Effect of ISO Certification on the Safety Performance Level of Petrochemical Industries in Arabian Gulf Countries

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Abstract

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Safety in the work place is a critical management issue and has serious dimensions in a petrochemical industry. Safety performance is closely linked with quality management. Quality being a competitive weapon has been the motivation for ISO 9001 certification. The primary objective of this research was to study and analyse the effect of ISO certification on the safety performance level of petrochemical industries in the Arabian Gulf region.

The literature review revealed the gaps that exist in the research efforts until now relating to the effects of ISO 9001certification on the safety performance in petrochemical companies. It also helped in identifying the 'instruments' for assessing safety performance more objectively.

The reactive safety performance data before and after ISO certification was collected from 10 ISO certified Petrochemical companies. Proactive safety performance data was collected from the same 10 ISO certified companies as well as from another 10 non-ISO certified companies. The safety culture data was collected through questionnaire surveys conducted in these companies. Qualitative safety data obtained were quantified using conventional scaling techniques.

Statistical analysis of the data showed significant improvement in safety performance level after the ISO certification. Results endorsed the view that positive safety culture is predominant in ISO certified companies. The research demonstrated the expediency of applying statistical models in analysing safety culture in Petrochemical industries.

It is concluded that implementation of ISO 9001 significantly improved the safety performance in petrochemical industries in Arabian Gulf countries, and it can be assessed objectively through statistical techniques. Based on the findings of the research a revised ISO/TS29001 process model with 'safety at the centre' is suggested.

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Above all, I want to glorify the Most Divine Source of Life and Energy who gave me strength and knowledge. I deeply know that without His great love and wisdom, any endeavor in this world is impossible.

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Keywords and Nomenclature

Keywords:

Quality and environment management, quality management systems, occupational health and safety, safety performance level, safety awareness, reactive and proactive indicators, hypothesis testing.

Nomenclature:

BSI	: British Standard Institution
BVQI	: Bureau Veritas Quality International
BLEVE	: Boiling Liquid Expanding Vapour Explosion
CIMAH	: Control of Industrial Major Accident Hazards
COMAH	: Control of Major Accident Hazards
DNV	: Det Norske Veritas
DTI	: Department of Trade and Industry
EC	: European Commission
EFQM	: European Foundation for Quality Management
EMAS	: Eco-management and Audit Scheme
EMS	: Environmental Management System
ETA	: Event Tree Analysis
FMEA	: Failure Modes and Effects Analysis
FTA	: Fault Tree Analysis
HAZOP	: Hazard and Operability Studies
HRA	: Human Reliability Assessment.
HSE	: Health, Safety and Environment
IMS	: Integrated Management System
ILO	: International labour Organisation
IOSH	: Institution of Occupational Safety and Health
ISA	: International Safety Auditors
ISO	: International Organisation for Standardization
ISRS	: International Safety Rating System
IAF	: International Accreditation Forum
MBNQA	: Malcolm Baldrige National Quality Award
NIOSH	: US national Institute of Occupational Safety and Health
OH&SMS	: Occupational health and Safety Management System
QMS	: Quality Management System
RoSPA	: Royal Society for the Prevention of Accidents

RS.C	: Royal Society of Chemistry
SME	: Small and Medium-sized Enterprise
TPM	: Total Productive Maintenance
TQM	: Total Quality Management
TQS	: Total Quality System
TSC	: Total Safety Culture
VCE	: Vapour Cloud Explosion

Definitions of Terms

Accident	Undesired event giving rise to death, ill health, injury, damage or other loss (OHSAS 18001:1999)
Incident	Event that gives rise to an accident or has the potential to lead to an accident (Note: Incident include "near misses" too) (OHSAS 18001: 1999)
Near Miss	An incident where no ill health, injury, damage or other loss occurs is also referred to as a "near-miss" (OHSAS 18001:1999)
Hazard	Source or situation with a potential for harm in terms of injury or ill health, damage to property, damage to the workplace environment or a combination of these (OHSAS 18001:1999)
HAZOP	Hazard and Operability Studies (HAZOP) is a systematic approach to recognizing and identifying possible hazards that may cause failure of a piece of equipment in new or existing facilities (Flynn and Theodore, 2002).
Harm	Death, injury, physical or mental ill-health, damage to property, loss of production, or any combination of these (Hywel, 1998)
Risk	Risk is the combination of the likelihood and consequence(s) of a specified hazardous event occurring (OHSAS 18001:1999)
Safety	Freedom from unacceptable risk of harm (OHSAS 18001:1999)
Risk assessment	Overall process of estimating the magnitude of risk and deciding whether or not the risk is tolerable (OHSAS 18001:1999)
Control features	Organisation's documented method to perform an activity under controlled conditions to achieve conformity to specified requirements (ISO/TS 29001:2003)

Chapter One: Statement of the Problem

1.1 Introduction

In order to gain a competitive edge in the global market, companies must be able to demonstrate that they have systems in place to provide a quality product. The demand for quality products and services brought about the development of the International Organization for Standardization (ISO)'s ISO 9000 series Quality Management System and made ISO certification an important factor in the international market place. A survey report by ISO shows that as of December 2003 there were 500,125 ISO certificates issued in 149 countries (ISO Press Release, 2004) ISO 9000 certification has almost become a pre-requisite for doing business in the global arena. This is especially true for companies that do business with the European Community. The new version of ISO 9001 asserts the role of Total Quality Management (TQM) model instead of the quality-assurance model of the previous version. The perceived pros and cons of ISO 9000 certified quality systems have been reported in a number of past studies. Lam and Tang (2002), note that ISO 9000 quality management system has a better quality of work, more efficient allocation of resources, less wasted materials, customer satisfaction, cost savings and better site safety. A regression model study by Calisir et al (2001) predicting large companies' satisfaction with ISO reveals that the satisfaction of large companies with ISO 9000 is influenced by operational improvements and overall success.

Even though customers, employees, shareholders and community are all concerned about safety at the work place, the management function of safety and loss control has often been neglected (Wilkinson and Dale, 1999). Prevention of accidents has traditionally been seen as an employer's legal and ethical obligation. Control of accidental loss can provide a significant cost saving, protect human resources, and has a positive impact on profitability. The Piper Alpha disaster in the North Sea in 1988, (Cullen, 1990) which killed over 165 people impacted the whole oil industry with an estimated financial loss of 2.5 billion dollars. The cost of Exxon Valdez, USA disaster is put at 3.5 billion dollars (Reason, 1991). The literature survey conducted as a part of this research revealed that in order to mitigate risk and improve safety performance organisations are adopting a multi-directional approach. Safety and risk aspects are studied at the design stage of the plant itself. Safety of processes, safety of plant & equipment and operations are addressed through risk assessment, Hazard and Operability (HAZOP) studies, accident and near miss studies, audit missions, preventive and corrective actions, proper handling, storage and transport of product and raw materials etc. Organisations are also focusing to develop expertise in the field of maintenance and operation, control its inspection activities, control technical standards, procedures and instructions to mitigate safety risk. Obviously, an organisation with an effective quality management system in place would normally be more likely to have systems and procedures, proper work instructions, systematic audits and corrective actions to improve the processes and services than would one which is unorganised.

Hence it is quite logical to think that an ISO 9000 certified company would normally perform at better safety levels and have lesser safety hazards and risks in comparison with a non-certified one. A Quality Management System thus, plays a key role in the safety performance and business continuity. Safety and risk management is a critical issue in a petrochemical industry and hence it is of value to study the effect of ISO 9001 certification on the safety performance of petrochemical industries. Arabian Gulf countries having the right concentration of those ISO9001 certified petrochemical industries made this particular research study a feasible one.

1.2 Background and Significance

Revolutionary changes occurring in today's workplace have far outpaced our understanding of their implications for work life quality and safety. Research is being carried out by various occupational safety, health and environment organisations looking for various aspects of working environment. Sweeping changes like globalization, restructuring, flexible employment, technological innovation, shifts in workforce demographics etc. are supposed to have an effect for worker health and safety. Reports in National institute for occupational safety and health (NIOSH) suggest directions for new research to understand and assess the impact of changes in work organisation (NIOSH, 2002). ISO 9000 Quality Management System is no longer the exclusive domain of manufacturing operations, and is also being applied to every kind of organisation like service, purchase, schools, colleges, consultancy services, local government departments etc.

Operational success is not possible without an overall improvement in safety aspects of the organisation. A study on improvement in organisational performance and self assessment by Van Der Wiele et al (2000) suggest that many of the companies showing improvement in quality of product, process and service had ISO 9000 series quality system in place. Prominent trends in the management systems are evident every where, but study of these management systems has not yet taken place from an occupational safety perspective. Implementing a quality system is a long term exercise. Tsekouras et al (2002) suggest that being a continuous process improvement, adoption of an ISO 9000 quality assurance scheme is beneficial in the long term and does not necessarily improve financial ratios in the short term. The tangible benefits are always noticed and reported but the intangible benefits need detailed analysis. Perceived benefits of ISO certification varies with the nature of business, in the petrochemical industry it is safety performance and risk mitigation that are of prime importance.

Responsible organisations are showing increasing concern about the well being of its employees and their working environment and the impact of their operations on their neighbourhood. Legislations were existing from many years back, Health and Safety at Work

Act 1974, Control of Substances Hazardous to Health Regulations 1988 are a few to mention. These regulations alone didn't achieve the necessary results as evident from the website of the UK Royal Society for the Prevention of Accidents (RoSPA). In the UK alone 1.6 million workplace injuries takes place every year and 25 million working days are lost annually as a result of work place accidents. Health and safety failures cost 6.5 billion pounds every year (RoSPA, 2000). The root cause analysis of all major disasters in the world highlights weaknesses in the system of operation, wrong quality spares, improper tools, wrong procedures and instruction, lack of training, etc; to name a few. Concerning these issues, quality management system has a major role to play. Report on the Bhopal gas tragedy in 1984, indicated that the protective systems like refrigeration systems, scrubbing system and flare system, which could have prevented or minimized the consequences were out of order. This shows the need for maintaining proper work environment and for safer design (Flynn and Theodore, 2002) and (Reason, 1991). The explosion of Phillips 66 Petrochemical Plant at Pasadena in 1988 resulted in the death of 23 workers and property damage amounting to nearly a billion dollar (Robert, 1990). The root cause analysis indicates that the wrong connection of an air hose to the actuator of a pneumatic valve during maintenance of the main reactor, which resulted in opening of the valve while it was supposed to be closed. A direct reference to quality of maintenance/construction activity carried out in the petrochemical plant. It may be noted that all these causes come under the purview of ISO 9000 quality management system and managing those relevant aspects of the quality management system can nurture a positive safety culture.

1.3 Rationale Behind the Study

Safety at the workplace is a collective responsibility of an organisation and its employees. Safety is based on the fundamental premise that accidents are preventable by eliminating unsafe acts or conditions in a systematic manner. At the same time, it may be noted that organisations are facing varied amount of safety risk due to lack of adequate Safety, Health and Environment measures taken by it. ABB had to pay £700m to settle the US claim of compensation to the former employees suffering from asbestos-related illnesses (Business week, 2002). There is room for improvement in the management of the technical standards that underpin the detailed design, construction and operation processes that ensure the appropriate management of risk. After a study of major fire and explosion incidents worldwide (1970-1994), Nolan (1996) noted that majority of these incidents were the result of small hydrocarbon leakages stemming from failure of system integrity, i.e., equipment failures or metallurgical failures of the process, showing a quality management issue. The root cause of Pennsylvania USA chemical plant explosion in 1994 was identified as uncontrolled reaction in chemical mixing. Explosion in the Inchon Seoul, South Korea in 1994 identified the root cause as overheated furnace, etc. These major incidents indicate that there exists a quality management issue in all these accidents. It is in this context, this research study becomes meaningful and one of the objectives was set to find out if there is a Quality Management issue related to accidents.

To ensure the utility value of any management system, we need to carry out proper gap analysis between requirements and expectation. ISO 9000 standard has been monitored continuously to serve its purpose, the revisions of 1994 and 2000 of the standard substantiates this claim. It is a powerful quality standard, it is also possible to follow it in many other areas. DNV Technica used ISO 9000 to assure the quality of HAZOP Studies, by defining a measure of the quality/objectives of HAZOP study (Charsley, 2001).

The successful use of quality tools leads to successful quality management and successful quality management should improve processes and product quality. Logically, in addition to enhanced quality performance, it should improve safety awareness and safety performance of the company as process quality improvement reflects in enhanced safety performance. Gulf Petrochemical Industries Company (GPIC), Bahrain which got ISO 9002 certification in 1995 claim that their ISO 9002 documented management system ensured them achieving the best safety performance among petrochemical industries (Yousif,1998). Twelve consecutive RoSPA Gold Awards, during 1991-2002, Lost-Time Accident free working record of over 5 million worker hours, RoSPA International Sector Award for Petrochemical Companies, 2001 etc substantiate their claim. Petrochemical Industries Company (PIC) in Kuwait claim one of the benefits of ISO certification as reduced risk liability (PIC, 2004). It was this aspect which was considered for detailed analysis in the research. There are many petrochemical companies that are certified with ISO 9000. In addition to ISO 9001:2000 and ISO 14001 certification, petrochemical companies are also adopting BS 8800, OHSAS 18001, TQM, Safety, Health and Environment (SHE) management system etc. All these systems, standards and guidelines are implemented separately or together as an "integrated" approach, each one claiming benefits of its own. It was the aspect of safety risk of ISO 9000 certified petrochemical companies of value for the research. Comparative study of various management systems was not the intent of this research; focus was made on the assessment of the safety performance levels of companies opting for ISO 9001 certification systems. The study will contribute its part to the drive towards a uniform system rather than many systems for unique purpose. Very few research studies have been conducted on this specific topic and the literature survey conducted by the author confirmed this fact.

Maintaining safety at petrochemical plants is a complex problem. Conventional safety practices do not address that complexity effectively. A tailor-made management standard taking in-to consideration the need of its users saves time and brings fruitful result. The aim of this research was to conduct a realistic assessment of the effect of ISO 9001 certification systems and procedures on the safety performance level of the petrochemical industries. There appears to be more show of concern and more effort to consult and involve the workforce. But is this safer? Does a company that has all quality procedures in place for the process it carries out demonstrate a better control of safety measures? When safety risk assessment is gaining more acceptances throughout the industrial spectrum, it is of value to study the safety risk assessment methods and strategies existing in the ISO certified companies. Real productivity being the balance between striving for excellence and protecting human resources, it is of value to find out the effect of ISO certification in the petrochemical industry. The majority of petrochemical companies of the Arabian Gulf are already ISO certified and the research focusing on these companies is very relevant.

1.4 Problem Statement

As per the new revision of ISO 9001:2000, consideration must be given to the work environment including health, safety, work methods, work ethics & ambient working conditions needed to achieve conformity of product and /or service. Businesses are coming under commercial, regulatory and ethical pressures to control risk and to comply with the appropriate legislation. In addition to ISO 9001, companies are also going for implementation of ISO 14001 and OHSAS 18001 in their quest for making work environment safe and healthy and to have a competitive edge in the global market. But are these companies really achieving their objectives by certification systems? Certification systems alone cannot provide assurance that people will not make omissions or mistakes. The history of all reported accidents, such as the Clapham and Cowden rail crashes in the UK, and accidents like Chernobyl, Bhopal, Piper Alpha, etc show that accidents are caused primarily by people doing unexpected things, or by not doing expected things. Errors often occur across interfaces, inadequate communication, in design, installation, maintenance, or operation. Obviously, a safety management system, involving identification of risk, responsibilities, training need and ensuring proper supervision will reduce the likelihood of accidents. However safety management systems alone cannot eliminate the possibilities of accidents of all kinds. The danger of placing too much emphasis on the safety management system cannot address the quality related safety issues.

Safety performance monitoring is getting more and more attention today. It enables companies to present positive figures on these areas that are vital to the overall business. However companies showing excellent safety records of 'Million Man-hours' without disabling accident etc had fatal/serious accidents for lack of following elementary safety practices. The Gas tragedy in the Union Carbide Plant at Bhopal, the Piper Alpha disaster in the North Sea and the TX Polyethylene Plant at Pasedena disaster are few examples. The logical question that arises in this context is: what effect ISO 9001 certified company has on those issues? The successful use of quality tools lead to successful quality management and successful quality management should improve process and product quality. Logically it needs to improve safety awareness and safety performance of the company. It is this aspect of safety performance which was analysed. Are well-documented, properly audited systems and procedures in all the areas of operation of company must be having a positive influence on the safety performance? Is it really happening? It may also be noted that safety risk exists in all spectrum of industry. The safety risk level is comparatively high in the petrochemical industry. It is of value to find out the relationship between the safety risk level and ISO certification? Do ISO 9001 certified companies demonstrate a better safety performance? Is it the regulatory obligation or the Certification that has more relevance? What is the comparison between ISO certified and non-certified companies in terms of safety record? Do the certified companies have other benefits?

Achieving better safety performance needs implementation of proper management systems and maintaining a positive safety culture. A culture is the pattern of shared attitudes, beliefs, assumptions and expectations which shape the way people interact in an organisation. People need to be aware of safety regulations, standard procedures etc. Development of the positive safety culture involves commitment, co-operation, communication, control and competence and a system to instil better attitudes, prudent approach to all aspects of job. Does implementation of ISO 9001 facilitate the formation of such an attitude and culture? What is the effect of ISO 9001 certification on the safety behaviour and attitudes of employees? Are the personnel working in the ISO 9001 certified companies showing better safety awareness level? What is the risk perception awareness level of managers in an ISO 9001 certified petrochemical company? What effect or influence does ISO 9001 certification have on the "risk elimination / mitigation" process employed by the petrochemical industries?

1.5 Research Goal and Objectives

The goal of this research was to find out the effect of ISO 9001 certification on the safety performance level of petrochemical industries in the Arabian Gulf countries. This was accomplished through statistical analysis of various quantitative and qualitative data related to safety such as proactive and reactive safety performance indicators, risk perception awareness, risk mitigation methods, and safety awareness among employees at all levels in petrochemical companies before and after ISO certification. Existence of a good safety culture is a pre-requisite for demonstrating a better safety performance level. Good safety culture needs elements like safe behaviour and attitude from personnel working within an organisation. The safety behaviour and attitudes are influenced by the safety awareness level of the personnel.

The objectives of the research were set on these factors. It is from this background checking of safety awareness level of employees was set as one of the objectives of this research. However there exist different categories of personnel within an organisation, and objectives were set to find out the safety awareness level of various categories of employees, safety and quality personnel and managers working in the petrochemical industries through well-structured questionnaire surveys.

Risk elimination is one of the top priorities in a petrochemical plant. Management commitment is a must for implementation of risk elimination/mitigation measures. Commitment of managers towards risk mitigation could reasonably be expected to depend on their risk perception awareness level. Hence, in addition to the testing of safety awareness level of managers an in-depth investigation on the risk perception awareness level of mangers working in the petrochemical companies is relevant and is considered as one of the major objectives of the research.

Keeping studying the effect of ISO 9001 certification on the safety performance level of petrochemical companies was the prime objective, the following specific objectives were also set:

1) To investigate the effect of ISO 9000 certification on the safety performance level of petrochemical industries.
2) To evaluate the impact of ISO 9000 certification on the safety awareness level of employees working in petrochemical plants.
3) To determine the impact of ISO 9000 certification on the safety awareness level of Safety and Quality professional working in a petrochemical plant.
4) To determine the impact of ISO 9000 certification on the safety awareness level of managers working in a petrochemical plant.
5) To find out the effect of ISO 9000 certification on the risk perception awareness level of mangers working in the petrochemical companies.
6) In addition to the above, it was also the objective of the research to find out the influence of ISO 9001 on the risk mitigation methods employed in a typical petrochemical company.

A very important expected outcome from this research work was whether statistical tools and techniques would be appropriate enough in analysing the safety culture of a petrochemical company. Since most of the factors that build up the safety culture are qualitative in nature, quantification would naturally be difficult. Literature does not provide information on such a work done before. Qualitative assessment cannot bring to light the biases, degree of errors and orientation. On the other hand quantitative assessment will be more accurate, measurable and impersonal. It can provide the researcher with the degree of confidence with which he can rely on the results obtained. Even if the population is qualitative, population parameters such as mean, variance and standard deviation could be used to analyse the data and inferences can be drawn through quantitative techniques. Therefore demonstration of the appropriateness of quantitative techniques in measuring the overall safety culture of a petrochemical company was set as an important objective.

1.6 Research Hypotheses

Any decision problem needs to be stated explicitly and put to rigorous tests before accepting or rejecting it. This statement is usually called a hypothesis and the procedure for making a decision out of such a statement is called hypothesis testing (Hines et al., 2003). Statistical hypothesis testing procedures were used in order to verify the research objectives in the light of the safety data available on companies before and after ISO certification.

The research objectives are to decide whether or not the mean safety performance level, the mean safety awareness level of employees, quality personnel and managers, and the risk perception level of managers of petrochemical companies improve or not after ISO certification. Expressed in words, the statements are as given in Table 1.1 below.

Table 1.1 Hypothesis Statements

	Null Hypotheses	Alternate Hypotheses
1	There is no significant improvement in the average safety performance level with ISO certification	There is significant improvement in the average safety performance level with ISO certification
2	There is no significant improvement in the average safety awareness level of front runner employees with ISO certification	There is significant improvement in the average safety awareness level of front runner employees with ISO certification
3	There is no significant improvement in average safety awareness level of Safety and Quality professionals with ISO certification	There is significant improvement in average safety awareness level of Safety and Quality professionals with ISO certification
4	There is no significant improvement in average safety awareness level of managers with ISO certification	There is significant improvement in average safety awareness level of managers with ISO certification
5	There is no significant improvement in risk perception level of managers with ISO certification	There is significant improvement in risk perception level of managers with ISO certification

To find out the effect of ISO 9000 on the risk mitigation methods employed by a petrochemical company requires.

Study of risk mitigation methods employed by a petrochemical company is an extensive exercise to be carried out on a case to case basis. The study must cover all the phases of the company including design, construction, operation, control and maintenance. Such an extensive study requires time, manpower and resources and doesn't come under the purview of the particular research and hence objective 6 couldn't state as a hypothesis.

However to reinforce the research findings a case study was conducted to find out the effect of ISO 9000 on the risk mitigation methods employed by a petrochemical company. The case study was also used to validate the statistical test models used for the first hypothesis test for the reactive safety data.

1.7 Methodology

Reactive safety performance indicator data of ten ISO certified petrochemical companies were collected. The data was classified as safety data before ISO certification and after ISO certification. Statistical analyses were then performed. To confirm the findings proactive safety performance indicator data were collected from ISO certified and non-ISO certified companies. Comparative analyses were conducted and conclusions noted.

A safety awareness questionnaire survey was conducted on sample respondents from front runner employees, quality and safety professionals and managers of ISO certified and non-ISO certified companies. Measurements were carried out using Likert scaling technique and statistical analyses were carried out and conclusions derived.

A risk perception questionnaire survey was conducted too, on similar lines, among managers of ISO certified and non-ISO certified companies.

To verify the findings, a case study was conducted on a representative petrochemical company which was not having any formal safety management system prior to ISO certification. The risk mitigation techniques adopted by the company before and after ISO certification were studied in detail and their relationship with ISO 9001 elements checked.

1.8 Assumptions and Delimitations

There are about 35 petrochemical companies in the Gulf region. A pilot study was first conducted on 27 of these companies. This survey covered 17 companies from the Kingdom of Saudi Arabia, 4 from Qatar, 3 from UAE, 2 from Kuwait and 1 from Bahrain. Then ten companies were selected as the sample. They included 3 companies from Saudi Arabia, 3 from Qatar, 2 from UAE, 1 from Kuwait and 1 from Bahrain. In order to avoid any kind of bias occurring while collecting data, extreme care was taken while choosing the sample. Lapin (1980) points out the less obvious sampling error which is the most dangerous in sampling, and against which nature offers little protection. This error is predominantly due to chance causes and biases. Understandably an absolute random sampling is out of question particularly when the statistical population is just about 35. Therefore ISO certification was taken as the main criterion for choice of the sample. The other criteria adopted for the selection of the companies were a) minimum number of operational years of the company b) type of products (petrochemical), oil or gas based c) capacity of production i.e. the scale of operation d) number of people employed e) company working in any one of the Gulf Co-ordination Council (GCC) countries and f) whether the company is ISO certified or not.

The initial selection based on the minimum criteria produced a list of 33 companies. From this preliminary list a second stage screening based on the most experienced from the list screened down the list to 14 companies and the final selection made based on availability of safety performance data and established contacts brought down the list to 10 companies. The same criteria were followed for Questionnaire survey on the ten non-ISO certified companies selected from the initial list.

Safety reactive indicators monitoring data and safety awareness survey data for the ISO certified and non-ISO certified companies were analysed and tested for the hypotheses formulated, (Table 1.1). Assessment of proactive safety indicators was done as a secondary analysis of reactive safety data for enhancing confidence in the results obtained. In addition, so as to investigate the risk mitigation techniques employed in an ISO certified company, a typical petrochemical company known to the researcher was selected on the basis of accessibility to sensitive risk assessment data for detailed study.

1.9 Overview of research

This report is presented in 6 chapters with four appendices. Chapter 2 presents the literature review of management standards with a special focus on "Safety" and "Risk" and its relationship to ISO 9001. Chapter 3 outlines the research methodology followed, the concept of reactive and proactive safety indicators used for the safety performance measurement and questionnaire survey used to assess the safety culture. Chapter 4 presents the research findings, Chapter 5 include discussion of results covering implication of results and reflection of issues raised in literature review and Chapter 6 draws out the conclusions and puts forth the researcher's recommendations.

1.10 Summary

This chapter has presented the scenario of the research work. The unique situation of petrochemical industries and the overpowering relevance of a safety system are briefly explained. The discussion furnishes the background, significance and rationale behind the research, too.

The goal and objectives of the reported research are discussed at length. The methodology adopted in carrying out this work and the associated delimitations are briefly highlighted. This chapter presented in a few words the various means by which data were collected, such as the questionnaire surveys, interviews, published documents and so on. Special mention was made about the biases in sampling and related assumptions. It was also described briefly how the hypotheses statements were arrived at, and how the appropriate statistical experiments were used in the work.

The extensive literature survey conducted by the researcher based on the research objectives was pointed out. The background and principles of ISO 9000 and application of ISO certification on a safety perspective analysed. The new industry specific standards ISO/TS 29001, related fields of study such as TQM, ISO 14000, safety management and risk management etc were also studied and are explained in detail in Chapter 2.

Chapter Two: Literature Review

2.1 Introduction

An extensive literature review was conducted on quality, safety, environment, and risk management systems with particular focus on the effect and links that ISO 9001 certification has on safety performance and risk mitigation in a petrochemical industry. The main objective of this search for the literature survey was to study quality standards such as ISO, BS etc., and to identify previous works done on the unique advantages of quality certification in petrochemical industries in relation to safety, environment and risk management. Other objectives included discovering the links, overlaps and gaps between various quality management systems in petrochemical industries. It was also expected that such an intensive study would yield valuable information on the gaps in research efforts on the issues reported here, in particular quality and safety management concepts.

2.2 Overview of Management Systems and Certification

As Nolan (1996) comments organisations have a blend of concerns like finance, human resources, quality of product/service, health, safety, environment, and customer relations etc. to manage. Different management systems exist to address those issues specifically. According to Boyle (2002), management systems can be divided in to four groups namely, Health, Safety and Environment (HSE) Management Systems, Quality Management Systems, Total Quality Management Systems and Integrated Management Systems. There exists a high degree of overlap between all these management systems. Management systems are devised and promulgated by national /international standard setting bodies like ISO and BSI, authoritative agencies such as Health and Safety Executive, UK and commercial and academic organisations (Boyle, 2002). Certifiable management systems like ISO 9001, ISO 14001 and OHSAS 18001 are practiced in order to ensure that a management system is adequate and effective. A valid certification process requires the management system to have a written standard, a body of competent and independent personnel to assess/audit the implementation and an authoritative body which verifies and approves the auditor's competency.

The Impact of standards on industrial development and trade especially in developing countries which face challenges and opportunities are discussed by Wilson (1999). If there is the drive to internationalize standards, the blurring of voluntary and mandatory can have important trade implications for developing countries. The researcher quotes the case of ISO 9000 series, the fastest growing international standard of all time.

By certification a company is demonstrating that an internationally recognized system is in place which has been verified by an accredited agency. Standards are detailed specifications for performing certain activities. Certification bodies check/audit the extent to which the norms are followed and complied with in an organisation and certify it. Certified System enables the management of any organisation to show their commitment towards Quality, Safety, Environment etc. Safety Management Systems include OHSAS 18001, a certifiable standard and BS 8800 which is not a certifiable standard (BS and OHSAS sources). ILO-OSH-2001 and HS (G) 65 are safety guideline standards. Existence of many safety standards creates confusion for certification (Boyle, 2002) ISO 9001 and ISO 14001 for Quality and Environment Management Systems are certifiable standards (ISO 14001:1996, ISO 9000:2000).

The certification bodies need to be accredited to an accreditation council. The Directory of ISO 9000 and ISO 14000 accreditation and certification bodies, lists 750 certification bodies, with full contact details (address, telephone, fax and, where available, e-mail address and name of a contact person etc) in 97 countries offering management system auditing and certification/registration services to the ISO 9000 (quality management) and ISO 14000 (environmental management) standards. It also includes entries for 52 national accreditation bodies, these are organisations established in a number of countries to approve certification bodies as being competent (ISO Press Release, 2004). ISO 9000:2000 is a series of three international standards for quality management systems. They specify requirements and recommendations for the design and assessment of management systems. It is the first group of standards to attempt standardization of management systems on an international scale.

2.3 ISO 9000 Series Quality Management Standards

2.3.1 Background of ISO 9000 - Standards

The author feels that it is relevant to scan through the 'history of quality' to visualise the evolution of ISO9000 standards. This is especially so since quest for quality has been a driving force in the continuous development of management systems. Right from F.W. Taylor's studies on time and motion and principles of scientific management, organizations have tried to achieve perfection and excellence. In 1968 NATO published Allied Quality Assurance Publications (AQAP) specifications defining the quality management system requirements to be adopted by all military subcontractors. In 1970 UK Ministry of Defence brought out Def-Stan 05-08 that was the UK version of AQAP-1. In 1972 BSI issued a guide to quality assurance BS 4891.Operation and Evaluation of Quality Assurance Systems BS 5179 was issued in 1974 which is still an excellent guide to the subject as it gives review and evaluation details for each recommendation (Hoyle, 2002). In 1979, BSI published BS 5750 series of standards on quality systems matching UK Defence Standards and AQAP standards. This standard provides guideline for internal quality management as well as external quality assurance. In 1981 Department of Trade and Industry (DTI, UK) formed a committee called FOCUS to examine areas where standardization could benefit competitiveness of British manufacturers. ISO set up a study group in 1983 to produce an international set of standards that all countries could use. Open Systems

Interconnection (OSI) was thus formed which ensured that those products from different manufacturers and different countries could exchange data and inter work in certain defined areas. Corporation of Open Systems (COS) was formed in 1986 to pursue similar objectives.

ISO first published a world standard for quality management ISO 9000 in 1987 (Hoyle, 2002). This standard was heavily based on BS 5750-1979 parts 1, 2 and 3 (Robinson, 2001). It was immediately ratified in UK and BSI published BS 5750 –1987 standard for QMS. At the same time UK Ministry of Defence published DEF STAN 05-91, 05-92 and 05-93 as their equivalents to ISO 9000 (DEF STAN 05-91/2: 2001). In December 1987, the Technical Board of the European Committee for standardization commission (CEN) approved and accepted the text of ISO 9000-1987 as the European standard without modification and republished it as EN 29000:1987. First revision of ISO 9000 was published in 1994. By the end of 1999 more than 60 countries approved ISO 9000 as their accepted quality standard (Tricker and Sherring, 2001). As more organisations went for ISO 9000 certification it became apparent that the existing structure of the standard would not suit all eventualities, especially for small organisations that did not necessarily have the resources to implement all the requirements. The refinement was made in the ISO 9001: 2000 revision. Thus the development of ISO 9000 standards has been a dynamic process. There is immense scope for innovation and incorporation of priceless contributions from researchers.

ISO 9000 provides a framework for assessing the extent to which an organisation meets the criteria related to quality of the goods or services. It gives guidelines on how to establish a quality system to manage the processes that affect its product and services. The quality system is required to be documented, and employees are expected to follow the documented procedures consistently. After the quality system is implemented, the firms obtain registration through an audit performed by an independent registrar (Quazi et.al, 2002). As on December 2003, the number of ISO 9001 certificates issued is 500125. China (96715), Italy (64120) and UK (45465) are the 3 top countries in terms of ISO 9001:2000 certified companies. Compared to 2002 figure, there is 200% increase in the number of certificates issued as noted at Table 2.1 (ISO Survey, 2004).

Table 2.1 ISO 9001:2001 Certificates Issued from 2001 to 2003 (ISO Survey, 2004)

Year	Total ISO 9001:2000 Certificates Issued	No of Countries
2003	500125	149
2002	167210	134
2001	44388	98

Organisations that have previously used ISO 9002:1994 and ISO 9003:1994 were allowed to be certified to ISO 9001:2000 through a reduction in scope by omitting requirements that do not apply to their particular organisation (Tricker and Sherring, 2001). By December 2003, 89 % of the transformation to ISO 9001 certificate completed (ISO Survey, 2004). This makes it the logical choice for any organisation that does business internationally or that serves customers who demand an international standard of quality.

2.3.2 ISO 9000 Family of Standards

The 1994 edition of ISO 9001, ISO 9002 and ISO 9003 have been integrated into ISO 9001:2000, Table.2.2 gives few relevant ISO standards applicable for quality management and relevant to the research (ISO Selection, 2004). ISO 9000 standards assist organisations to implement and operate effective QMS and promote quality and consistency in production or service (ISO 9000:2000) An ISO 9001 certified organization is expected to have implemented its QMS as per ISO requirements. The organisation has to identify customer needs and expectations, manage a series of interconnected processes to achieve those requirements and to measure, analyse and continually improve performance.

Items 1, 2 and 3 of Table 2.2 belong to the ISO 9000:2000 family. ISO 9001 standard makes it more logically structured, compatible with ISO 14001 EMS and is customer oriented. The standard is highly oriented towards meeting customer requirements and satisfaction. It expects an organisation to communicate with its customers and to measure and monitor customer satisfaction. The standard emphasizes the need to make improvements explicit. Specifically, ISO 9001 wants an organisation to evaluate the effectiveness and suitability of its quality management system, and to identify and implement systematic improvements.

Table 2.2 A Few Relevant Standards from ISO 9000:2000 Family (ISO Selection, 2004)

1.	ISO 9000:2000	Quality Management Systems- Fundamentals and Vocabulary
2.	ISO 9001:2000	Quality Management System-Requirements
3.	ISO 9004:2000	Quality Management Systems-Guidelines for Performance Improvements
4.	ISO/TR 10017:2003	Guidelines for Statistical Techniques for ISO 9001:2000
5.	ISO19011:2002	Guidelines for Quality and /or Environmental Management Systems Auditing
6.	ISO/TR 13352:1997	Guidelines for Interpretation of ISO 9000 Series for Application within the iron and Steel Industry
7.	ISO/TS 16949:2002	Quality Management Systems-Particular Requirements for the Application of ISO 9001:2000 for Automotive Production and Relevant service Part Organisations.
8.	ISO/IEC 90003:2004	Software Engineering-Guidelines for the Application of ISO 9001:2000 to computer service.
9.	ISO 10006:2003	Quality Management Systems –Guidelines for Quality Management in Projects.

ISO 9004:2000 consists of guidance and recommendations and was not intended for certification, regulatory or contractual use or as a guide to the implementation of ISO 9001 (Clause 1: ISO 9004). This standard can be used as guidance in designing, operating and improving a management system. ISO 9004 standard has references to aspects of financial management, marketing, protection of the environment health and safety management (Boyle, 2002). According to ISO 9004 "Non-conformity" refers to the failure of a product or service to meet its specification. Non-conformity also refers to a failure in the output from a process. Since no process is intended to have incidents or accidents as one of its outputs, incidents and accidents can also be thought of as non-conformities. Similarly, requirements are standards to be met and can be compared to risk control measures. Non-compliance in ISO 9004 refers to failure to meet a requirement, which can be related to failure to meet specified risk control measures. The second edition of ISO 9004 forms a consistent pair with ISO 9001. It uses a broader perspective of quality management to give guidance for performance improvement and customer satisfaction (Boyle, 2002).

Management needs to know and apply the relevant statutory and regulatory requirements (Clause 5.2.3, ISO 9004). ISO 9004 recommends that a detailed risk assessment to be carried out to assess the potential for, and the effects of possible failures or faults in processes (Clause 7.1.3.3, ISO 9004). Creation of suitable work environment considering safety, hygiene, cleanliness, pollution, work methods etc are included in clause 6.4 and it is more elaborated in comparison to ISO 9001. Clause 7.3.3 (Design and Development), deals with safety issues. With reference to continual improvement and corrective action, clause 8.5.2 includes safety and root cause analysis as potential aspects for review and corrective action. Requirement of loss prevention data collection and analysis for management review and its use as an input modification of plans are addressed in clause 8.5.3.

Self assessment is another main aspect referred to in ISO 9004. Clause 8.2.1.5 is used for judging effectiveness, efficiency of the organisation and knowing maturity of QMS. ISO 9004 thus goes beyond quality management requirements and provides organisations with guidelines for performance improvement. Besides being a guideline standard, it addresses safety and risk assessment more specifically, aimed at improving an organisation's overall quality performance, and towards achieving TQM.

2.3.3 Quality Management Systems Principles

ISO 9000:2000 is closely aligned to TQM, Business Excellence (BE) and Integrated Management Systems (IMS). The standard requires establishment of measurable objectives at relevant functions and levels. Measurements extended to system, processes, product and analysis of collected data on the performance of the QMS. Customer satisfaction is the most significant measure of system performance (Low, 2001). The standard emphasizes four main aspects via management commitment, process-based approach, customer service, and continuous improvement. The basis for the QMS standards within the ISO 9000 family is the eight quality management principles namely Customer Focus, Leadership, Involvement of

People, Process Approach, System Approach to Management, Continual Improvement, Factual Approach to Decision Making and Mutually Beneficial Supplier Relationships (ISO 9000, 2000).

2.3.4 ISO 9001:2000 Quality Management System (QMS) – Requirements

A requirement is a need, expectation, or obligation that can be stated or implied by an organisation, its customers, or other interested parties. The requirements include quality requirements, customer requirements, management requirements, and product requirements etc. ISO 9001:2000 specifies the requirements of QMS; where an organisation's capability to provide products that meets customer and regulatory requirements need to be demonstrated. ISO presents its requirements in sections 4 to 8 of ISO 9001:2000, which is given in Table-A1 in Appendix - A. A 'quality system' consists of a set of fixed business procedures and rules aiming to ensure that a product, process or service meets a predetermined and widely acknowledged set of standards (Vloeberghs and Bellens, 1996). It promotes adoption of process approach when developing, implementing and improving the effectiveness of QMS.

The standard has 'permissible exclusions' which permit organisations due to their nature of product, customers or regulatory requirement do not need to meet full requirements of ISO 9001:2000 formally "exclude' those non-applicable requirements of the standard, still can have conformance to ISO standard (Tricker and Sherring, 2001). This is a very important improvement, as it makes implementation more flexible and conformance less rigid, and meeting an organisation's unique needs. Hoyle (2002) condensed the entire requirements of ISO 9001:2000 to five generic requirements as given below:

- Organisation shall determine need and expectations of customers and other stake holders.
- Establish policies, objective and a work environment necessary to motivate the organisation to satisfy these needs.
- Design, resource, manages a system of interconnected processes necessary to implement the policy and attain the objectives.
- Measure and analyse the adequacy, efficiency and effectiveness of each process in fulfilling its purpose and objectives.
- Pursue the continual improvement of the system from an objective evaluation of its performance.

When an organisation deviates from these requirements, non-conformity occurs. When a product, process, procedure, system, or structure deviates from ISO requirements, a formal nonconformity exists.

2.3.5 Components of ISO 9000 Quality Management System (QMS)

According to Oakland (2000) the aim of quality system is to provide support to people by addressing the issues of process inputs (materials, information, equipment, methods etc) in order to ensure consistent process outputs. ISO 9001:2000 has process based structure and it includes all the key points from the 20 elements of ISO 9001:1994, but integrates them into following four major generic business processes:

- Management Responsibility (Policy, Objectives, Planning, System Review)
- Resource Management (Human Resources, Information, Facilities)
- Product Realization (Customer, Design, Purchasing, Production, Calibration)
- Measurement, Analysis and Improvement (Audit, Process/Product Control, Improvement)

ISO 9000 family of standard is based on process model. A symbolic representation of the standard that is intended to represent a process based QMS is given in Figure 2.1.

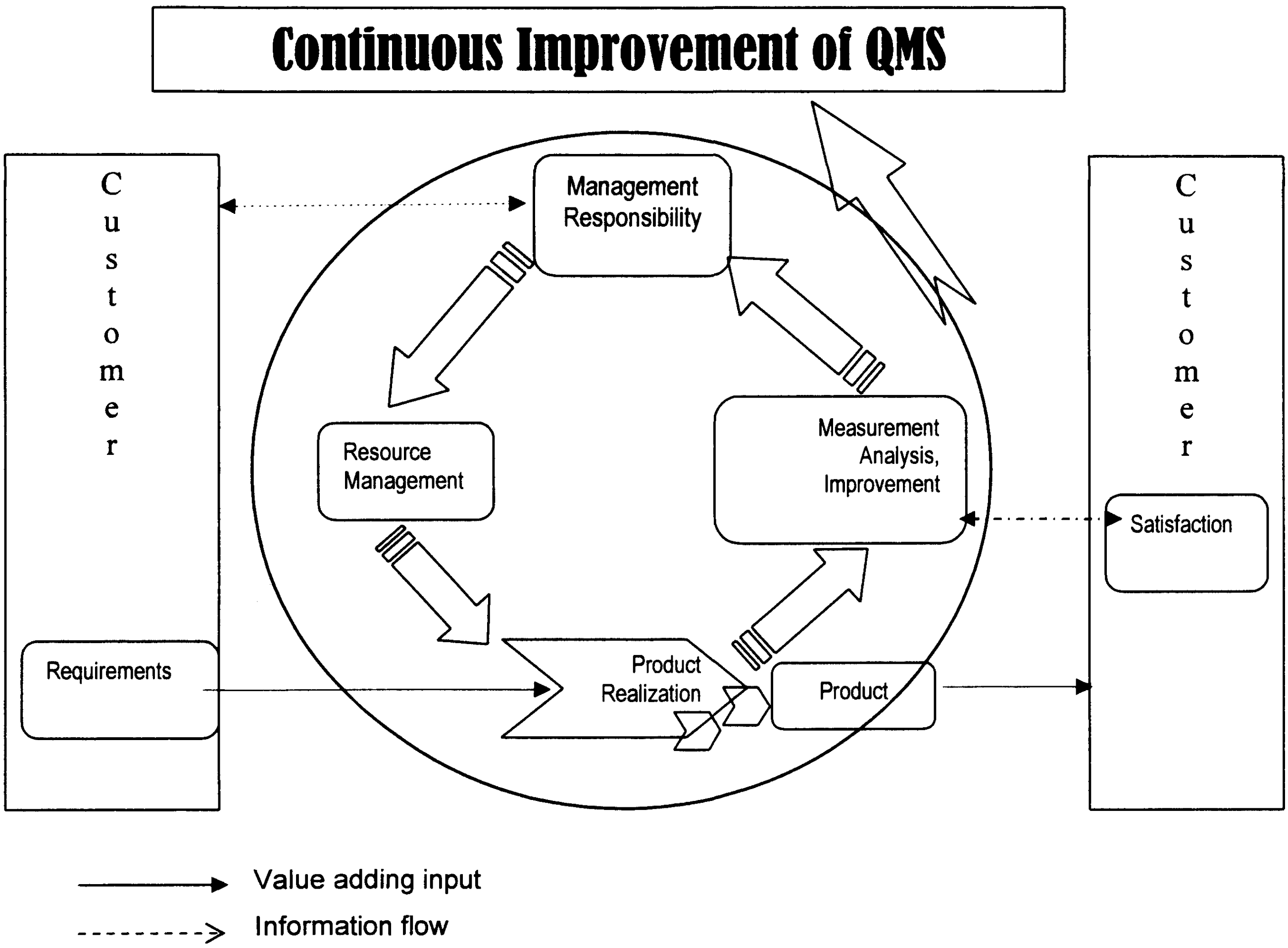


Figure 2.1 Quality Management Process Model (ISO 9001: 2000)

Quality system structure should ensure adequate control of any process that affects quality. The system should contain ways to avoid recurrence of problems without sacrificing the ability to respond to, and correct failures should they occur. Documentation is the main key to achieve these quality objectives. Documents like quality manual, quality plan, specification, guidelines, procedures, instruction, records etc to be used for QMS are detailed in the clauses (2.7.1 & 2.7.2) of the standard (ISO 9001:2000). The standard states that management must be committed to the development and implementation of a management system and continually improve its effectiveness and shall ensure that customer requirements are determined and met with the aim of enhancing customer satisfaction. Management needs to establish and implement quality policy and objectives and shall define and communicate the responsibilities and authorities within the organisation. They shall conduct review of the QMS at planned intervals. The organisation shall determine and provide the resources needed to implement and maintain the QMS and continually improve its effectiveness to ensure customer satisfaction. According to the standard, the work environment includes a combination of human, physical factors, work methods, safety rules etc. This is an important aspect for the research study. Product realization includes planning, customer related process, design and development, product and service provision, and control of measuring and monitoring devices. While realization processes result in products that add value to the organisation, support processes also are necessary and add value indirectly (ISO Standards Compendium, 2001). Organisation shall plan and implement monitoring, measurement, analysis and improvement processes needed to demonstrate conformity of product, to ensure conformity with QMS and continually improve its effectiveness (ISO 9001:2000).

While making measurements or checking goods or services, analyse information and use it to improve the system. The activities must be checked by an independent person, working on behalf of the organisation. The internal Quality Auditor need to ensure that the activities are being conducted as described in the documented system, and is sufficient to meet the requirements of ISO 9001. Where problems are found, the documented system or the activity itself must be altered. Auditors need to interpret the requirements and determine whether an organisation's system meets the standard intentions. Also an organisation needs to verify the effectiveness of corrective action that they have implemented and how well that action prevents the recurrence of the problem (Drickhammer, 2001). The cycle of audits, review, determination of changes and re-audits followed by review, etc is a never-ending cycle, which should lead to continual incremental improvements. While noting the role of Surveyors under ISO 9000 in the construction industry, Lam and Tang (2002) specify that the organisation shall determine, provide and maintain the infrastructure and work environment needed to achieve product conformity and imply that construction must be carried out under controlled conditions comprising approved method statement for construction process including surveying. They also specify use of suitable material and equipment, safe working environment, compliance with reference standards, codes, quality plans, monitoring and control of construction stages etc.

Provision of safe working environment for meeting QMS requirements relevant to petrochemical plants is the main focus of the research.

2.3.6 Effects of ISO 9000 Certification on the Organisational Performance.

Organisations implementing ISO 9000 are doing so because they expect these standards help them to do things better and to provide real benefit (ISO Press Release, 2004). Certification indicates to all customers of the organisation that its quality system complies with the standard and it shows the company's capability to provide products, which consistently conform to an agreed specification. Improved customer relationship, less complaints and improved sales potential are the claimed benefits. Logically an organisation with an effective quality system would normally be more likely to take more corrective action and to improve processes and service than the one which is disorganised. ISO 9000 standard serves to guide people to choose right things to do. Numerous benefits are claimed by various studies and surveys carried out among ISO 9000 certified companies. Rao et al. (1997) carried out a study to evaluate the effects of ISO 9000 on quality management practices and quality results. Their study carried out after collecting data from 649 respondents from USA, Mexico, India and China reports significant differences between ISO 9000 registered and non-registered firms in terms of quality management practices.

Perhaps the most common criticism of the standard is the extensive documentation often associated with its implementation and the potential for certification to become "consultant-driven paperwork" (Huarng et al., 1999). When a firm is pressured into attaining ISO 9000 registration, there is a possibility of short-term quality improvements for the certification process, but that performance could be the result of resource and effort loading that may be unsustainable. In such cases, certification is a "hollow achievement in the long run" (Terziovski et al 1997). When does the implementation of a managerial practice, such as ISO 9000, improve organizational performance is that it depends on how the practice is implemented. More Success is achieved if there is both thorough assimilation of the practice and going beyond what the practice literally requires (Naveh and Marcus, 2000).

The Hong Kong Housing Authority declared that ISO 9000 has been implemented with great success. They claim that they have achieved improved communication and efficiency, clear line of authority and responsibility, improved staff morale, easier training reduction of unnecessary and costly errors etc. In addition to benefits such as less waste, lower energy costs and reduced absence and employee turnover levels, creating a good 'image' that meets customer expectations can help the organisation to improve market share. A number of such benefits may materialize depending on the success of the quality system implemented in various organisations. The Majority of respondents to the Hong Kong based survey expressed the view that the benefits of the quality system outweighed its negative outcomes (Fryxell and Szeo, 2002).

An organisation that implements QMS as per ISO 9000 would automatically apply the eight quality principles which can result in improvement of the performance. Osman et al (1996) quote a study conducted by Lloyd's Register Quality Assurance (LRQA) team in 1992. It was based on interviews with 400 quality managers and senior managers from a cross section of LRQA' s customer base of a wide range of companies of different size and industry type. The study revealed better management control, ensured consistency of systems, productivity gains and increased efficiency, staff motivation, cost reduction, ability to open doors to previously closed market segments, expanding market share and valuable marketing tool as the benefits of ISO certification.

From a study of ISO 9000 certified UK firms, Chittenden et al (1998) concluded that a high majority of ISO 9000 users felt that the advantages of using ISO 9000 outweighed the disadvantages. Based on a study of ISO 9000 certified Norwegian firms, Sun (1999) noted that the standard was significantly correlated to quality results, especially reduction of defective products and customer complaints and improvement of productivity and profitability. However he noted that certification had no effect on environment protection and employee satisfaction. A study of ISO certified manufacturing firms in North America revealed that they adopted ISO certification in order to provide credible signals of quality assurance to external parties. Also it was adopted as a tool in a grand strategy of achieving competitive advantage through quality management and communicating quality results (Anderson et al, 2001). Calisir et al (2001) studied the influence of various factors on 73 ISO certified large Turkish companies to determine the level of difficulties/obstacles associated with ISO 9000 implementation and to measure the success in achieving improvements. They concluded that large companies might be more satisfied with ISO 9000 through increased emphasis on achieving operational improvements. Low (2001) noted that effects of ISO 9000 adoption are long term and strategic in nature.

ISO 9000:2000 is holistic and more customers oriented and have more in common with other quality and excellence models than earlier versions of ISO 9000. The emphasis is on processes, customers, continuous improvement, measurement, analysis and improvement, resource management and traditional management responsibilities. The alignment with the EFQM excellence model and other excellence models such as Baldrige is obvious although there are still substantial differences. Baldridge or EFQM Excellence models are a holistic all-spanning concept focusing primarily on self-assessment with an appropriately broad assessment process, whereas ISO 9001 provides the focus on detail, on compliance and third party audit, which can provide reassurance of responsibility, systems and resources within an excellence framework. ISO 9004 provide some framework for both self assessment and pursuit of excellence and in this sense it is closer to EFQM and Baldrige models (Bendell, 2000). It is interesting to note the comment made by Chatzkel (2000) that Baldrige award recipients brought together all their people, processes, strategies and technologies to produce outstanding results.

ISO 9000 certification can provide entry into European markets (Goodman, 1998). A study by Corbett et al (2004) on the financial impact of ISO 9000 certification among manufacturing firms in the US by tracking financial performance from 1987 to 1997 of all publicly traded ISO certified firms, indicated that there are significant improvements in financial performance. ISO certified companies follow systematic orientation, which helps them to build the right attitude by supporting it with the right policies, procedures, records, technologies, resources, and structures. Hence, establishing a quality attitude by creating a quality system helps to achieve world-class standard of quality. A cultural study of ISO 9000 certification conducted by Mallak et al (1997) suggest, that factors or cultural values like being decisive, team orientated, risk averse, valuing stability, paying attention to details and valuing high levels of organisation etc support ISO certification. Managing task and processes is not enough. Modern management must co-ordinate behavioural change and understand values too, which are helpful to achieve specific goals such as ISO 9000 and subsequent quality improvement. Their findings suggest that there is linkage between culture and ISO certification. As culture is very much linked to safety behavioural attitudes, the study to find out the correlation between ISO certification and safety is logical.

2.4 Total Quality Management (TQM)

2.4.1 Background of TQM

Bendell (1991) suggested that it is possible to trace the development of TQM through three periods: the American management commitment in early 1950s, the Japanese - simple tools, mass education, teamwork (late 1950s), and the new wave – awareness of 1970 to 1980. The roles of Deming, Juran, Feigenbaum and Crosby in shaping the development of TQM are noteworthy. They are identified as Quality "Gurus". The Japanese companies adopted their concepts earlier than the Americans, and concentrated on quality throughout their production process. They showed that this resulted in much higher productivity and improved quality than just focusing on quality control at the endpoint of the production process (Ishikawa, 1985). Feigenbaum suggested that quality control should be company wide. Deming propounded that consistent quality focus would reduce non-productive variables, such as product reworks, production errors, delays and production "snafus" (Hart, 2000). Japanese management techniques involving quality control circles (QCC's) were the next change (Feigenbaum, 1991). The U.S. Department of Commerce established Malcolm Baldrige National Quality (MBNQ) award to re-establish higher standards of manufacturing. Internationally, Japan was already giving the Japanese Deming Award to outstanding companies, and this award was regarded as the most prestigious of all quality awards. To aid the promotion of TQM in United States, Utah

State University established Shingo Prize for Excellence in Manufacturing in 1988. Later management writers identified that if the Total Quality Control concept involved management, it would be more effective since managers would have more authority and impact on organisations (Taylor, 1911). Haigh and Morris (2002) identified a number of "key elements" with relation to TQM. According to them any public sector manager would feel secure in the utilisation of these key elements, which are important while implementing TQM. These elements are 1) Quality Awareness 2) Management Leadership 3) Organising for Quality Improvement 4) Creating a Participative Environment 5) Training for Quality Improvement 6) Involvement of Every Function at all Levels 7) Customer and Supplier (internal and external) Involvement 8) Problem Prevention and Solving 9) Statistical Process Control 10) Measurement of Quality Performance 11) Recognition for Achievement and 12) Continuous Improvement. These points are corroborated by the researchers by a case study on National Health Services (NHS) which spends about $1/8^{th}$ of the public expenditure in the UK.

2.4.2 Basic Concepts of TQM

Despite the popularity and widespread interest surrounding it, there is no agreed definition or accepted theory of TQM. It is a phenomenon, which appears to have evolved over a period of time. Ahire et al. (1995) carried out a study of the published TQM literature during 1970 to 1993. They classified and analysed the 226 articles on a two-dimensional scheme of article orientation (overview, conceptual, case study, empirical, analytical and simulation) and article focus (leadership, information & analysis, strategic quality planning, human resource management, management of process quality, quality & operational results, customer focus and satisfaction) as defined by Malcolm Baldrige National Award criteria. They observed that until 1995 the primary focus was conceptual and practitioner-oriented, but less work was done on empirical and analytical research and the need to focus on realistic effectiveness testing of strategies in a multitude of setting was indicated. The core of TQM is the customer-supplier interfaces, both external and internal, and at each interface there exist a number of processes. This core must be surrounded by commitment to quality, communication of the quality message, and recognition of the need to change the *culture* of the organisation to create total quality. These are the foundations of TQM, and they are supported by the key management functions of *people*, *processes* and *systems* in the organisation (Jordan, 1995).

TQM focuses on managing the processes that produce results. The National Institute of Standards and Technology, USA put forward the definition of TQM as focus on performance excellence for the entire organisation in an overall management framework, identifying and tracking all-important organisational results: customer, product/service, financial, human resource and organisational effectiveness (Nonaka, 1995). The TQM approach is to improve competitiveness, effectiveness and flexibility of a whole organisation.

Bank (2000) noted that function of TQM is to ensure that the management adopts a strategic overview of quality, focusing on problem prevention within an organisation. The concepts must interact and support each other; no one concept should be applied in isolation. Corporate strategy was being considered as inherent in TQM. Even though there is potential for TQM to be a strategic driver, most of the companies normally have their strategies created at corporate level by the CEO's, MD's, board of directors and in many cases Senior Management team. The companies normally promoted the operational perspective of TQM. Leonard and McAdam (2002) conducted a research study into the strategic impact of TQM. They conducted 19 case studies of organisations which were involved in TQM and which had well-developed strategic planning processes. According to them it was found that there was an inconsistency in TQM terminology, especially with regard to TQM's integration with the strategic planning process and also TQM was only articulated as a means of achieving a target which has been set at strategic level. They found little evidence of a close interlink between corporate strategy and TQM. However the results of their study indicated that TQM plays a key role in strategy implementation, as distinct from strategic formulation, within the organisations. According to Feigenbaum (1991) the first and most important characteristic of total quality start with the customer's requirements and end successfully, only when the customer is satisfied with the way the product or service of the enterprise meets these requirements.

2.4.3 ISO 9000 and Total Quality Management

Quality systems are designed to provide both support and mechanism for the effective means to manage quality related activities in an organisation. The ongoing journey towards TQM must deliver the competitive advantage (Jordan, 1995). The ISO 9000 series certification can be the starting point for entering the competition. Crosby (1989) considers systems as the communication centres of operations. Quality systems offer organisations a framework for quality control practices to achieve quality control assurance through prevention of failure. Therefore a quality system must communicate the standards of organisational practice through documented procedures and records. Mc Adam and McKeown (1999) noted that businesses that gained the most from TQM had started with ISO9000 and focused on external factors like customer satisfaction and internal measures like scrap reduction, efficiency improvement, etc.

TQM requires that every person in the business becomes committed to a never ending drive to improve quality. TQM also demands close partnership between purchasers and suppliers, whereas third party assessment is the mainstay of ISO 9000 approach. ISO 9000 can provide a foundation for a total quality effort. As per ISO 9000 concept, people perform better when they are told what to do with reference to documented standards and procedures. The lessons learned from past, corrective actions taken etc, improve the overall quality of the organisation. The TQM concept gives freedom and skills and motivation for people to deliver quality in their work. ISO 9000 is important because of its systemic orientation. Standards of quality are achieved by institutionalising right attitude with the support of right policies, procedures, records, technologies, resources, and structures etc. ISO 9000 is aimed at improving an organisation's overall quality performance and provides a stepping stone to TQM. As noted by Leonard and McAdam (2002), there is a potential for TQM to be a strategic driver, but organisations are failing to achieve this. Hence there is need for much more work in this area from models to tools and techniques. Accredited quality management system forms a major pillar supporting the development and operation of TQM.

ISO 9004-QMS provides guidelines beyond the requirements given in ISO 9001 and considers the effectiveness and efficiency of a quality management system and consequently the potential for improvement of performance of an organisation. As the objectives of customer satisfaction and product quality are extended to include satisfaction of interested parties and the performance of the organisation, ISO 9004 can be considered as the stepping stone towards TQM. ISO delegate West describes ISO 9001:2000 as more of a starting point and the basic quality management system as the base of a pyramid (Drickhamer, 2001). At the top is MBNQ award or EFQM. Lean-manufacturing initiatives and Six Sigma techniques are the vertical tools that can help the organisations bridge the gap to the top. The compliance form of quality such as quality assurance, ISO 9000, and ISO 14000 and management excellence such as those contained in the Baldrige Award criteria have now become ingrained in the culture. A survey conducted by Sainfort and Carayon (1997) regarding implementation of TQM in American public organisations revealed that employees had developed positive attitudes with respect to Quality improvement (QI) programs and believe that QI make a difference in their jobs. However they also perceive that more need to be done at the structural and organisational level for QI to grow and flourish.

ISO 9001 can be considered as a foundation towards the achievement of total quality maturity through continual improvement and cultural changes. The concept can be correlated with a practical life example of acquiring a driving license and practicing good and safe driving habits. The driving license is given after verification of the requirements but it is only the basic foundation. The person who possesses the license needs to obey all rules and take necessary safety precautions like wearing seat belt, keeping a fire extinguisher in the vehicle etc. He has to practice safe driving habits like defensive driving etc which in a sense is a continuous risk assessment. He has to take care for his vehicle with proper preventive and corrective maintenance strategies. He has to obey traffic rules and signals that in a sense are obeying safety regulations on a continual basis. In brief all observance of these practices leads to good driving culture.

2.4.4 Total Safety Culture (TSC)

As Dale et al (1994) puts it, within the context of TQM, the term quality has evolved less from concern about improvements about products; to more of a concern about the productivity (improvement) of systems. TQM is a comprehensive management approach that deals with the people issues that aim to optimize the outcome. TSC has a similar management philosophy with a safety focus. Total Safety Culture (TSC) follows along the line of TQM with more emphasis on behavioural processes. Key elements of TQM framework include proper communication of mission, aims and objectives, collection of external intelligence required to understand the needs and expectations of its both external and internal customers, measurement of internal performance to control business processing and identification of improvement opportunities by establishing quality measurements of each area of activity. The organisation needs to create an environment that empowers and challenges its staff to change and improve their performance continually. The failure to address the culture of an organisation is frequently the reason for many management initiatives either having limited success or failing altogether. Understanding the culture of an organisation, and using it to map the steps needed to accomplish a successful change is an important part of the quality journey through safe means.

2.5 Safety and Safety Standards

Reason (1991) quotes three distinct models of Deborah Lucas for safety management - the personal model, the engineering model and the organisational model. All of them can coexist harmoniously within the same organisation. The personal model stresses psychological factors as prime causation for accidents. The progress is measured by personal injury statistics. Direct costs of accidents are only tip of the iceberg and can represent only 10 to 25 % of actual losses, work time loss, loss in earning power, lost time by supervisor/co-worker, loss of efficiency, hiring training of new person, damage to tools or process equipments, equipment down time, product/service loss, facility damage, product/service delay, overhead cost and other miscellaneous costs etc need to be accounted, which as a rule of thumb amount to 4 to 10 times the direct cost. The empirical basis, the 1:10:30:600 ratio (1-serious injury, 10 minor injury, 30 property damage and 600 incidents with no visible injury), provided by Bird and Germain (1997) substantiates that the accident statistics are under-pinned by the "iceberg" or "pyramid' views of accident causation. The Engineering model considers "safety" as something to be engineered into the system reliability engineering, traditional ergonomics, risk management and human reliability assessment all under the purview of this model (James, 2000).

2.5.1 Occupational Health and Safety Management Systems Specification: OHSAS18001

Occupational Health and Safety Management Systems (OHSMS) refers to a system of defining policy for health and safety, organising and planning to achieve policy (including risk management), implementing plans, measuring performance, reviewing and auditing the management system. The need for improvement of occupational health and safety performance was felt as a result of the loss of many million working days due to work related accidents. It is estimated that every year over 1.2 million workers are killed due to work-related accidents and diseases and 250 million occupational accidents and 160 million work-related diseases occur.

The economic loss related to these accidents and diseases are estimated to about 4% of world Gross National Product. OHSMS is a set of interrelated/interacting elements to establish occupational safety & health policy and objectives and to achieve those objectives (ILO-OSH, 2001). Often management of any organisation has statutory and corporate obligations and they provide systems and procedures, practices, appropriate technology and motivation for ensuring safety, health and environment protection measures. In the absence of a uniform ISO standard similar to ISO 9000 and ISO 14000, many standards and guidelines are available for fulfilling this requirement. Among them OHSAS 18001 has gained international acceptance and reputation as a standard for assessment of OH&S management systems.

European Union requirements mandate management audits, performance of risk assessments and design programs to reduce or eliminate risk. The Occupational Safety and Health Association's (OSHA) voluntary guidelines require employers to identify and control work-site hazards and to involve employees in all phases of the program. OSHA also promulgates an OHSMS programs standard 29 CFR 1910.700 with provisions similar to OSHA's voluntary guidelines. In the United Kingdom, the chemical and rail transport industries are required to develop a management system referred to as a "safety case", a detailed cradle-to-grave management plan for handling hazardous materials or executing high-hazardous operations (Noble, 2000). The focus of development of OHSMS, seem to be in UK and Australia. Linked to Australian development are those of the APOSHO (the Asian Pacific OSH Organisation) an ISO 14000 based standard for OSH management. From the UK we have HS (G) 65, BS 8800 and OHSAS 18001 as the main health and safety management systems. Related to the development of the non-certifiable British Standard BS 8800, SGS Yarsley developed its own ISA 2000 standard, which allows certification.

ILO-OSH 2001- Guidelines on OHSMS are not legally binding and are not intended to replace state laws, regulations or accepted standards and its application does not require certification (ILO-OSH, 2001). HS (G) 65 is another OSHMS system that has key elements for framework like policy, organizing, planning and implementing, measuring performance, reviewing performance and auditing (HS (G) 65, 1997). BS 8800 and OHSAS 18001 are the other two widely used OHSMS systems. BS 8800 is not a certifiable standard; however the pressure to comply with its guidance is based on statutory requirements. BS8800: 1996 was based on two previous models of management systems for health and safety. One is HSE's publication HS (G) 65 'Successful Health and Safety Management' and the other is BS EN ISO 14001:1996 Environmental management system- specification with guidance for use (BS 8800:1996).

However BS 8800 has been updated based on the regulatory changes and new Health and Safety Commission and HSE initiatives. BS 8800:2004 revisions give guidance on key areas such as risk assessment and risk management. According to BSI the revision of this standard reflects national and international OH&S issues which have arisen since publication of standards BS 8800:1996. OHSAS 18001, ILO-OSH 2001 and BS 8800:2004 claim that it is designed to enable the integration of OH&S management within an overall management system. The framework includes elements such as review, OH&S policy, organizing, planning and implementation, measuring performance, investigation and response, audit and reviewing performance. The standard contains improved annexes giving guidance on risk assessment and control and integration with other management systems (BS 8800:2004)

The successful introduction of the "systems" approach to management by ISO through its series on quality management ISO 9000 series and environmental management ISO 14000 series lead to the development of OHSAS 18001. The OHSAS certification system was developed by an association of national standard bodies, certification bodies and specialist consultancies. It is a standard against which safety management system can be benchmarked and certified. OHSAS 18001:1999 specification complies with the principles laid down in BS 8800:1996. A guideline corresponding to OHSAS 18001 was issued in January 2000. This guideline document is OHSAS 18002:2000. Amendment 1 for both OHSAS 18001:1999 and OHSAS 18002:2000 was issued in 2002.

OHSAS 18001 is specifically intended for certification purposes and is well aligned with the ILO guidelines for OH&S management systems and it is comparable in content to ISO 14001 and ISO 9001:2000. The certification bodies check compliance with the requirements of the OH&S management system. The similarity in structure and contents, especially when compared to ISO 14001, facilitates the integration of OH&S issues into any existing management system. OHSAS 18001 standard claims it can be applied to all types of organisations and OH&S management systems.

2.5.2 Safety Institutions, Councils, Certification and Regulatory Bodies

In today's world, where quality competition is a fact of life, the need for a work force proficient in the principles and practices of quality control is a central concern of many companies. Safety institutions, international bodies, certification and regulatory bodies provide occupational safety and health guideline and norms. These bodies basically educate and influence society to adopt safety, health and environmental policies, practices and procedures that prevent and mitigate human suffering and economic losses arising from preventable causes. Organisations cannot ignore legislation, such as the Environmental Protection Act 1990, the Health and Safety at Work Act 1974 and the Control of Substances Hazardous to Health Regulations 1988, where failure to have effective management systems in place can lead to heavy fines, prison sentence, loss of operating license or even plant closure. The list of well known institutions, councils and regulatory bodies are furnished in Table A3 of Appendix A. Certification is a mark of excellence. Conformance auditing and certification to recognized management systems by third party accrediting bodies assures credibility of the programs and periodic evaluation ensures maintenance and continued improvement.

2.6 ISO 14000 Series Environment Management System Standards

Although there are formal international standards for managing quality (ISO 9000) and environment (ISO 14000), there is no recognized (ISO) certifiable standard for occupational health and safety management. Though it appears to be unbelievable, a note published by the Environment, Health and Safety Committee (EHSC) under Royal Society of Chemistry, reports that ISO has been wary of becoming involved in occupational health and safety and at an ISO Workshop in 1996 it was concluded that the time was not right for an occupational health and safety management standard. Later in 2000, ISO rejected an approach from the International Labour Organisation (ILO) regarding an international standard (RS.C, 2005). Consequently, the ILO developed its own non-certifiable guidance, "Guidelines on occupational safety and health management systems, ILO-OSH 2001"

Nonetheless in an industrial set up environmental aspects and safety are so strongly interlinked that sometimes it is difficult to differentiate between the predominance of the two risks. Best examples are leakage of hazardous liquids and gases from industrial plants. It is hazardous from both safety and environment perspectives, except that the risk involved may vary depending upon the circumstances. However Environmental Management systems are more developed. With the development of ISO 14000 series of standards the industrial sector has been zealously following up any research that might be of value to its development.

2.6.1 ISO 14000 Family of Standards

The ISO 14000 series international standards emerged primarily as a result of Uruguay round of the General Agreement on Tariff and Trade (GATT) negotiations and Rio Summit on Environment held in the year 1992. While GATT concentrates on the need to reduce non-tariff barriers to trade, the Rio Summit generated a commitment to protection of the environment across the world. The Rio summit presented a set of guiding principles as a basis on which an environmental policy can be built for each nation. The 27 principles presented are often called Valdez Principles as they were developed following the Exxon Valdez disaster (Reason, 2000).

The first standard for Environmental Management Systems, BS 7750, was published in 1992. It was revised in 1994 and withdrawn in April 1997 following the publication of ISO 14001 in September 1996. ISO 14001 is the certification standard. It is a broad concept and is defined as the processes, practices, materials or products that avoid, reduce or control pollution, which may include recycling, treatment, process changes, control mechanisms, efficient use of resources and materials substitution (Dasgupta et al, 1997). ISO 14000 is a series of voluntary standards and guideline reference documents, which include EMS, Eco Labelling, Life Cycle Assessment, Environmental Auditing, Environmental Performance Evaluation and Environmental Aspects in Product Standards. A few relevant standards of the ISO 14000 family are given in Table 2.3.

Table 2.3: ISO 14000 Standards for Environmental Management Systems (Kolka J, 2002)

Standard Designation	Title	Remark
ISO 14001:1996	EMS-Specification with Guidance for Use	The only certifiable standard in the ISO 14000 series. Revisions issued in Nov 2004.
ISO 14004 :1996	EMS- General Guideline on Principles, Systems and Supporting Techniques	Revision issued in Nov 2004
ISO 19011:2002	Guideline for Quality/EMS Auditing	This replaces ISO 14010, 14011, 14012
ISO 14031:1999	Environmental Management-Environmental Performance Evaluation-Guidelines	

Earlier Kolka (2002) reported that ISO announced the period of making transition from certificates of conformity to ISO 14001:2004 version within 18 months from the revision publication date. As on December 2003 there were 66,070 certificates issued across 113 countries. Japan, UK and China are the first 3 topping the list of countries having maximum number of certificates issued (ISO Survey, 2004). On November 15, 2004, ISO 14001:2004 and ISO 14004:2004 revisions were released for publication.

2.6.2 Environmental Management System (EMS) Brief Outline

This section and the following section 2.6.3 present a brief outline of EMS, and the links between ISO 9001 and ISO 14001. The author feels that these sections are relevant from the quality management perspective since the continuous improvement, the main concern of ISO certification is discussed in these sections.

ISO 14000:1996 provides a framework for the development of an EMS. The EMS model for ISO 14001 consists of environmental policy, planning, implementation and operation, checking and corrective action, management review and continual improvement. ISO 14001 specifies the actual requirements for an EMS. It applies to those environmental aspects, over which the organisation has control, and over which it can be expected to have an influence. Guideline standards help a company to achieve registration to the specification and to address some specific environmental issues. ISO 14001 requires documenting current environmental conditions and then having a system in place to document targeted annual environmental improvements. ISO 14001 system requirements are based on traditional management structure," plan-do-check-act". The standard calls this a "dynamic cyclical process". ISO 14001 does not replace regulations, legislation and codes of practice that an organisation has to comply with. Rather it provides a system for monitoring, controlling and improving performance regarding those requirements (McCullum and Fredericks, 1997).

2.6.3 Links between ISO 14001 and ISO 9001

QMS aims at the efficiency of the production process and continuous improvement to meet customer requirements. ISO 14001 also aims to achieve customer requirements but customer is a broad term and includes regulatory, mandatory, governmental authorities etc. Continuous improvement is not only driven by customer expectations but also by priorities and objectives generated internally by the organisation. Both standards have the same fundamental systems like documentation control, management system auditing, operation control, audits, corrective and preventive action etc (McCullum and Fredericks, 1997) and are process driven. ISO 14001 has clearer statements about communication, competence and economics than are currently found in ISO 9000. However ISO 14001:2004 brings more clarity to these aspects (ISO Selection, 2004). ISO 14001 incorporates the setting of objectives and quantified targets, emergency preparedness, taking into concerns of interested parties and stake holders.

Both standards share many generic elements, a comprehensive list of common elements is provided at Table A2 of Appendix A. For companies with an existing QMS, the quality system can be used as a springboard for developing an environmental management system. ISO 9000:2000 harmonises with ISO 14000. Its organisation and approach make it easier to integrate quality and environmental management systems together. The majority of requirements stated in ISO 14001 can be integrated with ISO 9001 to form an all purpose management system. However requirements like "aspects" for ISO 14001 and "quality-planning" for ISO 9001 are unique for each standard. Whether a company intends to pursue separate management systems or a common system, the foundation for both systems is the same and good documentation is the supporting factor which must be generic and broad in nature to coexist. For example both standards require procedures for document control (ref: 4.4.5 of ISO 14001: 1996 and clause 5.5.6 of ISO 9001:2000) and a procedure that is broad enough to address both QMS and EMS (Wilson, 2001).

2.6.4 Advantages of ISO 14001 Certification

Environmentally conscious manufacturing and standards enable organisations to adopt remanufacturing and requires reduction in usage of material, water, energy, reduction in waste generation, innovation and technology development (Lam and Tang, 2002). Advocates of ISO 14001 propose many reasons for certification which include: improved regulatory compliance; increased market share; responsiveness to customer pressures; access to global markets; cost reduction from improved efficiency; and enhanced reputation (Fryxell and Szeo, 2002, and Harrington and Knight, 1999). As Raines (2002) noted there could be many drivers like reduced waste disposal cost, green marketing, overall reduced resource use, desire to reduce liability or insurance premium, incentive and pressures from government regulations etc. In Japan manufacturers see profit maximization and utility maximization assumptions as a benefit of ISO 14001 certification (Nakamura et al, 2001). Petrochemical industries are a major source of industrial pollution, its effect on nature are harsh and extensive, with destruction or overexploitation of flora and fauna, alteration of waterways, air and water pollution. Study by Dasgupta et al (1997) indicates that plants which institute the ISO 14000 type management procedures exhibit superior environmental performance.

2.6.5 Elements of ISO 14001 Having Special Relevance to Safety and Risk

Enhanced compatibility with ISO 14000 standards was identified by ISO/TC76 as an important customer need in its survey of improvements to the ISO system. This continual need for compatibility has led to significant improvements in structure, content, language and terminology, which can be incorporated in the future revision cycles. Clause 4.4 of ISO 14001, Implementation and Operation deals mainly with what is described as 'the four Cs' in HS (G) 65 Control, Co-operation, Communication and Competence. The checking and corrective action clause is equivalent to the active monitoring element of HS (G) 65 but there is more emphasis on recording the results of monitoring and measurement (Boyle, 2002). New ISO 14001:2004 standard Clause 4.4.3 Communication include Internal Communication and it is similar to OHSAS 18001 (Chatzkel, 2000). Identification of the significant environmental aspects including those, which occur during normal business operations, abnormal conditions, incidents and future activities are also safety issues. Many of the legal and other requirements which apply to the organisation's environmental aspects are linked to safety. Harmful emission of toxic gases is an environmental as well as a safety issue. As per ISO 14001, an organisation must have procedures for the appropriate response to accidents and emergency situations, which include the prevention and mitigation associated with the environmental impact. Hence, Emergency Preparedness and Response for identifying its potential for accidents and emergency situations are other main links with Safety Management Systems.

Hazard analysis under safety management programs like API RP 75 and Oil and Gas Producers (OGP) Guidelines (E&P forum) etc focus on incidents, whereas an analysis under ISO 14001 focuses on 'aspects and impacts' which is much broader in scope. Due to the inherently hazardous nature of the petroleum industry, most safety analyses are risk-based. For ISO 14001 the criteria for determining the significance of environmental aspects are hazard-based rather than risk-based. An environmental aspect/impact does not lose significance because the risk has been reduced due to an increase in the level of control. It is the function of the EMS to ensure that the correct controls remain in place to maintain an acceptable level of risk. The organisation must determine those environmental aspects which can have significant impact on the environment. Risk analysis techniques can form an important part of the procedure to identify and evaluate environmental aspects. ISO 14001 specifically states that environmental decision making should take into account relevant legal and regulatory requirements, financial, operational and business requirements and the views of interested parties.

Environmental risks and opportunities are to be viewed in the context of other risks and opportunities as facilitated by a risk management model (Raines, 2002). The commonalities between risk management and EMS elements include commitment of management, management review and continual improvement, training, communications, internal and external audits, identification of non-conformities and implementing corrective and preventive actions etc. In a petrochemical industry these elements become more relevant to both systems and most of the time the impact has a direct correlation to safety aspects also.

2.7 ISO/TS 29001 – Oil and Gas Industries-QMS

ISO/TS 29001:2003 Oil and Gas industry's unique and comprehensive QMS standard was published on 15th September 2003 to provide additional requirements to ISO 9001:2000 specifically intended for the petroleum, petrochemical and natural gas industries (ISO/TS 29001:2003). The main intent of the standard was to address the concerns of the oil & gas industry. The standard provides guidance and supplementary requirements for implementation of ISO 9001:2000. The standard highlights its goal as the development of a QMS that provide continual improvement, emphasizing defect prevention and reduction of variation and waste in the supply chain and from service providers. The standard also intends to avoid multiple certification audits and provide a common approach to QMS for petroleum, petrochemical and natural gas industries. This industry specific standard was developed jointly by ISO and international oil and gas industry due its critical nature. The oil and gas, petrochemical industry has to meet rigorous conformity to engineering, user and regulatory requirements. Hence additional requirements were needed for quality management systems of goods suppliers and service contractors with in the sector. This standard is prescriptive and incorporates the verbatim text of ISO 9001:2000. It includes sector specific requirements for design, development, production, installation and service of products (Peurifoy and Gookin, 2004).

To ensure additional safeguards for purchased products an organisation shall establish control features for the verification of the purchased product. Final acceptance of the product requires that personnel other than the persons who performed or directly supervised the production of the materials or products shall perform the final acceptance. The organisation shall also establish control features for the design of the product. Design review is to be conducted by individuals other than those who designed the product. These measures being carried out by petrochemical companies to some extent, there is a system of incorporating third party inspection requirement in the purchase order of critical items. ISO/TS 29001 addresses non-conforming product that is detected after delivery and usage, and they are termed as "field non-conformities". Procedures need to include field non-conformities. The vital aspect is that the organisation needs to track and analyse field failures. This aspect is presently addressed in the ISO 9001 certified sample petrochemicals in two ways. For internal non-conformities, it is through incident reporting system. In the sample petrochemical company studied indicate that they use Achiever Plus software to track non-conformities and incident reports analysis and status monitoring of corrective actions. For external non-conformities it is through claims handling systems and customer feed back. The new standard also requires minimum frequencies for management review and internal audits, this aspect also followed presently in most of the ISO 9001 certified companies under study as a part of the research.

ISO/TS 29001 necessitates that an organisation has to establish control features (ISO/TS 29001:2003). The logic behind it is the need for documented procedures or methods to perform processes under controlled conditions (Peurifoy and Gookin, 2004). The standard also mention about the necessity for establishing process control documentation in routings, travellers, checklist, process sheets or other types control features. This is a major change from ISO 9001. ISO/TS 29001 is a certification standard.

2.8 Integrated Management Systems

Recognition of the role that regulatory compliance, environmental protection, health, safety and quality assurance programs play in managing critical risks make it desirable to integrate these programs with other business management processes (Waite et al, 1997) .To maintain and demonstrate continual improvement in all aspects of chemical industries' operations Chemical Industries Association (CIA) suggested a Responsible Care Management System in their guidelines (RS.C, 2005). Dealing with separate management systems covering quality, environment and safety issues and ensuring that they align with the organisation's business strategy can be problematic and IMS is increasingly seen as part of the management portfolio of many organisations. System integration can be achieved in a number of ways and at different levels. In practice all management systems (QMS, EMS, OSHMS, and RMS) are mutually co-ordinated systems functioning almost independently. Integration enables synergetic effect and optimum workplace performance on all aspects of Safety, Health, Environment and Quality (Tricker and Sherring, 2001). In 1997, ISO set up an advisory group to study the integration of ISO 9000 and ISO 14000 series of standards. One of the purposes of the ISO 9000:2000 revision was to harmonise its requirements with ISO 14001. Though ISO 9001:2000 does not encompass environmental systems, its organisation and approach make it easier to integrate with environment systems (Noble, 2000). ISO 14001 is being introduced initially as a stand-alone system with the intention of integrating it with other systems later. Beechner and Koch (1997) point out that ISO 14001 requires communication of environmental requirements to suppliers, and they see a communication process with local authorities as being the same as communication with customers. By integrating quality, environmental health and safety systems management can significantly leverage the effectiveness of its efforts and resource utilization (Noble, 2000).

Corbett and Cutler (2000) analysed the relationship between quality management systems and environmental management systems. They argue that organisations can make use of their experience with quality management systems to develop the environmental management systems. They present case studies on seven plastic manufacturers in New Zealand. The most important quality management practices that need to be mapped on to the environmental management systems are found to be people practices, involvement of customers and suppliers, adopting a preventative approach or culture, and strict waste management control.

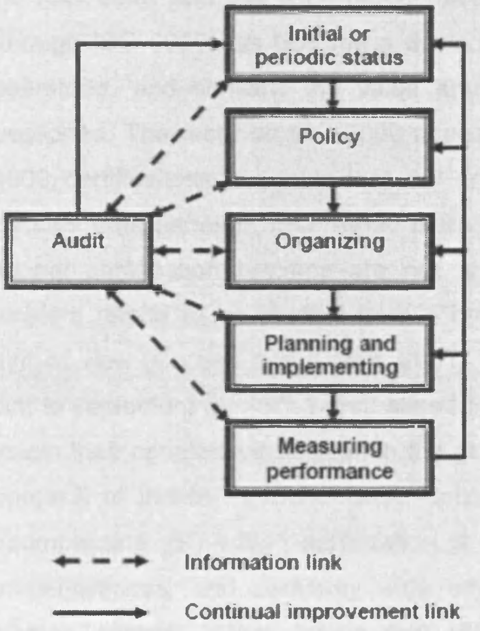
2.8.1 Integrated Safety Health and Environmental (SHE) Management System

A company needs to develop a core framework for the management of SHE issues that are required to be implemented across all its operations as part of the drive for excellence in management. The chemical industry has produced guidance on joint occupational health and safety management systems (OHSMS) and environmental management systems (EMS) and a number of organisations have now started to move down to this integration path. Research studies by Riemann and Sharratt (1995) and Hillary (1997) show increasing interest by companies towards integration. Implementation of BS 8800 can be concurrent to EMS Standard ISO 14001, and as such identifies the common areas in both management systems for reducing risk. Craddock (1997), Jarvis (1997) and Bacon (1997) emphasize the importance of continuous improvement in health and safety management systems, but Pooke (1997) does not include continuous improvement, or the measurement of performance, in the list of the essential minimum requirements of an OH&SMS. OHSAS 18001 and BS 8800 indicate the guidelines to integrate the management system with ISO 14001 (ISO 14001:1996, and BS 8800:2004, 2004).

2.8.2 Integration of Quality with SHE Management Systems

Dealing with separate management systems for quality, environment and safety issues and ensuring that they align with the organisation's business strategy can be problematic. Shillito (1995), Tranmer (1996) and Beechner and Koch (1997) have looked at the integration of safety, health, environmental and quality management and suggested how the problems of integration might be overcome. There are many common elements in the QMS and OH & S Management system like Management Commitment, Continuous Improvement, Training, Leadership, Employee Involvement, Corrective and Preventive Actions, Measurement etc (Noble, 2000). The common thread that connects most management systems developed over the last 20 years is PDCA principle (Plan-Do-Check and Act) used by Deming (1986) in the early 1950s. As Downs (2003) points out PDCA principle forms the basis for standards ISO 9000, ISO 14001 and OHSAS 18001. An organisation may opt to implement a mutually inclusive or mutually exclusive management system to ISO 14001 and may opt to integrate ISO 9001 in part or its entirety. This decision for inclusiveness or exclusiveness implies that ISO 14001, ISO 9001 and BS 8800 (or OHSAS 18001) can coexist as one management system, namely IMS (Integrated Managerial System). OHSAS 18001 and ILO-OSH are also compatible with ISO 14001, which may further be compatible with ISO 9001 (depending on needs and culture of an organisation).

In a note published by the Environment, Health and Safety Committee (EHSC) under Royal Society of Chemistry, an excellent comparison of occupational health and safety management systems, such as HS (G) 65, BS 8800:2004, OHSAS 18001, ILO-OSH 2001 and ISO 14000 are made. Though there are no fundamental differences between any of these management systems, they differ largely in scope and specific needs of OH&S requirements compared to quality and environmental specifications. Figure 2.2a and 2.2b show that the underlying principle in the new BS 8800:2004 model of occupational health and safety management system and the model of ILO-OSH approach is basically the Plan-Do-Check-Act principle (RS.C, 2005).



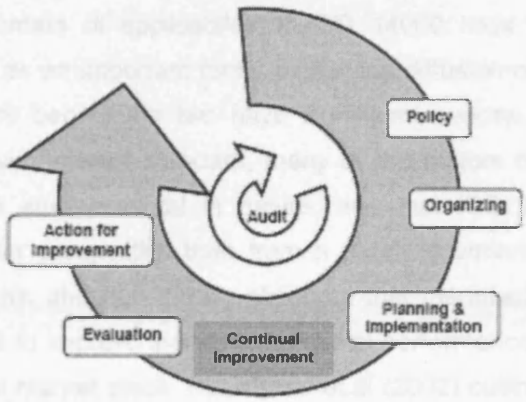


Figure2.2a. BS8800:2004 Model of OHS **Figure2.2 b ILO Model of OHS system**

Another approach is integrating selected parts of QMS, EMS and OH&SMS with other certified systems using identified linkages. Yousif (1998) feels that integration of safety functions into all aspects of business is crucial. Riemann and Sharratt (1995) consider grouping of similar concerns, particularly environmental and health and safety in high hazard operations, as an effective way of ensuring that the lessons learned in one system are passed on to the other. Craddock (1997) sees the use of the ISO 9000 series as the basis for an OH&SMS providing a systematic approach.

Gulf Petrochemical Industries (GPIC) in Bahrain, an ISO 9000 and ISO 14000 certified company, went for an integrated approach and they claim that they had achieved excellent performance in quality, safety and environment through integration. They have ISO 9000 documented system which ensures proper safety instructions and procedures in place and available for everyone in the organisation. They harmonized quality and environment. GPIC received RoSPA (Royal Society for Prevention of Accidents) award for 2001 and 2004 Chemical industry Safety Award for Oil and Gas sector. ISO 9001 is driven by customer requirements and ISO 14001 and BS 8800 are driven by different legislation. The three cannot be integrated in the way three colours can be mixed but they may be linked through similarities in their structure. Each system should be integrated into every function in the organisation and the policy and objectives of each must support the overall business policy and objectives.

2.8.3 Integration of Management Systems: Pros and Cons

The ISO 9000 and the ISO 14000 have generated much controversy among practitioners. Although ISO 9000 has become a de facto requirement for many firms, its effects are poorly understood, and similarly the value and domain of applicability of ISO 14000 have been questioned. The fact that ISO 9000 appears as an important factor explaining diffusion of ISO 14000 certifications suggests that the drivers behind the two have significant overlap. This indicates that, although ISO 14000 is an environmental standard, many of the factors driving national certification patterns are not at all environmental in nature, and that ISO 14000 therefore needs to be studied from a broader perspective than from a purely environmental point of view (Corbett and Kirsch, 2001). Chin and Pun (1999) observed that manufacturers want to implement the ISO 14000 based EMS to improve their environmental performance, and sustain their competitive position in the global market place. Ravikumar et.al (2002) outline the approach of Indian Petrochemicals Corporation Limited (IPCL), to environmental protection, encompassing ISO 14001 certification of one of its complexes leading to cost savings, raised competitiveness, and company wide employee commitment to resource conservation and pollution control. They argue that ISO 14001 provides a framework to institutionalise environmental protection and integrate environmental management practices in day-to-day activities. A very strong correlation between environmental standards and employee commitment are drawn by the authors in this work. These observations lead to integration of the management systems

Negative culture has negative influence on integration. Shillito (1995), Byrnes (1996) and Jarvis (1997) see cultural issues as hurdles that need to be overcome during integration. Garvin (1987) suggests that companies that carry out activities in sectors where environmental legislation is strict will be more concerned with environmental matters and will be more inclined towards integration. Integration is seen as combining systems based on the identified linkages between ISO 9000, ISO 14001 and BS 8800. The danger is that it simply becomes combining documentation in a way that would satisfy the certification bodies, and consequently policy, culture change and commitment to continuous improvement are not given sufficient emphasis. To avoid each system being seen as an island, integration of every function is required. Correspondence between OHSAS 18001 (1999), ISO 14001 (1996) and ISO 9001:2000 is provided in Table A2 of Appendix A (Boyle, 2002). Gilbert (1993), Jordan K.A. (1995), Riemann and Sharratt (1995) and Sunderland T.J (1997) all give reduction in effort and costs as reasons for integrating ISO 9001 and ISO 14001, but all except Riemann and Sharratt (1995) feel that it is often only seen in terms of auditing. There is risk involved at various levels with all management system aspects.

Management of risk is vital for integrating management systems. According to McCullum et al (1997) the fundamental consideration in linking management systems must be the nature of the link and an organisation must focus on a management system consistent with its business needs and looking for increasing the efficiency by integrating the management systems. Integration of EMS with QMS and occupational risk prevention can bring synergies through sharing of documentation and elimination of redundancies in the procedures (Byrnes, 1996). The certification scheme for OHSAS 18001 and BS 8800 does not follow the same centralised accreditation protocols of ISO 9001 or ISO 14001. However, registrars are providing registration as per OHSAS 18001 or OHSMS BS 8800 to those organisations volunteering for it.

2.9 Risk Management

Global businesses today are facing with a spectrum of risks which may be categorised within the areas of hazard, operational, strategic and financial, all of which can affect business continuity and shareholder value. While quality, cost, delivery and flexibility are generally acknowledged as the main competitive factors in manufacturing, awareness of strategic value of industrial safety is of growing importance. Each workplace involves risk. It is necessary that management system of performance, quality should be supported by workplace risk management system and OHSMS (Savic, 2001). The crucial aim of quality management is the implementation of strategic management plan which ensures system quality, whereas the aim of risk management is the retention of the system quality in case of possible risk occurrence (Vaughan, 1997). The tool used by organisations to ensure business continuity and shareholder value is risk management, broadly defined as the process of enabling the systematic identification, analysis and management of critical business risks. Energy industry world-wide has faced unprecedented change brought about by political and societal pressures, and risk management is in fact change management (Purdy, 1997). Middle East energy organisations have historically focused on the management of hazard risks only (Hywel, 1998). In order to have effective risk control and build a positive safety culture, a management system needs to have proper management arrangements (Level 1), risk control systems (Level 2) and workplace precautions (Level 3). The elements of risk management process include risk identification, risk assessment, risk control (risk avoidance, risk retention, risk transfer, risk reduction) and performance monitoring (audit/review) (Savic, 2001).

For any hazardous technology there are potentially four primary risk areas such as 1) personal injury or individual equipment damage risk, 2) risk due to errors committed by key front-line controllers leading to an organisational accident 3) risk due to accumulation of latent conditions within the maintenance, managerial and organisational spheres leading to damage of entire installation and 4) risk to third parties including investors, neighbourhood and environment (Reason, 1997). The Petrochemical industry has high risk of the first three and very high risk of the fourth type. Successful risk reduction depends upon both design and organisation. Safety in process plant starts at the design stage and consists of inherent safety; safety that is engineered. Inherent safety includes reducing the inventories or replacing of hazardous materials, using alternate process routes, and substitution by more efficient process means. Bhopal gas tragedy in India in December 1984 that killed nearly 2500 people was largely caused by the storage of excessive amounts of extremely dangerous intermediate product and poor maintenance of safety systems like flare, refrigeration systems (James, 1997). Properly designed, constructed, operated and maintained equipment will not fail catastrophically provided that mechanical design conditions are not exceeded.

2.9.1 Risk of Occupational Injuries

A remarkable work by Harrell (1990) is noteworthy here. He studied the various factors that influence perception of risk involved in work-related accidental injuries. He conducted his survey on a sample of 244 full-time employed men and women who were working under varying autonomy and freedom. He found out that the most influential factors of perceived risk were autonomy and freedom, even while the workers were exercising greatest control over their work perceiving the least risk of accidental injury. Two other dimensions of control over work-task repetitiveness and speed of pace-had weaker effects. Use of blue collar kinds of equipment felt was riskier than the use of white collar equipment or no equipment. Harrell argues that since the working conditions are determined by the number of hazards identified in the workplace, they are more influential in determining the perceived risk than previous accident history. The risk factors analysed involved incident rates, severity rates, and frequency rates.

2.9.2 Safety Assurance and Potential Hazards

The case study conducted by the author on a petrochemical company in the Gulf region revealed the fact that in addition to the direct employees, there were many contract employees working on a day to day basis. It was understood from documents inspection that on an average nearly 600 to 700 personnel are exposed to various levels of risk. The primary causes of accidents are many. As Kolka (2002) points out it could include mechanical failure, operational failure (human error), unknown or miscellaneous, process upset and design error. Figure 2.3 shows the relative number of accidents that had occurred in the petrochemical field, on percentage basis.

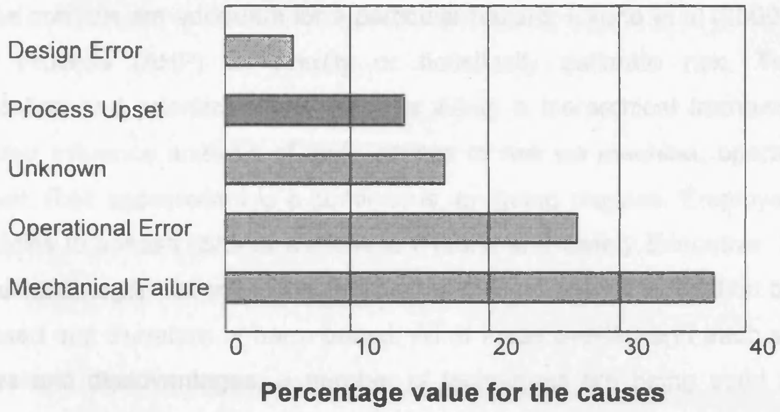


Figure 2.3 Causes of Accidents in the Petrochemical Field (Kolka, 2002)

Safety assurance requires identification of potential hazards using HAZOP technique and assessment of their frequency and consequences using quantitative risk assessment (QRA). Safety assurance must be an integral part of design procedures that is part of the overall quality assurance. A formal set of procedures need to be established to ensure that safety is considered at all points in the design process (Turney, 1990). Documented confirmation safety checks carried out based on the design safety guidelines and codes is an evidence for safety checks. Major hazards in the operation of a process plant are due to toxic and corrosive chemicals, fires and explosions, falls and dropped loads and equipments. Senior management, plant designers and operators are required to be aware of the hazards of their plants. Many of the worst accidents in the process industries are the result of bad maintenance practice. Piper Alpha and Flixborough are two particular examples. The causes of maintenance related accidents fall in two categories. They are improper maintenance procedures and unsafe conditions of the plant. Rigorous Permit to Work procedures can prevent accidents to maintenance personnel. It is important that permit to work system need to be correctly applied, Piper Alpha case there was a permit system existing but not operated correctly (Reason, 1991). Safety review needs to be applied to the documented procedures for carrying out the modification. Flixborough incident was the result of badly planned maintenance procedure (Reason, 1997). Skelton (1997) points out that the right organisation and right procedures must be established to ensure that both reactive and pro-active safety checks and reviews are carried out at all stages of design, construction, commissioning, operation and maintenance, and these procedures are to be regularly reviewed and audited.

2.9.3 Risk Assessment

Risk assessments should be reviewed on a regular basis as well as whenever there are any significant changes to hazard information, the premises, processes, work equipment, changes in technology, work activities or working patterns or shifts etc. There are no legal requirements on the format of the records of risk assessment. An essential requirement for risk assessment is access to up-to-date information. To identify hazards, analyse risks and arrive at an evaluation whether the controls are adequate for a particular hazard, Cagno et al (2000) proposed Analytic Hierarchy Process (AHP) to directly or holistically estimate risk. They proposed risk characterization and prioritization of hazards within a hierarchical framework. Their proposal also included influence analysis of main causes of risk via machine, operator, procedure and environment. Risk assessment is a continuous, on-going process. Employers have duties and responsibilities to assess risks at workplace (Health and Safety Executive, 2001). To carry out risk assessment, organisations follow three strategies namely 1) legislation based, 2) sources of hazard based and 3) nature of harm based. All of these overlap and each strategy has its own advantages and disadvantages. A number of techniques are being used to assess the risks associated with a defined system. Four main techniques used for risk assessment are HAZOP, FMEA, ETA and FTA (Boyle, 2002). Various regulations exists necessitating separate risk assessment which is not a feasible strategy. Even though regulations mostly speak of harm to people only, from an organisation point of view damage to property and environment also need to be included (Hywel, 1998). Table A4 of Appendix A, gives partial list of safety regulations. The concept of risk-based approach to Management Systems standards has been introduced by the Environmental Standard ISO 14001 and OHSAS 18001. Infrequent risks with minor consequences can be controlled, whereas significant ones with severe consequences must be managed, either by eliminating them or by working to reduce their frequency or severity. Organisations that have successfully applied ISO 14001 go through an environmental review of which an integral part is to consider significant environmental aspects relating to emissions to air, releases into water, waste management, contamination of land, use of raw materials and natural resources and other environmental and community issues keeping the objective of managing risk and preventing loss with respect to the environment.

There is a growing perception that safety culture is an important issue in modern risk management, HSE (2001) notes that developing a positive health and safety culture is important if high standards of health and safety are to be achieved and maintained. Organisational safety culture is what people think, say and do in the context of an organisation (Boyle, 2002). Safety culture consists of shared values, beliefs and practices concerning the importance of health and safety and its controls (IOSH:1994). Organisation culture relate to safety is a set of attitudes, beliefs and perceptions shared by a natural group as defining norms and values, which determine how they act and react in relation to risk and risk control systems. Measurement of safety culture involves measuring people's attitudes and beliefs as well as what people do and the measurement of how attitudes link with behaviour. According to Dale (1994), importance attached to safety by employees, creative mistrust, caring trust among each other, sense of involvement felt by all parties, openness in communication and integration of safety thinking to all aspects of work practice are some of the dimensions of the safety culture. Human contribution in eliminating occupational accidents and losses is the main issue to be tackled. Error causation emerges from human-machine mismatch and interface. Practical application of this approach includes HAZOPS, RAMS and HRA, technical safety audits ergonomic guidelines etc. The organisational approach views human error as a consequence than as a cause. The dictum that accidents 'do not happen' but are caused conveys the meaning that human errors accumulate one after the other, culminating in disaster. Errors are seen as a symptom that reveals the presence of latent conditions in the system. A series of erratic events lead to other erratic events and finally end up in an unsafe act and ultimate financial and human loss as depicted in the causation continuum given at Figure 2.4. This model of Savic (2001) emphasizes the necessity for proactive measures of "safety health' and the need for continual reforms of the system's basic processes. Attitude of all categories of employees is very important. Individual differences can lead to changes in attitudes and even beliefs. It determines individual and in turn collective conformance to safety norms and proactive measures. The ultimate losses are the end point in a long sequence which has its nucleation in individual differences. Thus Figure 2.4 shows the illustrative causation continuum that an organisation needs to focus on the precursors of the losses as a part of continual improvement strategy.

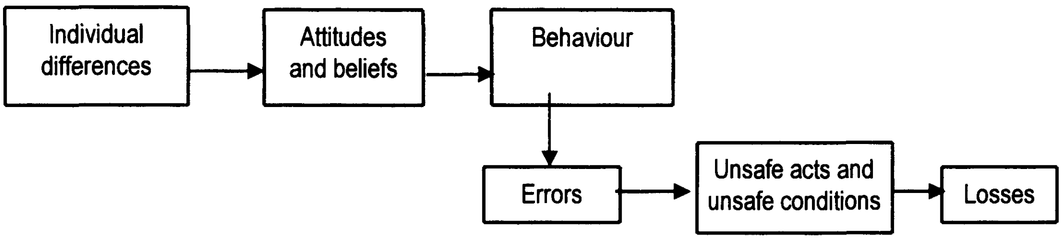


Figure 2.4 An Illustration of Causation Continuum (Savic, 2001)

An ISO 9000 certified organisation committed to continual improvement has the framework for corrective actions and preventive actions in place. A management strategy based on safety culture embedded in the continuous improvement framework can be very effective in risk control and loss prevention. The results of the study of risk mitigation techniques employed in a sample petrochemical plant is furnished in Section 4.4.6 of this report.

2.10 ISO 9000 Certification and Improvement of Safety Performance

The literature review of the ISO standard revealed that there are many elements of the standard which have direct impact on "safety" and a special relevance to the research. In the new revision of ISO 9000 standard the emphasis is on process approach towards QMS. The systematic identification and management of the processes employed within an organisation and the interaction between such processes are referred to as process approach in Clause 2 of ISO 9000. This aspect is highly relevant to the research to identify the effect of this approach on the safety performance of the organisation. As per Clauses 8.5.1 (Continual Improvement), 8.5.2 (Corrective Action) and 8.5.3 (Preventive Action) non-conformances of a product or service get evaluated continuously and the multiple root causes of the process failure are identified. This in turn leads to establishing corrective/preventive actions which helps to mitigate risk. Statutory and regulatory requirements include "safety" issues and requirements of customer and other stake holders. The key assessment considerations deficiency of which can cause a non-conformance or accident are listed in Table 2.4 (Noble, 2000). ISO 9001 address all these issues by various clauses indicated in the Table 2.4.

Table 2.4 Key Assessment Considerations (Michael T. Noble, 2000)

S. No	Key Assessment Criteria	ISO 9001 Relevant Clauses
1	Purchasing,	7.4
2	Methods (procedures, instructions etc),	7.5.1
3	Tools and equipment	6.3a & b
4	Environment	6.4
5	Personnel (Management & Supervision)	5.5, 6.2.2
6	Facilities	6.3
7	Materials	7.5.5
8	Maintenance	6.3,6.4,8.5
9	Training	6.2.2
10	Communications	5.5.3

Management commitment is the most important aspect which can have direct impact on safety performance (Clause 5.1) and Clause 5.5.3 of the standard requires that management needs to establish the appropriate communication processes within the organisation. Communication failure is one of the critical issues to prevent major industrial accidents. Resource management is one of the major generic business processes, to identify and manage the work environment. Adhering to Clause 6.2.2 Competence, Awareness and Training enable an organisation to achieve quality. There is less probability for accidents from a skilled and properly trained worker. Maintaining the infrastructure associated with equipment, workspace and utilities and managing a proper work environment as per Clause 6.3 and 6.4 not only benefits quality but has major influence in eliminating risk. Clause 6.3 states that organisations shall determine and provide and maintain the infrastructure to achieve conformity to product requirements. Infrastructure includes buildings, workspace, utilities, process equipment (hardware and software) and supporting services like transport and communication. Work environment includes safety, health, ambient conditions etc. As per Clause 6.4 the organisation shall determine and manage the work environment needed to achieve conformity to product requirements. The impact of quality of equipment, tools and instruments, etc used for production on safety performance is direct. Bursting of a low quality hydraulic hose, failure of a bolt or a nut, leak from a gasket used in a critical application of a petrochemical plant can all lead to major accidents.

Clause 7.4.1 (Purchasing Process), 7.4.2 (Purchasing Information) and 7.4.3 (Verification of Purchased Product) of ISO 9001 not only address the quality issue but safety as well. A wrong purchase of low quality material for a bolt or nut can lead to major disaster in a petrochemical process plant where pressure beyond 2000 Bar is being used. As per Clause 7.5.1 (Control of Production and Service Provision) an organisation shall plan and carry out production and service provision under controlled condition which include use of suitable equipment and work instructions, and both of them are related to safety as well. Properly drafted working instructions based on operating manuals of the machines are a main requisite for safe work. Management has to consider the human and physical factors which affect the suitability of product /service. This aspect of the standard is of special relevance to the research study. The effect of implementing this on the safety performance of a petrochemical company is also a fertile area for research.

The common elements such as management, policy, planning, training, communications, auditing, records, corrective action and management review etc. in different management systems namely, ISO 9001, BS 8800, OHSAS 18001 and ISO 14001, are relevant for this research, so as to find to what extent "safety" related issues are embedded in ISO 9001 standards. Safety culture/climate is influenced by the perceptions and appropriateness of behaviour of people in an organisation. Clause 6.2.2 requires an organisation to determine competence for personnel performing work, generate awareness and provide training to all of them. These are also aspects for maintaining a right safety climate. Employees were believed to develop coherent sets of perceptions and expectations regarding behaviour outcome contingencies and behave accordingly. Thus people tend to fit in and behave in a manner that is acceptable for a given environment. If there is a climate for "safety" people will generally behave safely (Hehir, 1997).

Clause 8 (measurement, analysis and improvement) has many items like internal audit (8.2.2) continual improvement (8.5.1) and corrective action (8.5.2) which if applied correctly can bring out safety issues along with quality issues for corrective action. Preventive action (8.5.3) to eliminate the causes of potential nonconformities is the core of risk management. The aspects and clauses of ISO 9001 like Clause 8.5 improvement, 8.5.2 corrective action and 8.5.3 preventive action etc indirectly help in mitigating the risk. Also, elimination and mitigation of risk are possible only with proper preventive action in place. Companies like DuPont regard process changes that improve quality as an opportunity to improve safety and environmental performance. Over the past 10 years they have increased shareholder equity by 300% and decreased environmental liability and injury illness rates by 60%. According to Noble (2000), investigation of serious process failures and injury or fatality always revealed that it involves multiple root causes in the management system.

For an effective risk management process, an organisation should develop a documented process for both qualitative and quantitative risk assessment. This process must include input from all affected stakeholders. It should be used to identify and prioritize potential operational process risk, the multiple root causes of process deviation or non conformance and changes to the process to mitigate risk. In the hierarchy of risk control strategies avoidance and control of risk at source is most cost effective way (Purdy, 1997). Avoidance of risk at source involves a change in culture. It is achieved through building awareness, communication, involvement, increasing motivation, empowerment and providing support with systems consistent with changes. All these are linked to ISO 9000. A management committed to implement ISO 9000 strictly adhering to its principles implement the above aspects.

Clause 5.1.a - of the standard explicitly states that top management shall provide evidence of its commitment to the development and implementation of the QMS, by continually improving its effectiveness by communicating to the organisation the importance of meeting customer as well as statutory and regulatory requirements. The QMS focuses on achieving quality objectives, which complement other objectives of the organisation including environment, occupational health and safety (Clause 2.11). This aspect is of prime interest for the research study to see to what extent those complementary objectives are met. An ISO certified company automatically gets many layers of protection for accidents and failures as indicated in Figure 2.5 (Purdy, 1997).

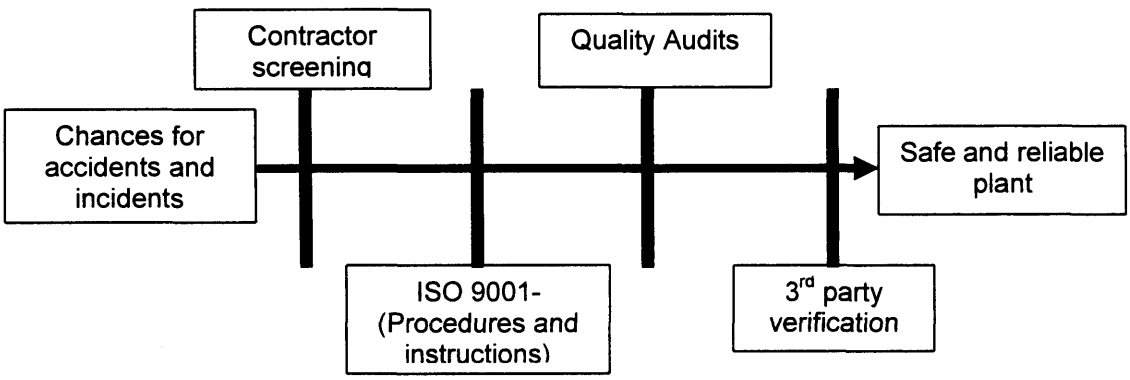


Figure 2.5 Levels of Protection Barrier Diagram (Purdy, 1997)

The point to be derived is that a company implementing these ISO clauses with the support of a committed management taking care of those issues can end up with a better safety performance.

2.11 Summary

The foregoing discussion focused on the various standards in quality management systems in organizations especially in petrochemical industries. The effect of implementation of these systems in such organizations was discussed. Various certification systems such as ISO 9001, BS8800, OHSAS 18001 and ILO OSH2001 and HS (G) 65 were studied and the links among these systems were discussed. The quality management process model was presented so as to highlight the importance of continual improvement resulting from implementation of quality management system standards. Relationship of total quality management (TQM) and total safety culture (TSC) from the safety perspective was verified. It was found that there are various OHSMS systems and standards for health, safety management policies which can be applied in organizations. They include Health and Environment Guidance otherwise known as HS (G) 65, the British Standard BS 8800:2004, Occupational Health and Safety Assessment series OHSAS 18001 and the International Labour Office ILO-OSH: 2001 guidelines. A detailed discussion on the concept of integration of safety, health and environmental (SHE) management systems and the relative advantages and disadvantages were presented.

Risk management, risk assessment and criteria for assessment are core ideas in safety performance of industries. A model depicting the causation continuum which points to the nuclei of all losses and risks was presented. The risk perception is enriched by this model which covers the entire gamut of risk elements. An integrated approach comprising of the following features is most appropriate. These features are:

i) defining of workplace process problems accurately
ii) identifying work as a process and its failure leads to reprocessing or rework, and accidents/incidents
iii) linking safety to company's quality improvement process
iv) identifying the critical processes in work environment
v) documentation of processes
vi) managing safety right through from design, procurement, production, and control to the end user

According to an EHSC note on OH&S, even with the presence of a number of formal international standards for managing quality (ISO 9000) and environment (ISO 14000) there is no recognised ISO certifiable standard for occupational health and safety. The note comments that at an ISO workshop in 1996, ISO rejected an approach from ILO regarding an international standard for OH&S management standard. So ILO reviewed about 20 national OH&S systems and developed the ILO-OSH 2001 (RS.C, 2005).

The extensive review of related literature revealed the fact that the safety management systems (SMS) in petrochemical industries needs to be investigated further since the research work done in this area is inadequate even at international levels, more so in the Gulf region. However, convincingly enough, ISO certification has a major influence in all the process stages. Existing literature of ISO 9000 does not explicitly address “safety” with the priority it deserves.

"Safety" needs to be ingrained in the "QMS" process model. Various elements of QMS shall include inherent safety, system safety, occupational safety and process safety. The concentration of the reported research is on proving that a systemic integrated approach to managing safety is achieved through ISO certification.

As detailed in the literature review of this report, various researchers bought out the positive effect of ISO 9000 certification. Rao et al (1997) noted that there exists a significant difference between ISO 9000 certified and non-certified firms. Fryxwell and Szeo (2002) mentioned ISO certification benefits outweighed its negative outcomes. Chitterden et al (1998s study of UK companies also notes that advantages of using ISO 9000 out weighed the disadvantages. Sun (1999) indicate that ISO 9000 certification significantly correlated to quality results, improvement of productivity and profitability. Low (2001) says there are long term and strategic effects of ISO certification. Calisir et al (2001) concluded that large companies might be more satisfied with ISO 9000 through increased emphasis on achieving operational improvements.

It is evident from the document research efforts that many elements of ISO standard have direct impact on safety and special relevance to the research. Clauses 8.2.2 (Internal audit), 8.5.1 (Continual improvement), 8.5.2 (Corrective action) and 8.5.3 (Preventive action) etc are of special relevance to the research. Non conformances of a product or service get evaluated continuously and the multiple root causes of the process failure are identified. Corrective and preventive actions help to mitigate risk. It is in this context the main and the first hypothesis of this research study was formulated to test whether there is significant improvement in the average safety performance level with respect to ISO certification or not. BS8800 was referred to formulate the indexes for safety performance measurement. The detail of research methodology adopted is given at 33.3.2 of Chapter -3 of this report.

A study by Mallak et al (1997) s that there is a linkage between culture and ISO certification. Also cultural values like being decisive, team oriented, risk aversive, valuing stability, paying attention to details and valuing high levels of organisation etc support ISO certification. As noted by Reason (1991) one of the three models for safety management is personal model which stresses psychological factors as prime causation for accidents. Failure to address the culture of an organisation can result in limited success or complete failure of management initiatives. Understanding the culture of an organisation and using it map the steps needed to accomplish a successful change is an important part of the quality journey through safe means. Culture must support systems and systems must support culture, a cycle of awareness, motivation can reinforce the desired behaviour and necessary cultural change.

Hehir (1997) noted that if there is a climate for "safety" people will generally behave safely. Competence, awareness and Training etc are the resource requirements for a proper QMS to enable an organisation to achieve quality (Clause 6.2.1 & 6.2.2). There is less probability for accidents from a skilled and properly trained worker. This aspect of linkage between culture and safety was considered while framing the second hypothesis that there is no significant improvement in the average safety awareness level of front runner employees with respect to ISO certification. Assessment of safety culture is carried out through conducting a questionnaire survey conducted among the front runner employees. The survey methodology is furnished at 3.4 of chapter.3.

Safety and Quality professionals are supposed to be the focal points for any safety and quality improvement initiatives in any organisation. They normally undergo many training programs related to management system. While assessing the safety culture it is thus important to separately survey this segment of the human resource to verify how their awareness level is different from the front runner employees. The third hypothesis statement that there is no significant improvement in average safety awareness level of Safety and Quality professionals with respect to ISO certification is stated considering this aspect are given at 3.4. 2 of chapter 3 of this report.

OSHA voluntary guideline requires employers to identify and control work-site hazards and to involve employers in all phases of the program. As noted by Purdy (1997) avoidance & control of risk at source is the most cost effective way. But it needs a change in culture building awareness, communication, involvement, increasing motivation, empowerment and providing support with systems consistent with changes etc. Involvement of management in all these items is important. As per clause 5.1 ISO 9001 standard, management need to provide its commitment to the development of the QMS to achieve quality objectives. Also it is very important to note that quality objectives complement safety objectives (Clause 2.11). Commitment of managers can be better achieved if they are fully aware about safety issues. The fourth hypothesis statement "There is no significant improvement in average safety awareness level of managers with ISO certification" is formulated in this context.

Perception is a logical and empirical precursor to actions that could reduce danger. As pointed out by Zohar (1980), management commitment to safety is a major factor affecting the success of safety programs of any company. It is important to measure the degree to which hazards in production operations are anticipated by the management and steps taken by them to mitigate risk. Accordingly the fifth hypothesis statement was formulated to test whether significant improvement is there or not on the risk perception level of the managers with respect to ISO certification. A risk perception measurement questionnaire survey was thus carried out as per the research methodology detailed at 3.4.4 of this report.

The Engineering model of safety management system as noted by James (2000) considers safety as something to be engineered into the system of reliability engineering, traditional ergonomics, risk management and human reliability assessment. As indicated by Noble (2000) deficiency of key assessment considerations furnished at Table 2.4 can cause non-conformance or accidents. Key assessment considerations includes facilities, materials and maintenance. Maintaining the infrastructure associated with equipments to achieve conformity to product requirements, workspace, utilities and managing a proper work environment not only affect quality but likely to have a major influence on eliminating risk. As quoted in the various examples of the literature survey quality and maintenance of facilities, equipments, tools used for production and maintenance also likely to have an influence on safety. It is also related to purchasing process as referred in the Clauses 7.4.1, 7.4.2 and 7.4.3 of ISO 9001 standard.

As noted by Savic (2001) to have an effective risk control and build a positive safety culture, a management system needs to have proper management arrangements (Level1), risk control systems (Level 2) and workplace precautions (Level 3). The elements of risk management process include risk identification, risk assessment, control and performance monitoring. As this being a laborious process requiring time and more resources it doesn't fall in the purview of this research. However a typical case study of a petrochemical plant has been conducted to verify the improvement in the safety culture of a petrochemical company after ISO certification in terms of work place precautions and risk mitigation. Also the case study was used to validate the statistical test models used for the first hypothesis testing. Details are furnished at 3.5 of the research methodology chapter.

Chapter Three: Research Methodology

3.1 Introduction

This chapter outlines the instruments, procedures, techniques and methods used for collecting and analyzing data. Eilon (1975) while describing the seven archetypes of research workers refers to the 'observer effect' that hampers realistic collection of data. In order to avoid any kind of bias or the 'observer effect', utmost care was taken in this vital exercise of the research. The literature review formed the basis for developing the instruments for measurement to find answers to the research questions. The sources of data were published documents of the companies contacted, personal interviews and questionnaire surveys. The data collection and the statistical analyses used for proving the research hypotheses are presented in the following sections.

3.2 Data Collection

Two types of data can be collected: qualitative and quantitative. Quantitative is usually relevant for factual elements, while qualitative data often reflects people's feelings and perceptions. All the data collection means such as inspection of published documents, company brochures, reports, interviews, questionnaires and observation were sought so as to ensure the quality of data. The target respondents included managers, safety personnel and employees. Samples were taken from the various petrochemical industries in the gulf region. Sampling is the systematic selection of representative elements of a population for data collection. The quality and quantity of data depend on the size and type of samples.

As Lapin (1980) suggests there are three primary types of samples, the convenience sample, the judgement sample, and the random sample. Convenience sampling is done when more convenient and unrestricted selection of elementary units are chosen from a population for observation. A judgement sample is obtained according to the discretion of someone who is familiar with the relevant characteristics of the population, where as a random sample allows for the equal probability that each elementary unit will be chosen. Since the author is closely associated with petrochemical industries in the Gulf region and the number of companies to be chosen from is just about 35, the logical selection of the sampling procedure fell on judgemental sampling. Obviously this method is highly prone to bias if not done judiciously. Therefore care was taken to avoid such biases and 'observer effect' while designing the questionnaire and collecting data. A structured approach is used to ensure this. Data collection methods are briefly described below.

3.2.1 Pilot Study and Sample Size

A pilot study was first conducted on 27 petrochemical companies in the Gulf region. This survey covered 17 companies from the Kingdom of Saudi Arabia, 4 from Qatar, 3 from UAE, 2 from Kuwait and 1 from Bahrain. Ten companies were selected from these 27 companies as the sample for the research study, on the basis of judgemental sampling procedure. They included 3 companies from Saudi Arabia, 3 from Qatar, 2 from UAE, 1 from Kuwait and 1 from Bahrain. In order to avoid biases, utmost care was taken while choosing the sample. The criteria used for the final selection were i) size of the organization in terms of number of employees, ii) minimum number of years of operation, iii) whether oil or gas based, iv) country of operation, v) ISO certification, vi) the availability of safety performance data before and after ISO certification and vii) the established contacts.

3.2.2 Documents Inspection and Personal Interviews

While examining documents key metaphors, boundaries, terms that denote good and bad characteristics, types that reveal culture and morale etc. are to be taken care off. Memos, notices, procedure manuals, policy handbooks and such other materials are to be inspected.

Obviously personal interviews need to be planned carefully. Interviewing steps include reading through background material, establishing interviewing objectives, deciding who to interview, plan and preparing the interview, carry out the interview, prepare written reports, and review the report with the interviewee and so on. Interviews can be structured or unstructured and the questions asked can be open ended or close ended.

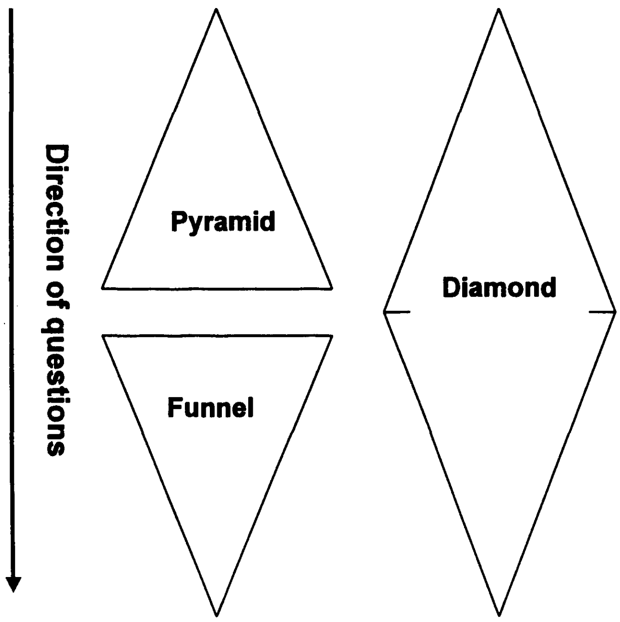


Figure 3.1 Interview Structures

Reliability, and precision of data are high in closed questions and skill required and analysis are easy, too. Four structural types are usually employed in interviews, namely pyramidal, funnel, diamond, and unstructured (Figure 3.1). A mix of these types was employed in this research so as to collect maximum quantity of quality data.

The close association of the author with the Industry in the Gulf region helped a lot in collecting data through personal interviews and documents investigation. Data from in-house magazines/periodicals/annual reports of companies were also used. Reactive indicators and pro-active health and safety indicators were used to collect safety data. Safety periodicals, research papers, published journals, magazines, books, web pages etc were referred. An extensive library search was also done to get more details regarding the relevant areas of the subject. Due care was taken before getting started with interviews.

Personal contact of the researcher with the management of various petrochemical companies in the Arabian Gulf countries was helpful to get valuable data for the analysis. Visits were made to some companies like Gulf Petrochemical Industries in Bahrain, Qatar Fertiliser Company etc. Telephonic and email contacts were utilized to the maximum possible extent. In addition to documents investigation, visits and contacts were useful in conducting the pilot study on questionnaire survey, the questionnaire design and data collection.

3.3 Measurement Techniques for Safety Performance and Culture

Measurement of safety performance and safety culture is not based on a single factor or aspect. In order to conduct a proper assessment the complete safety process need to be measured. Reason (2000) notes that the safety process measures can be classified into five broad clusters namely i) specific factors (incidents/accidents reporting, policy, emergency procedures etc) ii) management factors (management of change, leadership, communication, hiring placement, purchasing controls etc) iii) technical factors (maintenance management, levels of automation, human-system interface, engineering controls, design, hardware etc), iv) procedural factors (standards, rules, administrative controls, operating procedure etc) and v) training factors (formal versus informal methods, skills, competencies development, training department etc). The core of all these is cultural factors (commitment, competence and cognisance). Accordingly a set of measuring instruments such as reactive and proactive health and safety indicators were chosen to measure the safety performance covering the broad cluster areas mentioned above.

3.3.1 Safety Performance Data

The safety performance data collected consisted of both proactive and reactive safety data. Reactive data indicate data on safety performance in the past, like number of past accidents, near misses, medical cases and fatalities etc of an organisation. Where as proactive data indicate the safety measures taken and activities like training, preparation and implementation of procedures etc to prevent such accidents. Reactive safety data was collected from 10 ISO certified companies. The data was divided into two categories – namely the reactive safety data before ISO certification and after ISO certification. However proactive safety data was collected from ISO certified companies as well as non-ISO certified companies.

The data on safety performance was collected through personal interviews, investigation of documents and analysis of questionnaire responses. It consisted of data on i) incident rates, ii) frequency rates, iii) severity rates, iv) safety awareness, v) risk perception, and vi) prevention inspections. In addition, 'work place precaution' was assessed through a case study of an ISO certified petrochemical company's "risk management".

Safety awareness measurement and risk perception measurement were carried out through questionnaire surveys. The target group consisted of managers, safety and quality professionals and front-runner employees of the 10 "ISO certified" and 10 "non-ISO certified" companies.

3.3.2 Details of "Measuring Instruments"

Safety measures were determined from an extensive study of safety literature and standards. Measuring instruments of safety performance involves reactive and proactive measures. Proactive and reactive monitoring plays complementary roles in safety/risk assessment and control (Dale, 1994).Various definitions are available for these safety indicators. BS 8800:1996 Annexure-E is the reference for the definitions used in this thesis. Different standards use different combinations and the definition furnished here matches with what is practiced in the industry. Proactive indicators are used for active monitoring. Proactive monitoring is designed to control risks and prevent the occurrence of injuries and work-related ill health.

Reactive indicators were used for reactive monitoring. The calculations of reactive indicators are given in section 3.3.3.2.1. Reactive measures of performance monitor accidents, near misses, ill-health, incidents, insurance claims experience and other historical evidence of deficient health and safety performance. Failures in risk control were measured by reactive monitoring which enables organisations to check performance, learn from failures to improve safety performance.

Measuring health and safety culture of an organisation is an important factor in ensuring the effectiveness of risk control and safety performance. Activities like control, communication, cooperation and competence need to be measured for assessment of safety culture. Questionnaire survey is used in this research for assessing the safety culture. To assess whether risk control measures and work place precautions are in place in an ISO 9000 certified company, a sample petrochemical was studied in detail and the results analysed. Referring to standard BS 8800:1996, the following safety indicators and measuring instruments were used to measure and assess the safety performance level of the petrochemical companies identified for the research. .

a) Reactive indicators (To measure historical safety data - used for reactive monitoring).
b) Pro-active indicators (Proactive monitoring data include management factors)
c) Questionnaire survey for Safety awareness measurement (Safety culture)
d) Questionnaire survey for Risk perception measurement.
e) Assessment of Work place precautions (Risk management-Proactive approach).

Accordingly, Safety performance assessment was carried out by using the data collected and derived through the application of above referred instruments (a to e).

3.3.3 Data Analysis

Each data set (i.e. safety data before ISO certification and safety data after ISO certification was tested for normality using normal probability plots. This was an essential exercise. Otherwise nonparametric tests will have been more appropriate. Since judgemental sampling was done the normality of data had to be ensured for conducting paired t-tests and Analysis of Variance (ANOVA) tests. Comparison of means and variances of the two independent groups of data sets or the two populations, were done. The significance levels used were $\alpha = 0.01$ and 0.05.

It is to be noted here that paired t-tests for testing equality of two population means can be done only if three basic conditions are met, namely i) each experimental unit has a pair of observations ii) the data should be normal and iii) the two data sets must be homogeneous (Walpole et al, 2002). The first condition is met by the fact that observations were made in companies before and after ISO certification. The second condition is proved by the normal probability plots. These plots are shown in Appendix B, Annexure 1. The third condition is an extension of the first one since homogeneity of data set is ensured by the nature of operations in ISO certified and Non-ISO certified companies. Based on the primary objective of identifying the effect of ISO certification on the safety performance level of petrochemical industries, the following research hypotheses were formulated.

3.3.3.1 Research Hypotheses

Expressed in words the Null hypotheses are stated as follows:

1) No significant improvement in the mean safety performance level (SPL) after ISO certification i.e. $\mu_{1SPL} = \mu_{2SPL}$.
2) No significant improvement in the average safety awareness level of front runner employees (SAE) after ISO certification, i.e. $\mu_{1SAE} = \mu_{2SAE}$

3) No significant improvement in average safety awareness level of Safety and Quality professionals after ISO certification , i.e. $\mu_{1SAQ} = \mu_{2SAQ}$
4) No significant improvement in average safety awareness level of Managers after ISO certification, i.e. $\mu_{1SAM} = \mu_{2SAM}$
5) No significant improvement in risk perception level of Managers after ISO certification, i.e. $\mu_{1RPM} = \mu_{2RPM}$

Corresponding null and alternate hypotheses tested are tabulated below (Table 3.1):

Table 3.1 – The Hypotheses on Safety Measures Tested

Safety Measures being tested	Null Hypothesis, H_O	Alternate Hypothesis, H_A
Average Safety Performance Level	$H_O : \mu_{1SPL} = \mu_{2SPL}$	$H_A : \mu_{1SPL} < \mu_{2SPL}$
Average Safety Awareness level	$H_O : \mu_{1SAE} = \mu_{2SAE}$	$H_A : \mu_{1SAE} < \mu_{2SAE}$
Average Safety Awareness level	$H_O : \mu_{1SAQ} = \mu_{2SAQ}$	$H_A : \mu_{1SAQ} < \mu_{2SAQ}$
Average Safety Awareness level	$H_O : \mu_{1SAM} = \mu_{2SAM}$	$H_A : \mu_{1SAM} < \mu_{2SAM}$
Average Risk Perception level	$H_O : \mu_{1RPM} = \mu_{2RPM}$	$H_A : \mu_{1RPM} < \mu_{2RPM}$

In Table 3.1 μ_1 = Mean value before ISO certification, μ_2 = Mean value after ISO certification, and subscripts, SAE = Safety Awareness level of Employees, SAQ = Safety Awareness of Quality and Safety Professionals, SAM=Safety Awareness level of Managers, RPM = Risk Perception of Managers.

The illustration of one-tailed hypothesis testing procedure is illustrated in Figure 3.2.

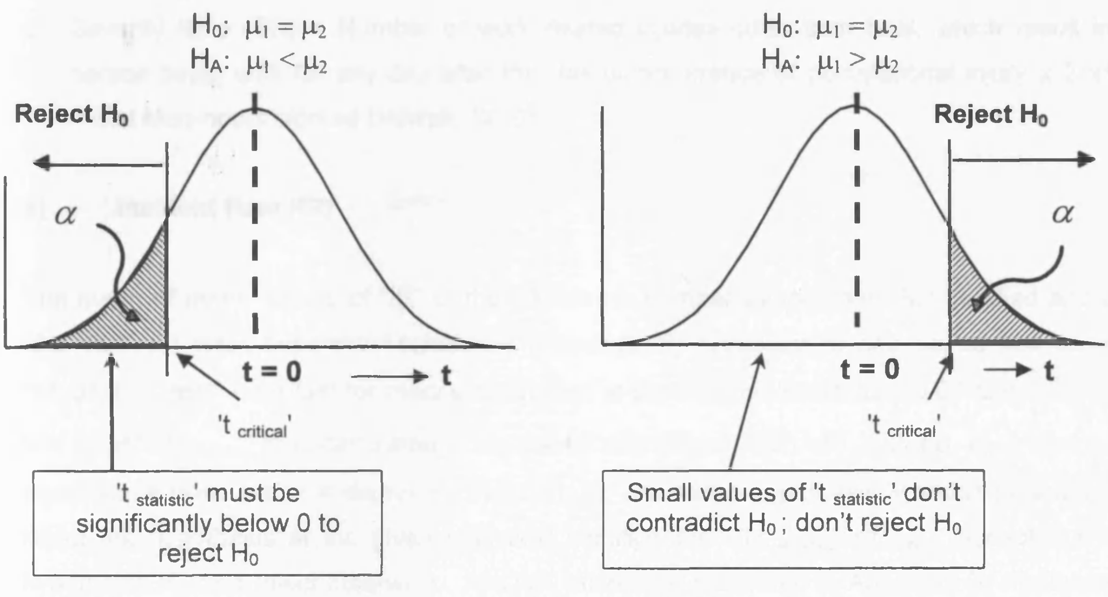


Figure 3.2 Hypothesis Testing (One Tailed)

3.3.3.2 Safety Performance Data Analysis

Safety performance data from a sample of 10 petrochemical companies in selected Arabian Gulf countries, namely Qatar, Kingdom of Saudi Arabia, United Arab Emirates and Bahrain were collected. The reactive safety data before and after ISO certification are tabulated and used for the analysis.

3.3.3.2.1 Reactive Indicators

The following reactive indicators, incident rates (IR values), frequency rates (FR values), and severity rates (SR values) were used for the measurement and analysis. Appendix B, Annexure 3, 4 and 5 present the mean values of IR, FR and SR values collected from the 10 companies before and after ISO certification.

Some companies publish data on IR, FR and SR directly in their annual reports, whereas few companies publish information on number of accidents, accident-free million man-hours worked etc. The calculation of IR, FR and SR in such cases is made by using the following calculations, (BS 8800:1996):

a. Incident Rate (IR) = Number of recordable incidents i.e. (fatalities + lost working days cases + restricted working day cases + medical treatment cases) x 2 x 10^5 /Total Man hours exposure.

b. Frequency Rate (FR) = Number of lost time injuries (fatalities + lost work day cases) 2 x 10^5/ Total man hour exposure.

c. Severity Rate (SR) = Number of work related injuries other than fatal, which result in a person being unfit for any day after the day of occurrence of occupational injury x 2 x10^5 /Total Man-hours worked (Harrell, 1990)

a) Incident Rate (IR)

The mean of mean values of "IR" of the 10 sample companies (ten non-ISO certified and ten ISO certified) were separately calculated (Appendix B, Annexure 3) and paired two sample "Student t – test" (one tail) for means conducted at significance levels, α = 0.05 and 0.01. The test statistic'$t_{statistics}$' thus calculated is compared with critical value of'$t_{critical}$', i.e. $t_{\alpha, v}$, where α= significance level and v = degree of freedom, for one tailed hypothesis in order to accept or reject the hypothesis at the given statistical significance. If'$t_{statistic}$' <'$t_{critical}$' accept the null hypothesis H_O and reject otherwise. ANOVA tables are presented in Appendix B, Annexure 2 where P- values are also used to accept or reject the hypotheses. P-value is defined as the probability of getting the observed data values or worse when the Null Hypothesis is true and worse data sets are therefore datasets which give larger values of the F-statistic than the value observed. In simple words if P-value< α value reject H_O. (Hayter, 1996)

b) Frequency Rate (FR)

The mean of mean values of "FR" of the 10 sample companies (before ISO certification and after ISO certification) were separately calculated (Appendix B, Annexure 4) and paired 2 sample "t test" (one tail) for means conducted at significance levels, α = 0.05 and at 0.01. The test statistic't $_{statistic'}$ thus calculated is compared with critical value of't $_{critical}$' which is same as $t_{\alpha, v}$ where α = significance level and v = degree of freedom, for one tailed hypothesis in order to accept or reject the hypothesis at the given statistical significance. If't $_{statistic'}$ <'t $_{critical'}$ accept the null hypothesis H_O and reject otherwise. ANOVA tables are presented at Appendix B-Annexure 2, where P- values are also used to accept or reject the hypotheses, where the norm is if P-value< α value reject H_O.

c) Severity Rate (SR)

The Mean of mean values of "SR" of the 10 sample companies (before ISO certification and after ISO certification) were separately calculated (Appendix B, Annexure 5) and paired 2 sample "t test" (one tail) for means conducted at significance levels, α = 0.05 and at 0.01. The test statistic,'t $_{statistic'}$ thus calculated is compared with critical value of $t_{\alpha, v}$, where α= significance level and v = degree of freedom, for one tailed hypothesis in order to accept or reject the hypothesis at the given statistical significance. If't $_{statistic'}$ <'t $_{critical'}$ accept the null hypothesis H_O and reject otherwise. ANOVA tables are presented in Appendix B- Annexure 2, where P- values are also used to accept or reject the hypotheses, where the norm is if P-value< α value reject H_O.

Accordingly the first hypothesis mentioned at Table 3.1 can be expanded and the related Null hypotheses can be stated as follows:

1) No significant decrease in the average Incident Rate (IR) values after ISO (μ_{2IR}) from Average IR values before ISO certification (μ_{1IR}), i.e. $\mu_{1IR} = \mu_{2IR}$
2) No significant decrease in the average Frequency Rate (FR) values after ISO from average FR values before ISO certification, i.e. $\mu_{1FR} = \mu_{2FR}$
3) No significant decrease in average Severity Rate (SR) values after ISO from average SR values before ISO certification, i.e. $\mu_{1SR} = \mu_{2SR}$

Corresponding hypotheses tested are tabulated below (Table 3.2):

Table 3.2 – The Hypotheses on Reactive Safety Indicators Tested

Reactive Safety Indicators tested	Null Hypothesis, H_O	Alternate Hypothesis, H_A
Mean Incident Rate (IR) values	$H_O : \mu_{1IR} = \mu_{2IR}$	$H_A : \mu_{1IR} > \mu_{2IR}$
Mean Frequency Rate (FR) values	$H_O : \mu_{1FR} = \mu_{2FR}$	$H_A : \mu_{1FR} > \mu_{2FR}$
Mean Severity Rate (SR) values	$H_O : \mu_{1SR} = \mu_{2SR}$	$H_A : \mu_{1SR} > \mu_{2SR}$
μ_1 = Average value before ISO, μ_2 = Average value after ISO		

Minitab13.2 was used for conducting the statistical analyses. Design Expert 6.0.5 was used for analysing the factor effects and interaction effects on the response variables i.e. IR, FR and SR values. The results are shown in Appendix B, Annexure 6.

The plots of interaction between certification and IR, FR and SR values indicate that remarkable interaction is seen in the case of FR and SR values whereas in the case of IR values it is not so predominant. In Design of Experiments (DOE), the design points are the identifiers of the model structure depending on which factorial points, axial points, centre points, vertices and centroid are defined.

These points are different from the Variance Inflation Factor (VIF) that measures how much the variance of the model is inflated by the lack of orthogonality in the design. If the factor is orthogonal to all other factors in the model, the VIF is one. Values greater than 10 indicate that the factors are too correlated together (they are not independent.) In the reported work, since statistical analysis rather than design of experiments are dealt, these points are insignificant.

3.3.3.2.2 Pro-active Indicators

Proactive indicator data were collected from ten ISO certified companies and 10 non-ISO certified companies. Proactive monitoring involves checking to ensure that the safety management system as defined by the company policy is adequate and is implemented, reviewed and updated. It helps to measure the progress towards objectives, defence against accidents etc. The following proactive safety indicators were used for analysis.

- Number of preventive inspections (Appendix D, Annexure 1)
- Number of trained people in the safety (Appendix D, Annexure 2)
- Applied documented procedures/instructions (Appendix D, Annexure 3)
- Personal protection equipment resources/employee (Appendix D, Annexure 4)

a) Analysis of Preventive Inspections

Job safety inspections can be a valuable resource for making safety management decision. Data collected through the use of check lists (Appendix D, Annexure 1) provide a wealth of information that tend to be more structured and consistent and helps to make comparison between successive inspections. Inspectors are to be trained to make consistent assessment. The number of preventive inspections carried out in the ISO certified companies during 2003 was compared with number of inspections planned. Percentage compliance was calculated. The safety inspections status of non-ISO certified companies were noted for comparative analysis.

b) Number of Trained People in the Safety

In order to ensure the active participation of employees in a safety program, they must receive occupational safety training. A study conducted by OSHA in 1992 following the explosion in Philips 66 plant in Pasadena, revealed that growing lack of safety and health training was one of the main issue leading to accidents in the petrochemical plant (Rao et al, 1997). Safety training provides the means for easier and more accurate prediction of accidents. The basic difference between safe employees and those who frequently get hurt is that safe employees can recognize hazards and hazardous actions and understand the consequences. Organisations should institute a system of continual re-education and re-training of employees in current safety and health issues (Mallak, 1997). Vredenburgh and Cohen (1995) noted that the level of perceived danger increased compliance with warnings and instructions. Hence it is critical that all employees are trained in the safety to identify the hazards associated with their workplace. Data on number of people undergone safety training from a sample of 100 from each ISO certified companies were found, and the percentage of compliance was compared with that of non-ISO certified companies data (Appendix D, Annexure 2).

c) Applied Document Procedures/Instructions.

Accidents 'do not happen', they are caused. As Deming (1986) suggests one effective way to prevent work place accidents is to establish proper procedures. Documentation and record keeping are essential for preventing unnecessary losses. Records can become the basis for process failure investigation and sharing the "lessons learned". They become a tool for the development of more effective procedures. The following five main elements based on OHSAS 18001 were used to assess the level of applied documentation (Table 3.3). Points were assigned based on the relative importance of each element. The objective was to find out to what extent the applied documentation of procedure/instructions related to safety matters, were used in a company, which does not have a certified safety management system in place.

Table 3.3 Applied Documentation Elements

S.No	Applied Documentation Elements	Points
1	Verification and Corrective Action	400
2	Implementation and Operation	300
3	Planning	200
4	Safety and Occupational Health Policies	50
5	Internal Analysis by the Organisation	50
	Total	1000

Companies were ranked in accordance with their compliance with the documentation procedures. Based on the relative importance of each element the maximum points that can be awarded to individual elements are first determined. The total score was fixed at 1000 (an arbitrary value selected for comparison).Safety & occupational health policy is the preliminary requirement of any safety management system and it is given 50 points (5%). Planning for hazard identification, risk assessment and risk control etc is an important element which deserve more ranking and hence given 200 points (20%). Implementation and operation include maintaining structure and responsibility, training, communication, documentation, operation control, emergency preparedness etc. All of these items are very important and 300 points (30%) is given to this element. Verification and corrective action is the most critical element of a safety management system. Performance measurement & monitoring, non conformances, carrying out corrective and preventive actions etc are very vital issues addressed by this element. Hence this element is given maximum of 400 points (40%). Internal review and analysis is normally done to satisfy the management system requirement and some times to satisfy documentation. Hence given a low ranking 50 points (5%).

A detailed check list was prepared and the 10 companies were asked to provide answers "Yes / No" for all the sub-questions on each element (Sample check list Appendix D, Annexure 4). The total score of each element was calculated for each company and percentage compliance noted. The points against each element were calculated by multiplying the maximum points with the percentage compliance. The results are given in Appendix D, Annexure 3.

d) Use of Personnel Protective Equipment (PPE) - Resource per Employee

Employees are exposed to various forms of risk in a petrochemical company in the day to day working environment. PPE is the last resort used to mitigate this risk. Hence it is a mandatory requirement in a petrochemical industry to always use PPE while working. Logically, any company following safety instructions ensures its employees that its employees are given adequate PPEs. Possession and use of PPE by an employee thus becomes a proactive indicator in the prevention of accidents and safety performance. The standard PPE's used normally are 1) Helmet, 2) Hand gloves, 3) Goggles, 4) Ear Plug 5) Safety Shoe 6) Overall and

7) Gas mask and breathing apparatus. During the questionnaire Survey the employees were asked to write if they used the following personnel protection items in position or whether they were accessible to them in case of emergencies. Points were assigned based on the relative importance of each PPE used by the employee and easiness of availability etc as indicated in Table 3.4.

Table 3.4 Personal Protective Equipments Used by Employees

Sl No	PPE item	Points
1	Helmet	25
2	Hand gloves	10
3	Goggles	10
4	Ear plug	10
5	Safety shoe	15
6	Overall	5
7	Gas mask/Breathing apparatus	25
	Total	**100**

The survey was conducted among 100 employees belonging to 4 companies from ISO certified petrochemical companies and 100 employees of non-ISO certified companies. The maximum point was set at 100 (an arbitrary value selected for comparison). In the case of any industry Helmet is of prime importance and given maximum points 25. In the case of petrochemical environment Gas mask / Breathing apparatus is a vital item due to the exposure to toxic gases and it is also given same ranking. The next priority item is Safety shoe and it is given next ranking of 15 points. Hand gloves, Goggles and Ear plug also are important PPE which can lead to serious injuries and permanent defects and all of them given 10 points each. In a petrochemical company, an Overall is a commonly used item. This is evident from the survey conducted as a part of this study. Therefore it is given minimum 5 points.

The points scored were tabulated and the mode value found out for each item company wise. The mode values (number of positive responses) were noted and the percentage compliance was calculated and presented in a table for comparative analysis. The results of these computations are presented in Appendix D, Annexure 4. Conventionally 'mode' is the statistic that gives value with the highest frequency in a given dataset whereas here it is used as the number of positive points i.e. the frequency of the mode value. The 'mode' value is written as 'point' in the table presenting the dataset.

3.4 Questionnaire Survey

Questionnaires are very useful and effective methods of data collection. Data about attitudes, beliefs, behaviour, characteristics, appearance etc can easily be gathered. Questionnaires must have a logical presentation and consistent style. The main problems encountered in questionnaire design are respondent associated errors. They include biases, misinterpreting the questions, stimulus–response pattern, reluctance to provide right answers, respondent's inability to answer the questions. They also include instrument-associated errors such as excessive length - monotony, ambiguous instructions and poor choice of words, spaces inadequate for answers, erratic sequencing, and requirement for mental gymnastics. Most of these can be solved if the following points like brevity, clarity, reality, uni-dimensionality, completeness, even-handedness and dignity etc are taken care off. (Schuman, and Kalton, 1985). A design approach was used chiefly to eliminate all biases mentioned above and to make the responses as realistic as possible. An examination of the questionnaires attached in Appendix C reveals this fact.

A questionnaire survey was conducted in conjunction with personal interviews. Questionnaires were tested on a pilot group and necessary corrections made. The questionnaires were sent through the post. Regular follow up was done through visits, emails and telephone calls. Personal interviews were carried out with Safety Managers in a few petrochemical companies in the GCC countries.

A sample of 10 ISO certified petrochemical companies operating within the selected countries in the Arabian Gulf was chosen on judgmental basis. The criteria used for this selection included the years of ISO experience, size of the companies in terms of number of employees, volume of business, and contact of the author with managers at the top echelon. Out of the 10 companies chosen, only one had 12 years of ISO experience, one with 9 years, five with 4 years and the remaining three with 3 years of ISO experience. The transcription of questionnaire survey did not include the name of the company or the name of the individual.

Similarly, 10 Non-ISO certified companies were also selected for the survey. The number of non-ISO certified companies in the GCC is limited. Therefore petroleum refineries and chemical companies meeting other criteria were included in the questionnaire survey. Thus 3 Non-ISO companies from Qatar, 3 from Saudi Arabia, 2 from UAE, 1 from Kuwait and 1 from Bahrain were selected. To keep confidentiality the companies are indicated with code numbers, ISO-C1, ISO-C2 etc for ISO certified companies and C1, C2 C3 etc for non-ISO certified companies.

The aim of questionnaire survey was to bring out evidence of issues of relevance to safety performance and safety culture. Three separate set of questionnaires were designed for collecting 'safety awareness' data from Employees working in the sample petrochemical companies within GCC countries. Separate surveys were conducted among the three sample groups from petrochemical companies identified for research.

i) Front runner employees who perform tasks at site (Appendix C, Annexure 1)
ii) Safety and Quality professionals within the company (Appendix C, Annexure 2) and
iii) Managers/Supervisory Group (Appendix C, Annexure 3)

A total of 250 front runner employees, 25 safety and quality professionals and 25 managers were the respondents from ISO certified companies. The same number of people was surveyed from the Non-ISO certified companies also.

In addition to the above mentioned three questionnaire set, a fourth questionnaire set was used for collecting data on 'risk perception' among Managers. Data from the selected 10 companies were used to get relevant data on risk perception. Typical issues were belief in the effectiveness of risk control measures, lack of fairness in selecting risk control measures, and belief that risk control measures are for management benefit and not for the benefit of those exposed to the risk. The behaviour of individuals with respect to risk management activities can give an indication of their commitment to risk management. Observation of whether communications on risk-related topics are done formally or informally and whether it is effective and whether, trust exist between employees and supervisors (Jordan, 1995). The questionnaire survey among managers focused to find out the level of administrative importance practiced by the company in the management of safety and risk; as well as, to what degree the company considers that subject its competitive advantage.25 Managers each from ISO certified and Non-ISO certified companies were the respondents.

3.4.1 Safety Questionnaire Survey - Employees

The main objective of the questionnaire survey was to measure the safety awareness level among the employees. A stratified random sample of 25 employees belonging to different departments of each of the 10 sample ISO certified petrochemical companies and 10 Non-ISO certified companies were selected for the study. Questionnaires were prepared in accordance with the requirements of OHSAS 18001. The response rate was more than 80 percent which is a good achievement indeed. The questionnaire was pre-tested among a small sample group to verify the appropriateness and clarity of the questions. A few changes were incorporated based on the feedback. Employees were asked to give their perceptions regarding various safety measures. The questionnaire used the Likert linear composite scale for recording relative preferences of respondents. Responses to each question were given ratings from 1 to 5.

The highest rating 5 was given for full agreement with a statement and a rating of 1 was given for disagreement with a statement. If a safety measure consists of 4 questions, the summed score for the measure could range from 4 to maximum of 20. A higher score would generally mean that there is higher level of safety awareness. Measurement was based on Likert scale of 1 to 5 rating with 1 indicating not showing any interest towards safety issues and 5 showing very good attitude towards safety issues (Figure 3.3).

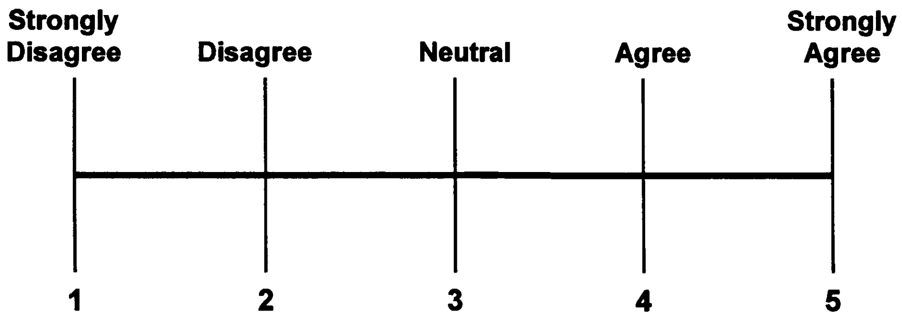


Figure 3.3 Likert Scale Used in the Questionnaire Survey

The intention was to measure how well the employees answer a test of multiple choice questions based on safety practices and methods. They were asked to indicate the number of years they had worked in the present task or tasks of similar nature. To measure the risk-taking tendency of employees they were asked to indicate their tendency to take risks in order to do their work or increase their output to please the superiors and their willingness to take risks to appear confident in the eyes of fellow employees etc. The employee's attitude towards other issues like using personnel protective equipment was also noted through the questionnaire. The degree of care and attention employees take to ensure their personal safety as well as the safety of their co-workers was also checked. The related issues addressed were, for example, what the employees thought of the benefits of safe practices, whether they thought accidents were predestined and so on. Similarly employees' perceptions of the frequency and thoroughness of safety inspections etc. were also addressed. Appendix C, Annexure 1, presents the questionnaire details and the results.

There were 31 questions in all. Mean value of scores was calculated on each individual employee level and then company level. Finally "mean" value of safety awareness level for all the ISO certified companies and non-ISO Certified companies identified for the research was calculated. Paired "t" test was conducted to compare the means of these two populations. Mean values of "Safety Awareness Level for employees" from the ISO certified companies, and non-certified companies were calculated so as to prove that "Safety Awareness Level for employees" from the ISO certified companies were better than that of non- ISO certified companies. The hypothesis statements were given in Table 3.1.

3.4.2 Safety Questionnaire Survey – Safety and Quality Professionals

Safety and Quality professional normally undergo many training programs related to management systems. There were 33 questions in total out of which only 29 questions were analysed using Likert scale. The other 4 questions were of general nature. The survey was carried out among 10 ISO certified and 10 non-ISO certified companies.

3.4.3 Safety Questionnaire Survey – Managers

Managers must lead, establish policy, take responsibility and remove barriers that impede safe and efficient execution of the work process (Robinson, 2001). Managers' attitude towards safety and their active and consistent involvement with safety are important for getting a high score on this questionnaire. The values, principles and priorities of the person who is controlling the various sectional activities were highlighted here. There were 30 questions of which 27 are used for the analysis.

3.4.4 Risk Perception Questionnaire Survey – Managers

Many surveys had been carried out over twenty years to determine the factors that affect the perception of risk, and a number of models had proposed (Savic, 2001). Research on perception of occupational risk is important because perceptions are a logical and empirical precursor to actions that could reduce danger. Culture must support systems and systems must support culture, a cycle of awareness and motivation, and systems which support positive motivation can reinforce the desired behaviour and the necessary culture change. In one of the investigations of safety climate, Zohar (1980) found that management commitment to safety is a major factor affecting the success of an organisation's safety programs. Various regulations like Regulation 3 of the Management of Health and Safety at Work Regulations 1999 require that every employer shall make a suitable and sufficient assessment of the risks to the health and safety of his employees to which they are exposed whilst they are at work. It is important to measure the degree to which hazards in production operations are anticipated by the management and steps taken by them to mitigate risk. It is also important to measure managers' interest towards safety conditions within the plant and the importance they give to safety, the level of priority given to execution of jobs ahead of safety rules etc. There were total 27 questions of which 23 were considered for analysis and 4 of them were of general type. The questions were addressed to find out the perception of managers on issues such as appreciation of group effort in work performance and handling of safety hazards etc. Paired't' test was conducted on two samples of 10 companies each from ISO certified and non-ISO certified companies to test if there is significant improvement in the risk perception level in companies that are ISO certified in comparison with those not certified. Details are furnished at Appendix C, Annexure 4. The hypothesis statements were given in Table 3.1

3.5 Measuring Workplace Precautions – A Case Study

To manage workplace risk effectively employers need to concentrate on three areas i) defining potential risks and control on facilities and equipments ii) educating supervisors and employees on how to recognize risks and control them and iii) evaluating hazardous material/waste storage, transportation process and disposal risks. To control risk, several work place precautions need to be carried out. Risk assessment process is the core, as it will define the precautions needed to control particular risks which must be included in the risk control system. Work place precautions consist of four "P" issues - Premises, Plant and materials, Procedures and People (Kochan et al, 1992). Monitoring compliance with defined workplace precautions is the major element in measurement activity. As part of the research a detail study was conducted in a sample petrochemical company to analyse how ISO 9000 certified petrochemical company carries out these precautions and what effect ISO 9000 certification had on the risk control measures.

3.5.1 Risk Description of a Sample Petrochemical Company

To conduct a detailed analysis on risk management in an ISO 9000 certified petrochemical company, a typical company from among the 10 sample petrochemical companies identified for the research was selected. The analysis included investigation into the company's methods of assessment and identification of risks, the specific steps taken to achieve stated objectives and targets for safety performance. The study also sought if achievable goals and objectives were established to reduce identified risks and the action plans to achieve goals/objectives. The selected company commenced commercial production in 1981 and does not have a formal certified safety management system like OHSAS 18001. Its main products are Low Density Poly Ethylene (LDPE), Ethylene and Sulphur. The company got ISO 9002:1994 certification in the year 1998 and was re-certified it's Quality Management System in accordance with ISO 9001:2000 in 2002. The Quality Management System was documented in accordance with the requirements of ISO 9001:2000 and specific company needs. The general information about the company is given in Table 3.5.

Table 3.5 – General information of the Sample Petrochemical Plant

Manufacturing activity	Petrochemical industry making Ethylene, Polyethylene and Sulphur
No of employees	879 as on September 2004 (Note: Man power raise to 4000 during major shutdown period)
Production capacity (MT) per annum	LDPE 360,000, Ethylene- 525,000, Sulphur- 70,000
Quality Management system	ISO9001-2000, Certified in 1998
Feed stock	Natural Gas
Technology	Ethylene-Steam cracking LDPE –Vessel reactor and Tubular reactor
Environmental system	ISO 14001 Certified in 2002

In addition to the job safety risk, the assets of the petrochemical firm are at risk due to fire and explosion. Process risk due to Vapour Cloud Explosion (VCE) and Boiling Liquid Expanding Vapour Explosion (BLEVE) and fire and explosion risk due to storage of large quantities of chemicals and raw materials and catalysts also exist. The safety risk in a petrochemical plant has many dimensions. Personnel working in a petrochemical plant are exposed to various magnitudes of risk depending upon their nature of job. Company assets and bulk storage materials are also at risk. The nature of various processes can add another dimension to the risk.

3.6 Limitations

Risk assessment is an extensive exercise to be carried out on a case to case basis based on a selected frame work. The case study carried out for this research served two purposes. In the first place, it helped in finding out the typical issues of risk mitigation which are linked to ISO 9001 QMS, ISO clauses and the derived benefits of ISO certification. The second objective was to validate the statistical models developed for hypothesis testing. There are certain limitations in this exercise, chiefly due to the fact that no organization would like to expose its drawbacks. In this age of information explosion, such blocking of information might ricochet on the organization. The recent trend is to disclose the safety data through annual reports for the knowledge of stake holders. However the region where the research is carried out is yet to catch up with this trend. The safety data used for the analysis were the data sourced through personal contacts of the author with personnel from various petrochemical companies.

3.7 Summary

The focus of the foregoing discussion was the methodology adopted for the research. The data types, collection of data through documents inspection, interviews, questionnaire design and surveys, the data representation and analyses were discussed. The sample proposed consists of 10 petrochemical companies in the selected few countries of the Gulf region. The homogeneity of data points was ensured by the simple fact that reactive safety performance data was collected from the same category of companies before and after ISO certification. The respondents targeted in the surveys consisted of a large number of personnel in these companies including managers, supervisors, safety and quality personnel, and front line employees. The overall safety performance was assessed in terms of the quantitative variables such as incident rates, frequency rates, and severity rates and immeasurable attributes such as safety awareness, risk perception and compliance with safety standards. Well defined proactive and reactive indicators were used in quantitative assessments. The qualitative data obtained through questionnaire surveys were quantified using Likert's linear composite scale. Description of the statistical analyses conducted to test the hypotheses on the mean safety performance levels before and after ISO certification was presented. Work place precaution and risk mitigation are studied by conducting a case study on a typical ISO 9001 certified petrochemical company. A summary table of techniques and analysis performed are given at Appendix A ,Table-5. The results of the statistical analyses and the findings from the case study are reported in detail in Chapter- 4 of this report.

Chapter Four: Research Findings and Implications

4.1 Introduction

The objective of this research was to assess and evaluate the effect of ISO 9001 certification on the safety performance level of petrochemical companies. The very foundation of the research study is built on the premises of the following questions.

a) How does ISO 9001 certification affect the safety performance level of a petrochemical company?
b) What is the effect of ISO 9001 certification on the safety behaviour and safety culture of petrochemical or similar process industries?
c) What is the effect of ISO 9001 certification on the "risk perception level" of managers working in petrochemical plants
d) What influence ISO 9001 certification has on the "risk elimination / mitigation" process employed by the petrochemical industries?
e) Does a determined effort for a "quality culture" positively influence development of the "safety culture" within a petrochemical company?
f) Is it possible to measure, assess or evaluate the 'quality culture' and its impact on the safety performance of a petrochemical company?

This chapter presents results of the research and the discussion of the cardinal questions under investigation. It concludes with a discussion on the findings of the study "Effect of ISO 9001 Certification on the Safety Performance Level of Petrochemical industries in Arabian Gulf countries". The results are compared on the basis of the findings and observations of literature survey.

4.2 Safety Data Analysis

In Statistical analysis, the use of techniques and interpretation of results demand great intellectual exercise from the researcher. Selection of the appropriate technique is extremely important. A detailed discussion on this aspect was presented in Section 3.3.3. Safety data on Reactive and Proactive indicators were used for the analyses. The statistical analyses on Reactive safety data before and after ISO certification are presented in Appendix B and the details analysis of Proactive safety data is furnished in Appendix D. Two values of significance level α = 0.05 and 0.01 were used for statistical analysis. The ANOVA tables for each hypothesis test are presented too.

4.2.1 Reactive Data Analysis

Reactive Safety Performance Indicators' Monitoring Data on Incident Rate (IR), Frequency Rate (FR) and Severity Rate (SR) of 10 sample petrochemical companies, in selected Arabian Gulf countries were collected. Annexure 1 page 1 of Appendix B present the mean values of IR, FR and SR values collected from the 10 companies before and after ISO certification. Mean and variance of the two independent group data, (i.e. safety data before ISO certification and safety data after ISO certification) were calculated. Two sample paired t-tests were conducted at 95% and 99% confidence levels (i.e. α = 0.05 and 0.01 respectively) for the three respective indicators IR, FR and SR.

As pointed out earlier normality of data is to be tested before applying paired sample t-tests. Minitab13.2 provides two goodness-of-fit statistics - Anderson-Darling (AD value) for the maximum likelihood and least squares estimation methods and Pearson correlation coefficient for the least squares estimation method – for comparing the fit of two distributions. The Anderson-Darling statistic is a measure of how far the plot points fall from the fitted line in a probability plot. The statistic is a weighted squared distance from the plot points to the fitted line with larger weights in the tails of the distribution. Minitab13.2 uses an adjusted Anderson-Darling statistic, because the statistic changes when a different plot point method is used. It is used to compare the fit of competing models. The test is a one- sided test and the hypothesis that the distribution is of a specific form is rejected if the test statistic, is greater than the critical value. The critical values for the Anderson-Darling test are dependent on the specific distribution being tested and need to be calculated for each distribution. A smaller Anderson-Darling statistic in comparison to the critical value indicates that the distribution fits the data better. If the data points (in the Minitab AD graph) show a linear trend, it support Normality assumption (Romeu).

For least squares estimation, Minitab calculates a Pearson correlation coefficient. If the distribution fits the data well, then the plot points on a probability plot will fall on a straight line. The correlation measures the strength of the linear relationship between the X and Y variables on a probability plot. The correlation will range between 0 and 1, and higher values indicate a better fitting distribution (Minitab Reference Manual, 2000)

Both Anderson-Darling statistic and Pearson correlation coefficient are used here to compare the fit of distributions for reactive data sets before and after ISO certification.

Table 4.1 below shows the AD* values based on maximum likely hood estimation and Pearson correlation coefficient based on least square estimation. It can be seen that normality of FR data after ISO certification is a little bit out of the ranges. These ranges are determined based on the 95% Confidence Interval represented by the bandwidth.

The normality plots for IR, FR and SR data before and after ISO certification are shown in Appendix B, Annexure 1. The AD values are obtained as 1.66 and 1.792 for IR data, 1.248 and 2.832 for FR data and 1.276 and 2.004 for SR data. It is seen that all these values of IR, FR and SR satisfy the conditions. This can be seen from the normal plots too. Except in the case of FR values after ISO certification all other plots are found to be perfectly within ranges. However this is not very significant diversion that demands a nonparametric test used for non-Normal data sets. Hence two sample paired t-tests as shown are carried out.

Table 4.1: Normality Tests of IR, FR and SR Values Before and After ISO Certification

	IR before	IR after	FR before	FR after	SR before	SR after
Company1	4.28	0.94	1.5	0.28	14.88	3.06
Company2	9.6	7.1	2.37	0.34	1.202	0.97
Company3	26	15.75	1.99	0.17	18.93	10.63
Company4	2.3	1.29	0.45	0.23	9.13	3.59
Company5	11.93	8	2.16	1.63	1.95	0.58
Company6	12.48	9.44	3.34	1.64	6.33	2.95
Company7	3.78	0.83	0.49	0.25	9.69	4.14
Company8	3.47	0.82	1.18	0.26	7.12	2.78
Company9	6.25	1.56	1.98	0.42	6.42	2.86
Company10	7.92	2.36	1.14	0.25	10.78	1.29
AD* (Max. Likelihood)	**1.66**	**1.792**	**1.248**	**2.832**	**1.276**	**2.004**
Pearson (Least Square)	**0.897**	**0.898**	**0.979**	**0.782**	**0.977**	**0.85**

4.2.1.1 Incident Rate (IR)

The hypothesis statements for Mean Incident Rates are:

$$H_O: \mu_{1IR} = \mu_{2IR} \qquad H_A: \mu_{1IR} > \mu_{2IR}$$

Where,

H_O: Mean Incident Rate before ISO certification = Mean Incident Rate after ISO certification

H_A: Mean **Incident** Rate before ISO certification > Mean **Incident** Rate after ISO certification

Paired two sample "t" test (one tailed) for means conducted at 95% significance level gave the result of '$t_{statistic}$' as 4.9965 and '$t_{critical}$' as 1.8331, which indicate that the Null Hypothesis H_O is to be rejected. P-Value 0.000371<Significance Level α = 0.05 also indicates that the Null Hypothesis is to be rejected. Therefore the alternate hypothesis that H_A: Mean Incident rate before ISO certification > Mean Incident rate after ISO certification is to be accepted. So, there is a significant improvement (reduction of incident rate) of the safety indicator "IR" in ISO certified companies.

Similarly the value of't $_{statistic}$ ' at 99% confidence level was 4.996 and't $_{critical'}$ for one tail was 2.821. The result showed significant improvement of the safety indicator IR for ISO certified companies at 99% confidence level. P-Value is again < 0.01 which indicate that the alternate hypothesis H_A: Mean Incident rate before ISO certification > Mean Incident rate after ISO certification is to be accepted and Null Hypothesis rejected.

As the difference in the Mean of "IR" values of the sample companies before ISO certification and after ISO certification is greater at confidence level of 99%, we can conclude that the difference is statistically significant, which indicate a significant improvement of "IR" values in ISO certified companies in comparison to non-ISO certified companies. The Pearson Correlation Coefficient R = 0.96322 indicates the strong correlation between the two data sets. The analysis of data and results are furnished in Appendix B, Annexure 3.

4.2.1.2 Frequency Rate (FR)

The hypothesis statements for Mean Frequency Rates are:

$$H_O: \mu_{1FR} = \mu_{2FR}$$

$$H_A: \mu_{1FR} > \mu_{2FR}$$

Where,

H_O: Mean Frequency Rate before ISO certification = Mean Frequency Rate after ISO certification

H_A: Mean Frequency Rate before ISO certification > Mean Frequency Rate after ISO certification

Just as in the previous case paired sample't' test (one tailed) for means was conducted for Frequency Rate at α = 0.05 significance level. The values of't $_{statistic'}$ was obtained as 5.3583 and't $_{critical'}$ as 1.8331. The value of't $_{statistic'}$ at α = 0.01 significance level was 5.3583 and't $_{critical'}$ for one tail as 2.8214. The difference in the mean of mean values of FR of the sample companies is greater at confidence level of 95% as well as 99 %. So we can conclude that the difference is statistically significant, which shows a significant reduction in FR values of ISO certified companies compared to non-ISO certified companies. The Pearson Correlation Coefficient R = 0.67641 indicates the strong correlation between the two data sets. Results are given in Appendix B, Annexure 4

4.2.1.3 Severity Rate (SR)

The hypothesis statements for Mean Severity Rates are:

$$H_O: \mu_{1SR} = \mu_{2SR}$$

$$H_A: \mu_{1SR} > \mu_{2SR}$$

Where,

H_O: Mean Severity Rate before ISO certification = Mean Severity Rate after ISO certification

H_A: Mean Severity Rate before ISO certification > Mean Severity Rate after ISO certification

Paired t test (one tailed) for means conducted for Severity Rate at 95% confidence level gave values of '$t_{statistic}$' as 4.6811 and '$t_{critical}$' as 1.8331. The values of'$t_{statistic}$' at 99% significance level is also 4.6811,'$t_{critical}$' for one tail being 2.8214. This again shows the significant reduction of 'SR' values in ISO certified companies with respect to non-ISO certified companies. The Pearson Correlation Coefficient R = 0.78957 indicates the strong correlation between the two data sets (Appendix B, Annexure 5).

Considering all the above three results the Null Hypotheses are rejected and it is concluded that there is a significant improvement in the overall safety performance based on the reactive safety monitoring data analysis.

4.2.1.4 Interaction of Companies and ISO Certification

The Analysis of Variance (Appendix B, Annexure 1,2, and 3) performed in conjunction with the Two-Sample t-test does not reveal fully if there is any error due to the effect of interaction between companies and certification. Interaction of treatments (Companies, 10 levels representing the 10 companies) and blocks (Certification, 2 levels namely ISO certified and non-ISO certified) occurs when the response is measured on a wrong scale (Hines and Montgomery, 2003). If a very high degree of interaction takes place, it can seriously affect and possibly invalidate the analysis of variance. Interaction inflates the error terms and affects the comparison of means.

Design Expert 6.0.5 was used to analyse the interaction effects. The effect of ISO certification on IR, FR and SR values are clearly indicated in the plots given in Appendix B, Annexure 6. As an example only Company 1 is given in the figure. Design Expert draws such graphs for all the 10 companies. In all the single factor plots, it is seen that IR, FR and SR values decrease after ISO certification. The single factor plots between IR, FR and SR values and Companies show that the values fluctuate randomly as expected. The interaction plots of company verses ISO certification, no remarkable interaction is observed in the case of IR values. But in the case of FR and SR values some interaction between Companies and ISO certification is observed. This is due to the fluctuations, sometimes increasing values of IR. FR and SR. FR and SR results for the Case Study also show such an indication, as discussed in section 4.4 below. This is against expectations and the assignable cause is enhanced documentation whereby more efficient reporting brings out more accurate data. Since the number of data points before and after ISO certification were different, Minitab was used to conduct the Un-stacked One Way Analysis of Variance on the IR, FR and SR values before and after ISO certification. The results are shown in Appendix D, Annexure 5, pages 1 to 3. The analysis also yielded box plots for the two sets of data points.

The plots of interaction between certification and IR, FR and SR values indicate that remarkable interaction is seen in the case of FR and SR values whereas in the case of IR values it is not so predominant. In Design of Experiments (DOE), the "design points" are the identifiers of the model structure depending on which factorial points, axial points, centre points, vertices, centroid are defined.

These points are different from the Variance Inflation Factor (VIF) that measures how much the variance of the model is inflated by the lack of orthogonality in the design. If the factor is orthogonal to all other factors in the model, the VIF is one. Values greater than 10 indicate that the factors are too correlated together (they are not independent.)

In the reported work, since statistical analysis rather than design of experiments are dealt, these points are irrelevant.

4.2.2 Proactive Data Analysis

The following proactive safety indicators were used for analysis. This safety performance assessment was done as a supportive analysis for reactive safety data analysis. Statistical significance tests were not carried out on the data. Qualitative analyses of the data are more appropriate here since the difference in the safety performance level is more manifested here and can be seen in the following data:

- Number of preventive inspections,
- Number of trained people in the safety.
- Applied documented procedures/instructions.
- Personal protection equipment resources/employee

4.2.2.1 Analysis of Preventive inspections

Job safety inspections or Safety audits are valuable resource for making safety management decision. Data collected through the use of check lists provide a wealth of information that tends to be more structured and consistent and help to make comparison between successive inspections. Inspectors are to be trained to make consistent assessment. Percentage compliance of preventive inspections carried out in the 10 sample ISO certified companies during 2003 is found significantly higher than that of the 10 non-ISO certified companies. Percentage compliance is calculated by dividing the number of inspections carried out/conducted by the companies surveyed with the number of inspections scheduled. Non-ISO companies did not have a schedule for carrying out the preventive inspections. Also it is noted that in 4 out of the 10 non-ISO companies surveyed, there was no safety audit system at all. Results are summarised in Table 4.2. Details of the survey are furnished in Appendix D, Annexure 1.

Table 4.2: Preventive Inspections in ISO Certified and Non-ISO Companies

Sample companies	ISO Certified: % Compliance	Non-ISO: No. of Preventive inspections/Safety audits
Company1	91.30	None
Company2	100.00	2
Company3	83.33	3
Company4	100.00	None
Company5	100.00	None
Company6	100.00	2
Company7	100.00	4
Company8	91.67	2
Company9	100.00	1
Company10	100.00	None

4.2.2.2 Number of Trained People in the Safety

The number of people who had undergone safety training in ISO certified and non-ISO certified companies were noted. A random sample of 100 personnel working in the surveyed petrochemical companies within the selected Arabian GCC countries were asked about the safety training they had received during the year 2003. It was found out that percentage compliance is higher for ISO 9001 certified companies in comparison to non-ISO certified companies. Results are given at Table 4.3. Details of the survey furnished in Appendix D, Annexure 2.

Table 4.3: Percentage Compliance of Safety Training in ISO Certified and Non-ISO Companies.

Sample Companies	ISO Certified - % Compliance of Safety Training	Non-ISO – % Compliance of Safety Training
Company 1	80%	40%
Company 2	66%	4%
Company 3	72%	6%
Company 4	48%	40%
Company 5	81%	6%
Company 6	79%	25%
Company 7	52%	22%
Company 8	51%	4%
Company 9	68%	12%
Company 10	72%	24%

4.2.2.3 Applied Documented Procedures and Instructions

Applied documentation of procedures and instructions existing in 10 ISO certified companies and 10 non-ISO certified companies were checked based on the point system explained at 3.3.3.2.2 & Table 3.3. The scores obtained out of a reference maximum score of 1000 points are presented in Table 4.4. The details are shown in Appendix D, Annexure 3. The values indicate that 9 out of 10 ISO certified companies surveyed showed above 50% compliance, whereas in the case of non-ISO certified companies 8 out of 10 were below 30% compliance. The documentation referred to are related to safety matters only. 3 ISO certified companies showed 70% and above compliance.

The conclusion is that all the companies whether ISO certified or not are following some forms of documentation for safety related procedures and instructions. ISO certified companies have got a better system of documentation to meet all safety elements.

Table 4.4 Scores Out of 1000, Obtained by ISO Certified and Non-ISO Companies for Applying Documented Procedures and Instructions

Sample Companies	ISO Certified: Documented Procedure Applied	ISO certified -%Score	Non-ISO: Documented Procedure Applied	Non-ISO - %Score
Company1	653.5	65.35	500	50
Company2	512.5	51.25	366	36.6
Company3	917.5	91.75	285.5	28.55
Company4	512.5	51.25	246.5	24.65
Company5	546.5	54.65	293	29.3
Company6	466	46.6	153.5	15.35
Company7	630	63	153.5	15.35
Company8	598	59.8	205	20.5
Company9	883.5	88.35	202	20.2
Company10	773	77.3	85.5	8.55

4.2.2.4 Personnel Protection Equipment (PPE) Resources per Employee

Survey was conducted among 100 employees belonging to ISO certified and non-ISO certified companies. Different types of Personnel Protection Equipments (PPEs) used by an employee was accounted to get a realistic assessment. The measurement and analysis of this pro-active indicator was done for supportive analysis only.

The survey revealed that, the mode value (number of positive responses) of usage of PPE, Helmet, and Safety Shoes was 25, for the 10 ISO certified as well as the 10 non-ISO certified companies. This could be due to the fact that these are the very basic PPEs commonly used.

However for all other items like hand gloves, goggles, ear plug, gas mask etc the mode values (number of positive responses) were predominantly high for ISO certified companies. The percentage score for the use of individual as well as complete set of "7" identified PPE is given at Table 4.5. The scores indicate that the overall percentage score for the complete set of PPE is distinctly higher for the employees working in ISO certified companies. The details are furnished at Appendix D, Annexure 4. The inference is that more items of PPE are used by employees working in ISO certified companies.

Table 4.5 Usage of Personal Protection Equipments Among Employees in ISO Certified and Non-ISO Companies

Proactive Indicator No.4 - Usage of PPE among employees (ISO Certified companies)					
S/No	Use of PPE tem	% Score for Company 1	% Score for Company 2	% Score for Company 3	% Score for Company 4
1	Helmet	100	100	100	100
2	Hand gloves	64	76	80	88
3	Goggles	44	72	80	56
4	Ear plug	72	68	68	68
5	Safety shoe	100	100	100	100
6	Overall	100	100	100	100
7	Gas Mask/	100	92	96	84
	Overall % score	88	89.6	91.8	87.2

Proactive Indicator No.4 - Usage of PPE Among Employees (Non-ISO)					
S/No	Use of PPE tem	% Score for Company 1	% Score for Company 2	% Score for Company 3	% Score for Company 4
1	Helmet	100	100	100	100
2	Hand gloves	64	76	80	72
3	Goggles	4	72	80	76
4	Ear plug	68	28	68	68
5	Safety shoes	100	100	100	100
6	Overall	100	100	100	100
7	Gas Mask/	0	0	0	0
	Overall % score	58.4	62.6	67.8	66.6

4.3 Questionnaire Survey

A questionnaire survey is a powerful tool for collecting data in similar conditions. In this study like operating in the GCC countries and oil or gas based, The following sections discuss results obtained on analysis of data obtained through a questionnaire survey on safety awareness level. The survey was conducted among the personnel working 10 ISO certified and 10 non-ISO certified companies with the objective of collecting safety awareness data among employees, safety and quality personnel, and mangers. Also the risk perception level among managers of ISO certified and non-ISO companies were checked through the survey. To keep confidentiality the companies are indicated with code numbers, ISO-C1, ISO-C2 etc for ISO certified companies and C1, C2, C3 etc for non-ISO certified companies.

4.3.1 "Safety Awareness" Survey - Employee

The total score of "Employees" participated in the questionnaire survey was calculated based on the Likert scale of measurement. For each company, the average score for the sample population of employees participated in the survey was found out. The average scores of employees working in ISO certified companies were then compared with average scores of employees working in the non-ISO certified companies. A two sample "t test" for unequal variance at 95% confidence level gave "$t_{statistic}$" as 26.4022 and "$t_{critical}$" as 1.7340. The results of the two sample "t test" for unequal variance at 99% confidence level were 26.4022 "$t_{statistic}$" and 2.5523 "$t_{critical}$". The results of both the tests indicate that there is a significant improvement in the "safety awareness" level among employees of the ISO certified petrochemical companies in comparison to non-ISO certified. Details are furnished at Appendix C, Annexure 1.

4.3.2 'Safety Awareness' Survey - Safety and Quality Professionals.

The total score of the safety and quality professionals participated in the survey were calculated by applying the Likert scale technique. The scores of the professionals from ISO certified companies were compared with scores of professionals from non-ISO certified companies. A 't-test' for 'unequal' variances at 95 % confidence level gave results '$t_{statistic}$' as 1.7724, '$t_{critical}$' as 1.6772 which shows that there is difference in safety awareness between safety and quality professionals working in the ISO certified petrochemical companies and non-ISO certified companies. The results indicate that at 95% confidence level, the professionals from ISO certified companies show a better awareness level. However a one tailed t-test conducted at 99% confidence level for unequal variances gave the results for '$t_{statistic}$' as 1.7724 and '$t_{critical}$' as 2.4208. The result indicate that at 99% confidence level there is no significant difference between Safety and Quality professionals working in the ISO certified and non-ISO certified companies. Details are furnished at Appendix C, Annexure 2.

4.3.3 "Safety Awareness" Survey - Managers

Questionnaire survey conducted among Managers consisted of 30 questions out of which 3 were general questions. The total score of each managers participated in the survey was calculated on the basis of the Likert scale. The average scores of managers working in ISO certified companies were then compared with average scores of managers working in the non-ISO certified companies.

A two sample 't-test' conducted at 95% confidence level for unequal variances showed '$t_{statistic}$' as 4.5676 and '$t_{critical}$' as 1.6819, showing that there is significant difference in the safety awareness level of managers working in the ISO certified companies compared to non-ISO certified companies.

The two sample 't-test' for equal variances at 99 % confidence level showed the '$t_{statistic}$' as 4.5676, and '$t_{critical}$' as 2.4065, which again show that there is significant difference in the safety awareness level between managers working in the ISO certified companies and non-ISO certified companies.

Thus, it can be inferred that the managers working in the ISO certified petrochemical companies are showing better awareness level towards safety related issues.

4.3.4 Risk Perception - Awareness Level of Managers

The questionnaire survey on risk perception conducted among managers consisted of 27 questions, out of which 4 were general questions. The total score of each manager participated in the survey was calculated on the basis of the Likert scale. The average scores of managers working in ISO certified companies were compared with average scores of mangers working in non-ISO certified companies. The two sample t-test conducted at 95 % confidence level for equal variances showed '$t_{statistic}$' as 7.1105 and '$t_{critical}$' as 1.6772, thus indicating that there is significant difference in the risk perception-awareness level of managers working in the ISO certified petrochemical companies in comparison to managers working in the non-ISO certified companies.

A two sample t-test at 99% confidence level for equal variances gave the value of '$t_{statistic}$' as 7.1105 and '$t_{critical}$' for one tail as 2.4065, which indicate that there is significant difference in the risk perception-awareness level of managers working in the ISO certified companies in comparison to non-ISO certified companies. Details of the analysis are furnished at Appendix C, Annexure 4.

4.4 Rationale behind the Case Study

The focus of the research is the experimental verification of the hypotheses formulated on the premise that ISO certification brings about improvement of the safety culture in petrochemical industries. Accordingly, the null hypotheses and alternate hypotheses were formulated for reactive indices and safety awareness data. The statistical analyses of the data showed that there was enough evidence to reject the null hypotheses that there is no improvement after ISO certification. In other words there is significant improvement in the safety culture after ISO certification.

However, validation of the statistical models of hypothesis tests is appropriate. This was done through the case study on an ISO certified petrochemical company. The primary objective was to verify if there was substantial improvement in the safety culture of the company after ISO certification, in terms of work place precautions and risk mitigation. The reactive indicators were measured separately, too. Study and analysis of the IR, FR and SR values before and after ISO certification yielded the results which are discussed at length in the following sections.

4.4.1 Reactive Indicators Data

The reactive indicators IR, FR and SR for the sample petrochemical company were collected and analyzed to study the trend before and after ISO certification. The results are given in Table 4.6 and 4.7 and charts 4.1, 4.2 and 4.3. The best fit of the data points was done using Microsoft Excel and the regression equations obtained using Minitab 13.2.

Table 4.6 Reactive Indicators IR, FR and SR Before ISO Certification

Yearly Reactive safety data	IR_1	FR_1	SR_1
1990	4.00	2.00	12.00
1991	3.90	0.35	3.70
1992	4.30	0.50	4.60
1993	5.10	1.10	8.40
1994	3.10	0.60	2.90
1995	3.30	1.60	12.00
1996	2.80	1.10	14.00
1997	1.90	0.70	20.00

Table 4.7 Reactive Indicators IR, FR and SR After ISO Certification

Yearly Reactive safety data	IR_2	FR_2	SR_2
1998	0.60	0.20	6.00
1999	0.40	0.26	8.70
2000	0.90	0.40	2.40
2001	1.60	0.50	3.20
2002	0.80	0.10	0.60
2003	1.00	0.12	0.38

4.4.1.1 Incident Rates Before and After ISO Certification

The incident rate (IR values) shows a decreasing trend before ISO certification with values of IR changing from 4 to 1.9, where as after ISO certification, it shows an increasing trend, but the range of variation is less from 0.6 to 1.0.

The regression equation for the fitted line of data before ISO certification is:

IR_1 = 601.6 – 0.3*Years before ISO

R^2 = 55.3%, R^2 (adj) = 47.8%.

The regression equation for the fitted line of data after ISO certification is:

IR_2 = -222.030 + 0.111*Years after ISO

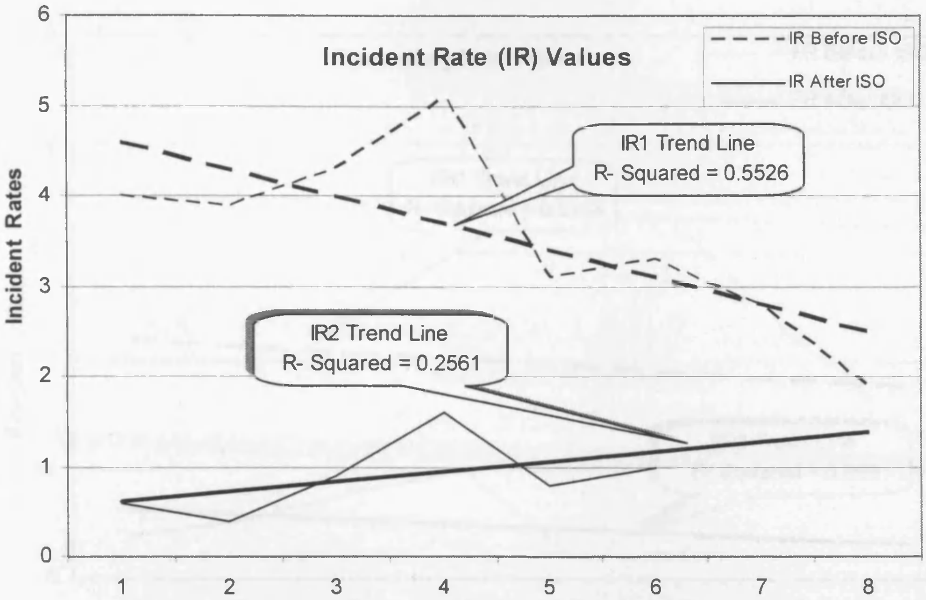
R^2 = 25.6%, R^2 (adj) = 7.0%.

R^2 value varies from 0 to 1 (or 0 to 100%). Larger values of R^2 close to 1 indicate that data points are closer to the fitted line. Even so a lower value doesn't indicate that the fitted line is not appropriate. As error variance, σ^2 decreases the data points are closer to the fitted line. Thus the value of R^2 describes the amount of variation in the observed response data explained by the predictor. The adjusted R^2 value takes into account the fact that R tends to overestimate the actual amount of variation accounted for in the population. The adjusted R^2 value decreases when the number of terms in the model increases (Hayter, 1996).

So it can be seen from both equations that before ISO certification 55.3% of the variation in IR values is explained by the X-value i.e. years passed and after ISO certification it is just 25.6%. This indicate that trend line after ISO certifications shows a closer fit than that before ISO certification, a closer fit in spite of the fact that data points after ISO is just 6 instead of 8. Therefore, it may be concluded that the trend line fit is less accurate before ISO considering the number of data points. This may be attributed to the fact that variation in the IR values before certification was more than the IR values after.

However it is against expectations that IR values should increase after ISO certification. On verification it was understood that the increasing trend could be due to enhanced documentation and reporting of types of incidents like first aid accidents, near misses etc. There is also a possibility that certification can lead to establishment of a proper reporting system that can bring out all issues and hence an increased rate of incident reporting. In addition to this, as pointed out the variation in the IR values before certification was more than the IR values after. This fact also point out to closer observation of incidents after certification.

Chart 4.1: Trend Plots of Incident Rates (IR) Values Before and After ISO



Years→ 1 to 8 = (1990 - 1997) Years before ISO Certification
Years → 1 to 6 = (1998 - 2003) Years after ISO Certification

4.4.1.2 Frequency Rates Before and After ISO Certification

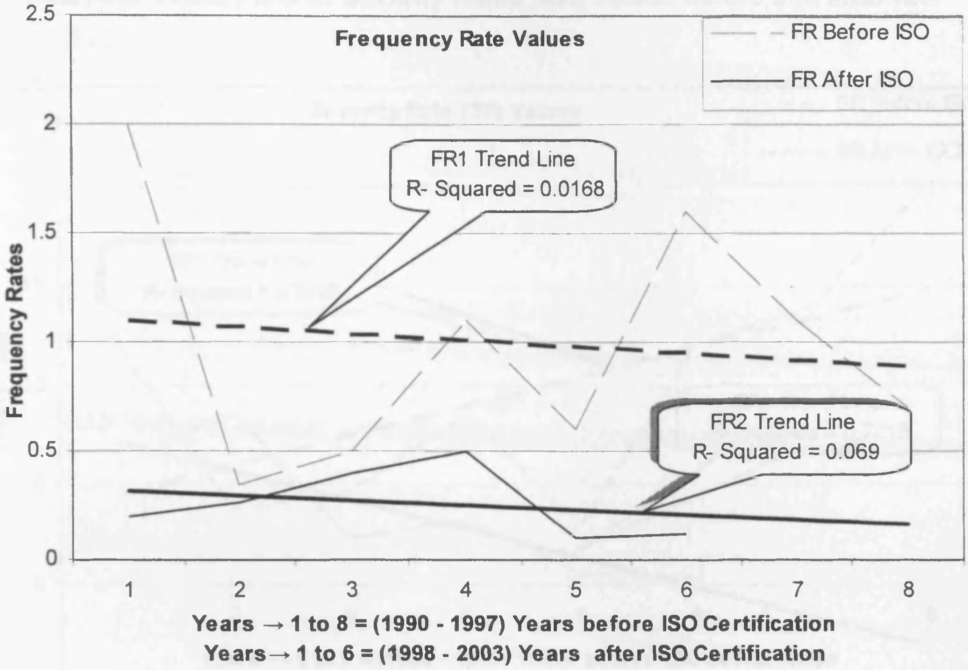
Frequency Rate shows a decreasing trend, FR values declined from 2 to 0.7 before ISO certification period, where the decline after the ISO certification trend from 0.20 to 0.12. This is really a positive sign and can be considered an improvement. As mentioned earlier the value of R^2 describes the amount of variation in the observed response data explained by the predictor. Similarly the adjusted R^2 value takes into account the fact that R tends to overestimate the actual amount of variation accounted for in the population.

The regression equation for the fitted line of FR data before ISO certification is:
FR_1 = 61.5107 - 0.0303571 *Years before ISO
R^2 = 1.7 % R^2 (adj) = 0.0 %

The regression equation for the fitted line of data after ISO certification is:
FR_2 = 44.8459 - 0.0222857*Years after ISO
R^2= 6.9 % R^2 (adj) = 0.0 %

So it can be seen from both equations that before ISO certification 1.7% of the variation in FR values is explained by the X-value i.e. years passed and after ISO certification it is 6.9%. The years after ISO certification, has more effect on the negative slope of the FR rates. It is observed that the trend line forecasts lower FR values.

Chart 4.2: Trend Plots of Frequency Rates (FR) Values before and after ISO



4.4.1.3 Severity Rates Before and After ISO Certification

Severity Rates (SR values) show an increasing trend before ISO certification. SR values increased from 12 to 20 whereas there is a reducing trend from 6 to 0.38, after ISO certification. This again is a very positive development and improvement in the safety performance.

The regression equation for the fitted line of data before ISO certification is:

SR_1 = -2937.83 + 1.47857 *Years before ISO

R^2= 37.5 % R^2 (adj) = 27.0 %

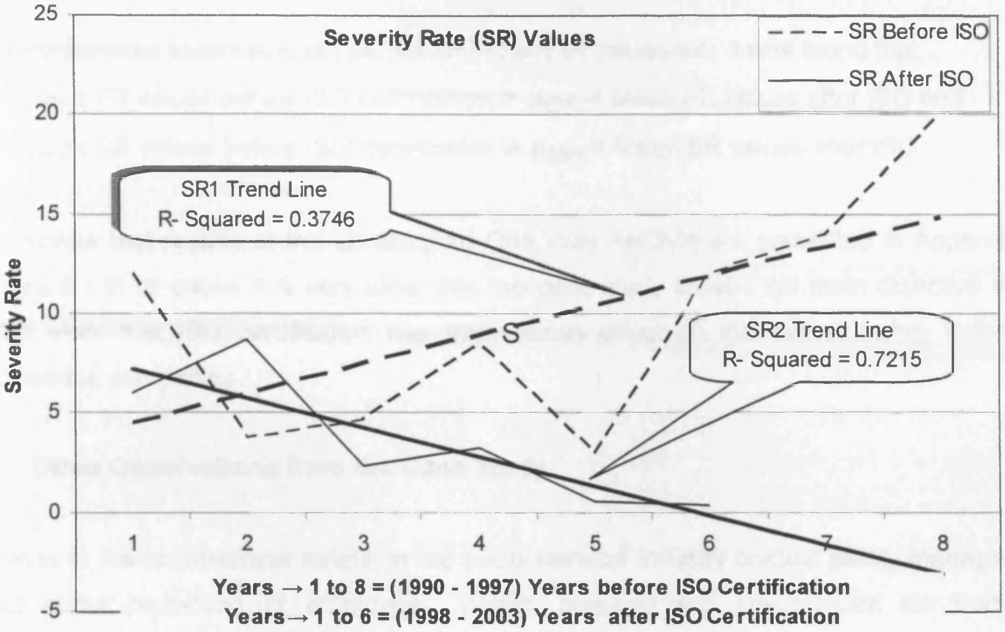
The regression equation for the fitted line of data after ISO certification is:

SR_2 = 2952.86 - 1.47429*Years after ISO

R^2= 72.1 % R^2 (adj) = 65.2 %

The R^2 value of 72.1 after ISO indicates tremendous reduction in SR values. On comparing the coefficient of years after ISO and years before ISO, it is clear that there is a shift from a positive trend to a negative trend in the Severity Rate values. This is graphically distinguishable from Chart 4.4.

Chart 4.3: Trend Plots of Severity Rates (SR) Values before and after ISO



4.4.1.4 Un-stacked One Way ANOVA

Table 4.6 and 4.7 show that the number of data points before and after ISO certification of the sample petrochemical company is not the same. Two-sample paired t-test is not feasible under such situations. Therefore Minitab was used to conduct an Un-stacked one way ANOVA, to test the hypotheses. The formulation of hypotheses is the same as before.

The hypothesis statements for Mean Incident Rates are:

$$H_O: \mu_{1IR} = \mu_{2IR}$$

$$H_A: \mu_{1IR} > \mu_{2IR}$$

Where,

H_O: Mean Incident rate before ISO certification=Mean Incident rate after ISO certification

H_A: Mean Incident rate before ISO certification > Mean Incident rate after ISO certification

μ_{1IR} = Mean IR values before ISO certification

μ_{2IR} = Mean IR values after ISO certification

The test results are shown in Appendix D, Annexure 5, Page 1 of 4. The high value of F= 38.05 very low p-value less than the significance level Alpha=0.05, indicates that the Null Hypotheses is to be rejected, which means that:

μ_{1IR} = Mean IR values before ISO certification > μ_{2IR} = Mean IR values after ISO certification. This analysis also supports the results of regression analysis. Box plots of the data points also clearly indicate the difference in means.

Similar Hypotheses tests were carried out on FR and IR values too. It was found that,
μ_{1FR} = Mean FR values before ISO certification > μ_{2FR} = Mean FR values after ISO and
μ_{1SR} = Mean SR values before ISO certification > μ_{2SR} = Mean SR values after ISO.

The complete test results of the Un-Stacked One Way ANOVA are presented in Appendix D, Annexure 5. In all cases it is very clear that the case study proved the main objective of the reported work that ISO certification has tremendous effect on the overall safety culture of petrochemical companies.

4.4.2 Other Observations from the Case Study

In addition to the occupational safety, in the petrochemical industry context safety management is also about protection of employees, public, property and environment etc from the consequences of undesirable incidents involving flammable liquids and highly hazardous materials. Thus management of process hazards, risk assessment and mitigation is an essential aspect for the improvement of safety performance.

The case study on the sample petrochemical plant referred in Table 3.5, on the risk mitigation aspect, revealed the extent to which risk mitigation is addressed in an ISO certified company. It may be noted that there was no formal risk management process existing in this company. OHSAS 18001 certified companies formally carry out risk assessment studies. Various dimensions of the risk were studied and the findings were categorized as i) Risk for personnel ii) Risk for company assets iii) Process risk and iv) Risk of bulk storage of materials. This company presently does not have a certified safety management system. However the company management has established a loss prevention program in order to mitigate the effect of loss to the company to avoid human distress and financial loss and maintain performance of processes and conformity of products. This prevention program is filed in the safety manual. Effective planning for loss prevention is based on evaluation of data generated from records related to performance of company processes and its products. Data are generated from records of application of Failure Mode and Effect Analysis (FMEA), measurement of process indicators, records of production process control, incident reports, inspection reports, review of customers' and other interested parties' needs and expectations, and lessons learned from previous experience and measurements of satisfaction of employees. Preventive measures to mitigate the hazards include risk assessment at the design stage of the equipments, development of necessary procedural safeguards (Kolka, 2002).

The relevance of the case study in respect of the reported research work, originates from the questions in respect of the usefulness of the statistical models and the results obtained. In other words the case study validates the statistical models for tests of hypotheses. The case study brought out the typical issues of risk mitigation which are linked to ISO 9001 QMS, ISO clauses and the derived benefits of ISO certification. The following sections discuss the relationship between the case study observations and the inferences drawn.

4.4.2.1 Dimensions of Risk

The multiple risk factors in a petrochemical company are due to the assets, the processes, and the bulk storage of chemicals. There are numerous assets which are open to risk in the sample petrochemical company including Ethylene Plant 525000 TPA, Low Density poly Ethylene Plant (LDPE1 & 2) 360,000 MTA, Sulphur recovery facilities and prilling unit of 200,000 TPA, and so on. There are many thermal and chemical processes which are highly prone to risk. For example high corrosion potential in the caustic treatment area, exothermic reaction in hydrogenation reactors, flash fire of plastic materials in ethylene and propylene recovery sections, low toxicity poisoning due to hydrogen sulphide, thermal expansion and contraction of pipe-work in furnaces. Risk due to fire and explosions in storage areas are of lower probability primarily due to stability in operating conditions.

4.4.2.2 Risk Mitigation Methods Employed

The risk mitigation methods and practices employed in the sample petrochemical company were studied thoroughly. In line with ISO 9001 process approach the company is involved in typical management functions such as production, maintenance, purchase, training, inspection, administration, marketing etc.

However, it was in fact the ISO certification of the company that provided a basis for an overall enhancement of these functions especially in those related to safety and risk mitigation. The dynamic setting that works out now comprises of a series of activities that help risk mitigation and are linked to ISO 9001 certification. The risk mitigation spans right from the design and construction of the plant as per international standards to fire proofing, fire protection, inventory isolation, instrumentation, control room enhancements, emergency shut systems, the inspection philosophy, vessel inspections by internationally recognized inspection agencies, periodic review of safety aspects, internal safety audits, team work, employee participation, training and rewards systems, empowerment, timely supply and quality of critical materials, supply chain management, proper work environment, and provisions to ensure production and services etc. These factors can have direct or indirect effect on the Safety performance results. The author feels that they would be useful for any future study in this fertile area of research.

4.5 Summary

This chapter focussed on the relevant research findings obtained from the statistical analyses conducted. The hypotheses statements represented the research objectives in statistical terms and were tested using the hypotheses testing procedures. The 'reactive safety indicators' specified by safety standards, namely the incident rates (IR values), frequency rates (FR values) and severity rates (SR values) were taken as the inputs to the statistical models. Questionnaire survey was conducted among employees of the 10 sample companies. The four proactive indicators data were collected and verified to reinforce the research findings. The findings of a detailed case study on the risk mitigation techniques put into practice in a typical ISO 9001 certified petrochemical company were listed and presented.

This case study was conducted with the main objective of validating the statistical models of hypothesis using real system outputs. The results obtained were tabulated and represented graphically. These findings and the data furnished along with the information obtained through the literature survey formed the basis for drawing out inferences. The conclusions arrived at and the recommendations are presented in Chapter 5.

Chapter Five: Discussion of Results

5.1 Introduction

The primary objective of this research was to evaluate the effect of ISO 9001 certification on the safety performance level of petrochemical companies using statistical techniques. Data was gathered from companies in the selected Arab countries. Diverse data gathering methods such as published documents, annual safety reports of the companies, interviews and questionnaire surveys among managers, quality and safety professionals and front runner employees, etc were used separately and in combination. The extensive literature review formed the basis for deciding a comprehensive measuring instrument for assessing the safety performance of the companies identified. Measurement of reactive safety monitoring data indicated ISO 9001 certified companies show a better safety performance. Proactive indicators measurement showed that positive impact of ISO 9001 certification is manifest in the areas of preventive inspections, better documentation of procedures and instructions, safety training for more personnel and use of personnel protective measures. Questionnaire survey results indicate presence of more positive elements of safety culture like safety awareness, better attitude and risk perception among people working in ISO 9001 certified petrochemical companies than in non-ISO certified companies.

5.2 Discussion and Implication of Results

In line with the objectives of the research, the literature survey included an overview of management systems, background of ISO 9000 standards, Quality Management System principles and requirements, concepts of TQM, OHSMS, Safety Certifications and Regulations, Environment Managements Systems, Integrated Management Systems, and application of ISO 9001 certification and its derived benefits in general and safety performance improvement in particular.

The literature review revealed that there are many elements of ISO 9001 which have a direct impact on the safety of a manufacturing plant, equipment and personnel. ISO 9001also acts indirectly by stimulating protection barriers through audits, third party verification, application of procedures and instructions etc. The key to this improvement is the management commitment as evident from the examples cited in the literature survey and the case study conducted by the author. The literature review offered a comprehensive performance measurement method involving measurement of reactive and pro-active monitors, safety behaviour, attitude and risk perception assessment.

Verification of reactive as well as proactive safety performance data was carried out to assess the improvement of safety performance. Safety behaviour, attitude, risk perception etc of personnel working in the petrochemical companies were measured through a questionnaire survey. The objective was to check to what extent a safety culture existed within an ISO 9001 certified petrochemical company. Existence of risk elimination / mitigation techniques within an ISO 9001 certified petrochemical company was also verified through a case study. There is clear indication of reduction in accidents and incidents. The overall improvement in safety performance can be attributed to other factors like safety culture, behaviour and multitude of proactive actions. Based on the results of the analysis, these factors and their links with ISO and other issues mentioned in the literature review are discussed and compiled in the following sections.

5.2.1 Reduction in Accident and Incident Rates – Improvement of Reactive Indicators

The statistical analysis of reactive indicators showed a positive correlation between ISO 9001 certification and safety performance of petrochemical companies operating in the selected Arabian GCC countries. At 99% significance level, all the three reactive indicators viz. incident rates, frequency rates and severity rates showed improvement in the performance, as expected. The major influencing factor behind this improved performance might be the corrective actions and preventive actions cited in Clauses 8.5.2 and 8.5.3 respectively. As seen from the case study the incident reporting increased immediately after the ISO certification and there was remarkable reduction in FR and SR levels. It may also be noted that ISO certified companies showed a better compliance level to preventive safety inspection activities. All the proactive activities might have influenced this improvement in the safety performance level.

5.2.2 Proactive Actions Indicator –Preventive Inspection

Measurement and analysis of proactive indicators were done to enhance the confidence in the results obtained and to what extent the conclusions derived from the analysis were accurate enough. An assessment of the "proactive indicator - preventive inspection" showed that a structured system exists in all ISO certified companies for preventive inspections. Inspections are carried out in accordance with a well planned schedule. Percentage compliance of preventive inspections is over 90% which is a positive safety indicator. In the case of non-ISO certified companies it is observed that there is no systematic program for preventive inspections is operational. Most of the non-ISO companies conduct safety audits arbitrarily and usually without any specific well structured plans. It is important to note that 4 out of 10 companies did not even have any such system in operation. Hence this increased level of compliance could reasonably be attributed to the action plan for continual improvement undertaken by ISO certified companies as per the Clause 8.5.1 which includes audits, corrective and preventive actions etc.

5.2.3 Proactive Actions Indicator –Safety Training

It was noted that ISO certified companies are following a yearly plan for the periodic refresher courses in safety. The results from the survey among a sample of 100 employees indicate that the average compliance level of employees undergoing safety training is much higher than that in a non-ISO certified company. Out of the 10 companies surveyed 7 had more than 60% compliance whereas in the case of non-ISO certified companies 8 companies out of 10 showed only 30% compliance towards meeting safety training. It points out the absence of a systematic approach towards safety training programs in non-ISO certified companies. An ISO certified company implementing the Clause 6.2.2 on competence, awareness and training gives importance to these aspects. The absence of a formal safety training program in non-ISO companies reveals the fact that higher compliance in ISO certified companies reasonably be attributed to the influence of the systematic approach specified in ISO standards.

5.2.4 Proactive Actions Indicator –Applied Documentation.

A comparison of the documentation of procedures and instructions in accordance with the documentation requirement levels of OHSAS 18001 was made to verify to what extent the companies practiced it. Both ISO certified and non-ISO certified companies had some form of safety policy statement and planning. However documentation for implementation, checking and corrective action and internal analysis are generally weak in the non-ISO certified companies. Checking and corrective action documentation is particularly very weak. Many ISO certified companies are following the same pattern of ISO 9000 documentation for safety management also and hence have a good level of documentation. A majority of the 10 companies surveyed meet more than 50% of the documentation requirements.

Documentation is the backbone of ISO 9000 conformance. In fact, the standards can be described as: "say what you do, do what you say, and document what you say and do". The U.K. British Standards Institute estimates that 47% of the companies who fail to achieve certification do so because of documentation deficiencies. Most of these deficiencies occur in compliance with the ISO 9000 section called "Document Control." And the remaining 53% of failures are in-part related to documentation in areas such as policies and procedures for process, inspection, testing and measurement (Smith, 1996). The influencing ISO factors for this enhanced documentation system in ISO certified companies could be a) availability of work instructions as in Clause 7.5.1, b) use of specific methods and procedures specified in Clause 7.5.2 and c) documentation requirements specified in Clause 4.2. Again the inference is based on the result of poor documentation compliance level of non-ISO companies.

5.2.5 Proactive Actions Indicator – Use of Personal Protective Equipments (PPE)

The survey result showed that the percentage compliance of usage of principal PPE items like "helmet", "safety shoes" and "overall" among employees of ISO certified and non-ISO certified companies is the same. However usage of items like "ear plug" and "hand gloves" was noted to have been given lesser importance in non-ISO certified companies. It may also be noted that gas masks were not available for use in the non-ISO certified companies. Indeed this might be due to the nature of products such as non-toxic chemicals that may not necessitate wearing of gas masks.

However, the overall trend shows that ISO certified companies have more percentage of employees using PPEs. This could be correlated to the safety awareness and better compliance with safety training programs conducted in the ISO certified companies. Many ISO factors could have been influential in this aspect. Competence, awareness, and training (Clause 6.2.2), associated utilities (Clause 6.3), work environment (Clause 6.4), Internal communication (5.5.3) and management commitment (Clause 5.1) etc would have influenced the employees safety attitude. Use of adequate PPE in the certified companies demonstrates the influence.

5.2.6 Effect of ISO Certification on Safety Culture

The questionnaire survey revealed that employees working in the ISO 9001 certified petrochemical firms showed a better safety awareness level in comparison to non-ISO certified firms. The statistical test at 99% confidence level indicates that there is good awareness level about safety matters among employees of ISO certified companies. This evidently points out to the benefits of systematic safety training programs implemented in the ISO certified companies. Better compliance level of proactive indicator "safety training" supports this conclusion.

Results of the questionnaire survey among safety and quality professionals working in the petrochemical companies indicate that, at 95% confidence level there is a difference in the safety awareness level before and after ISO certification, however at 99% confidence level this difference is found to be insignificant. This is applicable as safety and quality professionals undergo frequent training programs and conduct such programs for others in the company. Hence it is quite likely that the safety awareness level of safety and quality professionals from both populations are more or less the same. However, the imperative role of ISO becomes evident when the professionals put their knowledge into practice.

Managers working in the ISO certified companies showed a better level of safety awareness compared to managers working in the non-ISO certified companies. The questions were oriented on a commitment point of view. The involvement of people, requirement and need for procedures and other safety obligations were addressed in the questionnaire. The results reveal that managers of ISO certified companies are better informed about safety issues and process approaches. Frequent internal and external audit reports, preventive inspections, incident reports etc can be the contributors to this superior safety awareness level of managers of ISO certified companies.

Clause 6.2.2 of ISO 9001 requires an organisation to determine competence for personnel performing work, generate awareness and provide training. The questionnaire survey brought out the fact that there is remarkably higher level of safety awareness among employees and managers of ISO certified companies. Safety culture is influenced by the perceptions and appropriateness of behaviour of people in an organisation. The inference we get from the study result is that this improved safety awareness performance can be due to the systematic training conducted in the ISO companies.

A well-informed management is the pre-requisite for a safe plant. Risk perception awareness survey brought out the fact that many of the managers have a casual attitude towards "safety risk". Risks exist in petrochemical industry at various stages of its operation. The questionnaire was designed to capture the risk perception awareness level. Managers in the ISO certified petrochemical companies showed a better perception and understanding of the potential risks and risk mitigation methods compared to managers of non-ISO certified companies.

Clause 5.1 (a) of ISO suggests that the management communicate the importance of statutory and regulatory requirements to the organisation and this could have influenced the better risk perception of managers. Also the influence of quality & insurance audits cannot be ruled out.

5.2.7 Case Study Results

The case study on the ISO 9001 certified petrochemical company revealed that various workplace precautions are taken by the company and it has developed many levels of barriers of protection for safety and risk at various stages of design, purchase, execution and operation. The reactive safety data collected showed an evident change of IR (1.9 to 0.60), FR (0.7 to 0.20) and SR (12 to 6) during 1997-1998. It can be noted that 1998 is the year the company got ISO 9002 certification. There were no other noticeable events, during 1997-1998 period, such as changes in the top management, the operating philosophy, or the technology etc that happened in this company. Hence the logical conclusion is that the significant reduction of reactive safety indicator values (IR, FR and SR) was due to superior ways of doing things attributable to ISO certification. This observation is particularly relevant to the reported work, since the company selected for case study did not have a formal safety management system prior to ISO certification. After 1988, the company was following safety procedures in accordance with ISO 9000 guidelines.

ISO 9000 encourages adoption of the process approach to the management of the organisation as a means of identifying and using the opportunities for improvements. Clause 7.1.3.1 of the Guideline standard ISO 9004:2000 gives identification, assessment and mitigation of risk as a process. However ISO 9001:2000 explicitly doesn't mention this, but clause 7.2.1 of the ISO 9001 standard do clearly state that the organisation has to determine the statutory and regulatory requirements related to the product.

The case study showed evidence of following the process approach in all matters related to safety. The analysis of Reactive and Proactive indicators supports this too. The case study also verified the various safety protection phases like ISO procedures, instructions, Audits and 3rd party inspection systems established in a typical ISO certified Petrochemical Company.

5.3 Summary

The major feature of the reported work is that this type of an empirical research has not been done before and that it establishes a committed connection between ISO 9000 and safety performance in the context of petrochemical industry. Based on the statistical analysis of safety performance reactive measures and the supporting proactive measures and also the case study conducted etc it is obvious that there is a positive correlation between ISO 9001 certification and safety performance level of petrochemical companies in the Arabian Gulf countries.

A management system serves its purpose only if it is implemented and maintained effectively. While concentrating on quality aspect of the work processes, safety also need equal importance. One cannot improve work processes without identifying and eliminating safety risks. In addition to the quality perspective, more study is required on the safety perspective of work processes, too. Downtime, low productivity, poor quality etc are only one side of the coin. Injuries, safety risk, damage to equipment or facilities, product warranty or liability losses are to be controlled too, with a well-designed and implemented quality management system.

Hence while implementing a quality management system in a petrochemical plant, safety needs to be given first priority at each stage of implementation. If management commitment can nurture the necessary quality culture, safety culture comes along with it. Rather safety culture is an inevitable outcome of quality culture. Therefore safety performance benefits can be derived through effective implementation of generic standard ISO 9001:2000 in the petrochemical industry. This point has been established in this work.

Most of all the reported research work has also been efficacious in demonstrating that quantitative techniques are viable means for measuring the safety performance of petrochemical companies. Qualitative assessment of the performance of the petrochemical companies before and after ISO certification can easily be done fairly accurately on the basis of qualitative and quantitative data available. However, such an assessment cannot bring to light the biases, degree of errors and orientation. In contrast quantitative assessment would be more accurate, measurable and impersonal. It provides us with the degree of confidence with which one can rely on the results obtained. Even if the population is qualitative, population parameters such as mean, variance and standard deviation could be used to analyse the data and inferences can be drawn through quantitative techniques.

The author used statistical tools of pair-wise comparison of means using 't-statistic', hypothesis testing and regression analysis. One of the most commonly used, intuitive and appealing scaling technique called Likert's Scaling (John and Edward, 1981) was used for quantifying qualitative responses of employees, safety and quality professionals and managers in petrochemical industries. The responses were obtained through questionnaire surveys and then computing the means of the scores obtained on the linear composite scale. Quantification of reactive and proactive safety indicator data, and transforming them into meaningful averages were comparatively easier.

The outcome of the research points to the dire need for fostering a well-knit safety culture which is an inevitable consequence of a good quality management system.

Chapter Six: Conclusions and Recommendations

6.1 Introduction

Generally, any research work consists of some distinctive steps such as planning, designing the survey, data collection, data entry, data preparation and management, data analysis, reporting and the deployment. The foregoing chapters presented the first seven steps of the research work carried out by the author. The last step i.e. the deployment is completed only when the results are handed over to the beneficiaries in executable form. If the entire range of analytical exercises is considered as investments then the returns can be earned only when deployment of the research is done. This is possible only when the researcher is able to present the uniqueness of his work and establish how results of his work can act as catalysts for changes.

In his classical work 'Seven Faces of Research', Eilon (1975) classified researchers into seven archetypes, *the chronicler, the dialectician, the puzzle-solver, the empiricist, the classifier, the iconoclast, and the change agent*. The prime role of the change-agent is deployment of the research work to change a given system. The views on goals and solutions the system needs to adopt, are to be proposed explicitly, by arguing the advantages of his solutions, even if it has to be by participating in the responsibility for implementation.

The following sections discuss such conclusions, proposals and recommendations by the author on the basis of the entire work. It may be noted that most of these recommendations are complemented by the author's own professional life and close association with petrochemical companies in the Gulf region.

6.2 Conclusions

It was the prime objective of the research to investigate the effect of ISO 9001 certification on the safety performance level of Petrochemical industries. Also the following specific objectives were set in the beginning of the study:

- To evaluate the impact of ISO 9000 certification on the safety awareness level of employees working in petrochemical plants.
- To determine the impact of ISO 9000 certification on the safety awareness level of Safety and Quality professional working in a petrochemical plant.
- To find out the effect ISO 9000 on the risk mitigation methods employed by a petrochemical plant.
- To find out the effect of ISO 9000 certification on the risk perception awareness level of mangers working in the petrochemical companies.

- To demonstrate the appropriateness of quantitative techniques in measuring the overall safety culture of a petrochemical company.

In accordance with these objectives the following hypothesis statements were formulated and tested.

Null Hypotheses (H_O)	Alternate Hypotheses (H_A)
There is no significant improvement in the average safety performance level with ISO certification	There is significant improvement in the average safety performance level with ISO certification
There is no significant improvement in the average safety awareness level of front runner employees with ISO certification	There is significant improvement in the average safety awareness level of front runner employees with ISO certification
There is no significant improvement in average safety awareness level of Safety and Quality professionals with ISO certification	There is significant improvement in average safety awareness level of Safety and Quality professionals with ISO certification
There is no significant improvement in average safety awareness level of managers with ISO certification	There is significant improvement in average safety awareness level of managers with ISO certification
There is no significant improvement in risk perception level of managers with ISO certification	There is significant improvement in risk perception level of managers with ISO certification

6.3 Suggestions Related to the Study

Companies are not static, they are continually changing. The global economy has created considerable changes for companies throughout the world. In response to rapid, discontinuous and significant changes in the external and internal environments, many established companies have restructured their operations in fundamental and meaningful ways (Michael and Donald, 2002). Standardisation processes have a major role in bringing about these changes in operations. For example a company that standardise its occupational health and safety management systems is expected to accomplish:

- Minimisation of risk to employees and others by developing good working practices to prevent accidents and work-related ill health,
- Improvement in the business performance and establishment of a responsible image within the market place
- Continuous improvement in its performance beyond legal compliance
- Compliance with its OH&S policies and objectives.

By using any one of the OH&S management systems discussed in the preceding chapters, firms will be able to improve their safety culture. As a direct outcome, at least a reduction in accidents, ill-health, insurance claims, downtime and costs would be noted. The Royal Society of Chemistry (RS.C) believes overall improvement in safety culture would be manifested if organisations manage health and safety to the same standard as other core business activities. As such, health and safety should be seen as an integral part of an organisation's overall management system. So the adoption of a formalised occupational health and safety management system provides a sound basis for achieving these ideals (RS.C, 2005).

The goal of this research was to establish that the distinct advantages cited above are derivatives of ISO certification which evidently warrants substantial changes in corporate strategies. Needless to say, all petrochemical companies value excellence and make every effort for attaining competitive advantage over other companies. This is possible only through continuous improvement and corporate entrepreneurship.

The research has unambiguously proved that ISO 9001 certification has a direct impact on safety performance of the petrochemical industry in the Arabian Gulf countries. A number of positive changes in safety performance were observed in ISO certified petrochemical industries. It was statistically proved that these changes could be attributed to ISO certification. Indeed, standardisation provided more structured and formal operations and processes. Improved company systems and discipline, indirect contribution to changes in the industrial relations climate etc were other offshoot benefits.

The predominant feature noticeable in a company preparing for ISO certification is the dramatic changes these 'change processes' bring about inadvertently in the quality / safety culture. The implementation processes require substantial input from the company employees ranging from managers to operators and office staff. There is a dire need for comprehensive training programs. The formalisation of the program for implementation, as well as providing an opportunity for input from all levels of the company, creates a sense of joint ownership that would have a lasting effect on the company processes and operations. The elaborate documentation process that runs through the whole exercise creates dynamism at all levels from top to bottom. The drive for certification can thus be seen to be a major catalyst for cultural change, and an important stepping-stone to the implementation of a range of other initiatives such as empowered teams etc. The degree of risk associated with implementation of such programs can be seen to be reduced by the organisational experience with documenting current processes. Through structures and formalisation, improved systems, and changed industrial relations climate etc, ISO certification acts as a catalyst for this improvement. The case study results and safety performance data from companies before and after ISO certification substantiate these views.

Therefore, the author strongly recommends that all petrochemical companies go for ISO certification and safety map systems. As indicated above every step in the journey towards the ultimate goal would be rewarding.

It is noteworthy here that the unstinting support and involvement of senior management is essential for bringing about significant changes in the quality culture of a company. The dynamic nature of petrochemical companies might complicate organisational changes needed for ISO certification and implementation of related processes. Therefore the role of management is critical.

As noted in this research, there is confusion regarding various Safety Management Systems currently operational in the world. While implementing ISO 9001 requirement, a petrochemical company gives priority to safety issues above quality. This is so, because the issue at stake due to a seemingly minor unsafe act might be enormously serious and in many cases total destruction of the complete plant could be the net result. In the context of a petrochemical plant and with the advancement of technology by the use of distributed digital control system and programmable logic control etc the impact of manual intervention is felt more on safety. The new petrochemical industry specific standard ISO/TS 29001 published in December 2003 is a realization of the importance given to this industrial sector. However the standard does not explicitly mention "safety" as one of the prime concerns to be addressed while implementing the QMS. More detailed study is needed in this area.

This study has unequivocally demonstrated the relevance of proactive safety indicators and safety culture and how they get positively influenced by the documented procedures. In the real sense the control feature mentioned in the new standard does include 'safety'. Therefore, on the basis of the study results, the researcher strongly feel that the ISO/TS 29001 standard need to incorporate explicitly "Safety" as the predominant feature of the process model.

Accordingly a modified process model is proposed as given in figure 6.1. In comparison to the original version given at figure 2.1, Safety is put at the centre of this new process model as a core requirement. The relationship between the foremost requirements of the process model and 'safety' is illustrated in the new proposed model. The information flow between regulatory requirements and safety is indicated. The flow of value adding input to safety from regulatory requirements is shown too. Safety being a core requirement has many elements that interact with other requirements. The safety elements considered for establishing the link are safety policy, inherent safety, occupational safety, process safety and system safety.

Management responsibility includes establishing quality policy and objectives. The study showed that in the case of a Petrochemical facility a management cannot frame these policies without considering safety requirements. The questionnaire survey showed risk perception level and safety awareness level of managers from ISO certified companies were higher when compared to managers of non-ISO companies. Management responsibility also includes communicating to the organisation the importance of statutory and regulatory requirements (Clause 5.1 of ISO 9001:2000). ISO certified companies showed better safety awareness level among employees which indicate the effectiveness of communication of safety requirements.

Hence, the benefit is felt but the need is to state it explicitly, hence the link is shown in the recommended process model between 'safety' and 'management responsibility'.

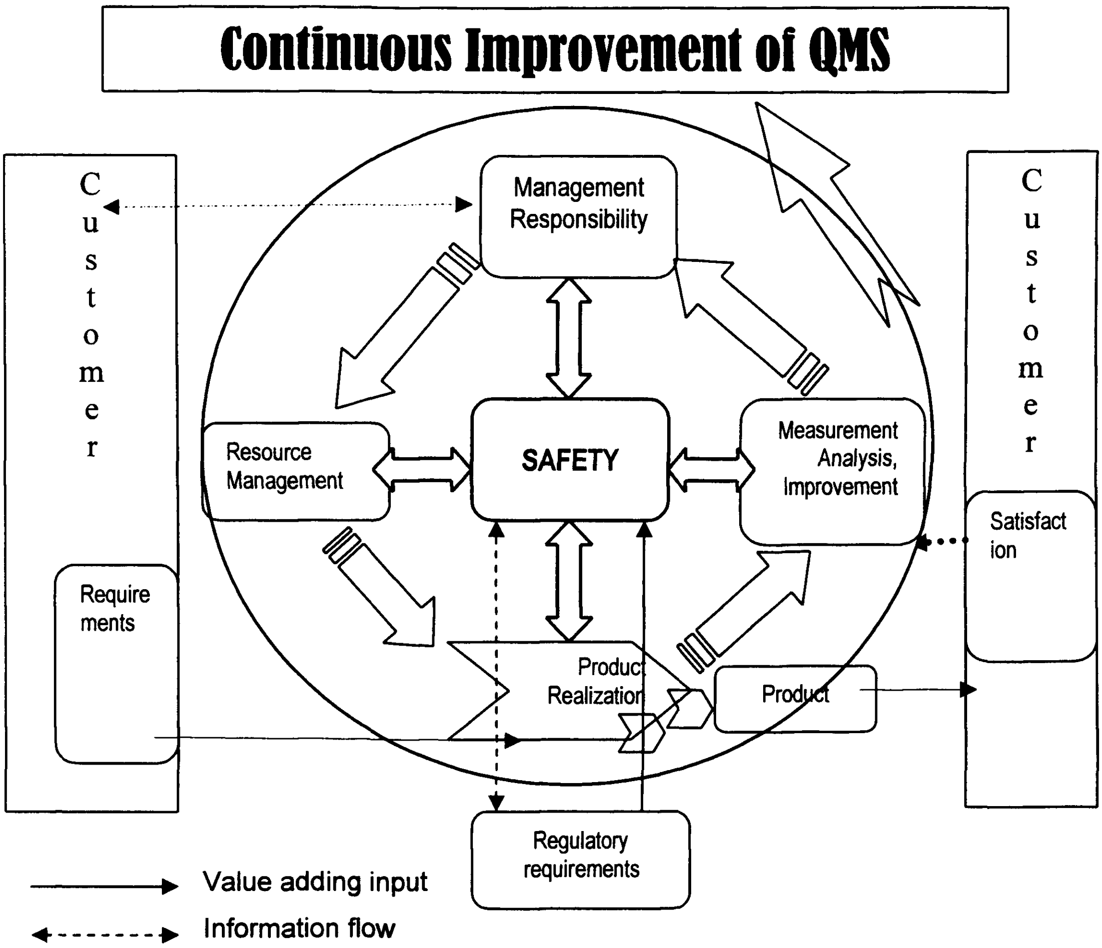


Figure 6.1 Proposed Quality Management Process Model

The role of safety awareness and training in occupational safety are imperative for enhancement of human resources competence which is a major QMS requirement of the resource management. The proactive indicator analysis of the study showed that more employees received safety training in the ISO certified companies. The study also showed that safety awareness level of employees in ISO certified companies were much superior to those in non-ISO companies. Hence it can be concluded that safety is also given importance while promoting quality awareness and developing competencies in the petrochemical facilities. Indeed, the occupational safety needs to be considered too, while meeting the requirement of resource management. Therefore, inclusion of the link between Resource Management and Safety in the process model is justified.

During the various stages of product realisation, safety of the item being purchased, designed or processed cannot be ignored. It must be considered as an essential requirement. Thus, process safety becomes an integral part of the petrochemical processing facility QMS. Process safety depends upon the control of process quality, deviation, exceptions and effective documentation system. Process safety information, employee involvement, process hazard analysis, operating procedures, safe work practices and permits, employee competence and training, design quality assurance, maintenance and mechanical integrity, process incident investigation and emergency response etc are some of its elements. Inherent safety of a product is a must to make it fit for the purpose for which it is intended. Introduction of the field non-conformities in the new ISO 29001 proves its importance.

The study of proactive indicators showed that company documentation of activities related to safety was carried out better in an ISO certified than a non-ISO company. The case study revealed that an ISO certified petrochemical company takes care of the process safety elements and has many levels of barriers in place while going through the above mentioned product realisation process. The relationship of the process safety elements with QMS was already mentioned. Therefore it is rational to think of a link between 'product realisation' and 'safety' in the recommended process model.

Measurement analysis and improvement require monitoring and measurement of processes and conducting regular internal audits. Internal audits bring out many issues and recommendations for improvement. Conducting HAZOP or implementing a check list for start up or commissioning, checking and improving the Safety Integrity Level (SIL) of process loops etc are all interlinked with process quality. The weaknesses in the HAZOP and check listing for SIL are normally noted too in the measurement and analysis parts of the audit process, even though the audit is aimed at quality procedures and not safety. Corrective and preventive actions are done based on the audits. The issues brought out may not be limited to quality alone. The case study revealed that preventive safety inspections are carried out more often in the ISO certified petrochemical companies than in non-certified companies. Thus a link between measurement, analysis, improvement and safety is established as shown in the recommended process model.

6.4 Contributions from the Study

The research could bring out to the focus an issue of safety in petrochemical companies which is linked to quality management system. As noted from literature review, past studies did not address the issue with the merit it deserve. The research highlights the fact that safety performance measurement is a complex issue involving reactive, proactive safety data and safety culture. The research methodology outlined at chapter 3 of this report furnishes a framework for future studies. The result of the first hypothesis showed that among the reactive safety data Frequency rate and Severity rate is decreasing with the ISO certification, this is an aspect of interest to the industry. Incident are always happening in any industry but most of them go without reporting especially if it is minor incidents or first aid cases or near misses.

The increasing trend in the incident rate as evident from case study shows the fact that ISO certification helps to improve the reporting culture of incidents which give the industry the scope for corrective action and improvement one of the core elements of ISO (8.5.1 & 8.5.2).

In general testing of hypotheses 2, 3 and 4 showed that the safety culture improves with respect to ISO certification. Competence, awareness and training are the resource requirements of ISO 9001 to achieve quality. The hypothesis testing result showed the fact that the effect of these clauses is felt in the improvement of safety awareness and safety culture itself. However in particular, hypothesis 3 showed that among safety and quality professionals the difference in the safety awareness level at 99% confidence level is insignificant. This could be due to the training received by those professionals irrespective of ISO certification.

The result of fifth hypothesis showed that perception level of managers significantly improves with respect to ISO certification. This is an indirect and important benefit of ISO certification which has been highlighted. As managers are the key personnel involved in the decision making process related to risk assessment and mitigation of a petrochemical industry it is very important that they have the right perception level about the risk involved in his company.

The case study helped to validate the statistical methods used for the hypothesis testing. It also highlighted how quality issues related to purchasing, facilities; materials, maintenance etc influence safety and help for carrying out work place precautions and risk mitigation.

The study showed improvement of safety performance in the Petrochemical industries with the application of the generic standard of ISO 9001. The industry specific ISO/TS 29001:2003 standard was a realisation of the need of the industry. ISO /TS 29001:2003 brings out new concepts of control features and field non-conformities. Control features imply performing the activity under controlled conditions to achieve conformity to specified requirements. The researcher is of the view that by explicitly incorporating safety in the ISO/TC29001 standard, the safety performance of the petrochemical industries will get improved tremendously. The relevant clauses related to safety and risk mentioned in ISO 9004:2000 (Guideline for Performance Improvements) can be made mandatory for the industry specific standard ISO/TS 29001: 2003. The generic process model shown in Figure 2.1 represents the 4 major requirements of the 3rd edition of ISO 9000: 2000 standard, namely, the management responsibility (clause 5), the resource management (clause 6), the product realisation (clause 7) and the measurement, analysis & improvement (clause 8) which are interconnected and interact together to form an integral structure of the QMS. As per clause 2.4 of ISO 9000, the standard encourages adoption of the process approach to the management of the organisation as a means of identifying and using opportunities for improvement. A proposal of the revised process model is shown in Figure 6.1.

The model illustrates how the entire range of management functions related to quality and aimed at continuous improvement can be harmonised by putting 'Safety at the Centre'. The petrochemical industry can promote such an initiative of incorporation. This will remove confusion and add value for the ISO certification giving safety the required priority.

Incorporating safety requirements in the industry specific ISO/TC 29001 standard can benefit the industry by eliminating a separate management system, separate audits thus optimising the resources. It reduces the documentation requirements.

This study reinforces the need for integration of the Quality and Safety Management Systems at least in the oil and petrochemical industries. It also highlights the strong correlation of safety and quality in a petrochemical industry.

In real life, implementation of some of these proposals brought out positive results in certain areas under the direct supervision of the author. One department under the responsibility of the author with 200 permanent employees of various nationalities and 100 contract employees has recently completed 2000 days of working without any lost-time accident. Various quality-related safety issues referred to in the research report, were applied and tested, the results were encouraging.

Personally, the researcher has benefited immensely from the study right from getting an opportunity for an in-depth study of the ISO 9001 quality standard and its application in petrochemical industries.

A great deal of research studies has been published on the overall benefits of ISO 9000 implementation especially on the financial and sales side. However not much work has been done and practically none has been published on its benefits on the safety aspects. It is the strong conviction of the researcher that the proposed 'Safety at the Centre' process model could be taken as the basis for carrying out such studies in other parts of the world too

6.5 Recommendations for Future Research

The author finds immense scope for future work related to this topic. For example, it would be worthwhile if an in-depth comparative study is made on the safety performance of petrochemical companies before and after ISO certification in the Gulf countries and rest of the world. Studying the influence of culture, religion, language, race, climatic conditions, per capita income and many other demographic and geographic factors seems to be a good candidate for research in this area.

To reinforce the findings of the work reported here on a wider perspective, further research is recommended especially in European countries where safety regulations are much more stringent. The differences in work culture across nations have always been a subject of discussions and debates in management circles. Such a study appears to be more relevant now since cooperation in petrochemical industry between nations is picking up momentum. To quote an example, it is reported that foreign companies are playing a major role in China's petrochemical, oil and gas sectors and EU companies alone account for contracted and planned investments of over 15 billion euro. The Working Group comprises more than 20 of the largest EU companies in the petrochemical, chemical, oil & gas sectors and they are actively involved in oil and gas exploration and production, oil product retails and downstream development, gas infrastructures and LNG imports. In petrochemical and chemicals sectors, foreign companies are actively involved in base, fine and speciality chemical manufacturing, R&D and marketing (Eurochambres, 2004).

The author finds much scope in the quantitative analysis that can be used for analysing the safety data from petrochemical companies. Though ISO certification brings about a multifaceted transformation in all spheres of the operations in a petrochemical company, the degree of change or the rates at which these changes take place may not be the same. Therefore the use of factor analysis and principal components analysis would bring about the weighted influence of various factors on the safety performance. Such an analysis would bring out the most influential factors on which the management can focus attention.

It is also recommended that the statistical analyses, which might seem to be unwieldy for managers and decision makers, be made user-friendly by installing application software for such analyses. It is to be noted here that most of the modern Information System based Management software applications incorporate such analysis tools.

Safety cannot be separated from quality and there is a need for further research in the dimensions of safety culture that can influence risk avoidance. For oil and gas and petrochemical industries, safety has been and still is the number one issue. The explosion of BP refinery in Texas on 23rd March 2005, with 14 fatalities and more than 100 injuries speaks volumes on the relevance of the subject to the industry. More research needs to be done on real integration of safety thinking and action in to all aspects of work practice rather than going for a separate management system and models.

The new petrochemical industry specific standard ISO/TS 29001 mentions about "control measures" but it doesn't explicitly highlight the importance of safety, for that the correlation between quality and safety in a petrochemical industry needs to be reinstated further through more research in different geographical areas. One of the benefits of the generic standard ISO 9001:2000 was reduction in documentation, but the ISO/TS 29001 indirectly stresses the need for more documentation. New industry specific standards in the area of automotive sector, aerospace, medical and petrochemical industries highlight the importance of safety to those sectors. Safety is a major concern in transportation and food processing industry too. Further research is required in these areas.

Probably the most noticeable limitation of ISO certification that one can trace out could be the fact that all ISO certified companies are not immune from quality-related problems. The daily task of ensuring processes and products would have to be continuously improved. In this sense ISO certification is a step in an ongoing journey, and not an end in itself.

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Table A1: ISO Requirements of Quality Management System

4. Quality Management System - Requirements
   - 4.1 Establish quality system - general requirements
     - 4.1.1 Develop quality management system.
     - 4.1.2 Implement quality management system.
     - 4.1.3 Improve quality management system.
   - 4.2 Documentation requirements for quality system
     - 4.2.1 Develop quality system documents.
     - 4.2.2 Prepare quality system manual.
     - 4.2.3 Control quality system documents.
     - 4.2.4 Maintain quality system records.
5. Management Responsibility - Requirements
   - 5.1 Management commitment (support quality)
     - 5.1.1 Promote the importance of quality.
     - 5.1.2 Develop a quality management system.
     - 5.1.3 Implement your quality management system.
     - 5.1.4 Improve your quality management system.
   - 5.2 Customer focus- Satisfy your customers
     - 5.2.1 Identify customer requirements.
     - 5.2.2 Meet your customers' requirements.
     - 5.2.3 Enhance customer satisfaction.
   - 5.3 Establish a quality policy
     - 5.3.1 Define organization's quality policy.
     - 5.3.2 Manage organization's quality policy.
   - 5.4 Carry out quality planning
     - 5.4.1 Formulate your quality objectives.
     - 5.4.2 Plan your quality management system.
   - 5.5 Control your quality system
     - 5.5.1 Define responsibilities and authorities.
     - 5.5.2 Appoint management representative.
     - 5.5.3 Support internal communications
   - 5.6 Perform management reviews
     - 5.6.1 Review quality management system.
     - 5.6.2 Examine management review inputs.
     - 5.6.3 Generate management review outputs.

Table A1: ISO Requirements of Quality Management System

6. Resource Requirements
    - 6.1 Provide quality resources
        - 6.1.1. Identify quality resource requirements.
        - 6.1.2. Provide quality system resources.
    - 6.2 Provide quality personnel
        - 6.2.1 Use competent personnel.
        - 6.2.2 Support competence.
    - 6.3 Provide quality infrastructure
        - 6.3.1 Identify infrastructure needs.
        - 6.3.2 Provide needed infrastructure.
        - 6.3.3 Maintain your infrastructure.
    - 6.4 Provide quality environment
        - 6.4.1 Identify needed work environment.
        - 6.4.2 Manage needed work environment.
7. Realization Requirements
    - 7.1 Control realization planning
        - 7.1.1 Plan product realization processes
        - 7.1.2 Develop product realization processes.
    - 7.2 Control customer processes
        - 7.2.1 Identify customers' product requirements.
        - 7.2.2 Review customers' product requirements
        - 7.2.3 Communicate with your customers.
    - 7.3 Control product development
        - 7.3.1 Plan, design and development.
        - 7.3.2 Define design and development inputs.
        - 7.3.3 Generate design and development outputs.
        - 7.3.4 Carry out design and development reviews.
        - 7.3.5 Perform design and development verifications.
        - 7.3.6 Conduct design and development validations.
        - 7.3.7 Manage design and development changes.
    - 7.4 Control purchasing function
        - 7.4.1 Control purchasing process.
        - 7.4.2 Document product purchases.
        - 7.4.3 Verify purchased products.
    - 7.5 Control operational activities
        - 7.5.1 Control production and service provision.
        - 7.5.2 Validate production and service provision.
        - 7.5.3 Identify and track your products.
        - 7.5.4 Protect property supplied by customers.
        - 7.5.5 Preserve your products and components.

Table A1: ISO Requirements of Quality Management System

- 7.6 Control monitoring devices
  - 7.6.1 Identify monitoring and measuring needs.
  - 7.6.2 Select monitoring and measuring devices
  - 7.6.3 Calibrate monitoring and measuring devices
  - 7.6.4 Protect monitoring and measuring devices.
  - 7.6.5 Validate monitoring and measuring software.
  - 7.6.6 Use monitoring and measuring devices.

8. Remedial Requirements
- 8.1 Perform remedial processes
  - 8.1.1 Plan remedial processes.
  - 8.1.2 Implement remedial processes.
- 8.2 Monitor and measure quality
  - 8.2.1 Monitor and measure customer satisfaction.
  - 8.2.2 Plan and perform regular internal audits.
  - 8.2.3 Monitor and measure quality processes.
  - 8.2.4 Monitor and measure product characteristics.
- 8.3 Control nonconforming products
  - 8.3.1 Develop a procedure to control non-conforming products.
  - 8.3.2 Identify and control your non-conforming products.
  - 8.3.3 Re-verify non-conforming products that were corrected.
  - 8.3.4 Control non-conforming products after delivery or use.
  - 8.3.5 Maintain records of non-conforming products.
- 8.4 Analyze quality information
  - 8.4.1 Define quality management information needs.
  - 8.4.2 Collect quality management system data.
  - 8.4.3 Provide quality management information.
- 8.5 Make quality improvements
  - 8.5.1 Improve quality management system.
  - 8.5.2 Correct actual non-conformities.
  - 8.5.3 Prevent potential non-conformities

Table A2: Comparison of Safety, Environment & Quality Management System

Clause No.	ISO 14001:1996	Clause No.	ISO 9001:2000 Standard	Clause No.	OHSAS 18001:1999
4.0	General Requirements	4.0	QMS requirements	4.0	OH&S Management System Elements
4.1	General requirements	4.1	General Requirements	4.1	General Requirements
4.2	Environmental Policy	5.3	Quality policy	4.2	OH&S Policy
4.3	Planning	5.4	Planning	4.3	Planning
4.3.1	Environmental aspects	5.2	Customer focus	4.3.1	Planning for Hazard Identification, Risk Assessment and Control
4.3.2	Legal and Other requirements	5.2	Customer focus	4.3.2	Legal and Other Requirements
4.3.3	Objectives and targets	5.4	Quality objectives	4.3.3	Objectives
4.3.4	EMS System programs	5.4.2	QMS planning	4.3.4	Occupational Health and Safety Management System Programs
4.4	Implementation and Operation	7	Product realisation	4.4	Implementation and Operation
4.4.1	Structure and Responsibility	5.1	Management commitment	4.4.1	Structure and Responsibility
4.4.2	Training Awareness and Competence	4.1.8	Training	4.4.2	Training Awareness and Competence
4.4.3	Communication	5.5.3	Internal communication	4.4.3	Consultation and Communication
4.4.4	Environmental Management System Documentation	4.2.1	General	4.4.4	Documentation
4.4.5	Documentation and EMS Record Control	4.5	Document and Data Control	4.4.5	Documentation and Data Control Records
4.4.6	Operational Control	4.2.2	Quality System Procedure	4.4.6	Operational Control
		4.3 4.4 4.6 4.7 4.8 4.9 4.15 4.19 4.20	Contract Review Design Control Purchasing Customer Supplied Product Product Identification Process Control Handling, Storage, Packaging, Preservation and Delivery Servicing Statistical Techniques		
4.4.7	Emergency Preparedness and Response			4.4.7	Emergency Preparedness and Response
4.5	Management Review: Checking and Corrective Actions	8	Measurement ,analysis and improvement	4.5	Management Review: Checking and Corrective Actions
4.5.1	Monitoring and Measurement	8.2	Monitoring and measurement	4.5.1	Performance Measurement and Monitoring

Table A3: List of Safety Institutions, Councils and Regulatory Bodies

Sl. No	Name of the body	Description	Remarks
1	IOSH	Institution of Occupational Safety and Health (IOSH), UK: founded in 1945	Europe's leading body with more than 24,000 members.
2	NIOSH	National Institute for Occupational Safety & Health (NIOSH), USA. Federal agency responsible for conducting research and making recommendations for the prevention of work-related disease and injury	Part of the Centers for Disease Control and Prevention (CDC).
3	OSHA	Occupational Safety Health Administration (OSHA), USA: OSHA's mission is to ensure safe and healthful workplaces in America. Agency was created in 1971.	OSHA developed PSM (Process safety management).
4	NSC	National Safety Council, USA: The National Safety Council, founded in 1913 and chartered by the United States Congress in 1953, is the US's leading advocate for safety and health. having its mission to educate and influence society to adopt safety, health and environmental policies, practices and procedures	
5	EASH	European Agency for Safety and Health at work	Have corporate website with an interface in all 11 official EU languages
6	BOHS	British Occupational Hygiene Society is a multidisciplinary learned society that has members from, around 30 countries. Objective is promotion and protection of occupational and environmental health and hygiene.	
7	BSC	British Safety Council is one of the world's leading occupational health, safety and environmental organizations, it is founded in 1957.Their mission is to promote health, safety and environmental best practice for the benefit of society and the increase of productivity.	Registered charity organizations.
8	EU-Directive 96/82/EC	European Council Directive (1996): This directive is on Control of Major accident hazards involving dangerous substances.	Does not apply to many activities like military establishment, activities of extractive industries concerned with exploration and the exploitation of minerals, transport of dangerous substances in pipeline etc.

Table A4: List of Safety Regulations

Sl. No.	Regulation	Regulation Name	Remarks
1		Management of Health and Safety at Work - UK	Covers general risk
2	Reg. 6	Control of Substances Hazardous to Health 1988	Covers specific risk
3	Reg. 5	Control of Asbestos at Work Regulations 1987	
4	Reg. 27 &28	Ionising Radiations Regulations 1985	
5	Reg. 4 & 5	Noise at Work Regulations	
6	Reg. 2	Health and Safety (Display screen equipment) 1992	
7	Reg. 4	Manual Handling Operations Regulations 1992	
8		Personal Protective Equipment at Work 1992	
9	Reg. 4 & 17	Control of Lead at Work Regulations 1980	

8.1: Appendix A Table- A5

Tabulation of Techniques used and Analysis performed

	Objectives	Hypothesis	Techniques & Analysis
1	To investigate the effect of ISO 9000 certification on the safety performance level of petrochemical industries.	Null:- There is no significant improvement in the average safety performance level with ISO certification. Alternate:- There is significant improvement in the average safety awareness level of front runner employees with ISO certification.	**Reactive and Pro-active safety data were used for the safety data analysis.** ***a) Reactive safety data analysis:*** 1) Data collection of Reactive indicators- Incident Rate (IR), Frequency Rate (FR) and Severity rate (SR). 2) Testing for normality for reactive safety data IR/FR and SR by using Normal Probability plots. 3) Regression analysis for IR/FR/SR data by using Minitab software. 4) Calculated mean values of IR/FR/SR values for ISO and non ISO certified companies. 5) Conducted paired two- sample Student "t" test (One tail) for means by using Microsoft Excel software. 6) Design Expert 6.0.5 used for analyzing factor effects and interaction effects on the response variables IR/FR/SR. ***b) Pro-active safety data analysis*** The following Pro-active indicators were used. *1) Number of preventive inspection.* *2) Number of trained people in the safety.* *3) Applied documented procedures/instruction.* *4) Personal protection equipment resources/employee.* *Analysis :* *1) No of preventive inspection:-* a) Data collection through check list. b) Number of preventive inspections carried out in 2003 compared against number of preventive inspections planned. *2) No of trained people in safety :-* a) Number of people undergone safety training from a sample of 100 from each ISO certified company noted. b) Calculated percentage compliance. c) Compared the calculated value with the calculated percentage compliance value for non ISO certified companies.

Tabulation of Techniques used and Analysis performed

	Objectives	Hypothesis	Techniques & Analysis
			3) Applied documented procedures and instructions:- a) Data collection through Check list. b) 5 Element based analysis done (Table 3.3). c) Points assigned based on the relative importance of each element (Annexure 3 of Appendix-D). d) Total scores for the 5 Elements was calculated for each company (Max score 1000). e) Percentage score for ISO certified and non ISO certified was tabulated and presented on Bar-chart for comparative analysis. *4) Use of personal protective equipment:-* a) Data collection through questionnaire survey. b) Points awarded with reference to Table 3.4. c) Mode value(Number of positive responses) was found out for each item. d) Percentage compliance calculated for each sample company. e) Chart prepared and presented for comparative analysis between ISO certified and non ISO certified companies (Annexure-4 of Appendix-D).
2	To evaluate the impact of ISO9000 certification on the safety awareness level of employees working in petrochemical plants.	Null:- There is no significant improvement in the average safety awareness level of front runner employees with ISO certification. Alternate:- There is significant improvement in the average safety awareness level of front runner employees with ISO certification.	1) Questionnaire survey conducted among group of front runner employees (random sampling) within ISO certified and non ISO certified companies. 2) The responses were tabulated based on Lickert linear composite scale (Figure 3.3). 3) Scores obtained for each employee was tabulated (Annexure-1-Appendix-C). 4) Mean score for the total number of employees participated in the survey was noted for each ISO certified and non ISO certified company. 5) Paired "t" test was conducted to compare the means of the two populations.

8.1: Appendix A Table- A5

Tabulation of Techniques used and Analysis performed

	Objectives	Hypothesis	Techniques & Analysis
3	To determine the impact of ISO 9000 certification on the safety awareness level of Safety and Quality professional working in a petrochemical plant.	Null:- There is no significant improvement in the average safety awareness level of Safety and Quality professionals with ISO certification. Alternate:- There is significant improvement in the average safety awareness level of Safety and Quality professionals with ISO certification.	1) Questionnaire survey conducted among the safety and Quality professionals within ISO certified and non ISO certified companies. 2) The responses were tabulated based on Lickert linear composite scale (Figure 3.3). 3) Scores obtained for each employee was tabulated (Annexure-2 of Appendix-C). 4) Mean score for each of the Safety & Quality professional from ISO certified as well as non ISO certified company was calculated. 5) Mean scores tabulated as two sets of population data. 6) Paired "t" test was conducted to compare the means of the two populations.
4	To determine the impact of ISO 9000 certification on the safety awareness level of Managers working in a petrochemical plant.	Null:- There is no significant improvement in the average safety awareness level of managers with ISO certification. Alternate:- There is significant improvement in the average safety awareness level of managers with ISO certification.	1) Safety awareness questionnaire survey conducted among the managers within ISO certified and non ISO certified companies. 2) The responses were tabulated based on Lickert linear composite scale (Figure 3.3). 3) Scores obtained for each employee was tabulated (Annexure-3 of Appendix-C). 4) Mean score for each of the managers from ISO certified as well as non ISO certified company was calculated. 5) Mean scores tabulated as two sets of population data. 6) Paired "t" test was conducted to compare the means of the two populations.
5	To find out the effect of ISO 9000 certification on the risk perception level of managers working in the petrochemical companies.	Null:- There is no significant improvement in the risk perception level of managers with ISO certification. Alternate:- There is significant improvement in the risk perception level of managers with ISO certification.	1) Risk perception questionnaire survey conducted among the Managers within ISO certified and non ISO certified companies. 2) The responses were tabulated based on Lickert linear composite scale (Figure 3.3). 3) Scores obtained for each employee was tabulated (Annexure-4 of Appendix-C). 4) Mean score for each of the Managers from ISO certified as well as non ISO certified company was calculated. 5) Mean scores tabulated as two sets of population data. 6) Paired "t" test was conducted to compare the means of the two populations.

Tabulation of Techniques used and Analysis performed

	Objectives	Hypothesis	Techniques & Analysis
6	To find out the influence of ISO 9001 on the risk mitigation methods employed in atypical petrochemical company. The above referred objective was split into two:- *6.1) Primary objective:-* To verify if there is substantial improvement in the safety culture of the company after ISO certification in terms of work place precautions and risk mitigation. *6.2) Secondary objective:-* To validate the statistical test models used for the hypothesis tests.	Case study only- Validation of statistical test models used for the first hypothesis by using reactive data.	*6.1) Primary objective was achieved through the following:-* a) Selection of a typical ISO certified petrochemical company for the Case study. b) Conducted detailed investigation of the typical petrochemical company's methods of assessment, identification and mitigation of risk. c) Typical issues of risk mitigation which are linked to ISO 9001 were studied and its derived benefits noted. d) Inferences made are presented at section 4.4.2 of this report. *6.2) Secondary objective- Validation of statistical models:-* a) Reactive indicators (IR/FR/SR) data before and after ISO certification noted. b) Best of fit of data points done using Microsoft Excel. c) Regression analysis carried out to check the closeness of fit for the fitted line of data by using Minitab. d) Trend lines plotted for IR/FR and SR data separately and inferences made and presented at section 4.4 of this report. e) Un-stacked one way ANOVA (using Minitab) test done separately for IR, FR and SR values to verify the hypothesis (Annexure 5 of Appendix D). f) Box plots of data points are also made to indicate the clear difference in the mean values before and after ISO certification.

Annexure 1: Normal Probability Plots of IR, FR and SR Values

Safety data - Incident Rate (IR) Values

Sample companies	Mean Values of "IR" Before ISO certification	Mean Values of "IR" After ISO certification
Company1	4.28	0.94
Company2	9.6	7.1
Company3	26	15.75
Company4	2.3	1.29
Company5	11.93	8
Company6	12.48	9.44
Company7	3.78	0.83
Company8	3.47	0.82
Company9	6.25	1.56
Company10	7.92	2.36

Safety data - Frequency Rate (FR) Values

Sample companies	Mean Values of "FR" Before ISO certification	Mean Values of "FR" After ISO certification
Company1	1.5	0.28
Company2	2.37	0.34
Company3	1.99	0.17
Company4	0.45	0.23
Company5	2.16	1.63
Company6	3.34	1.64
Company7	0.49	0.25
Company8	1.18	0.26
Company9	1.98	0.42
Company10	1.14	0.25

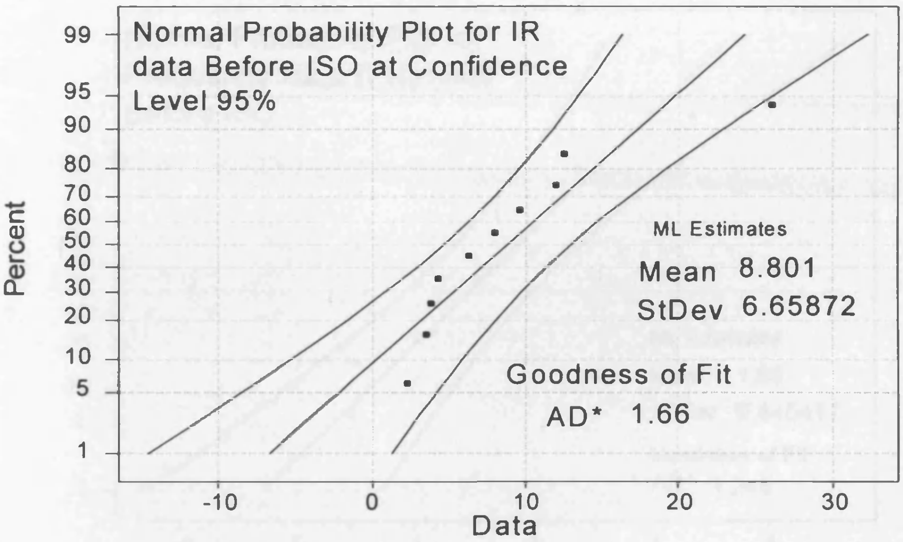
Safety data - Severity Rate (SR) Values

Sample companies	Mean Values of "FR" Before ISO certification	Mean Values of "FR" After ISO certification
Company1	14.88	3.06
Company2	1.202	0.97
Company3	18.93	10.63
Company4	9.13	3.59
Company5	1.95	0.58
Company6	6.33	2.95
Company7	9.69	4.14
Company8	7.12	2.78
Company9	6.42	2.86
Company10	10.78	1.29

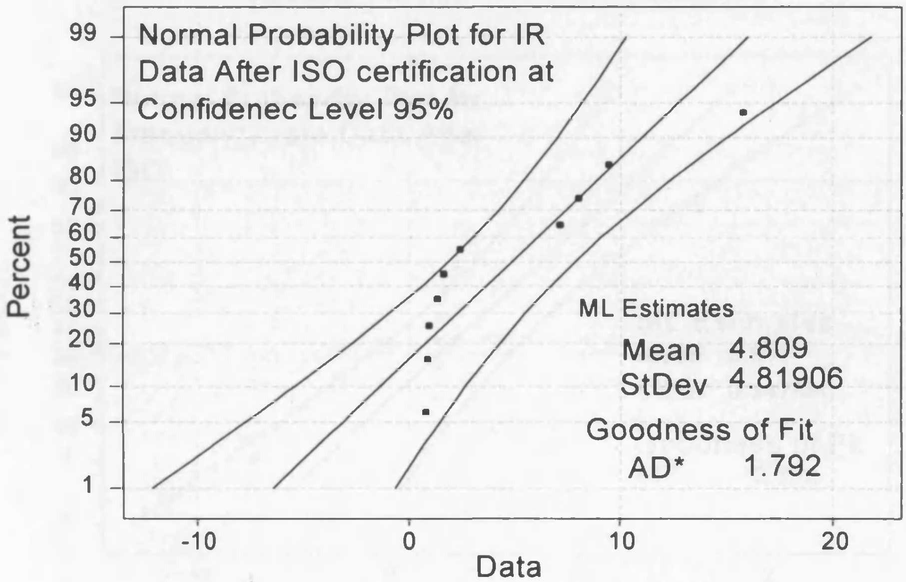
Annexure 1: Normal Probability Plots of IR, FR and SR Values

Test of Normality for Incident Rate Data for applying Pair-wise t-Test between Sample Means - IR values:-

Normal probability Plot for Incident Rate (IR) Data before ISO Certification at 95% Confidence Level



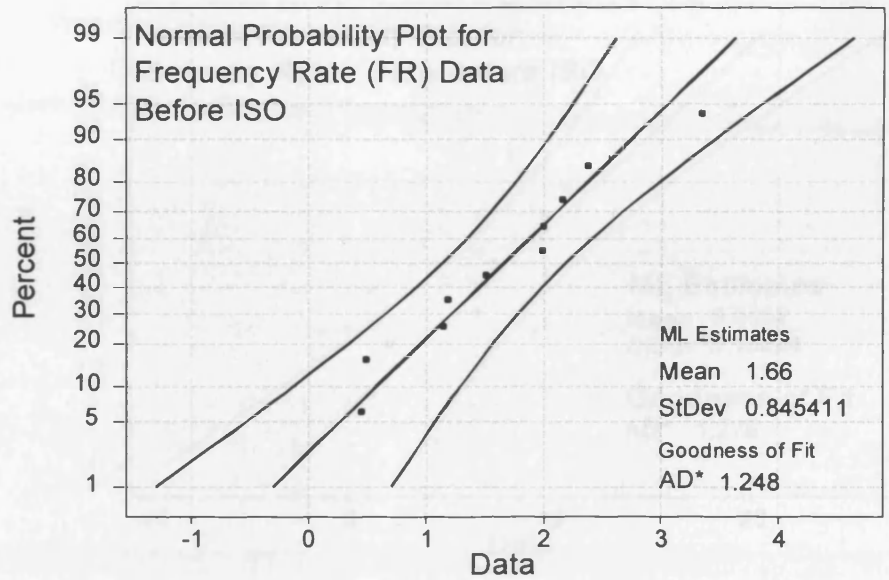
Normal probability Plot for Incident Rate (IR) Data after ISO Certification at 95% Confidence Level



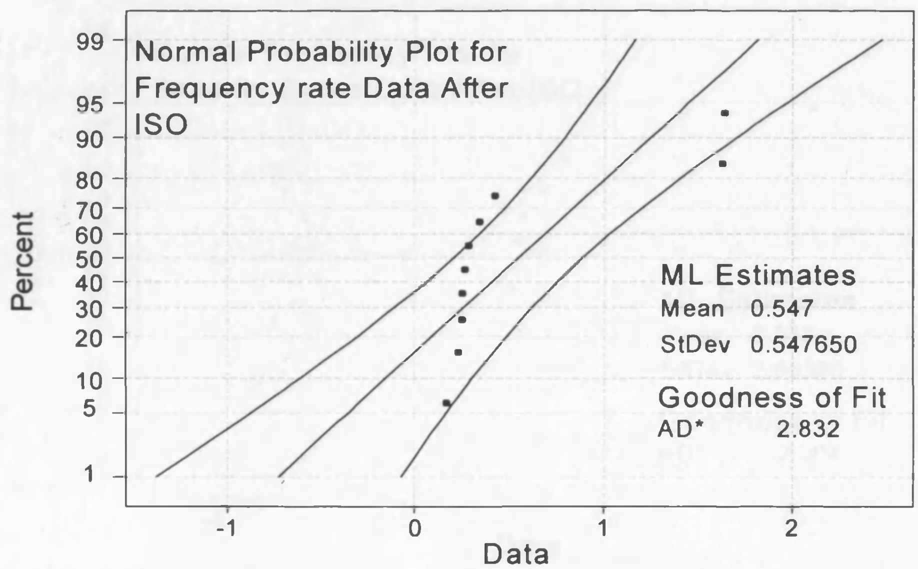
Annexure 1: Normal Probability Plots of IR, FR and SR Values

Test of Normality for Incident Rate Data for applying Pair-wise t-Test between Sample Means - FR values:-

Normal probability Plot for Frequency Rate (FR) Data before ISO Certification at 95% Confidence Level



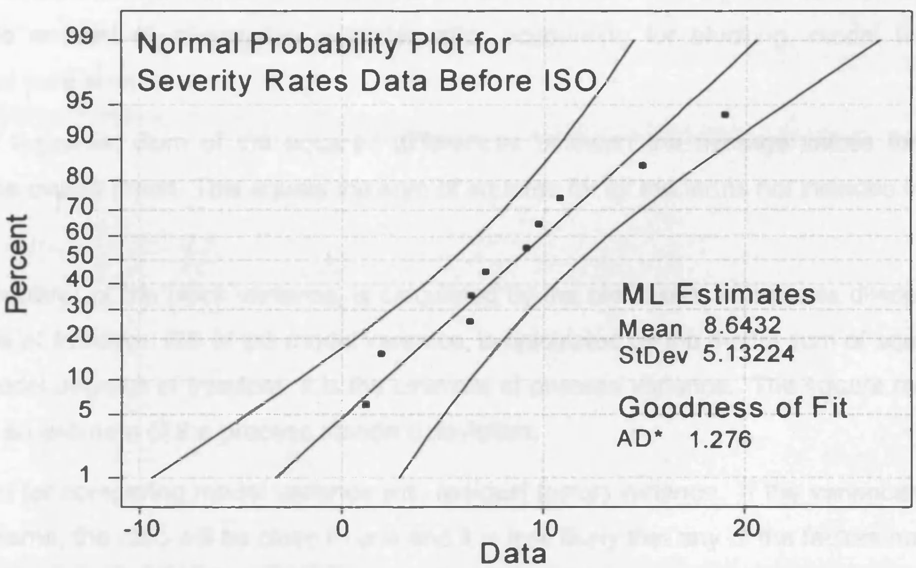
Normal probability Plot for Frequency Rate (FR) Data after ISO Certification at 95% Confidence Level



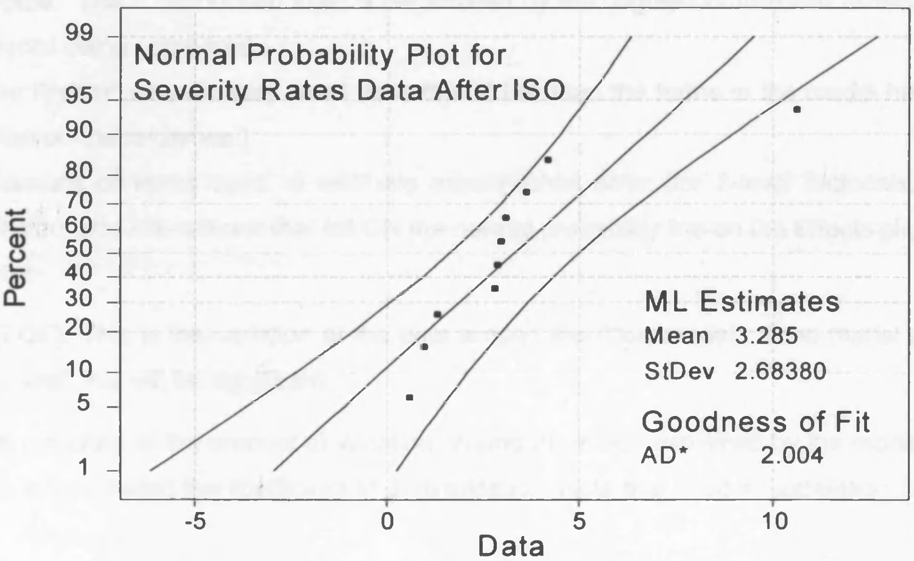
Annexure 1: Normal Probability Plots of IR, FR and SR Values

Test of Normality for Incident Rate Data for applying Pair-wise t-Test between Sample Means - SR values:-

Normal probability Plot for Severity Rate (SR) Data before ISO Certification at 95% Confidence Level



Normal probability Plot for Severity Rate (SR) Data after ISO Certification at 95% Confidence Level



Annexure 2: Regression analysis of IR, FR and SR values – Minitab Output

Minitab Output IR, FR & SR Values before ISO (IR1, FR1 & SR1) and after ISO (IR2, FR2 & SR2):

Definitions of terms:

DF: **Degrees of freedom** of **blocks**, generally equal to one less than the number of blocks. Degrees of freedom for the **model** is the number of model terms, including the intercept, minus one. It is the amount of information available after accounting for blocking, model terms, curvature, and pure error.

SS: **Sum of Squares**: Sum of the squared differences between the average values for the blocks and the overall mean. This equals the sum of squares for all the terms not included in the model.

MS: Mean Square: of the block variance, is calculated by the block sum of squares divided by block degrees of freedom. MS of the model variance, is calculated by the model sum of squares divided by model degrees of freedom. It is the estimate of process variance. The square root of this provides an estimate of the process standard deviation.

F Value: Test for comparing model variance with residual (error) variance. If the variances are close to the same, the ratio will be close to one and it is less likely that any of the factors have a significant effect on the response. F value is calculated by Model Mean Square divided by Residual Mean Square.

Prob > F: Probability of seeing the observed F value if the null hypothesis is true (there is no factor effect). Small probability values call for rejection of the null hypothesis. The probability equals the proportion of the area under the curve of the F-distribution that lies beyond the observed F value. The F distribution itself is determined by the degrees of freedom associated with the variances being compared.
(In short, if tne Prob>F value is very small (less than 0.05) then the terms in the model have a significant effect on the response.)
Residual: Consists of terms used to estimate experimental error (for 2-level factorials, the insignificant factors and interactions that fall ON the normal probability line on the Effects plot.)
Sum of Squares:

Lack of Fit (LOF): This is the variation of the data around the fitted model. If the model does not fit the data well, this will be significant.

R-Squared: A measure of the amount of variation around the mean explained by the model. R-squared. R-sq is also called the coefficient of determination. Note that R-sq = Correlation (Y, Y-hat)-squared. Also,
R-sq = (SS Regression)/(SS Total) (SS residual / (SS model + SS residual))

Annexure 2: Regression analysis of IR, FR and SR values – Minitab Output

R-squared adjusted: A measure of the amount of variation around the mean explained by the model, adjusted for the number of terms in the model. The adjusted R-squared decreases as the number of terms in the model increases if those additional terms don't add value to the model.

((SS residual / DF residual) / ((SS model + SS residual) / (DF model + DF residual)))

This is R-sq adjusted for degrees of freedom. If a variable is added to an equation, R-sq will get larger even if the added variable is of no real value. To compensate for this, Minitab also prints R-sq (adj). This is an approximately unbiased estimate of the population R-sq, and is calculated by the formula converted to percent. Here p is the number of coefficients fit in the regression equation. In the same notation, the usual R-sq is

R-sq = 1 – (SS Error / SS Total)

Annexure 2: Regression analysis of IR, FR and SR values – Minitab Output

Minitab Output IR, FR & SR Values before ISO (IR1, FR1 & SR1) and after ISO (IR2, FR2 & SR2):-

Regression Analysis - Fitted Line Plot for IR values Before ISO (IR1)

The regression equation is

IR1 = 601.6 - 0.3 Year Before

S = 0.714143 R-Sq = 55.3 % R-Sq (adj) = 47.8 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	3.78	3.78	7.41176	0.035
Error	6	3.06	0.51		
Total	7	6.84			

Regression Analysis - Fitted Line Plot for IR values After ISO (IR2)

The regression equation is

IR2 = -222.030 + 0.111429 ISO Year

S = 0.397193 R-Sq = 25.6 % R-Sq(adj) = 7.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.217286	0.217286	1.37730	0.306
Error	4	0.631048	0.157762		
Total	5	0.848333			

Annexure 2: Regression analysis of IR, FR and SR values – Minitab Output

Regression Analysis - Fitted Line Plot for FR values Before ISO (FR1)

The regression equation is

FR1 = 61.5107 - 0.0303571 Before ISO

S = 0.614204 R-Sq = 1.7 % R-Sq(adj) = 0.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.03871	0.038705	0.102600	0.760
Error	6	2.26348	0.377247		
Total	7	2.30219			

Regression Analysis - Fitted Line Plot for FR values After ISO (FR2)

The regression equation is

FR2 = 44.8459 - 0.0222857 After ISO

S = 0.171203 R-Sq = 6.9 % R-Sq(adj) = 0.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.008691	0.0086914	0.296530	0.615
Error	4	0.117242	0.0293105		
Total	5	0.125933			

Annexure 2: Regression analysis of IR, FR and SR values – Minitab Output

Regression Analysis - Fitted Line Plot for SR values Before ISO (SR1)

The regression equation is

SR1 = -2937.83 + 1.47857 Before ISO

S = 5.05438 R-Sq = 37.5 % R-Sq(adj) = 27.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	91.819	91.8193	3.59416	0.107
Error	6	153.281	25.5468		
Total	7	245.100			

Regression Analysis - Fitted Line Plot for SR values After ISO (SR2)

The regression equation is

SR2 = 2952.86 - 1.47429 After ISO

S = 1.91604 R-Sq = 72.1 % R-Sq(adj) = 65.2 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	38.0366	38.0366	10.3608	0.032
Error	4	14.6848	3.6712		
Total	5	52.7213			

Annexure 3: Incident Rate Analysis - Paired Two Sample t-Test for Means

Analysis of Incident Rate Values at Alpha = 0.05

Sample companies	Mean Valuesof "IR" Before ISO certification	Mean Valuesof "IR" After ISO certification
Company1	4.28	0.94
Company2	9.6	7.1
Company3	26	15.75
Company4	2.3	1.29
Company5	11.93	8
Company6	12.48	9.44
Company7	3.78	0.83
Company8	3.47	0.82
Company9	6.25	1.56
Company10	7.92	2.36

t-Test: Paired Two Sample for Means

Significance Level:	**0.05**	
	Mean Valuesof "IR" Before ISO certification	Mean Valuesof "IR" After ISO certification
Mean	8.801	4.809
Variance	49.26509889	25.80372111
Observations	10	10
Pearson Correlation	0.963218923	
Hypothesized Mean Difference	0	
df	9	
t Stat	4.996564037	
P(T<=t) one-tail	0.000371221	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.000742442	
t Critical two-tail	2.262158887	

Annexure 3: Incident Rate Analysis - Paired Two Sample t-Test for Means

Analysis of Incident Rate Values at Alpha = 0.01

Sample companies	Mean Valuesof "IR" Before ISO certification	Mean Valuesof "IR" After ISO certification
Company1	4.28	0.94
Company2	9.6	7.1
Company3	26	15.75
Company4	2.3	1.29
Company5	11.93	8
Company6	12.48	9.44
Company7	3.78	0.83
Company8	3.47	0.82
Company9	6.25	1.56
Company10	7.92	2.36

t-Test: Paired Two Sample for Means

Significance level:	**0.01**	
	Mean Valuesof "IR" Before ISO certification	Mean Valuesof "IR" After ISO certification
Mean	8.801	4.809
Variance	49.26509889	25.80372111
Observations	10	10
Pearson Correlation	0.963218923	
Hypothesized Mean Difference	0	
df	9	
t Stat	4.996564037	
P(T<=t) one-tail	0.000371221	
t Critical one-tail	2.821434464	
P(T<=t) two-tail	0.000742442	
t Critical two-tail	3.249842848	

Annexure 3: Incident Rate (IR) Analysis

IR Values Before ISO Certification

	Company1		Company2		Company3		Company4		Company5		Company6		Company7		Company8		Company9		Company10	
	Year	X1	Year	X2	Year	X4	Year	X5	Year	X6	Year	X6	Year	X6	Year	X6	Year	X6	Year	X6
1	1986	8.00	1996	8.67	1996	29.00	1994	3.4	1996	13.80	1990	17.20	1994	5.2	1992	5.90	1993	6.70	1992	11.84
2	1987	5.00	1997	9.29	1997	30.00	1995	1.47	1997	9.30	1991	10.12	1995	3.49	1993	5.40	1994	6.30	1993	9.68
3	1988	5.00	1998	9.91	1998	24.00	1996	2.65	1998	12.70	1992	10.13	1996	2.65	1994	4.20	1995	7.00	1994	7.31
4	1989	5.00	1999	10.53	1999	21.00	1997	1.67							1995	4.80	1996	5.00	1995	2.83
5	1990	4.00													1996	2.00				
6	1991	3.90													1997	4.10				
7	1992	4.30													1998	2.80				
8	1993	5.10													1999	0.90				
9	1994	3.10													2000	1.16				
10	1995	3.30																		
11	1996	2.80																		
12	1997	1.90																		
Mean		4.28		9.60		26.00		2.30		11.93		12.48		3.78		3.47		6.25		7.92

IR Values After ISO Certification

	ISO_C1		ISO_C2		ISO_C3		ISO_C4		ISO_C5		ISO_C6		ISO_C7		ISO_C8		ISO_C9		ISO_C10	
	Year	Y1	Year	Y2	Year	Y4	Year	Y5	Year	Y6	Year	Y6	Year	Y6	Year	Y6	Year	Y6	Year	Y6
1	1998	0.60	2000	11.27	2000	12.00	1998	1.77	1999	6.93	1993	10.05	1997	1.8	2001	1.02	1997	3.80	1996	2.69
2	1999	0.40	2001	11.77	2001	12.00	1999	1.78	2000	8.18	1994	9.27	1998	0.77	2002	0.87	1998	2.20	1997	3.48
3	2000	0.90	2002	4.77	2002	21.00	2000	1.06	2001	12.70	1995	8.68	1999	0.71	2003	0.56	1999	0.73	1998	3.31
4	2001	1.60	2003	4.77	2003	18.00	2001	1.01	2002	7.20	1996	13.80	2000	0.77			2000	1.30	1999	2.30
5	2002	0.80					2002	1.12	2003	5.00	1997	9.30	2001	0.67			2001	1.40	2000	2.49
6	2003	1.00					2003	1.02			1998	12.70	2002	0.65			2002	0.90	2001	1.23
7											1999	6.93	2003	0.46			2003	0.60	2002	1.89
8											2000	8.18							2003	1.40
9											2001	12.70								
10											2002	7.20								
11											2003	5.00								
	Mean	0.94		7.10		15.75		1.29		8.00		9.44		0.83		0.82		1.56		2.35

8.2: Appendix B

Annexure 4: Frequency Rate Analysis - Paired Two sample t-Test for Means

Analysis of Frequency Rate Values at Alpha = 0.05

Sample companies	Mean Valuesof "FR" Before ISO certification	Mean Valuesof "FR" After ISO certification
Company1	1.5	0.28
Company2	2.37	0.34
Company3	1.99	0.17
Company4	0.45	0.23
Company5	2.16	1.63
Company6	3.34	1.64
Company7	0.49	0.25
Company8	1.18	0.26
Company9	1.98	0.42
Company10	1.14	0.25

t-Test: Paired Two Sample for Means

Significance level	**0.05**	
	Mean Valuesof "FR" Before ISO certification	Mean Valuesof "FR" After ISO certification
Mean	1.66	0.547
Variance	0.794133333	0.333245556
Observations	10	10
Pearson Correlation	0.676408018	
Hypothesized Mean Difference	0	
df	9	
t Stat	5.35836341	
P(T<=t) one-tail	0.000228648	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.000457296	
t Critical two-tail	2.262158887	

8.2: Appendix B

Annexure 4: Frequency Rate Analysis - Paired Two Sample t-Test for Means

Analysis of Frequency Rate Values at Alpha = 0.01

Sample companies	Mean Valuesof "FR" Before ISO certification	Mean Valuesof "FR" After ISO certification
Company1	1.5	0.28
Company2	2.37	0.34
Company3	1.99	0.17
Company4	0.45	0.23
Company5	2.16	1.63
Company6	3.34	1.64
Company7	0.49	0.25
Company8	1.18	0.26
Company9	1.98	0.42
Company10	1.14	0.25

t-Test: Paired Two Sample for Means

Signifcance level:	**0.01**	
	Mean Valuesof "FR" Before ISO certification	Mean Valuesof "FR" After ISO certification
Mean	1.66	0.547
Variance	0.794133333	0.333245556
Observations	10	10
Pearson Correlation	0.676408018	
Hypothesized Mean Difference	0	
df	9	
t Stat	5.35836341	
P(T<=t) one-tail	0.000228648	
t Critical one-tail	2.821434464	
P(T<=t) two-tail	0.000457296	
t Critical two-tail	3.249842848	

Annexure 4: Frequency Rate (FR) Analysis

FR Values Before ISO Certification

	Company1		Company2		Company3		Company4		Company5		Company6		Company7		Company8		Company9		Company10	
	Year	X1	Year	X2	Year	X4	Year	X5	Year	X6	Year	X6	Year	X6	Year	X6	Year	X6	Year	X6
1	1986	2.40	1996	4.10	1996	3.00	1994	0.56	1996	1.90	1990	4.02	1994	0.56	1992	2.30	1993	2.60	1992	1.80
2	1987	2.20	1997	1.80	1997	1.50	1995	0.46	1997	2.60	1991	2.80	1995	0.46	1993	3.40	1994	2.00	1993	1.57
3	1988	3.00	1998	2.40	1998	2.00	1996	0.44	1998	1.98	1992	3.20	1996	0.44	1994	1.20	1995	1.90	1994	0.54
4	1989	2.50	1999	1.20	1999	1.47	1997	0.35							1995	0.90	1996	1.40	1995	0.64
5	1990	2.00													1996	1.00				
6	1991	0.35													1997	0.70				
7	1992	0.50													1998	0.50				
8	1993	1.10													1999	0.35				
9	1994														2000	0.30				
10	1995	1.60																		
11	1996	1.10																		
12	1997	0.70																		
Mean		1.59		2.38		1.99		0.45		2.16		3.34		0.49		1.18		1.98		1.14

Annexure 4: Frequency Rate (FR) Analysis

FR Values After ISO Certification

	Company1		Company2		Company3		Company4		Company5		Company6		Company7		Company8		Company9		Company10	
	Year	Y1	Year	Y2	Year	Y4	Year	Y5	Year	Y6	Year	Y6	Year	Y6	Year	Y6	Year	Y6	Year	Y6
1	1998	0.20	2000	0.40	2000	0.35	1998	0.34	1999	2.34	1993	1.11	1997	0.35	2001	0.33	1997	0.44	1996	0.12
2	1999	0.26	2001	0.22	2001	0.13	1999	0.33	2000	2.16	1994	1.08	1998	0.34	2002	0.22	1998	0.49	1997	0.46
3	2000	0.40	2002	0.41	2002	0.13	2000	0.32	2001	1.38	1995	1.20	1999	0.33	2003	0.24	1999	0.56	1998	0.33
4	2001	0.50	2003	0.40	2003	0.06	2001	0.08	2002	1.10	1996	1.90	2000	0.32			2000	0.38	1999	0.42
5	2002	0.10					2002	0.15	2003	1.18	1997	2.60	2001	0.08			2001	0.41	2000	0.10
6	2003	0.12					2003	0.15			1998	1.98	2002	0.15			2002	0.40	2001	0.19
7											1999	2.34	2003	0.15			2003	0.24	2002	0.19
8											2000	2.16							2003	0.19
9											2001	1.38								
10											2002	1.10								
11											2003	1.18								
	Mean	0.28		0.34		0.17		0.23		1.63		1.64		0.25		0.26		0.42		0.25

Annexure 5: Severity Rate Analysis - Paired Two Sample t - Test for Means

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Analysis of Severity Rate Values at Alpha = 0.05

Sample companies	Mean Valuesof "FR" Before ISO certification	Mean Valuesof "FR" After ISO certification
Company1	14.88	3.06
Company2	1.202	0.97
Company3	18.93	10.63
Company4	9.13	3.59
Company5	1.95	0.58
Company6	6.33	2.95
Company7	9.69	4.14
Company8	7.12	2.78
Company9	6.42	2.86
Company10	10.78	1.29

t-Test: Paired Two Sample for Means

Significance level:	**0.05**	
	Mean Valuesof "FR" Before ISO certification	Mean Valuesof "FR" After ISO certification
Mean	8.6432	3.285
Variance	29.26651573	8.003094444
Observations	10	10
Pearson Correlation	0.789567977	
Hypothesized Mean Difference	0	
df	9	
t Stat	4.681126698	
P(T<=t) one-tail	0.000575187	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.001150375	
t Critical two-tail	2.262158887	

Annexure 5: Severity Rate Analysis - Paired Two Sample t - Test for Means

Analysis of Severity Rate Values at Alpha = 0.01

Sample companies	Mean Valuesof "FR" Before ISO certification	Mean Valuesof "FR" After ISO certification
Company1	14.88	3.06
Company2	1.202	0.97
Company3	18.93	10.63
Company4	9.13	3.59
Company5	1.95	0.58
Company6	6.33	2.95
Company7	9.69	4.14
Company8	7.12	2.78
Company9	6.42	2.86
Company10	10.78	1.29

t-Test: Paired Two Sample for Means

Significance level:	**0.01**	
	Mean Valuesof "FR" Before ISO certification	Mean Valuesof "FR" After ISO certification
Mean	8.6432	3.285
Variance	29.26651573	8.003094444
Observations	10	10
Pearson Correlation	0.789567977	
Hypothesized Mean Difference	0	
df	9	
t Stat	4.681126698	
P(T<=t) one-tail	0.000575187	
t Critical one-tail	2.821434464	
P(T<=t) two-tail	0.001150375	
t Critical two-tail	3.249842848	

Annexure 5: Severity Rate (SR) Analysis

SR Values Before ISO Certification

	Company1		Company2		Company3		Company4		Company5		Company6		Company7		Company8		Company9		Company10	
	Year	X1	Year	X2	Year	X3	Year	X4	Year	X5	Year	X6	Year	X7	Year	X8	Year	X9	Year	X10
1	1986	35.00	1996	0.93	1996	22.00	1994	10.74	1996	1.89	1990	7.20	1994	10.74	1992	6.70	1993	7.88	1992	11.84
2	1987	21.00	1997	1.12	1997	20.00	1995	9.63	1997	2.88	1991	6.00	1995	9.63	1993	9.20	1994	6.30	1993	16.81
3	1988	27.00	1998	1.60	1998	18.00	1996	8.7	1998	1.09	1992	5.80	1996	8.7	1994	7.30	1995	5.35	1994	0.95
4	1989	18.00	1999	1.16	1999	15.72	1997	7.43							1995	8.20	1996	6.16	1995	13.50
5	1990	12.00													1996	8.70				
6	1991	3.70													1997	6.56				
7	1992	4.60													1998	7.10				
8	1993	8.40													1999	5.88				
9	1994	2.90													2000	4.44				
10	1995	12.00																		
11	1996	14.00																		
12	1997	20.00																		
Mean		14.88		1.20		18.93		9.13		1.95		6.33		9.69		7.12		6.42		10.78

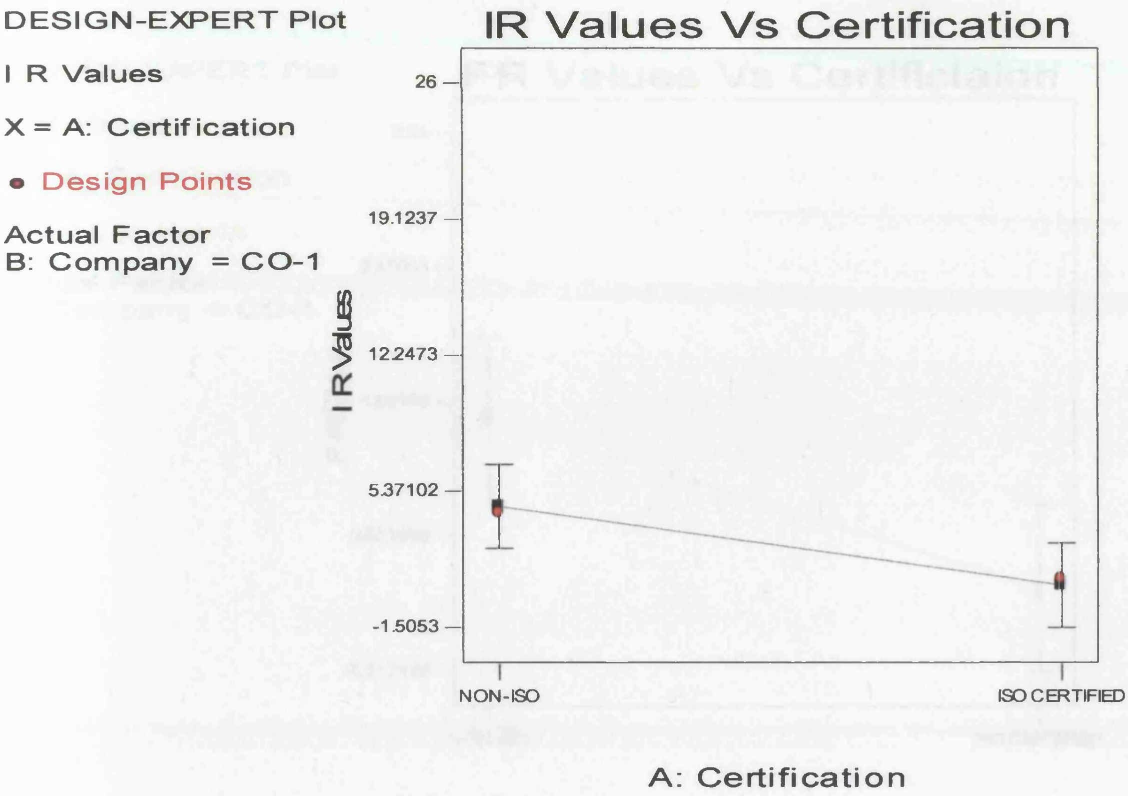
Annexure 5: Severity Rate (SR) Analysis

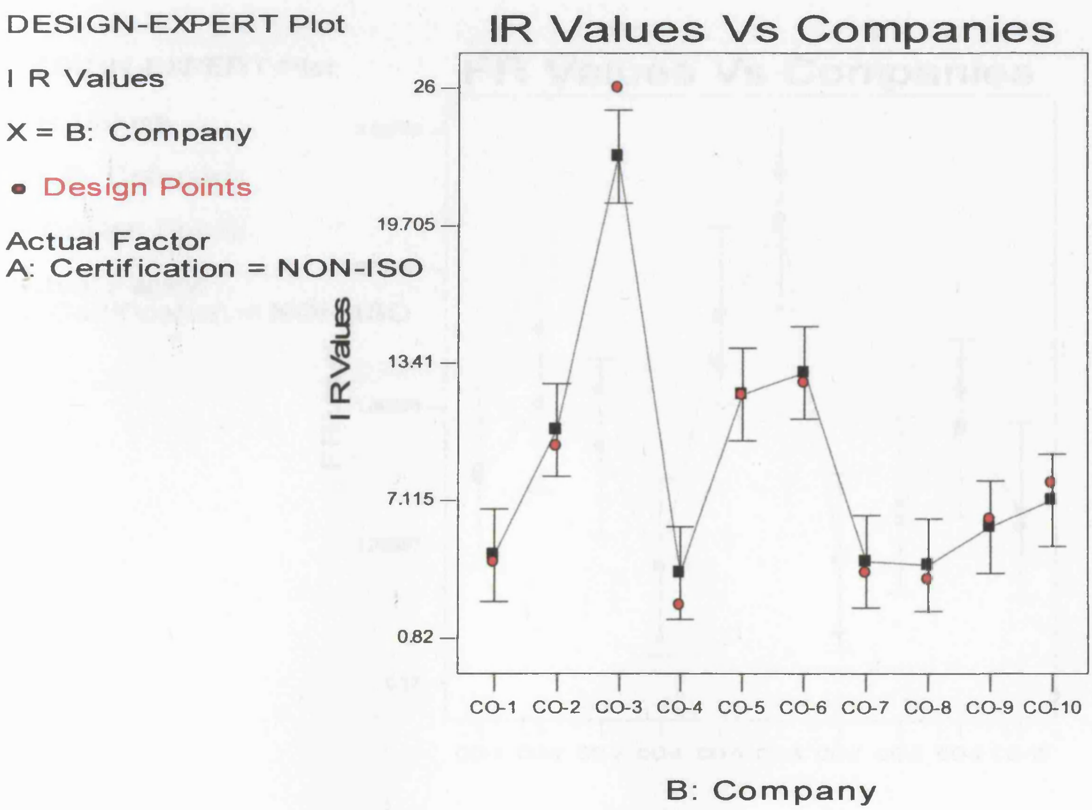
SR Values After ISO Certification

	Company1		Company2		Company3		Company4		Company5		Company6		Company7		Company8		Company9		Company10	
	Year	Y1	Year	Y2	Year	Y4	Year	Y5	Year	Y6	Year	Y6	Year	Y6	Year	Y6	Year	Y6	Year	Y6
1	1998	6.00	2000	0.62	2000	21.45	1998	6.2	1999	0.67	1993	2.80	1997	7.43	2001	4.02	1997	6.89	1996	0.24
2	1999	8.70	2001	1.11	2001	3.74	1999	5.06	2000	0.62	1994	7.30	1998	6.2	2002	3.10	1998	5.43	1997	2.20
3	2000	2.40	2002	0.93	2002	13.02	2000	3.95	2001	0.70	1995	4.02	1999	5.06	2003	1.23	1999	3.52	1998	0.33
4	2001	3.20	2003	0.87	2003	4.31	2001	3.12	2002	0.50	1996	3.76	2000	3.95			2000	2.00	1999	2.72
5	2002	0.60					2002	2.17	2003	0.40	1997	3.87	2001	3.12			2001	0.80	2000	1.89
6	2003	0.38					2003	1.05			1998	3.21	2002	2.17			2002	0.60	2001	0.85
7											1999	1.80	2003	1.05			2003	0.80	2002	1.61
8											2000	2.10							2003	0.50
9											2001	2.02								
10											2002	1.10								
11											2003	0.50								
	Mean	3.06		0.97		10.63		3.59		0.58		2.95		4.14		2.78		2.86		1.29

Annexure 6: Design Expert Output of Factor Effects and Interaction Plots

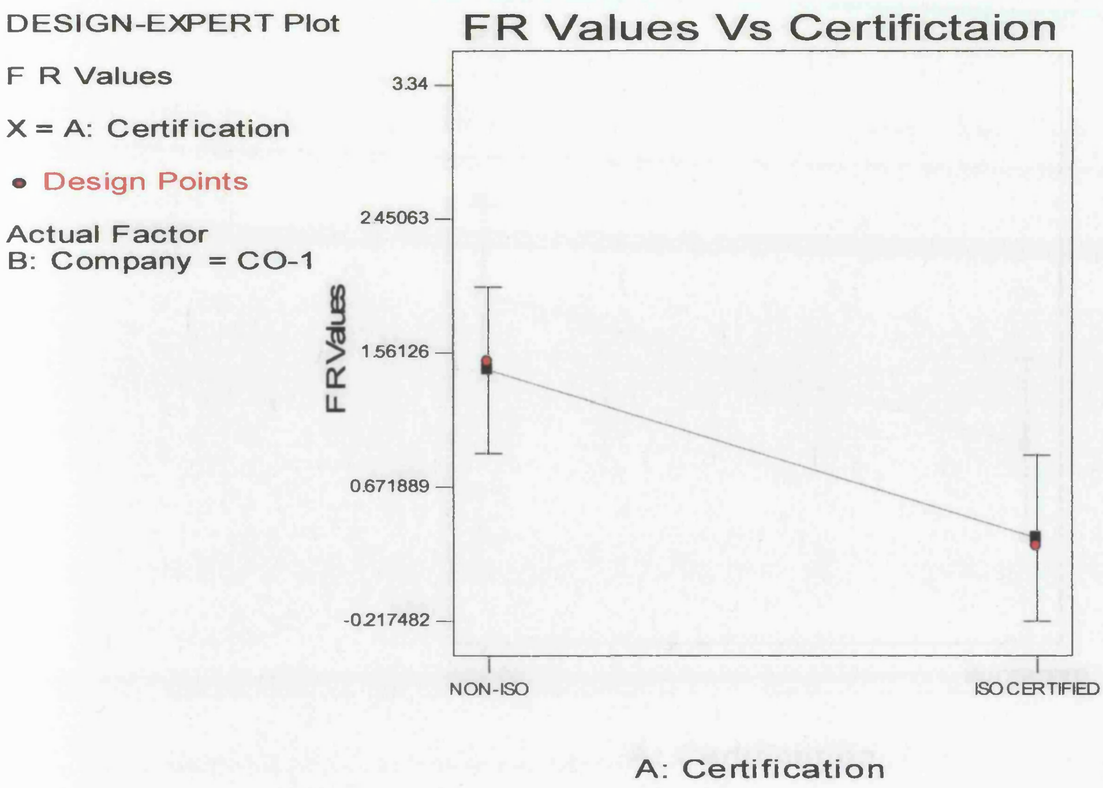
Effect of Certification on IR Values of Company1

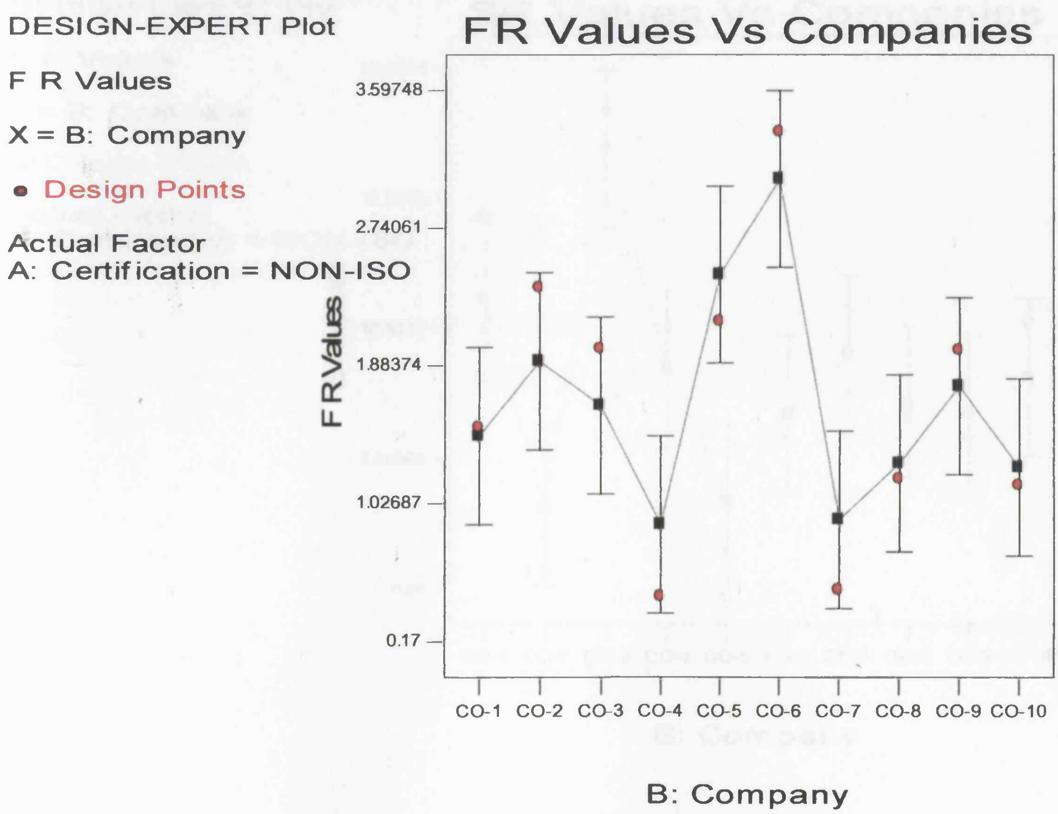




Annexure 6: Design Expert Output of Factor Effects and Interaction Plots

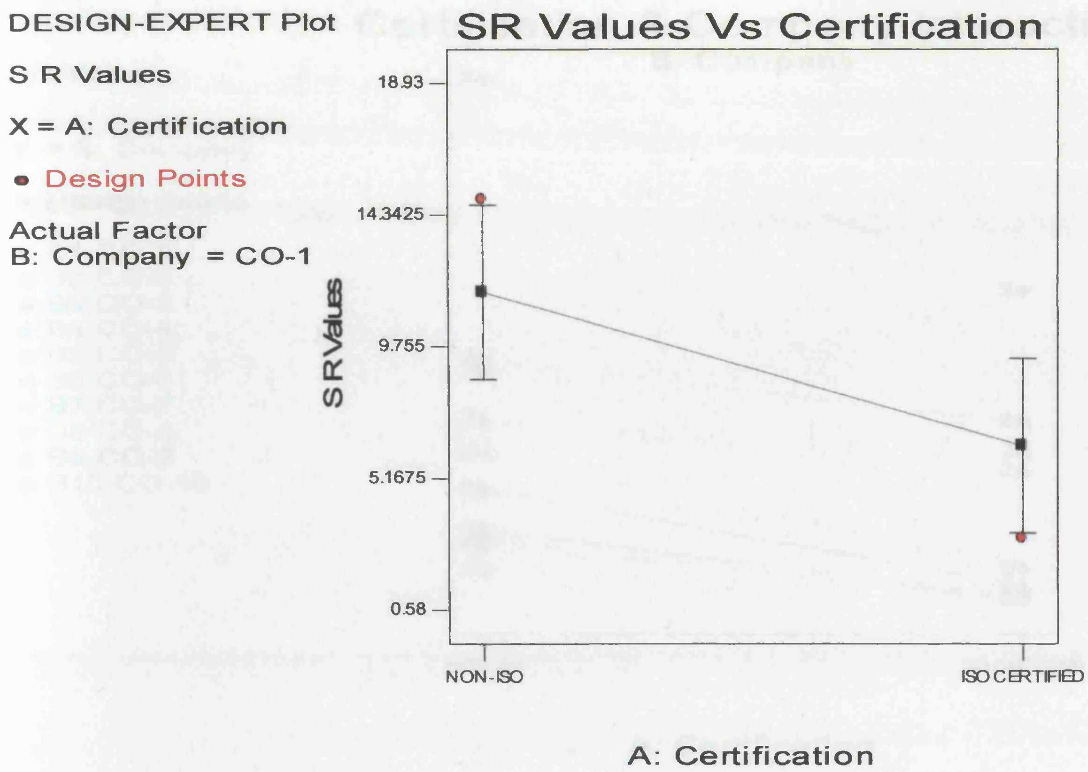
Effect of Certification on FR Values of Company1

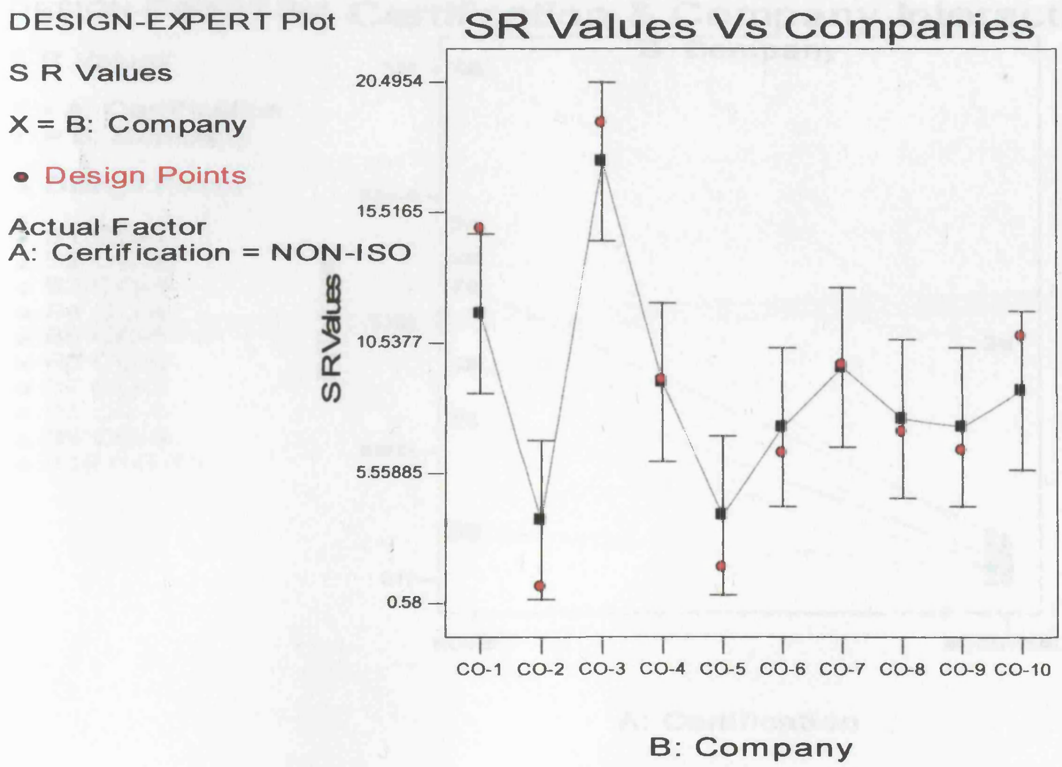




Annexure 6: Design Expert Output of Factor Effects and Interaction Plots

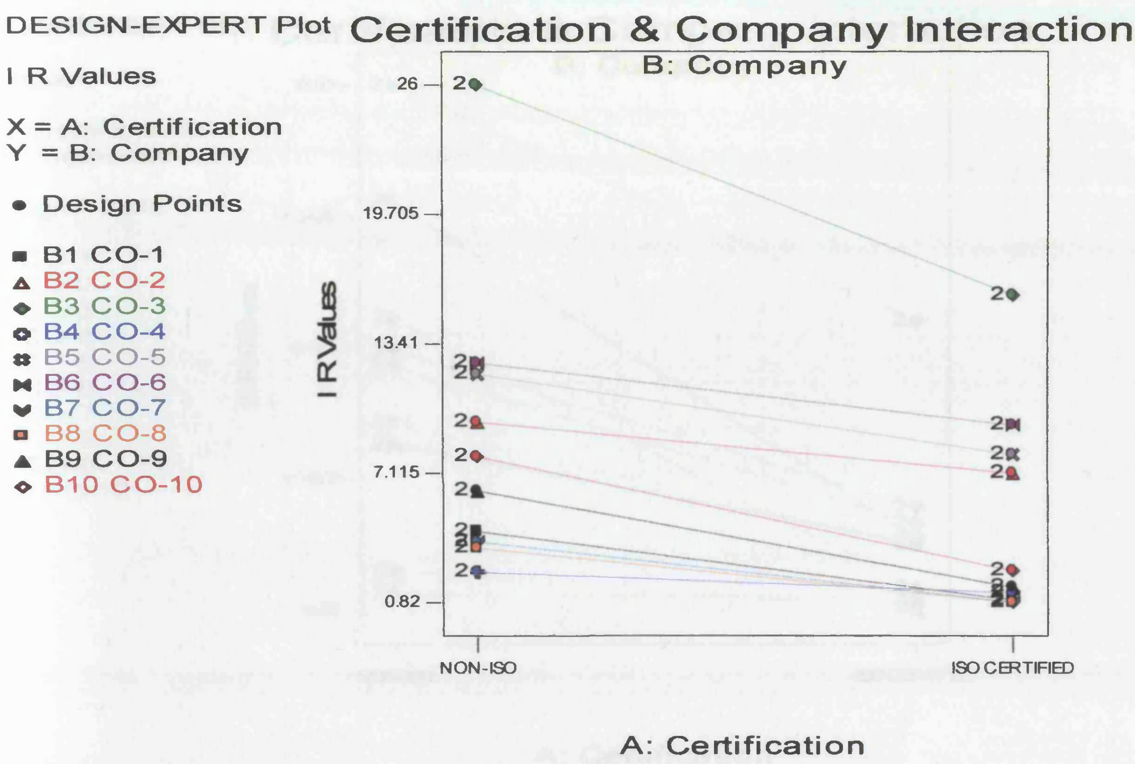
Effect of Certification on SR Values of Company1

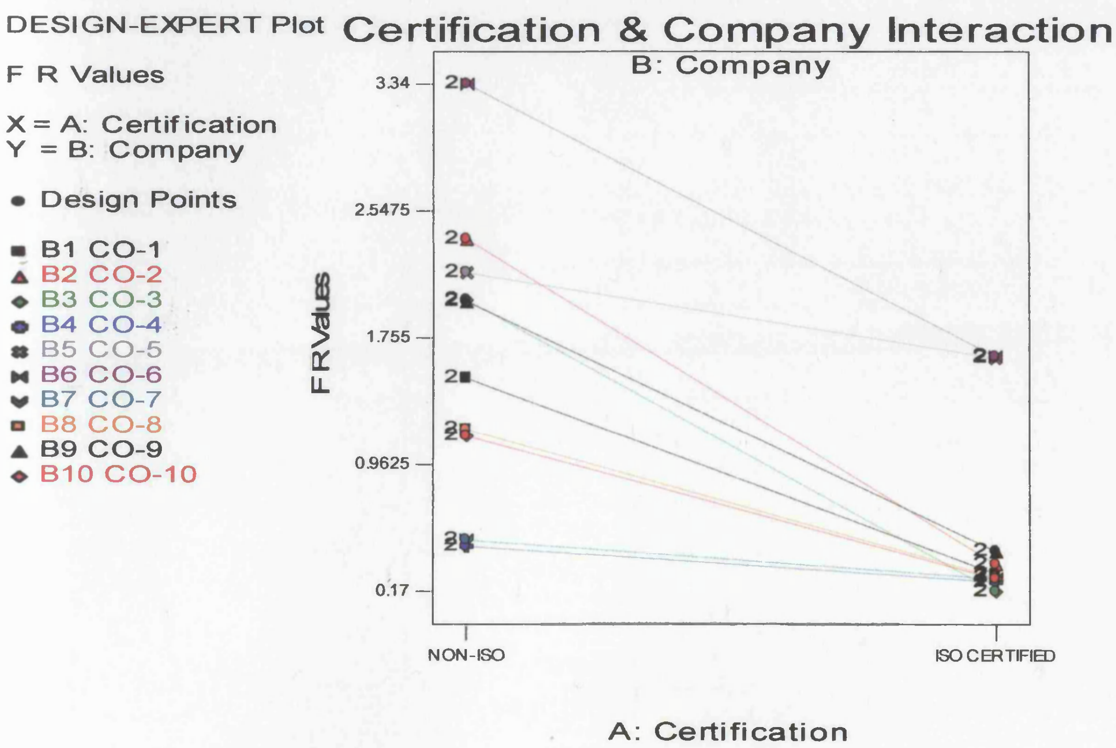




Annexure 6: Design Expert Output of Factor Effects and Interaction Plots

Interaction Plots: Certification Vs IR, SR and FR Values

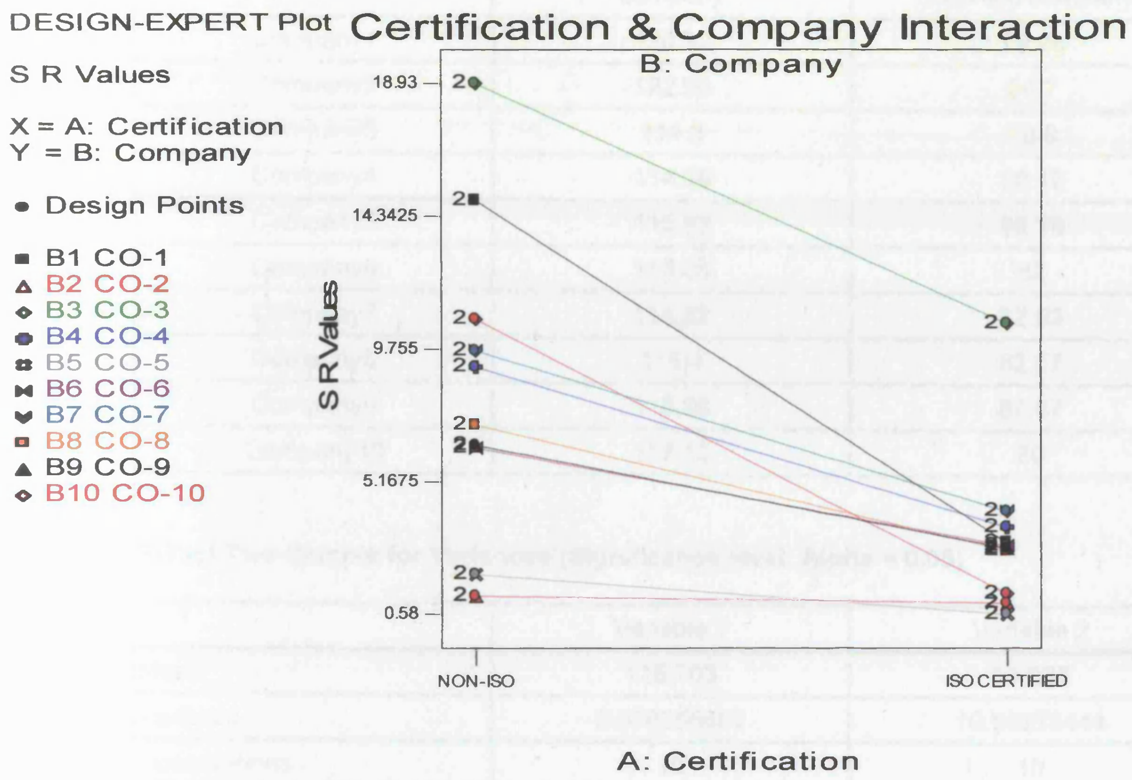




8.2 Appendix B

Annexure 6: Design Expert Output of Factor Effects and Interaction Plots

Interaction Plots: Certification Vs IR, SR and FR Values



Annexure 1: Questionnaire Survey - Employees

Safety Awareness Survey - Mean Scores for Employees

Sample companies	Mean score for ISO certified company	Mean score for ISO NOT certified company
Company1	120.32	79.96
Company2	122.96	84.7
Company3	114.8	79.9
Company4	114.28	80.12
Company5	115.92	82.16
Company6	115.04	82
Company7	114.32	72.59
Company8	115.4	82.57
Company9	116.86	82.67
Company10	117.13	80

F-Test Two-Sample for Variances (Significance level, Alpha = 0.05)

	Variable 1	Variable 2
Mean	116.703	80.667
Variance	8.076356667	10.55273444
Observations	10	10
df	9	9
F	0.765333072	
P(F<=f) one-tail	0.348402928	
F Critical one-tail	0.314575033	

t-Test: Two-Sample Assuming Unequal Variances (Alpha = 0.05)

	Variable 1	Variable 2
Mean	116.703	80.667
Variance	8.076356667	10.55273444
Observations	10	10
Hypothesized Mean Difference	0	
df	18	
t Stat	26.4022382	
P(T<=t) one-tail	3.80621E-16	
t Critical one-tail	1.734063062	
P(T<=t) two-tail	7.61242E-16	
t Critical two-tail	2.100923666	

Annexure 1: Questionnaire Survey - Employees

Safety Awareness Survey - Mean Scores for Employees

Sample companies	Mean score for ISO certified company	Mean score for ISO NOT certified company
Company1	120.32	79.96
Company2	122.96	84.7
Company3	114.8	79.9
Company4	114.28	80.12
Company5	115.92	82.16
Company6	115.04	82
Company7	114.32	72.59
Company8	115.4	82.57
Company9	116.86	82.67
Company10	117.13	80

F-Test: Two-Sample for Variances (Significance level (Alpha) = 0.01)

	Variable 1	Variable 2
Mean	116.703	80.667
Variance	8.076356667	10.55273444
Observations	10	10
df	9	9
F	0.765333072	
P(F<=f) one-tail	0.348402928	
F Critical one-tail	0.186876292	

t-Test: Two-Sample Assuming Unequal Variances (Alpha = 0.01)

	Variable 1	Variable 2
Mean	116.703	80.667
Variance	8.076356667	10.55273444
Observations	10	10
Hypothesized Mean Difference	0	
df	18	
t Stat	26.4022382	
P(T<=t) one-tail	3.80621E-16	
t Critical one-tail	2.552378646	
P(T<=t) two-tail	7.61242E-16	
t Critical two-tail	2.878441592	

Non ISO Certified Companies - Employees Questionnaire Survey Abstract

Employee total Score	Company1	Company2	Company3	Company4	Company5	Company6	Company7	Company8	Company9	Company10
E1	81	81	76	84	87	86	77	87	84	80
E2	80	87	82	82	84	75	65	84	92	74
E3	81	87	82	82	77	82	74	81	84	81
E4	76	91	80	72	88	77	66	81	78	80
E5	80	82	79	77	91	84	77	79	85	77
E6	78	82	83	86	85	80	75	83	82	81
E7	85	81	80	78	78	74	64	80	76	76
E8	83	81	81	80	78	74	64	81	85	84
E9	82	79	85	74	75	81	75	77	79	80
E10	81	82	79	82	88	78	68	89	86	80
E11	86	91	80	80	83	81	75	80	84	84
E12	83	88	77	81	83	87	80	75	76	76
E13	79	82	85	76	80	82	72	87	79	80
E14	75	83	80	78	82	88	78	82	83	84
E15	79	88	80	79	80	86	73	72	87	80
E16	83	83	78	83	82	83	68	86	86	81
E17	82	91	74	87	78	88	77	83	87	77
E18	84	86	82	87	84	90	73	82	74	83
E19	76	85	82	79	77	91	77	83	77	78
E20	76	84	76	76	82	73	70	85	85	86
E21	81		77	80	88		74	82	83	78
E22	78			79	80		75	89	82	
E23	72			80	84			91	81	
E24	78			81	81				89	
E25				80	79					
Mean score of Awareness Level	79.96	84.70	79.90	80.12	82.16	82.00	72.59	82.57	82.67	80.00

ISO Certified Companies- Employees Questionnaire Survey Abstract

Employee total Score	Company1	Company2	Company3	Company4	Company5	Company6	Company7	Company8	Company9	Company10
E1	114	134	125	110	115	115	128	104	115	109
E2	106	115	116	124	124	123	111	112	119	112
E3	126	112	112	123	120	111	121	109	109	118
E4	108	127	101	108	117	118	122	118	115	112
E5	119	119	114	109	116	117	109	123	111	116
E6	116	125	121	111	117	117	117	122	118	130
E7	121	117	110	110	106	113	119	106	120	109
E8	119	122	123	114	122	114	110	124	117	121
E9	129	129	127	118	118	113	119	117	118	119
E10	125	112	116	110	118	110	108	115	116	122
E11	104	122	111	124	120	114	120	116	121	120
E12	131	125	108	113	112	110	108	111	121	121
E13	115	135	112	112	107	110	112	108	113	115
E14	135	115	117	116	114	113	120	115	115	115
E15	126	116	113	128	122	120	131	116	109	116
E16	129	113	109	111	110	118	113	122	112	117
E17	124	124	108	102	109	114	112	111	112	112
E18	107	134	108	111	113	117	102	119	124	126
E19	132	126	115	106	114	115	112	124	118	118
E20	120	129	124	112	115	111	118	120	124	113
E21	124	134	114	121	107	115	107	107	127	116
E22	127	131	122	113	116	117	109	118		119
E23	123	126	125	114	127	121	117	116		122
E24	118	118	105	116	123		101	123		113
E25	110	114	114	121			112	109		
Mean Score of Awareness Level	120.32	122.96	114.80	114.28	115.92	115.04	114.32	115.40	116.86	117.13

Annexure-1: Questionnaire Survey – Employees

Safety Awareness Questionnaire

As you are aware Quality, Safety, Health and Environment Management Systems and Risk Assessment are becoming more and more popular now a days in the Petrochemical industry. Most of the Petrochemical Industry in the Middle East are ISO 9000 certified. As Petrochemical Industries is an export oriented industry. To be competitive in the market and to serve the society at large the importance of safety/risk in a petrochemical industry need to mention.

- I am conducting a research study about Management Systems existing in the Petrochemical Industry.
- The main objective of this survey is to find out safety awareness level of front line employees in the Petrochemical Industries.
- The requirement is to express your perception /view about various safety risks existing in your firm. Your valuable opinion will benefit the study and will be kept strictly confidential.
- Please complete this questionnaire and return it in the enclosed self-addressed envelope, if possible before 31/03/2004.

Thank you for your co-operation.

Yours sincerely,

Mohammed Al Mulla

Annexure-1: Questionnaire Survey – Employees

1. How many years experience you have in your present company?
   ☐ 1 to 5 ☐ 5 to 10 ☐ 10 to 15 ☐ 15 to 20 ☐ above 20

2. What is your present designation?
   ☐ Supervisor ☐ Foreman ☐ Sr. Techn/Sr. Fitter
   ☐ Sr. Operator☐Technician/Fitter ☐ Operator ☐ Others (Specify)

3. Is there an authorized Safety Policy issued by top management exists in your company?
   ☐ Yes ☐ Not Sure ☐No

4. Safety matters are given due importance in your company?
   ☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

5. The company has following Management Certification Systems.
   ☐ ISO 18001 ☐ ISO 9000 ☐ ISO 14000 ☐ Not Certified to any

6. Do Safety Audits conducted in your company?
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

7. Is Safety Data sheets of Hazardous materials exist in your company?
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

8. Personnel protection equipments are used while at work in my company.
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

9. Work permits are used for carrying out various works in the company.
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

10. Equipments in my plant are property labeled.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

11. Periodic medical check up exists in my company.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

12. First aid procedure exists in our company.
    ☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

13. Are safety rules followed willingly in our company?
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

14. Healthy and safety consequences of my day to day work/activities in the company is known to me.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

15. Improved performances of my work always have a direct benefit on the health and safety performance of the company.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

16. I am clear about my duties and responsibilities in case of an emergency.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

17. I am aware about potential consequences of departure from specified operating procedures of my work.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

Annexure-1: Questionnaire Survey – Employees

18. My company identifies and remedy shortfall of competencies and skills required for a job.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

19. I am provided with adequate training on safety.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

20. Role and responsibilities regarding safety issues are dear to me.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

21. My company carries out safety training and awareness program for contractors, temporary workers, visitors according to their level of exposure to work.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

22. Safety performance data is conveyed to all in my company.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

23. In my opinion, adequate training is required for carrying out a work having direct effect on OH&S.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

24. I am consulted by the management for making any changes that affect workplace health and safety.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

25. I consider employee awareness campaign is a must to build positive safety culture.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

26. I consider implementation of proper procedures to monitor and measure safety performance.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

27. My company has a permit system for entry/ exit of personnel to hazardous work site.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

28. My company has inspection/testing schedule for handling equipments like crane, fork lift etc.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

29. My company conduct safety practice drills as per predetermined schedule.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

30. My company has an evacuation procedure.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

31. My company uses symbols/labels to identify hazardous chemicals.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

Annexure 2: Questionnaire Survey - Safety and Quality Professional

Safety Awareness Survey - Mean Scores for Safety & Quality Professionals.

Safety Professional	Employee score for ISO certified companies	Employee score for ISO NOT certified companies
SP1	135	130
SP2	129	132
SP3	135	140
SP4	132	141
SP5	133	134
SP6	136	126
SP7	134	128
SP8	141	139
SP9	140	132
SP10	139	137
SP11	136	136
SP12	137	135
SP13	134	128
SP14	131	140
SP15	136	138
SP16	141	138
SP17	135	132
SP18	137	130
SP19	141	141
SP20	135	126
SP21	134	134
SP22	138	134
SP23	139	141
SP24	141	136
SP25	138	126

F-Test Two-Sample for Variances, Alpha = 0.05

	Variable 1	Variable 2
Mean	136.28	134.16
Variance	10.71	25.05666667
Observations	25	25
df	24	24
F	0.427431156	
P(F<=f) one-tail	0.021132064	
F Critical one-tail	0.504092768	

t-Test: Two-Sample Assuming Equal Variances, alpha = 0.05

	Variable 1	Variable 2
Mean	136.28	134.16
Variance	10.71	25.05666667
Observations	25	25
Pooled Variance	17.88333333	
Hypothesized Mean Difference	0	
df	48	
t Stat	1.772419958	
P(T<=t) one-tail	0.041335708	
t Critical one-tail	1.677224191	
P(T<=t) two-tail	0.082671417	
t Critical two-tail	2.01063358	

Annexure 2: Questionnaire Survey - Safety and Quality Professional

Safety Awareness Survey - Mean Scores for Safety & Quality Professionals.

Safety Professional	Safety Profesional score for ISO certified companies	Safety Profesional score for ISO NOT certified companies
SP1	135	130
SP2	129	132
SP3	135	140
SP4	132	141
SP5	133	134
SP6	136	126
SP7	134	128
SP8	141	139
SP9	140	132
SP10	139	137
SP11	136	136
SP12	137	135
SP13	134	128
SP14	131	140
SP15	136	138
SP16	141	138
SP17	135	132
SP18	137	130
SP19	141	141
SP20	135	126
SP21	134	134
SP22	138	134
SP23	139	141
SP24	141	136
SP25	138	126

F-Test: Two-Sample for Variances (Significance level (Alpha) = 0.01)

	Variable 1	Variable 2
Mean	136.28	134.16
Variance	10.71	25.05666667
Observations	25	25
df	24	24
F	0.427431156	
P(F<=f) one-tail	0.021132064	
F Critical one-tail	0.376072506	

t-Test: Two-Sample Assuming Unequal Variances, Alpha = 0.01

	Variable 1	Variable 2
Mean	136.28	134.16
Variance	10.71	25.05666667
Observations	25	25
Hypothesized Mean Difference	0	
df	41	
t Stat	1.772419958	
P(T<=t) one-tail	0.041877759	
t Critical one-tail	2.420802048	
P(T<=t) two-tail	0.083755518	
t Critical two-tail	2.701181074	

ISO Certified Companies - Safety & Quality Professional Questionnaire Survey Abstract

Quality/Safety Professional Total Score	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Total Score
SP1				5		4	5	5	5	5	5	5	5	5	4	4	4	5	5	5	4	5	4	5	5	4	5	5	5	4	4	4	5	135
SP2				4		4	4	4	5	5	4	5	5	5	4	3	4	4	5	5	4	4	4	5	5	4	5	5	5	5	5	4	4	129
SP3				5		4	5	5	5	5	5	5	5	5	4	4	4	5	5	5	4	5	4	5	5	4	5	5	5	4	4	4	5	135
SP4				4		4	5	5	5	5	5	5	5	5	5	4	5	3	5	5	4	5	4	5	4	4	5	5	5	4	4	3	5	132
SP5				4		5	5	4	5	5	3	5	5	5	4	3	4	5	5	5	4	5	4	5	5	5	5	5	5	4	5	4	5	133
SP6				5		4	5	4	5	5	4	5	5	5	4	5	4	5	5	5	4	5	4	5	5	4	5	5	5	5	4	5	5	136
SP7				5		5	4	4	5	5	3	5	5	5	4	5	4	5	5	5	4	5	4	5	5	5	5	5	5	4	5	3	5	134
SP8				4		5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	4	5	5	5	5	5	5	4	5	5	5	141
SP9				4		5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	4	5	4	5	5	4	5	5	5	5	5	5	5	140
SP10				5		5	4	4	5	5	5	5	5	5	4	5	5	5	5	5	4	5	4	5	5	4	5	5	5	5	5	5	5	139
SP11				5		4	5	5	5	5	5	5	5	5	4	5	4	5	5	5	5	5	5	5	5	4	5	5	5	4	3	3	5	136
SP12				5		5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	4	5	4	5	5	5	5	5	5	4	3	3	5	137
SP13				4		5	5	4	5	5	5	5	5	5	4	5	3	5	4	5	5	4	4	5	5	4	5	5	5	4	5	5	4	134
SP14				5		5	4	4	5	5	3	5	5	5	4	5	4	4	5	5	4	4	4	5	5	5	5	5	5	4	4	3	5	131
SP15				4		4	5	5	5	5	5	5	5	5	5	4	3	5	5	5	4	5	5	5	5	5	5	5	5	4	5	3	5	136
SP16				5		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	4	5	5	4	5	5	5	4	5	5	5	141
SP17				5		5	4	4	5	5	5	5	5	5	5	5	4	4	4	5	4	5	5	5	5	4	5	5	5	5	3	4	5	135
SP18				5		5	5	4	5	5	4	5	5	5	5	5	3	5	5	5	5	5	4	5	5	5	5	5	5	4	5	3	5	137
SP19				5		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	4	5	5	5	5	5	5	5	3	5	5	141
SP20				5		5	5	4	5	5	3	5	5	5	4	3	3	5	5	5	5	5	5	5	5	5	5	5	5	4	4	5	5	135
SP21				5		5	4	4	5	5	5	5	5	5	5	3	4	5	5	5	5	5	5	5	5	4	5	5	5	3	3	4	5	134
SP22				4		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	4	5	5	5	5	5	5	4	4	4	4	138
SP23				4		5	4	4	5	5	5	5	5	5	5	5	5	5	5	5	4	5	4	5	5	5	5	5	5	5	5	4	5	139
SP24				5		5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	4	5	5	5	4	4	5	5	141
SP25				5		5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	4	5	4	5	5	5	5	5	5	4	3	4	5	138
Questionwise Mean score				4.6		4.7	4.7	4.5	5.0	5.0	4.6	5.0	5.0	5.0	4.5	4.5	4.2	4.8	4.9	5.0	4.3	4.9	4.2	5.0	5.0	4.5	5.0	5.0	5.0	4.2	4.2	4.1	4.9	

Note: Questions 1, 2, 3 and 5 are general information and not considered for likert scale analysis.

Non-ISO Certified Companies - Safety & Quality Professional Questionnaire Survey Abstract

Quality/Safety Professional total Score	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Total Score
SP1				4		4	5	4	4	4	3	4	4	4	4	4	4	5	4	5	5	5	5	5	5	5	5	5	5	5	5	4	5	130
SP2				4		4	5	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	132
SP3				4		4	5	4	5	4	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	140
SP4				5		5	5	4	5	5	5	5	4	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	141
SP5				4		4	5	4	5	5	5	5	4	5	5	5	4	5	5	5	5	5	5	4	5	4	4	5	5	4	5	4	4	134
SP6				4		4	5	4	4	5	3	4	5	4	5	5	4	5	5	5	5	4	3	4	4	4	4	5	5	5	4	4	4	126
SP7				4		4	4	4	4	4	3	4	5	4	5	5	5	4	5	5	5	4	4	5	4	5	4	5	5	5	4	4	5	128
SP8				4		4	4	5	5	5	5	5	4	5	5	5	5	4	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	139
SP9				4		4	4	4	4	5	5	4	4	4	4	5	5	5	4	5	5	5	4	4	5	5	4	5	5	5	5	5	5	132
SP10				5		4	4	4	4	5	5	4	4	5	5	5	4	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	137
SP11				5		4	4	4	4	5	4	5	5	5	4	5	5	5	5	5	5	4	5	5	5	5	4	5	5	4	5	5	5	136
SP12				5		4	4	5	5	5	4	4	5	5	5	5	4	5	5	5	4	5	5	4	5	4	4	5	5	4	5	5	5	135
SP13				5		4	4	4	5	4	4	5	4	5	5	3	3	5	4	5	5	4	5	5	4	4	4	5	5	5	5	4	4	128
SP14				5		4	4	4	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	140
SP15				4		4	5	5	5	4	4	5	4	5	5	4	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	138
SP16				4		4	5	4	5	5	4	5	5	5	5	5	5	5	4	5	5	5	4	5	5	4	5	5	5	5	5	5	5	138
SP17				4		4	4	4	5	4	5	4	5	4	5	3	4	5	5	5	4	5	5	5	5	5	5	5	5	5	5	4	4	132
SP18				5		4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	4	5	4	5	4	5	4	5	4	4	4	130
SP19				5		4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	4	5	5	5	5	5	5	5	4	141
SP20				5		4	4	4	5	4	3	5	4	4	4	3	5	5	4	5	5	4	5	5	4	4	4	5	5	4	4	5	4	126
SP21				4		4	5	4	4	5	4	4	5	5	5	4	5	5	4	5	5	4	5	5	5	4	5	5	5	5	4	5	5	134
SP22				4		4	5	4	5	4	5	5	4	5	5	5	4	5	5	5	5	4	4	5	5	5	4	5	5	5	5	4	4	134
SP23				5		4	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	4	141
SP24				4		5	5	5	4	5	5	5	5	5	5	4	5	5	4	5	5	5	5	5	5	5	4	4	5	5	4	4	4	136
SP25				4		5	4	4	5	4	4	5	4	4	5	4	4	5	5	5	5	5	4	4	4	4	4	5	5	5	3	3	4	126
Questionwise Mean score				4.4		4.1	4.5	4.2	4.6	4.6	4.3	4.6	4.5	4.7	4.8	4.5	4.5	4.8	4.7	5.0	4.9	4.7	4.6	4.8	4.7	4.6	4.5	5.0	5.0	4.8	4.6	4.6	4.5	

Note: 1) @ 3 Professionals from 5 companies and 2 from another 5 companies(Total 25).
2) Q1, 2, 3 and 5 are general information only.

Annexure 2: Questionnaire Survey – Safety & Quality Professionals

Safety Awareness Questionnaire

Dear ______________________________,

As you are aware Quality, Safety, Health and Environment Management Systems and Risk Assessment are becoming more and more popular now a days in the Petrochemical Industry. Most of the Petrochemical Industries in the Middle East are ISO 9000 certified. As Petrochemical Industry is an export oriented industry. To be competitive in the market and to serve the society at large the importance of safety/risk in a petrochemical industry need no mention.

- I am conducting a research study about Management systems existing in the Petrochemical Industry.
- The main objective of this survey is to find out safety awareness level among **Safety and Quality professionals** working in the Petrochemical industries.
- The requirement is to express your perception /view about various safety risks existing in your firm. Your valuable opinion will benefit the study and will be kept strictly confidential.
- Please complete this questionnaire and return it in the enclosed self-addressed envelope, if possible before 31/03/2004.

Thank you for your co-operation

Yours sincerely

Mohammed Al Mulla

8.3: Appendix C

Annexure 2: Questionnaire Survey – Safety & Quality Professionals

1. How many years experience you have in your present company?
   ☐ 1 to 5 ☐ 5 to 10 ☐ 10 to 15 ☐ 15 to 20 ☐ above 20

2. What is your present designation?
   ☐ Safety Trainer ☐ safety Inspector ☐ Safety Engineer ☐ Others (Specify)

3. Is there an authorized Safety policy issued by top management exists in your company?
   ☐ Yes ☐ Not Sure ☐No

4. Safety matters are given due importance in your company?
   ☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

5. The company have following Management certification systems
   ☐ ISO 18001 ☐ ISO 9000 ☐ ISO 14000 ☐ Not Certified to any

6. Documented Safety standards exist in your company.
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

7. Safety Audits conducted are conducted regularly in our company.
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

8. Safety Data sheets of Hazardous materials exist in my company
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

9. I insist people working in the company always wear personnel protection equipments while at work
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

10. Work permit system is followed for carrying out various all works in the company
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

11. Equipments in my plant are property labeled.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

12. Labeling of equipment is a must for Safety.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

13. Periodic medical check up exists in my company.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

14. First aid procedure exists in your company.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

15. Safety rules must be followed willingly by all.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

16. My company has procedure for systematic identification of competencies required to carry out specific tasks.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

17. My company identifies and remedy shortfall of your competencies and skills.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

18. Safety training needs are to be identified timely in a systematic manner.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

Annexure 2: Questionnaire Survey – Safety & Quality Professionals

19. Adequate training on hazard identification, risk assessment and risk control must be provided to alt working personnel.
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

20. I consider role and responsibilities regarding safety issues need to be made dear to all.
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

21. Adequate safety training need to be provided for contractors, temporary workers, visitors according to their level of exposure to work.
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

22. Safety training records are maintained in my company.
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

23. Safety performance reports are generated and made available to all concerned.
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

24. I consider consulting my employees for matters that affect workplace health and safety.
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

25. I consider employee awareness campaign is a must to build positive safety culture.
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

26. I consider implementation of proper procedures to monitor and measure safety performance.
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

27. Accident/incident statistics regularly monitored and recorded in my firm.
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

28. Do you consider permit system is required for entry/ exit of personnel to hazardous work site?
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

29. Do you consider inspection/testing schedule and certification by approved agencies for handling equipments like crane, fork lift are required?
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

30. Do you consider requirement for establishing a procedure for safeguarding radiological sources?
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

31. Safety practice drills help to maintain safety awareness among employees
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

32. I consider mock drill need to be carried out for evacuation procedure
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

33. Use symbols/labels to identify hazardous chemicals reduce risk.
☐ Strongly Agree ☐Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

Annexure 3: Questionnaire Survey - Managers

Safety Awareness Survey - Mean Scores for Managers

Managers	Managers score for ISO certified companies	Managers score for Non ISO certified companies
M1	109	114
M2	134	113
M3	133	112
M4	122	112
M5	130	123
M6	120	109
M7	128	112
M8	132	131
M9	132	110
M10	134	110
M11	118	112
M12	132	112
M13	132	127
M14	106	109
M15	131	111
M16	131	113
M17	88	93
M18	131	105
M19	104	112
M20	126	95
M21	128	111
M22	130	114
M23	125	111
M24	135	120
M25	132	110

F-Test Two-Sample for Variances (Significance 0.05)

	Variable 1	Variable 2
Mean	124.92	112.04
Variance	135.7433333	63.04
Observations	25	25
df	24	24
F	2.153288917	
P(F<=f) one-tail	0.033071181	
F Critical one-tail	1.983757159	

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	Variable 2
Mean	124.92	112.04
Variance	135.7433333	63.04
Observations	25	25
Hypothesized Mean Difference	0	
df	42	
t Stat	4.567682232	
P(T<=t) one-tail	2.13784E-05	
t Critical one-tail	1.681951289	
P(T<=t) two-tail	4.27568E-05	
t Critical two-tail	2.018082341	

Annexure 3: Questionnaire Survey - Managers

Safety Awareness Survey - Mean Scores for Managers

Managers /Sectional Leaders	Managers score from ISO certified companies	Managers score from Non ISO certified companies
M1	109	114
M2	134	113
M3	133	112
M4	122	112
M5	130	123
M6	120	109
M7	128	112
M8	132	131
M9	132	110
M10	134	110
M11	118	112
M12	132	112
M13	132	127
M14	106	109
M15	131	111
M16	131	113
M17	88	93
M18	131	105
M19	104	112
M20	126	95
M21	128	111
M22	130	114
M23	125	111
M24	135	120
M25	132	110

F-Test: Two-Sample for Variances (significance 0.01)

	Variable 1	Variable 2
Mean	124.92	112.04
Variance	135.7433333	63.04
Observations	25	25
df	24	24
F	2.153288917	
P(F<=f) one-tail	0.033071181	
F Critical one-tail	2.659078291	

t-Test: Two-Sample Assuming Equal Variances (Significance 0.01)

	Variable 1	Variable 2
Mean	124.92	112.04
Variance	135.7433333	63.04
Observations	25	25
Pooled Variance	99.39166667	
Hypothesized Mean Difference	0	
df	48	
t Stat	4.567682232	
P(T<=t) one-tail	1.72662E-05	
t Critical one-tail	2.406577551	
P(T<=t) two-tail	3.45324E-05	
t Critical two-tail	2.682209015	

ISO Certified Companies - Managers Questionnaire Survey Abstract

Managers total Score	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Total Score
M1			5		4	3	5	5	3	4	4	4	5	4	3	3	4	4	4	4	4	5	4	5	3	4	5	4	5	2	109
M2			5		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	134
M3			5		5	5	5	5	5	4	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	133
M4			5		5	5	5	5	5	5	5	5	5	4	4	5	5	4	5	5	5	3	5	4	4	4	4	4	5	2	122
M5			5		5	5	5	5	5	5	4	5	5	5	4	5	5	5	5	4	5	5	4	5	5	4	5	5	5	5	130
M6			5		5	5	5	5	5	5	5	5	5	5	4	4	4	5	5	5	5	5	5	4	3	2	3	3	3	5	120
M7			5		5	5	4	4	5	4	4	5	5	4	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	4	128
M8			5		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	4	4	5	5	5	5	132
M9			5		5	5	5	5	5	5	5	5	5	5	4	5	5	4	5	5	5	5	4	5	5	5	5	5	5	5	132
M10			5		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	134
M11			5		4	4	5	5	5	5	4	4	5	3	4	5	4	4	4	4	4	4	4	4	5	5	5	5	5	3	118
M12			5		4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	5	5	5	5	5	5	5	5	5	132
M13			5		5	5	5	4	5	5	5	5	4	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	132
M14			5		5	5	4	5	4	4	4	4	4	4	4	4	3	3	4	4	3	3	4	4	4	3	3	4	4	4	106
M15			4		4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	5	5	5	5	5	5	5	5	131
M16			5		5	5	5	5	5	5	5	5	5	3	5	5	5	5	5	4	5	5	5	5	5	4	5	5	5	5	131
M17			5		4	2	3	4	4	2	3	4	2	4	5	4	1	2	2	3	5	4	4	4	3	3	5	1	3	2	88
M18			5		5	4	5	5	5	4	5	5	5	5	5	4	5	5	5	5	5	5	4	5	5	5	5	5	5	5	131
M19			5		3	4	3	4	4	4	4	3	4	3	3	4	4	4	3	5	4	5	3	5	5	3	4	5	4	2	104
M20			5		5	5	5	5	5	5	4	5	5	3	5	4	5	5	5	5	5	5	5	5	4	4	4	4	4	5	126
M21			5		5	5	5	5	5	4	5	5	4	5	5	4	5	5	5	4	5	5	5	4	5	4	5	5	4	5	128
M22			4		5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	4	5	4	5	5	5	5	5	5	4	130
M23			5		5	5	5	5	5	5	5	4	5	5	4	4	5	5	5	4	4	4	5	4	5	4	4	4	5	5	125
M24			5		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	135
M25			5		5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	4	5	5	5	5	5	5	132
Question wise Mean score			4.92		4.72	4.68	4.76	4.80	4.80	4.60	4.64	4.72	4.72	4.48	4.56	4.56	4.60	4.60	4.60	4.56	4.56	4.68	4.56	4.68	4.56	4.32	4.68	4.56	4.68	4.32	

Note: 1) Questions 1, 2 and 4 are general information and not considered for likert scale analysis.

2) Survey done from 3 Mangers from 5 Companies + 2 Managers from 4 Companies and 2 Managers from 1 Company.

Non-ISO Certified Companies-Managers Questionnaire Survey Abstract

Managers total Score	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Total Score
M1			4		5	5	5	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4	4	4	4	5	4	4	114
M2			5		5	4	5	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4	113
M3			5		5	5	4	4	5	4	4	4	3	3	4	4	5	4	4	4	4	4	4	4	4	4	4	5	4	4	112
M4			5		5	5	4	4	5	4	5	5	4	3	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	112
M5			4		5	5	4	5	5	4	5	5	5	5	5	4	5	5	5	4	4	4	4	4	4	4	4	5	5	5	123
M6			5		4	4	4	4	5	5	4	4	3	4	4	4	4	4	4	3	4	3	4	4	4	4	4	5	4	4	109
M7			4		5	4	4	5	5	4	4	4	3	4	5	4	4	4	4	4	4	4	4	4	4	4	4	5	4	4	112
M8			4		4	5	5	5	5	5	5	4	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	131
M9			5		4	4	4	4	4	5	5	4	4	4	4	5	4	3	3	3	4	4	4	4	4	4	4	5	4	4	110
M10			5		4	4	4	4	5	4	4	4	4	4	4	4	4	4	3	4	5	4	4	4	4	4	4	4	4	4	110
M11			5		5	4	4	4	5	4	4	5	4	3	4	4	5	4	3	4	4	4	4	4	4	4	4	5	4	4	112
M12			5		4	5	4	5	5	4	4	5	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	5	4	4	112
M13			5		5	5	4	5	5	5	4	5	5	5	4	5	5	4	5	4	5	4	5	4	5	4	5	5	5	5	127
M14			5		4	4	4	4	4	5	4	4	2	3	5	4	4	4	4	4	4	4	4	4	4	4	4	5	4	4	109
M15			4		4	5	5	5	4	4	4	5	4	2	4	4	4	4	4	4	4	4	4	4	4	4	4	5	4	4	111
M16			5		5	4	4	4	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	4	4	113
M17			5		4	4	4	4	5	3	4	4	3	4	4	3	4	3	3	3	3	4	2	3	3	3	3	2	3	3	93
M18			5		4	4	4	4	4	4	4	4	4	1	4	4	4	4	3	4	4	3	4	4	4	4	4	5	4	4	105
M19			5		5	4	5	5	4	5	5	5	4	1	5	4	4	3	4	4	4	3	4	4	4	4	4	5	4	4	112
M20			5		4	5	4	4	4	4	4	4	4	4	3	4	2	3	3	3	3	4	2	3	3	4	3	3	3	3	95
M21			4		4	4	5	4	4	5	4	4	4	3	5	4	5	4	4	3	4	4	4	4	4	4	4	5	4	4	111
M22			5		4	4	5	4	5	4	4	5	4	4	4	5	4	4	4	4	4	4	4	4	4	4	4	5	4	4	114
M23			5		4	4	5	4	5	4	4	4	3	4	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	111
M24			4		4	4	4	4	4	4	4	5	5	5	5	5	4	4	5	4	5	5	4	5	4	4	5	4	5	5	120
M25			5		4	4	4	4	5	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	5	4	4	110
Questionwise Mean score			4.72		4.40	4.36	4.32	4.28	4.68	4.28	4.20	4.36	3.84	3.60	4.24	4.20	4.24	3.88	3.92	3.80	4.08	3.92	3.92	4.00	4.00	4.00	4.04	4.60	4.08	4.08	

Note: 1) @ 3 Managers from 5 companies + 2 Managers from 4 companies+ 2 Managers from 1 company (Total 25).
2) Q1, 2 and 4 are general information only.

Annexure 3: Questionnaire Survey - Managers

Questionnaire Survey on Safety

Dear ______________________,

As you are aware Quality, Safety, Health and Environment Management Systems and Risk Assessment are becoming more and more popular now a days in the Petrochemical Industry. Most of the Petrochemical Industries in the Middle East are ISO 9000 certified. As Petrochemical Industry is an export oriented industry. To be competitive in the market and to serve the society at large the importance of safety/risk in a petrochemical industry need no mention.

- I am conducting Research Study about Management Systems existing in the Petrochemical Industry.
- The main objective of this survey is to find out the view of Managers working in the Petrochemical Industry about Safety.
- The requirement is to express your perception /view about various safety risks existing in your firm. Your valuable opinion will benefit the study and will be kept strictly confidential.
- Please complete this questionnaire and return it in the enclosed self-addressed envelope, if possible before 31/03/2004.

Thank you for your co-operation.

Yours sincerely,

Mohammed Al Mulla

Annexure 3: Questionnaire Survey - Managers

1. How many years experience you have in your present company?
   ☐ 1 to 5 ☐ 5 to 10 ☐ 10 to 15 ☐ 15 to 20 ☐ above 20
2. Is there an authorized Safety policy issued by top management exists in your company?
   ☐ Yes ☐ Not Sure ☐No
3. Safety matters are given due importance in my company.
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree
4. The company has following Management Certification Systems.
   ☐ ISO 18001 ☐ ISO 9000 ☐ ISO 14000 ☐ Not Certified to any
5. Documented Safety Standards exist in my company.
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree
6. Safety Audits conducted are conducted regularly in my company.
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree
7. Safety Data sheets of Hazardous materials existed and made accessible to concerned people.
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree
8. I insist use personnel protection equipments while at work.
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree
9. Work permits are must while carrying out various works in my company.
   ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree
10. Equipments in my plant are property labeled.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree
11. First aid procedure exists in my company.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree
12. In my opinion safety rules must be followed willingly by all at work.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree
13. Duties and responsibilities in case of an emergency are made clear to all in my department.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree
14. Systematic procedure is required to identify competencies required to carry out specific tasks.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree
15. I consider identification of training needs are in a systematic manner a must for safety.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree
16. Specific training on hazard identification, risk assessment and risk control required for better safety performance.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree
17. In my opinion safety training and awareness programme is a must for contractors, temporary workers, visitors according to their level of exposure to work.
    ☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

Annexure 3: Questionnaire Survey - Managers

18. Safety training records are to be maintained and made available to the employees for proper training need identification.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

19. Safety performance reporting helps to build a positive safety climate.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

20. Employee participation is a must to build positive safety culture
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

21. I consider proper procedure needs to be implemented to monitor and measure safety performance
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

22. I consider establishment of a clear policy is a must for safety management
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

23. Safety policy must be communicated to all employees
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

24. Proper clear objectives need for better safety management
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

25. Monitoring, review and corrective actions are to be carried for an effective safety management
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

26. Certification of overhead crane, mobile crane, fork lifts are to be carried out regularly
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

27. I consider it as a my prime duty to ensure safety of people work for me.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

28. Established procedures are required for safeguarding radiological sources existing in my company
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

29. Conducting safety practice drills at predetermined schedule helps safety awareness drive
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

30. Use symbols/labels to identify hazardous chemicals is a must to ensure safety.
☐ Strongly Agree ☐ Agree ☐ Not sure ☐ Disagree ☐ Strongly Disagree

Annexure 4: Risk Perception Survey - Managers

Risk Perception Survey - Mean Scores for Managers

Risk Perception survey Managers	Managers score from ISO certified companies	Managers score from ISO _NON certified companies
M1	114	85
M2	115	87
M3	114	87
M4	110	104
M5	111	87
M6	108	110
M7	89	90
M8	110	102
M9	113	88
M10	88	90
M11	111	85
M12	110	92
M13	107	88
M14	113	85
M15	109	78
M16	112	93
M17	108	85
M18	114	87
M19	112	91
M20	87	93
M21	113	79
M22	113	91
M23	86	106
M24	111	94
M25	113	82

F-Test Two-Sample for Variances at Significance, Alpha = 0.05

	Variable 1	Variable 2
Mean	107.64	90.36
Variance	84.90666667	62.74
Observations	25	25
df	24	24
F	1.353309956	
P(F<=f) one-tail	0.23206988	
F Critical one-tail	1.983757159	

t-Test: Two-Sample Assuming Equal Variances at Significance, Alpha = 0.05

	Variable 1	Variable 2
Mean	107.64	90.36
Variance	84.90666667	62.74
Observations	25	25
Pooled Variance	73.82333333	
Hypothesized Mean Difference	0	
df	48	
t Stat	7.110529117	
P(T<=t) one-tail	2.48935E-09	
t Critical one-tail	1.677224191	
P(T<=t) two-tail	4.97871E-09	
t Critical two-tail	2.01063358	

Annexure 4: Risk Perception Survey - Managers

Risk Perception Survey - Mean Scores for Managers

Risk Perception survey Managers	Managers score from ISO certified companies	Managers score from Non ISO certified companies
M1	114	85
M2	115	87
M3	114	87
M4	110	104
M5	111	87
M6	108	110
M7	89	90
M8	110	102
M9	113	88
M10	88	90
M11	111	85
M12	110	92
M13	107	88
M14	113	85
M15	109	78
M16	112	93
M17	108	85
M18	114	87
M19	112	91
M20	87	93
M21	113	79
M22	113	91
M23	86	106
M24	111	94
M25	113	82

F-Test: Two-Sample for Variances Significance Level (Alpha) = 0.01

	Variable 1	Variable 2
Mean	107.64	90.36
Variance	84.90666667	62.74
Observations	25	25
df	24	24
F	1.353309956	
P(F<=f) one-tail	0.23206988	
F Critical one-tail	2.659078291	

t-Test :Two sample Assuming equal variances at Alpha = 0.01

	Variable 1	Variable 2
Mean	107.64	90.36
Variance	84.90666667	62.74
Observations	25	25
Pooled Variance	73.82333333	
Hypothesized Mean Difference	0	
df	48	
t Stat	7.110529117	
P(T<=t) one-tail	2.48935E-09	
t Critical one-tail	2.406577551	
P(T<=t) two-tail	4.97871E-09	
t Critical two-tail	2.682209015	

Annexure 4: Risk Perception Survey - Managers (ISO Certified Companies)

ISO Certified Companies - Managers Risk Perception Questionnaire Survey Abstract

Managers total Score	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Total Score
M1			5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5			5	5	5	114
M2			5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	115
M3			5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5			5	5	5	114
M4			5	5	5	5	5	4	5	5	5	5	4	4	5	5	5	5	4	5	5	4			5	5	5	110
M5			5	5	5	4	5	5	5	5	5	5	5	5	5	4	5	5	5	5	4	5			4	5	5	111
M6			4	5	5	5	4	5	5	5	4	5	5	5	5	5	5	5	4	4	4	4			5	5	5	108
M7			5	4	4	3	4	4	4	4	4	5	3	3	4	4	4	4	4	4	4	4			3	4	3	89
M8			5	5	5	4	5	5	5	5	5	5	5	5	4	5	5	4	5	4	5	5			5	4	5	110
M9			5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5			5	4	5	113
M10			3	4	4	4	4	4	3	4	4	4	4	4	3	4	4	4	4	3	4	4			5	4	3	88
M11			5	5	5	4	5	5	4	5	5	5	5	4	5	5	5	5	5	5	5	5			5	4	5	111
M12			5	5	5	5	5	5	4	4	5	5	5	5	5	5	5	5	5	5	4	5			5	4	4	110
M13			5	4	4	5	5	4	4	5	5	4	5	5	5	5	5	4	5	5	5	4			4	5	5	107
M14			5	5	5	5	4	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5			5	5	5	113
M15			4	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	3	5	5			4	5	4	109
M16			5	4	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	5	5			5	4	5	112
M17			5	5	4	4	5	5	5	4	4	5	5	5	4	5	5	5	5	5	5	4			5	5	4	108
M18			5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	114
M19			5	5	5	5	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5			5	5	5	112
M20			4	4	3	4	4	3	3	3	4	4	3	4	4	4	4	4	4	4	4	4			4	4	4	87
M21			5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	4			5	5	5	113
M22			5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5			4	5	5	113
M23			3	4	4	2	·4	4	4	4	4	4	4	3	3	4	4	4	4	4	3	4			4	4	4	86
M24			5	5	5	5	5	5	4	5	5	5	5	5	4	5	5	5	5	5	5	4			4	5	5	111
M25			5	5	5	5	5	5	5	5	5	5	4	5	4	5	5	5	5	5	5	5			5	5	5	113
Questionwise Mean score			4.72	4.76	4.72	4.52	4.72	4.68	4.56	4.72	4.76	4.80	4.64	4.56	4.60	4.80	4.80	4.68	4.76	4.64	4.68	4.60	0.00	0.00	4.64	4.64	4.64	

Note: 1) Questions 1and 2 are general information and not considered for likert scale analysis.
2) Survey done from 3 Mangers from 5 companies+ 2 Managers from 4 companies and 2 Managers from 1 company.

Non-ISO Companies - Managers Risk Perception Questionnaire Survey Abstract

Managers total Score	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Total Score
M1			4	4	4	4	4	4	4	2	4	3	4	4	4	4	4	4	2	2	4	4			4	4	4	85
M2			5	4	4	4	4	5	4	2	4	2	4	4	4	4	4	4	4	4	4	4			4	1	4	87
M3			4	4	5	4	2	4	4	2	4	4	4	4	4	4	4	4	2	4	4	4			4	4	4	87
M4			4	4	4	4	4	4	5	5	4	4	5	5	5	5	5	4	5	4	5	5			4	5	5	104
M5			4	4	4	5	4	4	4	4	4	2	4	4	5	4	4	4	2	1	4	4			4	4	4	87
M6			5	5	4	4	5	5	4	5	4	5	5	4	5	5	5	5	5	5	5	5			5	5	5	110
M7			4	4	5	4	4	4	4	2	5	1	4	5	5	5	4	3	4	1	5	4			4	4	5	90
M8			4	5	5	4	4	4	4	5	5	5	5	5	5	4	4	3	4	4	4	4			5	5	5	102
M9			5	4	4	4	2	4	4	1	4	4	4	5	4	4	5	2	4	2	5	5			4	4	4	88
M10			4	4	4	4	4	4	5	4	4	4	5	4	4	4	5	2	4	4	4	4			4	1	4	90
M11			4	4	4	4	2	5	5	1	4	2	5	4	4	4	5	2	4	4	4	4			4	1	5	85
M12			4	4	4	4	4	4	4	2	4	5	4	4	4	4	4	4	4	4	4	4			4	4	5	92
M13			4	4	4	4	2	4	4	1	4	4	4	4	4	4	4	4	4	4	4	4			5	4	4	88
M14			4	4	4	4	4	4	4	2	4	2	4	4	4	4	4	4	4	2	4	5			4	2	4	85
M15			4	4	4	4	2	4	4	1	4	1	4	4	4	4	4	2	2	4	4	4			4	2	4	78
M16			5	4	4	4	4	4	4	4	4	4	5	5	4	4	4	4	4	4	4	4			4	2	4	93
M17			4	4	4	4	2	5	4	4	4	2	4	4	4	4	4	2	4	4	4	4			4	2	4	85
M18			4	4	4	5	4	4	4	2	4	4	4	4	4	4	4	2	2	3	5	4			4	4	4	87
M19			4	5	4	4	2	4	4	4	4	2	4	4	4	5	4	4	4	4	4	5			4	4	4	91
M20			4	5	4	5	4	4	4	4	4	4	4	4	4	5	4	4	2	4	4	4			4	4	4	93
M21			4	4	4	5	2	4	4	5	4	1	4	3	3	3	3	2	3	4	4	4			3	3	3	79
M22			5	5	4	4	2	4	5	4	4	2	4	4	4	4	4	4	4	4	4	4			4	4	4	91
M23			5	5	5	4	5	5	5	4	5	4	5	4	5	4	4	4	4	4	5	5			5	5	5	106
M24			4	4	4	4	4	5	4	2	5	2	4	4	5	4	5	4	4	4	5	5			4	4	4	94
M25			4	4	4	4	2	4	4	1	5	1	4	4	5	4	5	2	4	1	4	4			4	4	4	82
Questionwise Mean score			4.24	4.24	4.16	4.16	3.28	4.24	4.20	2.92	4.20	2.96	4.28	4.16	4.28	4.16	4.24	3.32	3.56	3.40	4.28	4.28	0.00	0.00	4.12	3.44	4.24	

Note: 1) @ 3 Managers from 5 companies + 2 Managers from 5 companies + 2 Managers from 1 company (Total 25).
2) Q1and 2 are general information only.

Annexure 4: Risk Perception Survey - Managers

Risk Perception Questionnaire

Dear________________________,

As you are aware Quality, Safety, Health and Environment Management Systems and Risk Assessment are becoming more and more popular now a days in the Petrochemical Industry. Most of the Petrochemical Industries in the Middle East are ISO 9000 certified. As Petrochemical industry is an export oriented industry. To be competitive in the market and to serve the society at large the importance of safety/risk in a Petrochemical Industry need no mention.

- I am conducting Research Study about Management Systems existing in the Petrochemical Industry.
- The main objective of this survey is to find out risk perception of **Managers** in the Petrochemical industries.
- The requirement is to express your perception /view about various safety risks existing in your firm. Your valuable opinion will benefit the study and will be kept strictly confidential.
- Please complete this questionnaire and return it in the enclosed self-addressed envelope, if possible before 31/03/2004.

Thank you for your co-operation.

Yours sincerely,

Mohammed Al Mulla

Annexure 4: Risk Perception Survey - Managers

1) Do you consider Risk Assessment is a primary responsibility of an Employer?

☐ Yes ☐ No

2) In your opinion, how thorough should your risk assessment should be?

☐ Adequate ☐ Suitable and sufficient ☐ Complete removal of risk

3) Crushing and impact hazard /risk exists in a petrochemical company?

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

4) Risk of high pressure fluid injection from hydraulic hoses exists in your firm?

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

5) An established procedure assist a company for assessment of risk and its control?

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

6) Risk assessment shouldn't reactive to any incident.

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

7) Slips/trips and falls hazard for personnel working on ladders/platform exists in a Petrochemical company?

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

8) A procedure is required to identify OH & S risk related to goods purchased.

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

9) A procedure is required to identify OH & S risk related to handling of equipments, materials and chemicals?

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

10) Direct and indirect contact electrical hazard from control panel exists in a Petrochemical Firm ?

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

11) A procedure is required to identify OH & S risk related to services purchased.

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

Annexure 4: Risk Perception Survey - Managers

12) Electrical hazard from short circuit /overload from motors exists in a Petrochemical company?

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

13) An emergency plan /procedure is required for a Petrochemical firm to tackle emergency situations to prevent likely injuries/damages.

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

14) Electrical hazard due to source of ignition/sparks from electrical equipments and heaters exist in a Petrochemical Company.

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

15) A corrective and preventive action plan is required to handle OH & S risks.

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

16) Do you consider pre-qualifying personnel for hazardous work ?

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

17) An evacuation procedure is a must for a Petrochemical company.

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

18) People working in a Petrochemical are exposed to risk due to **flammable** liquids/gas/fumes.

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

19) People in a Petrochemical firm are exposed to risk due to **toxic** gas, fumes.

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

20) People working in a Petrochemical company are exposed to biological/micro substance risk.

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

21) Emergency equipments like alarm systems, emergency lightings, means of escape, safe refuge, critical isolation valve, fire fighting equipments etc need to be identified and tested.

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

22) Petrochemical companies need to have hazardous area classification.

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

Annexure 4: Risk Perception Survey - Managers

23) People working in a Petrochemical company exposed to work environment hazard/risk due to noise/ vibration from equipments.

☐ Exist but controlled ☐ Not Sure ☐ Doesn't exist

☐ Not applicable

24) People in and around a Petrochemical firm are exposed to risk due to waste disposal.

☐ Exist but controlled ☐ Not Sure ☐ Doesn't exist

☐ Not applicable

25) Is mitigation of consequences of risk your last option of risk control ?

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

26) Do you consider people around your firm are continuously exposed to risk due to the activities of your firm?

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

27) Do you consider risk assessment to be carried out to have safe operation of your plant?

☐ Strongly Agree ☐ Agree ☐ Not sure

☐ Disagree ☐ Strongly Disagree

Annexure 1: Compliance of Preventive inspection

Pro-active Indicator-1: Assessment of Preventive Inspections done in 2003.

Sample companies	ISO certified companies			Non-ISO certified companies
	Number of preventive inspections planned	Number of preventive inspections/safety audits carried out during 2003: ISO certified companies	Compliance (%)	Number of preventive inspections/safety audits carried out during 2003: Non-ISO certified companies
Company1	23	21	91.30	NONE
Company2	12	12	100.00	2
Company3	6	5	83.33	3
Company4	3	3	100.00	NONE
Company5	12	12	100.00	NONE
Company6	3	3	100.00	2
Company7	6	6	100.00	4
Company8	12	11	91.67	2
Company9	2	2	100.00	1
Company10	2	2	100.00	NONE

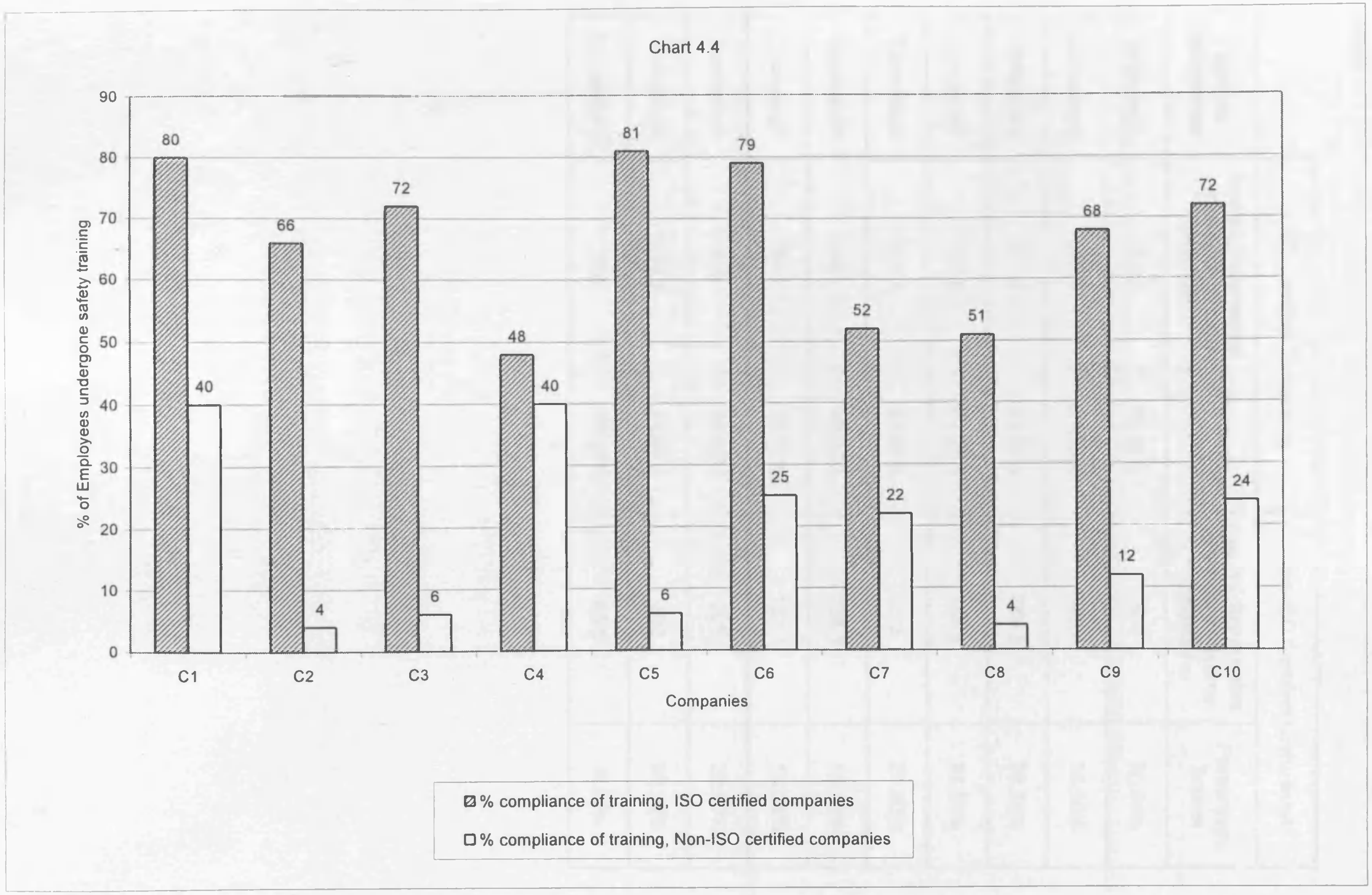
Annexure 2: Compliance of Safety Training

Pro-active Indicator-2: Number of people Under Gone Safety Training (Sample of 100)

	ISO Certified Companies		Non ISO Certified Companies	
Sample companies	Number of people undergone Training in Safety during 2003	% compliance of safety training	Number of people undergone Training in Safety during 2003	% compliance of safety training
Company1	80	80%	40	40%
Company2	66	66%	4	4%
Company3	72	72%	6	6%
Company4	48	48%	40	40%
Company5	81	81%	6	6%
Company6	79	79%	25	25%
Company7	52	52%	22	22%
Company8	51	51%	4	4%
Company9	68	68%	12	12%
Company10	72	72%	24	24%

Annexure 2: Compliance of Safety Training

Compliance of Safety Training

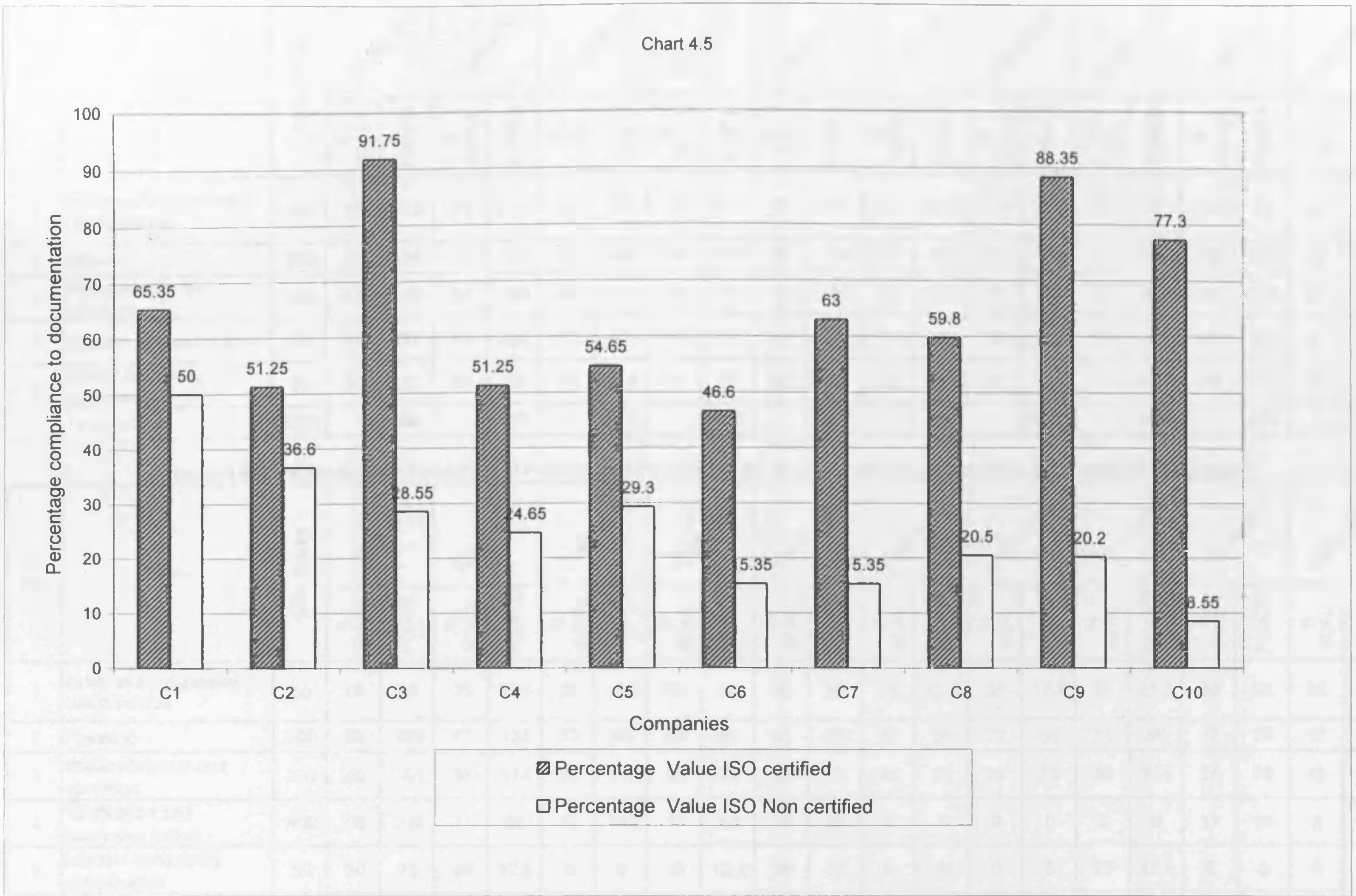


Annexure 3: Applied Documented Procedures

Pro-active Indicator-3: Applied documented procedure for Safety Management (Ref.: 1000)

	ISO Certified Companies		Non-ISO Certified Companies	
Sample companies	Applied documented procedure - Scores Obtained	Percentage Scores	Applied documented procedure - Scores Obtained	Percentage Scores
Company1	653.5	65.35%	500	50.00%
Company2	512.5	51.25%	366	36.60%
Company3	917.5	91.75%	285.5	28.55%
Company4	512.5	51.25%	246.5	24.65%
Company5	546.5	54.65%	293	29.30%
Company6	466	46.60%	153.5	15.35%
Company7	630	63.00%	153.5	15.35%
Company8	598	59.80%	205	20.50%
Company9	883.5	88.35%	202	20.20%
Company10	773	77.30%	85.5	8.55%

Applied Documented Procedures



Annexure 3: Applied Documented Procedures

Abstract Scores for Applied Documented Policies and Procedures for the Safety Management - ISO Certified companies

Sl. No	Index	Max Marks	COMPANY1		COMPANY2		COMPANY3		COMPANY4		COMPANY5		COMPANY6		COMPANY7		COMPANY8		COMPANY9		COMPANY10	
			% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS
1	Safety and occupational Health policies	50	75	37.5	75	37.5	100	50	75	37.5	75	37.5	75	37.5	100	50	75	37.5	100	50	100	50
2	Planning	200	67	134	50	100	83	166	50	100	67	134	67	134	83	166	67	134	100	200	83	166
3	Implementation and operation	300	63	189	50	150	88	264	50	150	50	150	50	150	63	189	63	189	88	264	88	264
4	Verification and corrective action	400	67	268	50	200	100	400	50	200	50	200	33	132	50	200	50	200	83	332	67	268
5	Internal analysis by organisation	50	50	25	50	25	75	37.5	50	25	50	25	25	12.5	50	25	75	37.5	75	37.5	50	25
	Total Score	1000		654		513		918		513		547		466		630		598		884		773

Abstract Scores for Applied Documented Policies and Procedures for the Safety Management - Non ISO Certified companies

Sl. No.	Index	Max Marks	COMPANY1		COMPANY2		COMPANY3		COMPANY4		COMPANY5		COMPANY6		COMPANY7		COMPANY8		COMPANY9		COMPANY10	
			% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS	% SCALE	POINTS
1	Safety and occupational Health policies	50	50	25	75	37.5	25	12.5	50	25	50	25	25	12.5	25	12.5	25	12.5	50	25	25	12.5
2	Planning	200	50	100	67	134	33	66	33	66	50	100	33	66	33	66	33	66	17	34	17	34
3	Implementation and operation	300	50	150	38	114	25	75	25	75	25	75	25	75	25	75	38	114	25	75	13	39
4	Verification and corrective action	400	50	200	17	68	33	132	17	68	17	68	0	0	0	0	0	0	17	68	0	0
5	Internal analysis by organisation	50	50	25	25	12.5	0	0	25	12.5	50	25	0	0	0	0	25	12.5	0	0	0	0
	Total Score	1000		500		366		286		247		293		154		154		205		202		85.5

Annexure 3: Typical Check List Used for Verification of Applied documentation of Procedures and Instruction

Company-1 (ISO Certified)

	Safety and Occupational Health Policy	**Yes**	**No**
1	Is the Safety policy statement established	X	
2	Safety policy communicated	X	
3	Policy statement signed by the Top management	X	
4	Policy reviewed periodically		X
	Total score	3	
	Percentage compliance	75%	
	Planning		
1	Documented procedure available for identification of hazards	X	
2	Documented procedure available for assessment of risks		X
3	Documented procedure available for implementation of necessary control measures		X
4	Organisation do have documented OH & S objectives	X	
5	Responsibility and authority for achievement of objectives clearly documented	X	
6	Means and time scale for achievement of safety Objectives documented	X	
	Total score	4	
	Percentage compliance	67%	
	Implementation and Operation		
1	Do roles responsibilities and authorities of those Managing activities having an effect on safety- defined and documented	X	
2	Do roles responsibilities and authorities of those Performing the activities having an effect on safety- defined and documented	X	
3	Do roles responsibilities and authorities of those verifying activities having an effect on safety- defined and documented	X	
4	Documented procedure exists for ensuring safety awareness among employees	X	
5	Documented procedure exists for ensuring competence among employees		X
6	Documents related to-Involvement of employees in the OH & S activities		X
7	Do the organisation have documented procedure to identify activities having risks		X
8	Documented procedure for emergency preparedness and response plans	X	
	Total score	5	
	Percentage compliance	63%	
	Checking and corrective action		
1	Documented procedure for measurement and monitoring	X	
2	Do the organisation have records of calibration of monitoring instruments	X	
3	Documented procedure for handling investigation of accidents, incidents and non-conformities	X	
4	Documented procedure for checking effectiveness of corrective and preventive action		X
5	Do organisation record changes in the documentation as a result of corrective and preventive action		X
6	Documented programme for safety audits	X	
	Total score	4	
	Percentage compliance	67%	
	Internal Analysis		
1	Do meetings for review the internal weaknesses recorded	X	
2	Documented procedure available for internal analysis		X
3	Do changes in the objectives recorded	X	
4	Documentation related to continual improvement activities exists		X
	Total score	2	
	Percentage compliance	50%	

Annexure 4: Use of Personnel Protective Equipments (PPE)

Pro-active Indicator-4: Overall Percentage Score for Usage of PPE

Sl. No.	Sample Companies	Use of PPE % Score - ISO Certified	Use of PPE % Score - Non ISO Certified
1	Company1	88	58.4
2	Company2	89.6	62.6
3	Company3	91.8	67.8
4	Company4	87.2	66.6

Annexure 4: Use of Personnel Protective Equipment (PPE)

Pro-active Indicator No. 4: Score Abstract for Usage of PPE among Employees (ISO Certified Company)

Sl. No.	Use of PPE	% Score for Company 1	% Score for Company 2	% Score for Company 3	% Score for Company 4
1	Helmet	100	100	100	100
2	Hand gloves	64	76	80	88
3	Goggles	44	72	80	56
4	Ear plug	72	68	68	68
5	Safety shoe	100	100	100	100
6	Overall	100	100	100	100
7	Gas Mask/Breathing apparatus	100	92	96	84
	Overall % score	88	89.6	91.8	87.2

Pro-active indicator No.4: Score Abstract for Usage of PPE among Employees (Non ISO Certified Company)

Sl. No.	Use of PPE	% Score for Company 1	% Score for Company 2	% Score for Company 3	% Score for Company 4
1	Helmet	100	100	100	100
2	Hand gloves	64	76	80	72
3	Goggles	4	72	80	76
4	Ear plug	68	28	68	68
5	Safety shoe	100	100	100	100
6	Overall	100	100	100	100
7	Gas Mask/Breathing apparatus	0	0	0	0
	Overall % score	58.4	62.6	67.8	66.6

Usage Scores of PPE per Employee (ISO Certified Companies)

Company1

	PPE Item	Points	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25	Points	Overall %
1	Helmet	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	100
2	Hand gloves	10			10		10	10	10		10			10	10	10	10		10		10	10	10	10	10		10	16	64
3	Goggles	10	10				10			10		10			10		10			10		10	10		10		10	11	44
4	Ear plug	10		10		10		10	10	10	10		10	10	10	10	10		10	10		10	10	10	10		10	18	72
5	Safety shoe	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	25	100
6	Overall	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	25	100
7	Gas Mask	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	100
		100	80	80	80	80	90	90	90	90	90	80	80	90	100	90	100	70	90	90	80	100	100	90	100	70	100		88

Company2

	PPE Item	Points	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25	Points	Overall %
1	Helmet	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	100
2	Hand gloves	10	10		10	10	10		10	10	10	10		10	10		10		10	10	10	10	10		10	10	10	19	76
3	Goggles	10	10		10	10	10		10	10	10	10		10	10		10	10	10	10		10	10		10	10		18	72
4	Ear plug	10		10		10	10			10	10	10	10	10	10	10	10		10	10		10	10			10	10	17	68
5	Safety shoe	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	25	100
6	Overall	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	25	100
7	Gas Mask	25	25	25	25	25	25	25	25	25	25	25		25	25	25	25	25	25	25	25	25	25	25		25	25	23	92
		100	90	80	90	100	100	70	90	100	100	100	55	100	100	80	100	80	100	100	80	100	100	70	65	100	90		89.6

Company3

	PPE Item	Points	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25	Points	Overall %
1	Helmet	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	100
2	Hand gloves	10	10	10	10	10	10	10	10	10	10	10	10				10		10	10	10	10	10		10	10	10	20	80
3	Goggles	10	10	10	10	10	10	10	10	10	10	10		10	10		10	10	10	10		10	10		10	10		20	80
4	Ear plug	10	10	10		10	10			10	10			10		10	10		10	10		10	10	10	10	10	10	17	68
5	Safety shoe	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	25	100
6	Overall	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	25	100
7	Gas Mask	25	25	25		25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	24	96
		100	100	100	65	100	100	90	90	100	100	90	80	90	80	80	100	80	100	100	80	100	100	80	100	100	90		91.8

Company4

	PPE Item	Points	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25	Points	Overall %
1	Helmet	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	100
2	Hand gloves	10	10	10	10	10	10	10	10	10	10	10	10	10	10		10		10	10	10	10	10		10	10	10	22	88
3	Goggles	10				10			10	10	10			10	10		10	10	10	10		10	10		10	10		14	56
4	Ear plug	10		10		10	10			10	10	10	10	10	10	10	10		10	10		10	10			10	10	17	68
5	Safety shoe	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	25	100
6	Overall	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	25	100
7	Gas Mask	25	25	25	25		25		25		25	25		25	25	25	25	25	25	25	25	25	25	25	25	25	25	21	84
		100	80	90	80	75	90	55	90	75	100	90	65	100	100	80	100	80	100	100	80	100	100	70	90	100	90		87.2

Usage Scores of PPE per Employee (Non-ISO Certified Companies)

Company 1

	PPE Item	Points	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25	Mode	Overall %
1	Helmet	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	100
2	Hand gloves	10			10		10	10	10		10			10	10	10	10		10		10	10	10	10	10		10	16	64
3	Goggles	10																	5									1	4
4	Ear plug	10						10	10	10			10	10	10	10	10	10	10	10	10	10	10	10	10		10	17	68
5	Safety shoe	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	25	100
6	Overall	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	25	100
7	Gas Mask	25																										0	0
		100	45	45	55	45	55	65	65	55	55	45	55	65	65	65	65	55	70	55	65	65	65	65	65	45	65		58.4

Company 2

	PPE Item	Points	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25	Mode	Overall %
1	Helmet	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	100
2	Hand gloves	10	10		10	10	10		10	10	10	10		10	10		10		10	10	10	10	10		10	10	10	19	76
3	Goggles	10	10		10	10	10		10	10	10	10		10	10		10	10	10	10		10	10		10	10		18	72
4	Ear plug	10												10		10	10			10			10			10	10	7	28
5	Safety shoe	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	25	100
6	Overall	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	25	100
7	Gas Mask	25																										0	0
		100	65	45	65	65	65	45	65	65	65	65	45	75	65	55	75	55	65	75	55	65	75	45	65	75	65		62.6

Company 3

	PPE Item	Points	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25	Mode	Overall %
1	Helmet	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	100
2	Hand gloves	10	10	10	10	10	10	10	10	10	10	10	10				10		10	10	10	10	10		10	10	10	20	80
3	Goggles	10	10	10	10	10	10	10	10	10	10	10		10	10		10	10	10	10		10	10		10	10		20	80
4	Ear plug	10	10	10		10	10			10	10			10		10	10		10	10		10	10	10	10	10	10	17	68
5	Safety shoe	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	25	100
6	Overall	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	25	100
7	Gas Mask	25																										0	0
		100	75	75	65	75	75	65	65	75	75	65	55	65	55	55	75	55	75	75	55	75	75	55	75	75	65		67.8

Company 4

	PPE Item	Points	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24	E25	Mode	Overall %
1	Helmet	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	100
2	Hand gloves	10	10	10	10					10	10	10	10	10	10		10		10	10	10	10	10		10	10	10	18	72
3	Goggles	10	10	10	10	10	10	10	10	10	10			10	10		10	10	10	10		10	10		10	10		19	76
4	Ear plug	10		10		10	10			10	10	10	10	10	10	10	10		10	10		10	10			10	10	17	68
5	Safety shoe	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	25	100
6	Overall	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	25	100
7	Gas Mask	25																										0	0
		100	65	75	65	65	65	55	55	75	75	65	65	75	75	55	75	55	75	75	55	75	75	45	65	75	65		66.6

Annexure 5 : One way Un-stacked Analysis of Reactive Safety Data (From the case study on the sample company)

IR1= IR Values before ISO certification,
IR2 = IR Values after ISO certification
One-way ANOVA: IR1, IR2

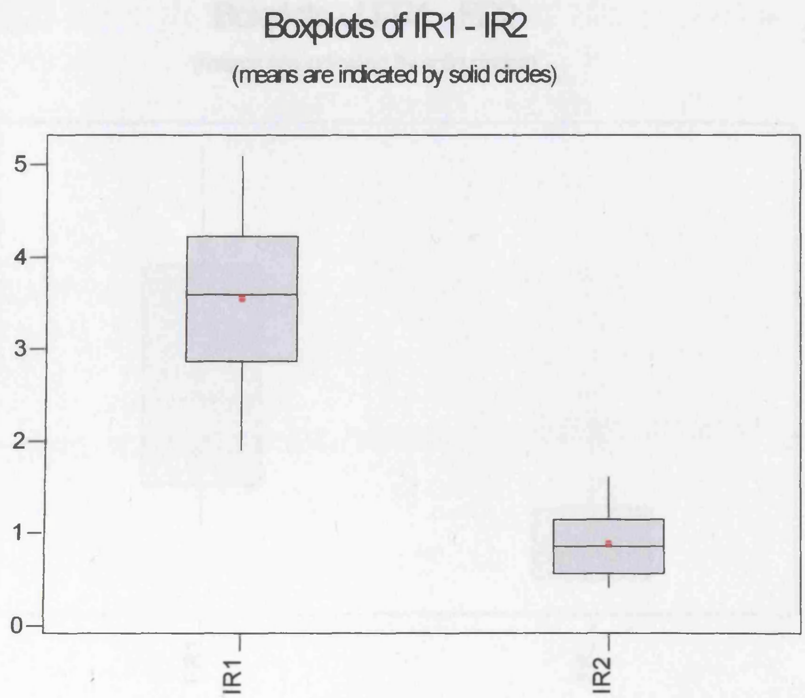
Source	DF	SS	MS	F	P
Factor	1	24.381	24.381	38.05	0.000
Error	12	7.688	0.641		
Total	13	32.069			

Individual 95% CIs For Mean

Based on Pooled StDev

```
Level    N    Mean     St.Dev  ---------+---------+---------+-------
IR1      8    3.5500   0.9885                      (-----*-----)
IR2      6    0.8833   0.4119  (-----*-----)
                               ---------+---------+---------+-------
Pooled StDev =  0.8004               1.2       2.4       3.6
```

Box plots of IR1 - IR2



Annexure 5 : One way Un-stacked Analysis of Reactive Safety Data (From the case study on the sample company)

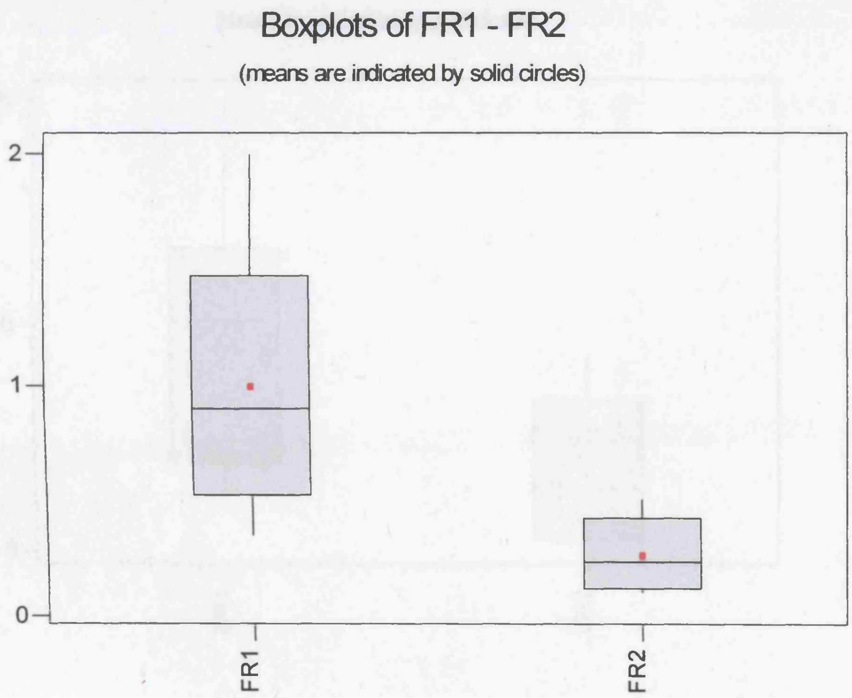
FR1= FR Values before ISO certification,
FR2 = FR Values after ISO certification
One-way ANOVA: FR1, FR2

Source	DF	SS	MS	F	P
Factor	1	1.829	1.829	9.04	0.011
Error	12	2.428	0.202		
Total	13	4.257			

```
                                Individual 95% CIs For Mean
                                Based on Pooled StDev
Level   N    Mean   StDev   ----+---------+---------+---------+--
FR1     8  0.9938  0.5735                   (--------*--------)
FR2     6  0.2633  0.1587   (---------*---------)
                            ----+---------+---------+---------+--
Pooled StDev = 0.4498          0.00      0.40      0.80      1.20
```

Individual 95% CIs For Mean
Based on Pooled StDev

Box plots of FR1 - FR2



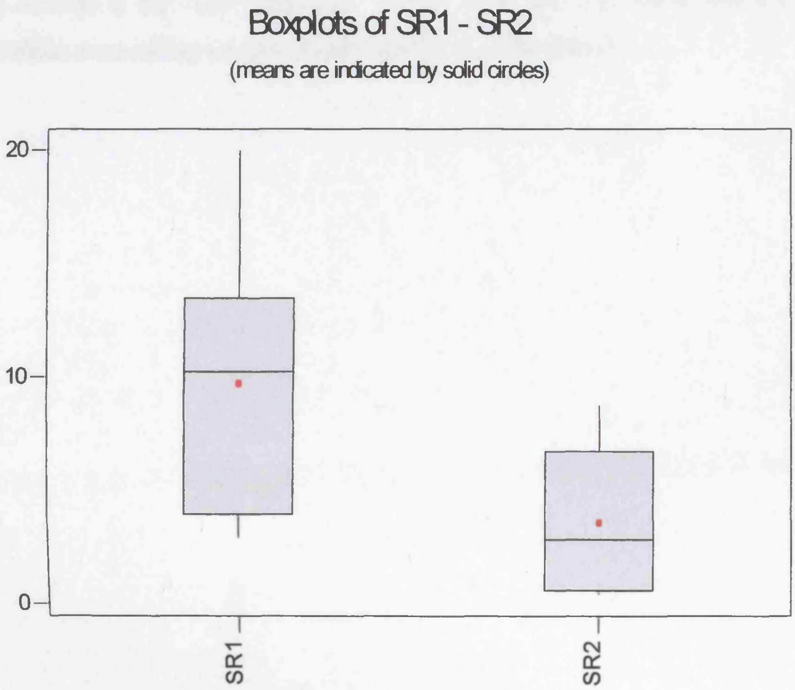
Annexure 5 : One way Un-stacked Analysis of Reactive Safety Data (From the case study on the sample company)

SR1= SR Values before ISO certification,
SR2 = SR Values after ISO certification
One-way ANOVA: SR1, SR2

Source	DF	SS	MS	F	P
Factor	1	129.8	129.8	5.23	0.041
Error	12	297.8	24.8		
Total	13	427.6			

```
                                  Individual 95% CIs For Mean
                                  Based on Pooled St.Dev
Level    N    Mean    StDev  ---+---------+---------+---------+---
SR1      8   9.700    5.917                 (--------*---------)
SR2      6   3.547    3.247  (----------*----------)
                             ---+---------+---------+---------+---
Pooled StDev =   4.982          0.0       4.0       8.0      12.0
```

Boxplots of SR1 - SR2



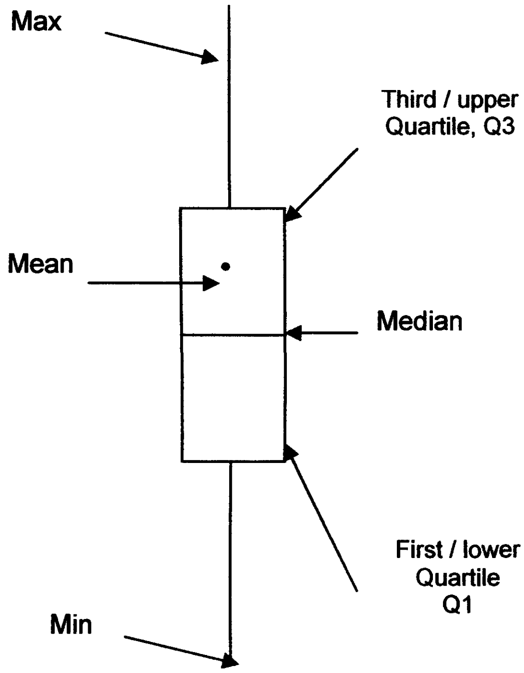
Box Plots

Box plots, also called box-and-whisker plots, are particularly useful for showing the distributional characteristics of data. By default, a box plot consists of a box, whiskers, and outliers.

A line is drawn across the box at the median. By default, the bottom of the box is at the first quartile (Q1), and the top is at the third quartile (Q3) value. The whiskers are the lines that extend from the top and bottom of the box to the adjacent values. The adjacent values are the lowest and highest observations that are still inside the region defined by the following limits:

Lower Limit: Q1 - 1.5 (Q3 - Q1)

Upper Limit: Q3 + 1.5 (Q3 - Q1)



Outliers are points outside of the lower and upper limits. The mean lies within the box to the top or bottom of the median depending on the concentration of point values.