

Benchmarking of process safety management elements in the South African Process industry

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◆————— Dedication —————◆

This work is dedicated to:

My precious, caring, and loving wife,
Mrs. Rukayat Olayinka Isiotan-Popoola,

whose irimitable affection, support, tolerance and understanding afforded me the willpower, resolve, and
motivation to accomplish this work;

and

all the victims and martyrs of the Lal-Masjid (Red Mosque) in Pakistan. May Allah grant tranquillity and
benediction to their noble souls.

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Subhannaka Allahummah wa bihamdika wa ash'adu an laailaha ila anta, astaghfiruka wa atubu ilaika¹.

¹ Islamic epilogue meaning: Glory and praise be to you, O Allah, and I bear witness that there is no god but You, I seek Your forgiveness and I am penitent towards You.

Abstract

This study is a benchmarking exercise aimed at identifying the variation in the practice - within the South African process industry - of three process safety management (PSM) elements, namely: Management of Change (MOC), Emergency Preparedness Program (EPP), and Process Safety Incident Investigation (PSII) programs. Structured questionnaires were developed for each of the three PSM elements, and sent to over 180 process plants. Typically, the study experienced a low response rate.

However, data were gathered from a total of 39 process facilities which include chemical, pharmaceutical, gas, petrochemical, metal extraction, and processing plants. Observed, is a wide variance in the practice of the PSM elements among the industry. Juxtaposed against international standards, the industry practice is some degrees lower than international benchmarks. Nonetheless, there is a positive attitude to PSM among the sampled facilities. Recommendations were made for the industry stakeholders.

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List of Acronyms

Acronyms	Meanings
AFR	Accident Frequency Rate
AHP	Analytical Hierarchical Process
ALARP	As Low As Reasonably Practicable
AMC	Australian Manufacturing Council
ANC	African National Congress
API	American Petroleum Institute
ASOSH	Association Of Societies For Occupational Safety And Health
CBA	Cost Benefit Analysis
CCPA	Canadian Chemical Producers Association
CCPS	Centre For Chemical Process Safety
CMA	Chemical Manufacturers' Association
COIDA	Compensation For Occupational Injuries And Diseases Act
COMAH	Control Of Major Accident Hazards Regulations
DNV	Det Norske Veritas
DOL	Department Of Labour,
EH & S	Environment, Health And Safety
EMS	Environmental Management Systems
EOC	Emergency Operation Centre
EPA	Environmental Protection Agency
EPA	Environmental Protection Agency
EPP	Emergency Preparedness And Response
EPP	Emergency Preparedness Program
EU	European Union
FAFR	Fatal Accident Frequency Rate
FAR	Fatality Accident Rate
FMEA	Failure Modes And Effects Analysis
GDP	Gross Domestic Product
HAZOP	Hazard And Operability
HHC	Highly Hazardous Chemical
HSE	Health And Safety Executive
HSRC	Human Science Research Council
IET	Institution Of Engineering And Technology
ILCI	International Loss Control Institute
ILO	International Labour Organization
IOHA	International Occupational Hygiene Association
IoSM	Institute Of Safety Management
IQRS	International Quality Rating System
ISO	International Organization For Standardization
ISRS	International Safety. Rating System
LPG	Liquefied Petroleum Gas
MAAP	Major Accident Prevention Policy
MBO	Management By Objectives
MBOD	Medical Bureau For Occupational Diseases
MHI	Major Hazard Installations

MHSA	Mine Health And Safety Act
MOC	Management Of Change
MSRS	Mines Rating System
MWO	Maintenance Work Orders
NOHSC	National Occupational Health And Safety Commission
NOSA	National Occupational Safety Association
OECD	Organization Of Economic Co-Operation And Development
OH&S	Occupational Health And Safety
OHS	Occupational Health And Safety
OHSAS	Occupational Health Safety Assessment System
OHSMS	Occupational Health And Safety Management Systems
OSHA	Occupational Safety And Health Administration
PAC	Prevention Of Accidents Committee
PHA	Process Hazard Analysis
PSII	Process Safety Incident Investigation
PSII	Process Safety Incident Investigation
PSM	Process Safety Management
PSSR	Pre-Start-Up Safety Review
R&D	Research And Development
RAGAGEP	Recognized And Generally Accepted Good Engineering Practices.
RIK	Replacement In Kind
RMP	Risk Management Program
SADC	Southern African Development Community
SEPA	Scottish Environment Protection Agency
SHE	Safety, Health And Environment,
SHEQ	Safety, Health, Environment And Quality
SHERQ	Safety, Health, Environment, Risk And Quality
SMS	Safety Management Systems
SPM	Safety Performance Measurement
SRU	Safety Research Unit
TQM	Total Quality Management
UAI	Universal OHSMS Assessment Instrument
VPP	Voluntary Protection Programs

CHAPTER ONE

INTRODUCTION

1.1 Background

The fallout of dioxin caused by a runaway reaction at Seveso, Italy, in 1976, and the 1984 disaster of Bhopal, India, led to major changes in safety laws all over the world. Government and industrial entities devoted major efforts toward risk reduction and hazard control. Also, interest in the organisation's culture for safety has grown in the wake of a number of high profile incidents, including the Clapham Junction rail disaster (Hidden, 1989) and the Piper Alpha disaster in the North Sea (Cullen, 1990). In 1993, South African government enacted the Occupational Health and Safety Act 85 (85/1993) and the corollary regulations; to provide for the health and safety of persons at work and for the health and safety of persons in connection with the use of plant and machinery; the protection of persons other than persons at work against hazards to health and safety arising out of or in connection with the activities of persons at work.

For a developing country, South Africa has an unusually large chemical industry which is of substantial economic significance. However, the industry is responsible for a range of highly hazardous operations as well as the production and use of a wide range of dangerous substances. These industrial activities pose serious risks to workers, the public, and the environment. It is for these reasons that the industry is subject to special regulatory measures and a relatively high level of inspection and control.

Companies' management in the last decade, has widely agreed on the importance of the implementation and certification of structured management systems, such as quality management systems, environmental management systems, and recently, occupational health and safety (OH&S) management systems (Arezes and Miguel, 2003). The positive impact of introducing occupational safety and health (OSH) management systems at the organisational level, both on the reduction of hazards and risks and on productivity, is now recognized by governments, employers and workers alike (ILO, 2001).

Most organisations in the global process industry including South African manufacturers, integrated their systems for safety. However, their safety programs are strictly compliance-oriented. Consequently, technical requirements mandated by regulations and industry standards are too narrowly focused and

lack the momentum for continuous improvement. Solutions for individual safety problems become short-term, merely addressing symptoms rather than causes (Stephen & Yu, 2000).

Until the late seventies, process industry world-wide still used numbers of fatalities and injuries as parameters for measuring safety performance (Keren, 2003). In South African process and chemical industries this reactive approach (which involves counting fatality rate, recordable incidents, etc) has, for many years predominated as the practical way for reducing accident losses. Although, major progress (in terms of reduction in industrial fatality rate) was accomplished since the seventies, (Keren, 2003); this approach has many shortcomings. The most serious is that it permits many fatalities and injuries to occur in order to evaluate needs and priorities of safety improvement measures.

However, organisations, academicians, and legislators world-wide, realized that since the number of catastrophic incidents is becoming low, the numbers of fatalities and injuries are not reasonable indicators for measurement of safety performance. The absence of a very unlikely event is not, of itself, a sufficient indicator of good safety management (EPSC, 1996). Injuries, illnesses, and losses should be measured, but they should only be part of the bottom line of safety performance, and as such, they are not good as a feedback for safety management.

Thus, there is a need for a systems approach to measuring industrial safety, health and environment (SHE) performance. An approach which measures "leading factors" (i.e. SHE management elements) and not trailing "factors" (fatality rate, recordable incidents, etc). South African process industry is recently realising this reality. Major milestones in this trend are the formation of National Occupational Safety Association, NOSA's Management By Objectives (MBO) with five-star grading; and the adoption of Responsible Care® by major players in the process industry. It was realised that in today's international business environment where non-tariff barriers to trade are becoming increasingly real for South African companies, Responsible Care® initiative is a strategy for survival and growth (CAIA, 2007).

Although, Responsible Care® requires members' commitment to a set of business ethics which are characterised by doing what is right rather than only what is legally required; it is not known to have a comprehensive, independent safety management system specifically developed for process industry. NOSA's documents on the other hand, are generally strong in addressing traditional occupational health and safety management issues, but very weak in areas often considered central to safety management

system. The system addresses and measures compliance-based items more strongly than management system items (ILO, 1998).

American OSHA Process Safety Management (PSM) and the EPA's Risk Management Program (RMP) regulations provide a virile and dynamic baselines and framework for development of systemic SHE programs and procedures in the process industry (OSHA, 1992 and EPA, 1996). OSHA PSM system itself is performance-based. Thus safety management practices often vary among process facilities and it is of course, difficult to claim with certainty what is meant by regulatory compliance, even in developed countries, (West *et al*, 1998). Therefore, there is a critical need to determine for a particular industry, the PSM benchmarks or Recognized and Generally Accepted Good Engineering Practices (RAGAGEP).

1.2 Statement of the Problem

In the globalised world of the 21st century, business success is becoming increasingly judged on the ability to maintain balance among the triple bottom line dictates of sustainability namely, economic vitality, environmental integrity, and social equity (Sasol, 2001). For South African manufacturers to maintain an edge in the global business competition, they need to adopt a safety management system that is internationally acceptable. National Occupational Safety Association, NOSA's *Management-Based Objective (MBO) Five Star* SHE system, is the most widely adopted local SHE management audit system; while the ISO's generic standards (ISO 9001 and ISO 14001), OHSAS and OSHA standards are used by some companies with global outlook.

From the background, we see that the NOSA being a compliance-oriented safety system is defective in core areas. With NOSA's system, safety measures that address different types of hazards and exposures are managed and executed by separate staff, often under different technical disciplines. These different groups of people may use different safety management and analysis techniques, leading to contradictory approaches and actions in different parts of the organisation. Such inconsistency inhibits safety communication and hinders the process of internal learning throughout the organisation. This problem is particularly magnified in multi-site organisations where a common safety language has not been developed. In a compliance-oriented safety management system, safety is also not integrated throughout the organisation. Instead, it is isolated in the hands of safety professionals and functional managers who assume all the responsibilities for safety. Unfortunately, these safety professionals and functional managers cannot identify and resolve all the safety problems themselves.

Using NOSA's system, a mine or process factory for example could maintain a Five-star rating year after year without making any changes (McEndoo, 2007). Conversely, using international safety system such as OSHA PSM requires a steady improvement to retain compliance, and making it more suitable for facilitation of internal and external benchmarking.

The adoption of integrated systems like OSHA helps process industry improve their organisation and the internal order of doing things. However, due to the performance-based nature of OSHA PSM regulatory requirements, there is a wide variation in the developed PSM programs and practices, (Keren, 2003). Thus, PSM practices often vary and it is of course, difficult to claim with certainty what is meant by regulatory compliance, even in the developed countries, (West *et al*, 1998). Therefore, there is a critical need to determine the industry PSM benchmarks or Recognized and Generally Accepted Good Engineering Practices (RAGAGEP).

On the international plane, benchmarking of PSM elements is mostly conducted among facilities, in individual plants. But neither the questionnaires, results nor the reports are available to the general public, (Keren, 2003). It becomes necessary to investigate and benchmark the variation in the practice of process safety management among the South African process industry.

1.3 General Aim of the Study

This study is a benchmarking exercise aimed at identifying the best practice (within the South African process industry) of three PSM elements, namely- Management of Change (MOC), Emergency Preparedness and Response (EPP), and Process Safety Incident Investigation (PSII) programs.

1.4 Specific Objectives of the Study

- Extraction of the requirements for three PSM elements - management of change (MOC), Emergency Preparedness Program (EPP), and Process Safety Incident Investigation (PSII) - as contained in OSHA and other PSM handbooks.
- Decomposition of the three PSM elements into various measurable and auditable categories and subcategories.
- Investigation of diversity in the practices of the three PSM elements among sampled South African process facilities

- Benchmarking of PSM practice among sampled South African process facilities against international PSM standards
- Recommendations for future policy development of benchmarks for the various subcategories of the PSM elements

1.5 Significance of the Study

Benchmarking is the search for best practices that will lead to superior performance (Camp, 1989). It is also a structured discipline for analyzing a process system to find improvement opportunities (Bergman and Klefsjo, 1994). Benchmarking of PSM elements helps to determine whether the efforts invested by companies toward safety improvement lead to the desired results. The outcomes of this study will facilitate the measurement, and audit of PSM elements in the South African process industry. Benchmarking can help establish PSM best practice by assisting enterprises to analyze, compare, and improve what they do. It also helps to determine the areas that will lead to major reduction of losses and reduction in the number of incidents.

1.6 Scope of the Study

This work studies the variance in the practice of process safety in the South African process industry. The scope of this work is limited to plants and facilities whose activity or combination of activities includes use, storage, manufacturing, handling, or the on-site movement of hazardous chemicals. This list does not include certain types of facilities, such as retail facilities, where hazardous chemicals would normally be present in small containers; oil or gas well drilling or servicing operations; or normally unoccupied remote plants or facilities.

1.7 Limitations

Major limitation to this study is the low response rate. It has not been possible to conclude on the reasons for missing responses. Probably, it is due to the suspicious attitude of the respondents to the survey. A common excuse given by some sampled facilities was that they received excessive similar questionnaires including regulatory surveys.

1.8 Definitions of Terms

In this study, the following terms have the meanings hereby assigned to them:

- **Accident:** An incident involving a single injury and/or minor property damage (AIChE, 1993).
- **Audit:** A systematic, independent, and documented process for obtaining evidence and evaluating it objectively to determine the extent to which defined criteria are fulfilled. This does not necessarily mean an independent external audit (an auditor or auditors from outside the organisation) (ILO, 2001).
- **Benchmarking:** a structured discipline for analyzing a process to find improvement opportunities (Bergman and Klefsjo, 1994).
- **Change /modifications:** A temporary or permanent substitution, alteration, replacement (not in kind), modification by addition or deletion of critical process equipment, applicable codes, process control, catalysts or chemicals, feed stocks, operating limits, mechanical procedures, electrical procedures, safety procedures, emergency response equipment from the present configuration of the critical process equipment, procedures, or operating limits.
- **Contractor:** A person or an organisation providing services to an employer at the employer's worksite in accordance with agreed specifications, terms, and conditions.
- **Emergency Change:** Any change to equipment, procedures, raw materials or chemical additives, facilities, or process parameters such that the time required for a normal MOC procedure would result in unreasonable risk to personnel, the environment, or equipment, or a significant production loss (OSHA, 1992)
- **Facility:** means the buildings, containers or equipment which contain a process (OSHA, 1992)
- **Failure Modes and Effects Analysis (FMEA):** a systematic, tabular method for evaluating and documenting the causes and effects of known types of component failures (AIChE, 1993).
- **Hazard:** An inherent physical or chemical characteristic that has the potential for causing harm to people, property, or the environment. In this study, it is the combination of a hazardous material, an operating environment, and certain unplanned events that could result in an accident (AIChE, 1993).
- **Hazard and Operability (HAZOP):** a systematic method in which process hazards and potential operating problems are identified, using a series of guide words to investigate process deviations (AIChE, 1993).
- **Hazard assessment:** A systematic evaluation of hazards (ILO, 2001).
- **Hazardous chemical:** means a substance possessing toxic, reactive, flammable, or explosive properties (OSHA, 1992).

- **Hot work:** means work involving electric or gas welding, cutting, brazing, or similar flame or spark-producing operations (OSHA, 1992)
- **Incident:** An unplanned event which has the potential for undesirable consequences (AIChE, 1993).
- **Major accident:** an incident involving multiple injuries, a fatality, and/or extensive property damage (AIChE, 1993).
- **Management of change (MOC):** Application of management principles to a temporary or permanent substitution, alteration, replacement (not in kind), modification by addition or deletion of critical process equipment, applicable codes, process control, catalysts or chemicals, feed stocks, operating limits, mechanical procedures, electrical procedures, safety procedures, emergency response equipment from the present configuration of the critical process equipment, procedures, or operating limits (AIChE, 1993).
- **Near-miss incident:** An unplanned sequence of events that could have caused harm or loss if conditions were different or were allowed to progress, but actually did not ((AIChE, 1993).
- **OSH management system:** A set of interrelated or interacting elements to establish occupational safety and health policy and objectives, and to achieve those objectives (ILO, 2001).
- **Normally unoccupied remote facility:** means a facility which is operated, maintained, or serviced by employees who visit the facility only periodically to check its operation and to perform necessary operating or maintenance tasks. No employees are permanently stationed at the facility. Facilities meeting this definition are not contiguous with, and must be geographically remote from all other buildings, processes or persons (OSHA, 1992).
- **Process:** means any activity involving hazardous chemicals including any use, storage, manufacturing, handling, or the on-site movement of such chemicals, or combination of these activities. For purposes of this definition, any group of vessels which are interconnected and separate vessels which are located such that a hazardous chemical could be involved in a potential release shall be considered a single process (OSHA, 1992).
- **Process safety:** the protection of people and property from episodic and catastrophic incidents that may result from unplanned or expected deviations in process conditions (AIChE, 1993).
- **Process safety auditing:** A formal review that identifies process hazards relative to established standards; for example examining plant and equipment, often using a checklist or audit guide (AIChE, 1993).

- **Process safety management (PSM):** an application of management systems to the identification, understanding, and control of process hazards to prevent process-related incidents and injuries (AIChE, 1993).
- **Process safety management (PSM) system:** comprehensive sets of policies, procedures, and practices designed to ensure that barriers to episodic incidents are in place, and in use, and effective (AIChE, 1993).
- **Replacement in kind (RIK) ("like for like"):** a replacement which satisfies the design specification.
- **Risk:** the combination of the expected frequency (events/year) and consequence (effects/event) of a single accident or a group of accidents (AIChE, 1993).
- **Risk assessment:** The process of evaluating the risks to safety and health arising from hazards at work (ILO, 2001).
- **Risk management:** the application of management policies, procedures, and practices to the tasks of analyzing, assessing, and controlling risk in order to protect employees, the general public, the environment, and company assets (AIChE, 1993).
- **Root causes:** management system failures, such as faulty design or inadequate training, which led to an unsafe act or condition that resulted in an incident; underlying cause. If the root causes were removed, the particular incident would not have occurred (AIChE, 1993).
- **Standard:** any established measure of extent, quantity, quality, or value. Any type, model, or example for comparison; or a criterion of excellence (AIChE, 1993).
- **What-if analysis:** a brainstorming approach in which group of experienced people familiar with the subject process, ask questions or voice concerns about possible undesired events (AIChE, 1993).

CHAPTER TWO

LITERATURE REVIEW

2.1 Historical Overview of Industrial Safety Practice

Industrial safety movements had their beginnings in Europe. By the middle of the 19th century, efforts to improve unacceptable conditions brought about by the industrial revolution were made both by governments and trade guilds or trade unions. By the time the organized safety movement started in North America, it already had a considerable body of safety literature to draw from. In Germany, in particular, excellently illustrated books were available, dealing with the hazards involved in a wide range of industrial occupations, activities and outlining safety measures to be taken for their control (Heinrich, 1959).

2.1.1 Evolution of Industrial Safety in UK

The concept of the safety of employees goes back to the start of Industrial Revolution in Britain. However, with the scale-up of plant sizes in the 1950s and 1960s, new safety concerns were recognized; it was not only the slips, trips, falls and similar events but also the process events. So was developed the concept of Safety and Loss Prevention (IChemE, 1960). By the 1960s it was recognized that there were other more insidious hazards associated with process plants. These were hazards which affected the health of the employee. Finally, in the 1970s there was a clear recognition that industry could also adversely affect the environment, not only locally, but globally. Now many companies use the acronym SHE (safety, health and environment) for those activities – tasks undertaken to safeguard the environment, employees' health and safety - not as separate units but as one entity (Crawley and Ashton, 2002).

2.1.2 Evolution of Industrial Safety in US

With no workmen's compensation laws, all states in US used to handle industrial injuries under the common law, which gave defences to the management of industry that almost ensured that they would not have to pay for accidents. The passage of workmen's compensation laws in 1911 marked the beginning of the first era in industrial safety management (Petersen, 1975). Petersen identified six eras in

the evolution of safety management in America's history – Inspection Era, Unsafe Act and Condition Era, Industrial Hygiene Era, Noise Era, Safety Management Era and the OSHA Era.

Inspection Era witnessed the cleaning up of plants which significantly reduced the number of industrial fatalities. Industrial safety movement was born during this era. Coincidentally, the publication of W.H. Heinrich's *Industrial Accident Prevention* set the stage for practically all organized safety work from that time on. Heinrich (1931) text ushered in the Unsafe Act and Condition Era. He suggested that *unsafe acts* are the cause of 85% accident and *unsafe conditions* are the cause of the rest (except for some acts of God). Learning from his work, safety professional started a two-pronged approach: cleaning up unsafe conditions and trying to teach and train workers in the "safe" way of working.

In the late 1940s, we had the Industrial Hygiene Era; during which the safety focus was split into three: looking at the physical conditions, the workers' behaviour and the environmental conditions. Prior to the Noise Era in 1951, hearing loss was not compensable under the law, for deafness was not considered to impair earning power and a fundamental concept of workmen's compensation had been that its purpose was to compensate for loss of earning power as well as medical bills. During this era it became law to reimburse employees for hearing loss. (Petersen, 1975).

The Safety Era during 1950s and 1960s witnessed the birth of professionalism in safety management. Management tools and techniques were adopted to solve safety problems. There was also a considerable re-examination of safety guiding principles; and the better definition of the scope and functions of safety professionals. Injury frequency rate dropped markedly signalling the success of safety profession. However, from 1961 through 1971 the frequency rates consistently got worse; the injuries severity rates still improved. In 1970, the Occupational Safety and Health Act, was passed ushering in the latest era – OSHA Era. OSHA era appears to emphasize the inspection with state and federal control. OSHA era required safety professional to concentrate on two primary things: (1) complying with the law (the standards) and (2) controlling production losses. Petersen (1975) claimed that the next era will be what he called the *Psychology of Safety Management Era*.

2.2 Health and Safety Regulations

In case of a toxic chemical release, fire, or explosion, there are major catastrophic consequences not only to employees but also to residents as well as environment. In addition, financial losses caused by

the damage of the facility are enormous, and it takes long time to repair the facility; these bring other impacts such as insufficient supplies of raw materials to the related industries. To prevent such major industrial accidents many countries in US and EU have been implementing chemical accident prevention system.

OSHA in USA announced the plan to declare a special law to prevent major industrial accidents in USA, and thus the PSM regulation was enacted in November, 1992 (AIChE, 1989). In 1982, European Union adopted EC Directives (Seveso Directives) which was similar in structure to PSM system in USA. EC Directives presented minimal legal standards for country in European Community to observe; the objectives of this directive were to prevent major industrial accidents and mitigate the damage to people and environment.

A dire need for national plan of chemical accident prevention arose after the chemical release in Bhopal, India resulted in fatalities of 2500 in December 1984 (ILO, 2001). ILO announced the declaration in 1985 that there should be a systematic procedure for preventing major industrial accidents

2.2.1 Need for Safety Regulation

Regulations may only be necessary if there is some doubt about the efficacy of voluntary codes. Then there needs to be a legal sanction which can be imposed by a Court on those who ignore 'good practice'. Provision of legal sanction requires enforcement, and when the subject is related to detailed technical matters then a competent enforcement authority is needed. The aim of all "Safety and Loss Prevention" activities and philosophies is to "prevent before a cure is needed" (Jones, 1987). In these circumstances, it is necessary to identify the possibilities for potential accidents, and then to introduce means of reducing the chances of these accidents. Whilst this may be a normal procedure for some industries it is not always to the same standard, nor do all industries follow such good practice. This is another situation where there may be scope for 'Regulations' to be of benefit. Thus 'Regulations' are a way of drawing attention to the measures needed to prevent accidents.

2.2.2 Review of International Safety Regulation

Major hazard installations (MHI) are greatly needed for every country in order to provide industry, agriculture, transportation etc. with energy. MHIs store large quantity of hazardous substances and energy in one place. The typical types of MHIs are the refineries, petrochemical plants, chemical

production plants, LPG storage, water treatment plants, etc. (ILO, 1988). Experience shows that major hazardous facilities pose a risk to the workers and the neighbours of the plants. Following the accident in Seveso (Italy) in 1976, the major hazard regulations in various countries were put together and integrated to align with the Seveso Directive. This Directive, on the major accident hazards of certain industrial activities, has been in force since 1984 (ILO, 1988). Major hazard control differs from one country to another. The essential steps of major hazard control are outlined by the International Labour Organization (ILO, 1988). The following sections review, in brief, the major international regulations and guidelines on industrial safety.

2.2.2.1 ILO Convention

The International Labour Organization (ILO) in 1993 adopted a new convention on the prevention of major industrial accidents (Convention No. 174). This provides a framework for the establishment of a national major hazard system for the prevention of industrial accidents and to mitigate the consequences of such an accident. It requires the formulation, implementation, and periodic review of a coherent national policy concerning the protection of employees, the community and environment, against risk from major hazards. Major provisions include: the preparation of a safety report containing technical, management and operational information covering the hazards and risks of a major hazard facility and their control; reporting of all major accidents; establishment of off-site emergency plans; and site selection policy for the separation of a proposed major hazard facility from residential areas, public facilities and existing major hazard facilities (NOHSC, 2003).

2.2.2.2 ILO Major Hazard Control Manual

One of the technical tools developed by the ILO is a major hazard control manual. The manual identifies and discusses the various components of major hazard control system. The manual also highlights that major hazard control system can be achieved through identification of the installations with major potential accident hazards. Also given in the manual is the guidance about organisational and preventive measures against hazards, emergency planning, and the implementation of major hazard control system (ILO, 1988).

2.2.2.3 European Union Seveso II Directive

The most important change internationally in recent years has been the introduction of the Seveso II Directive by the EU. Seveso II fully replaces its predecessor - the original Seveso Directive - from February 1999. The aim of the Seveso II Directive is twofold:

- (1) The prevention of major accident hazards involving dangerous substances; and
- (2) The limitation of consequences of such accidents, not only for man, but also for the environment.

Important changes were made and new concepts introduced into Seveso II, which included: a revision and extension of scope of directive; the introduction of new requirements relating to safety management systems (SMSs), emergency planning, and land use planning (Vermeulen and Hands, 1993).

2.2.2.4 UK Safety Regulations

In the UK, the Control of Major Accident Hazards (COMAH) Regulation of 1999 has brought UK into compliance with the new Seveso II Directive. The UK regulations outline two tiers of establishments, depending on the quantities of dangerous substances held at their establishments. Operators of all establishments subject to the regulations must notify the regulator (the “competent authority”) of their activities before operations begin. The competent authority comprises the Health and Safety Executive (HSE), the Environment Agency for England and Wales and the Scottish Environment Protection Agency (SEPA) working together.

All operators must “take all measures necessary to prevent major accidents and limit their consequences to people and the environment”. The regulation also requires lower-tier operators to prepare a document setting out their policy for preventing major accidents (a major accident prevention policy or MAAP). In 1999 the UK established the hazardous installations Directorate in order to control and reduce risk in high hazard industries De Cort, (1994).

2.2.2.5 US Safety Regulations

In the USA, OSHA Process Safety Management standard and EPA’s Clean Air Act Amendments (1990) rule (112r-Risk Management Program (RMP) Rule – which basically adopted the PSM with several exceptions) require employers to take a systematic approach to addressing safety and health hazards.

This includes obligations to identify and prioritize all hazards in terms of seriousness and track progress in controlling them. Other elements of PSM include employee participation and an emphasis on flexible performance-based obligations under which firms can develop risk management plans tailored to site-specific conditions. The EPA rule further requires that a plan be developed to document how a facility will comply with RMP. Among other matters, the plan must detail methods and results of the hazard assessment, accident prevention and emergency response program (NOHSC, 2003).

2.2.3 Industrial Health and Safety Legislation in South Africa

Surveys of occupational safety and health practice have found that Southern African workers are exposed to new chemical, psychosocial, and physical hazards that are emerging from new forms of industrial processes and work organisations (Loeweson, 1996). Before further review of the current situation of industrial health and safety practice in South Africa, a cursory look at the South African history of industrial health and safety legislation, will be appropriate at this juncture.

2.2.3.1 Historical Overview

South Africa was steeped in racism which has affected all aspects of the body politic, and underlies the development of the occupational health and industrial safety system (Jonathan and Ian, 1989). Industrial development began at the end of the 19th century with the discovery of diamonds and gold. The mining industry brought with it new patterns of industrial and political relations in which White mine owners, White skilled mine workers, and both Black and White unskilled mine workers were thrown together in a situation fraught with potential conflict and compounded by language-group hostilities among the Whites. Craft-based unions organized by White workers excluded Blacks on grounds of skill and race. Attempts by management to eliminate mining skills and to replace White with cheaper Black labour together with poor working and health conditions on the mines, led to a period of sustained conflict in the first two decades of the 20th century, culminating in an unsuccessful insurrection by White miners in 1922 (Katz, 1979).

This period was associated with a significant updating of occupational health and compensation legislation. The development of occupational health and safety in South Africa has always been prompted by labour activity. Organized White labour succeeded in obtaining many concessions from capital such as preventive legislative and compensation legislation for miners' phthisis (a combination of tuberculosis and silicosis) and work-related accidents. Compensation benefits for pneumoconiosis

among White mine workers were in advance of conditions enjoyed by workers in the developed countries of Europe and North America as far back as 1956. After separate but parallel struggles over health issues, Black workers succeeded in obtaining some coverage, although benefits were invariably racially discriminatory (Jonathan and Ian, 1989).

According to Jonathan and Ian (1989) South African occupational health legislation has generally followed two parallel tracks, one covering the mining industry, and the other dealing with non-mining industry, commerce, and services. Various laws relating to mining health and safety preceded the formation of the Union of South Africa in 1910. In 1901 the Government Mining Engineer in the Transvaal reported high mortality rates from miners' phthisis. This was followed by the first Commission of Inquiry into Phthisis in 1902, and three years later by the first mining regulations created to abate the dust hazard. The regulations were not particularly effective, and another commission, the Mining Regulations Commission of 1907, was set up to investigate dust control. The Commission's report in 1910 showed that the mortality of White miners was six times higher than that for adult males on the Witwatersrand. At this time small *ex gratis* payments were made by the mining companies to widows of victims of miners' phthisis (Jonathan and Ian, 1989).

The Colonial laws that existed prior to Union were consolidated into the Mines and Works Act, 12 of 1911, which was intended to provide for preventive measures and the protection of the health and safety of mine workers. The Act related mainly to the control of machinery. A further commission of medical practitioners was established to look into miners' phthisis and tuberculosis and to make recommendations for compensation. This resulted in the Miners' Phthisis Act of 1911 which introduced compulsory compensation for phthisis. These two Acts led, after various commissions and amendments, to the two main Acts — the Mines and Works Act, 27 of 1956, and the Occupational Diseases in Mines and Works Act, 78 of 1973. These Acts provide for the control of the work environment on the mines, for risk or fitness examinations relating to miners' fitness for underground work, and for benefit examinations for occupational disease compensation (Jonathan and Ian, 1989).

Outside of the mining industry, the Workmen's Compensation Act No 25 of 1914 and an amendment of 1917 provided the first coverage for industrial accidents and occupational diseases, respectively. Disease had to be presented along with disablement, and had to be causally related to work. Posthumous benefits were available only if death was caused by the occupational disease. Cyanide rash, lead, and mercury poisoning were the three occupational diseases recognized and they were handled

administratively as if they were accidents. These were augmented by ankylostomiasis in 1934, and by 1941, 15 occupational diseases including silicosis were scheduled as occupational diseases.

The first Factories Act was passed in 1918, and from 1924 industry was administered by the Department of Labour. Prior to this the mines and industry had been jointly administered by the Department of Mines and Industry. Limited coverage for white collar workers in offices was provided by the Shops and Offices Act, 41 of 1939. The new Factories, Machinery and Building Work Act, 22 of 1941, replaced the outdated 1918 law; it laid down basic conditions such as hours of work and regulations pertaining to the control of machinery. For the first time a Factories Inspectorate was constituted within the Department of Labour, with duties to inspect workplaces and investigate reportable accidents (Jonathan and Ian, 1989).

In 1958, the Minister of Labour appointed a departmental committee to investigate and make recommendations on the incidence of occupational diseases. The committee reported back in 1963 providing evidence of widespread occupational disease in South African industry, but the report did not result in any substantial preventive or compensation measures. The Shops and Offices Amendment Act, 75 of 1964, introduced new health and safety-related protective measures relating to hours of work and other conditions of employment for white collar workers in shops and offices. The Factories Act was amended again in 1967 and some general health regulations were introduced but, with the exception of regulations relating to noise control, no regulations specifically dealing with occupational hazards were promulgated until the mid 1980s (Jonathan and Ian, 1989).

The Workmen's Compensation Act, No. 30 of 1941 was repealed by the Compensation for Occupational Injuries and Diseases Act, No. 130 of 1993. Also, the Labour Relations Act enacted in 1956 has been repealed by the Labour Relations Act, No. 66 of 1995. Another Act enacted in 1980s is Basic Conditions of Employment Act, No. 3 of 1983; but now repealed by Basic Conditions of Employment Act, No. 75 of 1997.

2.2.3.2 Current Safety Legislation and Policies in South Africa

No over-arching national health and safety policy or statutory requirements exist in South Africa to stipulate the provision of occupational health services (Jeebhay and Jacobs, 2000). Various laws however exist with a direct bearing on the delivery of occupational health services by requiring medical surveillance and evaluation of the work environment. The most important of these are the Occupational

Health and Safety Act (OHSA) of 1993 and its regulations on hazardous chemical substances and lead; and the Mine Health and Safety Act (MHSA) of 1996. These laws are enforced by the Department of Labour (excluding mines) and Department of Minerals and Energy (mines) respectively (see Table 2-1) (Jeebhay, 1996). The MHSA also has under its provisions a dedicated medical inspectorate to enforce the required occupational health standards (Lewis and Jeebhay, 1996).

Table 2-1 Legislation pertaining to occupational health and safety services in South Africa

Act	Function	Enforcement Agency
Occupational Health & Safety Act (OHSA), 1993	Ensures a healthy and safe environment in factories and offices	Dept. of Labour
Compensation for Occupational Injuries & Diseases Act (COIDA), 1993	Provides for medical cover and compensation of occupational injuries or diseases in all work-places	Dept. of Labour
Mine Health & Safety Act (MHSA), in mines/quarries 1996	Ensures a healthy and safe environment	Dept. of Minerals & Energy
Occupational Diseases in Mines & Works Act (ODMWA), 1973	Provides for compensation of occupational lung diseases in mines and quarries	Dept. of Health
Medicines and Related Substances Act, 1965	Provides for an authorisation permit to be issued to a nurse dispense schedule 1-4 substances at workplace health services	Dept. of Health

Source: Lewis and Jeebhay (1996)

Moodley and Bachmann (2002) believe that occupational health and safety in the newly democratic South Africa is gaining momentum as legislation and trade union action are making employers and workers aware of their duties and rights to a safe and healthy working environment. Occupational health has received high priority in government policies such as the union-supported Reconstruction and Development Programme (African National Congress, ANC, 1994a) and the ANC's National Health Plan for South Africa (African National Congress, ANC, 1994b). These policies are in keeping with the International Labour Organization's (ILO) recommendation (Rantanen and Fedotov, 1998; ILO, 1995; and ILO, 1985) that each country should implement and periodically review a coherent national policy on occupational health services. Such services should protect the health of workers against potential hazards at work, ensure that each worker is suited to their job, provide emergency and definitive management for injuries or illnesses arising out of work, and maintain or improve health by education and promotion of primary health care (Felton, 1992).

Conversely, an audit by Loeweson (1998) of Southern African Development Community (SADC) member countries indicated that South Africa has not ratified some of the ILO Conventions that pertain to occupational health and safety. Loewenson does however indicate that South African laws are in compliance with most of the provisions in the ILO Convention 155 (1981), the most central Convention governing health and safety, except for the right to refuse dangerous work (outside the mines).

2.2.3.3 South African Regulations Related to Process Industry Safety

Summarily, there are three main Acts as far as occupational health and safety in South Africa are concerned:

- 🐉 Occupational Health and Safety Act 85 of 1993
- 🐉 Mine Health and Safety Act 29 of 1996
- 🐉 Compensation for Occupational Injuries and Diseases Act 130 of 1993

These Acts with their respective Regulations are cornerstone legislations which control most aspects of health and safety in industrial and business undertakings. However, other Acts also address the prevention of occupational accidents, diseases and the control of the environment. Such Acts include:

- 🐉 Hazardous Substance Act 15 of 1973
- 🐉 Occupational Diseases in Mines and Works Act 78 of 1993
- 🐉 Atmospheric Pollution Prevention Act 45 of 1965
- 🐉 Environment Conservation Act 73 of 1989
- 🐉 National Building Regulations and Building Standards Act 103 of 1977

However, only the Occupational Health and Safety Act 85 of 1993 and its various Regulations have a general and direct bearing on the operations of process and manufacturing factories in South Africa. The Act (85/1993) is meant to “provide for the health and safety of persons at work and for the health and safety of persons in connection with the use of plant and machinery; the protection of persons other than persons at work against hazards to health and safety arising out of or in connection with the activities of persons at work; to establish an advisory council for occupational health and safety; and to provide for matters connected therewith”.

The major contents of Occupational Health and Safety Act 85 of 1993 which are relevant to safety in the process industry; are as follows:

- An employer is required to prepare a written policy concerning the protection of the health and safety of his employees at work, including a description of his organisation and the arrangements for carrying out and reviewing that policy.
- Every employer shall provide and maintain, as far as is reasonably practicable, a working environment that is safe and without risk to the health of his employees. By taking such steps as may be reasonably practicable to eliminate or mitigate any hazard or potential hazard to the safety or health of employees, before resorting to personal protective equipment.
- Every employer shall conduct his undertaking in such a manner as to ensure, as far as is reasonably practicable, that persons other than those in his employment who may be directly affected by his activities are not thereby exposed to hazards to their health or safety.
- Any person who designs, manufactures, imports, sells or supplies any article for use at work shall ensure, as far as is reasonably practicable, that the article is safe and without risks to health when properly used and that it complies with all prescribed requirements.
- Subject to such arrangements as may be prescribed, every employer whose employees undertake listed work or are liable to be exposed to the hazards emanating from listed work, shall, after consultation with the health and safety committee established for that workplace- identify the hazards and evaluate the risks associated with such work constituting a hazard to the health of such employees, and the steps that need to be taken to comply with the provisions of this Act.
- Without derogating from any specific duty imposed on an employer by this Act, every employer shall- as far as is reasonably practicable, cause every employee to be made conversant with the hazards to his health and safety attached to any work which he has to perform, any article or substance which he has to produce, process, use, handle, store or transport and any plant or machinery which he is required or permitted to use, as well as with the precautionary measures which should be taken and observed with respect to those hazards.
- Every employee shall at work, take reasonable care for the health and safety of himself and of other persons who may be affected by his acts or omissions;
- Every employee shall at work, as regards any duty or requirement imposed on his employer or any other person by this Act, co-operate with such employer or person to enable that duty or requirement to be performed or complied with.

- Every employee shall at work, carry out any lawful order given to him, and obey the health and safety rules and procedures laid down by his employer or by anyone authorized thereto by his employer, in the interest of health or safety;
- Every employee shall at work, if any situation which is unsafe or unhealthy comes to his attention, as soon as practicable report such situation to his employer or to the health and safety representative for his workplace or section thereof, as the case may be, who shall report it to the employer; and
- Every employee shall at work, if he is involved in any incident which may affect his health or which has caused an injury to himself, report such incident to his employer or to anyone authorized thereto by the employer, or to his health and safety representative, as soon as practicable but not later than the end of the particular shift during which the incident occurred, unless the circumstances were such that the reporting of the incident was not possible, in which case he shall report the incident as soon as practicable thereafter.
- Every chief executive officer shall as far as is reasonably practicable ensure that the duties of his employer as contemplated in this Act are properly discharged.

Since its enactment, about twenty-one regulations have been promulgated to realize the provisions of the Acts; namely –

- 🏢 General Administrative Regulations
- 🏢 Asbestos Regulations
- 🏢 Regulations concerning the Certificate of Competency
- 🏢 Diving Regulations
- 🏢 Electrical Installation Regulations
- 🏢 Environmental Regulations for Workplaces
- 🏢 Facilities Regulations
- 🏢 Hazardous Chemical Substances Regulations
- 🏢 Regulations for Integration of the Occupational Health and Safety Act of 1995
- 🏢 Lead Regulations
- 🏢 Lift, Escalator and Passenger Conveyor Regulations
- 🏢 Driven Machinery Regulations
- 🏢 General Machinery Regulations
- 🏢 General Safety Regulations
- 🏢 Vessels under Pressure Regulations

- 🏆 Major Hazard Installation Regulations
- 🏆 Regulations for Hazardous Biological Agents
- 🏆 Explosives Regulations
- 🏆 Noise-induced Hearing Loss Regulations
- 🏆 Construction Regulations

2.2.4 Organized Industrial Safety Associations in South Africa

In the coming section, a brief description of services offered by specific industrial safety bodies is given.

2.2.4.1 South African Chamber of Mines – Mine Safety Division

Prevention of Accidents Committee, PAC was formed in 1913, as one of the world's pioneers in safety. It is only one year younger than the National Safety Council of US. Originally, PAC's safety and health activities were only conducted on the gold mines of the Witwatersand, but later the area of operations was extended to include coal and other mineral mines which became members of the Chamber. PAC established Mines Safety Rating System (MSRS) to cater exclusively for the mining industry. It comprises of sixteen main elements. This system also awards one to five stars for health and safety performance, with gold stars featuring at a higher level of performance. These elements have to be implemented within a certain period of time (De Beers and Heyns, 2005)

2.2.4.2 National Occupational Safety Association (NOSA)

NOSA is a public company, registered under the Companies Act as an association not for gain. It was established in 1951 by major employer organisations in conjunction with the then Workmen's Compensation Commissioner. NOSA's objectives are to prevent occupational accidents and diseases and to eliminate their causes. It deals with all matters relating to occupational health and safety in South Africa by giving advice and guidance.

NOSA is perhaps better known for its *Management by Objectives* system with five-star grading which was developed in the early seventies. The system is grouped into five main groups containing sixty-nine (69) elements. The groups include: *Premises and Housekeeping, Mechanical, Electrical and Personal Safeguarding, Fire Protection and Prevention, Accident Recording and Investigation, Health and Safety Organization*. Elements relating to environmental control were formally integrated into the rating system in 1999 (De Beers and Heyns, 2005).

Altogether, sixty-nine (69) elements are used in the assessment of the safety, health, and environmental control (SHE) aspects of a company. Each element is weighted according to its importance. This is then converted to a percentage; and one to five stars are awarded. Five stars are awarded if the score is between 91% and 100%; four stars are earned if the score is 75% up to 90%; etc. Apart from the physical conditions, the Disabling Injury Incidence Rate, DIIR is also brought into play for awarding stars. Although, NOSA can be applied to some twenty-seven (27) classes of South African industries, it is mainly used by manufacturing and process industries.

2.2.4.3 Det Norske Veritas' (DNV) ILCI System

DNV South Africa is another formidable role-player in health and safety worldwide. Particularly in South Africa, it uses the International Loss Control Institute (ILCI) system in its approach. The system is under the control of a Danish company – Det Norske Veritas (DNV). The total DNV Programme has three legs: ISRS, IQRS, and IERS -addressing safety, quality, and environment respectively (De Beers and Heyns, 2005). The ISRS has basically the same elements as the two latter programmes mentioned above, but in this case, there are twenty of them. There are two major categories of recognition: standard and advanced. Rating is done over ten levels of achievement, with level one being the lowest. In order to qualify for an award, certain of the elements are combined; and must be implemented satisfactorily. As the award level progresses, more elements are included until all are integrated, with minimum percentage for each, and within a certain time limit for the highest level.

2.2.4.4 CAP™ System

CAP™, currently in use by IRCA, is a management system audit. It was developed to help build an effective system for incident and accident prevention. It assists in detecting and correcting system failures which can cause accidents. The trend in management system audits is to become increasingly prescriptive, detailed, and complex. As a result their users often lose touch with the practical lessons learned regarding incident control. CAP™ addresses these concerns by maintaining a balance between the scope and the length of the audit and a reliance on the competency of those using it. It tries to limit the bureaucracy which often accompanies the implementation of a safety, health, and quality system.

According to De Beers and Heyns (2005), CAP™ approach attacks and prevents failures in the management system that lead to losses. This allows CAP™ to be flexible and effective in controlling safety, health, environmental and quality incidents. The system is designed to either include or exclude

the environmental and quality processes from the audit. CAP™ is organized into fifteen (15) elements. There are also a number of optional technical elements that can be included into the audit.

2.2.4.5 Safety First Association

Established in 1932, making it the oldest association of its kind in South Africa. It aims to promote an awareness of accident situations and environmental health problems at home, work and play (De Beers and Heyns, 2005)

2.2.4.6 Association of Societies for Occupational Safety and Health (ASOSH)

Established in 1978, the Association aims at the formation of an inter-disciplinary organisation through which member societies can do the following (De Beers and Heyns, 2005):

- ☞ Exchange views, ideas and knowledge
- ☞ Focus cooperation in furthering the understanding and promotion of occupational health, safety and environmental health matters in Southern Africa

The ASOSH membership consists mainly of societies and associations, but it also provides support to companies and individuals as members.

2.2.4.7 Institute of Safety Management (IoSM)

The IoSM is an organisation not for gain whose main aim is to promote the art and science of accident prevention and loss control, both among its members and the general public (De Beers and Heyns, 2005). Its members cover a wide field of disciplines which include occupational injury and accident prevention, loss control, fire defence, elements of security, ergonomics, risk management, occupational hygiene, as well as a comprehensive range of management skills. The Institute is dedicated to upgrade the professional skills of its members and as such provides various training courses throughout South Africa.

2.3 Industrial Health and Safety Management

Industrial accidents not only provoke a decrease in human capital; they also generate financial losses due to disruptions in industrial processes, damage to production machinery and technology, and harm to the firm's reputation. They consequently have a negative effect on the competitiveness and economic

potential of both companies and countries. Their consequences highlight the need to develop strategies to prevent accidents, or at least to cushion their adverse impacts (Khan and Abbasi, 1999), which involves developing hazard management plans and up-to-date emergency preparedness in these process industries. This increasing emphasis on chemical process safety over the past two decades has led to the development and application of powerful hazard analysis and risk assessment tools (Fang *et al*, 2004; Reniers *et al*, 2005).

But major accidents are not the only incidents impacting on industrial processes; numerous events occur that reflect a potentially dangerous situation. Near misses disrupt the workflow in industrial processes and generate substantial economic losses (Heinrich, 1959). Moreover, repeated disruptions are identified by Sonnemans and Körvers (2006) as precursors or warning signs of accidents. Because of the possibility of major accidents occurring, effective safety management is of huge importance to the chemical industry (Reniers *et al*, 2005), and near misses should be treated as a serious warning that a significant accident could occur. They should therefore be controlled and integrated into such management systems (Jones *et al*, 1999).

The global cost of accidents is far too high. The National Safety Council estimates that the total cost attributable to occupational fatalities and injuries reached \$125.1 billion in the United States in 1998 (Brown *et al*, 2000). Thus, safety at work is nowadays considered a high-priority activity in all sectors, because of its important social and economic implications. The investigation of these accidents and near misses has become a crucial task for all types of firm (Jones *et al*, 1999), with the aim being to detect not only the direct causes, but also the root causes, and to obtain a total control of losses. Research findings on safety reveal that the human factor plays a fundamental role in an organisation's safety performance (Attwood, *et al* 2006; Donald and Young, 1996; Hughes and Kornowa-Weichel, 2004; Jo and Park, 2003). Nowadays, the human factor is considered to contribute to accidents occurring by over 80%, due to the high reliability of electronic and mechanical components and the new role of human operators in complex systems. Employees are the last barrier against risks, and their behaviour is critical for avoiding both material and personal losses (Hofmann and Stetzer, 1996).

However, unsafe worker behaviour is frequently the result of latent failures in the organisation and management systems that predispose workers to act unsafely (Hughes and Kornowa-Weichel, 2004; Kawka and Kirchsteiger, 1999; Reason, 1997; Sonnemans and Körvers, 2006). These defects include, particularly, the lack of instructions or appropriate training (Attwood *et al*, 2006; Hughes and Kornowa-

Weichel, 2004; Kwon, 2006), de-motivation (Kletz, 1993), the lack of work procedures, the poor design of tasks, the lack of control, low management commitment to safety (Rundmo, 1996), and, in short, inadequate safety measures and management systems (Hofmann *et al*, 1995; Kwon, 2006). Thus, it is currently recognized that safety management plays an important part in achieving and maintaining a high level of safety (Mitchison and Papadakis, 1999) and in reducing losses.

A safety management system reflects the organisation's commitment to safety, and it is an important ingredient in employees' perceptions about the importance of safety in their company. This system comprises a set of policies and practices aimed at positively impacting on the employees' attitudes and behaviours with regards to risk, thereby reducing their unsafe acts. Its aim is to raise awareness, understanding, motivation, and commitment among all workers. Thus, the safety management system can be regarded as an antecedent of a firm's safety climate, with this being understood as the employees' attitudes and perceptions about the importance the organisation attaches to safety (DeJoy, Schaffer, Wilson, Vandenberg, and Butts, 2004).

The safety climate and the safety management system are regarded in various studies as a manifestation of the organisation's safety culture (Cooper, 2000; Kennedy and Kirwan, 1998). However, the literature has focused on measuring and analyzing the safety climate (Brown and Holmes, 1986; Seo *et al*, 2004; Silva, *et al*, 2004; Zohar, 1980). There have been few attempts to produce coherent and comprehensive models of a safety management system (Basso *et al.*, 2004; Hale *et al*, 1997; Hurst, 1997), and few scales have been developed allowing researchers to measure the degree of implementation of safety management systems in organisations.

Various previous works focus on an analysis of one specific element of the management system, such as risk analysis (Demichela *et al*, 2004; Reniers *et al.*, 2005), review (Basso *et al.*, 2004) or communication (Kelly and Berger, 2006), but few works analyze the influence of the system as a whole on safety performance (Hurst, 1997). Hale, Baram, and Hovden (1998) indicate that the field of safety management research is still young, and especially needs empirical evidence that links the organisation to safety performance.

There are studies that emphasize the importance of safety management systems, and that describe how to implement them (Hale *et al.*, 1997; Mitchison and Papadakis, 1999), but there are very few works

providing a specific tool to measure the degree of implementation of the policies and practices making up this management system in organisations.

2.3.1 Safety Management System: Conceptualization and Dimensions

Managing risks in an integrated way with the operations of the organisation has been of increasing importance in recent years. This approach reduces accident rates (Petersen, 2000), and improves the firm's productivity and economic and financial performance (Andreoni, 1986; HSE, 1997; Rechenthin, 2004; Smallman and John, 2001). However, very little attention has been paid to defining what constitutes an effective health and safety management system (Santos-Reyes and Beard, 2002). It is a concept that has not yet been fully defined, nor consequently operationalized (Fernández-Muñoz *et al*, 2006). A safety management system can be understood as a set of policies, strategies, practices, procedures, roles and functions associated with safety (Kirwan, 1998).

This management system is therefore rather more than just a "paper system" of policies and procedures (Mearns *et al*, 2003). Safety management systems are mechanisms that are integrated in the organisation (Labodová, 2004), and designed to control the hazards that can affect workers' health and safety. At the same time, they allow the firm to comply with the current legislation easily. In order for this system to be effective it must get the employees' involvement. In other words, the system must promote a positive safety climate. To do this, strong commitment and support is required from all the managers in the firm (CAVA, 2002; Zohar, 1980).

The literature includes a large number of studies analyzing the practices and procedures involved in an adequate safety management: risk assessment, communication, accident analysis, emergency response, near miss reporting (Basso *et al.*, 2004; Demichela *et al.*, 2004; Hale *et al.*, 1997; Hurst, 1997; Kelly and Berger, 2006). According to ILO (2001), an adequate safety management system should contain the main elements of policy, organizing, planning and implementation, evaluation and action for improvement, as shown in figure 2-1. However, there have been few empirical studies to date, and no consensus has been achieved about the specific dimensions making up the safety management system (Fernández-Muñoz *et al*, 2006).

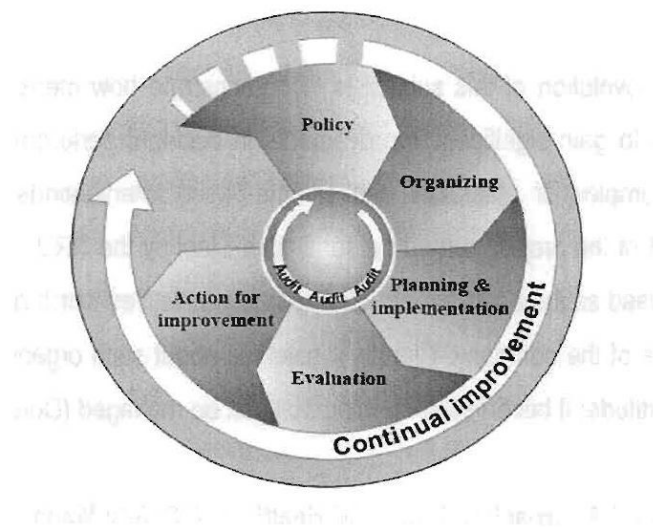


Figure 2-1: Elements of safety management system (ILO, 2001)

2.3.2 Human Factors in Safety Management

Human factors have been widely recognized as playing a significant role in the safety performance of organisations. Initially, interest in the contribution of human factors to an organisation's safety performance focused on physical design and its relationship to operators i.e. ergonomics. In many senses, this perspective kept the issue of safety on the industrial shop floor and in the realm of engineers and ergonomists. This remained the case when concerns shifted to the examination of cognitive factors in which tasks were considered in relation to their propensity to elicit human error (Reason, 1990). While the task and hardware approaches played a significant role in the great improvements in industrial safety up until the 1980s, many organisations' accident figures have been found to plateau at a persistent level with further improvements becoming seemingly impossible (Donald and Young, 1996).

As a consequence of this, new approaches were sought, and attention began to move towards safety attitudes, climate, and culture within organisations. One of the first papers to be published that examined the role of safety climate was by Zohar (1980). While this work suggested a relationship between safety climate and safety performance, it was based on expert judgments and fell short of demonstrating an empirical relationship between climate and accident rates. A major study carried out during the mid-1980s by the Safety Research Unit, SRU for British Steel demonstrated a clear correlation between attitudes and safety performance (Canter and Donald, 1990). As a result of SRU research and other

researches it is now reasonably well accepted by practitioners and researchers in the field as well as organisations that climate, attitude, and culture play a part in accidents (Donald and Young, 1996).

The next stage in the evolution of this subject is to demonstrate how measures of safety culture and attitudes can be used to gain significant improvements in accident performance. Recent studies have begun to provide examples of attitudinal and climate-based interventions that have led to safety improvements. As part of the project carried out for British Steel by the SRU (Canter and Donald, 1990), safety attitudes were used as the basis for introducing safety initiatives which resulted in improvements in the safety performance of the company. Clearly, if safety is about such organisational characteristics as climate, culture, and attitude; it becomes something that can be managed (Donald and Young, 1996).

2.3.2.1 Behavioural Approach to Industrial Health and Safety Management

Behavioural approaches to safety management are now commonplace (Cooper *et al.*, 1994; Cox and Cox, 1996) and are designed to improve workplace safety by promoting those behaviours deemed critical to health, safety and risk control. This is not surprising given that between 80% and 90% of all workplace accidents and incidents can be attributed to unsafe behaviours (Hollnagel, 1993; HSE, 2002). The UK Health and Safety Executive (HSE) have suggested that effective risk control depends, in part, on the behaviour of individuals at all levels within an organisation (HSE, 2002) and have thus highlighted the importance of people-focused initiatives. Behaviour-based safety interventions are people-focused and are often based upon one to one or group observations of employees performing routine work tasks, feedback on safety related behaviour, coaching and mentoring.

The majority of initiatives have a proactive focus, encouraging individuals and their work groups to "consider the potential for accident involvement, and their own behaviour as safe versus unsafe before somebody gets hurt" (Sutherland *et al.*, 2000). Connor (1992) conducted a review of previous research and reports of interventions, from which it is possible to develop a list of the human factors that influence workplace safety. Many of these factors fall under four overlapping headings: attitudes, perceptions, motivation and behaviour and include personal characteristics, individual attitudes, consideration of possible outcomes and a person's intentions as well as social context.

According to IET (2007), behavioural safety intervention is a proactive approach to safety improvement, and provides an early warning to accidents and incidents, allowing the measurement of safe/unsafe

behaviour in the workplace. It gives individuals the opportunity to share feedback on safety performance with their peers, encourages involvement in safety, improves self-awareness and heightens risk perception, within a fair and just culture. Behavioural safety intervention challenges traditional safety management thinking towards prevention of events (see Figure 2-2).

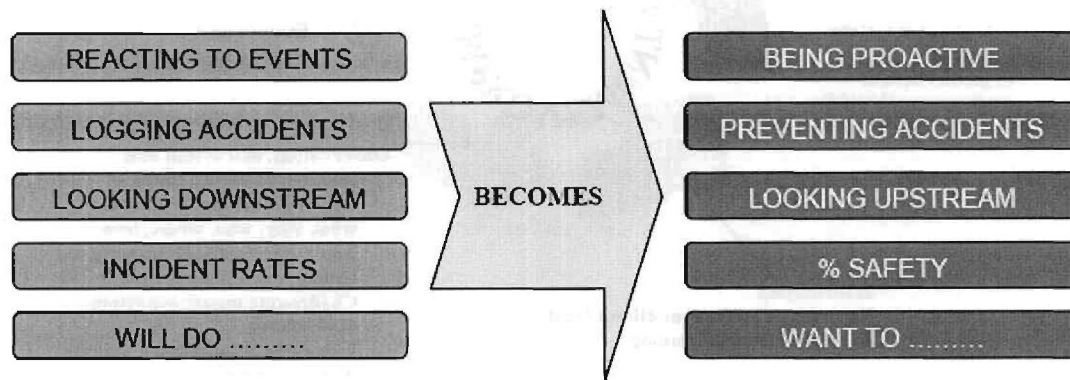


Figure 2-2: Behavioural safety and traditional safety management (IET, 2007)

Since behavioural approach to safety involves observation of behaviour, trained observers who can be both managers and shop floor employees, engage in open communication challenging unsafe behaviour and promoting safe behaviour in and around the working environment. Behavioural safety intervention delivers a selection of tools and techniques within a continuous improvement (Figure 2-3) process (IET, 2007):

Komaki *et al.* (1978) conducted one of the first studies utilising behavioural analysis to improve worker safety and concluded that this mode of safety intervention was effective in significantly improving employee safety performance. They also reported that not only did employees react favourably towards the behavioural safety intervention, but also that the study organisation was able to maintain the initiative with a continuing decline in the injury frequency rate. A number of safety researchers have supported the findings of Komaki *et al.* highlighting the effectiveness of applying behavioural analysis techniques to reduce unsafe behaviours and thus lower injury rates (see for example Cooper *et al.*, 1994; Krause *et al.*, 1999). However, recent evidence (HSE, 2002) appears to suggest that the implementation and sustainability of behavioural safety interventions has been variable and many seemingly successful initiatives, that previously reported improvements in health and safety performance, have lost momentum.

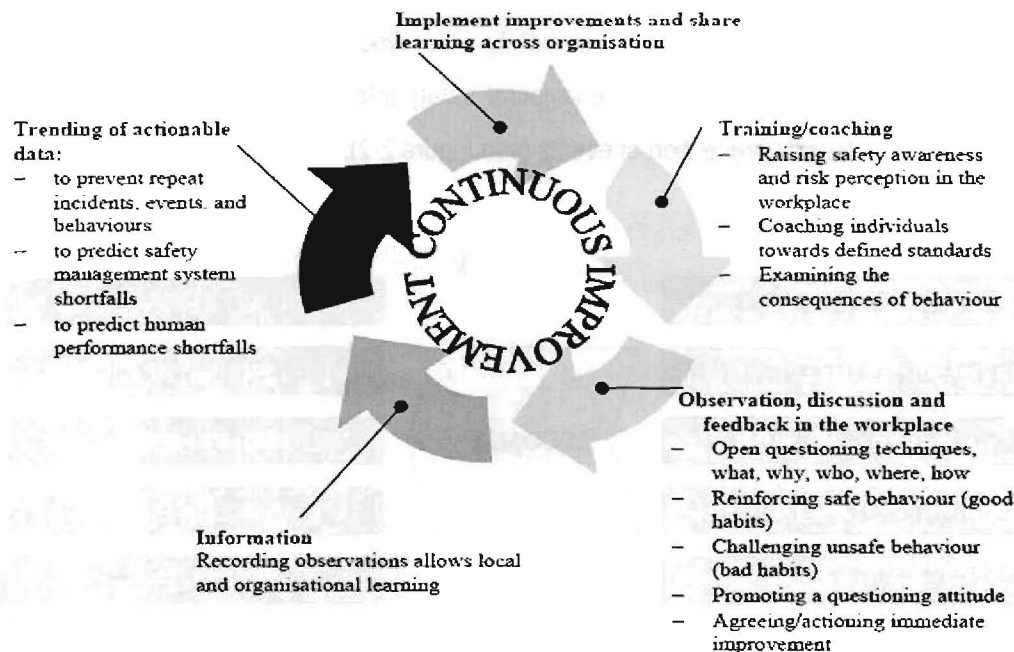


Figure 2-3: Continuous improvement in behavioural safety (IET, 2007)

Behavioural approaches to safety management characteristically focus on changing employee behaviours rather than attitudes. The underlying assumption being that once a person's behaviour has changed, a change in attitudes will follow (Bem, 1967). Safety researchers have continued to debate this assumption in the literature (see for example Lee and Harrison, 2000); and opinions as to the direction of change vary. To secure long-term positive changes in safety performance, researchers suggest that it is necessary to change both behaviour and attitudes (Fishbein and Ajzen, 1975).

Theories of motivation have also had an impact on the behavioural safety management approach. Studies conducted in Australia found that safety motivation is an important factor in predicting compliance (Griffin and Neal, 2000). Behaviour-based safety initiatives can thus motivate employees to behave in a safe manner by increasing individual confidence in performing work related tasks and by focusing on individual safety improvement goals. Locke and Latham's (1991) reasoned that a person's goals or intentions play a key role in determining their behaviour. In applying this theory to behavioural safety it is important to systematically identify challenging (but realistic) goals for individuals to aspire to as well as providing them with accurate and timely feedback via observations.

Trust, within and amongst operational teams, is an essential component if behavioural safety initiatives are to be an effective aspect of an organisation safety management system. Trust has been identified as an important construct in organisation studies (Lane and Bachmann, 1998), however a limited number of researchers have examined the concept within the realms of safety research. De-Pasquale and Geller (1999) are one of only a handful of researchers that have acknowledged the significance of interpersonal trust in relation to behaviour-based safety initiatives.

De-Pasquale and Geller (1999) recognized the importance of trust in management; and co-workers' abilities and intentions as being critical to the success of a behavioural safety initiative. This is understandable given that employees are required to observe each other performing routine work tasks and feedback information related to safe and unsafe behaviours on both an individual and site wide level (Jones *et al.*, 2004). If there is a lack of trust in management and co-workers' intentions and abilities the process will fail i.e. if employees perceive the approach to be a way in which management can monitor their work or co-workers can 'rat' on each other, the effectiveness of the process will be minimal (De-Pasquale and Geller, 1999).

2.3.2.2 Roles of Climate and Culture in Safety Management

The terms "safety culture" and "safety climate" have been used to describe the output of an organisation in terms of such an assumption of the value given to safety issues by individuals or groups of individuals. The use of the term "climate" seems to indicate a temporary or seasonal characteristic (Rundmo *et al.*, 1996). On the opposite, the use of "culture" assumes the existence of an acquired and developed knowledge, and in this way, implying some stability. Zhang *et al.* (2002), in a comprehensive review of the concept of safety culture, establish the following definitions:

Safety culture: is the enduring value and priority placed on worker and public safety by everyone in every group at every level of an organisation. It refers to the extent to which individuals and groups will commit to personal responsibility for safety; act to preserve, enhance, and communicate safety concerns.

Safety climate: is the temporal state measure of safety culture, subject to commonalties among individual perceptions of the organisation. It is therefore situationally based and it refers to the perceived state of safety at a particular place and time, relatively unstable, and subject to change depending on the features of the current environment or prevailing conditions.

For authors working in this area, the most important influence in the definition of safety behaviour is the safety culture of the organisation they belong to (HSE, 1997). Safety culture is deeply related with organisational culture. The existence of such a culture supposes an organisation where people share values, which will affect and influence the attitudes and behaviour of its members (Cooper, 2000a). The safety culture is a sub-dimension of the organisational culture, which supposedly influences the attitude and behaviour of the organisation members in relation to an occupational health and safety performance (Donald, 1998; Cooper, 2000b).

According to Groover (2001), one of the challenges that organisations face is the risk recognition and the appropriate reply by its collaborators. If risk is not well perceived or recognized, the continuous safety performance improvement is hardly achieved. The knowledge of workers' risk perception and attitudes concerning safety is needed for the development and understanding of safety culture (Williamson *et al.*, 1997). On the other hand, the safety culture seems to have a significant effect in risk behaviour (Rundmo *et al.*, 1997). Further, the relationship between safety and total quality management (TQM) has also been discussed. It is now reasonably well accepted by practitioners and researchers in the field as well as organisations that climate, attitude, and culture play a part in accidents (Donald and Young, 1996).

The utility of safety culture is based essentially, on the assumption that this could have an influence in workers' behaviour changing and, through that, influence the safety performance. However, it should be noted that this assumption is not always observed and consensual. Hale *et al.* (2000) for example, verified that safety performance could be improved without any significant change in safety culture. These authors go further, pointing out that there is little evidence that the opposite can occur, i.e. a changing in safety culture could improve safety performance.

From various studies, it is possible to conclude that the occupational health and safety culture of an organisation is an important factor in ensuring the effectiveness of risk control. The occupational health and safety management system has an important influence on the safety culture, which in turn impacts on the effectiveness of the occupational health and safety management system. Measuring aspects of the safety culture is, therefore, part of the overall process of measuring occupational health and safety performance. Many of the activities which support the development of a positive safety culture need to be measured.

2.3.3 Systems Approach to Industrial Health and Safety Management

Many novel approaches have been tried to further improve performance such as behaviour-based safety techniques, improved health and safety auditing concepts, and management systems schemes. There is no doubt that many other approaches will also be tried in the future. Nevertheless, one of the newer techniques is the use of a systems approach. This section of the literature review has been adapted from the 1998 report submitted by the International Occupational Hygiene Association, IOHA to International Labour Offices. The report is titled *Occupational Health and Safety Management Systems Review and Analysis of International, National, and Regional Systems and Proposals for a New International Document* (ILO, 1998).

The systems approach to occupational health and safety, OHS, is based on systems theories developed primarily in the natural and social sciences. Four elements common to general systems theories are: input; process; output; and, feedback. Systems are further characterized as either open or closed systems. In the case of open systems, there are identifiable pathways whereby the system interacts - exchanging information with and gaining energy - from its external environment. This phenomenon is readily observed in biological systems. Conversely, closed systems do not have such pathways, and thus limit their ability to adapt or respond to changing external conditions (ILO, 1998).

In traditional OHS management approaches, the focus has been on trailing indicators (outcomes or outputs), such as illness, injury, and fatality statistics. In a systems approach, regulatory compliance and trailing indicators are not neglected; however, there is a shift in focus towards performance variables and metrics from the input and process components of the system. These components can be thought of as being "upstream" from the system output. An important distinction to make in an OHS systems approach is that between what are customarily referred to as "programs" and "systems". The distinction is made here between traditional programmatic approaches and the newer systems approaches to OHS management.

In the paradigm shift suggested by the development and implementation of OHS management systems, a program operates as singular, vertical, and based on traditional command-control regulations. The focus is on compliance with the program standard/regulation, not the broader impact on OHS. Programs traditionally do not have strong, if any, feedback or evaluation mechanisms whereby the program is adjusted or modified to accommodate changing circumstances. Conversely, a systems approach - while

not losing sight of programmatic requirements and opportunities for improvement broadens in perspective to address the manner in which the program affects other programs, and the extent to which the program may or may not improve worker health and safety (ILO, 1998).

Furthermore, a systems approach focuses on OHS improvement, not exclusively on programmatic regulatory compliance. A key distinction of a systems approach is that there are clear feed-back and evaluation mechanisms whereby the system responds to both internal and external events. In this context, an example of program compliance would be with a single standard, such as a lock-out-tag-out standard for construction or an asbestos standard for general industry. A systems approach integrates individual programs within the business operations and the external environment, and is thus more comprehensive than any single program.

One could argue that this program/system dichotomy is a potentially weak distinction. That is, the programmatic approaches do in fact contain systems qualities and conversely, the systems approaches do in fact contain programmatic qualities. This observation is valid. However, the point of presenting the dichotomy is to elucidate the fact that programmatic OHS management approaches do not reflect or embrace systems concepts. Furthermore, such systems approaches potentially offer previously unrealized opportunities for advancement in OHS (ILO, 1998).

The OHS management systems variables that are central to a systems approach as identified by Redinger and Levine (1998) are as follows:

- ☞ Communication system/feedback channels;
- ☞ System evaluation, specially the development/measurement of auditing/self-inspection, and root-cause analysis;
- ☞ Continual improvement;
- ☞ Integration; and,
- ☞ Management review

2.3.4 Importance of Occupational Health and Safety Management Systems (OHSMSs)

Many of the industrially developed countries of the world have seen injury and illness rates decline drastically over the last 50 years. However, these rates have generally reached a plateau over the last

decade. For example, in the United States, since the passage of the Occupational Safety and Health Act of 1970, the incidence rate of occupational fatalities has been reduced by 76 percent, and total injury/illness case-rates by 27 percent. Even with these positive changes, the frequencies of occupational health and safety (OHS) fatality and injury/illness incidents, coupled with a stubbornly high and unchanging total lost-work-day case rate, continue to affect adversely the lives of millions of workers and their dependents, and present a substantial burden on the cost of health care in the United States.

This was recently confirmed in a comprehensive study which, among other things, found that approximately 6,500 job-related deaths from injuries, 60,300 deaths from disease, and 862,200 illnesses are estimated to occur annually in the American work force. The total direct and indirect costs are estimated to be \$171 billion (Leigh, 1997). A similar problem is found in many other developed countries.

Interest in OHSMSs grew as the need for a global approach to OHS management was recognized as a logical and necessary response to the growth of the "global economy", as the benefits of "systems" management approaches become apparent, and a result of the impact of ISO standards for quality and the environment. First, most major companies in the industrially developed world are multinational and favour a standardized approach to safety and health. Japan, for example, has been manufacturing products and dealing with safety concerns around the world for a considerable period of time.

Most companies recognize the need and benefits of meeting world standards or best practices for OHS while striving to meet local requirements of the host country. Second, current management science theories suggest that performance is better in all areas of business, including OHS, if it is measured and continuous improvement sought in an organized fashion. Third, central to the ISO approach is to harmonize existing standards or create new ones that promote free trade. Two of ISO's recent standards, ISO 9000 and 14000, developed by the world community, address areas analogous to OHS. Both standards integrate these functions within a business (management) framework (ILO, 1998).

One of the advantages of an OHS systems approach is resolution of the common criticism that OHS is rarely integrated into business systems but rather is typically a stand alone adjunct in most companies. Additional values realized through the use of OHS systems include (ILO, 1998):

- ☞ alignment of OHS objectives with business objectives;
- ☞ integration of OHS programs/systems into business systems;

- ☞ establishment of a logical framework upon which to establish an OHS program;
- ☞ establishment of a universal set of more effectively communicated, policies, procedures, programs, and goals;
- ☞ applicability to, and inclusiveness of cultural and country differences;
- ☞ establishment of a continuous improvement framework; and,
- ☞ provision of an auditable baseline for performance worldwide.

Some would argue that there are an equal number of disadvantages as well. Those most commonly cited include no need for change from present approaches and practices, social and legal barriers internationally that cannot be overcome by a standardized approach, bureaucracy and cost.

2.3.5 Industrial Safety Management Standards and Guidelines

With the goal of reducing occupational injury, illness, fatalities and their associated costs, strategies for augmenting traditional command-and-control regulatory and management approaches have been explored, notably over the past few years. One such approach is the application of systems models to occupational health and safety (OHS) management. The current attention being given to OHS management systems (OHSMS) stems from developments in the International Organization for Standardization (ISO), nation-states, professional societies, industry bodies; and, health, safety and environmental consultancies (ILO, 1998).

2.3.5.1 Common OHSMS Variables

In 1997, researchers in the Michigan Occupational Health and Safety (OHS) Policy Group at the University of Michigan developed a universal OHSMS assessment instrument (UAI). The UAI structure can be described as containing: five (5) Organizing Categories; 27 Sections (16 primary and 11 secondary); 118 OHSMS Principles; and, 486 Measurement Criteria. These variables are listed below:

☞ Initiation (OHS Inputs)

- ☞ Management Commitment and Resources (1.0)
 - ☞ *Regulatory Compliance and System Conformance (1.1)*
 - ☞ *Accountability, Responsibility, and Authority (1.2)*
- ☞ Employee Participation (2.0)

☞ Formulation (OHS Process)

- ☞ Occupational Health and Safety Policy (3.0)

- 📄 Goals and Objectives (4.0)
 - 📄 Performance Measures (5.0)
 - 📄 System Planning and Development (6.0)
 - 📄 *Baseline Evaluation and Hazard/Risk Assessment (6.1)*
 - 📄 OHSMS Manual and Procedures
- 📁 **Implementation/Operations (OHS Process)**
 - 📄 Training System (8.0)
 - 📄 *Technical Expertise and Personnel Qualifications (8.1)*
 - 📄 Hazard Control System (9.0)
 - 📄 *Process Design (9.1)*
 - 📄 *Emergency Preparedness and Response System (9.2)*
 - 📄 *Hazardous Agent Management System (9.3)*
 - 📄 Preventive and Corrective Action System (10.0)
 - 📄 Procurement and Contracting (11.0)
- 📁 **Evaluation (Feedback)**
 - 📄 Communication System (12.0)
 - 📄 *Document and Record Management System (12.1)*
 - 📄 Evaluation System (13.0)
 - 📄 *Auditing and Self-Inspection (13.1)*
 - 📄 *Incident Investigation and Root Cause Analysis (13.2)*
 - 📄 *Health/Medical Program and Surveillance (13.3)*
- 📁 **Improvement/Integration (Open System Elements)**
 - 📄 Continual Improvement (14.0)
 - 📄 Integration (15.0)
 - 📄 Management Review (16.0)

2.3.5.2 Review of some Safety Management Standards and Guidelines

The ILO search for publicly available OHSMS models and approaches yielded 31 standards, guidance documents, and codes of practice; 24 of which were included their analysis. A summary of the 24 documents is listed below in Table 2-2. Included in the 24 documents analyzed are: 18 published and final models and approaches; five (5) models and approaches that are under development; and, one ISO OHSMS (TC 67) that has been suspended. The publishers of these documents include national governments; state/provincial governments; national standards organisations; and professional health/safety associations.

Table 2-2 Standards, Guidance Documents, and Codes of Practice for OHSMS

	Country for Region	Publisher	Reference No.	Title
1.	Australia/New Zealand	Standards Australia Standards New Zealand	AS/NZS 4804:1997	Occupational health and safety management systems - General guidelines on principles, systems and supporting techniques
2.	Australia Victoria	Health and Safety Organization (HSO), Victoria	Safety Map	Safety Management Achievement Program (Safety MAP)
3.	Brazil	Ministry of Labour	NR-9 (PPRA)	Environmental Risk Prevention Program
4.	European Union	The Council of the European Communities	Council Regulation No. 1836/93	Community Eco-Management and Audit Scheme (EMAS)
5.	India	Ministry of Labour	Section 41F of the Factories Act, 1948, revised 1988	Various
6.	International	Oil Industry International Exploration and Production Forum (E & P Forum)	Report No. 6.36/210	Guidelines for the Development and Application of Health, Safety and Environmental Management Systems
7.	International	International Organization for Standardization - Technical Committee 67, Subcommittee 6, Workgroup 1	ISO/WD 14 690, N46 rev.2	Petroleum and natural gas industries - HEALTH, SAFETY AND ENVIRONMENTAL MANAGEMENT SYSTEMS
8.	International	International Organization for Standardization - Technical Committee 207	ISO 14001:1996	Environmental management systems - specification with guidance for use
9.	Ireland	The National Standards Authority of Ireland	OH and S	Draft Standard for Code of Practice for an Occupational Health and Safety (OH and S) Management System
10.	Jamaica	Jamaica Bureau of Standards	Draft OHandS ½	Draft Jamaican Standard Guidelines for Occupational Health and Safety Management Systems - General Guidelines on Principles, Systems and Supporting Techniques
11.	Japan	Japan Industrial Safety and Health Association	March 1997	Occupational Health and Safety Management System (OHS-MS): JISHA Guidelines
12.	Korea	Ministry of Labour, Republic of Korea	1998	Labour Laws of Korea, Industrial Safety and Health Act, Chapter II - Safety and Health Management Systems.
13.	The Netherlands	Nederlands Normalisatie-Instituut	NPR 5001	Dutch Technical Report: Guide to an occupational health and safety management system
14.	Norway	Norges Standardisingsforbund	96/402803 August 27, 1996	Norwegian Proposal: Management Principles for Enhancing Quality of Products and Services, Occupational Health and Safety, and the Environment
15.	Poland	Phare Programme to the Polish State, Labour Inspector	Worker Protection Programme PL 9407 November 1996	Safety and Health Management in SME's: Best EU Practices Regarding Safety and Health Management in Small and Medium enterprises (SME's), How Can Labour Inspection Support Labour Prevention
16.	South Africa	National Occupational Safety Association	Reg. No. 51/0001/08; HB 0.0050E	The NOSA 5 Star Safety and Health Management System
17.	Spain	Asociación Española de Normalización y Certificación	UNE 81900 December 1996	Prevention of occupational risks: General rules for implementation of an occupational safety and health management system
18.	United Kingdom	British Standards Institution	BS 8800:1996	Occupational health and safety management systems
19.	United Kingdom	Chemical Industries Association	Third Edition, 1998	Responsible Care Management System
20.	United States	American Industrial Hygiene Association	AIHA OHSMS 96/3/26	Occupational Health and Safety Management System: An AIHA Guidance Document
21.	United States	Chemical Manufacturers Association	Employee Health and Safety Code	Responsible Care: A Resource Guide for the Employee health and Safety Code of Management Practice
22.	United States	Occupational Safety and Health Administration	Federal Register, 4/12/88	Voluntary Protection Programs
23.	United States	Occupational Safety and Health Administration	None yet 1910.700	Draft Proposed Safety and Health Program Standard
24.	United States, California	Department of Labour and Industrial Relations - Cal OSHA	Title 12, Subtitle 8, Part 2, Chapter 60-2	General Safety and Health Requirements: Safety and Health Programs

Source: ILO, 1998

The types of OHSMS models and approaches published by these organisations included: auditable standards; non-auditable standards; guidance documents; and, national/state/provincial regulations that contain some OHSMS components. Strictly speaking, ISO 14001:1996 is not an OHSMS (ILO, 1998).

Using the 27 OHSMS variables (see section 2.3.5.1 above) identified in a comprehensive universal OHSMS model as the primary basis for analysis, ILO (1998) found out that 19 of the 24 models and approaches were generally strong in addressing traditional occupational health and safety (OHS) management issues, such as, hazard control, training, evaluation, and risk/hazard assessment. Conversely, there is a general weakness throughout the models and approaches in areas often considered central to management system approaches. These include management commitment, resource allocation, continual improvement, OHSMS integration with other organisational systems, and management review (see Figure 2-4).

A further weakness found throughout what are otherwise strong OHSMSs is the lack of medical surveillance and health programs. In view of the importance of this aspect of preventive health management, this is somewhat surprising. An additional weakness is the manner that employee participation is addressed. While 20 of the 24 models and approaches reviewed contain some level of employee participation language, there is wide variation in the strength of the language (ILO, 1998).

Of particular interest is the comment on South African National Occupational Safety Association (NOSA) Management by Objectives. According to the report, "NOSA system addresses and measures compliance based items more strongly than management system items. It is more compliance based as opposed to management based. The companion audit workbook includes a section on environmental issues; based on ISO 14001. In overall emphasis, the Five Star system resembles the DNV International Safety Rating System. This is a valuable tool/system to get started, but will have limited returns as an organisation handles the compliance issues (ILO, 1998)". Missing system variables include:

- ✎ *"Management commitment and resources. This can be inferred, but not explicitly stated as an audit criterion. Management commitment is not required. Actions are stated, but not commitment.*

Figure 2.4: IOHA-ILO summarized analysis of the 24 OHSMS.
Source: (ILO, 1998).

Management System Variable		Australia/New Zealand	Australia, SafetyMap	Brazil	EU - EMAS	India	E&P Forum	ISO 14001	ISO TC 67	Ireland	Jamaica	Japan	Korea	The Netherlands	Norway	South Africa, NOSA	Spain	UK, BS8800	UK, CIA	US, AIHA	US, CMA	US, VPP
1.0	Management Commitment and Resources	X	X		X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X
1.1	Regulatory Compliance and OHSMS Conformance	X	X		X	X		X	X	X	X			X	X		X	X	X	X		
1.2	Accountability, Responsibility, and Authority	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2.0	Employee Participation	X	X	X		X				X	X	X	X	X	X	X	X	X	X	X	X	X
3.0	Occupational Health and Safety Policy	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
4.0	Goals and Objectives	X		X	X		X	X	X	X	X			X	X		X	X	X	X		X
5.0	Performance Measures	X			X		X	X	X	X	X			X	X		X	X	X	X		X
6.0	System Planning and Development	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X	X	X
6.1	Baseline Evaluation and Hazard/Risk Assessment	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X
7.0	OHSMS Manual and Procedures	X	X		X		X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
8.0	Training System	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
8.1	Technical Expertise and Personnel Qualifications	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
9.0	Hazard Control System	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
9.1	Process Design	X	X		X	X	X	X	X		X	X	X	X	X	X			X	X	X	X
9.2	Emergency Response	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
9.3	Hazardous Agent Management	X	X			X	X					X	X	X		X			X	X		
10.0	Preventive and Corrective Actions	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
11.0	Procurement and Contractor Selection	X	X		X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X
12.0	Communication System	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
12.1	Document and Record Management System	X	X		X		X	X	X	X	X		X	X	X		X	X	X	X	X	X
13.0	Evaluation System	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X
13.1	Auditing and Self-Inspection	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
13.2	Incident Investigation and Root Cause Analysis	X	X		X		X		X	X	X	X		X	X	X	X	X	X	X	X	X
13.3	Health/Medical Program and Surveillance	X	X			X					X	X	X		X	X				X	X	X
14.0	Continual Improvement	X			X		X	X	X	X	X			X	X		X	X	X	X	X	X
15.0	Integration	X	X		X	X	X	X	X	X	X			X	X		X	X	X	X		X
16.0	Management Review	X	X		X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X

- ✗ *Regulatory compliance - not explicitly covered.*
- ✗ *Goals and objectives and performance measurement - not explicitly covered. By inference, the audit workbook does cover this issue. However, an audit criterion is not the development of goals and objectives nor performance measurement. These variables are covered in the environmental section, but it is explicitly stated that from an audit perspective, it is for environment...not health and safety.*
- ✗ *System planning and development - not explicitly covered.*
- ✗ *Documentation and record management - not explicitly covered. Addressed in a vertical sense, but not a horizontal sense. Not covered in the way other management systems do.*
- ✗ *Continual Improvement - not addressed.*
- ✗ *Integration - not addressed".*

2.3.6 Integration of Safety, Environment and Quality Management System

Since the release of the environmental standards (such as the BS 7750, EMAS and recently the ISO 14001), both private and public sector organisations are replacing the old, rigid "command and control" (Black, 1998) systems and procedures with the adoption of proactive measures. Implementation and integration of Environmental Management Systems, EMS, with other standards such as quality and/or OHS, (Baird, 2000), is providing organisations with a more flexible, open and cost effective option. Cichowicz (1996) in her article shows that an important way of reducing ISO 14000 registration costs (which could be up to 30 per cent higher as compared to that of ISO 9000) is by integrating the standards.

Various efforts have already been made to integrate process safety, quality, and environmental management using quality standards as a model. For example, the Canadian Chemical Producers Association (CCPA) has produced a document which defines the management of their Responsible Care™ Codes of Management Practice using the framework established by ISO 9001. The British Standards Institute has produced BS 7750 which defines an environmental management system using the framework provided by their quality standard, BS 5750.

In the opinion of White (1999) the integration process depends on a number of factors, excluding the costs, expertise and resources availability. These factors include complexity of the company (single/multiple sites; national/multinational. To be effective the integration process should be initiated

from the first stage of product design and development to its disposal (cradle-to-grave approach) in an attempt to identify opportunities to minimize. For the integration process to be uniform throughout the organisation it is essential that a fully integrated system be implemented as opposed to the current practice of integrating only the documentation and recording elements. Some aspects of the business that can be integrated in an organisation include (Wassenaar and Grocott, 1999) purchasing; staff induction, training and development; and; identifying and documenting responsibilities and accountabilities.

A number of tangible and intangible benefits of integration have been identified in the literature by Hale (1997), Black (1998), Picard (1998), Sultana (1998), Wassenaar and Grocott (1999); such as:

- ☞ Simpler, more focused management systems in the organisation.
- ☞ Reduction in duplication of policies, procedures and records, resulting in reduced effort for system implementation and maintenance. This also results in the decrease in volume of paper and number of forms in the company.
- ☞ Reduced costs and more efficient re-engineering, due to improvement in data and personnel management. The costs are also reduced as the audit team has to travel to the facility only once.
- ☞ More efficient use of internal audits to prepare for third party assessments.
- ☞ Greater acceptance by employees as the three objectives of customer satisfaction, environmental compliance and employee safety are considered for all operations resulting in higher staff motivation and lower inter-functional conflicts.
- ☞ It saves time for adopting different systems as common objective of continuous improvement are being followed.
- ☞ Improves communication across different organisational levels.
- ☞ Demonstration of due diligence.
- ☞ Better scope for input by stakeholders.
- ☞ Enhanced confidence of customers and positive market/community image.

However, the extent of integration of the different systems would be determined by the culture, nature and size of the business. Though the similarities are important, recognizing the differences between the various management systems is equally consequential before the integration. For instance, although both ISO 9000 and ISO 14000 standard series have the same “management systems focus, they greatly differ

in their roles, applications, complexity, documentation and most importantly the people they affect – both in their nature (i.e. businesses) and customers/consumers” (Picard, 1998).

2.4 Occupational Accidents and Injuries

As well as being a period of rapid organisational change, the past decade has been characterized by a series of major disasters affecting such diverse technologies as nuclear installations, chemical plants, oil tankers and ferries, railway networks, oil platforms and of course, commercial and military aircraft. Despite the obvious differences in the industries involved and their technologies, it has become apparent from the analysis of such disasters that, at a contextual level, there are many common characteristics (Reason, 1990).

2.4.1 Causation of Occupational Accidents

Heinrich (1931) suggested that unsafe acts are the cause of 85% accident and unsafe conditions are the cause of the rest (except for some acts of God). Thus, considerable attention has been paid: to the complexity of the contributory causes in accident analysis; to the multiplicity of ways in which systems can fail; to the predominance of human factor contributions to failure; to perceptual and information difficulties and, not least; to the appreciation of the historical dimension; and to the fact that disasters often have a long incubation period (Höpfl, 1994). This widening of the boundary around safety issues has resulted in a move away from what Toft (1992) has described as a “propensity to look for simple causal solutions...shaped by the technical concerns of the engineering community”, towards a commitment to the recognition of the social and organisational context of incidents and accidents.

A number of theorists have wrestled with the above-mentioned aspects of safety. Reason (1990), among others, points to the significance of the “latent failures” which only become evident when they occur with a “precipitating event” which cause the system to fail. Moreover, Reason contends that “there is a growing awareness...that attempts to discover and remedy these latent failures will achieve greater safety benefits than will localised efforts to minimize active failures”. For example, in the nuclear industry, failure to perform necessary maintenance activities, i.e. latent failure has played a major role in incidents and accidents in nuclear installations (Rasmussen, 1980).

Consequently, Reason (1990) argues that safety specialists need to direct their attention to the identification and neutralization of latent failures, rather than attempting to prevent “active” or front line

failures. Yet, it is generally to the identifiable aspects of safety that most attention is paid. In the face of major accidents and disasters, many organisations have become concerned to demonstrate a visible commitment to safety. Unfortunately, this may lead to a well intentioned commitment to the visible aspect of safety at the cost of what is not immediate and apparent.

In his now classic study of disaster, Turner (1978) in line with Reason's theory, argued that large-scale accidents have an "incubation period" in which there is a series of unnoticed events which are likely to run counter to established beliefs about the way that the system operates or that risks are defined. Turner encouraged safety researchers to concern themselves with "the cultural disruption which is produced when anticipated patterns of information fail to materialize" in order to develop an appreciation of the way in which individuals "gradually come to develop and rely on a mistaken view of the world". "The problem of understanding the origins of disaster is the problem of understanding and accounting for harmful discharges of energy which occur in ways unanticipated by those pursuing orderly goals" (Turner, 1978).

2.4.2 Review of South African Occupational Accident

The nature of occupational health service provision in South Africa is to a large extent determined by the profile of occupational injuries and diseases experienced in a particular province. Some industries are privately insured (e.g. mining) and other groups, e.g. domestic workers are not covered by compensation legislation. The occupational diseases diagnosed at referral centres do not reflect the true incidence of occupational disease in various industries since they represent sentinel cases. Published statistics are also skewed by reporting bias and some figures are quite dated (Jeebhay and Jacobs, 1999). Despite the limitations, the figures in the following sections give some insight into the spectrum of occupational diseases encountered by occupational health services.

2.4.2.1 Occupational injuries in South Africa

The pattern of occupational injuries reported is documented in the Compensation Commissioner's annual report as required by the Compensation for Occupational Injuries and Diseases Act (COIDA), which replaced the previous Workmen's Compensation Act. A total of 242,424 occupational accidents were reported in 1993. This represented an accident rate of 33.4 accidents per 1000 workers covered by the Compensation Fund (Department of Labour, 1997a). Figures for 1990 indicate that Gauteng (32%), Western Cape (21%) and KwaZulu-Natal (19%) reported a substantial proportion of the accidents

(Department of Health, 1996). These provinces being the most industrialized accounted for more than 70% of all reported cases. More than 80% of injuries affected men and more than 80% of the cases reported were from urban areas.

Published statistics for 1990 showed that the average national accident frequency rate for all industries was 7.21 injuries/million person-hours worked and the severity rate was 1.11 days lost/1000 person-hours worked (Department of Labour, 1990). Figures for 1994 indicate the proportional contribution to total injuries of various sectors in the country to be: manufacturing – non-metallic (29%), manufacturing – metallic (20%), transport (16%), service (13%), construction (9%), agriculture (6%), commerce/trade (6%) and mining (5%). The major sectors contributing to high fatality (severity) rates were transport (39%), agriculture (16%), construction (13%), service (11%), manufacturing – non-metallic (9%), manufacturing – metallic (6%) and commerce (4%) (Loewenson, 1998). It must be noted that the portion of the mining sector that is privately insured was not included in these figures.

These data do not reflect the actual levels experienced by this sector which has historically had one of the worst safety records in the world (Lewis and Jeebhay, 1996). Corrected data for 1995 indicate that the mining sector had the highest fatality rates, followed by transport, building and construction and agriculture (Department of Labour, 1997b). An analysis of frequency of accidents reported for 1993, according to anatomical site, indicated that the most commonly reported part of the body affected were the fingers (24%), legs (15%) and trunk (12%). Injury to the fingers was also documented to be the major cause of permanent disablement (57% of all cases). This has major implications for the rehabilitation of workers in this country since a substantial proportion is manual workers.

2.4.2.2 Occupational diseases in South Africa

The pattern of occupational diseases reported is documented in the Compensation Commissioner's annual report - Department of Labour (as required by COIDA) and the Report of the Medical Bureau for Occupational Diseases (MBOD) - Department of Health (as required by the Occupational Disease in Mines and Works Act). In 1990 occupational diseases constituted only 0.05% (128) of all compensation claims certified by the Compensation Commissioner in the Department of Labour (Department of Health, 1996). Pneumoconiosis (asbestosis and silicosis) comprised 77% of all claims certified. Official data on claim acceptances under COIDA have not been published for the past eight years. More recent figures of compensation claims submitted (not necessarily certified) to the Compensation Commissioner indicate

that 5679 claims for occupational diseases were reported (see Figure 2-5). The common occupational diseases outside the mining industry were noise-induced hearing loss (56%), major depression/traumatic stress (13%), dermatitis (12%), tuberculosis (5%), pneumoconioses (4%), and occupational asthma (3%).

Disease	Number of claims reported		
	1996	1997	1998
Hearing impairment - noise-induced	1 219	1 903	3 175
Dermatitis	305	388	678
Tuberculosis	205	231	306
"Major depression"/Post traumatic stress	192	605	734
Occupational asthma	141	184	180
Asbestosis	129	149	149
Silicosis	59	93	95
Pneumoconiosis	52	-	4
Mesothelioma	52	54	65
Bronchopulmonary disease	37	58	5
Pleural thickening	29	-	0
Fibrosis of the lung	14	-	1
Byssinosis	16	11	8
Over-straining of muscular tendinous insertions	8	78	32
Brucellosis	9	10	2
Erosion of the oral or nasal cavity (nasal septum perforation)	4	5	24
Chronic obstructive airways disease	0	9	29
Hepatitis	0	3	6
Hand-arm vibration syndrome (Raynaud's phenomenon)	0	2	13
Chemical bronchitis	0	3	70
Tendonitis	0	0	39
Bronchospasm	0	0	35
Total number of all cases reported	2 482	3 795	5 679

Figure 2-5: Statistics of occupational disease in South Africa (Jeebhay, 1996)

(Note: Figures are for the period 1 January to 31 December. Actual compensation outcome is unknown. Does not include cases reported in the mining sector)

2.5 Economics of Industrial Safety Risk Management

In response to increasing public concern regarding the safety of industrial installations that process, or handle, potentially dangerous substances such as radioactive materials and hazardous chemicals, companies have developed more sophisticated ways to improve industrial safety. These developments have been accompanied by the introduction of safety management systems. While the characteristics of a management framework are generic, and apply to the management of any industrial safety activity, the system elements are not universal. These elements are determined by the type of organisation and the

nature of the industrial hazard. Nevertheless, an element common to all industrial safety management systems is risk.

Risk management has been defined (British Standard 4778: 1991) as *"the process whereby decisions are made to accept a known, or assessed risk, and the implementation of actions to reduce the consequences or probability of occurrence"*. On this basis, risk management is concerned with the systematic identification, analysis, the evaluation and control of potential risks. Evaluation of risks is undertaken to establish acceptability, with regard to relevant criteria and determine requirements for risk reduction and mitigation. Frequently, the acceptability of risk is established by management judgment and experience. There are many inputs and factors involved in risk evaluation decisions, not all of them being explicit. Cost Benefit Analysis (CBA) has been used in industry as one of the decision tools for considering the costs of project options, safety related risks, and potential benefits. The evaluation of risk and the use of CBA have been developed in several industries (John Council, 1993).

2.5.1 Industrial Safety Risk Evaluation and Cost-Benefit Analysis

The main conditions that apply when evaluating industrial risk involve establishing whether:

- ☞ the risk is so great that it is unacceptable and must be refused altogether; or
- ☞ the risk is so small as to be insignificant, and is generally acceptable; or
- ☞ the level of risk falls between the unacceptable and the insignificant levels

A concept that has been introduced by the UK Health and Safety Executive, HSE (1992) as an input to establishing acceptable risk is "tolerability". In this approach, a level of risk, falling between what is judged to be unacceptable and that which is insignificant, is regarded as tolerable. The tolerable risk boundaries are defined by many considerations and society's preferences. Several inputs are therefore considered in arriving at a consensus of what constitutes a tolerable level of risk. These include:

- ☞ *guidelines from the appropriate Government Agency and Regulatory Authority*
- ☞ *discussions and agreements with the parties affected by proposed developments*
- ☞ *industry standards*
- ☞ *international discussions and agreements*
- ☞ *legal requirements*

A zone that has been defined as "tolerable" can be regarded to be justifiable if it can be established that a risk has been reduced to a level where to continue to reduce the risk would cause an unwarranted drain on resources. The balance between risk and cost varies with risk, increasing as the risk rises towards intolerable levels. In the UK, there is a requirement to demonstrate that risk has been reduced to a level As Low As Reasonably Practicable (ALARP). Reasonably practicable being taken to imply that risk should be reduced until there is a gross disproportion between the expenditure involved and the corresponding reduction in risk. One technique that has been applied when deciding whether a particular health risk has been reduced to the optimum and therefore a justifiable level is CBA.

2.5.2 Chemical Process Industry Approach to Cost-Benefit Analysis

The use of a safety performance index, the Fatal Accident Frequency Rate (FAFR), is advocated in the UK chemical industry. This accident rate expresses the number of deaths occurring in a group of people, during their working lives. The average UK value for the chemical industry is 3.5. Kletz (1977) suggested that for risk management purposes, the aim should be to achieve levels of safety above the FAFR average. However, when the risk reduction measures cost more than \$1.4 millions per life saved, it is necessary to look for a lower cost solution. There is no claimed justification for the chosen monetary value of \$1.4 millions. Nevertheless, this figure became a quoted norm for many process industries when arriving at practical improvements to safety.

2.6 Occupational morbidity costs in Southern Africa

South African records provide an indicative data set of national level of lost time. Out of 9,979 incidents in South Africa in 1993, the distribution and total of lost work time are shown in Table 2-3. This data indicates an average lost work time for injuries and fatalities combined, of 2 person years/ incident, and for injuries alone of 0.62 person years / incident. Applying these rates to Zimbabwe's total injuries in 1994 of 18 144 and fatalities of 219 would yield 11 551 lost person years. Applying this to annual average earnings for that year of Z\$12 303 / employee would yield a cost of US \$18 million in direct costs of lost earnings (Loewenson, 1996).

This represents 3% of the national GDP at that time. Notably, this excludes estimates of disease, and does not include the indirect losses of production, equipment losses, and medical expenses. It has been estimated in other studies in the Southern African Development Community, SADC Region (BIDPA 1997) comparing wages to output, that each employee produces 4.7 times the amount they are paid. This

would yield a production loss of US \$83 million in 1994 due to occupational injury, or 14% of GDP. While this cost analysis is crude, it signifies huge amounts of potential loss, and a clear cost benefit ratio in terms of costs spent on prevention for injury averted (Table 2-3).

Table 2-3: Lost Work Time Due to Injury, South Africa 1993

Period of Work Time Lost	Total	Aggregate Time Lost(*) Years
0-2 weeks	1 623	31.2
2-4 weeks	4 063	234.4
4-16 weeks	3 047	586.0
16-52 weeks	284	185.7
permanent disablement >52 weeks	233	4 660.0
Killed	729	14 580.0
TOTAL	9 979	20 277.3

Source: South African Dept of Labour: Labour Statistics 1994

(*)Using the median time lost for those returning to work; and assuming fatalities or non-return after 52 weeks lead to 20 years (median work span) lost

Clearly, this is no more than an indicative figure: on the one hand labour surpluses and the high level of unskilled production make injured labour relatively easy to substitute in Africa, and this is often the case, so that the production losses may be lower. On the other hand, the costs of the loss of a wage earner may ripple widely to the larger number of households dependent on that wage earner and may lead to unmeasured and even intergenerational health and social costs. Further, the available data provides little information on injury and its costs in the informal sector, nor on the costs of occupational disease (Loewenson, 1996).

2.7 Structure of South African Process Industry

The process industry (especially chemical industry) was developed in the late 1800s to supply explosives for the local mining industry. At present the chemical industry consists of three major local companies: Sasol, AECI and Sentrachem. All three have extensive manufacturing facilities and an incredible diversity of products which are sophisticated by world standard. AECI was started by ICI which still holds a significant number of shares in the company. The other two were started by the government, but all three are now public listed companies with a combined turnover of around US\$4 billion. The overall value of the South African chemical industry, excluding fuel and oil, is estimated at around US\$9.8 billion. Some

100,000 people (around 7% of the manufacturing work-force) are employed in the chemical sector (Baker, 1992).

In addition a number of multinational (mainly European) companies have manufacturing and trading operations but these are smaller in scale. Amongst these companies are Bayer, BASF, Shell, Unilever, Ciba Specialty Chemicals, du Pont, ICI, CH Chemicals, Monsanto and Rohm and Haas. There are a few local manufacturers such as Fine Chemicals Corporation, but these are comparatively very small operations. The formulation and blending sector is, however, very active. There are, for example, more than 68 companies making flavours and fragrances and local companies producing sunscreen preparation (Simon and Sohal, 1995). A large number of smaller companies are involved with manufacturing a wide range of specialties and in formulating and converting.

Due to the decision of the then South African government in the late 1950s and early 1960s to “go it alone” in the face of sanctions, strategic plants were built with little regard to their strategic viability up until 1980s. Examples of these include the fuel from coal complex at Sasol, the fuel from the gas process used by Mossgas (which arguably require subsidies or inflated petrol prices to remain profitable), and the synthetic rubber plant which was built and subsequently closed down by Sentrachem at enormous cost (Simon and Sohal, 1995).

While the population of South Africa is around 40 million, which is comparable to a number of European countries, the majority of the South African population has economically been impoverished due to apartheid policies of previous governments. So the economically active population is much smaller. This means that a number of the plants built for strategic reasons on an import substitution basis have not been able to achieve the economies of scale in global setting as they were meant to service a small domestic market.

The government ensured the survival of these plants by instituting imports tariffs and other protectionist policies such as import quotas. In addition, a number of these plants were built with the aim of providing employment and so often automation and instrumentation usage were limited (Simon and Sohal, 1995). The chemical industry suffers two other maladies: poor levels of education, literacy and training of the work force; and a poor work ethic. Good managers are scarce and overworked. The cultural outlook is often also different from that of the workers, and this has led to communication problems as well as general distrust in a few situations (Horler, A. and Gabhardt, (1993), The HSRC, 1993).

Technology has generally been licensed from first-world countries, and in most cases is competitive. Often, it has been modified to suit general conditions. There is a marked lack of personnel in the country. South Africa produces ten times fewer scientists and engineers when compared to first-world countries such as USA. For this reason, R&D effort is focused on the implementation rather than the development of technology. Less than 1% of sales revenue of the industry is directed towards R&D (Jones, 1994). Raw material is either produced locally or imported depending on the specific case. Europe is the major source of low-cost commodities although the Pacific-rim is making inroads into this market. Plants are often not competitive against world-scale plants and it has been an excessive drain on tax revenues. (Simon and Sohal, 1995).

Be that as it may, the industry is large, strong with superb infrastructure and has excellent potential to become a force in the world. For a developing country, South Africa has an unusually large chemical industry and it is of substantial economic significance. In 2006 the chemical industry still contributes 5% to the GDP and 25% of manufacturing sales. Now that South Africa is once again part of the international community, the chemical industry is focusing on the need to be internationally competitive and the industry is reshaping itself accordingly. Exports were R22 billion and imports R31 billion in 2005 with the gap declining. However, signs that the industry will emerge leaner and more competitive are clearly apparent (CAIA, 2007).

In conclusion, during its 100 years of existence, the development of the chemical industry has been dominated by three factors: the demand for explosives by the mining industry, the abundance of relatively cheap coal, and the political and regulatory environment in which it operated between 1948 and 1994. Based in a country with no proven oil reserves, until recently little natural gas and abundant coal resources it is not surprising that the gasification of coal became a major factor in the development of the industry. This was aided and abetted by a political system which increasingly forced the industry to look inwards and to focus on import replacement. It led also to the construction of small-scale plants with production geared to local demand. As a consequence locally-produced commodity chemicals and processed goods have generally been less than competitive in export markets.

2.8 Process Safety Management (PSM)

Process safety is defined by the AIChE (1993) as *“the protection of people and property from episodic and catastrophic incidents that may result from unplanned or unexpected deviations in process*

conditions". However, the handling and processing of materials with inherent hazardous properties can never be done in the total absence of risks. In other words process safety is an ideal condition toward which one strives (AIChE, 1989). *"Process safety management (PSM) is the application of management principles to the identification, understanding, and control of process hazards to prevent process-related injuries and incidents"* (AIChE, 1992). According to Kim, et al. (2002) PSM is *"a scientific safety management system that requires submission of manufacturing process reports such as safety operation plan, installation plan, etc. in the case of new installation, transfer and/or modification of hazardous facilities for the prevention of serious accidents"*. It encompasses many activities for controlling process-related hazards in the workplace.

2.8.1 Elements of Process Safety Management (PSM)

PSM entails development and implementation of programs or systems to ensure that the practices and equipment used in hazardous processes are adequate and are maintained appropriately. The primary categories of programs or systems have come to be called elements of PSM. However, the basic elements of PSM have been defined by many groups in a number of ways. Table 2-4 below lists the elements of PSM systems from various industry and government groups. Many of the elements with different names have essentially the same meaning.

For instance, "maintenance and inspection of facilities," together with some aspects of "personnel" practices, both under CMA's Process Safety Code of Management Practices, are essentially the same as the single element, "mechanical integrity," under OSHA PSM standard. However, some safety management regulations, especially EPA's proposed risk management program, New Jersey's Toxic Catastrophe Prevention Act, and Nevada's Highly Hazardous Substances Act, have elements (requirements) that are unique to those programs. The following sections focus on those PSM systems (or the PSM sections of other hazard and risk management systems) with requirements similar to those of OSHA PSM standard (OSHA 29 CFR 1910.119).

Table 2-4: Comparison of PSM Systems

OSHA 29 CFR 1910.119	American Petroleum Institute	AIChE	CMA Process Safety Code
Employee Participation (EP)	Process Safety Information	Accountability	Management Leadership ☞ <i>Commitment</i> ☞ <i>Accountability</i> ☞ <i>Performance Measurement</i> ☞ <i>Incident Investigation</i> ☞ <i>Information Sharing</i> ☞ <i>CAER Integration</i>
Process Safety Information (PSI)	Process Hazard Analysis	Process Knowledge and Documentation	Technology ☞ <i>Design Documentation</i> ☞ <i>Process Hazards Information</i> ☞ <i>Process Hazard Analysis</i> ☞ <i>Management of Change</i>
Process Hazard Analysis (PHA)	Management of Change	Project Reviews and Design Procedures	Facilities ☞ <i>Siting</i> ☞ <i>Codes and Standards</i> ☞ <i>Safety Reviews</i> ☞ <i>Maintenance and Inspection</i> ☞ <i>Multiple Safeguards</i> ☞ <i>Emergency Management</i>
Operating Procedures (OP)	Operating Procedures	Risk Management	Personnel ☞ <i>Job Skills</i> ☞ <i>Safe Work Practices</i> ☞ <i>Initial Training</i> ☞ <i>Employee Proficiency</i> ☞ <i>Fitness for Duty</i> ☞ <i>Contractors</i>
Training (TNG)	Safe Work Practices	Management of Change	
Contractors (CONT)	Training	Process Equipment Integrity	
Pre-start-up Safety Review	Critical Equipment QA and Mechanical Integrity	Incident Investigation	
Mechanical Integrity (MI)	Pre-start-up Safety Review	Training Performance	
Hot Work Permit (HWP)	Emergency Response and Control	Human Factors	
Management of Change (MOC)	Process-Related Incident Investigation	Standards, Codes and Laws	
Incident Investigation (II)	Auditing of PHM Systems	Audits and Corrective Actions	
Emergency Planning and Response (EPR)		Enhancement of Process Safety Knowledge	
Compliance Audits (CA)			
Trade Secrets (TS)			

Source: AIChE, 1994

2.8.2 About OSHA PSM Standard

During the 1970s and 1980s, the anti-technology attitudes and environmental advocacy of the 1960s were reinforced by public reaction to chemical releases of national and even international significance. The final report of the EPA's Acute Hazardous Events Database, issued in 1989, documents more than 11,000 events in a period of eight years. In response, the petrochemical industry initiated programs to increase chemical safety. The American Petroleum Institute issued RP750, "Management of Process Hazards," and the Chemical Manufacturers' Association launched the Responsible Care directives. Government response included Section 304 of the 1990 Clean Air Act Amendments, which also addressed catastrophic releases and required the Secretary of Labour to promulgate a chemical process safety standard in coordination with the administrator of the EPA (Mason, 2001).

The OSHA Process Safety Management (PSM) standard was published in the Federal Register on Monday, February 24, 1992. Its development was characterized by strong supportive commentary. BP Oil Company (OSHA Preamble, 1992) regarded the proposed regulation as "of major importance." The American Petroleum Institute commented that "API member companies support OSHA effort to develop an effective PSM rule. API believes PSM is the most effective approach available in the prevention of catastrophic releases" (OSHA Preamble, 1992). The representative from Oryx Energy Company testified, "I know of no other system that is better than the system that is proposed by OSHA."

The standard intended to prevent or minimize the consequences of a catastrophic release of toxic, reactive, flammable or explosive highly hazardous chemicals (HHC's) from a process. A process according to the standard is any activity or combination of activities including any use, storage, manufacturing, handling or the on-site movement of HHC's (OSHA, 1992). A process includes any group of vessels which are interconnected and separate vessels which are located such that a HHC could be involved in a potential release. The rule intends to accomplish its goal by requiring a comprehensive management program integrating technologies, procedures, and management practices (EHSO, 2007).

The standard applies to a process which contains a threshold quantity or greater amount of a toxic or reactive HHC as specified in Appendix A of the standard. Also, it applies to 10,000 pounds or greater amounts of flammable liquids and gases and to the process activity of manufacturing explosives and pyrotechnics. It does not apply to retail facilities, normally unoccupied remote facilities and oil or gas well drilling or servicing activities. Hydrocarbon fuels used solely for work place consumption as a fuel are not covered, if such fuels are not part of a process containing another HHC covered by the standard.

Atmospheric tank storage and associated transfer of flammable liquids which are kept below their normal boiling point without benefit of chilling or refrigeration are not covered by the PSM standard unless the atmospheric tank is connected to a process or is sited in close proximity to a covered process such that an incident in a covered process could involve the atmospheric tank (OSHA, 1992).

As a whole OSHA PSM standard is to aid employers in their efforts to prevent or mitigate episodic chemical releases that could lead to a catastrophe in the workplace and possibly to the surrounding community. To control these types of hazards, employers need to develop the necessary expertise, experiences, judgment and proactive initiative within their workforce to properly implement and maintain an effective process safety management program as envisioned in the OSHA standard. It is required by the Clean Air Act Amendments as is the Environmental Protection Agency's Risk Management Plan. Employers, who merge the two sets of requirements into their process safety management program, will better assure full compliance with each as well as enhancing their relationship with the local community (OSHA, 1992). A brief description of the various requirements of the PSM standard follows.

2.8.2.1 Element 1: Process Safety Information (PSI)

Employers are required to complete a compilation of written process safety information before conducting any process hazard analysis required by the standard. The compilation of written process safety information, completed under the same schedule required for process hazard analyses, will help the employer and the employees involved in operating the process to identify and understand the hazards posed by those processes involving highly hazardous chemicals. Process safety information must include information on the hazards of the highly hazardous chemicals used or produced by the process, information on the technology of the process, and information on the equipment in the process (OSHA, 1992).

2.8.2.2 Element 2: Process Hazards Analysis (PHA)

The process hazard analysis is a thorough, orderly, systematic approach for identifying, evaluating, and controlling the hazards of processes involving highly hazardous chemicals. The employer must perform an initial process hazard analysis (hazard evaluation) on all processes covered by this standard. The process hazard analysis methodology selected must be appropriate to the complexity of the process and must identify, evaluate, and control the hazards involved in the process (OSHA, 1992). OSHA has mandated that PHAs be carried out by a team with expertise in engineering and process operations. The team must include at least one employee familiar with day-to-day operations and one member

knowledgeable in the specific PHA method to be used. Development of "what if?" scenarios and the use of checklists can serve as a platform for PHA. Hazard and operability study (HAZOP) procedures, FMEA and fault tree analysis are also recommended techniques. Other equivalent methods or a combination of methods may be used if appropriate for the complexity of the particular process.

2.8.2.3 Element 3: Operating Procedures (OP)

The employer must develop and implement written operating procedures, consistent with the process safety information, that provide clear instructions for safely conducting activities involved in each covered process. OSHA believes that tasks and procedures related to the covered process must be appropriate, clear, consistent, and most importantly, well communicated to employees (OSHA, 1992). OP must be in writing and provide clear instructions for safely conducting activities involving covered process consistent with PSI. It must include steps for each operating phase, operating limits, safety and health considerations and safety systems and their functions; be readily accessible to employees who work on or maintain a covered process. It must also be reviewed as often as necessary to assure they reflect current operating practice; and must implement safe work practices to provide for special circumstances such as lockout and tag out and confined space entry (EHSO, 2007).

2.8.2.4 Element 4: Employee Participation

Employers must develop a written plan of action to implement the employee participation required by PSM. Under PSM, employers must consult with employees and their representatives on the conduct and development of process hazard analyses and on the development of the other elements of process management, and they must provide to employees and their representatives access to process hazard analyses and to all other information required to be developed by the standard (OSHA, 1992).

2.8.2.5 Element 5: Training

Employees operating a covered process must be trained in the overview of the process and in the operating procedures addressed previously. This training must emphasize specific safety and health hazards, emergency operations and safe work practices. Initial training must occur before assignment or employers may certify that employees involved in the process have required knowledge, skills and abilities. Documented refresher training is required at least every three years or more often if necessary; to each employee involved in operating a process to ensure that the employee understands and adheres to the current operating procedures of the process (EHSO, 2007)

2.8.2.6 Element 6: Contractors

When selecting a contractor, the employer must obtain and evaluate information regarding the contract employer's safety performance and programs. Facility owner must identify responsibilities of work site employer and contract employers with respect to contract employees involved in maintenance, repair, turnaround, major renovation or specialty work, on or near covered processes. Contract employers are required to train their employees to safely perform their jobs, and document that employees received and understood training, and assure that contract employees know about potential process hazards and the work site employer's emergency action plan. They must also ensure that employees follow safety rules of the facility, and advise the work site employer of hazards contract work itself poses or hazards identified by contract employees (EHSO, 2007).

2.8.2.7 Element 7: Pre-Start-up Safety Review

It is important that a safety review takes place before any highly hazardous chemical is introduced into a process. PSM, therefore, requires the employer to perform a pre-start-up safety review for new facilities and for modified facilities when the modification is significant enough to require a change in the process safety information. Prior to the introduction of a highly hazardous chemical to a process, the pre-start-up safety review must confirm the following (OSHA, 1992):

- Construction and equipment are in accordance with design specifications;
- Safety, operating, maintenance, and emergency procedures are in place and are adequate;
- A process hazard analysis has been performed for new facilities and recommendations have been resolved or implemented before start-up, and modified facilities meet the management of change requirements; and
- Training of each employee involved in operating a process has been completed.

2.8.2.8 Element 8: Mechanical Integrity

OSHA believes it is important to maintain the mechanical integrity of critical process equipment to ensure it is designed and installed correctly and operates properly. PSM mechanical integrity requirements apply to the following equipment:

- Pressure vessels and storage tanks;
- Piping systems (including piping components such as valves);

- Relief and vent systems and devices;
- Emergency shutdown systems;
- Controls (including monitoring devices and sensors, alarms, and interlocks); and
- Pumps.

The employer must establish and implement written procedures to maintain the ongoing integrity of process equipment. Employees involved in maintaining the ongoing integrity of process equipment must be trained in an overview of that process and its hazards and be trained in the procedures applicable to the employees' job tasks. Each inspection and test on process equipment must be documented. Equipment deficiencies outside the acceptable limits defined by the process safety information must be corrected before further use. In constructing new plants and equipment, the employer must ensure that equipment as it is fabricated is suitable for the process application for which it will be used. The employer also must ensure that maintenance materials, spare parts, and equipment are suitable for the process application for which they will be used.

2.8.2.9 Element 9: Hot Work Permit

A permit must be issued for hot work operations conducted on or near a covered process. The permit must document that the fire prevention and protection requirements in OSHA regulations have been implemented prior to beginning the hot work operations. It must indicate the date(s) authorized for hot work; and identify the object on which hot work is to be performed. The permit must be kept on file until completion of the hot work (OSHA, 1992).

2.8.2.10 Element 10: Management of Change (MOC)

OSHA believes that contemplated changes to a process must be thoroughly evaluated to fully assess their impact on employee safety and health and to determine needed changes to operating procedures. To this end, the standard contains a section on procedures for managing changes to processes. Written procedures to manage changes (except for "replacements in kind") to process chemicals, technology, equipment, and procedures, and change to facilities that affect a covered process, must be established and implemented. These written procedures must ensure that the following considerations are addressed prior to any change:

- The technical basis for the proposed change,
- Impact of the change on employee safety and health,

- Modifications to operating procedures,
- Necessary time period for the change, and
- Authorization requirements for the proposed change.

Employees who operate a process as well as maintenance and contract employees whose job tasks will be affected by a change in the process must be informed of, and trained in, the change prior to start-up of the process or start-up of the affected part of the process. If a change covered by these procedures results in a change in the required process safety information, such information also must be updated accordingly. If a change covered by these procedures changes the required operating procedures or practices, they also must be updated (OSHA, 1992).

2.8.2.11 Element 11: Incident Investigation

A crucial part of the PSM program is a thorough investigation of incidents to identify the chain of events and causes so that corrective measures can be developed and implemented. Accordingly, PSM requires the investigation of each incident that resulted in, or could reasonably have resulted in, a catastrophic release of a highly hazardous chemical in the workplace.

Such an incident investigation must be initiated as promptly as possible, but not later than 48 hours following the incident. The investigation must be by a team consisting of at least one person knowledgeable in the process involved, including a contract employee if the incident involved the work of a contractor, and other persons with appropriate knowledge and experience to investigate and analyze the incident thoroughly. An investigation report must be prepared including at least (OSHA, 1992):

- Date of incident,
- Date investigation began,
- Description of the incident,
- Factors that contributed to the incident, and
- Recommendations resulting from the investigation. A system must be established to promptly address and resolve the incident report findings and recommendations. Resolutions and corrective actions must be documented and the report reviewed by all affected personnel whose job tasks are relevant to the incident findings (including contract employees when applicable). The employer must keep these incident investigation reports for 5 years.

2.8.2.12 Element 12: Emergency Planning and Response

If, despite the best planning, an incident occurs, it is essential that emergency pre-planning and training make employees aware of, and able to execute, proper actions. For this reason, an emergency action plan for the entire plant must be developed and implemented in accordance with the provisions of other OSHA rules (29 CFR 1910.38(a)). In addition, the emergency action plan must include procedures for handling small releases of hazardous chemicals. Employers covered under PSM also may be subject to the OSHA hazardous waste and emergency response regulation (29 CFR 1910.120(a), (p), and (q)).

2.8.2.13 Element 13: Compliance Audits

To be certain that PSM is effective, employers must certify that they have evaluated compliance with the provisions of OSHA standard at least every three years. This will verify that the procedures and practices developed under the standard are adequate and are being followed. The compliance audit must be conducted by at least one person knowledgeable in the process and a report of the findings of the audit must be developed and documented noting deficiencies that have been corrected. The two most recent compliance audit reports must be kept on file.

2.8.2.14 Element 14: Trade Secrets

OSHA (1992) requires that employers make available all information necessary to comply with PSM to: those persons responsible for compiling the process safety information; those developing the process hazard analysis; those responsible for developing the operating procedures, and those performing incident investigations, emergency planning and response, and compliance audits, without regard to the possible trade secret status of such information. Nothing in PSM, however, precludes the employer from requiring those persons to enter into confidentiality agreements not to disclose the information.

2.9 Measurement of PSM Performance

As a part of the occupational health and safety management system, the performance measure is as important as other issues, such as financial, production or service delivery management. As far as it concerns occupational health and safety management systems, the safety performance measurement (SPM) can provide information, help in introspection, in decision-making, and in addressing different information needs (HSE, 2001). The primary purpose of SPM is to provide information on the progress and current status of the strategies, processes and activities used by an organisation to control risks to occupational health and safety. Measurement information sustains the operation and development of the

occupational health and safety management system, and consequently risk control, by providing information on how the system operates in practice, identifying areas where remedial action is required, establishing a basis for continual improvement and providing feedback and motivation.

While the general business performance of an organisation is subject to a range of positive measures, for occupational health and safety it is frequently done with a few negative measures - lost time injuries, total injuries, lost work days rates, etc. - (Williams, 1999). Some companies also report, as a performance measure, the occupational health and safety compliance indicating, for example, how many citations and penalties or fines relating to safety issues the company had in the period being measured. Occupational health and safety differs from many areas measured by managers because success results in the absence of an outcome (accidents or illness) rather than a presence. A low accident or ill-health rate, even over a period of years, is no guarantee that risks are being controlled and will not lead to accidents or professional diseases in the future (Arezes and Miguel, 2003).

This is particularly true in companies where there is a low probability of accidents but where major hazards are present. Here the historical records of accidents and illnesses can be a deceptive indicator of safety performance. Organizations need to recognize that there is no single reliable measure of occupational health and safety performance. What is required is a variety of measures, providing information on a range of occupational health and safety activities (Arezes, and Miguel, 2003). As organisations recognize the importance of managing occupational health and safety, they become aware of the problems with using accidents and ill-health statistics alone as the unique measure of occupational health and safety performance. The use of accident rates, particularly when related to reward systems, can lead to such events not being reported in order to "maintain" performance, or to reduce accident assurance classification.

Additionally, whether a particular event results in an injury or accident is often a matter of chance, so it will not necessarily reflect whether or not a hazard is under control. In small or low-risk companies, these inconveniences could be accentuated, because a hypothetical low accident rate can lead to complacency, and also result in a few data points available. Because of the disadvantages associated with the use of accident and ill-health data alone when measuring performance, some organisations have recognized the need of more proactive measures of performance. Generally, this is translated into a search for things, which can be easily counted, such as number of training courses or number of inspections.

2.9.1 Recent Contributions to Measurement of PSM Performance

Most organisations that employ measurements of process safety elements within facilities developed these measurements by a local staff, and some of them involved consulting companies that helped to develop the measurement system to address the facility's unique characteristics. The Centre for Chemical Process Safety (CCPS) of AIChE developed a measurement system for measurements of PSM elements in facilities. A computerized program version has been launched (Pro-Smart) by AIChE. The program is useful toward measurement of progress of a certain facility. Furthermore, the results are more credible when the same user makes the evaluations over time (Keren, 2003). The general concept of the measurement system is emphasized in a paper written by AIChE executives and members, and published on the web (Campbell *et al.*, 2003). Most of the efforts in the development of process safety performance measurements are invested toward measuring the industry as a whole and with some efforts directed toward performance measurements of federal agencies.

OSHA incidence rate is a statistical index that measures illnesses and injuries per 100 worker years (U.S. Department of Labour, 2003). The Fatality Accident Rate (FAR) is a European index mostly used by the British and is a statistical index that measures the number of fatalities per 1000 employees working their entire lifetime (50 working years per employee). Indices such as FAR and Incidents Rate which represent failure to effectively control risks are called Trailing Indicators. These indices are important, and can be used to measure performance in the process industries (as well as in any other industry). However, fatalities, injuries, and illnesses are only the outcomes of a safety culture.

Recognizing that safety management input should be measured as well as outcomes, many entities developed indices that address inputs. Indices that measure the level of risk reduction (inputs) are called Leading Indicators. Travers (2001) considered three groups of Indicators. Travers' work is preliminary and may answer SPM questions in the future. Newell (2001) presents a very well developed concept of process safety performance measurements. In his work, Newell analyzes in detail OSHA database as a sole source of data for performance measurements. Newell recommends using the OSHA rates for measurements only as part of comprehensive balanced assessments that include other key information. Newell calls for use of leading, trailing and financial indicators rather than trailing indicators only. His work is based on the balanced scorecard, which is best emphasized by (EPSC, 1996) "Accentuate the positive to eliminate the negative". This concept has been widely used since the early nineties and is common to many suggestions for performance measurement systems. Newell's work describes the features of the

trailing, and leading indicators, but it does not actually develop the indicators. Although this work does not introduce the indicators, its contribution is significant in the phase where data sources are considered and in the phase of defining the indicators.

Similar works have been done by Ritwik (2001), Walker *et al.* (2001), Morrison (2001), and Toellner (2001). All of these works contribute to some of the process safety performance measurement issues but none of them is comprehensive, well defined, and developed. The European Organization of Economic Co-operation and Development (OECD) launched a project related to the development of Safety Performance Indicators for Chemical Accidents Prevention, Preparedness and Response (Toellner, 2001; Grenier (2001)), six years after publishing guiding principles for chemical accident prevention, preparedness and response that was implemented by 29 countries including Canada. OECD distinguishes between the industry and the public, and Toellner (2001) discusses the Canadian stakeholder view of accident prevention, emergency preparedness, and response. Its indicators have many similarities to the OSHA VPP program. OECD Toellner (2001) introduces the general concept for process safety performance indicators.

As can be seen from the foregoing, PSM performance indicators have been developed in three different phases: traditional, transitional, and modern phases. The first one is, as mentioned previously, characterized by traditional indicators, such as the statistical issues (accidents and ill-health statistics), and the percentage of the budget allocated to occupational health and safety. The second one, as the name may suggest, represents a transitional phase, and is characterized by the use of indicators of trends and other economic indicators, such as the savings obtained through prevention. Finally, the last one is characterized by the use of positive indicators in measuring occupational health and safety (Pardy, 1999).

2.10 Benchmarking

According to Robert Camp, benchmarking means “the search for best practices that will lead to superior performance” (Camp, 1989). Other definitions often extend this e.g. “a structured discipline for analyzing a process to find improvement opportunities” (Bergman and Klefsjo, 1994). In Japan, the corresponding concept is called *dantotsu* which means, roughly, “striving to be the best of the best”. The inherent notion is, then, to make a careful comparison of a company process with the same or similar process at another company or division of one's own company and benefit mutually from the comparison.

The Australian Manufacturing Council, AMC (1994) study opined that “benchmarking is the single practice that most clearly separates *Leaders* from *Laggers*”. Perhaps the most eloquent and hard-hitting description of the importance of benchmarking is the following quote from Greene (1993). He says “benchmarking is a critical technique for making organisation transformation easy. It provides the authority for change. Provoking the humility for change, it breaks the spell of an organisation's excessive self-love and narcissism.Another profoundly powerful thing about benchmarking is that undertaking it requires a certain threshold of willpower. This is important. This threshold of organisational willpower is itself a key benchmark. Companies unable to muster the willpower to compare themselves with the world's best of breed are not able to implement any quality approach, however simple”.

Comparing own key processes with exemplary processes, leads to:

- ☞ True assessment of own strengths and weaknesses
- ☞ Thorough understanding of best practices
- ☞ Prioritization of improvement initiatives
- ☞ Stimulation of innovation and breakthrough thinking
- ☞ Accelerated improvement / quantum leap improvement

Facility or organisational PSM performance may be benchmarked against:

- ☞ Past performance;
- ☞ Industry average;
- ☞ Best in class; and
- ☞ Best in practice

2.10.1 Benchmarking of Safety Management

Although poor safety performance has been reported to have a significant impact on companies' profits (Davies and Teasdale, 1994), health and safety is still often perceived as an area of operational management where costs exceed benefits (Wright, 1998). Whilst total quality management is driven by motives to satisfy customer needs and the desire to continuously improve performance, health and safety management is more often driven by a desire to comply with legislation (Osborne and Zairi, 1997). Factors that have been identified as motivating companies to initiate health and safety improvements are therefore not related to financial or quality issues but to the fear of loss of corporate credibility and the

belief that it is morally correct to comply with legislation (Wright, 1998). It is not surprising, in this context, that companies place importance on health and safety initiatives that include a public demonstration of their achievements such as proprietary award schemes, which provide symbolic ratings of performance (Wright, 1998).

Benchmarking provides a complementary technique, which analyses audit results, identifies strengths and weaknesses and provides a route to step change improvements in management performance (Zairi and Leonard, 1996). Effective auditing and benchmarking both require ongoing performance measurements so gathering data is expensive and time-consuming. Therefore, whilst they seek to benefit from the opportunities offered by auditing and benchmarking, companies also endeavour to reduce resource requirements whenever possible in order to improve their cost-benefit ratios (Fuller, 1997).

The use of performance measurements to initiate continuous improvements in health and safety management appears to lag behind the level used for core business activities. This has been attributed to a belief within companies that, apart from reactive measures such as accident frequency rate (AFR), effective measurement of health and safety performance is difficult in comparison to core business activities (Osborne and Zairi, 1997). However, without good quality performance data, it becomes impossible to successfully implement continuous improvement and benchmarking strategies. Next sections review literature on the benchmarking of PSM elements relevant to this study.

2.10.2 Benchmarking of Management of Change

Major part of this section is adapted from Keren's (2003) work on modelling safety performance measurement.. According to the model developed by Keren two types of inputs are required for measuring Management of Change (MOC) program performance measurements: (1) periodical measurements, such as the number of Maintenance Work Orders (MWOs) that were miss-classified in the time period under investigation; and (2) characteristics of the program, such as techniques that are available for hazard identification. The MOC program consists of a variety of performance influencing factors. Keren (2003) suggested a performance evaluation system of MOC program practices according to six factors problem (Figure 2-6):

1. Scope of program: areas in the plant that are subject to the MOC program
2. Authorization process: the process of authorization of the various types of MOC

3. MOC training: training frequencies, type of training, and employees that participated in the training program.
4. Internal audit process: content that is addressed by the audit program.
5. Hazard identification: capabilities of the MOC program to detect change-related hazards.
6. Outcomes: measurement of flaws, e.g., the number of failures in miss-classifying Maintenance Work Orders (MWOs) as MOCs.

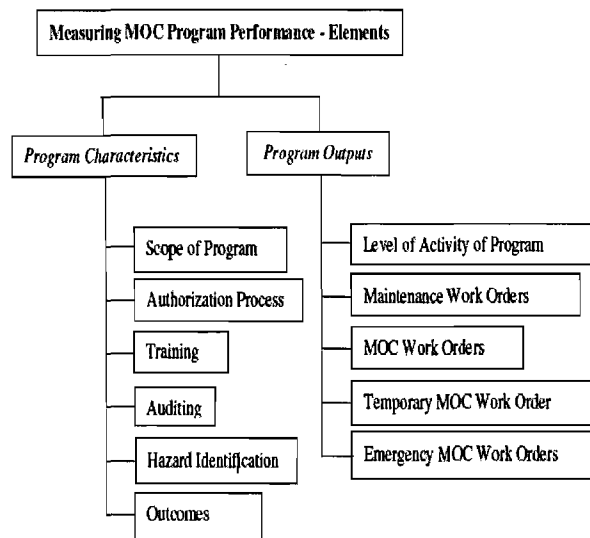


Figure 2-6: MOC Performance: Measurable elements

2.10.2.1 Scope of Program

Paragraph 29 CFR 1910.119(1) of the OSHA PSM standard requires that employers must write and implement procedures to manage changes in processes that are covered under the OSHA PSM. However, Management of Change procedures are implemented in diverse ways. Although the requirements of OSHA PSM are limited to specific systems, other systems that are not covered under OSHA PSM can be crucial to the safe operation of the plant. The result of a study of MOC program practices (Keren, West, and Mannan, 2002) reveals that implementation of the MOC program varies from a level that is considered a violation of the PSM requirements to a level at which all disciplines in the organisations are subject to MOC programs, including organisational changes. Facilities in plants can be divided to four major groups (Keren, 2003):

1. Group A – Critical Areas
2. Group B – Utility Areas
3. Group C – Associated Areas
4. Group D - Organizational Changes

Group A, Critical Areas, encompasses process areas such as hazardous chemical storage, other areas that are covered by OSHA PSM, petroleum bulk storage, tank farms, control rooms, main power distribution control board rooms, central fire extinguishing systems, and similar facilities. Utility Areas provide the facilities for the process to take place, and failure in one of these areas will cause uncontrolled shutdown. These areas include facilities such as power plants, cooling towers, and air plants. Associated sub-areas include facilities where failure in their operation has no significant effect on the safe operation of the plant, or at least it will allow a safe shutdown. These include wide range of areas such as laboratories, conveyors, and central office buildings.

2.10.2.2 Authorization Process

Several criteria affect the level of MOC authorization. Among these criteria are the financial resources that are required to implement the change, which include human resources requirements. The authorization process integrates these factors. The following types of MOCs are identifiable from the literature: regular MOC; temporary MOCs; and emergency MOCs. MOC authorization can be done by any or combination of the following; and their relative importance in judging the appropriateness of MOC authorization has been documented by Keren (2003):

- ✓ MOC Coordinator
- ✓ Operation Manager
- ✓ Maintenance Manager
- ✓ Plant Manager
- ✓ EH & S Officer
- ✓ Engineering / Instrumentation
- ✓ Executives

2.10.2.3 MOC Training

There are many methods for evaluating the effectiveness of a training program. These methods consist of two components: (1) quality and appropriateness of the content and (2) proper implementation of the

program. Elaborate methods have been developed to address the quality and appropriateness of training program content (ASSE, 2001). Other methods attempt to establish correlation and a statistical relationship between accident rates and training effectiveness (Re Velle and Stephenson, 1995). However, a low rate of events and poor accident data jeopardize the validity of the results. The scope of performance measurements of a MOC training program in this study includes:

- ✓ Topic addressed by the program. A MOC training program is expected to consist of the following elements:
 - Formal awareness training
 - Procedure updates
 - Information transfer practices (e.g. informing new shift on activities that involves MOC during the previous shift, such as notes with regard to night work orders in the logbook, review of logbook when returning from vacation, etc.)
- ✓ Type of employees that are subjected to training. It is possible to divide plant employees into several groups and for this study employees are divided into three groups as follows:
 - Administrative employees
 - Field operation employees (including maintenance, operators, operation management, engineering, technical staff, and purchasing)
 - Contractors
- ✓ Frequency of training; OSHA PSM requires that training will be conducted at least once every three years. Even though higher training frequency will yield better results, especially in the introductory phase of the program. Therefore, frequency of training will be a function of the program maturity. However, the appropriateness of the training frequency will be considered later.

2.10.2.4 MOC Auditing

Audit process consists of several components (AIChE, 1993). Audit criterion consists of two sub-criteria: (1) the content that the audit procedure addresses; and (2) appropriateness of the audit frequency. The following six elements are measured:

- ✓ Implementation of MOC Training

- ✓ Misclassification of MOCs
- ✓ Temporary MOCs
- ✓ Emergency MOCs
- ✓ Authorization Process
- ✓ Hazard Evaluation

2.10.2.5 Hazard Identification

The main purpose of the MOC program is to verify that safety aspects are addressed appropriately in the design and implementation of changes. Hazard detection capabilities of a MOC program are dependent on the methods that are "offered" by the program (risk screening capabilities). Moreover, these capabilities depend on training to identifying the need for implementation of such techniques (Awareness Training) as well. The risk screening capabilities element consists of four major group techniques:

- ✓ Safety review
- ✓ Checklist, What-if, What-if/Checklist
- ✓ Advanced PHA techniques, such as HAZOP, FMEA, and FTA.
- ✓ Human reliability analysis techniques

2.10.2.6 Outcomes

"Outcomes" is a complicated criterion. Unlike the other criteria, the outcomes criterion measures the results of MOC program implementation. This criterion consists of six elements, which are analyzed according to three sub-criteria. Although the relative effects on the performance of each element were developed in Keren's study, further work is required to quantify each of the elements in this criterion. The "Outcomes" criterion consists of the following sub-criteria:

- ✓ Hazard identification failures: This sub-criterion represents elements that are relevant to hazard identification failures
- ✓ Authorization failures: The Authorization sub-criterion represents the relative effects of MOC work orders for which the authorization process was not completed appropriately on the performance of the Outcomes criterion.
- ✓ Classification failures: The classification failure criterion represents the effect of the Maintenance Work Orders that should have been identified as MOCs but were miss-classified on the

performance of the outcomes criterion.

The following information is required for the outcome measurement (Keren, 2003):

- ✓ Number of MWOs that were not classified as regular MOCs – (MWO-MOC miss-classifications element)
- ✓ Number of MWOs that were not classified as Temporary MOCs - (Failure to Apply Temporary MOCs element)
- ✓ Number of MWOs that were not classified as Emergency MOCs (Failure to Apply Emergency MOCs element)
- ✓ Number of MOC work orders for which the authorization process was not completed appropriately (Failure to Appropriately Authorize element)
- ✓ Number of improper hazard evaluation technique applications (Failure to Apply Appropriate Hazard Evaluation Techniques element)

2.10.3 Benchmarking of Emergency Preparedness Programs Practices

Process safety of a chemical plant encompasses several layers of protection. Control measures, shutdown systems, release absorption, accumulation of releases by dikes, and protection by barriers, are layers of protection that are intended to prevent the development of an event because of deviations from normal operation conditions. Emergency Response is the next layer of protection that is intended to control an event if possible, or to reduce consequences in cases of loss of control. However, a reliable response to an emergency event requires planning. Unanticipated circumstances may yield emergency events. Emergency Planning adds additional layer of protection to circumstances where all of the other layers of protection failed to prevent the incident. Figure 2-7 demonstrates the three major components of emergency planning. OSHA PSM and EPA RMP requirements with regard to emergency planning are briefly summarized by Dennison (1994) as follows in the next paragraphs.

Emergency preparedness requires a multi-domain deployment. Preparedness process begins with identification of credible scenarios based on which consequence analyses are conducted, and appropriate response strategies are developed. The analysis of resources and capabilities that are required for response to the emergency scenarios is part of the preparedness stage. This analysis examines the resources and the capabilities at the facilities, at neighbouring sites, and the resources that

are available at the local community. The development of resources is conducted according to the resource assessment and the level of corporation amongst these parties and other emergency support organisations.

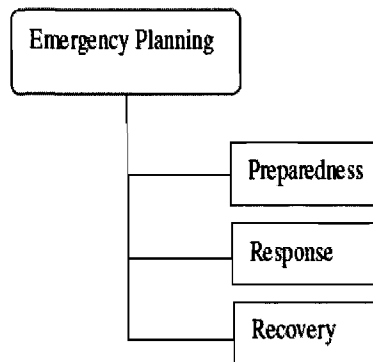


Figure 2-7: Block diagram of emergency preparedness program (Keren, 2003)

Figure 2-8 presents a flow chart of emergency preparedness stage. Since at least two parties are involved in emergency situations, in addition to the network within the facility, communication system becomes crucial element to a successful execution of emergency plans in real time situations as well as in drills.

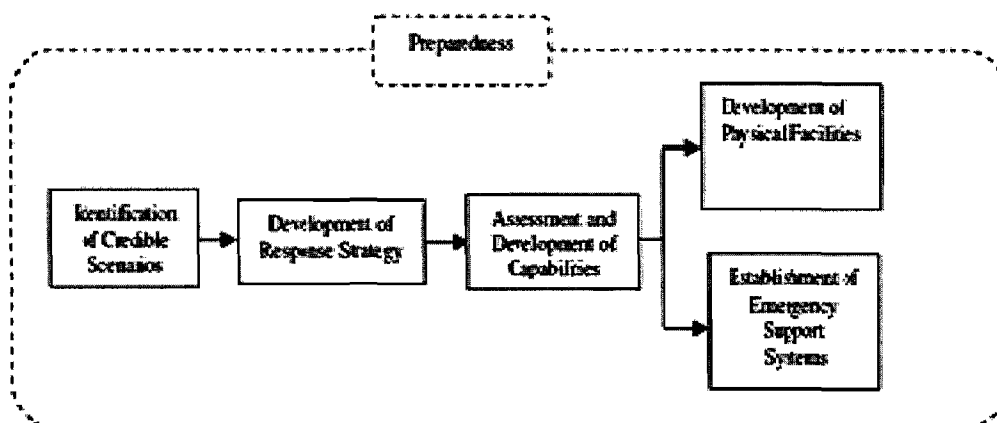


Figure 2-8: Flow chart of emergency preparedness stage (Keren, 2003)

The complex nature of emergency events requires a very clear hierarchy of command, and a procedure that should be clear of ambiguities. Training and assessments of the potential collaboration among the parties that are involved in the response to emergency events are extremely important. Quite often, preparedness programs are re-established due to assessments of drills. The development of physical infrastructure for emergency events consists of the following:

- ✓ Development of shelters and safe havens
- ✓ Establishment of Emergency Operation Centre (EOC)
- ✓ Development of emergency communication capabilities, and
- ✓ Development of appropriate medical support infrastructure

Emergency systems are developed parallel to the development of physical facilities. Following is a typical list of emergency systems:

- ✓ Emergency power supply
- ✓ Emergency water supply
- ✓ Communication systems
- ✓ Emergency management support computer system
- ✓ Site and community alert systems
- ✓ Adequate incident command transportation
- ✓ Appropriate control room protection measures

2.10.4 Benchmarking of Process Safety Incident Investigation Practice

Facilitating a well-developed Incident Investigation procedure is a crucial component in process safety programs. OSHA requires that regulated facilities develop a procedure to investigate incidents. The regulations specify a timeframe for the initiation of an investigation and basic requirements for an investigation team. Incident Investigation is a thorough process and is implemented in various ways. Incident investigations may vary in the major approach to the investigation, the type of techniques that are used, the way evidence is treated, and other characteristics. The definitions of several of the major parameters in incident investigations may vary slightly in the literature. The following definitions were adopted from Keren's (2003) work.

- ✓ Root Cause: - an underlying prime reason why an incident occurred
- ✓ Deductive Approach: - Deductive logic progresses from the general to the specific. A

major event is placed in the top of the problem and the logic progress backward in time and examines possible scenarios that can develop a path to the top

- ✓ Inductive Approach: - In Inductive Approach, the logic progress from a selected event or set of facts, and moves forward in time, examining possible effect, results, and consequences
- ✓ Multiple Root Cause Analysis: - A deductive search for all credible scenarios in which an event could occur.

PSII is not an exact science (Keren, 2003) and the degree of freedom in judgment during implementation of PSII techniques may vary widely. Implementation of PSII techniques in one plant may be very prescriptive and may reduce user's subjectivity to minimum, while implementation of the same technique in other plant can be strongly dependent on user identity. Incident related databases could be helpful in learning from the experience of others, sharing information with others, and identifying areas of weaknesses, benchmarking performance, and more.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 The Research Target

South African manufacturing/process industry is large, strong, with superb infrastructure and has excellent potential to become a force in the world. For a developing country, South Africa has an unusually large chemical industry which is of substantial economic significance. In addition to the South African majors such as Sentrachem, Sasol, and AECI; a number of multinational (mainly European) companies have manufacturing and trading operations but these are smaller in scale. The formulation and blending sector is, however, very active. There are, for example, 68 companies making flavours and fragrances and local companies producing sunscreen preparation (Simon and Sohal, 1995).

A large number of smaller companies are involved with manufacturing a wide range of specialties and in formulating and converting. 12% of the country's 14 million economically active persons are engaged in manufacturing and processing industry. In 2006, the South African chemical industry still contributes 5% to the GDP and 25% of manufacturing sales. By crude calculation, the manufacturing industry i.e. the process industry contributes about 20% of the GDP. The overall value of the South African chemical industry, excluding fuel and oil, is estimated at around US\$9.8 billion (Baker, 1992).

However, the industry is responsible for a range of highly hazardous operations as well as the production and use of a wide range of dangerous substances. Both pose serious risks to its workers, the public and the environment and it is for these reasons that parts of the industry are subject to special regulatory measures and a relatively high level of inspection and control. The manufacturing industry contributes 49% of the South African occupational injuries and 15% occupational fatalities (Loewenson, 1998).

3.2 The Sampling Procedure

The study population comprised of South African processing and manufacturing plants identified by the author. The sampled population was randomly chosen from large and small scale processing plants to achieve a balanced spectrum of refining, petrochemicals, gas, pharmaceutical, chemical (commodity and fine chemicals), utilities and food processing plants. Multi-nationals and local manufacturers are sampled with the intention to investigate the process safety management (PSM) practice in their various facilities.

The questionnaires were administered to plants and facilities based on their operations with no regards to the parent company. Since there is a variance in PSM practice even among facilities owned by the same company; two or more of the sampled plants might belong to the same company. Confidentiality does not permit details on the sampled plants.

3.3 The Research Instruments

Both primary and secondary instruments were used in the course of this research. To generate the items contained within the domain of PSM system, an exhaustive review of the literature on industrial safety management, PSM performance measurement and benchmarking was carried out. The structured questionnaire developed from the literature survey was used as the secondary instrument for data collection.

3.4 Questionnaire Design

PSM programs are implemented in diverse ways. Because of the performance-based nature of PSM programs, they can be implemented to meet at the minimum OSHA PSM requirements or on the other hand PSM programs can be implemented with the desire to achieve the best practice (Keren, 2003). This section documents the development of measurable components of PSM performance measurement system.

3.4.1 Development of the Questionnaire Parameters

The questionnaire design started in September, 2006 and went through phases of development for six months. The model developed by Keren (2003) for MOC performance measurement has been extensively adapted to develop the parameters used to benchmark the practice of MOC among the South African process industry. Keren (2003) applied his model to a similar industry in US. Due to the dynamic nature of the safety management industry and the difference in the research targets, some of the parameters have been modified based on experts' advice. For the benchmarking of emergency preparedness program (EPP) practices among the facilities in the process industries; the author relied on the "Guidelines for Technical Planning for On-Site Emergencies" (AIChE, 1995) as the major guideline. The questionnaire parameters used to benchmark the process safety incident investigation (PSII) were developed from the "Guidelines for Investigating Chemical Process Incidents" (AIChE, 1992).

3.4.1.1 Benchmarking Parameters for Management of Change (MOC)

The MOC program consists of a variety of performance influencing factors. Keren (2003) suggests a performance evaluation system of MOC program practices according to six factors:

- ▢ Scope of program: areas in the plant that are subject to the MOC program
- ▢ Authorization process: the process of authorization of the various types of MOC
- ▢ MOC training: training frequencies, type of training, and employees that participated in the training program.
- ▢ Internal audit process: content that is addressed by the audit program.
- ▢ Hazard identification: capabilities of the MOC program to detect change-related hazards.
- ▢ Outcomes: measurement of flaws, e.g., the number of failures to miss-classify Maintenance Work Orders (MWOs) as MOCs.

With the objective of benchmarking the diversity in practice of the above parameters and their sub-elements as reviewed previously in section 2.10.2; questions similar to those in Keren's model were developed. Necessary changes were made to the questionnaires but attempt was made to maintain similarity with Keren's model so as to allow comparison of findings. The questionnaire has 23 sub-headings which include: Facility Profile, Scope, Policy Development, Size of MOC program, Emergency MOCs, Temporary MOCs, MOC records management, Audit, Audit Results, MOC software, MOC Program Awareness Training, Impact on Risk Management Plan (RMP), MOC initiation, Process Hazard Analysis (PHA) revalidation, Environmental and Quality, Risk Screening or Ranking MOC, Safety Review of MOC, Authorization, Training in the MOC, Pre-Start-up Safety Review, Metrics, Organizational Changes, and the respondent Impressions about his plant MOC practice. The questionnaire is reproduced in entirety in Annexure I.

3.4.1.2 Benchmarking Parameters for Emergency Planning Programs (EPP)

The development of the following questionnaire is aimed at identifying the variance in the implementation of the EPP practices in the industry. Emergency preparedness requires a multi-domain deployment. Preparedness process begins with identification of credible scenarios based on which consequence analyses are conducted, and appropriate response strategies are developed. The analysis of resources and capabilities that are required for response to the emergency scenarios is part of the preparedness stage. OSHA requirements as regards EPP are contained in the Compliance Guidelines and

Recommendations for Process Safety Management (Non-mandatory). - 1910.119 App C and they are as summarized below:

"Emergency preparedness or the employer's tertiary (third) lines of defence are those that will be relied on along with the secondary lines of defence when the primary lines of defence which are used to prevent an unwanted release fail to stop the release.

Employers will need to decide if they want employees to handle and stop small or minor incidental releases. Whether they wish to mobilize the available resources at the plant and have them brought to bear on a more significant release.

Employers will need to select how many different emergency preparedness or tertiary lines of defence they plan to have and then develop the necessary plans and procedures, and appropriately train employees in their emergency duties and responsibilities and then implement these lines of defence.

Employers at a minimum must have an emergency action plan which will facilitate the prompt evacuation of employees in event of an unwanted release of highly hazardous chemical. The intent of these requirements is to alert and move employees to a safe zone quickly. The use of process control centres or similar process buildings in the process area as safe areas is discouraged.

If the employer wants specific employees in the release area to control or stop the minor emergency or incidental release, these actions must be planned for in advance and procedures developed and implemented. Preplanning for handling incidental releases for minor emergencies in the process area needs to be done, appropriate equipment for the hazards must be provided, and training conducted for those employees who will perform the emergency work before they respond to handle an actual release.

There must be emergency control centre(s) which would be sited in a safe zone area so that it could be occupied throughout the duration of an emergency. The centre would serve as the major communication link between the on-scene incident commander and plant or corporate management as well as with the local community officials. The communication equipment in the emergency control centre should include a network to receive and transmit information by telephone, radio or other means. It is important to have a backup communication network in case of power failure or one communication means fails. The centre should also be equipped with the plant layout and community maps, utility drawings including fire water, emergency lighting, appropriate reference materials such as a government agency notification list, company personnel phone list, material safety data sheets, emergency plans and procedures manual, a listing with the location of emergency response equipment, mutual aid information, and access to meteorological or weather condition data and any dispersion modelling data."

The above requirements are basically identical to parameters documented in AIChE's "Guidelines for Technical Planning for On-Site Emergencies" where they have been reduced to measurable elements. The questionnaire for this benchmarking exercise was developed in consideration of the measurable elements. Thus, the EPP questions were structured with such headings as: Facility Profile, Identifying Credible Incidents; Capabilities and resources assessments; Physical facilities and systems, Communication, Metrics, Emergency Functional Positions; and Training. The entire questionnaire and is contained in Annexure II.

3.4.1.3 Benchmarking Parameters for Process Safety Incident Investigation (PSII)

OSHA PSM standard as regards PSII is summarized below:

- (1) The employer shall investigate each incident which resulted in, or could reasonably have resulted in a catastrophic release of highly hazardous chemical in the workplace.*
- (2) An incident investigation shall be initiated as promptly as possible, but not later than 48 hours following the incident.*
- (3) An incident investigation team shall be established and consist of at least one person knowledgeable in the process involved, including a contract employee if the incident involved work of the contractor, and other persons with appropriate knowledge and experience to thoroughly investigate and analyze the incident.*
- (4) A report shall be prepared at the conclusion of the investigation which includes at a minimum:*
 - (i) Date of incident*
 - (ii) Date investigation began:*
 - (iii) A description of the incident;*
 - (iv) The factors that contributed to the incident; and*
 - (v) Any recommendations resulting from the investigation.*
- (5) The employer shall establish a system to promptly address and resolve the incident report findings and recommendations. Resolutions and corrective actions shall be documented.*
- (6) The report shall be reviewed with all affected personnel whose job tasks are relevant to the incident findings including contract employees where applicable.*
- (7) Incident investigation reports shall be retained for five years*

As was previously reviewed in chapter two, regulation is not enough for process safety management. Thus, companies look for guidance in professional and academic guidelines for the development and improvement of their safety systems. One of such valuable guidelines on PSII is the "Guidelines for

Investigating Chemical Process Incidents" (AIChE, 1992). The handbook identifies the following major elements of a PSII system:

- ✓ Major incident investigation
- ✓ Near-miss reporting
- ✓ Follow-up and resolution
- ✓ Communication
- ✓ Incident reporting
- ✓ Third-party participation as needed

The questionnaire has been developed with the above in mind and the sub-headings include: Facility Profile, General Investigation Approach, PSII Techniques, Databases, Management Commitment, Investigation Team, Evidence, Recommendations and Metrics. A copy of the questionnaire is in Annexure III.

3.5 Validity and Reliability of the Survey Instrument

The reliability of the survey instrument (i.e., its ability to yield consistent results for repeated administrations) was established in multiple ways and these are documented in the following sections.

3.5.1 Validation of the Source Theoretical Model

Keren's theoretical model, from which these questionnaires were extracted, was validated by a team of PSM experts and professionals (Keren, 2003). These experts include:

- ✓ Dr. M. Sam Mannan: Professor of Chemical Engineering at Texas A&M University, College Station, Texas, Director of the Mary Kay O'Connor Process Safety Centre (MKOPSC), at Texas A&M University (TAMU), internationally recognized process safety expert, and a reviewers of several process safety journals.
- ✓ Dr. Harry H. West: a member of the Steering Committee and the Technical Advisory Committee of the MKOPSC TAMU, and internationally recognized expert and process safety consultant.
- ✓ Mr. Roy E. Sanders: a senior process safety executive, a member of the Technical Advisory Committee at the MKOPSC, TAMU, lecturer of several courses as part of the Continuing

Education program of the MKOPSC, TAMU, and lecturer of courses that are offered by the Centre of Chemical Process Safety (CCPS). Moreover, Mr. Sanders wrote the well-recognized book "Management of Change in Chemical Plants; Learning from Case Histories".

- ✓ Mr. Skip W. Early: process safety consultant, a member of the Technical Advisory Committee at the MKOPSC, TAMU, lecturer of several courses as part of the Continuing Education program of the MKOPSC, TAMU.
- ✓ Mr. Adrian L. Sepeda: Served many years as a safety executive at Occidental Chemicals. Upon his retirement, Mr. Sepeda offers his services as a process safety consultant, and is currently consultant to the CCPS, at the American Institute of Chemical Engineers. Among his duties Mr. Sepeda is a lecturer with the Continuing Education program at the MKOPSC, TAMU.
- ✓ Mr. Donald W. Jenkins: worked as a project engineer with Amoco Production for many years, was among the group that defined PSM for Amoco Production in the 1990's. Upon his retirement, Mr. Jenkins returned to BP Amoco as a consultant, and is in charge of MOC in the offshore projects office.

3.5.2 Validation by South African Professionals

Due to time lag between Keren's work and the present study, and moreover the difference in the research targets; there is need for further validation of the survey instrument. After modification, the questions were given to a panel of South African experts in process safety management for review and comments. This panel includes:

- ✓ The Coordinator of PSM implementation in a South African Wax plant. The company started PSM implementation since 2004.
- ✓ The Production Manager of the Wax plant
- ✓ A Safety, Health, Environment, Risk and Quality, SHERQ officer in a South African chemical plant
- ✓ Mr. Andre Dreyer of SD&T. Andre is a safety programs facilitator and safety consultant to some Southern African chemical and petrochemical companies.

Their comments were solicited through e-mails and oral communication. Corrections were made to the questionnaires based on their reviews.

3.5.3 Recommendations from the Study Leader

The corrected questionnaires were sent to the Study Leader, Professor Harry Wichers for his reviews and comments. Among his recommendations are:

- ✓ That the number of questionnaires should be limited to one per respondent due to the technical content of the survey.
- ✓ That the length of each questionnaire should be moderated considering the time available to potential respondents
- ✓ That the clarity of the questions in the survey instrument should be reviewed to avoid vague questions which attract invalid responses

This researcher worked by his recommendations by limiting the questionnaires to one per respondent. The response rate was enhanced by allowing electronic filling of the questionnaires. After corrections on question statement clarity, a second draft of the questionnaires was ready for further validation.

3.5.4 Pilot Survey

The next phase of validation was through a pilot survey. The survey was conducted among the researcher's work colleagues including Shift Supervisors, Shift SHERQ Reps and first-line Managers. This researcher is on process operational training with a major player in the South African process industry. Their understanding of the questionnaires was tested and their comments were used to correct the survey instrument as necessary.

3.5.5 Split-half Method for Validation

The last phase of validation was done using the split-half technique where a person's responses to one half of the survey's items (randomly selected) were correlated against his responses to the other half. The classmates of this researcher were used for this reliability test. Results here found a high degree of reliability. This technique reveals interesting difference in peoples' understanding of questions. Consequently, this researcher sometimes repeated important questions in other wordings to confirm the respondents' answers. The final drafts of the questionnaires were administered as explained in the coming sections.

3.6 Data Gathering

The final questionnaires were made up of 23 main questions for benchmarking MOC practice, and eight (8) sections for benchmarking EPP; and nine (9) sections for benchmarking PSII. The questionnaires were hosted on the web. The service of Problem Free™, UK was engaged between February and June, 2007 for the online hosting of the surveys. The online survey software is accessible via the company's URL address – www.freeonlinesurveys.com. An Extra Account was created by this researcher, and three different surveys were floated to carry out the benchmarking surveys for MOC, EPP and PSII. A URL link was generated for each of the surveys and these links were e-mailed to the sampled plants. After two months, reminder e-mails were sent to the same recipients.

The target safety functions in the sampled plants included the safety officers, safety managers, PSM coordinators and in few cases, the plant managers where there were no designated SHE, HSE, SHEQ or SHERQ officers. To encourage high response rate, anonymous filling of the surveys was made the rule. Also, e-mails or the IP addresses of the respondents were not tracked. As the surveys were being completed, the researcher received completed questionnaires while the online software made a database for the responses.

3.7 Data analysis

The most essential limitation to the analysis of this study is the low response rate. Out of over 120 questionnaires sent out for each survey; 14 (8%), 12 (6%) and 13 (7%) usable responses respectively were received for the MOC, EPP and PSII benchmarking surveys. Analogous problems with low response rate have been seen in similar studies (Kok and van Steen, 1994, and Harms-Ringdahl *et al.*, 2000). An analysis of the correspondences revealed some of the reasons for the low response. Some plants claimed that they did not fit into the study definition of process plants; while others refused response because they regularly received superfluous number of similar and regulatory surveys.

A preliminary statistical analysis of the gathered data was done by the Problem Free™ online survey software. Further analyses of the investigation were carried out with the aid of Microsoft™ Excel. This tool was chosen because of the ease of use and simplicity it offers. It has equally proved to be one of the best tools available for tabulation and for plotting graphs.

CHAPTER FOUR

RESULTS, ANALYSIS AND DISCUSSION

4.1 Benchmarking of Management of Change

The MOC benchmarking survey represented in this chapter was conducted between the months of February and September 2007. Questionnaires were prepared and distributed to more than 180 plants, out of which 14 facilities responded. The questionnaire is reproduced in its entirety in Annexure I. The majority (85%) of the sampled companies are listed on Johannesburg Stock exchange (JSE), meaning that most of them subscribed to the JSE King II Code of corporate social responsibility. Surprisingly, only 35% of the facilities are NOSA-graded. Perhaps, this is due to the fact that NOSA was emerging from a temporary state of non-existence when the survey was being conducted. 85% of the facilities are members of South African Responsible Care™ (see Figure 4-1).

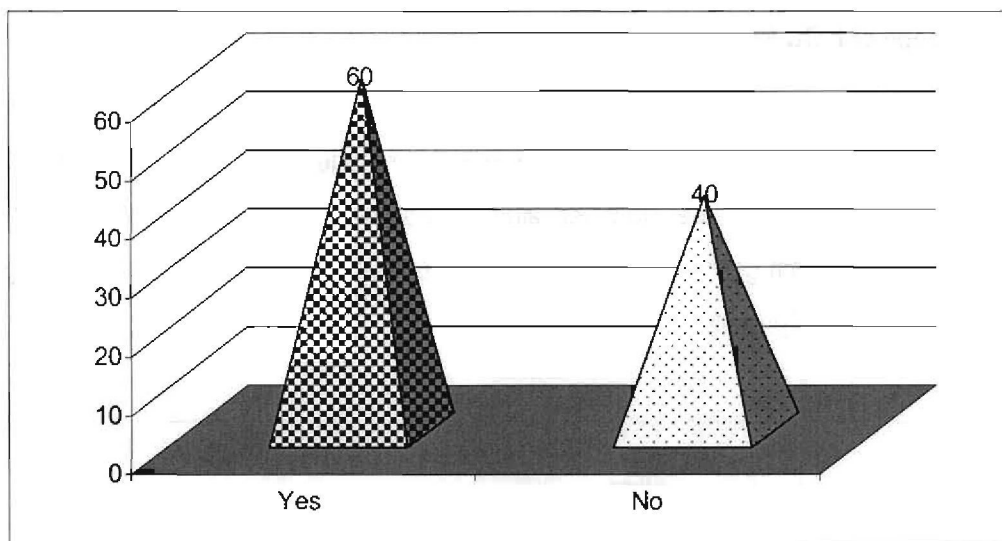


Figure 4-1: Membership of Responsible Care™

With this profile, one expects a high degree of process safety practice. The plants surveyed had 400 to 13000 employees. Figure 4-2 below shows the distribution of facilities based on the type of plants. The facilities had an average of seven (7) separate process areas; with minimum and maximum of one (1) and thirteen (13) processes respectively. The industries represented consisted of chemicals, refineries, petrochemicals, pharmaceutical, food, utilities, metal extraction and processing, gas plants etc.

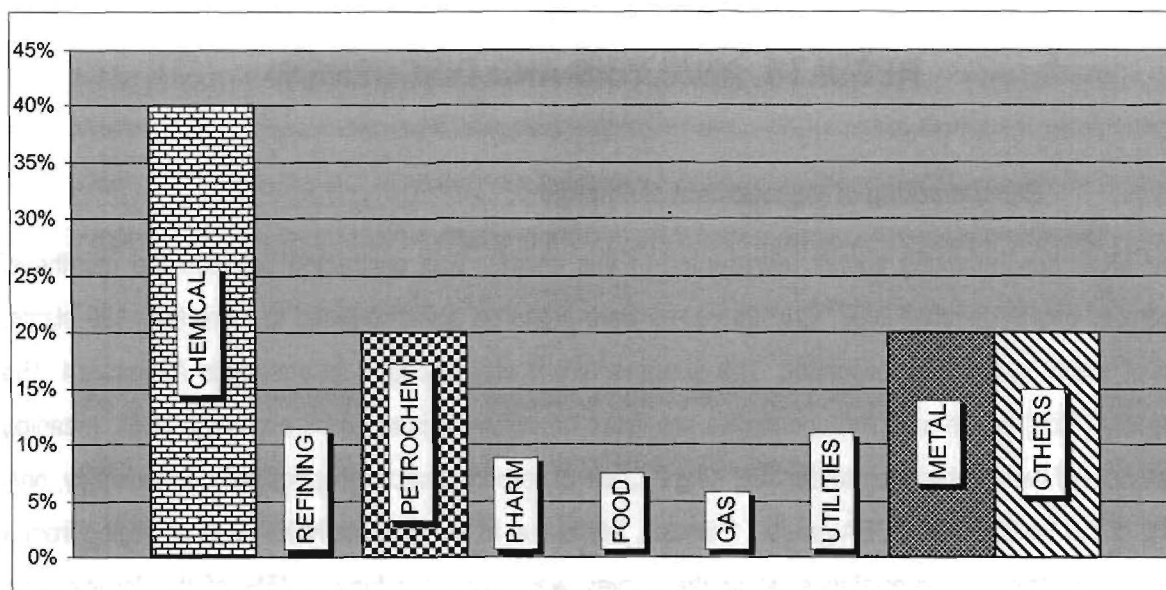


Figure 4-2: Distribution of facilities based on type of plants

4.1.1 Scope of MOC Program

Eighty percent (80%) of the respondents reported that MOC programs had been implemented "plant - wide". As shown in Figure 4-3, only 20% of the respondents reported limited implementation based on determination of regulatory coverage. However, almost all of the respondents reported that the MOC program was covering steam generation or waste water treatment areas and other utilities. Figure 4-4 shows the popularity of applying MOC to the tank farms.

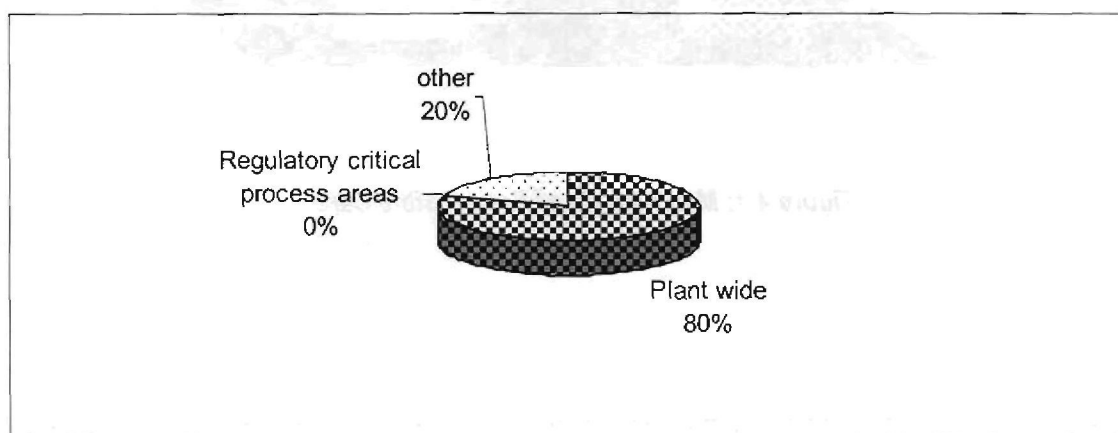


Figure 4-3: Coverage of MOC implementation

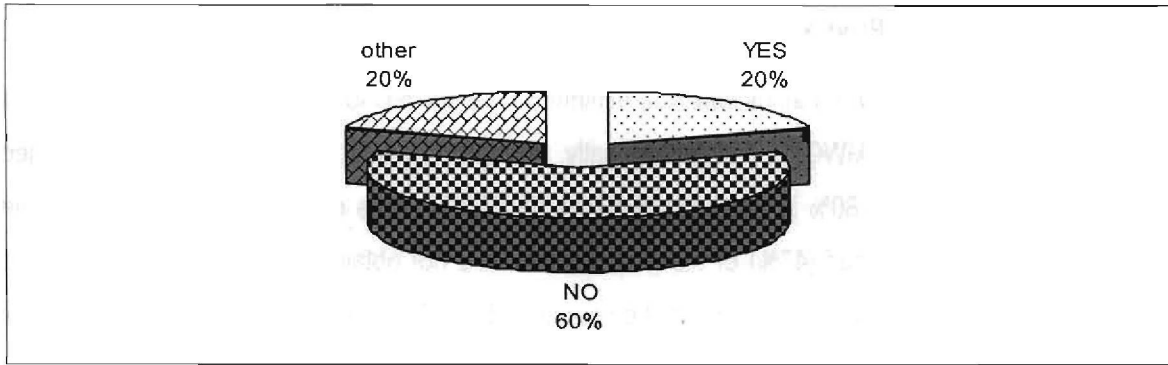


Figure 4-4: Application of MOC to Atmospheric Tank Farm

4.1.2 Policy Development

MOC procedures are developed by corporate plant staff in most (60%) of the facilities with little or no external PSM consultant assistance, and with little assistance from local plant staff (Figure 4-5). Also, highly significant efforts are made to maintain consistent MOC procedures with other plants within the corporation (Figure 4-6).

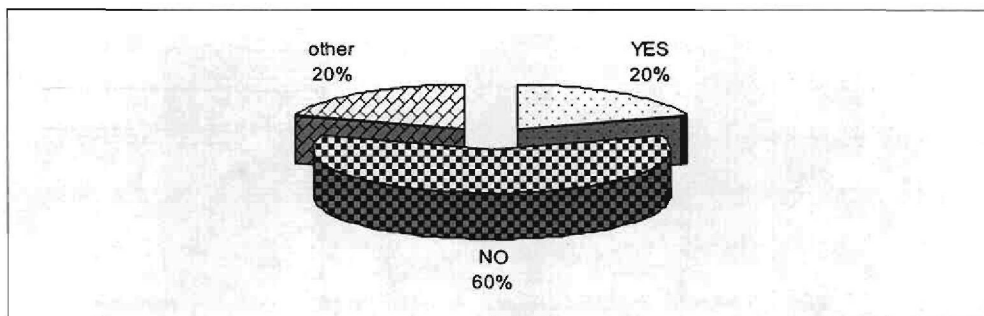


Figure 4-5: Development of MOC Policy

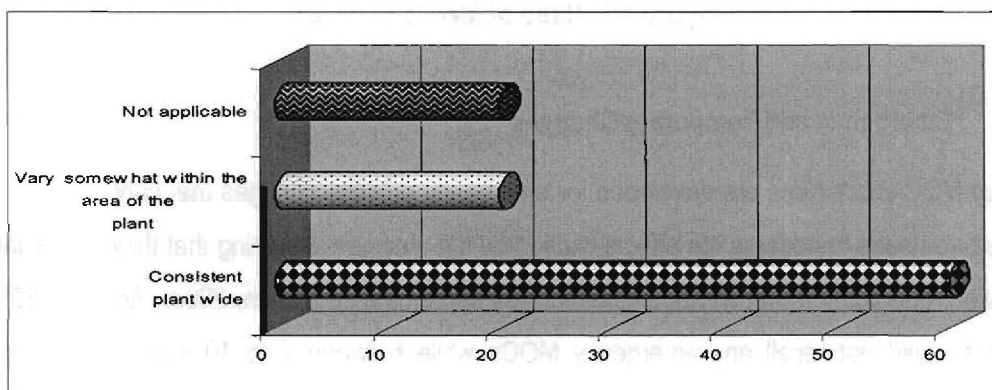


Figure 4-6: Consistency of MOC

4.1.3 Size of MOC Programs

A significant fact revealed by the study was that minimum of about 200 to a maximum of over 10,000 of Maintenance Work Orders (MWO) is initiated annually. In addition, a vast number of MOCs is initiated annually out of which about 80% is approved and only about 20% were eventually not approved. The study revealed that almost half (43%) of the participants could not obtain the number of Maintenance Work Orders (MWO) initiated annually. About, the same number (42%) could not estimate the number of MOC orders initiated annually.

Hundreds of MWOs are initiated annually in the majority of the plants, but ridiculous figures such as two (2) and five (5) MWOs were also reported, though, by the smallest facilities. On the average, each facility initiated several hundred MOCs annually. The ratio between the number of annual MWOs initiated and the annual MOCs initiated ranges between 1 and 7, with an exception value of 100 which probably indicates poor MOC implementation (see Figure 4-7). Majority (75%) of the plants indicated that they do not keep records of unapproved MOCs.

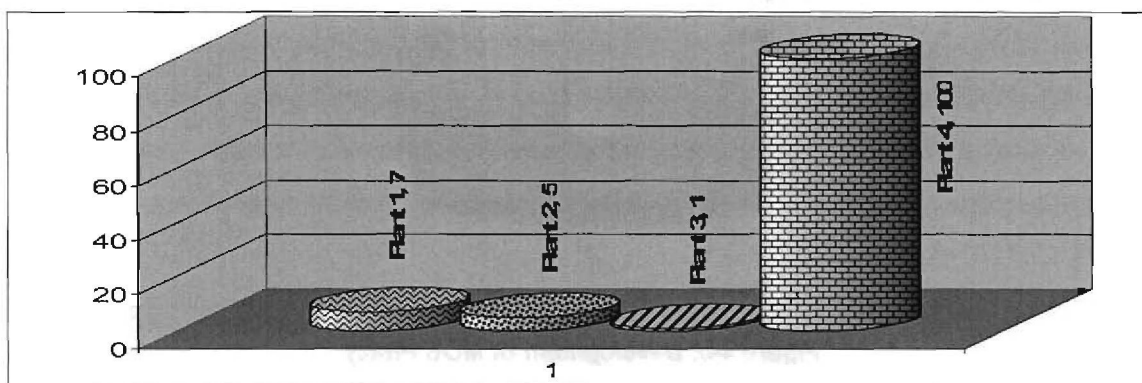


Figure 4-7: Ratio of MWOs to MOCs

4.1.4 Emergency and Temporary Changes

Emergency MOC procedures are developed for emergency process changes that cannot be postponed. The procedure needs to address the effects caused by the changes assuming that they will be taken into consideration, and confirm that all documentation will be completed (Keren, 2003). Annually 35% of the respondents could not recall any emergency MOCs while between 7 to 10 emergency MOCs were initiated. One of the respondents remarked that there was no need for emergency changes in their facility.

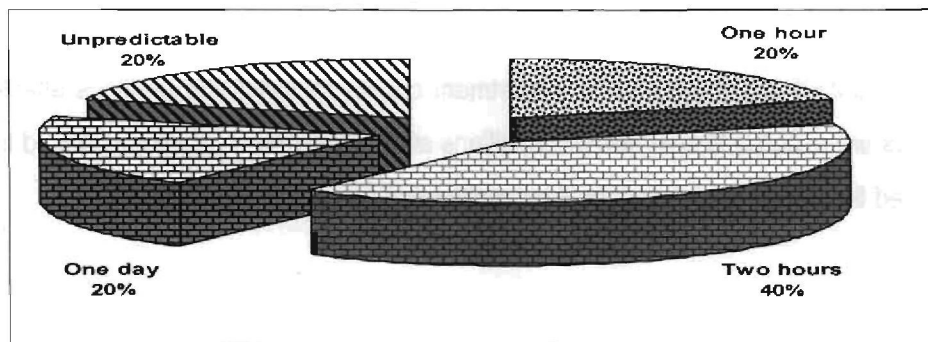


Figure 4-8: Duration for Approval of Emergency MOC

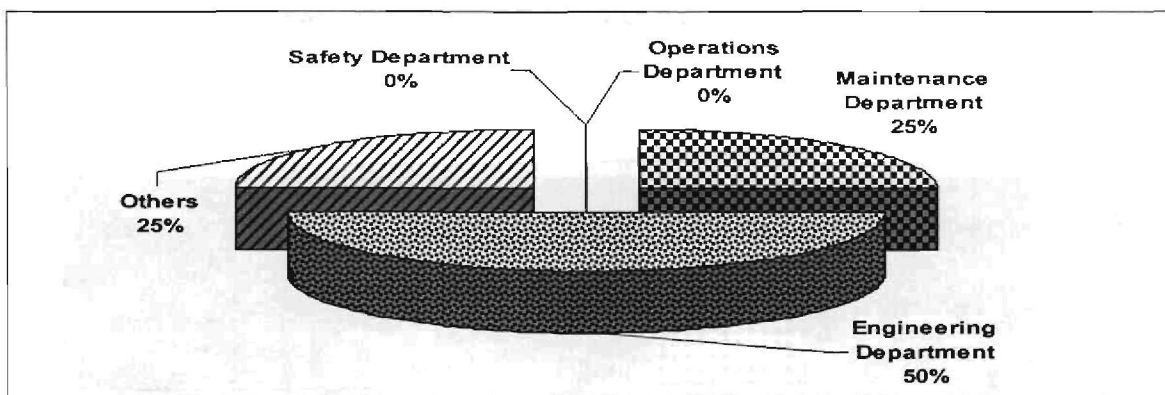


Figure 4-9: Authorization for Emergency MOCs

Figure 4-8 above shows that 20% of the respondents needs an hour, another 20% responded that about a whole day is needed, 40% responded that they needed about two hours to approve emergency MOCs, while another 20% responded that the time is unpredictable since the process safety department are on 24hrs standby, however the proposed change must be properly evaluated for safety. 66.7% of the respondents reported that emergency MOCs are audited or checked as soon as practicable, while 33.3% of the respondents reported that delays are met. A few number of the respondents reported that 12% of emergency MOCs require remedial actions or violate the company/site procedure, while others make no distinction between normal and emergency other than that they try to complete the process quicker.

The departments responsible for authorizing emergency MOCs varied from plant to plant (see Figure 4-9 above). The responses revealed that emergency MOCs were authorized by Maintenance department, Engineering department, and in some cases by process safety department. In most cases there were multiple authorization requirements. It should be noted that the data revealed a few cases of between 5 to 25 temporary MOCs annually. It was deduced that there is a high consistency of auditing of temporary

changes, so as to restore them to their previous condition. However, there was no consistency as to who or what department was responsible for restoration of temporary changes to previous conditions. 75% of the respondent reported that the operation department checks to see if the changes affected by the temporary MOCs are restored to their normal conditions after the expiration of the authorised time period and 25% reported that the check is conducted by engineering and safety department.

4.1.5 MOC Record Management

Half of the responses indicated the preference for storing MOC documentation in the plant central record storage area while other responses indicated that it lies within each respective plant area. Further analysis shows that all respondents keep both hard copies and electronic copies of their MOC records. As illustrated in Figure 4-10, 75% of surveyed plants, operation department maintains the MOC files.

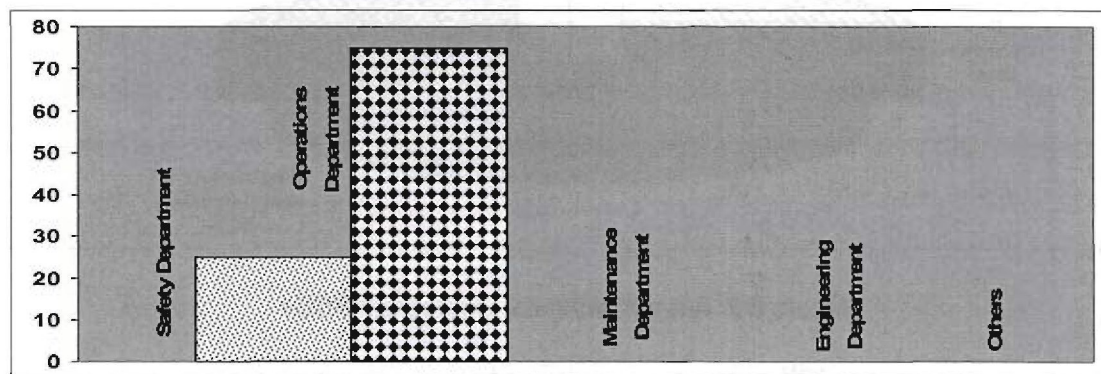


Figure 4-10: Control of MOC files

4.1.6 Audit

Not more than 33.3% of the respondents apply the minimum standard required by the PSM regulations for audits (i.e., 3-year PSM audit) for auditing MOC programs. All of the participants reported that MOC audits were conducted by corporate staff not normally located at the plant, more than 65% involved external consultants as well. The results from the audits revealed that there was a large number (67%) of miss-classified MOCs (see Figure 4-11 below). About 70% of the respondents also indicated that their audits reveal field changes that were not subjected to MOC procedures while 33.3 % of the respondent reported that their audit did not reveal any maintenance work orders that should have been classified as MOCs.

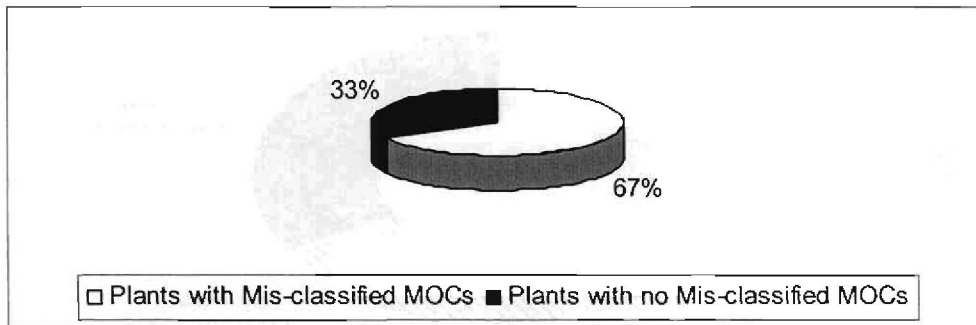


Figure 4-11: Mis-classified MOCs

66.7% respondents identified that there were recommendations for upgrading of their MOC programs. These include recommendations on the following subjects:

- Staff MOC awareness
- MOC procedure documentation
- MOC coverage area
- MOC audit frequency

4.1.7 MOC Software

66.7% of the respondent does not use any special software to facilitate the MOC procedure while 33.3% use it. 33.3% of the respondent reported that the software was developed "in-house", while all participants concurred that the use of commercial software products is not satisfactory at the moment.

4.1.8 MOC Program Awareness Training

As depicted in Figure 4-12, 34% of the respondents used formal training classes for new employees' MOC program awareness. A few number respondents stated that additional MOC program awareness training was provided at other occasions, such as informal toolbox safety meetings. Other facilities reported that they offered on-the-job training and/or informal training only. No facilities reported no training at all, and no facility reported computer-based training only. Formal training classes, wherever provided, were scheduled on an annual basis. In general, a great number of the respondents stated that MOC program awareness training is not separate from other PSM awareness training. Majority of the respondent does not use video describing the need for MOC awareness training programme.

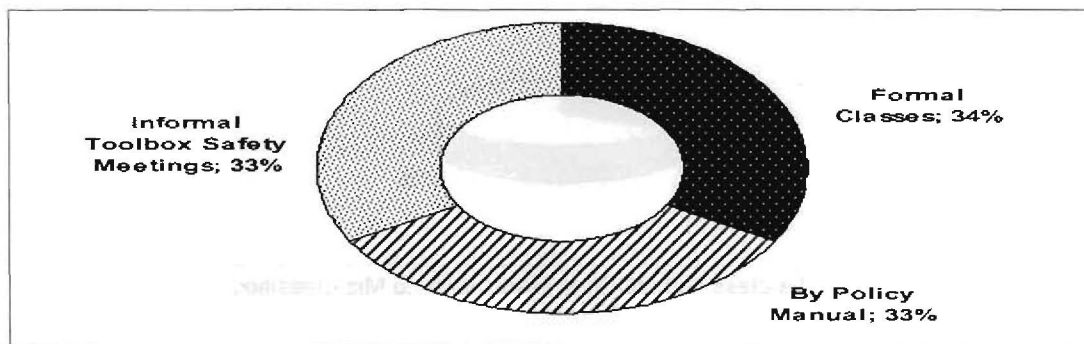


Figure 4-12: Media used for MOC training

4.1.9 Impact on Risk Management Plan (RMP)

One-third of the respondents stated that the safety department was responsible for checking whether a change will result in revising the RMP, while the remaining two-third shares the opinion that either the operations department or the SHE department was responsible. Over 65% of facilities indicated process changes that resulted in update and re-submittal of the RMP.

4.1.10 MOC initiation

Majority (64%) reported that all work orders require a corresponding MOC authorization number or explanation. Figure 4-13 shows the pattern in the departments responsible for identifying that a work order is NOT replacement -in-kind, and is therefore work that requires an MOC. It was generally agreed upon that DCS software changes are documented using the MOC procedure. The maintenance of the DCS software varies from plant to plant.

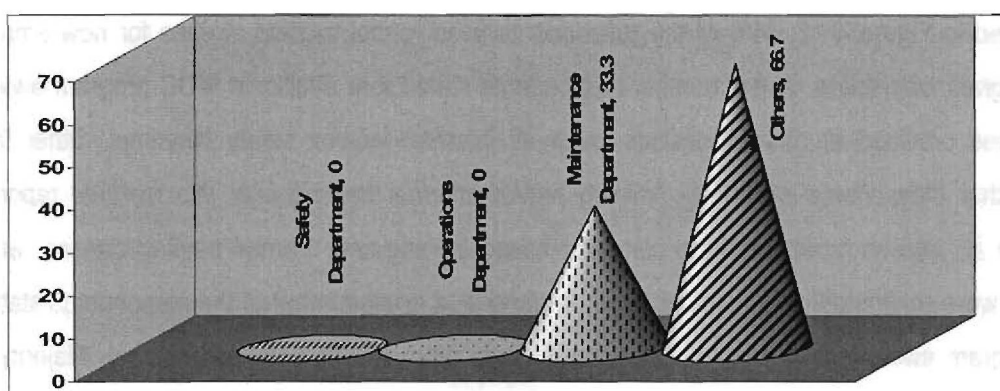


Figure 4-13: Responsible department for deciding that MWOs is NOT a replacement-in-kind

4.1.11 PHA Revalidation

The questionnaire asked for the criteria used by the respondents for making decisions regarding the need for a PHA associated with MOCs. The common criteria for determination of the need for performing PHA are: complexity and type of change; and any replacement that is not in kind. All of the respondents stated that the PHA's performed for MOC varied in the degree of detailed review and documentation. More than 65% of the respondent reported that PHA revalidation reviews MOC records and find changes that were not identified in the MOC records.

4.1.12 Environmental and Quality

All respondent plants were accredited under ISO 9000. Majority of the respondents indicated that environmental personnel were consulted as part of the MOC review; and that the PSM MOC program was integrated with the quality configuration management program (QCMP) and that the records are well consolidated (see Figure 4-14 below).

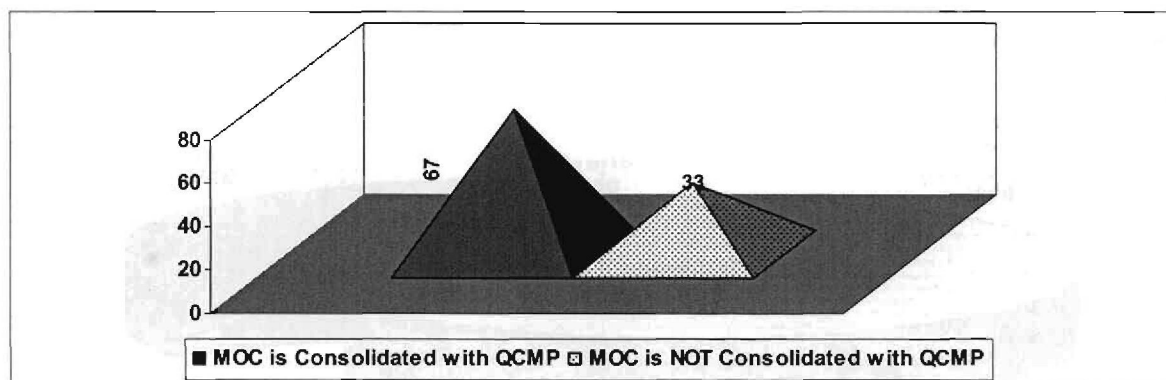


Figure 4-14: Consolidation of MOC with QCMP

4.1.13 Risk Screening or MOC Ranking

The MOC questionnaire contained a series of questions that are based upon the concept that proposed MOCs should be screened to provide the appropriate resources in order to evaluate the impact on safety from the proposed change. About 67% of the respondents stated that they were doing risk screening of MOCs (Figure 4-15). Outside consultants developed most (67%) of the screening procedures with some input from corporate PSM groups. MOC coordinator is in all cases responsible for MOC screening. Risk screening procedure should determine categories of risk in order to classify the screening results. The number of categories varied between 5 to 7, 66.7% of the respondents reported that potential

consequences and potential events were evaluated separately in the determination of risk categories. Checklists and staff experience were reported as the most popular evaluation methods for risk screening.

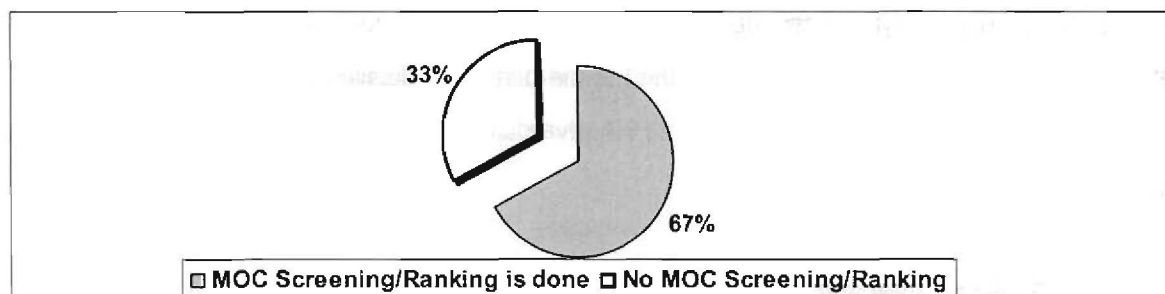


Figure 4-15: Popularity of MOC Screening and Ranking

4.1.14 Safety Review of MOC

Both OSHA and EPA regulations mandate safety review of MOCs. The optimal stage to initiate a safety review is when preliminary engineering design of the change has been completed. Thus, the safety review should take place before the detailed design stage.

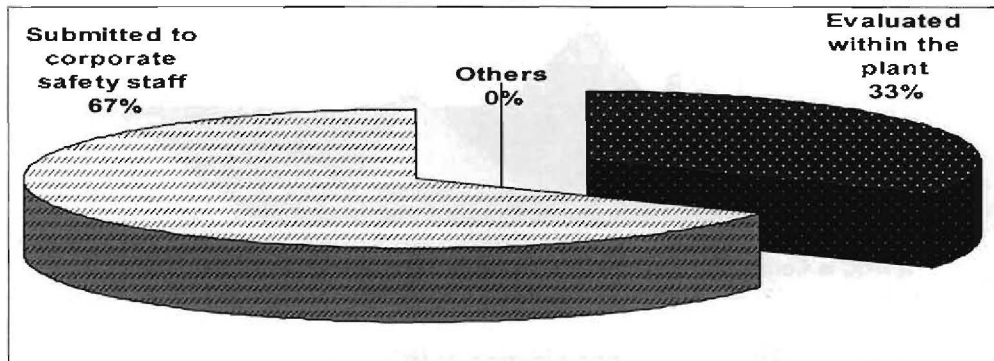


Figure 4-16: Safety review of high-risk MOCs

The survey revealed that most of the facilities that used risk screening of MOCs, used the same safety review techniques for different categories of risk. 50% reported that a checklist is most commonly used for low risk MOCs. As shown above in Figure 4-16, majority (67%) of the facilities submit their high risk safety reviews to corporate safety staff for evaluation.

4.1.15 Authorization

The number of authorizations for MOC approval varied widely with generality of the respondents requiring different levels of applicable authorization for each MOC risk category (such as authorization at the process unit area or plant manager level). Over 65% of the respondents indicated that the actual number of authorizations is determined on a case-by-case basis according to the risk level. Most (67%) of the facilities use different number and different levels of authorizations for screening as well as for all MOC risk categories (see Figure 4-17).

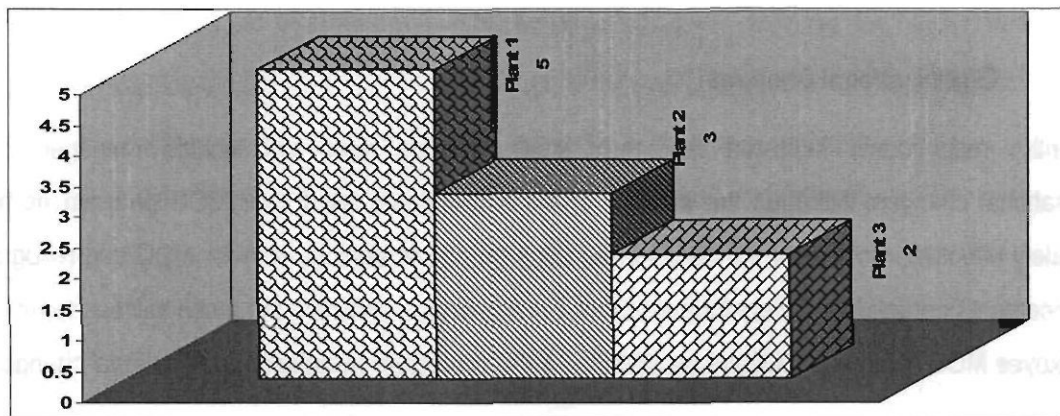


Figure 4-17: Number of authorization for MOC requests

4.1.16 Training in the MOC

It is generally indicated that the training department is responsible for conducting training regarding the impact of the MOC; and when risk screening was used the same training requirement was applicable to each MOC risk category. Less than 40% of the respondent indicated night orders or logbook notation was used for informing staff of low risk MOC changes

4.1.17 Pre-start-up safety Review (PSSR) and MOC Metrics

Majority of the respondent indicated that the PSSR program is considered closure of the MOC program. It is largely indicated that the engineering, maintenance, and operations department conduct PSSR. Only 33.3% indicated that MOC coordinator conducts it too. According to the survey, majority (67%) did not have a metric system to measure MOC effectiveness (see Figure 4-18); and 50% of those who have metric systems adapted them from other sources.

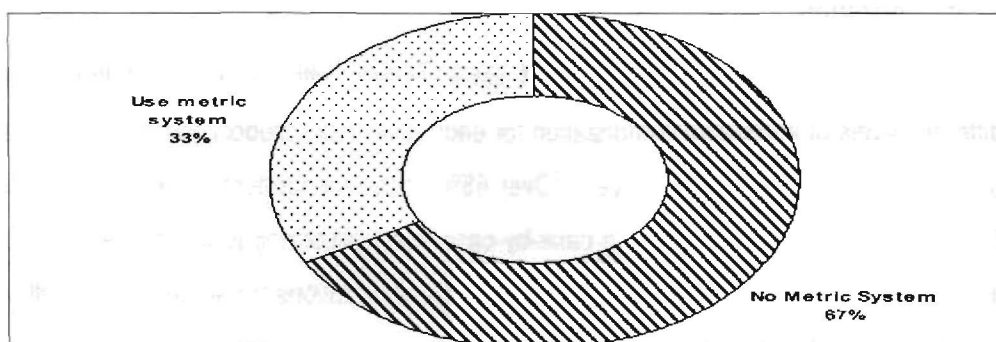


Figure 4-18: Variation in the usage of MOC metric system

4.1.18 Organizational Changes

The entire respondents indicated that their MOC program does not include management of organisational changes. Although the majority of the respondents rated their MOC program as being moderately effective, more work still needs to be done on risk screening, PHA for MOC and recognition of replacements not-in-kind. Others indicated that it is moderately effective but much still has to be done on employee MOC awareness. Others wanted their MOC procedure to include organisational changes.

4.2. Benchmarking of Emergency Preparedness Programs

The analysis of resources and capabilities that are required for response to the emergency scenarios is the major part of the preparedness stage.

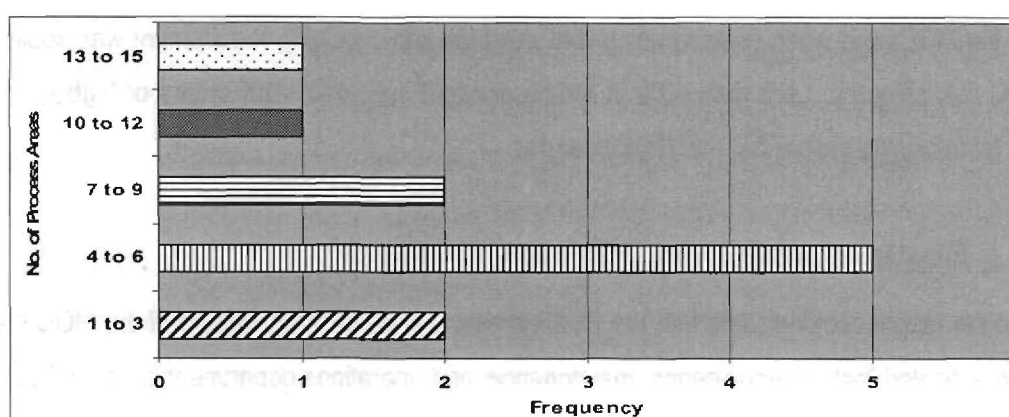


Figure 4-19: Number of processes in the sampled plants

This analysis examines the resources and the capabilities at the facilities, at neighbouring sites, and the resources that are available at the local community. Twelve (12) chemical plants - one (1) refining, one

(1) petrochemical facility, two (2) gas plants, and a single pharmaceutical facility, participated in the survey study. Figure 4-19 above shows that the number of processes in the plants varies from a single process gas plant to a 13 process site. The range of number of employees varies between 54 to above 13,000 employees.

4.2.1 The Process of Identification of Credible Scenarios

The process of identifying credible scenarios reveals events that emergency planning should address. A process hazard evaluation will lead to a long list of potential incidents. This list should be assessed to determine likelihood and consequences of each of the incidents and then prioritized according to the risk associated with them. For each incident it is possible to determine the worst-case scenario. Loss of containment, where all the material is being released instantaneously is a worst-case scenario. However, the likelihood of development of such a scenario is extremely low.

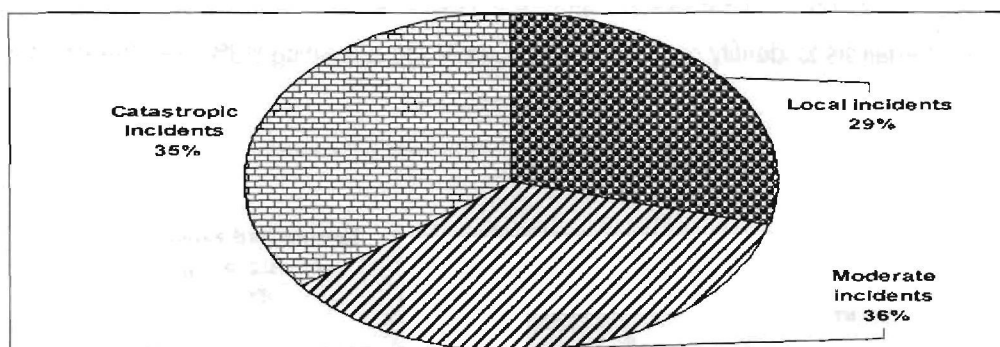


Figure 4-20: Industry variation in magnitude of events covered by EPPs

Preparedness for emergencies that consist of worst-case scenarios requires enormous resources and may overwhelm the business operability of a facility. For each scenario, the outcomes should be listed, and the consequences and probabilities should be evaluated, while considering the facility's management control. Events such as instantaneous loss of containment are of major concern in the process industries, however, measures, such as control systems, overpressure relief, alarms; mechanical as well as non-destructive tests reduce the likelihood of development of such scenarios. All the plants considered worst-case scenarios in the development of their emergency plans. These plans cover all three levels of magnitudes of events: local, moderate, and catastrophic. Corresponding percentages of incident coverage by EPP of sampled plants are shown in Figure 4-20 above.

4.2.2 Identification of Process Areas with High Hazards

It is impractical to plan for all emergencies, therefore, it is necessary to analyze and prioritize the scenarios. The results of examination of the plant with these techniques lead to a list of ranked areas that are analyzed to identify credible scenarios. However, the results of the analysis may vary if the analysis does not consider protection system failure. Only eight (8), i.e. 67% of the plants took into consideration failure of protection systems in the process of ranking scenarios for emergency planning.

4.2.3 Techniques for Identification of Credible Scenarios

As with identification of areas with major hazards, variety of techniques is available to identify credible scenarios. The depth of analysis can vary from an informal review that involves intuition to a full Process Hazard Analysis session. The majority of the facilities used PHA results for the process of identifying credible scenarios. As demonstrated in Figure 4-21, 42% of the plants conducted quantitative risk analysis, while 8.3% used unstructured expert brainstorming. 42% conducted investigation of the Process Hazard Analysis to identify credible incidents, while the remaining 8.3% use other methods.

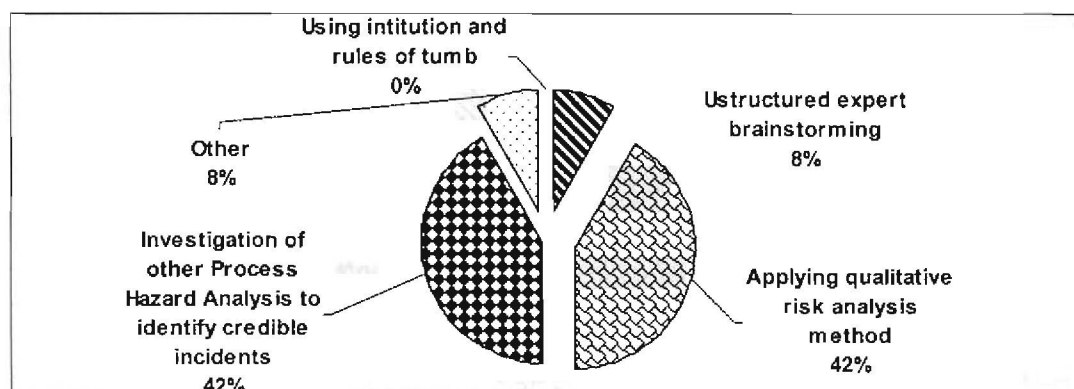


Figure 4-21: Techniques for the identification of credible incident

Consequence analysis is a thorough procedure that requires major efforts; thus commercial software is often necessary to achieve this goal. The survey reveals that currently none of the plants are using tailored software for consequence analysis. However, 18.2% are using simple calculations to assess the consequences of the various scenarios. 55% use home-made software (see Figure 4-22 below). Long-term as well as short-term effects on the environment are being considered in the plans of 91.7% of the plants.

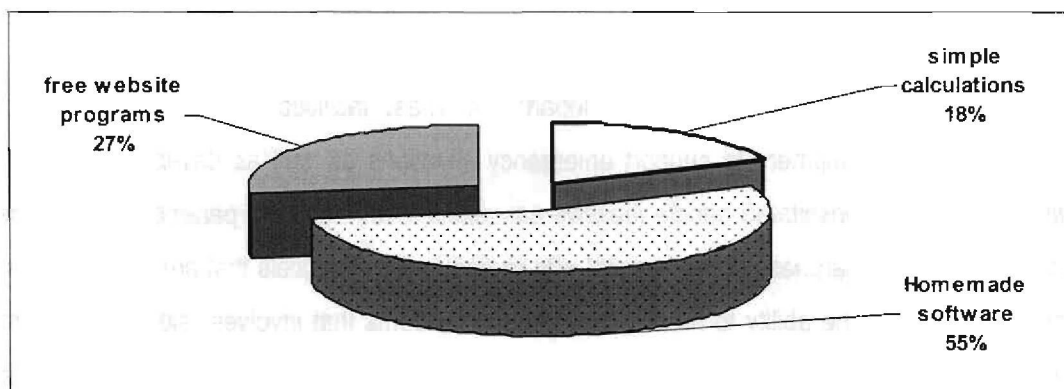


Figure 4-22: Method of incidence consequence analysis

4.2.4 Emergency Support Facilities

The magnitude of incident that the credible scenarios will cause is the input to the process of assessment of resources and capabilities.

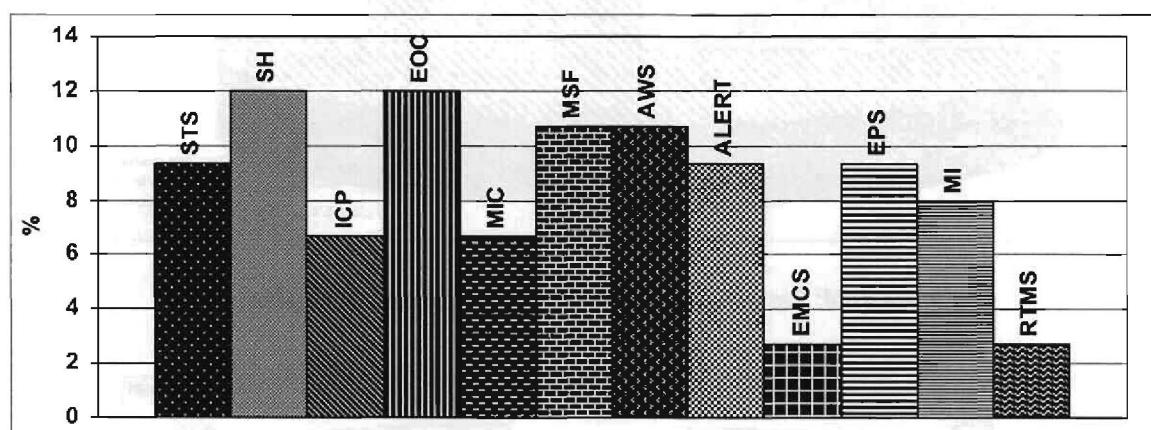


Figure 4-23: Availability of emergency support facilities

Figure 4-23 above demonstrates the level of availability of these facilities among the plants. Safe havens (SH) and emergency operation centre (EOC) are each available at 12.0% of the plants. Short-term shelter (STS) is available at 9.3% and alternative water supply (AWS) and medical support facility (MSF) (other than the first aid room), each of which are available at 10.7% of the plants. Community and facility alerting systems (ALERT) and incident command post (ICP) are available at 9.3% and 6.7% of the sampled plants respectively.

4.2.5 Medical Facilities

Ten (10) plants have capabilities of a medical department. These facilities consist of medical doctors, nurses, and variety of equipment to support emergency situations as well as day-to-day needs. The capability of the nearest hospital to handle massive casualties is an important parameter in emergency planning. Furthermore, awareness of the hospital with regard to the chemicals that are being used in the plant could be crucial to the ability to handle casualties in incidents that involves release of hazardous materials (Keren, 2003). 75% of the plants indicated that hospitals in their area could handle massive casualties (see Figure 4-24). As shown in Figure 4-25, hospitals nearest to 10% of the plants were aware of the chemicals in the facilities, hospital near 50% of the plants had no idea of the chemicals in the facility and hospitals near the other 40% have a general idea only.

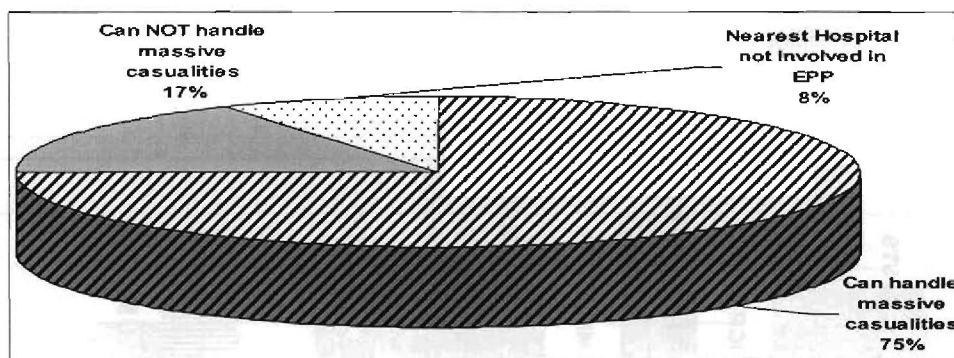


Figure 4-24: Causality capacity of hospitals nearest to plants

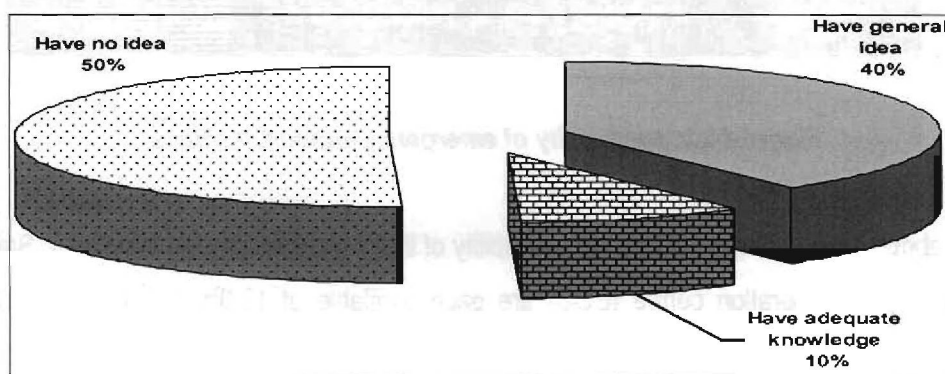


Figure 4-25: Nearest hospital awareness of plants process chemicals

However, 83.3% of the plants increased their emergency net to medical facilities other than the nearest one. In 83.3% of the plants investigated, local emergency agencies were familiar with the plant layout and hazards, out of which 36.6% indicated that neighbouring sites were aware of and prepared for their facility emergencies.

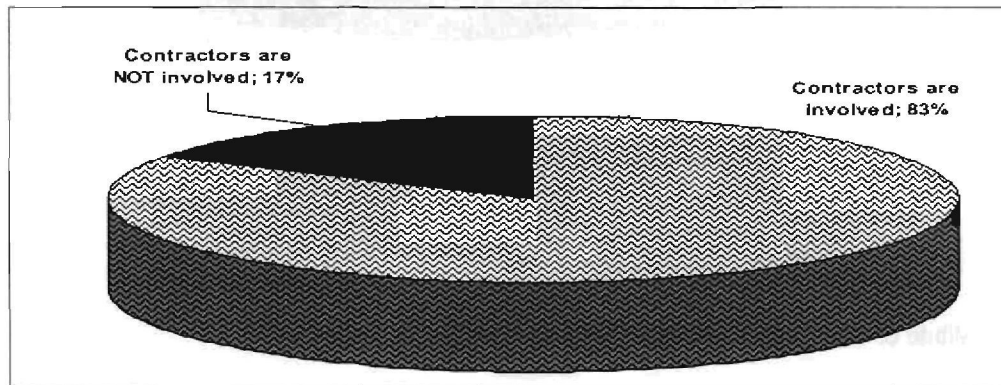


Figure 4-26: Contractors' involvement in EPP

36.4% recorded that SHE officers coordinated the emergency preparedness and responses, while other had corporate committee established and mutual periodical drills operated. Figure 4-26 shows that 83% of the facilities included their contractors as part of plant emergency response program out of which 66.7% of the contractors were trained on their jobs. Management of change procedure addressed changes to emergency program in 66.7% of the plant and personnel structure changes did not cause emergency program re-evaluation in 58.3% of the plants.

4.2.6 Fire Fighting

On-site fire brigade were available at 75% of the plants, and their fire fighters were available outside of daytime shift (see figure 4-27). Local community fire brigades participated in site drills of 33.3% of the plants. Only 40% of the plants had some form of mutual assistance and equipment sharing, shared equipment include: fire trucks, airlifted fire fighters, fire fighter helicopters, fire foam tankers, etc. However, some of the plants had equipment with at least a single fire truck. One of the plants noted that all their equipment were listed on a master database.

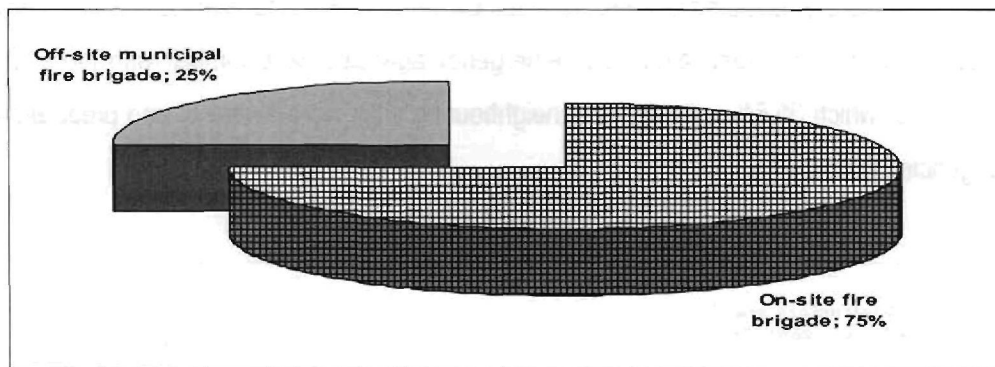


Figure 4-27: Fire fight teams availability

4.2.7 Physical Facilities and Systems

American Institute of Chemical Engineers (1995) defines the following:

- "Shelters - provide passive protection for inhabitants when ventilation is off and all windows and other openings are closed".
- "Safe havens – Provide protection by providing alternative source of breathing air supply".

Control rooms can be used as shelters or safe havens. Control rooms were used as shelters at 35% of the plants without any safe haven. At 45% of the plants control rooms were used as safe havens in emergencies, and in the remaining 22%, control rooms were shelters with other facilities serving as safe haven (see Figure 4-28).

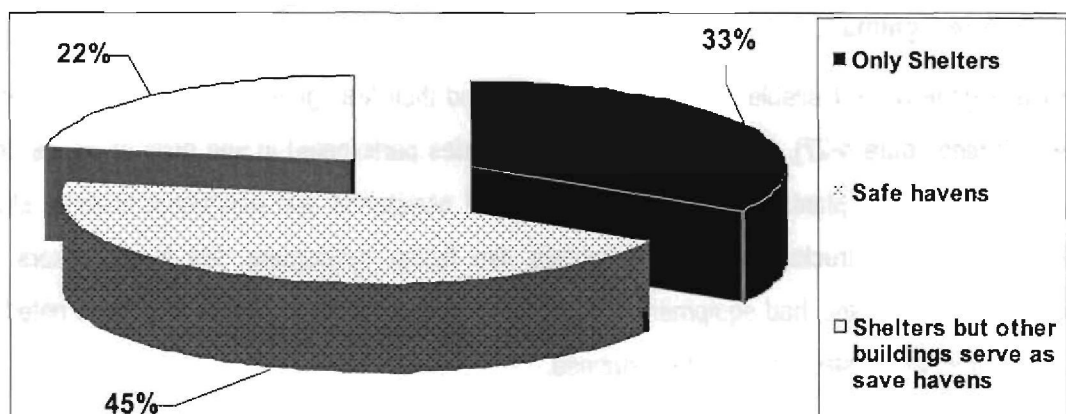


Figure 4-28: Use of control rooms as emergency gathering points

The Emergency Operation Centre (EOC) allows the emergency management and staff to effectively supervise the activities and to make decisions with regard to development of events in the area. Factors such as the facility that is being used as EOC, distance of the EOC from processes, and the design of EOC have an enormous effect on the effectiveness of emergency operation and management. Control room, arbitrary office/room, conference room, and other specially designed building can be used as EOCs. Specially designed buildings were being used by 60% of the plants as EOC. 20% were using conference room, while in the remaining 20% control room served as EOC. Seventy percent of the plants reported having an alternative EOC. Two of the plants indicated that the alternative EOC was located at a distance of about 50metres from the nearest process, three of the plants had their EOC located between 50-100metres from the nearest process, and the remaining plant had their EOC located at 100-300metres from the nearest process.

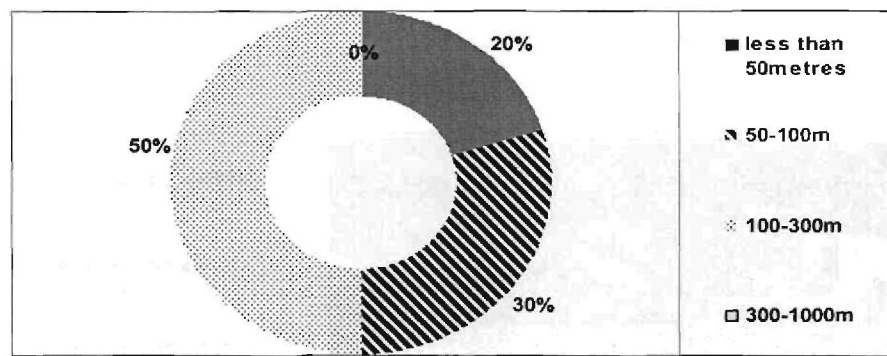


Figure 4-29: Variation in distances of alternative EOCs from nearest process unit

In four of the plants 1-10 employees could be accommodated in the EOC during emergency, in three other 10-20 employees, two plants 20-50 employees, while the rest of the plants could absorb a higher number of employees. The EOCs were designed as shelters at 40% of the plants and as safe havens in the others. The distance between the EOC and the processes is one of the factors that determine the EOC sensitivity to the intensity of the events. Figure 4-29 shows the range of distances of EOCs from the nearest process in the plant. Alternative power supply is crucial in emergencies, 50% of the plants reported a lack of alternative power supply for their EOC.

4.2.8 Communication

An effective communication net is essential for communication between the following: EOC and on-site responders, EOC and off-site responders, EOC and local agencies, EOC and corporate management,

EOC and local medical facilities, EOC and employees, Incident Commander and responders, EOC and employees' families, and EOC and media. A convenient way to maintain communication is by maintaining an open channel between the local off-site agencies and the plant, as indicated by 50% of the respondents. The majority of the plants coordinated and communicated their emergency planning with the Fire department officers, 20% the plants coordinated and communicated their emergency planning with the Emergency Management Agency, and 10% of the plants involved the Municipal Emergency Service Directors in their plans.

Tone alert system was available at 80% of the Plants. Tone alert system codes vary, but some respondents had reported: fire and gas alarms. Local communities could be informed about emergency situations via tone alert systems in 70% of the plants and computerized telephone dialling systems were used by 10%. Cable TV override system was not being used by any of the plants. This fact is graphically represented in Figure 4-30 below.

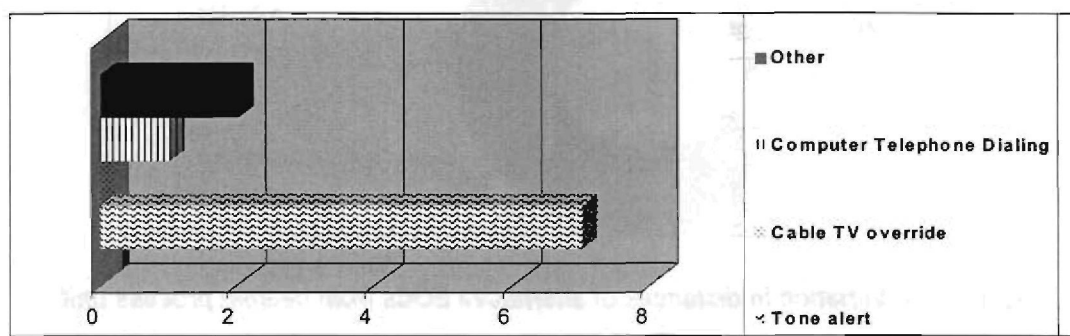


Figure 4-30: Community emergency alerting system

The local authority was identified as another way to communicate the emergency to the local community by 20% of the plants. Common to these plants is that this type of alerting system was the only measure to warn the community a developing emergency event. On-site alarm system was tested weekly by majority of the plants. Off-site alarm systems were tested weekly by 10% and monthly by 30%, and annually by one of the plants. 10% tested their off-site alert system every six months. The other 30% did not test the alert system or an off-site alert system was not part of their emergency system. An emergency program may be supported by variety of organisations.

Figure 4-31 illustrates the level of involvement of these organisations in emergency planning among the plants. As can be expected, emergency medical centre support most of the programs. 5.4% of the plants

involved the Local Emergency Planning Committees (LEPCs) in their Plans, 18.9% involved Red cross, 21.6% involved Public and private hospitals, 2.7% involved Highway department, 13.5% involved Department of health, 2.7% involved civil defence agency, 5.4% involved emergency preparedness organisation, while remaining 5.4% involved office of emergency service in their plans.

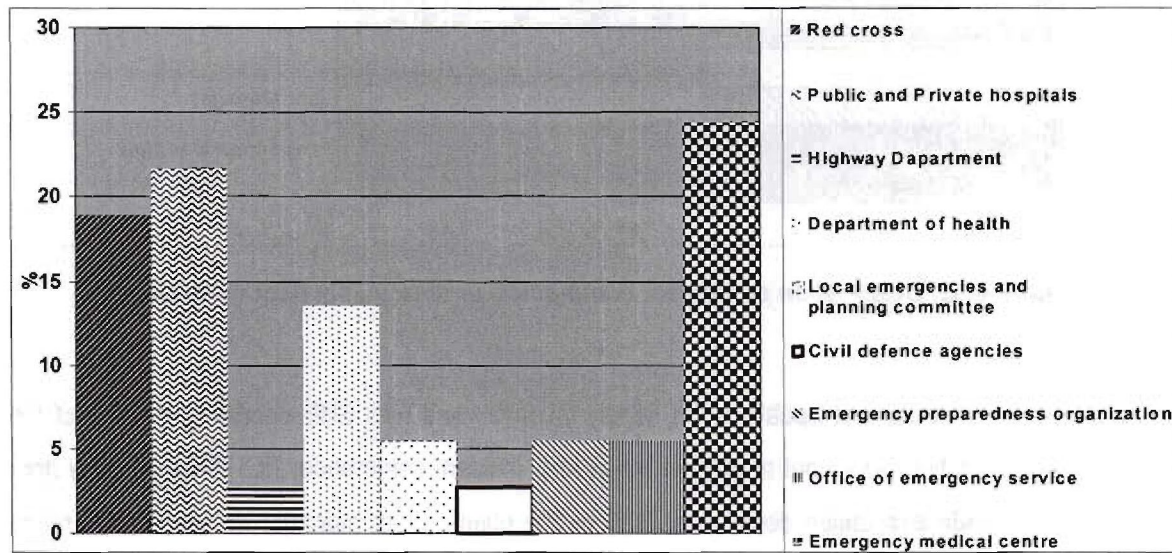


Figure 4-31: Agencies used to support emergency operation

4.2.9 Metrics

Only 80% of the plants had developed procedures to measure the effectiveness of their emergency program. The procedure was being used to measure the adequacy of existing emergency facilities, supplies, and equipment in 90% of these plants. Moreover, at 60% of the plants, the procedure examines the effectiveness of coordination with off-site emergency response agencies. 50% of these plants had their metric system developed by own staff, while 40% adapted from other sources and these methods does not apply to 10%.

4.2.10 Positions

Four (40%) plants used relevant production manager, two (20%) plants used SHE officer while the rest used relevant plant manager as Incident Commander (IC) during an emergency (see Figure 4-32). Determination of the severity of an event, decision with regard to the level of escalation, and timing of this decision has tremendous effect on the consequences. Therefore, the personnel assigned to make this decision carry a heavy burden. At 60% of the plants, SHE officer was responsible for this decision.

Production officers were responsible for this decision at the other 10%. At 30% of the plants the decision on evacuation was in the hands of the Incident Commander.

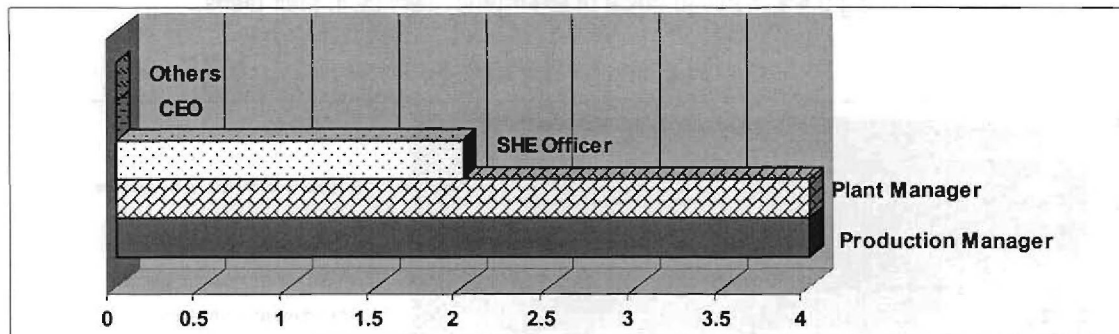


Figure 4-32: Designation of incident commander or emergency floor controller

The responsibility of equipment updating and supply inventory lied with SHE personnel at 50% of the plants and with operation personnel at 50% of the plants. Incident commander (IC) or Emergency floor controller (EFC) made evacuation decision at 80% of the plants, plant manager or SHE officer made evacuation decision at 10% of the plants.

4.2.11 Training on Emergency Preparedness

Employees are required to be trained for emergency awareness and response, regardless of their responsibilities during emergencies. The survey reveals that contract employees were provided the same training as other employees at 60% of the plants only.

The responsibility to coordinate training for emergency preparedness was mainly in the hands of SHE officers in 60% of the plants, at 30% of the plants the human resources was responsible while in the remaining 10% the PSM team was responsible for coordinating training for emergency preparedness. As for training records, only one of the plants reported that these records were not kept. 50% of the plants simulated crisis communication in their drills. Figure 4-33 shows the variation of the training subjects.

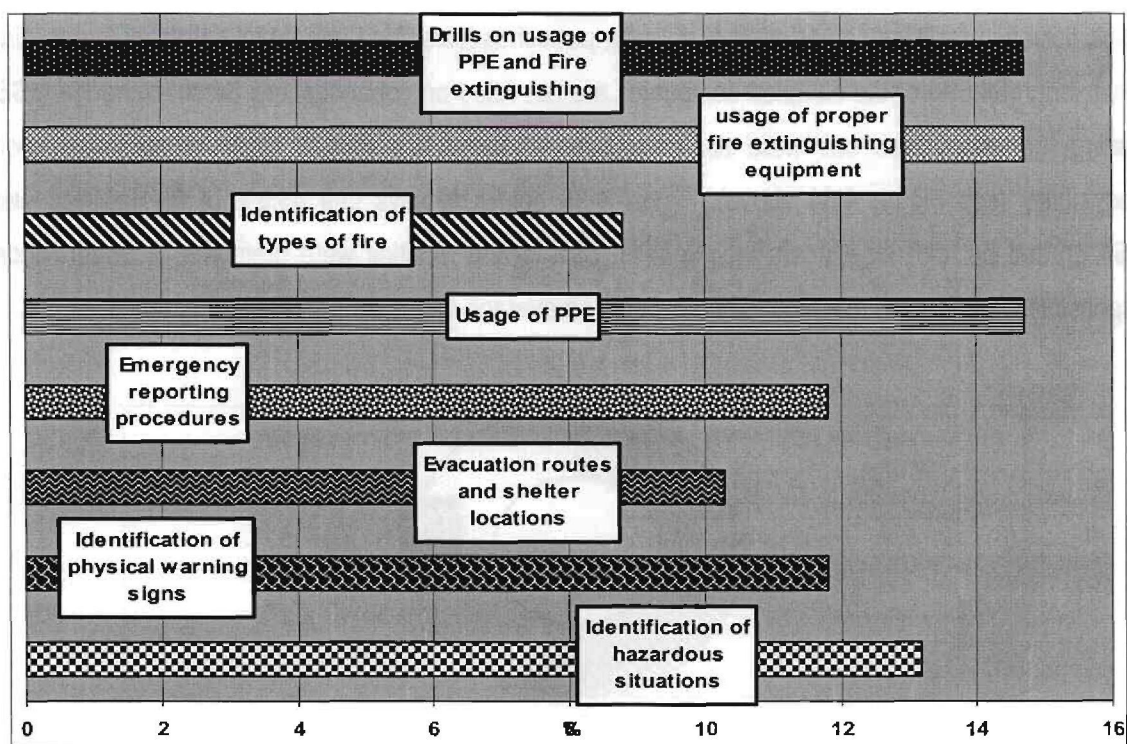


Figure 4-33: EPP training subjects and their implementation distribution among plants

4.3 Benchmarking of Process Safety Incident Investigation

The PSII questionnaires were prepared and distributed to more than 150 plants, out of which 13 facilities responded. The plants surveyed had 37 to 4500 employees. The facilities had an average of six (6) separate process modules; with minimum and maximum of one (1) and thirteen (13) processes respectively.

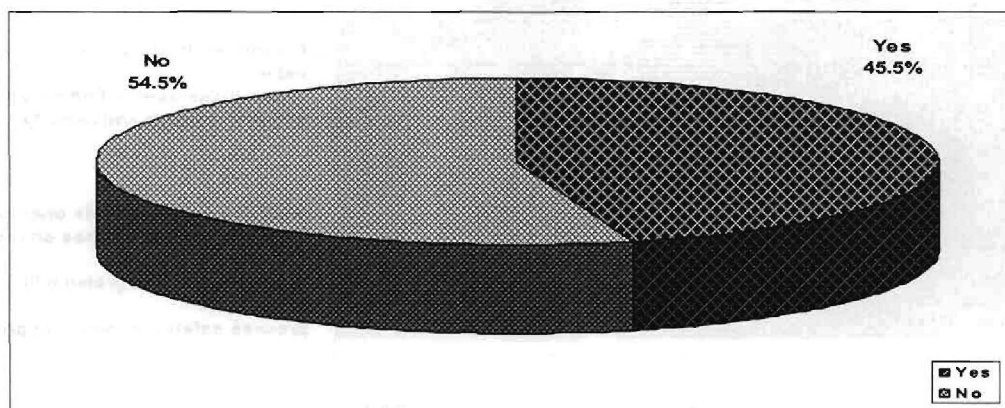


Figure 4-34: Percentage of JSE listed plants

The participating facilities consisted of chemicals, petrochemicals, food and metal extraction/processing. The majority (54.5%) of the sampled companies are not listed on Johannesburg Stock exchange (JSE), meaning that more than half were not subscribed to the JSE's King II Code of corporate social responsibility (see Figure 4-34 above). Figure 4-35 below displays that 45,5% of the facilities were NOSA-graded but did not indicate their grades. 55% of the facilities were members of South African Responsible Care™. With this profile, one expects an average degree of process safety practice.

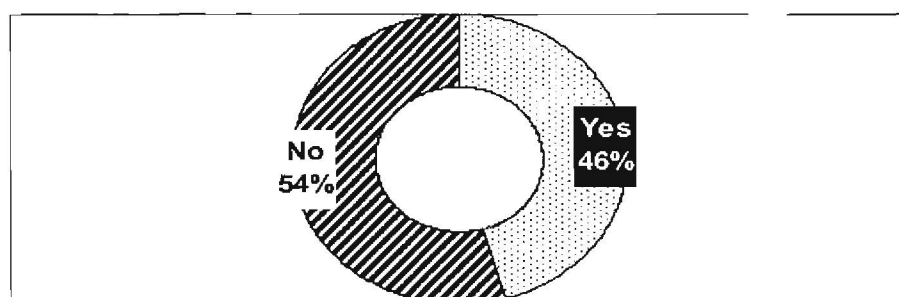


Figure 4-35: NOSA-graded Plants

4.3.1 PSII: Approach and Techniques

The most popular approach to PSII (used in 46% of sampled plants) was committee-based investigation using expert judgement to find credible solution of cause and remedy.

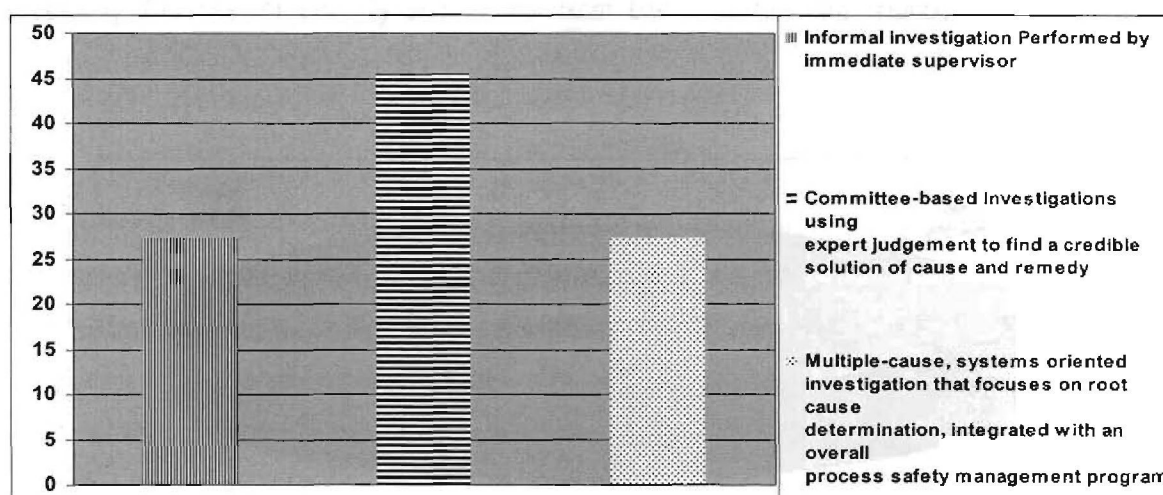


Figure 4-36 General approach to PSII techniques

Few (27%) participating facilities adopted multiple-cause system-oriented investigation approach. The rest still practised informal incident investigation conducted most times by the shift supervisors. This fact is displayed in Figure 4-36. As shown in Figure 4-37, in 70% of the plants, PSII techniques were deductive while inductive techniques were used in few plants (20%).

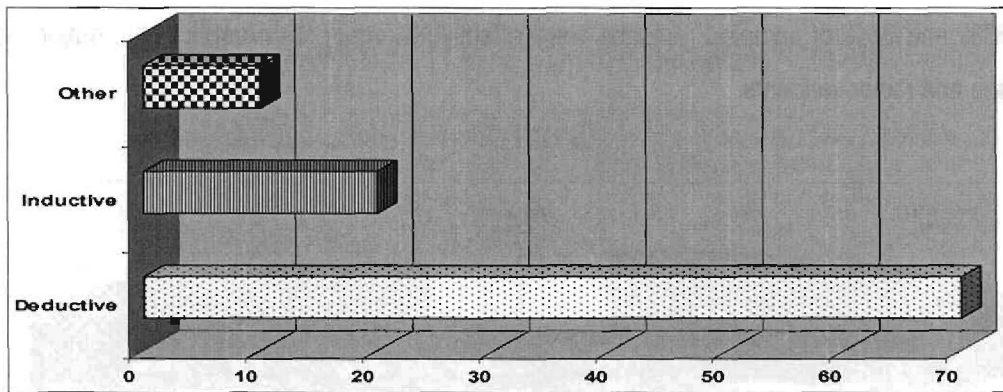


Figure 4-37: Description of Analytical PSII Techniques

Although, there is no uniformity, Hazard and Operability (HAZOP) analysis (20%) and Fault Tree Analysis (FTA) (20%) were the commonest techniques used in sampled plants.

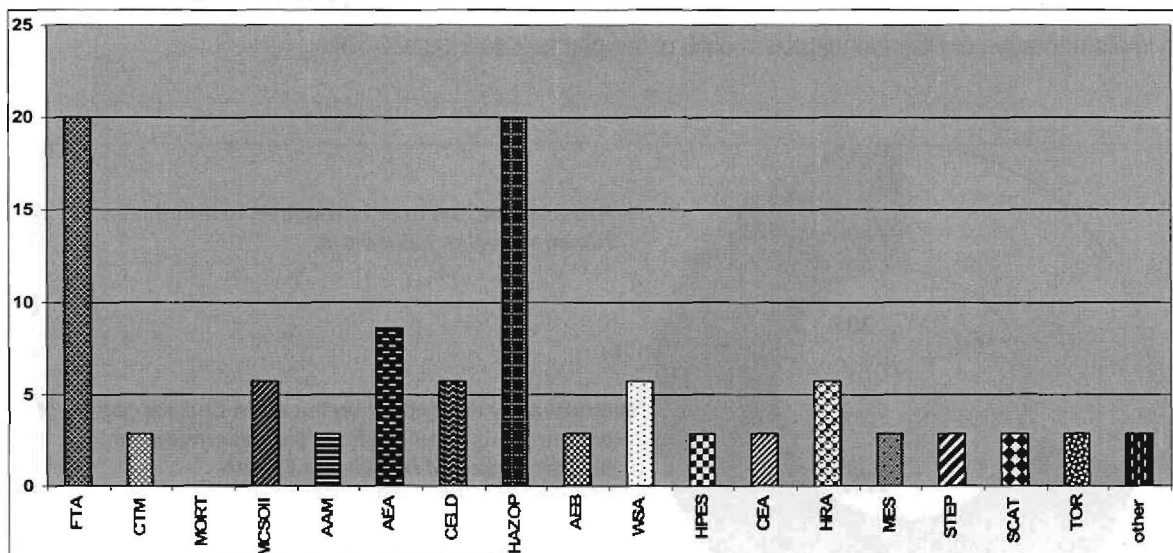


Figure 4-38: Variation in PSII techniques

Action Error Analysis (AEA) was the next popular techniques (used in 9% of plants) while the rest adopted various other techniques such as: Causal Tree Method (CTM), Multiple-cause System-oriented

Incident Investigation Technique (MCSOII), Accident Anatomy Method (AAM), Action Error Analysis (AEA), Cause-Effect Logic Diagram (CELD), Hazard and Operability Analysis (HAZOP), Accident Evolution and Barrier (AEB), Work Safety Analysis (WSA), Human Performance Enhancement System (HPES), Change Evaluation/Analysis (CEA), etc, (see Figure 4-38). Due to the complexity of these techniques, most plants (70%) adopt computer in the implementation of the techniques. PSII techniques in 37%, 33% and 30% of sampled factories were effective in supporting respectively: major incidents, near-misses and minor incidents.

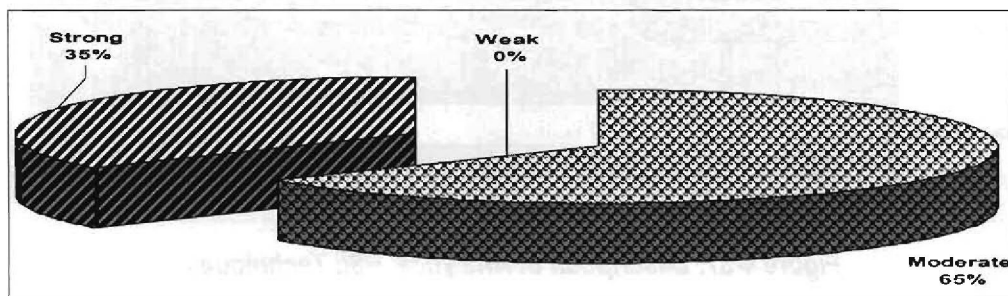


Figure 4-39: Acknowledging standards and guidelines in PSII implementation

More than half (64%) of the respondents indicated that their plants moderately acknowledged standards and guidelines in their implementation of PSII techniques. Standards and guidelines had strong influence on implementation of PSII techniques in 35% of the plants (see Figure 4-39).

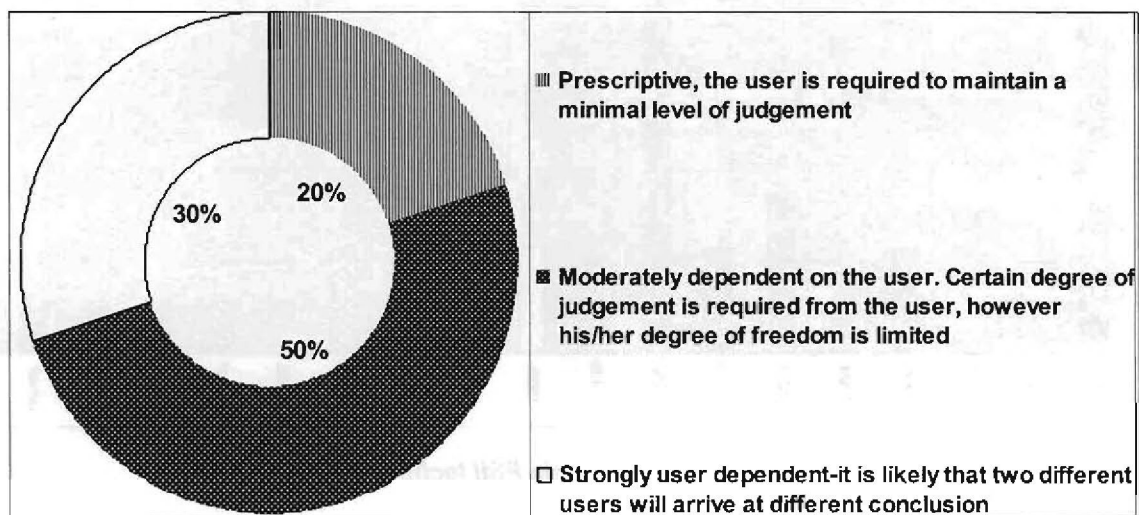


Figure 4-40: Influence of user's judgement

Represented in Figure 4-40 is the influence of user's judgement on PSII techniques which was moderately allowed by half of the participating plants; strongly accommodated in 30% while 20% used prescriptive techniques which reduce the user's judgement to the minimal level.

4.3.2 Incident Databases

Incident related databases could be helpful in learning from the experience of others, sharing information with others, and identifying areas of weaknesses, benchmarking performance, and more. All but one sampled plants (90%) kept record of equipment reliability performance and the same percentage maintained a central equipment reliability database for the record. Many plants (70%) indicated that they used historical information from incident databases but did not indicate which one.

4.3.3 Management Commitment

All but one plant reported that their PSII implementation focused on finding cause of incidents rather than focusing on assigning blame (Figure 4-41). This is a praiseworthy PSII culture for the fledging South African process industry. Fewer plants (36%) claimed that insufficient resources were committed to incident investigation in their plants. Although, the level of implementation of recommendations from PSII is among the indicators of the commitment of the management system to process safety, only two plants (18%) paid strong attention to the implementation of recommendations from incident investigation. Only some (18.2%) plants exerted high effort on the implementation of recommendations from incident investigation (see Figure 4-42). This phenomenon is detrimental to the growth of PSM in the industry.

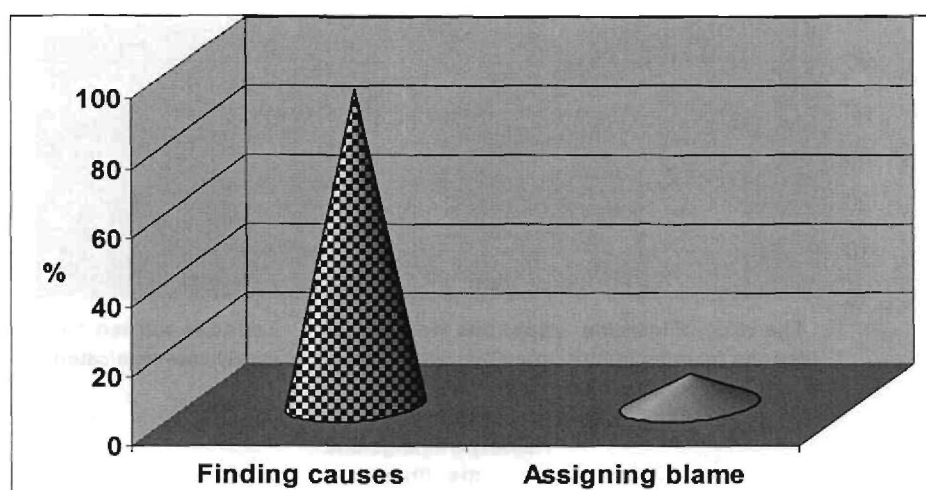


Figure 4-41: Focus of PSII implementation

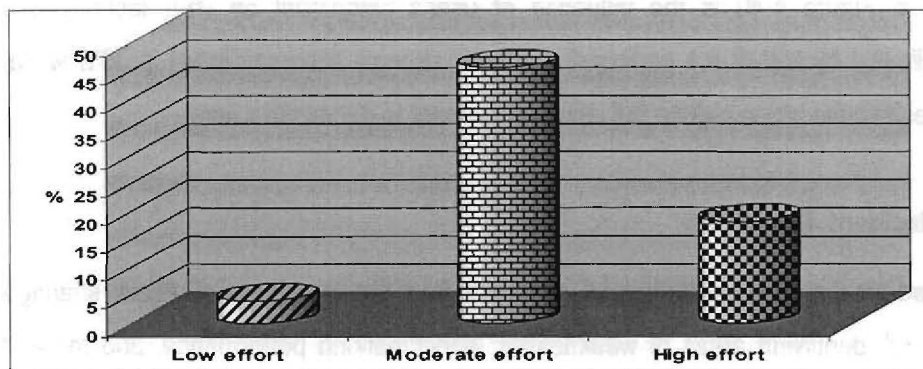


Figure 4-42: Implementation of PSII recommendations

Another indicator of management commitment is the communication of lessons learnt from incidents. Shown in Figure 4-43 is the variation in the communication of lessons learnt. More than half (55%) of the plants communicated lessons learnt in formal occasions such as safety training while another 27% indicated strong management commitment on learning from incidents. Lessons learnt from incidents were rarely communicated in 18% of the sampled plants. Near-misses were precursors of accidents and as such it was a good practice to investigate them. Near-misses were investigated in 64% of participating plants; out of which 67% investigated all near-misses to a varying extent. Although more plants (64%) encouraged incidents and near-misses reporting, only one facility (11%) investigated near-misses to the same extent as for major incidents. More than half of the plants indicated that periodic publications were used to communicate lessons learnt from investigations. No other means of communicating lessons learnt was described by the respondents.

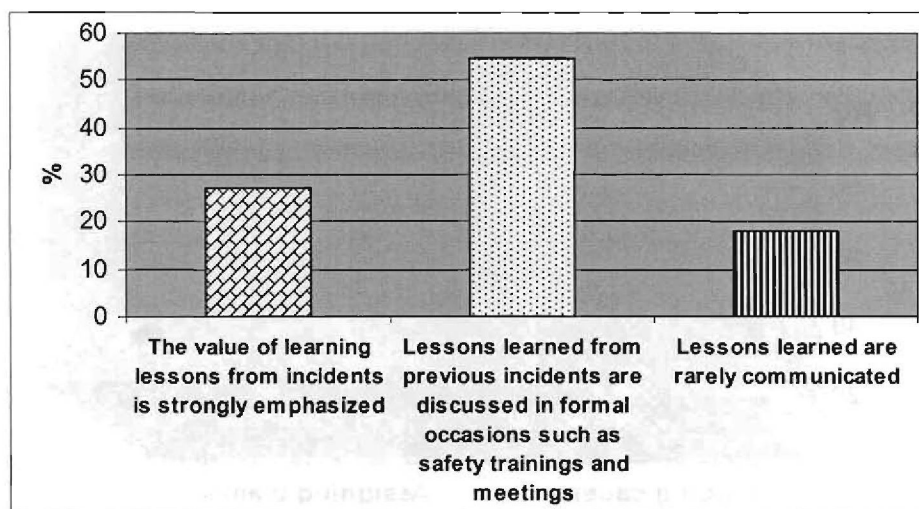


Figure 4-43: Communication of lessons learnt from PSII

4.3.4 PSII Objectives, Investigation Team and PSII Training

The extent of incidents and near-misses varies, and affects the need, size and structure of the investigation team. No response was returned for the method used by facilities to classify near-misses and other incidents. South Africa OHS Act 85 of 1993 requires that *“every incident which must be recorded in terms of sub-regulation (1) ... be investigated by the employer, a person appointed by him or her, by a health and safety representative or a member of a health and safety committee within 7 days from the date of the incident and finalized as soon as is reasonably practicable, or within the contracted period in the case of contracted workers.”* Off-site staff were included in investigation teams in most plants (82%) while 64% plants permitted local community and regulatory agencies representation in the investigations of near-misses and incidents that might effect the population in this community.

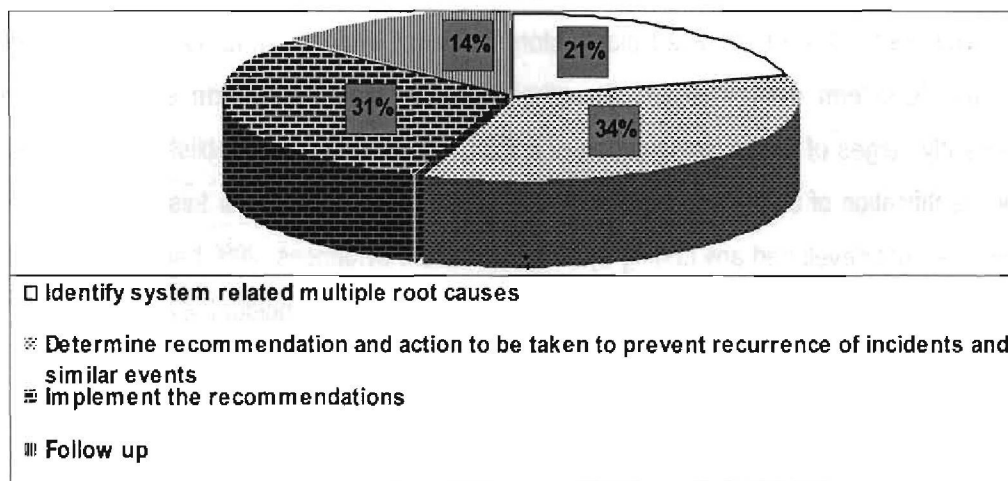


Figure 4-44: Objectives of PSII Implementation

As displayed above in Figure 4-44, there is no consistence in the major objectives of PSII. However, 34% of plants conducted PSII to determine recommendations and actions to be taken to prevent recurrence of incidents and similar events, while 31% carried out PSII so as to implement the consequent recommendations. Another 21% used PSII outcomes to identify system-related multiple root causes. PSII is a thorough procedure that requires competent personnel, so training is essential. In majority (70%) of the facilities, training and refresher training was conducted on a regular basis for: mid-level management in most plants (71.4%); and first-line supervisors in the rest (see Figure 4-45). No response was received on who leads the investigation teams. Furthermore, all but two plants (80%) included recommendations on disciplinary actions in the mandate of the incident investigation teams.

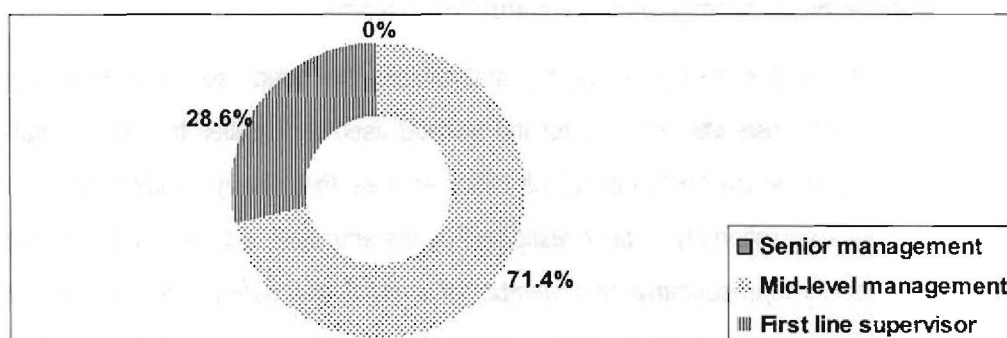


Figure 4-45: PSII training groups

4.3.6 Evidence

Long-term and short-term incident evidences are kept for regulatory compliance and are also necessary for PSII improvement. 60% of surveyed plants stores incident evidence; one half of which stored both short-term and long-term evidences and the other half only stored long-term evidences if required. Among the early stages of the implementation of a PSII procedure is the establishment of a protocol of systematic identification of all the expected evidence, and a coding system for this evidence. Half of the respondents had not developed any coding system for incident evidences. 20% had developed protocols for identifying evidence while another 20% had coding system for incident evidences. This fact is illustrated in Figure 4-46.

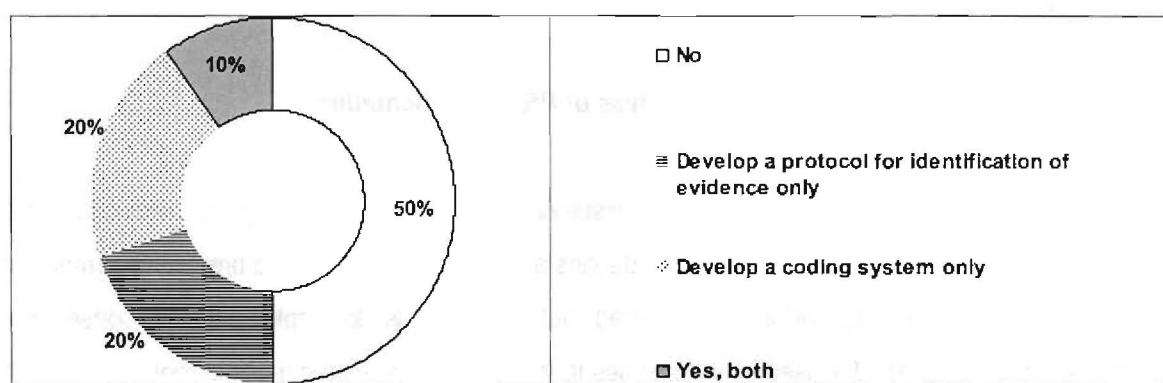


Figure 4-46: Usage of Protocol and Coding System for PSII Evidences

Document control is the backbone of evidence handling and must be done in systematic way. 8 (80%) of the 10 participating facilities had document control procedure embedded in their PSII system. Size and scope of investigation however, mandated the extent of document control in more than half (57%) of the

plants. Simulations and re-creations of events in cases of gaps or contradictions were used for PSII in only 40% of the plants; even though it assists in drawing lessons from incidents and the consequent necessary improvement of PSM practice.

4.3.7 Recommendations from Incident Investigation

Among the recommendations required of PSII teams in 67% of sampled plants was establishing criteria for restart and operations following an incident investigation. In all the plants, PSII procedure called for improvement that aims for inherently safe design; and the regulatory agencies have jurisdiction and authority over restarts following incidents. This is possibly in compliance with OHS Act provision that

"n the event of an incident in which a person died, or was injured to such an extent that he is likely to die, or suffered the loss of a limb or part of a limb, no person shall without the consent of an inspector disturb the site at which the incident occurred or remove any article or substance involved in the incident therefrom: Provided that such action may be taken as is necessary to prevent a further incident, to remove the injured or dead, or to rescue persons from danger."

It was a prevalent practice (in 80% of plants) to have a session between the PSII team and area management responsible for the operation of the line that experienced the incident. The session was used to present and review the recommendations from the PSII exercise. It is beneficial to review emergency plan in the light of PSII findings, as the PSII reveals the weaknesses in a factory emergency plan. Thus, 60% of the plants directed their PSSI exercise towards a validation of their emergency plan. Incident classification is a prevalent practice among process plants worldwide.

Table 4-1: Incidents categorization by various plants

Plant	Categorization
A	✓ Minor Incidents ✓ Major Incidents ✓ Catastrophic Incidents
B	✓ Catastrophic Incidents ✓ Significant Incidents ✓ Major Incidents ✓ Minor Incidents ✓ Near Miss
C	✓ Fatal Incidents ✓ Serious Incidents ✓ Light Incidents

The categorization however differs. This survey reveals categorization used by the partaking facilities and this is presented in Table 4-1. One plant reported that it adopted DOW™ classification system.

4.3.8 PSII Metrics

For effectiveness and improvement purposes, PSII performance should be measured as an element of a plant PSM system. It is a preponderant practice (60%) among the sampled plants to measure the effectiveness of their PSII system. Out of this 60%, half used a home-made PSII metrics while the other half outsourced their metric system.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

In chapter one, a background to the study was presented along with the statement of the research problem. The specific objectives of the study were enumerated along with justification and motivation for this study. The scope of the study was discussed and limitations encountered during the research exercise were documented. In the final section of the chapter, a list was made of conceptual definition of terms.

A thorough review of relevant literature was conducted in chapter two of this dissertation. The researcher traced the origin and time-space evolution of safety management, safety regulations, and safety organisation. Process safety management was defined and conceptualized in the chapter. OSHA PSM standard was analysed and its 14 PSM elements were itemised. Each element was discussed and measurable parameters were identified for benchmarking purpose. PSM requirements in other guidelines and handbooks were also developed into sub-elements under the OSHA PSM elements. Sections in the chapter were devoted to the review of available international safety regulations and guidelines.

Safety regulations in South Africa were examined with the objective of identifying legal provisions that are relevant to industrial and especially process safety management. In a particular section safety management was conceptualized and different approaches to safety management were analysed. International safety standards were also reviewed and a mention was made of the common elements or variables of OHSMS. An exposition was done of occupational accidents and injuries and their economic impacts with particular reference to the South African process industry. A literary tour of the South African process and chemical industry was conducted. The chapter also focused attention on measurement and benchmarking of PSM performance. Earlier in the chapter an attempt was made to describe the concept of benchmarking.

Chapter three documents the methodology of the empirical investigation. Light was thrown on the survey target. Sampling procedure and the research instruments were explained in details. Questionnaire design process was demonstrated and the benchmarking parameters were developed using the Keren's (2003)

model. The validation procedure and the data gathering process were described in the chapter. Tool used for the data analysis was also discussed.

Documented in chapter four are the findings and results from the research surveys. Interpretations were given to the findings. Charts and graphs were used to present the survey findings. Tabulations were sometimes used to illustrate the findings.

Chapter five summarises the previous chapters. Conclusions drawn from the analysis of the surveys are documented in this chapter. Recommendations are made for future policy development and for further studies.

5.2 Conclusions

OSHA PSM is a comprehensive standard. The compartmentalization of the PSM requirements in the standard (into elements) creates an opportunity to develop measurement models for each of the elements separately. The performance-based nature of the MOC element is apparent from a reading of the regulatory requirements. Practices of OSHA PSM elements often vary and there is a need to *determine an industrial consensus or Recognized and Generally Accepted Good Engineering Practices (RAGAGEP)*.

The objective of this study was to benchmark the practice of three PSM elements among the South African process industry. Generally, this survey reveals a wide variance in the practice of the three surveyed PSM elements among the South African process industry. Juxtaposed against Keren's (2003) findings about the US process industry, the South African process industry PSM performance is expectedly some degrees lower than international benchmarks. Nonetheless, there is a positive attitude to process safety management among the sampled facilities. Conclusions reached from the survey findings are presented in the coming sections.

5.2.1 Benchmarking of Management of Change (MOC)

Majority of the sampled facilities has an average level of MOC performance. This might not be unconnected with the companies' subscription to Responsible Care™ and the NOSA grading system. Implementation of MOC is predominantly plant-wide without discrimination between covered or non-covered areas. This is an indication of good MOC application in that the industry practice is better than

required. Perhaps due to the nascent nature of PSM practice in South African industry, MOC policies are outsourced by most plants. It is hoped that PSM experts will abound in couple of years.

South African process industry is old with a vast number of maintenance and modification works being done annually. However, documentation of maintenance activities as regards to safety management is still far from being mature. Distinguishing between emergency and temporary MOCs seems ambiguous to significant number of safety practitioners in the industry. Otherwise, one wonders why a company that issued a vast number of MWOs would not have a single emergency MOC. Although there is great room for improvement on MOC documentation, the survey reveals a functioning system for initiation, authorization, post-mortem assessment, and recording of MOC activities.

Furthermore, MOC auditing is preponderantly done by external consultants who most times recommend upgrading of the MOC programs. There is a prevailing low confidence in MOC software; as a result most facilities still use homemade tools. Awareness training on MOC is still in embryonic stage in most facilities judging from the scant resources committed to it. In majority of plants, risk management plan is updated following modification and there is a structure in place to verify changes that require MOC including DCS software changes. PHA revalidation after critical MOCs is a commonplace practice. Another widespread practice is that quality and environmental personnel are consulted during MOC implementation. There is a working procedure for risk screening with corresponding safety review either by staff or by consultants.

MOC authorization is formalized industry-wide with little consistence in number of authorizations required for implementation. Training on MOC is still handled by human resources training department – another confirmation of the evolving nature of MOC practice in the industry. For a mature PSM system, training is usually conducted by the MOC coordination department or by the SHE department with dedicated resources and budgetary allocation.

The South African process industry is deficient in measuring the performance of MOC programs, although MOC execution is rightly ended by PSSR. Organizational change may be critical to a process safety especially when experienced personnel depart a facility resulting in partial loss of “company safety memory”. This factor is downplayed by South African process industry, as most MOC programs have not integrated it into their PSM systems.

5.2.2 Benchmarking of Emergency Preparedness Programs (EPP)

A popular EPP culture in the South African process industry is the consideration of the worst case scenario and strong recognition of possible failures of protection systems. Process Hazards Analysis, PHA is used by most plants for the identification of credible emergency scenarios. Risk consequence analysis is a cardinal feature of EPP among the industry and this is achieved often times with homemade software.

The inventory level of emergency support facilities available to the facilities shows a dreadful EPP resource capability. Community alerting systems and emergency utility supplies are under-developed. Occupational medical centres are provided in many facilities in addition to including near hospitals in their EPP net. More needs to be done on acquainting the nearest medical facilities with the chemicals used in the factories. Relationship between the local community emergency agencies and the process plants seems satisfactory while EPP coordination between neighbouring sites needs major improvement.

Staff and contractors alike, are properly trained in plants emergency procedures and MOC procedure is generally applied to changes made to EPP. Operational fire fighting teams which collaborate with the municipal fire fighters are maintained in facilities, and sometimes share resources with neighbouring sites. Control rooms are the popular safe havens and shelters as well as emergency operation centres (EOC) for most plants. This is not a prudent practice except they are specially designed to withstand over-pressures from shockwaves resulting from explosions in the process area. The survey reveals carefully designed and moderate capacity EOCs across the industry with alternative power and utility supplies.

The emergency communication structure can be described to be moderately adequate. Alert and warning systems are maintained on-site and off-site and the emergency planning is communicated with the municipals. Besides hospitals in their emergency network, other groups such as Red Cross, department of health also support the industry emergency response. A general practice in the South African process industry as indicated by the survey is the performance assessment of EPP. The metric systems are either developed locally or are adapted from other sources, and through this, emergency resource capability is evaluated among other things. Emergency evacuation procedures are generally well developed and incident control and line of command are clearly stated.

5.2.3 Benchmarking of Process Safety Incident Investigation (PSII)

Deductive approach is widely adopted for incident investigation with committee-based investigation which relies on expert's judgment. Although this complies with OHS Act 85 of 1993, the approach is not proactive enough to dig out the multiple root causes of incidents. Though no serious consistency in PSII techniques, computerised fault tree analysis (FTA), and hazard and operability (HAZOP) are the commonest techniques used for PSII among the facilities. Nonetheless, the techniques are often times non-prescriptive allowing for user's subjectivity and bias. The industry needs to develop or acquire prescriptive techniques with least tolerance of user's bias. Databases are developed to keep records of incidents which are probably not shared with third parties.

The overall industry management commitment to PSII is lower than expected. Although resources are averagely committed to PSII, its recommendations are rarely implemented and little emphasis is given to communication of lessons learnt from PSII. The industry recognises near-misses as forerunners of major incidents and accordingly investigate them but to a varying extent. This is laudable safety climate. It is customary to constitute the PSII teams with elements of off-site corporate staff. Regulatory body and municipal representations are rare in incident investigation except for fatal incidents or incidents that affect the local community. No uniform PSII objectives can be defined for the entire process industry but a frequent expectation from a PSII exercise is recommendation for disciplinary actions.

A regular PSII training is adopted by most companies but this is often times restricted to middle-level management. Coding of incident evidences is in budding phase across the industry while period of storage of the evidences is inconsistent across the industry. Incident investigation documentation is commendably standardized. However, the PSII practice is not yet exhaustive as the industry has not imbibed the practice of incident events re-creation and simulation. Mandating PSII teams to establish criteria for restart and operations following an incident investigation is another admirable practice. It is also a tradition of the industry to hold a recommendation review session between PSII team and the area management responsible for the operation of the line that experienced the investigated incidents.

Incident categorization is a widespread phenomenon but taxonomy varies across the South African process industry. Just like the industry EPP performance measurement, homemade software is used for the PSII metric system. Juxtaposed against international benchmarks (such as US experience as

revealed by Keren (2003)), the overall rating of the PSM practice among the South African process industry judging from the survey findings is below average.

5.3 South African PSM practice and international standards

In this section, a comparison is made of the PSM practice among the South African process industry (as revealed by this study) with some international standards. The industry practice is compared with the relevant codes and recommendations contained in CCPS' PSM guidelines (AIChE, 1989), API recommended practice (API, 2004), CMA's process safety code and the OSHA PSM standard. Tables 5-1, 5-2 and 5-3 below summarize the comparison exercise.

Table 5-1: South African MOC practice versus international standards

MOC Sub-elements	International Benchmarks	South African Industry Practice	Comments and Recommendations
Scope of MOC application	OSHA standard entails application of PSM to "covered process areas" only excluding utility, labs, and other associated areas. Other consulted standards seem to present vague positions on whether or not MOC should be implemented in areas not covered by regulation.	MOC is applied plant-wide in most partaking South African process facilities. Steam stations, atmospheric tank farms, labs and waste recycling were all covered by MOC programs	This is a trail-blazing MOC practice which ought to be sustained.
	API wants the development of MOC procedures that are flexible enough as to accommodate both major and minor changes in facilities and personnel.	Nearly all the facilities have written MOC procedures developed locally by either corporate or plant staff.	While the current practice is acceptable, it is recommended that the South African process industry tap from the global PSM experience by engaging local consultants and international experts in developing MOC procedures. Involvement of plant staff should also be encouraged
Policy Development	All the other standards mandate the implementation of MOC programs and procedures in one form or the other.	Local plant staff and consultants are rarely engaged for policy development.	

Documentation and Record Management	OSHA specifies a form or clearance sheet as the least document to facilitate MOC procedure. On record management, nearly all consulted standards are silent on the minimum duration for keeping MOC records. API mandates that any documentation about modified equipment should be kept for minimum of two years. Also no specific storage media is specified nor are the functionalities responsible for keeping MOC files recommended.	Keeping record of Maintenance Work Orders (MWO) and MOC orders initiated is becoming acceptable. A common industry practice is preference not keep records of unapproved MOCs. Another consensus practice in the industry is that the operations department is responsible for keeping of soft and hard copies of MOC records either at the plant central record storage area or within each respective plant area.	Although there is a great room for improvement on MOC documentation, the survey reveals a functioning system for initiation, authorization, and recording of MOC activities. It is here recommended that the industry should adopt the culture of keeping approved and unapproved MOCs for a certain period of time. Something similar to what OHS Act specifies for keeping evidences of incident investigation. This will aid learning from previous initiatives and proposals; thus assists the facilities in making informed decisions about future changes.
	PSM standards encourage a system of initiating MOC but AIChE further recommends that maintenance work orders may be used as a document for initiating MOC. AIChE advises that such work orders may have section to indicate whether or not MOC is necessary.	Industry-wide, nearly all work orders require a corresponding MOC authorization number or explanation; and the engineering departments identify work orders which are NOT replacement -in-kind, and are therefore work that requires an MOC.	This is a superb PSM climate which ought to be sustained with enabling legislations. South African Department of Labour may design sample maintenance work order(s) which will include sections for indicating whether or not the proposed work is NOT a replacement -in-kind
	Consulted standards require procedure for the authorization and approval of change that necessitates MOC. However, all are silent on who should approve what change, and on the minimum number of approvals. A sample change form included in AIChE guidelines suggests multiple approvals and authorizations. Also the relevant clause in the OSHA mentions "authorization requirements" – this again suggests multiple approvals.	The number and levels of authorizations for MOC approval varied widely with MOC risk category.	Another good MOC practice for the industry. Multiple and multidisciplinary authorizations should be sustained since informed MOC reviews require experts from diverse fields with different experiences.

MOC Training	OSHA requirement as regards this sub-element is that employees involved in operating a process and maintenance including contract employees whose job tasks will be affected by a change in the process shall be informed of, and trained in, the change prior to start-up of the process or affected part of the process. API, AIChE and CMA have similar requirements	It is generally indicated that the training department is responsible for conducting training regarding the impact of the MOC, via formal training classes, and at other occasions, such as informal toolbox safety meetings and on-the-job training.	Training in PSM practice involves imparting specialized skills, it will be better if the safety departments are saddled with the conduct of MOC training. MOC training should be given to all relevant employees and contractor.
	OSHA non-mandatory requirements entail the differentiation of temporary and permanent changes. Also, AIChE distinguishes emergency changes and also specify that MOC procedure be followed for temporary changes with some additional considerations. These considerations include time limits for the change; control step to ensure that all modified equipment and procedures are returned back to their normal mode at the end of the approved time for the change; etc.	A high consistency of auditing of temporary changes, so as to restore them to their previous condition.	Standardization is needed in two areas:
	AIChE guidelines lead other standards to specify that software changes must be subjected to MOC procedures including changes to alarms, DCS graphics, interlock set points and by-passes, etc.	However, there was no consistency as to who or what department was responsible for restoration of temporary changes to previous conditions.	• The department responsible for ensuring the restoration of temporary changes to previous conditions • Time limits for the execution and restoration of temporary changes
	AIChE and API guidelines mandate the application of MOC procedures to organisational changes.	It is a general practice in the industry to document DCS software changes using the MOC procedure.	In computer-controlled process, a slight reckless change in DCS software can be very disastrous, so it is best safety practice to apply MOC procedures.
Organizational Changes	AIChE requires that after personnel changes or re-organisation should be tested for consistency with the operational demands of all different circumstances, including both normal and emergency operations.	The department responsible for the maintenance of documentation for DCS software changes varies from plant to plant.	It may be a good practice if the regulatory agency can specify the department responsible for the documentation
		The findings from the survey show that the South African process industry at the moment does not include management of organisational changes in MOC program.	One can conclude that the present practice is an indication of a growing MOC culture.
It is suggested that process factories should review organisational changes as an integral part of their MOC program.			

SHE Review of MOC	API specifies that MOC procedures identify and control hazards associated with change and maintain the accuracy of safety information.	PHA revalidation after critical MOCs is a commonplace practice. Another widespread practice is that quality and environmental personnel are consulted when implementing MOC.	The industry practice is scored high in MOC safety review considering the survey findings.
	Further, CMA codes require the consideration and mitigation of the potential safety effects of expansions, modifications, and new sites on the community, environment, and employees.	There is a working procedure for risk screening with corresponding safety review either by staff or by consultants. Checklists and staff experience were reported as the most popular evaluation methods for risk screening.	The adoption of other advanced risk and hazard evaluation techniques should be encouraged especially for complex changes. These techniques include: what if, HAZOP, MORT, FTA, etc.
	CMA's Responsible Care® codes entail the safety reviews on all new and modified facilities during design and prior to start-up.	Majority of the respondent indicated that the PSSR program is considered closure of the MOC program.	Good MOC practice. Areas of improvement should be sort.
	According to AIChE, the optimal stage to initiate a safety review is when preliminary engineering design of the change has been completed. CMA Responsible Care® codes demand from its members the measurement of MOC performance.	It is widespread for the engineering, maintenance, or operations department to conduct PSSR. Metric system for examining MOC effectiveness separate from general PSM assessment is non-existent at the moment.	OHS Act regulations should cover this area of PSM and it should compel facilities management to conduct PSSR as necessary. This is an area of serious improvement. Management of process facilities should either develop metric system for measuring MOC performance or outsource this vital control mechanism, as one can not assess what you do not measure.
Pre-Start-up Safety Review (PSSR)			
Metrics			
Audit	PSM audits for compliance and implementation of corrective actions are specified by all the standards. No specific audit is however required for MOC procedures by the standards. AIChE	Independent auditing of MOC programs is not yet a fashionable culture. However the OSHA minimum standard of three years PSM audit is becoming a trend in the industry.	The industry practice meets the requirements of the international standards, although there is always room for improvement.

Table 5-2: South African EPP practice versus international standards

EPP Sub-elements	International Benchmarks	South African Practice	Comments and Recommendations
Identification of Credible Scenarios	AIChE requires that for each possible emergency scenario: the outcomes should be listed, and the consequences and probabilities should be evaluated, while considering the facility's management control.	Majority in the industry considers worst-case scenarios in the development of their emergency plans with significant attention paid to protection system failure.	High level of conformance can be observed from the industry practice.
	AIChE also requires facilities to analyze, rank, and prioritize the possible scenarios with consideration given to failure of protection system. AIChE advise the development of the following physical infrastructure for emergency events:	These plans cover all three levels of magnitudes of events: local, moderate, and catastrophic.	Future South African process safety regulations should require listing, evaluation and ranking of possible emergency scenarios.
Emergency Support Facilities	AIChE advise the development of the following physical infrastructure for emergency events:	Despite scant availability, consideration is rarely given to the designed functions of emergency support facilities and.	The present situation signals low level of emergency preparedness.
	• Development of shelters and safe heavens • Establishment of Emergency Operation Centre (EOC) • Provision of alternative power and water supplies OSHA goes a step further to discourage the use of process control centres or similar process buildings in the process area as safe areas. AIChE requires a facility emergency network to include nearest medical centres besides the occupational health centres run by the plants.	Most emergency support centres lack required infrastructures as control rooms are often upgraded for this purpose. Provision of alternative water and power supplies is not yet fashionable among the industry players Medical centres are established in most facilities and inclusion of nearest hospitals in emergency network is a widespread practice.	The situation should be promptly arrested to fortify preparedness for unforeseeable. Department of Labour can assist the industry in specifying the minimal infrastructures for emergency support centres.
Medical Facilities	CMA advises regular facility tours for offsite emergency responders to promote emergency preparedness and to provide current knowledge of facility chemicals and operations.	No scheduled regular facility tour is evident from this study; however the industry players indicate that the nearest hospitals are familiar with their operations.	Strictly speaking the current practice is acceptable internationally. South African process industry can go further by: • Listing the medical centres on the emergency network and their awareness forums; • Scheduling facility tours by emergency responders.

Fire Fighting Capability Emergency Communication and Control Training on Emergency Preparedness Metrics	The standards require availability of functional fire-fighting teams and operational fire equipment on-site or offsite. Conduct, analysis and critique of drills based on realistic scenarios is also encouraged by the standards; to correct any weakness in the facilities emergency plan. CMA mandates the communication of relevant and useful emergency response planning information to the local emergency agencies. OSHA specifies warning systems for alerting both the employees and the local community; although it is silent on how often the alarms should be tested. AICHE states that: regular and contract employees are required to be trained for emergency awareness and response, regardless of their responsibilities during emergencies. It also requires the facilities to keep record of this training. Although, no specific metrics is recommended for measuring effectiveness of emergency preparedness, all standards encourage performance measurement for all PSM elements.	On-site fire brigades are available day and night at most facilities. Equipment sharing between neighbouring facilities sharing is not yet popular. Emergency programs are popularly coordinated with community emergency agencies including municipal fire fighters. Tone alert systems with varying tone codes are used in most facilities for warning the employees and the local community about emergency. Emergency command is assigned to no specific position. In the industry, both the employees and contractors are subject to same EPP training. Operational metrics procedure is being used to measure the adequacy of existing emergency facilities, supplies, and equipment; and to examine and review the effectiveness of coordination with off-site emergency response agencies.	As regards fire-fighting capability, significant compliance level is observed in the industry. Areas of improvement include: fire-fighting drills and listing of fire equipment on master database. Good emergency management in practice. More effort needs to be exerted on the standardization of emergency alert locations, tone codes, and testing of alert systems. Guidelines are required on the management function responsible for command of emergencies. Best of available practices in this field. Good practice.
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Table 5-3: South African PSII practice versus international standards

PSII Sub-elements	International Benchmarks	South African Practice	Comments and Recommendations
PSII Approach and Techniques	AIChE recommends a deductive PSII approach with a capability of multiple-cause investigation. The techniques must have the ability of exposing the immediate and underlying causes of incidents.	Deductive committee-based PSII approach is popular using expert judgement. The industry moderately acknowledges standards in the implementation of PSII techniques. Nonetheless, the techniques are often times non-prescriptive, thus allowing for user's subjectivity and bias.	A system-oriented approach which investigates multiple-cause of incidents needs to be encouraged. Safety experts should be trained for necessary competence in handling these techniques.
Incident Investigation Follow-up	AIChE also emphasizes the designation of an individual to follow up the implementation of PSII recommendations. It also considers it beneficial to review emergency plan in the light of PSII findings, as the PSII reveals the weaknesses in a factory emergency plan CMA commits members to share relevant lessons learned from PSII with industry, government and the community. Document control, and keeping of incidents records as well as incidents evidences is recommended by most PSII standards.	It is a prevalent practice to have a session used to present and review the recommendations from PSII exercise. PSSII exercise is directed towards a validation of their emergency plan. Facilities communicate lessons learnt PSII often times in formal occasions such as safety training.	The current practice can be improved by enjoining communication of lessons learnt across the industry, since similar management failures exist in other facilities.
Evidence and Incident Databases	Establishment of a protocol of systematic identification of all the expected evidence, and a coding system for this evidence is also persuaded. Simulations and re-creations of events in cases of gaps or contradictions are also advised by AIChE. Also advised is the review of incident databases from other facilities.	Although, there is a functional documentation procedure, the development of coding system for incident evidences is not yet being practised by the industry. Long-term and short-term incident evidences are kept for regulatory compliance and PSII improvement. Historical information from incident databases is being another resource for the industry PSII. Understandably, re-creation and simulation of incident events is not yet being widely practised.	Incident related databases could be helpful in learning from the experience of others, sharing information with others, and identifying areas of weaknesses, benchmarking performance, and more. Thus, it is will be helpful if the DOL can float such PSII database and make it accessible to the process industry. Also the DOL may help establish and standardize incident coding system and evidence identification protocol.

Management Commitment PSII Objectives and Investigation Team PSII Scope Training on Emergency Preparedness Metrics	As a show of management commitment, AIChE expects PSII focus not to be for assigning blame but for finding the cause of incidents. AIChE also requires sufficient resources to be committed to PSII implementation. Another measure of management commitment is the level of efforts exerted on implementing lessons and recommendations from PSII. From the consulted PSM manuals, PSII teams should most times be constituted on need basis; and preferably be multi-disciplinary in composition. AIChE advise involvement of relevant contractors and third parties for credibility of the PSII report. As noted above, the focus of a meaningful PSII effort should not be for disciplinary actions; so that the true events of incidents can be got from interviews of witnesses. Incident classification is a prevalent practice among process plants worldwide. The categorization however differs from standards to standards. AIChE promotes investigation of some near-misses because many lessons can be learned since the same causes and modes of failure are present in both major incidents and near-misses. CMA expects PSII team to be assembled by the employer and be trained in the techniques of investigation including how to conduct interviews of witnesses, needed documentation, and report writing. For effectiveness and improvement purposes, all codes canvass that PSII performance is measured as an element of a plant PSM system.	Sufficient resources are committed to PSII implementation with focus on finding cause of incidents rather than on assigning blame. Strong attention is at the present not being paid to implementation of recommendations from PSII. Off-site staffs, community and regulatory agencies representation is allowed in investigation teams as necessary. The industry still includes recommendations on disciplinary actions in the mandate of the incident investigation teams. No indication of established incidents categorization. Near-misses are investigated are investigated to a varying extent. In the industry, training and refresher training are conducted on a regular basis for: mid-level management and first-line supervisor. It is a preponderant practice in the industry to measure the effectiveness of PSII system, using home-made or outsourced PSII metrics.	This is a praiseworthy PSII culture for the fledging South African process industry; but for the implementation of recommendations from PSII. The mandates of PSII are not yet favourable for meaningful PSII. Focus of PSII efforts should be limited to uncovering root causes and implementation of lessons learned. DOL should come up with standardized guidelines on categorization of incidents for the process industry. Best practice. World-class practice. The industry can adopt a standard metrics system for easy benchmarking.
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5.4 Recommendations for Policy Development

To start with, PSM practice in the South African industry is still emerging and it will take a while to reach maturity. International standards such as OSHA PSM standards are drawn from wide range of trans-national process safety experiences. For global competitiveness, South African process industry needs to adopt internationally acceptable PSM standards. As a backbone to the development of PSM practice, the regulatory body (Department of Labour) should develop regulations that are specific to the South African process industry. These regulations should be compartmentalized to encourage performance measurement. South African PSM regulations can be adapted from the OSHA, AIChE, Chemical Manufacturers' Association (CMA) and the American Petroleum Institute's (API) PSM standards. These standards are recommended because of their performance-based nature; however European Union, EU PSM codes, ILO guidelines and the likes should also be consulted.

Sharing of incident information among the process facilities will be very useful in the implementation of PSII. The Department of Labour should sponsor the development of database for storing process safety incidents and near-misses. This database will be different from the one that is maintained by the Compensation Commissioner, in that it will record the incident root causes and offered solutions to prevent future reoccurrence. Department of Labour can also help enforce the sharing of information on near-misses among the process facilities. The process facilities need to go further by extending the MOC training to other production and operation personnel. Specifications for location, design and furnishing of emergency operation centre should be embedded in national policies and regulations.

The South African process industry needs to commit resources to development, acquisition and maintenance of PSM software. Academic support for PSM development in South Africa is much needed at this stage. The industry must be ready to sponsor researches, support, and collaborate with the academia on PSM subjects. The overall industry management commitment to PSII is lower than expected. Management commitment to PSII implementation recommendations should be encouraged. This can be achieved either by making it an auditable parameter or an enforceable PSM sub-elements.

Also, regular PSII training should be given to all categories of production and safety management personnel. Thorough PSII practice should be encouraged by imbibing the practice of incident events recreation and simulation. Another recommendation is that the Department of Labour or organized safety bodies in South Africa should develop a uniform taxonomy for classification of incidents and coding of

incident evidences within the process industry. Finally, it is suggested that the Department of Labour should organise a forum where safety experts and consultants from the academia, public and private sectors can exchange ideas and experiences on industrial safety practice.

5.5 Suggestion for Further Study

The focus of this research was the benchmarking of three PSM elements. It is here suggested that future research efforts should focus on the other eleven elements. The validity of Keren's analytical hierarchical process (AHP) model for measuring MOC performance should be examined among the South African process industry. Similar models should be developed for the other elements of process safety management.

ANNEXURE I

Questionnaire for benchmarking Management of Change (MOC)

Management of Change (MOC) is a relatively recent procedure enunciated by the US OSHA Process Safety Management regulation. The objective of the questions contained herein is to identify the diversity of MOC application within the South African processing and manufacturing industry. Please complete the questionnaire appropriately; and leave blank fields that are not applicable to your plant or factory.

1 Facility Profile

1.1. How many employees (including temporary and contract staff) work at this site? For uniformity, include everyone on the payroll, including the administrative and contract personnel.

1.2. How many separate process areas are within your plant complex?

1.3. Which of the following best characterizes the process operations in your plant or factory? (Check only one)

Chemical
Refining
Petrochemical
Pharmaceutical
Food
Gas Plant
Utilities
Metal Extraction and Processing
Other (please specify _____)

1.4 Is your company listed on any national stock exchange?

Yes
No

1.5 Is your company a member of the Responsible Care®?

Yes
No

1.6 Is your plant NOSA graded?

Yes (please state how many stars rating _____)
No

2 Scope

2.1. Is MOC applied plant-wide or only for regulatory critical process areas? (Check only one)

Plant-wide
Regulatory critical process areas

2.2. Is MOC applied to atmospheric tank farm areas? (Check only one)

Yes
No
Not applicable

2.3. Is MOC applied to utilities, such as steam generation or waste-water treatment areas? (Check only one)

Yes
No
Not applicable

2.4. Are there any process areas within your plant that are NOT subjected to formal MOC procedures? (Check only one)

Yes (Describe _____)
No

3 Policy Development

3.1. Was your company's MOC policy and procedures developed by corporate staff and then introduced to each plant? (Check only one)

Yes
No

3.2. Was your company's MOC policy and procedures developed by local plant staff? (Check only one)

Yes
No

3.3. Were PSM consultants used to initially develop MOC policy and procedures? (Check only one)

Yes
No

3.4. Are MOC procedures consistent plant-wide or vary somewhat within each area of the plant? (Check only one)

Consistent plant-wide
Vary somewhat within each area of the plant

3.5. Is there any effort to maintain consistent MOC procedures with other plants within your corporation? (Check only one)

Yes
No
Not applicable

4. Size of MOC program

4.1. How many maintenance work orders (replacement-in-kind) are initiated annually?

4.2. On the average, how many MOCs (all MOCs including emergency and temporary MOCs) are initiated annually?

4.3. Do you keep records of MOCs that are not approved? (Check only one)

Yes
No

4.3.1. If answer to 4.3 is yes, how many MOCs were eventually not approved?

5. Emergency MOCs

5.1. How many emergency MOCs are initiated annually (average)?

5.2. Who approves emergency MOCs? _____

5.3. How long does it take to get approval of an emergency MOC?

5.4. Are emergency MOCs audited/checked as soon as practicable? (Check only one)

Yes
No

5.5. How many emergency MOCs require remedial actions or violate the company/site MOC procedures?

6. Temporary MOCs

6.1. How many temporary MOCs are initiated annually?

6.2. Who checks to see if the changes affected by the temporary MOCs are restored to their normal conditions after the expiration of the authorized time period?

6.3. Are temporary MOCs audited/checked as soon as practicable to determine if the change has been restored to the original condition? (Check only one)

Yes
No

7. MOC records management

7.1. Are MOC files maintained in a plant central records storage area or within each respective plant area? (Check only one)

Plant central records storage area
Within each respective plant area

7.2. Are MOC files maintained electronically or do paper copies exist? (Check only one)

MOC files maintained electronically
Paper copy
Both

7.3. Who is responsible for maintaining MOC files? (Check only one)

Safety department
Operations department
Maintenance department
Other (specify _____)

8. Audit

8.1. Have there been additional audits of the MOC program beyond the standard required 3-year PSM audit? (Check only one)

Yes
No

8.2. Is the PSM Audit conducted by corporate staff not normally located at the plant? (Check only one)

Yes
No

8.3. Were outside consultants involved in the Audit? (Check only one)

Yes
No

9. Audit Results

9.1. Did the Audit reveal any MOCs were mis-classified? (Check only one)

Yes (please, indicate approx. % of MOCs audited which had issue _____%)
No

9.2. Did the Audit reveal any field (referring to plant) changes that were not subjected to MOC procedures? (Check only one)

Yes (please, indicate approx. % of MOCs audited which had issue _____%)
No

9.3. Did the Audit reveal any maintenance work orders that should have been classified as MOCs? (Check only one)

Yes (please, indicate approx. % of MOCs audited which had issue _____%)
No

9.4. Were there any recommendations for upgrading your MOC program from the latest audit? (Check only one)

Yes
No

9.4.1. If so, what were these recommendations?

10. MOC software

10.1. Do you use any special software to facilitate the MOC procedure? (Check only one)

Yes
No

10.2. Was this software developed in-house? (Check only one)

Yes
No

10.3. If commercial software is used, is it satisfactory? (Check only one)

Yes (List name of software used _____)
No

11. MOC Program Awareness Training

11.1. How are new employees and contractor employees made aware of the MOC policy and procedures? (Check all that apply)

Formal training classes
Provided with policy manual
Informal toolbox safety meetings
Other (Describe _____)

11.2. If training classes are provided, how often are classes scheduled?

11.3. Is MOC training separate from PSM program awareness training? (Check only one)

Yes (List name of software used _____)
No

11.4. Is a video describing the need for MOC used within your MOC awareness training program? (Check only one)

Yes (List materials used _____)
No

12. Impact on Risk Management Plan

12.1. Who is responsible for checking changes requiring an MOC for impact on the RMP plan? (Check only one)

Safety department
Operations department
Maintenance department
Other (specify _____)

12.2. Have any change requiring an MOC ever caused an RMP update?

13. MOC Initiation

13.1. Do all work orders require a corresponding MOC authorization number or explanation "why MOC is not required"? (Check only one)

Yes
No

13.2. Who is responsible for identifying a work order is NOT a replacement-in-kind, and is therefore work that requires an MOC? (Check only one)

Safety department
Operations department
Maintenance department
Other (specify _____)

13.3. Are DCS software changes documented using the MOC procedure? (Check only one)

Yes
No

13.3.1 If so, who maintains the DCS software change documentation (Check only one)

Operations department
Engineering department
Other (provide function name _____)

14. Process Hazard Analysis (PHA) revalidation

14.1. What criteria are used to determine whether or not a PHA must be performed with an MOC?

14.2. Do PHA's performed for MOCs vary in the degree of detailed review and documentation (If yes, please explain)?

Yes (_____)
No

14.3. Did the PHA revalidation team review MOC records? (Check only one)

Yes
No

14.4. Did the PHA revalidation team find any changes that were not identified in the MOC records? (Check only one)

Yes (please indicate approx % of MOCs audited which had issue ____%)
No

15. Environmental and Quality

15.1. Are environmental staff consulted as part of the MOC review? (Check only one)

Yes
No

15.2. Is the plant accredited under ISO 9000? (Check only one)

Yes
No

15.3. Is the PSM MOC program consolidated with the Quality configuration management program? (Check only one)

Yes
No
15.3.1. If so, are records consolidated? (Check only one)

Yes
No

16. Risk Screening or Ranking MOC

(The following group of questions is based upon the concept that proposed MOCs should be screened in order to provide the appropriate resources to evaluate the impact on safety of the proposed change.)

16.1. Does your site use Risk Screening or Ranking of MOCs?

Yes
No

16.2. Who developed the risk screening procedure?

Local in-house staff
Corporate PSM staff
Outside consultants
Other (Describe _____)

16.3. Who conducts the risk screening? (Check only one)

MOC initiator
MOC Coordinator

16.4. How many risk categories are available?

16.5. Are potential consequences and potential event frequency evaluated separately in the determination of the appropriate risk category? (Check only one)

Yes
No

16.5.1 If yes, how is potential consequences and potential event frequency evaluated? (Check only one)

Checklists
Staff experience only

17. Safety Review of MOC

17.1. If risk screening is used, are different safety review techniques applicable to each MOC risk category? (Check only one)

Yes
No

17.2. Are checklists available for low risk MOC? (Check only one)

Yes
No

17.3. Are high-risk MOC categories evaluated within the plant or required to be submitted to corporate safety staff? (Check only one)

Evaluated within the plant
Submitted to corporate safety staff

18. Authorization

18.1. How many authorizations are required on a MOC request to proceed with the change?

18.2. If risk screening is used, are different authorization levels applicable to each MOC risk category? (Such as authorization at the process unit area or plant manager level.) (Check only one)

Yes
No

18.3. If risk screening is used, is different number of authorizations applicable to each MOC risk category? (Check only one)

Yes
No

19. Training in the MOC

19.1. Who is responsible for conducting training regarding the impact of the MOC? (Check only one)

MOC coordinator
Operations
Training department
Other (list function _____)

19.2. If risk screening is used, are different types of training requirements applicable to each MOC risk categories? (Check only one)

Yes
No

19.3. Are night orders or logbook notation used for informing staff of low risk MOC changes? (Check only one)

Yes
No

20. Pre-Start-up Safety Review

20.1. Is the PSSR program considered closure of the MOC program? (Check only one)

Yes
No

20.2. Who is responsible for conducting the PSSR? (Check only one)

Operations
MOC coordinator
Other (Describe _____)

20.3. Is start-up safety review following turn-around handled separately than PSSR? (Check only one)

Yes
No

21. Metrics

21.1. Have you developed a program to measure MOC effectiveness? (Check only one)

Yes
No

21.2. Did you develop your own metrics or adapted it from other sources? (Check only one)

Developed own metrics
Adapted metrics from other sources

22. Does your MOC program include management of organisational changes? (Check only one)

Yes
No

22.1. If answer to question (22) is yes, what is the highest level in your organisation that requires a management of organisational change?

23. Please describe any general impressions of the MOC program at your plant, such as plans to extend the MOC program to other areas, portions of the MOC program that are causing difficulty, suggestion to improve the efficiency of MOC program, etc.

ANNEXURE II

Questionnaire for Benchmarking Emergency Preparedness Programs (EPP)

1. Facility Profile

1.1. How many employees (including temporary and contract staff) work at this site? For uniformity, include everyone on the payroll, including the administrative and contract personnel.

1.2. How many separate process areas are within your plant complex?

1.3. Which of the following best characterizes the process operations in your plant or factory? (Check only one)

Chemical
Refining
Petrochemical
Pharmaceutical
Food
Gas Plant
Utilities
Metal Extraction and Processing
Other (please specify _____)

1.4. Is your company listed on any national stock exchange?

Yes
No

1.5. Is your company a member of the Responsible Care®?

Yes
No

1.6. Is your plant NOSA graded?

Yes (please state how many stars rating _____)
No

2. Identifying credible incidents

2.1. A lot of efforts are invested in order to define 'worst credible incidents' in order to plan an emergency program. In some cases, worst possible incidents (incidents with severe consequences, but with very poor likelihood) are taken into consideration during emergency planning. Were worst possible incidents taken into consideration in your facility's emergency planning?

Yes
No

2.2. Our emergency program covers incidents with the following magnitude: (Check all that are applicable.)

Local incidents
Moderate incidents
Catastrophic incidents

2.3. Which of the following best describes the process of identifying credible incidents in your facility's emergency planning:

Using intuition and rules of thumb
Unstructured expert brainstorming
Applying quantitative risk analysis methods
Investigation of the Process Hazard Analysis to identify credible incidents

2.4. Incident prioritizing is also necessary for emergency planning. The likelihood of initiation of incident is fundamental to the prioritizing process. However, estimation of the likelihood of failure of the protecting system can contribute to this process and change priorities. Does your emergency planning consider protecting systems failures in the prioritizing process?

Yes, consider incident events and protection systems failure for prioritization
No, consider only incident events for prioritization
Don't know

2.5. Commercial incident modelling software is available to evaluate incidents consequences. How did your emergency planner evaluate these consequences?

Simple calculations
Homemade software

Commercial software (specify _____).

2.6 Incidents can have long-term effects on the environment. These effects are not simple to estimate. Has your emergency program considered long-term environmental effects?

Yes
No

2.7 Has a catastrophic scenario due to terrorist attack been considered in your emergency planning?

Yes
No

3. Capabilities and resources assessments

3.1 A variety of facilities may be used to support emergency operations. Below is a representational list of facilities. Check all that is available in your plant:

Short-term shelters
Safe havens (Shelter with alternative air breathing source)
Incident command post
Emergency Operation Centre (EOC)
Media Information Centre (MIC)
Medical support facility (other than the first aid room)
Alternate water supply
Community and facility alerting systems
Emergency management computing system
Emergency power system
Meteorological instruments
Real-time modelling system

3.2 If a medical facility other than the first aid room is available, briefly describe its capabilities and limitations (in terms of number of medical personnel and sick bays):

3.3 Preparedness of the nearest hospital may be crucial to the consequences of incidents. Is the nearest hospital capable of handling massive casualties?

Yes
No
The hospital is not involved in our emergency program

3.4 If choose "yes" in 3.3, is the hospital aware of the chemicals used in your facility?

They have general idea
No
Yes

3.5 Is/(are) other medical centre(s) part of your facility's emergency net?

Yes
No

3.6 Are medical airlift resources available and prepared?

Yes
No

3.7 Are local emergency agencies familiar with the plant layout and hazards?

Yes
No

3.8 Are neighbouring sites aware of and prepared for your facility emergencies (and Vice-versa)?

No
They have a general idea
SHE officers coordinate the mutual emergency preparedness and responses
Corporate committee established and mutual periodical drills are operated

3.9 Are contractors a part of the plant emergency response program?

Yes
No

If yes, are they trained to their jobs?

Yes
No

3.10 Do personnel structure changes cause emergency program re-evaluation?

Yes
No

3.11 Does Management of Change procedure address changes to your emergency program?

Yes
No

3.12 Check the box that applies in your site:

The site consists of a fire brigade
The site depends on local fire department

3.12 Are fire brigade personnel available outside of daytime shift?

Yes
No

3.14 Does the local community fire brigades participating in the site drills?

Yes
No

3.15 Using neighbouring sites' emergency equipment is efficient in terms of cost-benefit, and can be justified for certain types of equipment. If this case applies to your plant, list the shared type of emergency equipment:

4. Physical facilities and systems

4.1. From AIChE, Guidelines for Technical Planning for On-Site Emergencies,

- "Shelters - provide passive protection for inhabitants when ventilation is off and all windows and other openings are closed."
- "Safe havens - Provide protection by providing alternative source of breathing air supply."

Mostly, control rooms are used as shelters or safe havens. Control rooms in your facility are designed as:

Shelters
Shelters, but other buildings are serving as safe havens
Safe havens

4.2. Which of the following has been assigned to be used as Emergency Operation Centre (EOC)?

No EOC in the plant
Control Room
Selecting arbitrary office/room
Conference room
Specially designed building (or part of a building)
Other (specify _____)

4.3. How many employees are required to be in the EOC in emergency?

1-10
10-20
20-50
Higher

4.4. What is the distance between the EOC and the nearest process?

Less than 50 yards
50 - 100 yards
100 - 300 yards
300 - 1000 yards
More than a mile

4.5. Is an alternative EOC available?

Yes
No

4.6. The EOC is designed as a (see 4.1 for explanation of terms):

Shelter
Safe haven

4.7. Is an emergency power supply available to the EOC?

Yes
No

4.8. Which of the following best describes your medical support facility (MSF)?

First aid room
Day to day emergency clinic
A large room equipped to become MSF
Designated building (or part of building) to serve as MSF

4.9. An industrial fire truck is a powerful piece of equipment in certain scenarios.
Does your plant employ one?

Yes
No

5. Communication

5.1. Do local, off-site agencies hold open emergency open channel(s) to the plant?

Yes
No

5.2 who are the local community representatives that your plant is coordinating and communicating with?

Emergency Management agency
Fire department officers
County emergency service director
City manager officers
Mayor
Other (specify _____)

5.3 Is a tone alert system installed in your plant?

Yes
No (if other systems then tone alert, specify)

5.4 List the tone alert system codes and their meanings:

5.5 What type of alert system(s) is being used to inform the local community regarding emergencies?

Tone alert system
Cable television override system
Computer telephone dialing system
Other (specify _____)

5.6 How often are on-site and off-site alarm systems tested?

On-site

Not tested at all
Weekly
Monthly
Quarterly
Every six months
Annually
Not applicable

Off-site

Not tested at all
Weekly
Monthly
Quarterly
Every six months
Annually
Not applicable

5.7 An emergency program may be supported by variety of agencies and organisations. Check those that are applicable in your plant's emergency program:

Salvation Army
Red Cross
Public and private hospitals
Highway department
Department of health
Local emergency planning committee
Civil defence agency

Emergency preparedness organisation
Office of emergency service
Emergency medical centre

6. Metrics

6.1 Have you developed procedures to measure your emergency program effectiveness?

Yes
No

6.2 Did you develop your own metrics or adapted from other sources?

Developed own metrics
Adapted from other sources
Not applicable

6.3 Is your metric procedure designed to measure the adequacy of existing emergency facilities, supplies, and equipment?

Yes
No
Not applicable

6.4 Is your metric procedure designed to measure your level of coordination with off-site emergency response agencies?

Yes
No
Not applicable

6.5 How frequently is your emergency program reviewed:

Annually
Minimally, as required by OSHA PSM regulation
Minimally, plus after major changes applied
Other: _____

7 Positions

7.1 Who is designated to serve as Incident Commander (IC) or Emergency Floor Controller (EFC)?

Relevant production manager
Relevant plant manager
SHE officer
Vice president
CEO
Other: _____

7.2 Who is responsible for determining the severity of an incident (Local, moderate, catastrophic)?

Plant manager
SHE officer
Production manager
Incident Commander (IC) or Emergency Floor Controller (EFC)

7.3 Who is responsible for updating the emergency equipment and supply inventory lists?

Operation personnel
SHE personnel
Contractor
Other: _____

7.4 Who makes the evacuation decision?

Plant manager
SHE officer
Production manager
Incident Commander (IC) or Emergency Floor Controller (EFC)
Other: _____

8. Training

8.1 Employees, regardless of their responsibilities during emergencies, are required to be trained for emergency awareness and response. Below is a list of subjects that can be covered by non-emergency team employee training. Check all the subjects that are applicable in your facility:

Identification of hazardous situations
Identification of physical warning signs (smoke, smell,...)
Evacuation routes and shelter locations
Emergency reporting procedures
Usage of PPE
Identification of types of fire
Usage of proper fire extinguishing equipment
Drills on usage of PPE and fire extinguishing

8.2 Are contractor employees trained like other employees?

Yes
No

8.3 Who is responsible for coordinating the emergency training program?

Plant manager
SHE officer
PSM team
Human resources
Other: _____

8.4 Is simulated crisis communication drilled?

Yes
No

8.5 Are training records kept in your plant?

Yes
No

Questionnaire for Benchmarking Process Safety Incident Investigation (PSII) Programs

1. General Approach

1.1 There are three major approaches to conduct PSII. Check the one that best describes the approach in your plant:

- ☐ Informal investigation performed by immediate supervisors
- ☐ Committee-based investigations using expert judgment to find a credible solution of cause and remedy
- ☐ Multiple-cause, systems oriented investigation that focuses on root cause determination, integrated with an overall process safety management program

2. PSII Techniques

2.1 Which of the following types of analysis are mainly used for PSII in your plant?

- ☐ Deductive
- ☐ Inductive

2.2 The following list consists of large number of techniques for PSII. Please check all the techniques that are being used in your plant for PSII:

- ☐ Fault Tree Analysis (FTA)
- ☐ Causal Tree Method (CTM)
- ☐ Management Oversight and Risk Tree (MORT)
- ☐ Multiple-cause, system-oriented Incident Investigation Technique (MCSOII)
- ☐ Accident Anatomy Method (AAM)
- ☐ Action Error Analysis (AEA)
- ☐ Cause-Effect Logic Diagram (CELD)
- ☐ Hazard and Operability Analysis (HAZOP)
- ☐ Accident Evolution and Barrier (AEB)
- ☐ Work Safety Analysis (WSA)
- ☐ Human Performance Enhancement System (HPES)
- ☐ Change Evaluation/Analysis (CEA)
- ☐ Human Reliability Analysis (HRA)
- ☐ Multi-linear Event Sequencing (MES)
- ☐ Sequentially Timed Event Plot (STEP)
- ☐ Systematic Cause Analysis Techniques (SCAT)
- ☐ Technique of Operations Review (TOR)
- ☐ TapRoot™ Incident Investigation System

2.3 Most of the techniques listed above were originally developed as computer-based techniques. Are computer-based PSII techniques implemented in your plant?

- ☐ Yes
- ☐ No

The validity of PSII techniques consists of many parameters. Several of these parameters are listed in the questions below.

2.4 PSII techniques in your plant are effective in supporting the following (Check all that apply):

- ☐ Near-misses
- ☐ Minor Incidents
- ☐ Major Incidents

2.5 The extent of acknowledging standards and industrial guidelines in the implementation of PSII techniques in your plant is as follows:

- ☐ Weak
- ☐ Moderate
- ☐ Strong

2.6 PSII is not an exact science. The degree of freedom in judgment during implementation of PSII techniques may vary widely. Implementation of PSII techniques in one plant may be very prescriptive and may reduce user subjectivity to minimum, while implementation of the same technique in other plant can be strongly dependent on user identity. Implementation of PSII techniques in your plant is:

- ☐ Prescriptive, the user is required to maintain a minimal level of judgment

Moderately dependent on the user - certain degree of judgment is required from the user, however his/her degree of freedom is limited

Strongly user dependent – it is likely that two different users will arrive at different conclusions

3. Databases

Incident related databases could be helpful in learning from the experience of others, sharing information with others, and identifying areas of weaknesses, benchmarking performance, and more. The following questions aim to reveal the level of incorporation of databases in the process of PSII.

3.1 Is equipment reliability performance recorded in your plant?

Yes
No

3.2 Are these records submitted to a database?

Yes
No

If yes, are these records submitted to a central reliability database (similar to the equipment reliability database that the centre for Chemical Process Safety maintains)?

Yes (Please specify: _____)
No

3.3 Does the PSII procedure in your plant use historical information from incident databases such as EPA ARIP (Accident Release Information program), EPA Risk Management Program (RMP), etc.?

Yes (Please specify: _____)
No

4. Management Commitment

4.1 Which of the following best describes the characteristics of implementation of PSII procedure in your plant?

Focus on finding causes
Focus on assigning blame

4.2 In your opinion, is the resource of PSII sufficient to sustain the investigation?

Yes
No

4.3 The level of implementation of recommendations from PSII is among the indicators of the commitment of the management system to process safety. Which of the following best describes the level of effort invested in implementation of PSII recommendations?

Low
Moderate
High

4.4 As with level of implementation of recommendations, the level of communication of "lessons learned" is among the indicators of management commitment to process safety. Which of the following best describes the situation in your plant?

The value of learning lessons from incidents is strongly emphasized
Lessons learned from previous incidents are discussed in formal occasions such as safety trainings and meetings
Lessons learned are rarely communicated

4.5 The investigation of near-misses may have the same benefits as PSII. However, these investigations are not as common as PSII. Are near misses investigated in your plant?

Yes
No

If yes, are there any parameters governing the decision to investigate near-misses?

No. All near-misses are investigated
All near-misses are investigated; however, the extent of the investigation varies
Yes, the parameters are as follows: _____

4.6 Does the system in your plant establish a positive and comfortable environment that encourages reporting incidents and near-misses?

Yes
No

4.7 Briefly describe the way lessons learned are being communicated in your plant: _____

4.8 Organizations use periodic publications of incident abstracts to communicate lessons learned. Does your organisation use periodic publications for that purpose?

Yes
No

5. Investigation Team

5.1 The extent of incidents and near-misses varies, and affects the need, size and structure of the investigation team. Please specify the way incidents and near-misses are classified in your plant, and the way it affects the structure of the team:

5.2 Are off-site members included in your investigation team?

Yes
No

5.3 Are representatives of the local community and of regulatory agencies involved in the investigations of near-misses and incidents that might effect the population in this community?

Yes
No

If yes, please specify: _____

5.4 There are several major objectives of PSII. Please check those that are the responsibility of the investigation team:

Identify system related multiple root causes
Determine recommendations and actions to be taken to prevent recurrence of incidents and similar events
Implement the recommendations
Follow up on the

5.5 Are PSII training and refresher training conducted on a regular basis?

Yes
No

If yes, which of the following groups are subjected to this training:

Senior management
Mid-level management
First line supervisors, etc.

5.6 Specify who are mainly appointed as team leaders in PSII:

5.7 Are recommendations on disciplinary actions in the scope of the PSII team?

Yes
No

6. Evidence

6.1 Physical evidence is required for two distinct phases: the immediate and the long-term. Does the PSII procedure in your plant address storage for evidence:

No
One central storage area is dedicated for short and long-term evidence storage
Long-term evidence is storage appropriately if required

- 6.2 Among the early stages of the implementation of a PSII procedure is the establishment of a protocol of systematic identification of all the expected evidence, and a coding system for this evidence. Does the PSII procedure in your plant develop such a protocol and coding system?

No
Develop a protocol for identification of evidence only
Develop a coding system only
Yes, both

6.3 Does the PSII procedure in your plant consist of a procedure for document Control?

No
Yes

If yes, does the size and scope of investigation mandate the extent of the documentation?

No
Yes

6.4 Does the PSII procedure in your plant call for simulations and re-creations in cases of gaps or contradictions of information?

No
Yes

7. Recommendations

7.1. In this stage preventive action is developed and examined for each of the root causes. Evaluation of the selected preventive actions for Management of Change (MOC) at this stage can save time and effort if the preventive action under investigation does not satisfy the MOC program criteria. Which of the following applies in your plant?

Evaluation for MOC is conducted at this stage
Evaluation for MOC is conducted only at the last stage before implementation of the preventive actions
The PSII procedure does not address MOC.
Other: _____

7.2 Does the PSII procedure in your plant require establishing criteria for restart and operations following an incident investigation?

No
Yes

7.3 Does the PSII procedure in your plant call for improvement that aims for inherently safe design?

No
Yes

7.4 Do regulatory agencies have jurisdiction and authority over restarts following incidents in your plant?

No
Yes

If yes, please specify: _____

7.5 Presentation and review of the recommendations with the area management responsible for the operation of the line that experienced the incident can be extremely beneficial. Is such a session required by the PSII procedure in your plant?

No
Yes

7.6 Does the PSII procedure in your plant aim to examine the validity of your emergency plan?

No
Yes

7.7 Please describe the incident classification criteria employed in your plant:

8. Metrics

8.1 Have you developed a program to measure PSII effectiveness?

No
Yes

8.2 Did you develop your own metrics or adapted them from other sources?

Developed own metrics
Adapted metrics from other sources

8.3 Please describe any general impressions of the PSII procedure at your plant, portions of this program that are causing difficulty, suggestion to improve the efficiency of the PSII program, etc.

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