (2007)[online] from:
http://www.lonelyplanet.com/maps/africa/libya/
[Accessed: 12 February 2007].

The Atmosphere, Climate & Environment (2009)[online]from:
http://www.lordgrey.org.uk/~f014/usefulresources/aric/resources.html
[Accessed:01 January 2009].

Sulphur-Dioxide (2009)[online]from:
http://www.ace.mmu.ac.uk/eae/air_quality/Older/Sulphur_Dioxide.html
[Accessed: 10 January 2009]

Appendix A

Interviewees List

Managers and Head of Departments at Libya Cement Factories.

1- Engineer A (EA), Director of Maintenance and Production NCC.

2- Engineer B (EB), Maintenance Manager LCF.

3- Engineer C (EC), Maintenance Manager SCF.

4- Engineer D (ED) , Maintenance Manager ZCF.

5- Engineer E (EE), Head of Maintenance Department MCF.

6- Engineer F (EF), Production Manager LCF.

7- Engineer H (EH), production Manager SCF .

8- Engineer G (EG), Production Manager ZCF .

9- Engineer I (EI), Head of department of production MCF.

10- Engineer J (EJ), Head of department of planning and programming LCF .

11- Engineer K (EK), Head of department of planning and programming SCF.

12- Engineer L (EL), Head of department of planning and programming ZCF.

13- Engineer M (EM), Head of department of planning and programming MCF.

14- Engineer N (EN), Head of department of research and planning & programming NCC.

15- Engineer O (EO), Head of storage factory LCF.

Appendix B

Interviewee Introduction Letter - Sample

8th September 2007.

Dear Mr./Mrs/Dr. xxxxx,

My name is Mustafa Mohamed Graisa and I am a researcher at Nottingham Trent University. Currently I am conducting my research, as required for the completion of my PhD degree in TPM (Total Productive Maintenance).

The subject of the research is “Total Productive maintenance (TPM)’’ implementation in the Cement company in Libya – Case study. Its main objective is to conduct an overview and investigation of the key successful factors and affecting productivity for implementing TPM in Cement Factories.

I would be grateful if you could give me the opportunity to discuss with you the above-mentioned subject through personal interview, phone or by email. An interview by phone could be arranged according to your preferable date and time via the telephone or the Internet. Before the interview day, receive an e-mail with the questions, so that you will have the time to respond to these questions. Please, note that our discussion by email or phone will be confidential (No names of companies or person will be disclosed without you premises) and used only for the purposes of this study.

We would appreciate therefore if you could communicate with us at your earlier convenience, in order for the interviewee’s details to be arranged.

If you need any further information or if not needed you have any questions, please don’t hesitate to contact me .

Sincerely Yours

Mustafa Mohamed Graisa
mmgraisa@yahoo.com
Research Student
University Graduate School, Art & Design and Built Environment
Dryden Centre - Room 211
Nottingham Trent University
Burton Street
Nottingham
NG1 4BU
Tel: +44 (0)115-848-2521
Mob. 00447882112687

Appendix C

List of Published Papers From This Thesis:

1- Graisa .Mustafa and A. Al-Habaibeh (2007) Total Productive Maintenance (TPM)-Case Studies from Human Factor and Technology Perspectives, November 2007, at ASME international Conference in Bahrain.

2- M. Graisa and A. Al-Habaibeh, and D. Su (2009) The Application of Computer Simulation for Evaluating Cement Production in Libya. International Conference on Advanced design and Manufacture 2009, Harbin, China

3- M. Graisa and A. Al-Habaibeh (2009) An Investigation into the Need and Implementation of Total Productive Maintenance (TPM) in Libyan Cement Industry, Completed References Journal of Manufacturing Technology and Management, 2010.

Appendix C 1

Total Productive Maintenance (TPM)-
Case Studies from Human Factor and Technology Perspectives

M. Graisa and A. Al-Habaibeh
Advanced Design and Manufacturing Engineering Centre
School of Architecture, Design and Built Environment
The Nottingham Trent University,
Nottingham, UK
mmgraisa@yahoo.com ; *amin.al-habaibeh@ntu.ac.uk*

Abstract:

TPM is a generic maintenance philosophy that transforms maintenance activities from what is considered to be the 'necessary evil' into an essential part of the business. In TPM, maintenance and downtime is integrated within the production system and scheduled as an essential part of the manufacturing process. This paper introduces TPM main concepts and presents two case studies to highlight the importance of TPM from human factor and technology perspectives. The results found indicate that for successful TPM strategy, both aspects should consider and optimised.

Keywords: Total Productive Maintenance, CBM, condition monitoring, cement manufacturing, embedded systems.

Appendix C 2

The Application of Computer Simulation for Evaluating Cement Production in Libya

M. Graisa, A. Al-Habaibeh , and D. Su
Advanced Design and Manufacturing Engineering Centre
School of the Built Environment
The Nottingham Trent University
Burton Street, Nottingham, NG1 4BU,UK
http://www.admec.ntu.ac.uk/

Emails: Mustafa.Graisa@ntu.ac.uk, Amin.AL-Habaibeh@ntu.ac.uk

Abstract

As industry becomes increasingly capital intensive, and the relative cost of assets increases, so does the importance of utilising and maintaining these assets. This tendency is particularly true for industries with continuous process. Here, both the economic, safety, and the environmental consequences of equipment failure can be enormous. The increasing complexity of the equipment also has a profound influence on its productivity, maintenance and process improvement. This Paper investigates the use of computer simulation for evaluating the performance of Cement Production in *Libda* cement factory in Libya and to investigate design modification to enhance its productivity. The results indicate that simulation could provide a useful tool for critical evaluation of factories and to plan design and modification activities.

Appendix C 3

An Investigation into the Need and Implementation of Total Productive Maintenance (TPM) in Libyan Cement Industry

Mustafa Graisa and Amin Al-Habaibeh
Advanced Design and Manufacturing Engineering Centre
Nottingham Trent University
Burton Street, Nottingham, NG1 4BU
Emails: Mustafa.Graisa@ntu.ac.uk, Amin.AL-Habaibeh@ntu.ac.uk

Abstract
Purpose- The purpose of this paper is to investigate maintenance and production problems in the cement industry in Libya with particular emphasis on Total Productive Maintenance (TPM).

Methodology/ Approach**-** The paper presents the use of case study approach of production data and history, field visits, a survey methodology using a detailed questionnaire with employees and interviews with top and middle managers in four cement factories.

Findings- It has been found that the four factories under investigation have low productivity and production levels when compared with the design values. There is no clear TPM strategy and it has been also found that the lack of training and personal development is the main cause of this problem. In addition, employees are found not to be motivated as a result of the lack of poor management strategy and reward structure.

Implications- Based on the findings, a new framework for TPM has been developed. This TPM strategy could be implemented in other Libyan factories as a result of the potential similarities in the cultural and environmental aspects.

Practical implications- The comparative analysis is developed into a model for international strategy design and implementation.

Originality/Value of paper- The paper highlights limitation is the cement factories in Libya in relation to TPM and production strategies. The importance of adopting a realistic strategy and framework by managers is discussed. This work is developed as collaboration between Academia and Libyan Cement industry for solving productivity problems and develops a strategic framework of TPM for improving the Libyan industry.

Keywords- Total Productive Maintenance, Libya, Cement production.

Paper type- Research paper.

Appendix C 4

Questionnaire

Choose one of the five figures
1= Always, 2=sometimes, 3=rarely, 4= never, 5=I do not know

NO.	Question	1	2	3	4	5
1	Q1: Have you ever noticed a shortage of raw materials in the factory?					
2	Q2: Does the standard of raw materials meet the specifications required for the manufacture of cement?					
3	Q3: Do you have a suitable process in place to test the raw material ?					
4	Q4: Have you undertaken a training course to enhance your understanding regarding raw materials and their testing?					
5	Q5: Is there sufficient transportation to maintain the right level of raw materials in production?					

Choose one of the five figures
1= Always, 2=sometimes, 3=rarely, 4= never, 5=I do not know

NO.	Question	1	2	3	4	5
6	Q6: Is there a shortage of spare parts for the transportation system?					
7	Q7: Is the number of skilled engineers and workers in the production area sufficient?					
8	Q8: Do you have shortage of spare parts in the production area?					
9	Q 9: Are spare parts for the operation area available locally?					
10	Q10: Does production operate on a regular schedule?					

Choose one of the five figures
1= Always, 2=sometimes, 3=rarely, 4= never, 5=I do not know

NO.	Question	1	2	3	4	5
11	Q11: Do you modernise your production equipment and facilities when needed?					
12	Q12: Is the number of skilled technicians and engineers who work in maintenance sufficient?					
13	Q13: Is the process of reporting and communicating regarding factory equipment efficient?					
14	Q14: Are the control devices and equipment inspected regularly and to schedule?					
15	Q15: Are spare kiln bricks readily available?					

Choose one of the five figures
1= Always, 2=sometimes, 3=rarely, 4= never, 5=I do not know

NO.	Question	1	2	3	4	5
16	Q 16: Do the brick ovens meet thermal specifications to produce good quality?					
17	Q17: Is equipment and machinery cleaned regularly?					
18	Q18: Are cleaning materials and tools available?					
19	Q19: Is there a high level of dust in the factory?					
20	Q 20: Is there a program for the inspection of machinery and equipment?					

Choose one of the five figures
1= Always, 2=sometimes, 3=rarely, 4= never, 5=I do not know

NO.	Question	1	2	3	4	5
21	Q 21: Is there a process in place to inspect equipment and machinery regularly based on the inspection programme?					
22	Q 22: Do you have a preventive maintenance programme?					
23	Q23: Is the number of skilled staff to conduct the maintenance sufficient in every shift?					
24	Q 24: Is there a system for recording maintenance data or information?					
25	Q25: Do you have some ideas for improving productivity or reliability of some of the machines or equipment in the factory?					

Choose one of the five figures
1= Always, 2=sometimes, 3=rarely, 4= never, 5=I do not know

NO.	Question	1	2	3	4	5
26	Q26: Is plant's non-productive time due to technical malfunctions?					
27	Q27: Do you want to move to another job role?					
28	Q28: Are you well treated by senior management?					
29	Q29: Are there recreational programme/trips organised by the factory?					
30	Q30: Have you received any certificate of appreciation during the period of your work?					

Choose one of the five figures
1= Always, 2=sometimes, 3=rarely, 4= never, 5=I do not know

NO.	Question	1	2	3	4	5
31	Q31: Did you have any training courses in the past?					
32	Q32: Do you need training courses to fulfil your role?					
33	Q33: Do you have any knowledge of TPM strategies?					
34	Q 34: Does your salary include a performance related incentive?					
35	Q35: Do you undertake external work your finical needs?					

Choose one of the five figures
1= Always, 2=sometimes, 3=rarely, 4= never, 5=I do not know

NO.	Question	1	2	3	4	5
37	Q37: Do you have a program for calibration of monitoring devices?					
38	Q38: Is there a policy for re-using or recycling of material such as iron, cardboard, wood and empty cement bags?					
39	Q39: Is waste (e.g. Lubrication oil) used and disposed of in an environmentally appropriate manner?					
40	Q 40: Do you measure the waste gases and pollution level emerging from the chimney?					

Choose one of the five figures
1= Always, 2=sometimes, 3=rarely, 4= never, 5=I do not know

NO.	Question	1	2	3	4	5
41	Q41: Are gases and dust emitted from the chimney be treated to prevent environmental damage?					
42	Q42: Do the filters operate to a high standard?					
43	Q 43: Are there any penalties for the failure of wearing protective equipment?					
44	Q44: Is an emergency system in the factory ready for action in case of fire or any other incident?					
45	Q45: Did you have training to deal with an emergency situation (health and safety training)?					

أستبيان

نامل من الاخوة المهندسين قراءة الاستبيان اولاً ثم وضع علامة صح على أحد الارقام في الجداول المبينه والتالية حيث ان الارقام مرقمة حسب الآتي

1= دائما , 2= احيانا , 3=نادرا , 4= ابدا , 5= لاأعرف

رقم	السئوال	1	2	3	4	5
1	هل سبق وأن لاحظت اى نقص فى المواد الخام داخل المصنع ؟					
2	هل معايير المواد الخام تلبى المواصفات المطلوبة لتصنيع الاسمنت ؟					
3	هل يوجد لديك عملية ملائمة لاختبار المواد الخام ؟					
4	هل تحصلت على دورة تدريبية لتحسين مفاهيمك للمواد الخام وأختباراتها ؟					
5	هل هناك وسائل نقل كافيه للمحافظة على مستوى المواد الخام فى الانتاج ؟					

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رقم	السئوال	1	2	3	4	5
6	هل هناك نقص فى قطع الغيار الخاصة بمنظومة النقل ؟					
7	هل عدد المهندسين والعمال الاكفاء كافٍ فى منطقة الانتاج؟					
8	هل عندكم نقص فى قطع الغيار بمنطقة الانتاج؟					
9	هل قطع الغيار الخاصة بمنطقة الانتاج متوفرة محلياً؟					
10	هل الانتاج يعمل بجدول دورى؟					

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رقم	السئوال	1	2	3	4	5
11	هل تقوم بتحديث أدوات و مرافق الانتاج عند الضرورة؟					
12	هل عدد الفنيين المهره والمهندسين كافٍ فى الصيانة؟					
13	هل عملية أعداد التقارير والاتصال بشان معدات المصنع فعالة ؟					
14	هل اجهزة ومعدات التحكم تفحص بشكل دورى حسب الجدول ؟					
15	هل الطوب الحرارى الاحتياطى متوفر بسهولة؟					

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رقم	السئوال	1	2	3	4	5
16	هل طوب الافران يقابل المواصفات الحرارية لانتاج جودة عالية ؟					
17	هل الالآت والمعدات تنظف بانتظام ؟					
18	هل ادوات ومواد التنظيف متوفرة ؟					
19	هل معدل الغبار عال فى المصنع؟					
20	هل هناك برنامج لفحص الالآت والمعدات ؟					

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رقم	السئوال	1	2	3	4	5
21	هل يوجد فحص دورى للالآت والمعدات اعتماداً على برنامج الفحص؟					
22	هل هناك برنامج للصيانة الوقائية؟					
23	هل عدد الموظفين المهرة للصيانة كاف ؟					
24	هل هناك منظومة لتوثيق بيانات او معلومات الصيانة؟					
25	هل هناك مقترحات لتحسين الانتاج والاعتمادية لبعض الالات والمعدات فى المصنع؟					

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رقم	السئوال	1	2	3	4	5
26	هل توقف المصنع نتيجة لاعطال فنية؟					
27	هل ترغب فى الانتقال الى وظيفة اخرى؟					
28	هل تعامل بشكل جيد من قبل الادارة العليا؟					
29	هل هناك برامج ورحلات ترفيهية منسقه من قبل المصنع؟					
30	هل تحصلت على شهادة تقدير خلال فترة عملك؟					

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رقم	السئوال	1	2	3	4	5
31	هل تحصلت على دورة تدريبيه فى السابق؟					
32	هل تحتاج لدورة تدريبيه لمواكبة عملك؟					
33	هل لديك أى معرفة باستراتيجيات ال ت. بى . أم ؟					
34	هل يتضمن مرتبك حوافز مرتبطة او متعلقة بالاداء؟					
35	هل تقوم بعمل خارجى لتلبيه حاجاتك المالية ؟					

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رقم	السئوال	1	2	3	4	5
37	هل لديكم برنامج لمعايرة اجهزة المراقبة؟					
38	هل هناك سياسة لاعادة استخدام او تدوير المواد مثل الحديد – الكرتون –الخشب-اكياس اسمنت؟					
39	هل النفايات مثل الشحوم والزيوت تستخدم او ترمى بطريقة ملائمة بيئياً؟					
40	هل تقيسون مستوى الغازات العادمة والتلوث الصادرة من المدخنة؟					

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رقم	السئوال	1	2	3	4	5
41	هل يتم معالجة الغازات والاغبرة الصادره من المداخن لمنع التلف البيئى؟					
42	هل تعمل المصفيات لمعايير عاليه؟					
43	هل هناك عقوبات لعدم ارتداء ملابس ومعدات الوقائيه؟					
44	هل منظومة الطوارى جاهزة للعمل فى حالة الحرائق او اى حوادث اخرى؟					
45	هل يوجد تدريب للتعامل مع حالات الطوارى؟					