THE ROLE OF LEADERSHIP AND DEVELOPMENT OF MANAGEMENT SYSTEMS TO ENSURE EFFECTIVE SAFETY PERFORMANCE

A Thesis

by

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ABSTRACT

Safety is one of the crucial issues that industry has aimed at improving for many decades and continues to progress. Discoveries show that organizations optimize their effort when they provide effective management systems to support front line employees, supervisors, and senior level managers. In this research, the role of leaders regarding safety in the energy industry is studied, and moreover, how to develop safety management systems to ensure an effective safety performance is surveyed.

Leadership has the greatest impact on safety improvement. Leaders by different techniques can increase their influence on employees; set the mission and vision for staff; implement rules; provide resources; improve the teamwork; make effective communication from top to bottom, bottom to top and along the organization, educate staff, develop a safety management system, and create safety culture in the organization. By organizational safety culture, I mean the shared common values that drive organizational performance, more commonly defined as "the way we do around here."

While there are regulations regarding safety, every organization requires self-standard beyond the codified rules to have effective safety programs. Regulations should follow new research to develop new management systems to ensure the highest standards for safety. Developing safety systems to have a sustainable safety performance is an obligation. Hence, for the energy system, some components have to be considered in safety matters: type of resources, support characters, and their relation to safety issues. In addition, other components include the time frame for productions (exploration), the output shape and associated hazards, area that these resources are located at, and distribution systems and hazards.

A safety management system helps leaders and managers control and evaluate safety by using safety metrics such as leading and lagging indicators. Management systems such as process safety management, risk management plan, and Seveso Directive are some management programs that organizations are still arguing for complete and correct implementation to become a zero-incident-organization.

DEDICATION

I would like to dedicate this research to all of the people who have lost their lives at work and their family left behind. These are people who lost their lives due to that lack of strong leadership and strong safety management systems.

I wish to express here my sincere appreciation and thanks to my parents who were my first teachers and all teachers that have had, directly and indirectly, helped me throughout my life.

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NOMENCLATURE

ACC	American Chemistry Council
ACSNI	Advisory Committee on Safety of Nuclear Installations
AIChE	American Institute of Chemical Engineers
ARAMIS	Accident Risk Assessment Methodology for Industries
API	American Petroleum Institute
BLS	U.S. Bureau of Labor Statistics
BOE	Barrel of Oil Equivalent
BSEE	Bureau of Safety and Environmental Enforcement
CCPS	Center for Chemical Process Safety
CFR	Code of Federal Regulations
CSB	U.S. Chemical Safety and Hazard Investigation Board
DART Rate	Days Away/ Restricted/ Job Transfer Rate
EHS	Environment, Health and Safety
EMR	Experience Modification Rating
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Act
EPR	Emergency Planning and Response
EU	European Union
FMEA	Failure Modes and Effects Analysis
FTA	Fault Tree Analysis
HAZOP	Hazard and Operability
HSE	U.K. Health and Safety Executive
IAEA	International Atomic Energy Agency
MAPP	Major Accident Prevention Policy
MAH	Major Accident Hazards
MI	Mechanical Integrity
MOC	Management of Change
MORT	Management Oversight & Risk Tree
NFPA	National Fire Protection Agency
OGP	International Association of Oil and Gas produces

OSHA	Occupation Safety and Health Administration
PHA	Process Hazard Analysis
PRD	Pressure Relief Device
PSI	Process Safety Information
PPE	Personal Protective Equipment
PSLG	Process Safety Leadership Group
PSM	Process Safety Management (OSHA Regulation)
PSPI	Process Safety Performance Indicators
RAS	Reference Accident Scenarios
RIR	Recordable Incident Rate
RMP	Risk Management Program
SADT	Structure Analysis and Design Techniques
SCQPI	Safety Climate Questionnaire for Process Safety
SEMS	Safety & Environment Management System
SIC	Standard Industrial Classification
SMS	Safety Management System
SOOB	Summary of Operation Barriers
SPI	Safety Process Indicators
SR	Severity Rate
STAA	Safer Technologies and Alternatives Analysis

1. INTRODUCTION

Within the last three decades, new concerns have been raised regarding new technologies and developments. The energy industry is one of the fastest growing industries. The demand continues increasing as the population keeps snowballing. Therefore, changes in management systems, legal and regulatory frameworks are required to respond to the supply, public concerns, public opinions, safe production, climate issues and the price. Increasing the production will increase the risk of incidents, therefore, having safety and risk management systems are necessary to not only keep the facilities safe but also keep the employees safe and obtain the required licenses to operate. An example is the number of nuclear reactor facilities that have been closing around the world such as in Japan or Germany after Fukushima Daiichi incident.

Workplace injuries and incidents that cause employees miss 6 or more days of work cost United States of America's employers $52.9 million in 2014 (BLS, 2014). Many researchers have argued that major incidents will affect organizations' capital cost, income, investment confidence, insurance cost, and organizations' reputation. In other words, if management wants to reduce incidents and related injuries, illnesses, loss-production events, and/or other associated costs, everyone must place much-needed emphasis on safety subjects similar to other core management issues, such as production, sales, and quality control (Roughton and Mercurio, 2002b). Nuclear power plants, oil and chemical industry, wind, solar and hydrogen resources are some examples of energy sectors. At all levels of the design, exploration, production, storage, transportation, and maintenance, a robust safety management system is needed. Leaders and senior executives should create sustainable safety systems and organization development, and push everyone to be involved to have a zero-incident-organization. The primary goal of safety leaders, whether at the site or corporate level, is to reduce the amount of exposure that occurs in the workplace- referred to as the "working interface" (Krause, 2000). These exposures have a different level of severity. Reducing the exposure and the severity is the primary mechanism of safety improvement.

The annual report from European Environment Agency indicates, among others, that the trend of incidents has been constant over the last 20 years (Hourtolou and Salvi, 2003a). The oil, gas and process safety industries have a successful portfolio in improving occupational safety, but the same is not true with regard to process safety and major incident performance (Pitblado and Nelson, 2013). In figure 1, the number of nonfatal injuries and illnesses in the U.S. for the petrochemical industry from 2007 to 2015 is illustrated. As it is shown in the figure, the number of injuries has been reduced. However, the property damages loss did not reduce significantly (property damages happen mostly due to major incidents).

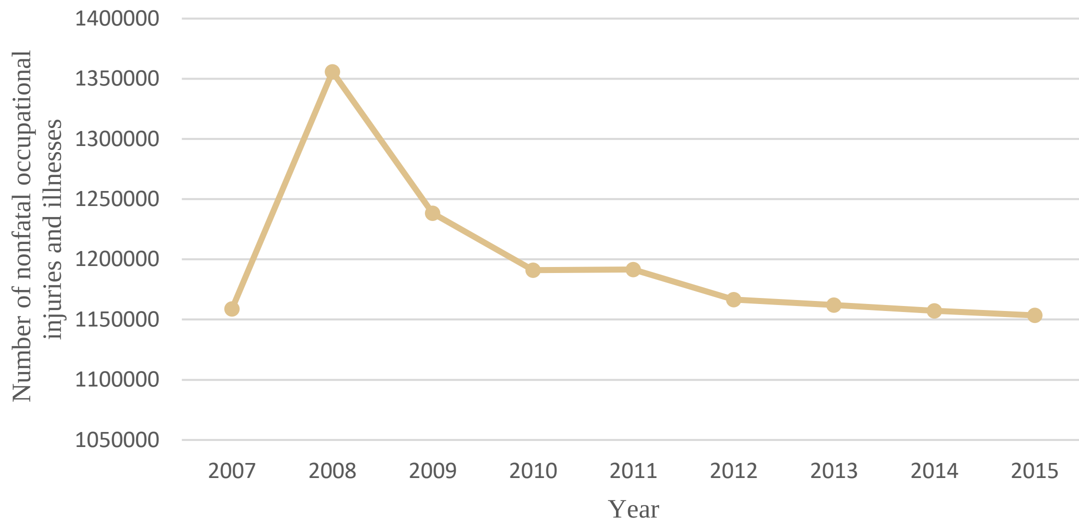

Figure 1- Nonfatal occupational injuries in the U.S. for Petrochemical industry (BLS, 2017)

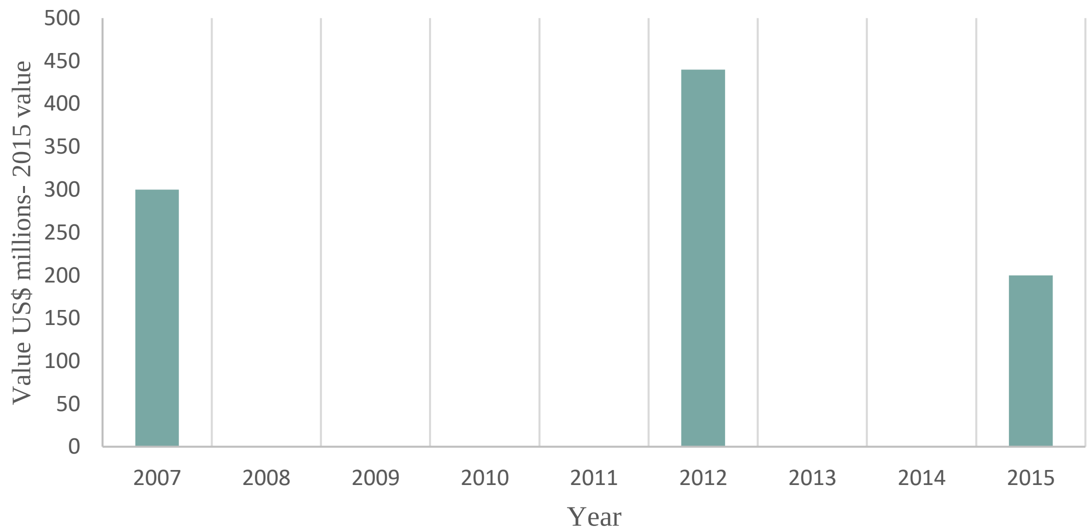

Figure 2-Petrochemical property damage losses (Marsh, 2016)

Managing safety is different from leading safety. Managerially, keeping a plant safe is complicated. Strong leadership is demanded to set directions by defining their mission, vision, and aligning people toward safety. Leadership has the greatest impact to enhance the safety in a company (Killimett, 2006), establish “safety spirit” among employees, and communicate with them and exert the influence on followers. Indeed, if management is about doing things the right way, leadership is about doing the right things; however, everyone from top managers to supervisors, frontiers, and contractors are responsible for safety.

Most incidents are caused by human and organizational malfunctions such as incomplete hazard analysis, poor facility design, and layout, poor safety culture, prioritizing production over safety, ignoring warning signs, improper training, and improper maintenance.Therefore, many relevant studies have been surveying the role of leadership and developing management systems for safety, either on Personnel Safety or System Safety (Barling et al., 2002a). In terms of personnel safety, leadership studies the relation between leaders and employees’ communication, and leaders’ influence on employees that can make a united team, in which everyone is responsible and accountable for safety. Safety in teamwork involves the organizations’ behavior, personnel’s behavior, and their interaction, which attributed to safety performance (Garavan and O'Brien, 2001; Neal and Griffin, 2002a; Wu et al., 2008).

Failures of the management system are shown as the reason for over 85 percent of the reported incidents (EC, 1996b). System safety refers to processes and procedures regarding safety. Safety Management Systems (SMS) have been designed for systematic approaches to mitigate the associated risks and hazards to a reasonable level, and therefore different types of Safety Performance Indicators (SPI) have been introduced to ensure Safety Performance is monitored continually to approach zero incident organization. Because of the mounting cost of health and employees’ compensation, organizations have been increasing their effort to improve their safety performance or more aggressively manage their risks and hazards by developing their safety systems. In any energy sector, there is a non-failure tolerance for incidents since an incident can lead to a catastrophe. In fact, failure to manage safety process will never bring successful process performance. As demonstrated in BP Texas refinery incident investigation, it is possible to have a good occupational safety record and still have a high level of process safety incidents (Khan et al., 2010). Such an incident like BP does not happen without warning. This is supported for many major incidents that have already happened where the weakness of process safety performance was the main reason. Hence, a comprehensive and suitable system to measure process safety is required. Dennis Hendershot quote “you cannot manage what you cannot measure” (Hendershot, 2007).

2. BACKGROUND

2.1 Process safety management

In the late 60s, numerous incidents including explosions and fires happened in West-European countries, which led to putting efforts to exchange knowledge and expertise among engineers. In 1971, the Institution of Chemical Engineers organized a conference on Loss Prevention and Safe Operation of chemical plants to gather all experts, engineers and researchers. Afterwards, a day after the first international symposium in Delft, 1974, which the merits of 'risk analysis' were put forward and discussed, Nypro plant (Flixborough, UK) disaster happened. This disaster, which over the years became one of the most extensively investigated incidents, proved once again how urgent the study of safety is (Buschmann et al., 1974). After Flixborough disaster attentions shifted over human errors and behaviors (Pasman and Suter, 2004). This disaster resulted in introducing risk analysis methodologies like Hazard Operability (HAZOP) in the management of process operations risks by DOW Chemical Company. During the 1980s, companies became much more aware regarding the importance of human reliability. They noticed technical improvements were not enough to reach the full integrity of processes. Therefore, written procedures on human behaviors for process maintenance and operation were developed. In the result of Bhopal incident, the United States Congress passed the Emergency Planning and Community Right-to-Act (EPCRA) of 1986, which assist contingency planning for potential chemical incidents and make communities available with proper information on possible hazards and risks caused by the chemical processes (EPA, 2012). Afterward, a series of explosions and fires which ended up with 23 fatalities in Pasadena, Texas in 1989, established the process safety management (PSM) of Highly Hazardous Chemicals by Occupational Safety and Health Administration (OSHA, 2000). On the other hand, U.S. Environment Protection Agency (EPA) in 1989 reported 11,000 events in eight years regarding Acute Hazardous Events (Mason, 2001). As a result, EPA also implemented Section 112(r) to the Clean Air Act called the risk management program (RMP) regulation, which addresses hazard assessment, prevention, and emergency response program (EPA, 2017).

On February 24, 1992, Occupation Health and Safety Chemical standard (29 CFR 1910.119) passed the process safety management. In fact, OSHA PSM focuses on the protection and safety of staff from hazardous chemical risks within the plant borders, while EPA RMP addresses the potential hazards that the facility may carry out on close comminutes (Kim et al., 2012). US OSHA defined PSM as “the proactive identification, evaluation and mitigation or prevention of chemical releases that occur as a result of failures in processes, procedures, or equipment” (OSHA, 1992).

After Macondo incident in the Gulf of Mexico in 2010, Safety and Environment Management System (SEMS) regulatory requirement regarding offshore oil and gas operation in the US introduced by Bureau of Safety and Environmental Enforcement (BSEE, 2017). The purpose of SEMS is to improve the safety of operations by reducing the frequency and severity of incidents.

Measuring PSM performance is important to act toward continuous improvement. Various indicators should be hired by the energy organization to evaluate their PSM. Many types of research (Ale, 2009; Allford, 2009; Azizi, 2016; Dyreborg, 2009; Hale, 2009) studied the relationship between PSM performance efficiency on PSM program. Indeed, it is necessary that any energy facility that includes processing procedures should apply effective Measuring (lagging and leading) indicators as a part of the overall EHS management system indicators. Dr. Mannan stated that leading or proactive indicators are appropriate for monitoring and evaluating objectives achievements, compliance with procedures and standards, auditing effectiveness, and state of documentation. Meanwhile, lagging indicators (reactive measures) suitable for monitoring of injuries, material losses and damages, plant deteriorations, and incidents (Mannan, 2016). However, choosing the right indicators and evaluating those indicators is not easy. American Petroleum Institute (API) in its recommendation (754) stated that “Selecting appropriate indicators using unbiased and broad-based input will lead to a high-performing program” (API, 2010).

Safety barriers have been used to protect humans and properties from enemies, fires, and natural hazards from last centuries. Haddon developed a model in 10 sections for incident prevention (Haddon, 1980). Simultaneously safety barriers also have an important role in Management Oversight & Risk Tree (MORT) concept in 1980 (Johnson, 1980). Different terms with similar performing or meaning have been used crosswise between industries and countries such as barrier, defense, protection layers, critical safety element, safety function, lines of defense, and defense in depth. IAEA describes the defense-in-depth principle as “compensate for potential human and mechanical failures, a defense in depth concept is implemented, centered on several levels of protection including successive barriers preventing the release of radioactive material to the environment. The concept includes protection of the barriers by averting damage to the plant and the barriers themselves. It includes further measures to protect the public and the environment from harm in case these barriers are not fully effective” (IAEA, 1999). During recent years, the emphasis in using barriers accelerated as Fleming and Silady stated that “the definitions of defense-in-depth have evolved from a rather simple set of strategies to apply multiple lines of defense to a more comprehensive set of cornerstones, strategies, and tactics to protect the public health and safety” (Fleming and Silady, 2002).

A barriers system may consist of different type of elements such as technical, operational, human and software barriers to prevent and mitigate an accident or incident. A commonly used categorization is to distinguish between physical and non-physical barriers (Sklet, 2006). Svenson categorized barrier systems as physical, technical, or human factors-organizational systems (Svenson, 1991) while Kecklund and his colleges classify barriers as technical, human, or human/organizational (Kecklund et al., 1996). Department of Energy has a similar viewpoint as Kecklund and discriminates between physical and management barriers (DoE, 1997). Management barriers may be seen as a kind of organizational control. Hopwood described administrative, social, and self-control as three types of organizational controls (Hopwood, 1974). Several authors distinguish between passive and active barriers (CCPS, 2001; Hale, 2003; Kjellén, 2009). In ARAMIS European project barriers are divided into passive, active and procedural barriers (Hourtolou and Salvi, 2003a). The concept of Safety barriers is not well defined yet, but different authors have different definitions, which overlap sometimes.

2.2 Safety culture

Safety Culture emerged after the Chernobyl nuclear disaster on April 26, 1986, which “was the most severe in the history of the nuclear power industry, causing a huge release of radionuclides over vast areas of Belarus, Ukraine, and the Russian Federation (IAEA, 2016)”. ACSNI Human factors study group, HSE (1993) defined the safety culture of an organization is “the product of the individual and group values, attitudes, perception, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management” (HSE, 2002). Hale describes safety culture as “the attitudes, beliefs, and perceptions shared by natural groups as defining norms and values, which determine how they act and react about risks and risk control systems. (Hale, 2000). At the beginning of the twenty-first century, debates about the role of organizational safety culture in implementing an effective PSM program was again triggered by the occurrence of BP Texas City refinery mishap in 2005, although the safety culture concept has been known since the 1980s after the Chernobyl nuclear disaster. The process industry should find a way to implement leading indicators that measures the effectiveness of leadership and safety culture practices more quantitatively. Therefore, CCPS published some guidelines for process safety metrics in 2009 (CCPS, 2009). Pasman and Sulter graphed the safety performance evaluation since 1960 in the process safety.

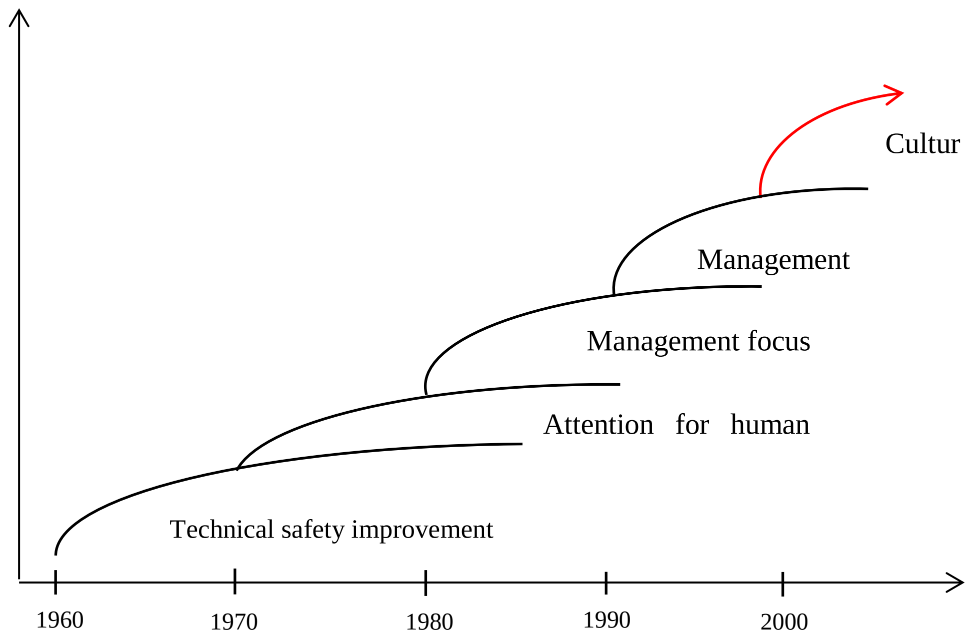

Figure 3-The evaluation of process safety (Pasman and Suter, 2004)

2.3 Seveso directive

The European Union amended so-called Seveso Directive is aiming at reducing the risks of potential major incidents associated with hazardous substances was initiated few months after a catastrophic incident in a chemical plant at Seveso, Italy in 1976. (EU, 2012). The Seveso incident is being recognized as an environmental disaster from toxic chemical exposure, which happened based on exposure to TCDD (2,3,7,8-terachlorodibenzo-p-dioxin) (Mannan, 2012a). In 1982, the Seveso adopted and replaced with Seveso II Directive in 1987 and Seveso III in 2012 to include the facilities that store dangerous substances. These regulations are aiming at preventing accident release of highly hazardous substances in the process industry, protecting staff, the neighbors, and nearby community from exposure to those hazards.

In general, U.S. regulations are based on process safety management and are developed into a mixture of perspective and performance-based approach (Pitblado, 2011), while EU regulations have been a focus on providing a performance-based approach where bigger weight is on a risk-based approach. The safety barriers are looked upon as the fundamental elements in improving process safety in the EU. Although the performance-based tactic takes more energy to evaluate safe amenability, it can supply accommodate new technologies and different conditions (Sutton, 2014).

Uncontrolled release of dangerous materials and failure of several levels of protection were only a few reasons of a catastrophic incident in Bhopal, India on December 3, 1984, and the Piper Alpha disaster in the North Sea on July 6, 1988. Therefore, safety in the process industry became a critical issue for governments and professional organizations in order to promulgate regulations to enhance process safety. Accidents such as Sierra Chemical Company in 1998 at Mustang, NV, Union Carbide Corp on 1999 at Hahnville, LA, and explosion at Pascagoula, MS on 2003 proved that implementing the regulations just by themselves are not enough. Therefore, the need emerged to go beyond legal compliance to prevent incidents.

3. IMPACT OF MAJOR INCIDENTS

Based on National Safety Council's statistics in 2010, employers paid $1 billion per week for direct workers' compensation costs. In 2009, the economic impact of workplace incidents in the U.S. reported approximately $142.2 billion each year and the production loss due to injuries is equivalent to 80 million days lost each year (Council, 2009). Each incident has different impacts on the business. In addition to fatalities and injuries which are the irreversible impacts, there are some environmental and financial effects involve. Safety is not a cost. In fact, if everything is done safely the production will increase or at least no reduction in the production. Liberty Mutual in a survey conducted among executives that (Mutual, 2001):

- 9% indicated safe workplace has a positive impact on companies' financial performance
- 61% suggested that for every $1.00 safety invested, $3 or more return was seen
- 13% reported that $10 is returned for each $1.00 invested in safety
- 40% felt between $3.00 and $5.00 of indirect costs for each $1 direct costs of injury or incident

From the devastating legacy of Bhopal tragedy in 1984 to the Macondo disaster in the Gulf of Mexico in 2010, it has been proved that incidents can affect people, environment, the reputation of the company, and end up with other legal issues such as criminal charges. (BP, 2010; Mannan et al., 2005; Mannan, 2017). The adverse effects of industrial incidents to the societal loss have been evaluated in numerous studies (Carter and Hirst, 2000; J.K.Vrijling and Gelder, 1997; Kim et al., 2012; Prem et al., 2010). Moreover, there are other economic implications such as property damages, business interruptions, and legal expenses. Economic consequences such property damages include the recovery time and its expenditures, and the insurance cost. Based on 2015 property damages values, the total accumulated value of the 100 largest losses is more than 33 billion U.S. dollars (Marsh, 2016).

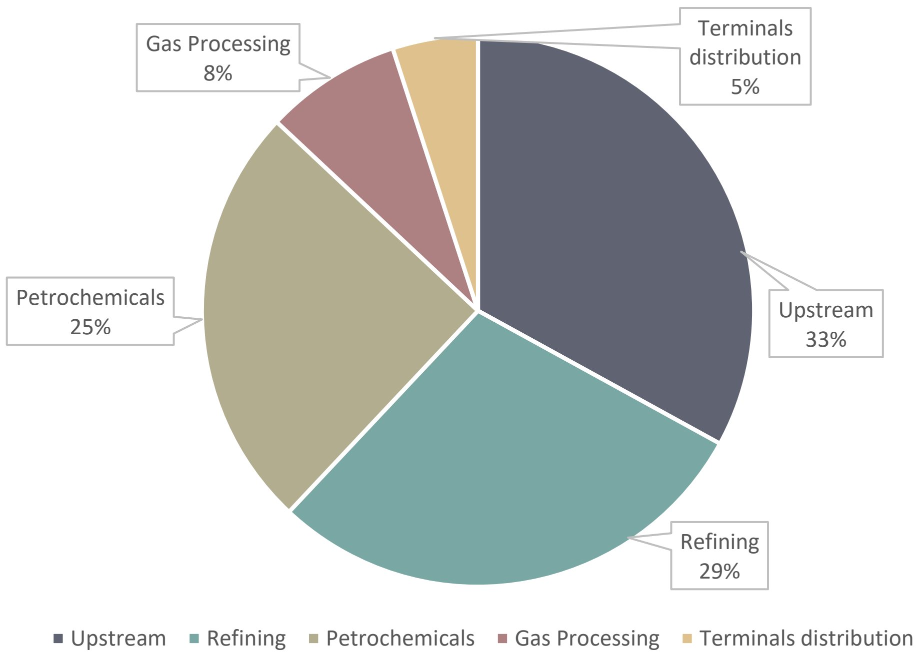

Figure 4-Property damage values of 100 largest losses by sector in 2015 (Marsh, 2016)

Business interruptions can end up in stopping the production or even some prohibition, and affect the organization's market share, its customers, and their orders deadlines. Legal expenses such as the cost of lawyers that should be hired by the company, settlements, and fines. For instance, some estimations evaluate the BP incident about 62 Billion dollars plus "BP settlement of criminal charges related to the Deepwater Horizon disaster was followed by incidents for two rigs supervisors. Each one faces up to 199 years in prison, charged manslaughter for 11 deaths in the blowout" (Justice, 2013). Also, the reputation of BP hurts from this incident and not just BP the whole industry. Another disaster, Piper Alpha oilrig explosion occurred on July 6, 1988, which is to this day the worst offshore oil accident regarding the number of fatalities. The amount of monetary estimation was approximate $4 billion (Hopkins, 1999). The incident led to insurance payments of more than $1.4 billion in property liability claims, $ 187 MM in depth payments to 142 of the victims, $990,000 to the injured employees, and also Occidental responded to the incident cost the company additional $55.4 MM (Kim et al., 2012).

In addition to the fatality, which is irreversible and injuries that may happen because of incidents, some of the studies found a significant drop in stock market mainly due to environmental damages (Blancard and Laguna, 2010; Klassen and McLaughlin, 1996; Rao, 1996). However, all studies do not agree with this hypothesis (Jones and Rubin, 2001).

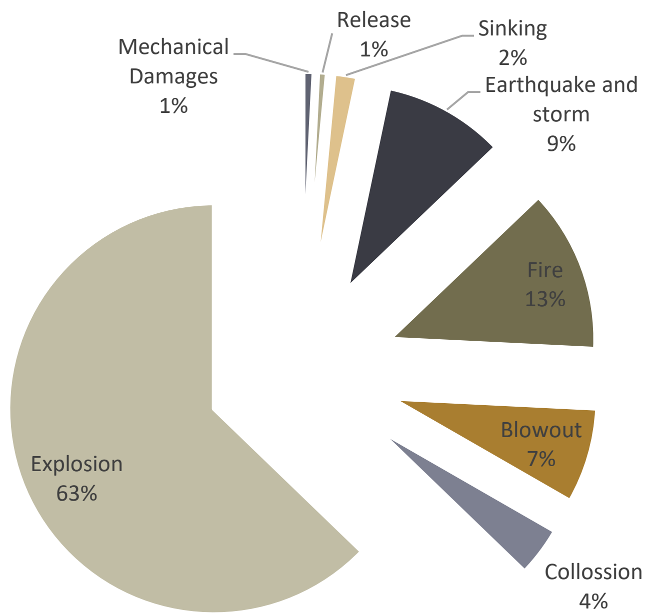

Figure 5-Property damage values of 100 largest losses from 1974 to 2015 (Marsh, 2016)

When Bhopal incident happened, Union Carbide faced with a dramatic reduction in revenue due to the assessed damages, cleanup costs, liability costs, production loss, employees injuries and fatalities (Mannan, 2012a). In addition, the production from another facility, which used methyl isocyanate (the substance that was released at Union Carbide Limited plant), had to stop for further investigations. The bottom line is that Union Carbide, which was one of the most competitive chemical manufacturers, no longer exists. The reputation of the whole industry was tarnished. Moreover, in the result of the tragedy. A number of regulations were established to protect public from the use of and production of hazardous chemicals in chemical facilities. The refinery explosion at Texas City in 2005 caused 15 fatalities injured more than 170, and more than 1 billion dollars in financial losses to the company. In addition, the citations for several violations led to fines of $21 million dollars. The Macondo incident, which was the catastrophic disaster in the US offshore history is estimated to have caused +$20 billion of losses for the companies involved mainly from litigations, fines, and cleanup efforts (Kim et al., 2012).

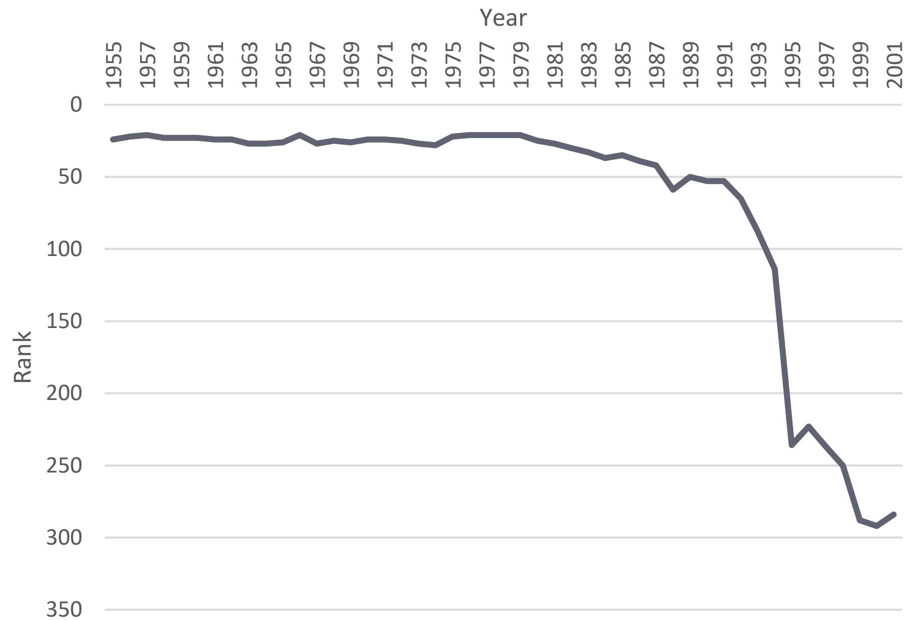

Figure 6-Fortune 500 rank of Union Carbide based on annual revenue (Fortune 500, 2017)

4. LEADERSHIP

“Strong leadership is a cornerstone of best-in-class safety management” (Mannan et al., 2013), where leaders’ and managers' behavior and their commitments can bring and maintain safety in any organization. Good leaders lead by examples, and leaders’ and managers’ behavior are influenced by organization behaviors. Organizational behavior is “ a field of study devoted to understanding, explaining, and ultimately improving the attitudes and behaviors of individuals and groups in the organization” (Wesson et al., 2017). Moreover, supervisory attitudes, which predicted adequate financial performance, overlap with the behaviors that result in effective safety performance (Eakin, 1992; Mattila et al., 1994).

Leadership involves not just about the people in the board room or the chairman of the companies but all levels of the organization, starting naturally with the chairman, board of directors, the president of the company, and various levels of leaders. All these people have responsibilities regarding safety. As evidence when these people are not entirely engaged and fully committed to safety, it would be tough to accomplish best-in-class safety culture. In addition, when we talk about leadership commitment there is a need to think about leaders’ accountability and responsibility. In order for leaders or senior managers to be responsible and accountable, they should be highly competent and involved in occupational and organization safety. Stakeholders hold leadership to higher standards of occupational and organizational safety and prevailing laws in many countries make it illegal to compromise safety for profit. Many recent incidents happened as a result of either personal or process safety management failures, or both. Table 1 shows some of these incidents.

Table 1-Example incidents

Incident	**Date of occurrence**	**Personnel impact**
BP/ Transocean rig explosion in the Gulf of Mexico	2010	11 killed
Explosion and fires at the Tesoro refinery in Anacortes, Washington	2010	4 killed 4 injured
Imperial Sugar Company dust explosion and fires, Georgia **(CSB, 2009)**	2008	14 killed 37 injured
Chemical explosion, T2 laboratories. Jacksonville, Florida **(CSB, 2009b)**	2007	4 killed 32 injured
Texas City BP refinery Explosion	2005	15 killed 180 injured
Bunce field explosion, Hertfordshire oil storage, England **(BMIIB, 2008)**	2005	43 injured
Explosion and fire in Formosa Plastic Cooperation, Illiopolis, Illinois **(CSB, 2007b)**	2004	5 killed 3 injured
Dust explosion, Kinston, North Carolina **(CSB, 2004)**	2003	6 killed 36 injured
Pasadena, polyethylene release- fire and explosion, Phillip 66, Houston, Texas **(Yates, 2011)**	1989	23 killed 130-300 injured
Piper Alpha oil rig explosion, North Sea **(Mannan, 2012d)**	1989	142 killed 21 hospitalized
Bhopal disaster, India **(Mannan, 2012c)**	1984	3,787 killed 558,125 injured
Mexico City, fire, and explosion, San Juanico company **(Pietersen, 1988)**	1984	542 killed 4200 injured
Flixborough (Nypro) explosion, UK **(Mannan, 2012b)**	1974	28 killed 36 injured
Texas City disaster **(Stephens, 1997)**	1947	581 killed +5000 injured
East Ohio gas co, tank overloaded **(Mannan, 2005)**	1944	131 killed 225 injured

Leaders need to be highly visible, and they need to provide necessary encouragement to accomplish good safety performance. With the understanding that leaders must to be competent in safety, it means that leaders can demonstrate the personal commitment that conveys safety as a core value. Safety as a first priority is a good approach, but it is not enough since priorities may change by the circumstances. For example, priorities those parents have for their child changes in time. However, the core value, which is always to raise responsible children, is a core value to parents.

Different things can motivate a leader to push the staff to do the job safely such as regulatory compliance avoiding legal liabilities. However, safety goes beyond the regulations. Safety is not just filling the papers to satisfy the rules. A leader should make sure that managers use skilled employees for inspection, leading frontiers, understanding risks, etc. Other factors are necessary to make a leader a perfect safety leader such as a degree from management school, management experience in safety, design experience, and operation experience. For example, in Dow Chemical organization at the first level of leadership, the person who is responsible for a group of people or a unit should participate in the 3-month probation period. At the end of the three months, the leader has to demonstrate her/his knowledge on the process safety of the facility in front of a committee of experts. This program is not intended to be part of the training of the leader. The training should have occurred before the session (Mannan, 2017).

Safety leadership begins at the cooperate level where the mission and objectives are established. The cooperate level leadership commands safety management systems and site-level mechanisms. For example, incident investigation, safety committees, safety tracking systems, maintenance and inspections policies, hazard analysis, behavior observation, and feedback loop system are cooperative level commands. Moreover, the corporate level usually sets up an audit system to measure how well commands are implemented on-site.

In 1998, Cooper introduced two important behaviors for a leader: safety caring and safety controlling (Cooper, 1998). Blair in 2003 pointed out seven leadership behaviors for building safety excellence: establish expectations, exemplary behavior, engineering support, educate employees, enable employees, encourage employees, and evaluate effectiveness (Blair, 2003).

4.1 Role of leadership in assuring personnel competency for process safety

The Center for Chemical Process Safety (CCPS) included personnel competency as an element of risk-based for evaluation process safety (CCPS, 2007). Snowball has shown that more than 50% of major incidents are caused by human failures (Snowball and Travers, 2012), which can be much more than this number. Many incidents are somehow related to human factors.

Indeed, people are a huge part of safety issues in personal safety management, and all levels of the organization affect process safety management. For instance, if the senior executive does not completely understand risks and hazards or relies entirely on the designed system(system where risks have not been detected in the design yet) then a disaster can result. Another example is site managers who focus more on production than safety or expect specialists just take care of safety. Frontiers who failed recognize hazards, underestimate circumstances, perform shortcuts, or do not participate in training classes can cause catastrophes in the organizations as well.

Human factors can directly have an effect on safety performance, either on personnel themselves or those who are responsible for all aspects of the design and operational processes by controlling the existing procedures. Barry Kirwan called this human-human interaction and the interaction between society's complex infrastructures and human behavior a “soft system” (Kirwan, 2002), which means, the system is not purely technical or social in character.

Process safety is different from personal safety. Process safety mostly focuses on scenarios with a lower probability that might result in major incidents, but personal safety focuses on scenarios with low consequences and a high probability such as falls or slips. A good leader should emphasize both and cannot ignore either. Some guidelines and leaders’ responsibilities that can improve the safety performance of an organization are discussed below:

4.1.1 Set direction by power and influence

The first task of a leader is setting the direction for employees. A leader makes the employees’ mission and vision clear to avoid any mixed messages and push everyone toward the best safety performance and zero-incident-organization. Mostly middle managers and frontiers look at the senior leaders in the organization to set the directions regarding safety. This action and behavior of senior leaders will determine the level of importance and commitment placed on safety. Making a balance between decisions is not easy. For instance, investing money in improving safety is a long-term investment, and if the profit of the organization goes down, the leader will lose his/her job. Therefore, the way that the leader convinces shareholders and sets the directions inside the company is vital. When the leader does not pay enough attention to the safety and just sets directions on the production, managers and frontiers will recognize that at the end of the day their numbers regarding production is crucial. Hence, they primarily focus on production rather than safety. When the safety is treated as the core value in leaders’ directions, the safety performance will improve. Moreover, leaders must be able to create and share a safety vision among staff and enable the workforce to deliver that vision. Leadership is the most important key to making changes in the organization. Leaders should be well trained to be able to influence the staff and carry out the necessary changes to include safety behaviors.

To set everyone on the right track, leaders benefit from their ranking power and personal power. Ranking power is given by the organization and includes legitimation, reward, coercion, and information sources. Subordinates give personal power and include expert, reverent, persuasive, and charismatic sources (Lunenburg, 2012). Leaders influence safety performance through their movements and their failure to act (technology, 2004). Leaders can benefit from different influencing power tactics such as legitimating tactics, rational persuasion, inspirational appeals, coalition tactics, upward appeals, and Leader-member exchange on followers.

4.1.1.1 Organizational commitment

Not having enough talented employees to perform a job is an important issue. The key factor to have a safe organization is to have talented staff along with low employee turn-over. High turnover can increase the cost of training and increase the probability of incidents due to the lack of experienced employees. The U.S. Bureau of Labor Statistics estimates that the average American will have 10.8 jobs between ages 18 and 42 (Shepherd, 2010), which is not satisfactory regarding safety issues. The turnover loss cost estimated between 90 percent and 200 percent of an employee's annual salary in 2010 (Allen et al., 2010). Due to the above reasons, it is better to engage employees more with the organization. Increasing employees' commitment to the organization will help to improve the job performance and reduce the turnover.

There are different methods to categorize organizational commitment. Based on Dr. Wesson and his cohorts, commitment is divided into three different types (Wesson et al., 2017):

- Affective commitment (Emotion-based)
- Continuance commitment (Cost-based)
- Normative commitment (Obligation-based)

Affective commitment defines as a willingness to stay with the organization due to some emotional reasons such as friendship, the atmosphere, the culture of the company, the job satisfaction, etc. Continuance commitment can be defined as a desire to stay with the organization because of financial consequences. For instance, if an employee leaves the job she/he will lose some bonuses or need time to find another job, so she/he may prefer to stay with the organization. Normative commitment is the feeling to stay with the organization because of the sense of obligation (Allen and Meyer, 1990). For instance, the employee feels responsible to the boss because the organization has invested so much time to train her/him.

All these three types of commitment can create an overall sense of psychological attachment to an organization. Of course, each employee is different and affected by a specific factor more. Therefore, a leader should try to make employees more engaged by improving their commitment. Hiring skilled and responsible managers with a good personality along with the ability to work with teams effectively is an executive example that a leader can enhance their normative commitment.

4.1.2 Resources

Having sufficient resources for improving safety performance is an obligation. Resources can be divided into two types: human resources, and budget resources. A leader has to make sure that the organization has enough employees and managers to rotate staff between shifts since human failures cause significant numbers of incidents as a result of fatigue. In fact, rotating staff between shifts can reduce these errors. Not having enough human resources will increase pressure on employees to finish the job on time. Being under staffed may also increase employee turnover that causes a massive increase in training cost and risks of incidents due to the lack of enough practice.

Budget is another sort of resource. Cost-cutting has an effect on the safety margin (Zwetsloot et al., 2014); Rasmussen introduced “drift to danger” from the tension between safety and productivity, which can be a drift to disaster in hazardous companies (Rasmussen, 1997). Laying off employees to a level where low-level staff becomes detrimental to safety or replacing low educated staff with higher qualified staff to reduce cost will hinder safety performance. A leader must ensure their budget resource provides enough physical resources such as tools, equipment, and safety. A great example is the Bhopal catastrophe, which ended up with +3000 fatalities and several failures blamed on budgeting.

Leadership must, therefore, launch a process that shall be used in selecting, investing and prioritizing among the many corporate projects that need funding and decide which project intends to improve safety performance.

4.1.3 Align staff -teamwork and support

After setting direction, a leader should align staff with that particular direction. Leaders and managers motivate employees to work together along with respecting each other since, with better behavior, a healthier work environment will result. The work environment is in the top three reasons that employees quit their job, and the resulting turnover increases risks. Therefore, a leader has to create a supportive psychosocial work environment with appropriate and fair workloads for everyone.

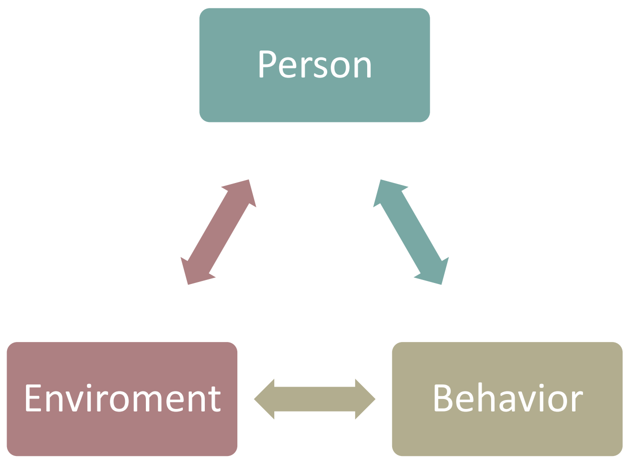

Figure 7-Behavior, Environment, and Person relation

The senior leaders should make sure to give the vision to the staff to understand and "see" what safety performance superiority would look like in the organization. It is important to know that conveying this vision should be done in a compelling manner, and not only through their words but also through actions (Krause, 2004).

Team work increases safety commitment and ultimately lessens incidents (Barling and Frone, 2004). In fact, when a company has effective teamwork, each employee becomes a safety leader and indeed, becoming a zero-incident-organization would be much easier when staff is on the same page about safety issues. Everyone should be a team worker, from shareholders to the lowest ranked employee in an organization. Establishing a process safety management forum can help managers to share their experience with others, which leads to improving managers' commitment as well.

Leaders are responsible for establishing supporting standards and systems. A supporting standard is critical for the organization to adhere to and a supporting system is vital to protect and support the staff. Policies such as sexual harassment and workplace safety are examples of supporting standard regulation to protect employees.

4.1.4 Accountability

An excellent safety leader gives employees a fair evaluation of safety efforts and results, clearly, communicates people's role in safety and looks after the sense that the public is accountable for the level of safety in their group unit. To develop accountability, a leader can establish clear safety responsibilities for direct reports from lower ranks to higher ranks. For some leaders, this is problematic since they accept too much themselves. The leaders might identify behaviors such as asking those direct reporting how they would handle a problem instead of simply suggesting a solution.

4.1.5 Communication

A leader should be an excellent communicator and maintain an effective strong relationship with people working under his supervision. The leader can go on the shop-floor, speak to employees, and evaluate their hazard understanding and how they manage excited risks. A leader must be a sympathetic listener and be able to ask the right questions from employees. Having open communication can build trust between staff, leaders, and managers. When trust comes to organizations, employees fell ownership, and they will report any unfavorable report truthfully. This communication should be in all directions: up to down, down to up, and across the organization. Leaders must have a strong internal communication with the staff and external communication with local communities, as well as local, state, and federal organizations.

Process employees and contractors are the main internal stakeholders for a safe process. Effective leaders' communication engages employees more to participate in process safety activities, safety risk management, incident investigation, procedure developments, training courses, inspections, and maintenance programs. "A well-functioning process safety program depends on maintaining successful communication interfaces between each involved employee or stakeholder and the many other employees or stakeholders that person must interact with" (Kelly and Berger, 2006).

4.1.6 Push and pull

Pulling means leaders should set their expectations and rules for all staff in order to pull employees follow their orders. At the same time, leaders should award employees when they are following rules and procedures. In fact, they should push employees to do tasks safely. Leaders should apply regulations completely in their organizations and motivate all staff to follow them along with other standards. Also, management system should have reliable documentation system to document employees' performance regarding safety.

4.1.7 Educate employees

Any leader has to make sure the organization has a proper education program. Just training employees to do the job safely is not enough. Leaders should establish an education program, which coaches employees to think safely and tries to give them a "safety spirit." Indeed, education is the main body of knowledge; meanwhile, training refers to the necessary knowledge and tools for a specific operation or task. Having a consistent training and forum increases employees' knowledge and makes them more involved in acting safer.

Managers' training classes should revalidate each year. By changing technologies, regulations, and procedures, new training classes are required to improve staff awareness and prepare them to implement new rules or technologies. In other words, "process installations have become even more complex today than ever before. Process control and safeguarding equipment are more complex, thereby increasing newer risk which is often unforeseen" (Qi et al., 2012). Therefore, more advanced education programs are unavoidable. Training and competency of employees are not only legal requirements, but also are a way to improve personnel commitment, PSM program, and safety performance. Companies have to ensure that their employees are fully trained and competent to perform operations, do maintenance, and work in compliance with the operating procedures.

Another aspect of education systems must include learning system. Organizations should have a learning system to use the feedback from normal and abnormal situations and make the proper changes or improvements to the designs, operations, and maintenance programs to reduce the risks and improve the safety of the organization.

4.1.8 Understanding risk and communicating meaning of risk to others

There are always some risks associated with any type of production. Hence, it is leaders' responsibility to understand the situation, type of plant, materials, production, etc. to evaluate the risk with respect to the public and the governmental expectations. In fact, a leader, by developing a system to address, prioritize, and ranking the risks, can perform the hazard management more efficiently. Risk assessments may involve identifying and evaluating hazards and risks, selecting the hazards to address, and deciding how to reduce associated risks.

4.1.9 Flexibility

All leaders should make sure that the organization and the staff have the ability to detect, adapt, and react to any external disturbance. These disturbances can be natural such as an earthquake, or any human-technological incident. A leader should ensure to hire resilient engineers and develop a system that is flexible and can absorb such events. "Resilience engineering helps to recover system states after incidents happen rather than prevent incidents from occurring. Incident prevention is a subject of study in other process safety areas (e.g., risk assessment)" (Dinh et al., 2012). In other words, "work system design must be flexible, recognizing that variability management is as important as variability reduction. In fact, the design should support the natural human strategies for coping with hazards, rather than enforce a particular strategy" (Costella et al., 2009).

4.1.10 Control and evaluate effectiveness

"The safety goal is to ensure that activities take place in controlled, and therefore safe, manner" (Mannan, 2014). Hence, precise measurements have to be taken to evaluate safety in an organization. There are different indicators and evaluation methods, which will be discussed later in this paper. Safety leaders need leading indicators, which predict injuries with statistical validity. Such indicators help the organization to have some proactive measures that prevent injuries (Krause, 2004). An obligation of leadership is to ensure that adequate oversight and supervision are provided to all workers. Adequate oversight is based on the maturity of workers and safety culture of the organization. As organization benefits from basic controlling program issues such as weak compliance to following standards, procedures, and practices, poor use of a work PPE will disappear.

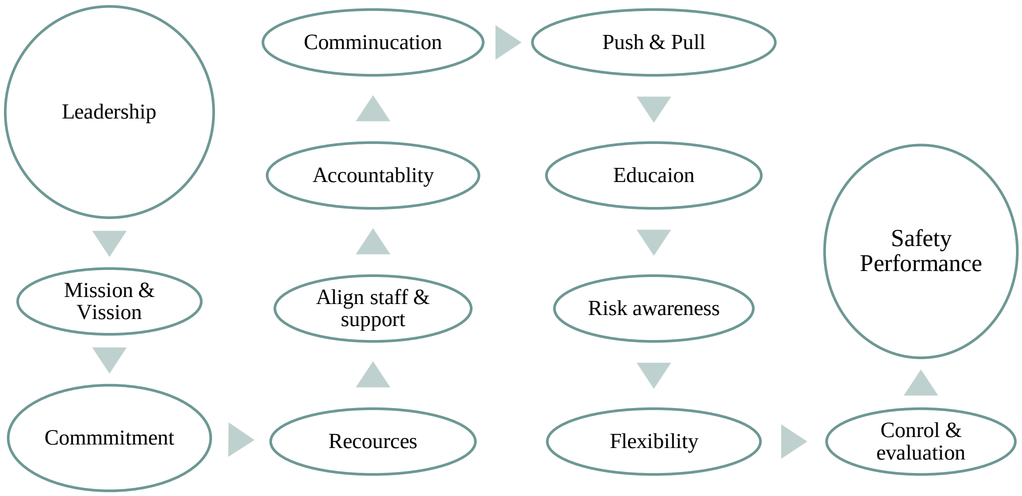

Figure 8-Role of leadership in improving the Safety performance

After Buncefield, the UK Process Safety Leadership Group gathered in 2007 to drive safety improvements. This group, made of representatives from Chemical Industries Association (CIA), Tank Storage Association, The UK Petroleum Industry Association, the UK Onshore Pipeline Association Unite, which was representing Trade Union Congress, the Scottish Environment Protection Agency, the Environment Agency and Health & Safety Executive (HSE), set out eight guidelines, which emphasize the importance of strong leadership from the board to the companies' floors to manage the risks of potential hazards. They stated that (PSLG, 2007):

- Positive and transparent process safety leadership is at the center of managing major hazards and is critical to guarantee that risks are effectively managed
- Process safety leadership requires board level involvement and competence
- Effective safety management does not happen by chance and requires constant active engagement
- Board level visibility and promotion of process safety leadership is critical to establish a positive safety culture throughout the organization
- Leaders should bring a system to engage workforce to achieve a good process safety management
- Monitoring process safety performance based on both lagging and leading indicators in central to ensure risk being effectively managed

- Publication of process safety information provides important public assurance about the management of risks by an organization
- Sharing best practices across the organization, and learning and implementing from relevant incidents in other organizations, are important to maintain the sharing culture of knowledge and aptitude

5. PROCESS SAFETY MANAGEMENT SYSTEM

Although some regulations and standards exist, a zero-incident-organization should set agendas for itself. The methods to mitigate hazards are far beyond the codified regulations. Leaders and managers can benefit from regulations to manage risks. However, these regulations are not enough. Regulations should follow new research to develop new management systems to ensure the highest standards for safety. For instance, when the West, TX explosion happened, the OSHA inspector had been there 28 years earlier and had issued them a fund for $35, so OSHA is not enough on its own (Mannan, 2017). Leaders should form and develop process safety management systems in a way to learn from others' incidents and accidents, provide efficient process design, format maintenance systems, be responsible for providing hardware as needed, guarantee safety procedures, and create a safety culture.

Developing safety systems to have a sustainable safety performance is an obligation, hence for an energy system; some additional associated components have to be considered in safety matters: type of resources, support characters, and their relation to safety issues. In addition, other components include the time frame for productions (exploration), the output energy's shape and associated hazards, area that these resources are located at, distribution systems and hazards. There is a series of elements that are significant such as tools, procedures, process design, and clear task-schedules i.e. what, where, how, and by whom, tasks must be done. Who should monitor all results, clarification of the methods, and other unknowns. Evaluating the results, reporting how the system works, consist plan improving, and at the end documenting outputs are some other elements of designing a sustainable management system.

There are several safety systems (standards and regulatory systems) to practice and measure process safety:

- OSHA, January 2017
- HSG254: Developing process safety indicators, A step-by-step guide for chemical and hazard industries, HSE, 2006
- Process Safety Leading and Lagging Metrics, CCPS
- Process Safety Performance Indicator for the refining and petrochemical Industries, American Petroleum Institute (API), RP 754, Version 3, 2016
- EPA Risk Management program (Federal Register 40 CFR part 68), 2017

- American Chemistry Council
- Process Safety-Recommended Practices on Performance Indicators, International Association of Oil &Gas production (OGP)
- Guidance on Process Safety Performance Indicators, CEFIC
- SEVESO Directive III, 2015

For instance, Occupational Safety and Health Administration (OSHA) promulgated a 14 element regulation for PSM with the purpose of preventing catastrophic release of energy or substances that are hazardous chemicals and avoiding or minimizing the consequences of disasters such as the release of toxics, reactive, flammable, explosive, or a combination of these properties to employees, the community and the environment (OSHA, 2000). In fact, PSM is the proactive identification, evaluation and mitigation or prevention of chemical release that could occur as a result of a failure in the process, procedure, or equipment.

Table 2-PSM-OSHA Standards

Elements	Presses Safety Management Elements	OSHA Standard
5.1	Employee Involvement	1910.119(c)
5.2	Process Safety Information	1910.119(d)
5.3	Process Hazard Analysis	1910.119(e)
5.4	Operating Procedures	1910.119(f)
5.5	Training	1910.119(g)
5.6	Contractors	1910.119(h)
5.7	Pre-Startup Safety Review	1910.119(i)
5.8	Mechanical Integrity	1910.119(j)
5.9	Hot Work Permit	1910.119(k)
5.10	Management of Change	1910.119(l)
5.11	Incident Investigation	1910.119(m)
5.12	Emergency Planning and Response	1910.119(n)
5.13	Compliance Audits	1910.119(o)
5.14	Trade Secret	1910.119(p)

5.1 Employee participation

Safe operation and maintenance need both staff and employers participation. Therefore, OSHA requires employees involvement to address all core elements of the PSM program. There are different participation methods, such as through anonymous communication, employee representation, direct involvement, and consultation. Employees participation output data can help to find the performance of PHA programs, incident prevention plans, and the conduct of incidents investigations, audits, and other activities. The employer must provide a written Employee Participation Plan (OSHA, 1995). This plan should contain a clear statement of purpose and statement, which all employees at all ranks within the plan will be directly involved. All staff must be kept informed regarding PSM and have easy access to the statement.

5.2 Process safety information

Process safety information (PSI) is a compilation of written guidelines for process safety and is made accessible to all levels of employees to facilitate the understanding and recognizing of hazards (Mannan et al., 2001). Before the starting investigating of other accidents/incidents, training, PHA, or management of change, PSI is needed. There are different types of PSI information (OSHA, 2017):

The chemical information shall consist of at least the following:

- Toxicity
- Permissible exposure data
- Physical data
- Reactive data
- Corrosivity data
- Thermal and chemical stability data
- Hazardous effects of inadvertent mixing of dissimilar materials

Technology information must contain at least the following:

- Simplified process flow diagram or a block flow diagram
- Process chemistry
- Process limitation (pressure, temperature, composition, flows)
- Maximum intended inventory
- Consequence of process deviation

Equipment information in the process must include the following:

- Materials of construction
- Piping and instrumentation diagrams
- Electrical classification
- Ventilation systems
- Material and energy balances
- Relief system design and design basis
- Designed codes and standards employed
- Safety systems: interlock, detection, monitoring and suppression

5.3 Process hazard analysis (Process Safety Analysis)

In many forms of energy systems, hazardous chemicals are involved. Process Hazard Analysis (PHA) is being used as a systematical approach to identify, evaluate, and control hazards in the system. The PHA methodology should address the hazards correctly, evaluate previous hazardous incidents, provide engineering and administrative controls applicable to dangers such as providing early warning of releases, evaluate human factors and consequences of the failure of controls, and estimate the effect of failure on employees. A team is needed to have an efficient process hazard analysis. This team consists of people with different expertise in engineering and process operations, an employee who has work experience in that process, and a member that has knowledge in the particular PHA method that is being used.

A leader and facility should establish a systematic way to address the team's finding and recommendations, assure recommendations are resolved promptly, documetns resolutions, instruct what should get done, complete the actions in the specific time frame, plan a schedule for actions, and transfer and communicate the actions to related employees and managers.

The facility shall keep all documents on file and make them available to EPA and/or OSHA on request and at least every five years. The process hazard analysis should be updated and revalidated by a team to ensure the PHA is consistent with the current process. Hiring a trained PHA leader can be very helpful, especially when there is a process that changes more than once per five years.

PHA must be selected appropriately regarding the complexity of the processes and units. The hazards can be evaluated and determined by one or more of following methods:

Checklists: Primarily used for a process that is covered by standards, codes, and industry practices. Highly related to the experience of the people who developed them; if the checklist is not filled out completely, the analysis may not identify hazardous situations.

What-if: This method includes different incident scenarios, consequences, and safeguards to recommend some possible risk reduction alternatives.

What-if/checklist: Can help to identify hazards and accidents that are beyond the team members' experience.

HAZOP: Originally developed to determine both hazards and operability problems at chemical plants.

Fault Tree Analysis (FTA): This method is a deductive technique. Focuses on a specific incident or main system failures and provides a method for determining cases of the event. Graphic display of equipment failures and human errors that can result in an incident are available. Suitable for highly redundant systems (AIChE).

Failure Modes and Effects Analysis (FMEA): Evaluate the ways in which equipment fails and the system's response to the failure. The FMEA focus is on single equipment failures and system failures. Usually, suggest recommendations for equipment consistency, does not examine human errors directly, is not effective when cascade equipment accident happens, and can be updated for design or system changes.

Below tables are adapted from AIChE guidelines and incidents and show what techniques are more appropriate for particular steps in a process design and operation.

Table 3-PHA techniques vs. phases

Phase	PHA Techniques					
	Checklist	What-if	What-if/Checklist	HAZOP	FMEA	FTA
R&D		✓				
Design	✓	✓	✓			
Pilot plant operation	✓	✓	✓	✓	✓	✓
Detailed Engineering	✓	✓	✓	✓	✓	✓
Construction	✓	✓	✓			
Routine operation	✓	✓	✓	✓	✓	✓
Modification	✓	✓	✓	✓	✓	✓
Incident investigation		✓		✓	✓	✓

Table 4-Timing and Staffing for PHA techniques vs. steps

Time and staffing for PHA Techniques (AIChE)						
Steps	Checklist	What-if	What-if/Checklist	HAZOP	FMEA	FTA
Small System						
Number of Crew	1-2	2-3	2-3	3-4	1-2	2-3
Preparation	2–4 h	4-8 h	6-12 h	8-12 h	2-6 h	1-3 h
Modeling						3-6 d
Evaluation	4-8 h	1-3 d	6-12 h	1-3 h	1-3 d	2-4 d
Documentation	4-8 h	1-2 d	4-8 h	2-6 d	1-3 d	3-5 d
Large/Complex Process						
Number of crew	1-2	3-5	3-5	5-7	2-4	2-5
Preparation	1-3 d	1-3 d	1-3 d	2-4 d	1-3 d	4-6 d
Modeling						2-3w
Evaluation	3-5 d	4-7 d	4-7 d	1-3 w	1-3 w	1-4 w
Documentation	2-4 d	4-7 d	1-3 w	2-6 w	2-4 w	3-5 w

W= 40 hours a weekly; h= hours; d= eight hours a day

5.4 Operating procedures

Operating procedure of the plant must be documented in writing to provide a clear required instructions to personnel regarding safety. Steps for each phase: normal operation steps, operation procedures for upset conditions, temporary operations, start-up, and shutdown should also be complete and make readily available and be kept up to date. Operating Limits. These phases should be stated clearly and reviewed as often as needed. Many incidents have resulted from inadequate work practice or a failure to follow existence procedures. Employees must certify annually that the operating procedures are current and accurate.

5.5 Training

The regulation requires that organizations certify employees who are responsible for operating facilities. The effective training is a significant step. It must cover safe work practices, emergency operations, safety and health hazards, refresher training, maintenance training, and operation training. The refresher training must occur as often as it is needed (at least every three years).

5.6 Contractors

The PSM regulation identifies responsibilities on or near covered process of the employees regarding contractors performing maintenance or repair, turnaround, major renovation or specialty work, (OSHA, 2000). The contractor should ensure that contract employees are being trained well and document that training, explain facility's emergency action act, and periodically monitor contractor's safety performance. Contract employees follow the facility rules like others, inform contractors of potential process hazards, and advise host contractor regarding potential hazards as well.

5.7 Pre-start-up safety review

This element of the PSM requires a pre-start-up safety consideration of all new and modified facilities to confirm the integrity of equipment, and that training of operating has been completed.

This element also assure proper safety, maintenance, and emergency procedures are in place and authenticate that process hazard analysis has been performed. Three out of thirty-eight major incidents investigated by the United States Chemical Safety and Hazard Investigation Board (CSB) since 1998 occurred during startup of continues process equipment (CSB, 2014). Changes usually happen during maintenance, and therefore, maintenance staff should be well proficient in pre-startup safety appraisal procedure (Mannan et al., 2001).

5.8 Mechanical integrity (MI)

This element considers the importance of maintaining the mechanical integrity of critical process equipment to ensure it is designed and installed appropriately and operates well. The employer should provide written instructions. Involved employees must be trained in an overview of that process and its hazards. MI is committed to providing the benefits of the most up-to-date inspection technologies. These controls and tests may happen weekly, monthly, and annually based on manufacturers' recommendations and facilities engineers experience. MI is not just about maintenance; however, maintenance is a major part of it. In constructing new plants and equipment, the employer must make sure that equipment is suitable for the task, equipment is installed properly, and appropriate checks and inspections have been designed. Based on OSHA PSM, Mechanical Integrity requirements apply to the following equipment:

- Pressure vessel and storage tanks
- Piping systems including piping components
- Relief and vent systems and devices
- Controls including monitoring devices and sensors, alarms, and interlock
- Pumps

5.9 Hot work permit

This step guarantees that employees are aware of the hot working environment and equipment before the start working. The permit shall be issued for hot work operations conducted on or near a covered process. The fire prevention and protection permit in OSHA regulation must be implemented before beginning the hot work operation.

5.10 Management of change

Management of Change (MOC) is a written program to manage changes in technology, procedure, equipment, chemicals, and new safety instructors. This written program should ensure to include necessary time needed for changes, authorization for changes, the technical basis for change, and the impact of the changes on employee safety and health, and modification of operating procedures. Employees and contract employees who operate a process and maintenance that are affected by changes should be informed and trained. The employer should update process safety information and operating procedure as necessary.

5.11 Incident investigation

This element is to find the incident's root cause to avoid it happening later; incidents investigation is dramatically necessary. The Incident Investigation element orders employers to start the investigation of the incident as soon as possible, within less than 48 hours. The investigation team must consist of at least one person knowledgeable in the process involved, including contract employees if the worker was involved, and other people with appropriate knowledge, investigation experience, and analyzing investigation skills. The team should document findings, and reports must be retained for five years.

5.12 Emergency planning and response

In any organization, the employer should develop and implement emergency action plans to respond effectively to any hazardous situation. OSHA regulation requires companies with more than ten employees to prepare a plan of urgency in the case of hazardous chemical release (OSHA, 2000). OSHA established emergency action plan according that requirements of 29 CFR1910.38 (a) and 29 CFR1910.120 (a), (q), and (p).

5.13 Compliance audits

This element helps the employer and the organization, in general, to certify that they have evaluated compliance with process safety requirements at least every three years. There are two major purposes for auditing. The first is to assess whether the management system in place sufficiently addresses all elements of PSM. The second is to evaluate whether the management system has been adequately applied to all levels of facilities or processes. There are different types of auditing: self-audits and independent audits, PSM system audits, detailed PSM performance audits, and regulatory compliance audits (OSHA PSM and EPA RMP).

5.14 Trade secrets

The trade secrets facility of PSM information should be available to employees: those persons who are developing the process hazards analyses, those responsible for developing the operating procedures, those responsible for performing incident investigations, those who are responsible for emergency planning and responses, and those who are compliance audits. The regulation permits employers to enter into confidentiality agreements to prevent disclosure of trade secrets.

6. PROCESS SAFETY RISK MANAGEMENT APPROACH

Risk and safety are connected both conceptually and logically. The conceptual relation can be described by defining risk and safety. Risk has been defined as the likelihood that something unwanted can happen or a situation that includes exposure to danger. Safety likewise has been defined as the absence of unwanted events, which means the absence of risk. The logical relation is that by having safer processes or environment, the risk of an incident happening (unwanted event) would be lower. Reducing risk to zero is logically impossible, and something always can go wrong. Therefore, to ensure safety by preventing events from happening, reducing risk to the level of elimination is the best choice. Reducing risk is not possible except by knowing the risks and hazards that are associated with the process and the facility. Hence, there are considerable numbers of well-established risk assessments methods and risk management programs (Aven, 2013; EPA, 2004; EU, 2012). Risk can be categorized in different areas as is shown in Table 5.

Table 5-Risk analysis categories

Risk analysis category	Purpose
Health	• Disease and loss of life
Safety	• Natural disasters • Technologies • Systems and procedures
Security	• War and Riot • Terrorism • Crime • Misinformation
Financial	• Individual • Organizational • Societal monetary losses and gains
Legal	• Probability of innocence or guilt beyond reasonable doubt • Hypothesis tests
Environmental	• Losses due to noise • Contamination • Pollution in the ecosystem

Energy companies based on their location and the countries, which they are operating should adopt the necessary regulations and make a risk management program to prevent, mitigate, and respond to unacceptable risks. There are three types of risk assessment: quantitative risk assessment, semi-quantitative risk assessment, and qualitative risk assessment. The risk in quantitative assessment is calculated in the form of numerical probability or frequency of an event and the consequences' distribution. Semi-quantitative assessment use order of magnitude for frequency and outcome magnitude for non-sensitive parts of a system. Qualitative risk assessment uses ordinal scales like low, medium and high. This type of assessment is often used for screening risk assessment and should be applied to advise stakeholders and provide a system for the deliberation of their cultural, socioeconomic, and religious values, as well as the risks to human health and the environment associated with the pollution of Department of Energy facilities and their remediation (ResearchCouncil, 1994). A leader should provide a trusting atmosphere, and by the board members support, senior managers, and expert staff combine these three types of techniques to understand hazards better, use appropriate barriers in order to reduce the risk of hazards, and avoid unpleasant events.

As demonstrated in the BP Texas refinery incident investigation, it is probable to have a good occupational safety record and still have a high level of process safety (Khan et al., 2010). Such an incident like BP does not happen without warning. This is supported by many major incidents that have occured happened where the weakness of process safety performance was the main reason. Hence, a comprehensive and suitable system to manage and measure process safety is required.

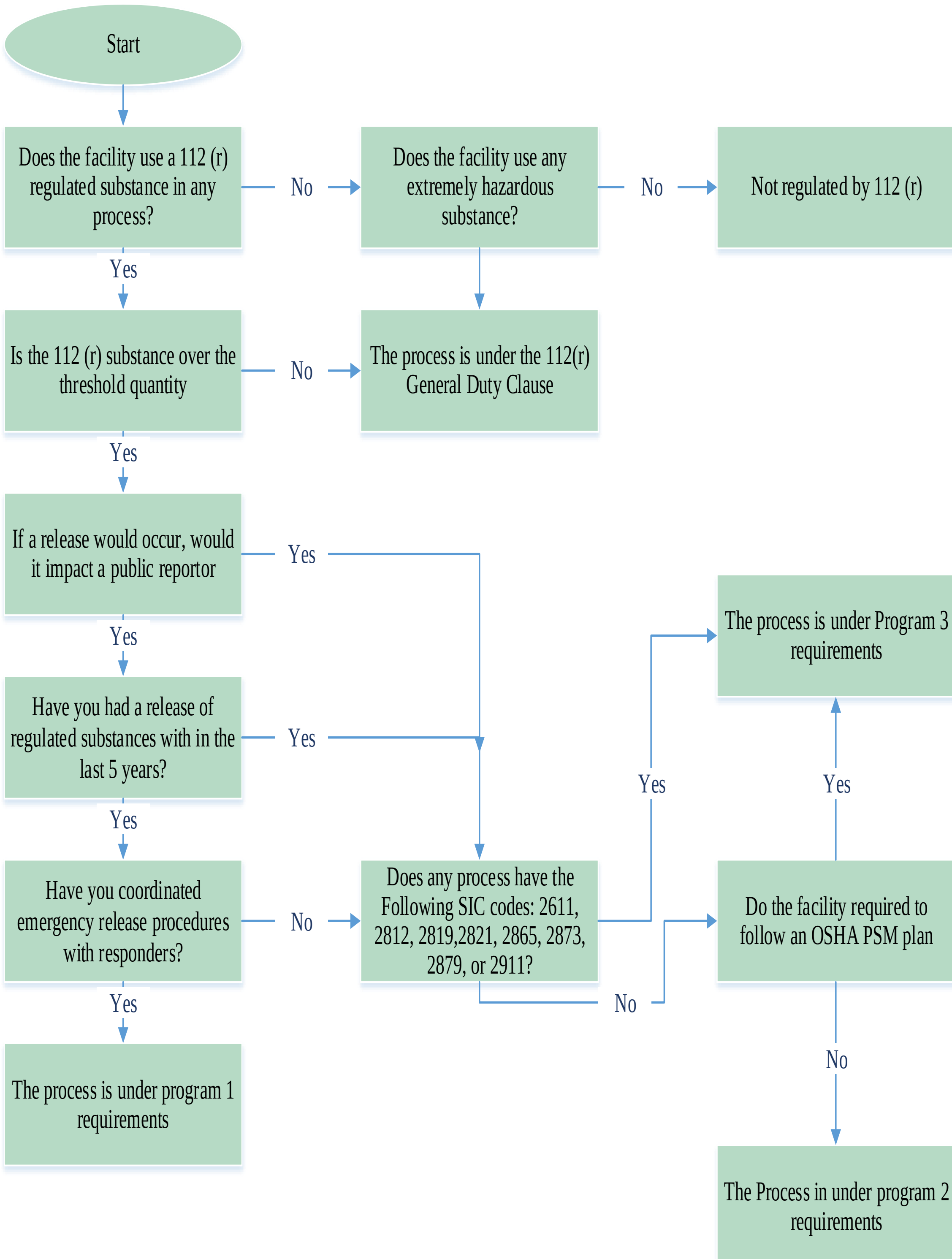

Figure 9-EPA Risk identification

6.1 EPA Risk management program

EPA, under the Clean Act Amendment obligates any energy organization that owns tanks, drums, pipes, containers, or other processes at its facility that contains hazardous toxic and/or flammable substances listed in the CFR (Code of Federal Regulation) at 40 CFR 68.130 in an amount above the threshold quality specified for those materials should implement a risk management program (RPM) (EPA, 2009). The purpose of risk management program is to prevent incidental releases of substances that can cause severe damage to the public and the environment from short-term exposure and to mitigate the severity of releases that do happen.

EPA in 2016 proposed to revise its Risk Management Program (RMP) regulations to enhance "chemical process safety, assist local emergency authorities in planning for and responding to incidents, and improve public awareness of chemical hazards" (GPO, 2017). The origin of the proposal is President Obama's Executive Order (EO) 13650, which was issued after the disastrous explosion that happened in April 2013 that killed 15 people in West, Texas.

Three main changes after the President's EO are targeting the core of the RMP. First, the proposed rule would want all facilities with program 2 and 3 to conduct a "root cause analysis" as a portion of an accident investigation of a catastrophic release or an incident that could have rationally lead to a catastrophic release (i.e. near miss) (Bergeson, 2016). Second, regulated facilities must contract with an independent third party to perform a compliance audit after the facility has a reportable release if they are at Program 2 or 3. The previous rule authorized self-audits. Third, the proposal would require owners and operators of facilities with Program 3 which regulated processes, to implement safer technologies and alternatives analysis (STAA) as a part of their process hazard analysis, and to assess the possibility of any inherently safer technology (IST) identification (Bergeson, 2016; Keim et al., 2015).

Generally, part 68 requires the following:

- Covered facilities must develop and conduct a risk management program
- Maintain documentation of the program at the site
- The risk management programs include an analysis of potential offsite consequences of a worst-case scenario of release
- A five-year accident history
- Release prevention program (like OSHA)
- Emergency planning (like OSHA)

- Risk management plans should be submited to EPA- The RMP is available to federal, state, and local government agencies and public with some restrictions
- Covered facilities must update their RMP periodically or when certain process or other changes occur

Organizations should have safety managers to evaluate whether or not they are subject to the rules, determine the level of requirements and the programs that are applicable to cover the process, realize what specific risk management program activities must be implemented, select a strategy for conducting a risk management program, etc. The first step is determining if any of processess are covered by this RMP program, and if yes, which?

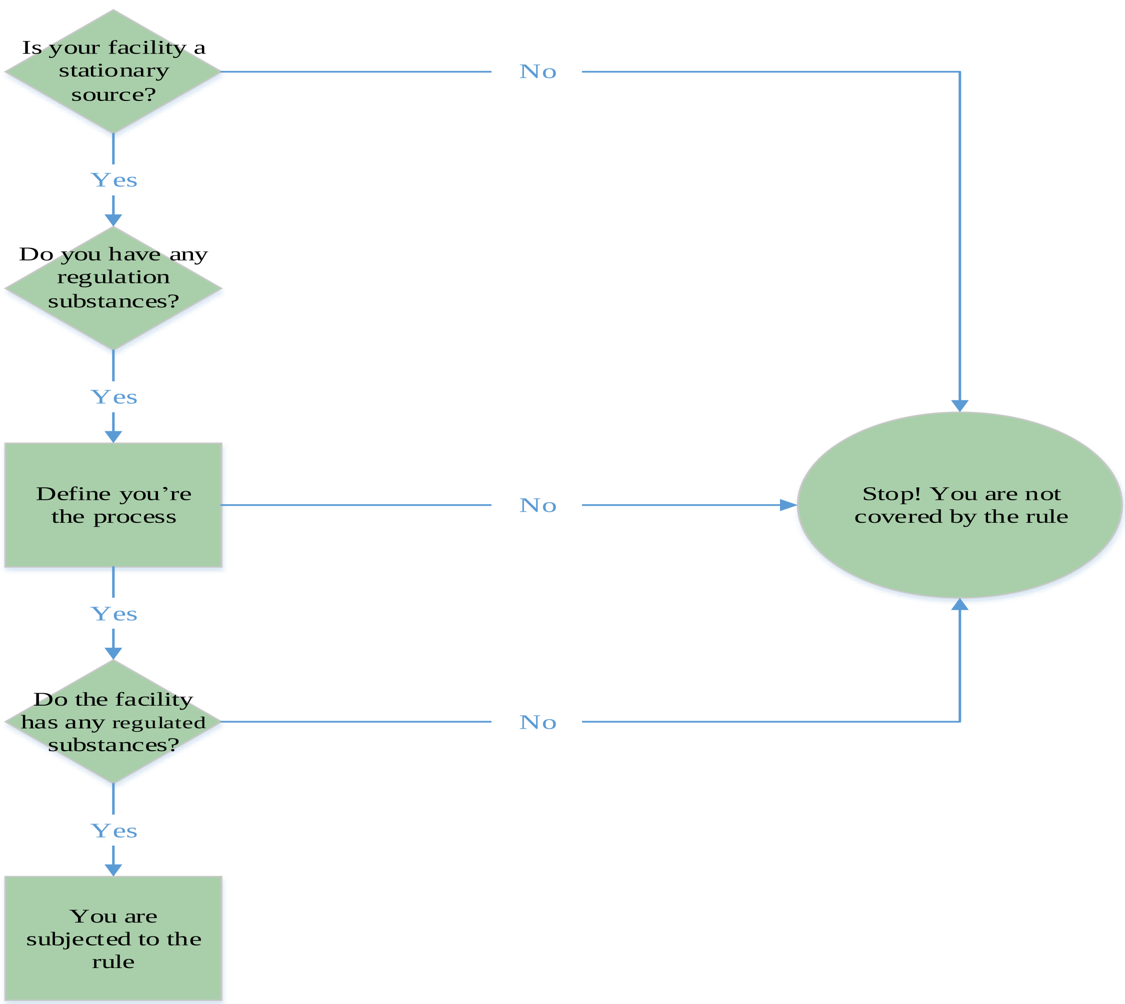

Figure 10-Deciding whether the facility is subjected to RMP or not?

The second step would be determining the level of the program for each covered process. As the safety managers identify which process or processes are subject to the rules, they must decide what actions must be taken to comply. The rule defines three program levels based on processes' relative potential for public effects and the level of effort required to prevent accidents. The rule clarifies requirements that reflect the level of risk and effort associated with the process for each program level. These program levels have been defined as below:

- Program 1-Processes which would not affect the public in the case of a worst-case release and also have not had incidents with specific offsite consequences within the past five years are eligible for program one. This program requires limited hazard assessment to minimize hazard, prevent incidents, and prepare emergency responses (Emergency Response coordinates with local responders)

- Program 2- Process which is not eligible for Program 1 or subjected to Program 3 are considered as Program 2. Streamlined prevention programs, additional hazard assessments, process safety management, and emergency responses are required

- Program 3- In this program, processes are not eligible for program 1 and either subjected to OSHA's PSM standard under federal (state) OSHA programs or classified in one of nine specified SIC codes that are placed in Program 3.

The third step is EPA's requirements for the facility and each covered process which are shown in Figures 11 and 12. The last step is assessing the operations to identify current risk management activities and review the regulations and EPA's guidelines to develop a strategy for conduction the additional actions the facility requires to take for each covered process. "Leaders are required to discuss these issues with managers and staff. Early involvement of both management and employees will help develop effective program" (EPA, 2009). Table 6, a summary of these three programs is presented:

Table 6-RMP programs descriptions

Program 1	Program 2	Program 3
Hazard Assessment	**Hazard Assessment**	**Hazard Assessment**
Worst-case analysis	Worst-case analyses	Worst-case analysis
5-years history	5-years history	5-years history
No additional step required		
	Management Program	**Management Program**
	Document management system	Document management system
	Prevention Program	**Prevention Program**
	Safety information	Process hazard analysis
	Hazard review	Opiating procedures
	Operation procedures	Training
	Training	Mechanical Integrity
	Maintenance	Incident Investigation
	Incident investigation	Compliance audit
	Compliance audit	Management of Change
		Pre-startup safety review
		Contractors
		Employee participation
		Hot work permits
	Emergency Response Program	**Emergency Response Program**
	Develop plan & program	Develop plan & program

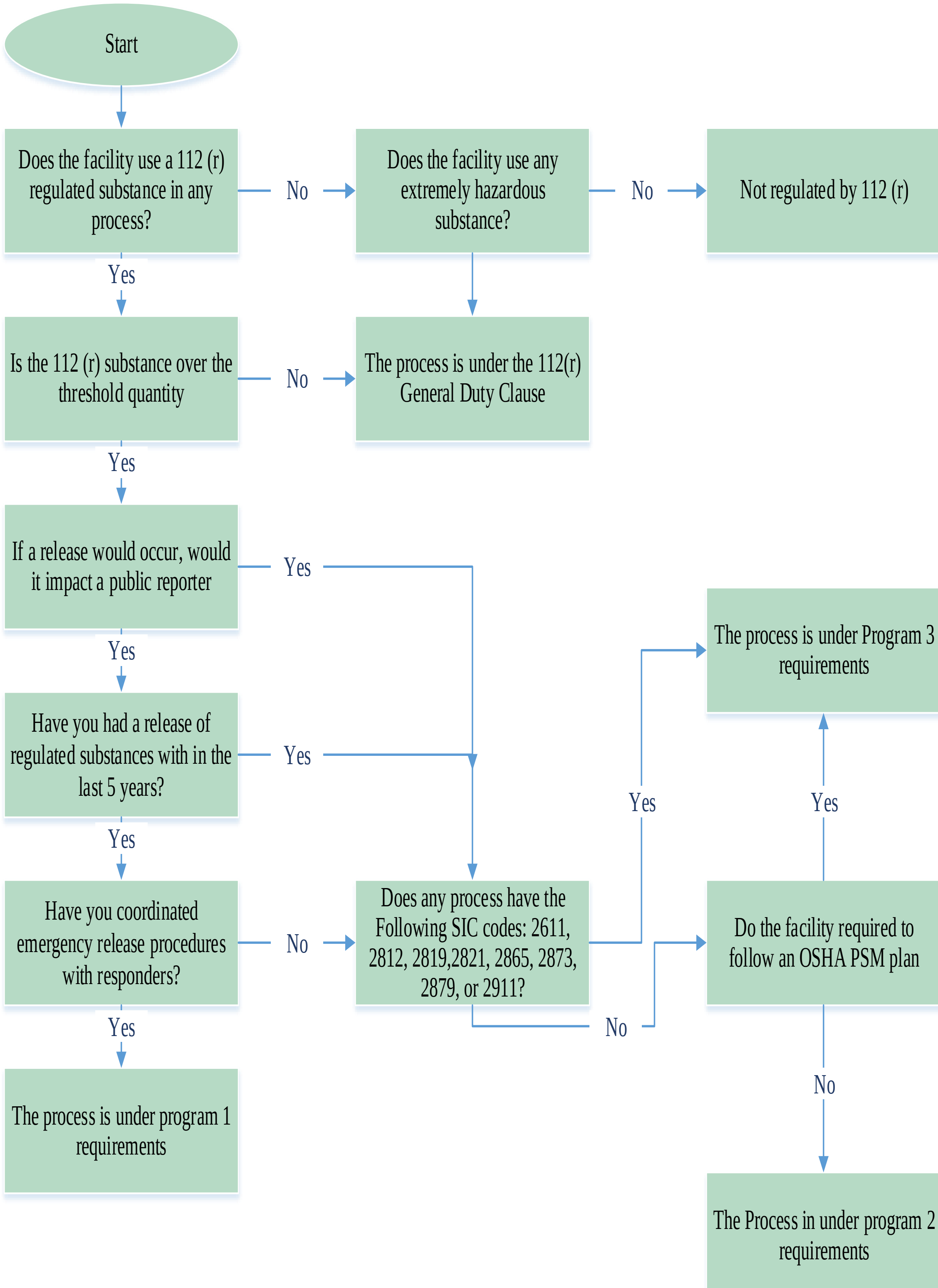

Figure 11-112(r) decision tree (EPA, 2004a)

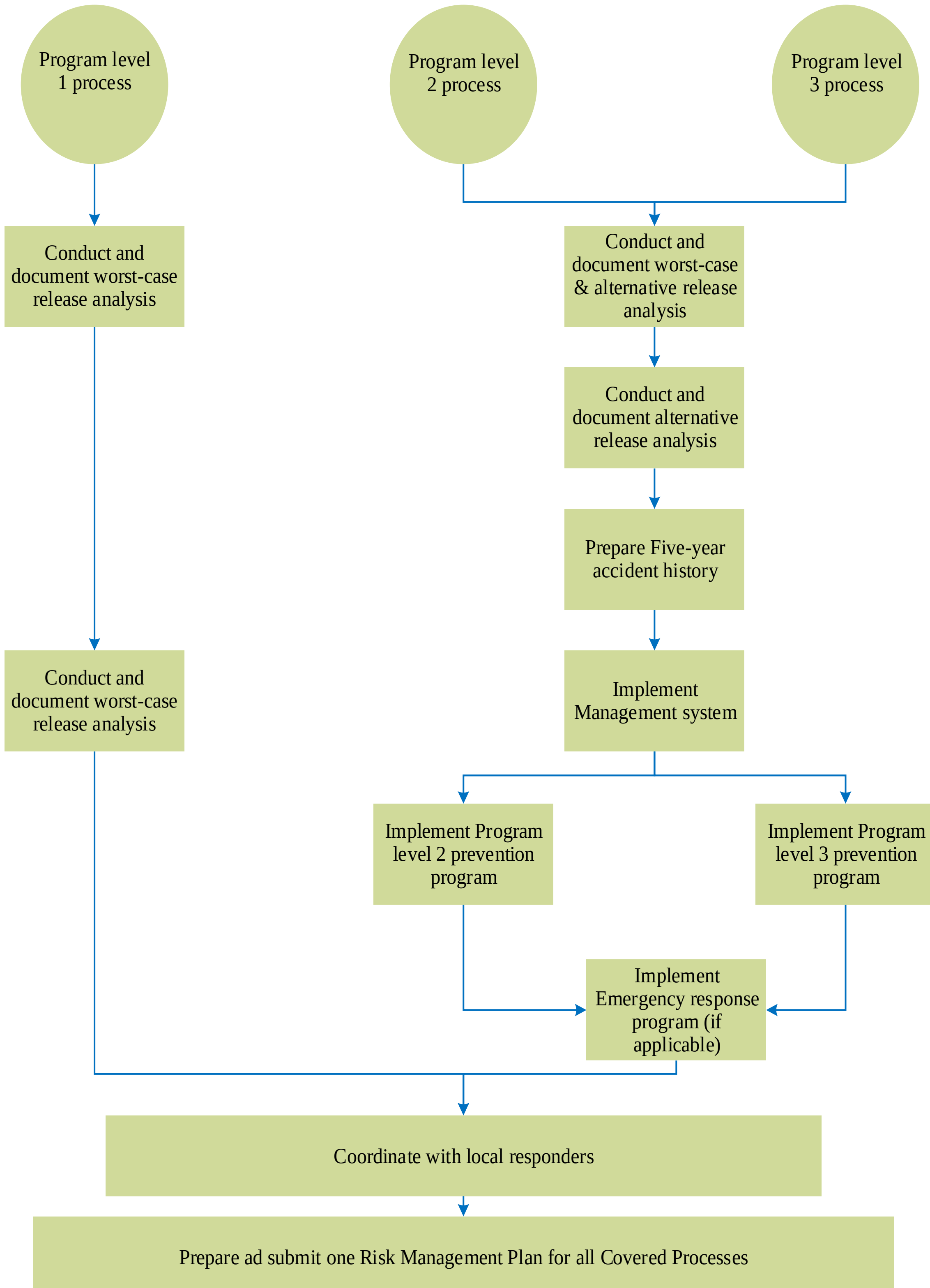

Figure 12-Risk Management Program (EPA, 2004a)

EPA’s risk management program has a different set of exemptions than the OSHA PSM standard; EPA exempts some processes that OSHA does not exempt and vice versa. The principal areas in which requirements of the EPA differ from OSHA rules are:

- A different chemical and threshold list for some chemicals. For instance, The RMP threshold quantity for Acrolein is 5000 lbs., but in the case of PSM threshold quantity is 150 lbs.
- EPA requires hazard assessments that include analyses of the worst-case incident consequences but not OSHA
- EPA requires preparation of written risk management plans to document the RMP but not OSHA
- RMP must be registered with the EPA but not OSHA

6.1.1 Management system

If energy organizations have at least one of the Program 2 or Program 3, the management is required to (EPA, §68.15) develop a system to manage the implementation of the risk management program elements and task a qualified individual or position with the overall responsibility for the development, execution, and integration of the risk management program elements. Moreover, the management system needs to document the names of individuals or positions and explain the lines of authority through an organizational plan (chart) or a similar document. Defining the lines of authority, roles and responsibilities of staff will help to make sure operative communication about process changes exists between divisions, to clarify the roles and responsibilities related to process safety, to avoid conflicts and problems among the employees that are responsible for applying elements, and to ensure that the program elements are cohesive within a continuous approach for recognizing hazards and managing risks.

Managements’ commitment to process safety is a necessary part of any facility’s risk management program since the program requires ongoing implementation of incident prevention and emergency response measure. More importantly, managements’ commitment should not stop after the risk management plan is submitted to EPA (EPA, 2004).

6.2 SEVESO directive

Continued use of Risk-informed principles and safety barriers in European regulation such as SEVESO III Directive, Seveso II Directive (EC, 1996a), Machinery Directive (EC, 1998), national regulations as the management regulation from Petroleum Safety Authority Norway (PSA, 2001), and standards such as IEC: 61508 (IEC:61508, 1998), IEC: 61511 (IEC:61511, 2002), ISO: 13702 (ISO, 1999) confirm the status of safety barriers in order to reduce the risk of incidents. Different techniques have been used in the various sectors of the energy industry such as, the Swiss cheese (bow tie risk model) or "Success pathways" and "Defense in Depth" in the nuclear industry, and techniques such PHA and/or detailed risk assessment studies in the oil and gas sectors.

Council Directive 96/82/EC repealed by Directive 2012/18/EU (SEVESO III Directive), which was effected June 1, 2015, aims at prevention of major accidents including dangerous substances and limitation of their consequences. The provisions contained in the directive were developed following a fundamental review of the implementation of Council Directive 82/501/EEC (SEVESO I). The Directive introduced two levels of requirements corresponding to "lower tier" and "upper tier". There is a requirement for lower tier "establishment" to draw up a Major Accident Prevention Policy (MAPP) designed to assurance a high level of safety for humans and the environment with proper tools including suitable management systems. "Establishment means the whole location under the control of an operator where dangerous substances are presented in one or more installation" (EU, 2012). Lower tier and upper tier are defined regarding substances' quantities.

6.2.1 Major accident prevention policy

MAPP shall be written to ensure that it is applied properly. The MAPP shall be designed to guarantee a high level of safety for human health and the environment. MAPP shall be balanced based on major accident hazards. It shall contain the operator's overall aims and principles of action, the role and accountability of management, the confermation of in the direction of nonstop improvement of the control of major accident hazards, and confirming a high level of protection. MAPP shall be adopted by nations laws and sent to the competent authority within a specific time. Moreover, MAPP shall be implemented by appropriate means, structures and by a safety management system proportionate to the major accident hazards and the complexity of the organization or the actions of the establishment.

6.2.2 Safety management System

Failures of the management system are shown as the reason for over 85 percent of the reported incident (EC, 1996b). There are different terminologies to define management, however, the "management loop" concept, which consists of agreeing on an objective, defining a plan to attain that objective, formulating the exhaustive work required to implement the plan, carrying out the work, monitoring the outcome of the plan, and planning and taking appropriate corrective actions, is vastly accepted.

Safety management systems should hold the part of the general management system, which consists of the organizational structure, tasks, practices, procedures, processes and resources for defining and applying the MAPP. SMS shall be proportionated to the hazards, industrial activities, and the complexity of the organization in the establishment and be based on an assessment of the risk. The operator must draw up a document setting his MAPP out, which intends to give an overall view of how the operator ensures a high level of protection for man and the environment. Seven areas shall be addressed by the safety management system:

- Organization and personnel
- Identification and evaluation of major hazards
- Operational control
- Management of change
- Planning for emergency
- Monitoring performance
- Audit and review

6.2.2.1 Organization and personal

The roles and responsibilities of personnel involved in the management of major hazards at all levels of the organization shall be clear. Training courses for staff, involved employees and subcontracted personnel working in the establishment are necessary and shall be addressed by SMS.

SMS should reflect the employees' commitment and the safety culture of the organization. The responsibility of whoever is involved in the management of major hazards should be clarified at all levels of organization. Skills and abilities needed by such personnel should be identified. The operator must ensure the involvement of employees and contractors. In particular, the operator should make sure that contractors receive the necessary information and training to enable them to be aware of the involved hazards and to satisfy safety policies.

6.2.2.2 Identification and evaluation of major hazards

The management system should have a combination of systematic, theoretical, and practical approaches in order to identify and evaluate major hazards. Different techniques may use to identify risk such as incident data, checklist analysis, brainstorming, what if, HAZOP, FMEA, task analysis, event tree, fault tree, etc. The hazard identification and evaluation should apply to all step of the project, including:

- Potential hazards arising from planning, designing, engineering, construction, commissioning, and development activities
- Hazards of decommissioning, abandonment, and disposal
- Potential hazards from past activities
- Hazards from nature like unnormal temperature, fire, earthquake, etc.
- Hazards from neighbor activities
- Hazards from process operation such as start-up, shut-down, maintenance
- Hazards from material failures, human factors, and SMS failure
- Operating conditions
- Incident and possible emergencies

6.2.2.3 Operating Control

The following issues regarding operational control shall be addressed by a safety management system:

- Adoption and implementation of procedures for safety operation including maintenance of plant, process and equipment, alarm management and temporary stoppage
- Inventory of the establishment's equipment, strategy, and methodology for monitoring and controlling of conditions of the equipment
- Appropriate follow-up actions and any necessary countermeasures

- Management and control of the risk associated with old equipment installed in the establishment and corrosion
- Taking available information on the best practices for monitoring and auditing into account, with a view of reducing risk of system failures

In particular, these procedures should cover (EC, 1996b):

- Commissioning
- Start-up and normal periodic shut-down
- All steps of normal operations, including test, maintenance, and inspection
- Detection of and response to departure from normal operating conditions
- Temporary or special operations
- Operation under maintenance conditions
- Emergency operations
- Decommissioning

All these written procedures should be provided to all staff who are directly or indirectly responsible for operations, and they should be subject to periodic review to ensure employees are aware of following the procedures.

6.2.2.4 Management of Change

Management of change is "adoption and implementation of procedures for planning modifications to, or the design of new installations, process or storage facilities" (EU, 2012). Management practices involve recognition of change situations, the evaluation of hazards, the decision on whether to allow the change to be made and necessary risk control and follow-up measures (CCPS, 2007). This approach should address following issues:

- Identify potential change situations
- Evaluate possible impact
- Type of changes
- Schedule for implementing the change
- Duration of change
- Assignment of responsibilities and authorities for initiating change

- Documentation of the change proposed and its implementation
- Definition and implementation of appropriate post-change review procedures and corrective mechanisms
- Tools and techniques available to change review
- Training requirement

6.2.2.5 Planning for Emergencies

"Adoption and implementation of procedures to identify foreseeable emergencies by systematic analysis, to prepare, test and review emergency plans to respond to such emergencies and to provide specific training for the staff concerned. Such training shall be given to all personnel working in the establishment, including relevant subcontracted personnel" (EU, 2012). An organization shall have internal and external emergency plans.

6.2.2.6 Monitoring Performance

Organizations should implement a procedure for monitoring and controlling the compliance of objectives, which has been set by the safety management system and regulations. This step helps to build a mechanism for investigating and taking corrective actions in case of non-compliance. This monitoring should include reporting procedures that report major incidents, near misses, failure of barriers, and lesson learnt. In addition, this monitoring helps to evaluate the performance of indicators and changes that are necessary to improve the safety.

6.2.2.7 Audit and Review

Every organization shall implement and adopt a procedure for periodic systematic assessment of the major accident prevention policy and the effectiveness and sustainability of the safety management system. The result should be documented and reviewed by senior managements. Senior managers should apply new updates and changes as needed.

6.2.3 ARAMIS project

ARAMIS (Accident Risk Assessment Methodology for Industries), the project was accepted for funding in 2001 by European Commission. This three-year project started in 2002 based on conclusions and results of ASSURANCE and I-Risk projects in 5th Framework program for research and technological development in the field of "Energy, Environment, and Sustainable Development." The objective function of ARAMIS was to establish and develop a risk assessment methodology for evaluating the risk level associated with the process by operators in order to prevent and measuring the vulnerability to the environment. In fact, this project plans to determine the effects of severity of scenarios with respect to Reference Accident Scenarios (RAS), the prevention management effectiveness, and environment vulnerability estimation. In safety risk management system, it should be realized that safety management focuses on prevention and mitigation of incidents. Consequently, its efficiency can primarily be expressed by how much likelihood of major consequences can be reduced, rather than by the absolute magnitude of worst-case consequences.

ASSURANCE stands for Assessment of the Uncertainties in Risk Analysis of Chemical Establishments. This project was a benchmark exercise, which designed at an understanding of the sources and types of uncertainties connected with risk analysis. One of the main conclusion of this project was the differences were present both in the valuation of frequencies and in the assessment of consequences which profoundly effect on the relevant risk-informed decision principally in land use planning, emergency planning, and acceptability of risks.

The initial statement of I-RISK project, I for integrated, was the idea that Quantitative Risk Assessments (QRA) and safety management audits were two separate tools. Two separate tools would be valuable to integrate both to address major hazard management. As a result, the main purpose was first to develop a management prototypical for risk control and monitoring, then to implement this model into a dynamic QRA. The conclusion of the project proved that the integrated technical and management model was very robust and helped audit organization in a new way.

The need for a methodology that gives a consist rules to identify incidents scenarios and taking into account both prevention and mitigation measures for peculiar plant emerged from both projects and experiences in each European country. Those safety measurements should control by SMS and risk assessment methods in order to reach a consensus amongst risk experts from industry and competent authorities to reduce uncertainty and make risk-informed decisions. ARAMIS project has been set up to the proposition to achieve these two requirements.

The most important EU Directive is at aiding to protect people and the environment from major accident hazards is the SEVESO III Directive. This put on to industries that use “significant amounts of hazardous substance” (EU, 2012). These industries shall apply a major accident prevention policy, and they applied suitable prevention and mitigation procedures (measured) controlled and monitored in a safety management system (Hourtolou and Salvi, 2003a).

The main purpose of ARAMIS project is to combine the strengths of both deterministic and risk-based approaches and create a new integrated risk assessment methodology by combining the existed techniques in a way that different nation cultures can adapt it. ARAMIS has three distinct and independent indexes. The first one is to assess the consequence severity of first defined reference scenarios. The second index is to evaluate prevention management effectiveness, and the third index is to estimate the environment vulnerability by assessing the sensitivity of potential targets.

ARAMIS is based on a definition of risk. The risk is the probability that an element of the territory sustain damage (Salvi and Debray, 2006b). The probability can also define in terms of frequency. The level of expected damage is calculated by the vulnerability of the element and the intensity of the incident. In ARAMIS, the combination of frequency and intensity has been called the severity (Salvi and Debray, 2006b). This method aims at calculating vulnerability and severity separately to give two identification to decision makers to assess the resulting risk.

$$frequency \times intesity = severity$$
$$intensity \times vulnerability = damages$$
$$risk = frequency \times intensity \times vulnerability$$

ARAMIS assumed that the frequency or probability of an incident is determined by the frequency of initiating events, and the reliability and efficiency of the safety barriers that avoid the occurrence of this scenario. The efficiency and reliability of safety barriers are closely related and influenced by the quality of the management. The barriers should be designed properly, installed well, used right, maintained excellent, and developed frequently. All these features are addressed through the safety management system. In order to have efficient management system employees should contribute and have a clear understanding of how they can interact with the safety of the installations, which are related to safety culture.

6.2.3.1 Key Features of the ARAMIS methodology

ARAMIS is separated into the six major steps as follow in figures 13 and 14:

- Affiliation of major accident hazards (MIMAH)
- Identification of the safety barriers and assessment of their performance
- Appraisal of safety management efficiency to barrier reliability
- Identification of Reference Accident Scenarios (RAS)
- Assessment and mapping of the risk severity of reference scenarios
- Evaluation and mapping of the vulnerability of the plant's surrounding

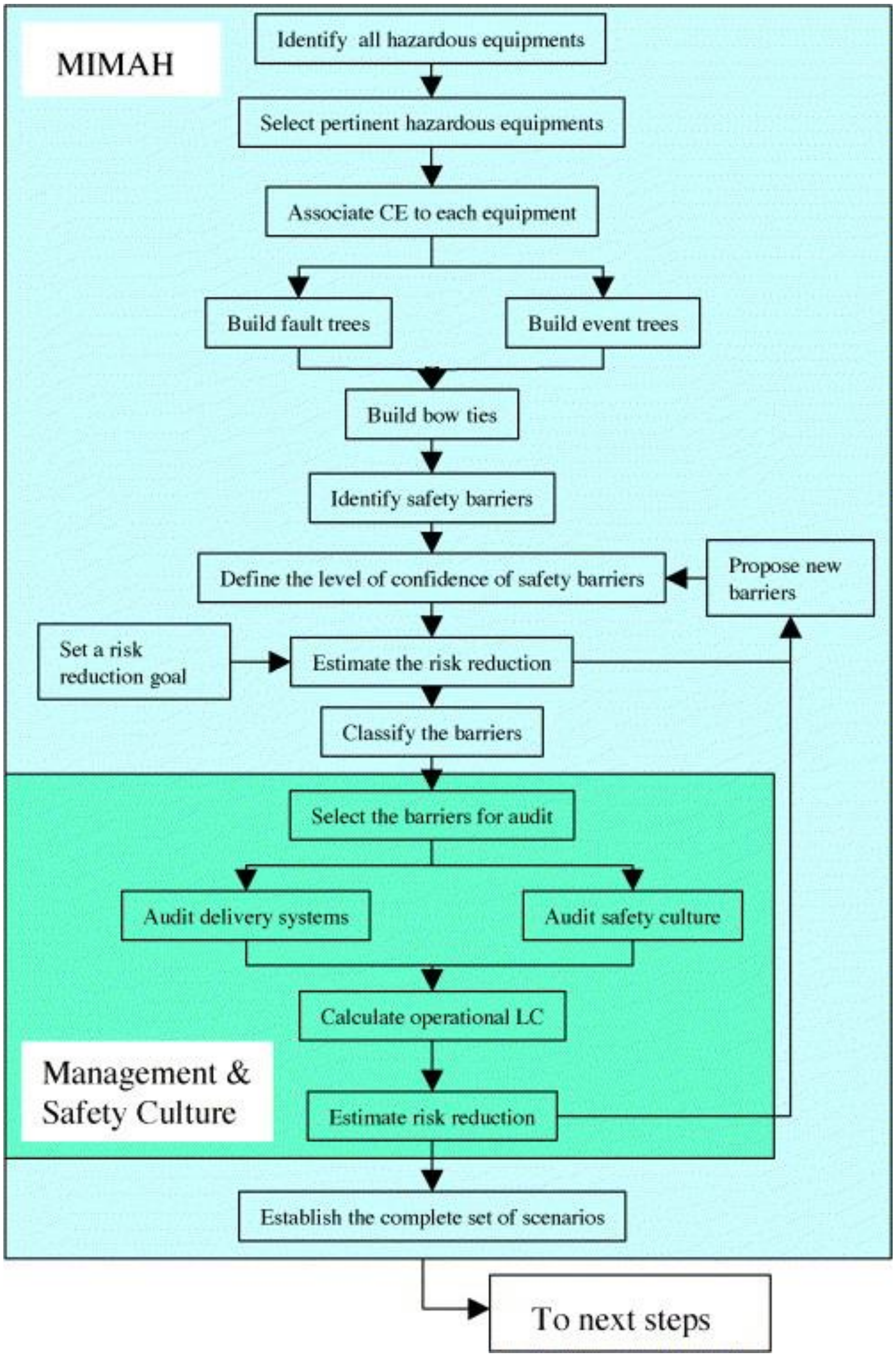

Figure 13-ARAMIS major steps (Salvi and Debray, 2006a)

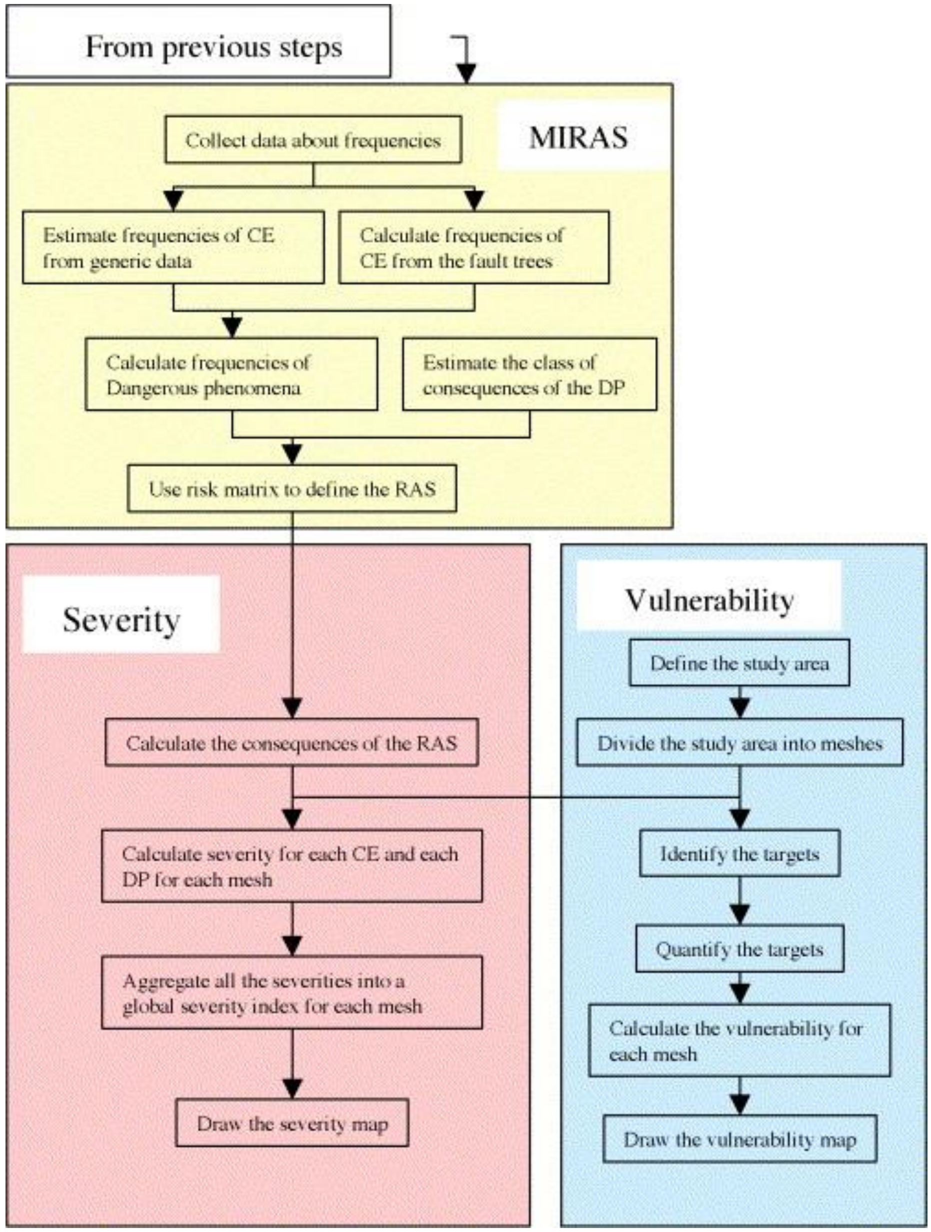

Figure 14-ARAMIS major steps (Salvi and Debray, 2006a)

6.2.3.1.1 Identification of major accident hazards (MIMAH)

MIMAH is the method for identification of major accident hazards, which is mostly based on bow tie diagram, composed of a fault tree and an event tree (Delvosalle et al., 2004). The major input of ARAMIS was to define an accurate bow-tie structure and describe precisely and comprehensively the list of equipment, potential critical events, and their consequences. The description of the plant including chemical substances has been used, produced or stored, able

MIMAH to list all critical events susceptible to occur in the plant. Then, for each of these critical events, MIMAH allows recognizing all their consequences regarding subsequent events and hazardous phenomena. Afterward, MIMAH provides the user with a set of generic fault trees, which are based on the most frequently observed causes (Debray et al., 2004). It is important to notice that both the fault and event trees are considered without safety barriers, which will be introduced in the next step of ARAMIS method to make an explicit distinction between hazard and risk. The first phase allows identifying the hazards, and the next one aims to determine the associated risks, which result from the hazard scenarios and the fault of safety barriers. Part of the outcome of the risk analysis is the identification of existing barriers is to be considered largely or lines of defense.

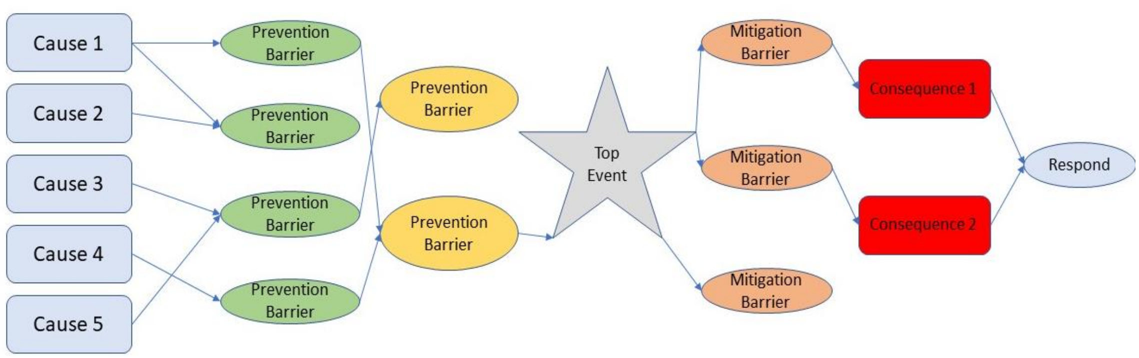

Figure 15-Bow-tie model

6.2.3.1.2 Safety management system

The management has a strong impact on controlling the risk. ARAMIS provides tools to evaluate the safety management system (SMS) and the safety culture and by the competent authorities help the operator to recognize the opportunity for enhancing safety management. Safety management is defined as the set of management actions that guarantee that hazards are effectively identified, understood, and minimalized to a level that is sensible achievable. In ARAMIS project, minimizing risks mainly happens by implementing and maintaining safety barriers or lines of defense. Therefore, safety management includes two major components:

- Hazard and risk analysis

- Selection, conducting, and maintaining of safety barriers as the tools of minimizing the risks

After all safety barriers are identified and selected, the next task of safety management is to ensure the effectiveness of safety barriers during their lifetime. In fact, the barriers' lifecycle should manage and modify to the plant. The Seveso III Directive requires an update every five years.

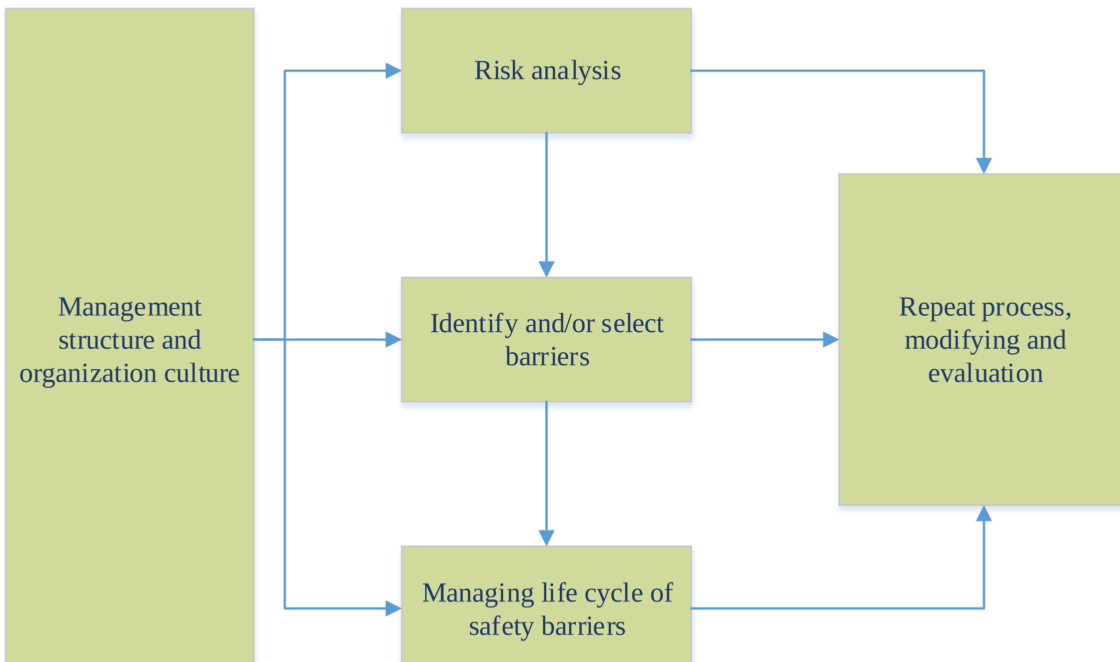

Figure 16-Selecting barriers for SMS

A safety management system should draw a framework for its employees, and the discrimination of different levels of safety management is as follow:

- Policy: Establishing the rules and policies on plant safety with considering the existent regulations plans.
- Organizations: Organization safety means clarifying responsibilities, resources, scheduling, etc.
- Training, educating and evaluating competence of employees
- Maintaining the operation, procedure, technical systems, induction of new safety tools

- Keeping up hazard awareness, e.g. by updating risk assessments
- Leadership: implementing a successful safety management system requires strong leadership. Keeping policies consist, and drawing a mission and vision for employees are part of leader responsibility. A leader has an enormous impact on daily plant management. A leader should create shared values and attitudes regarding safety specifically. Notice that creating the best-class-safety-culture is not possible without a strong leadership

Safety management system should also go under some analysis to evaluate and develop how the system is performing as follow:

- Analysis of the effectiveness of safety devices providing safety barriers and lines of defense according to their characteristics
- Analysis and comparison of specific safety management system and how safety policies are implanted in the company's overall management system
- Using theoretical modeling of management risk, with Structure Analysis and Design Techniques (SADT) or function oriented modeling (I-RISK project)
- Proficient judgment, in particular to priories the management factors for evaluation purposes
- Defining safety performance indicators using audit techniques, questionnaires techniques, and analysis of incident reports
- Development and validation of audit techniques

As the quality of above structure improves, the safety will improve inside the company. These various elements play critical rules regarding the task of managing the life cycle of safety barriers. Indeed, The ARAMIS consist in an audit protocol on the activities relating to the life cycle of the safety barriers. In this approach, ten structural elements are distinguished:

1. Risk identification
2. selection and specification of safety barriers
3. Distribution of people and responsibilities for safety barriers management
4. Monitoring, feedback, learning and management of change

5. Workforce planning & availability
6. Competence & suitability
7. Commitment, compliance & conflict resolution
8. Communication & Coordination
9. Procedures, rules & goals
10. Hard/software purchase, build, interface, install, inspect, maintain, replace

Barriers life cycle consists of design, installation, maintenance, and improvement activities, which for each of these activities some structural elements are evaluated as is shown bellow (fig 17). The result of the audit will compare to the result of safety culture questionaries gathered from employees to achieve to some level of confidence mainly regarding behavioral barriers. Dujim and his colleagues developed SCQPI (a questionnaire refers to SCQPI- Safety Climate Questionnaire for Process Safety (Duijm et al., 2005)). SCQPI, which includes 12 parts that characterize a company's safety culture and work environment aspects developed in 2002-03. This questionary is based on Herning Hospital Occupational Health Department Medicine, the National Inst. of Occupation Health (AMI), and Risø National Laboratory incorporating outcomes and experience of Nordic and UK sources as well as international results from questionnaire development and validation in the field of industrial health and safety culture.   The questionnaire consists of 12 parts as below:

1. Reporting of accidents (12 items)
2. If and when incidents and accidents (all types) do not become reported, this is because … (10 items – proposed reasons for not reporting)
3. Safety instructions and attitudes (14 items)
4. If and when incidents and accidents happen (all types) this is generally because …… (10 items – proposed causes of incidents/accidents)
5. Prioritization of safety at work (7 items)
6. Employee involvement in decisions about safety (6 items)
7. Who do you think should be taking responsibility for safety? (6 items)
8. Who do you think is, in fact, taking responsibility for safety? (same six items)
9. Commitment by management and leaders to safety (12 items)
10. Trust and fairness (8 items)

11. Work and social relations (13 items)
12. Your personal suggestions

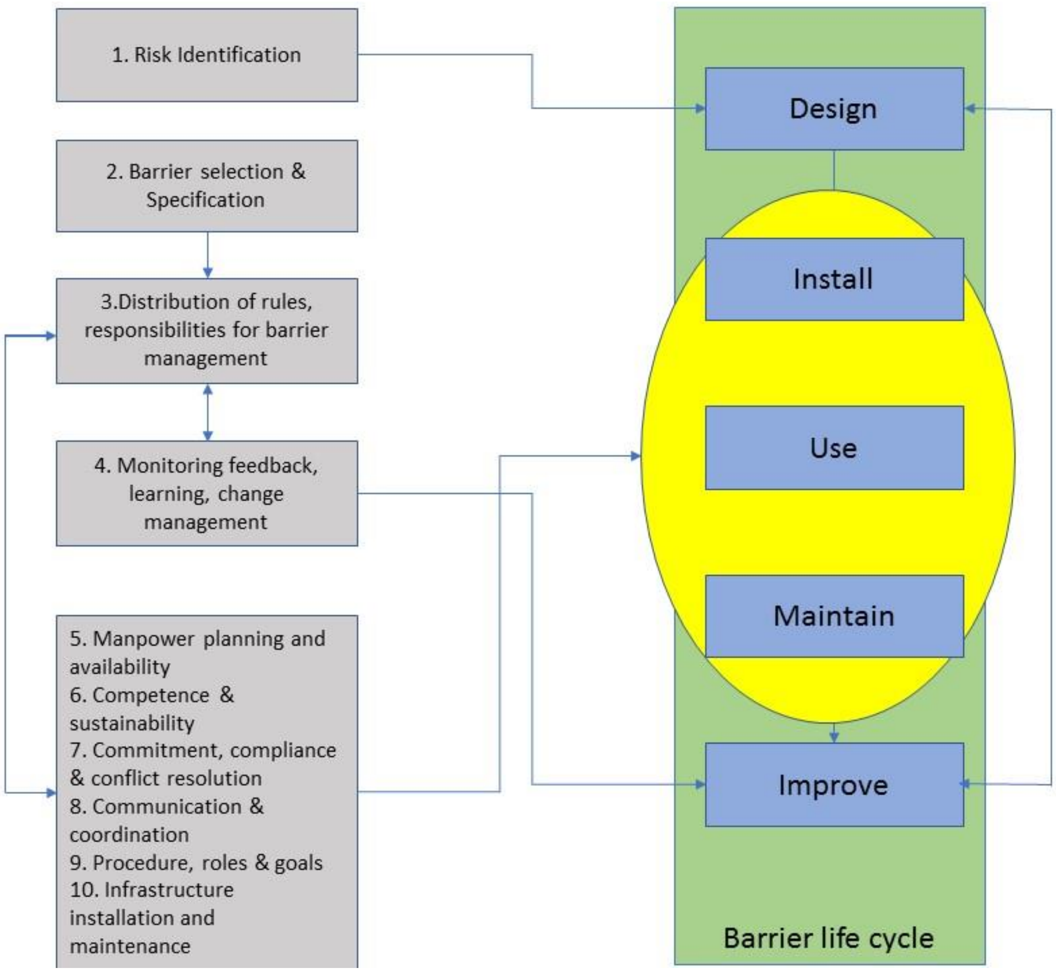

Figure 17-Barriers life cycle

In ARAMIS project for industrial installation, the major accident hazards (MAH) will be primary well-defined with an algorithm based on the labeling of the materials and the circumstances of their use such as temperature, pressure, flow rate, etc. (Union, 1967). Then the RAS will be determined from the MAH and deliver the review of accidents/incidents, which happened on similar units. Based on the current installation, which operates, RAS will define realistic scenarios. These scenarios will describe the potential hazards and evaluate the severity of the major accident.

6.2.3.1.3 Evaluation of effects severity of scenarios

The objective of this step is to define a severity index S depending only on physical parameters (fire, explosion, dispersion) and describing the likely effects of different scenarios. Each RAS is defined by an initial event, which leads to different phenomena. For each of phenomena, a specific severity index has been defined (Delvosalle et al., 2006; Planas et al., 2005). The purpose is to quantify and compare the severity of any dangerous consequence with a single scale ranging from 0 to 100. This scale has been arbitrarily divided into four categories: 0-24, 24-49, 50-74, 75-100. The corresponding distance can be calculated with respect to these four categories. For example, the distance at which the associated value of thermal radiation, or blast, etc. will occur. Table 7, presents a case of severity values associated with phenomena.

Table 7-Severity values associated with phenomena

S_{DP_i}	Distance (m)	Overpressure (mbar)	Radiation (W/m^2)
0	D_0	1	1000
25	D_1	30	1800
50	D_2	50	3000
75	D_3	140	5000
100	D_4	250	8000

As mentioned above the Risk Severity is defined for one scenario as the combination of the level of frequently with the intensity of the effects. The combination of risk severity with the vulnerability of the targets produces that actual risk. Risk severity for a given critical event, at a certain distance d, will be a combination of a Specific Risk severity indices (S_{DP}) and the probability of occurrence of DP_i.

$$S_{CE}(d) = \sum_{i=1}^{n} P_{DP_i} \times S_{DP_i}(d)$$

In this equation n is the total number of dangerous phenomena (DP) associated to the RAS. Therefore, the risk severity is obtained by the multiplying the frequency of each RAS with its specific indexes.

$$S(d) = \sum_{i=1}^{n} f_{RAS_i} \times S_{RAS}(d)$$

In this equation n is the total number of critical events for all RAS corresponding to the installation. The parameters that need to be considered in RAS are (Hourtolou and Salvi, 2003b):

- The potential domino effects: fragment emission, interlocking of delayed phenomena
- The affected area concerned with the phenomena
- The phenomenon kinetics
- The capacity of intervention/ to mitigate the disaster

6.2.3.1.4 Vulnerability Assessment

This phase aims at addressing the vulnerability of the environment independently of the hazardous site (Tixier et al., 2004). To reach this objective, the area of attention in the vicinity of a plant will separate into meshes. The potential targets for different populations, nature, and human-made environment will be identified and localized with the support of Geographic Information System (GIS) i.e. on a given spot of the environment; the vulnerability is accordingly characterized by the quantity of potential targets and their relative vulnerability to different phenomena

7. SAFETY PERFORMANCE AND SAFETY METRICS

Dennis Hendershot stated “you cannot manage what you cannot measure” (Hendershot, 2007). Many studies have surveyed numerous aspects of process safety and safety performance (Azizi, 2016; CCPS, 2009, 2011; Erikson, 2009; Hinze et al., 2013; Kenan and Kadri, 2014a; Killimett, 2006; Krause and Henshaw, 2005; Payne et al., 2009; Webb, 2009; Wreathall, 2009). Indicators can evaluate both quantitative and qualitative safety factors. Wreathall defines safety indicator as “Indicators are proxy measures for items identified as important in the underlying model(s) of safety” (Wreathall, 2009). Many organizations are pursuing how to understand safety performance by monitoring their safety processes and staff’s behaviors. Gathering valuable information such as accident reports, incident reports, and root causes can be tracked by organizations safety performance (Mannan, 2014). Safety Performance Indicators (SPI) are valuable tools that can provide significant information about plant processes, personal behaviors, and maintenance of organizations to effectively measure hazards and risks to develop plans and mitigate them to become a zero-incident organization. However, Wilkinson, after studying offshore petroleum safety, concluded that personal safety measures such as Lost Time Injury or similar metrics seem to be still given too much prominence by companies despite their well-known weaknesses regarding major incident prevention (Wilkinson 2011).

Choosing accurate indicators is the key. The objective of hiring matrices must be clear to determine suitable indicators. However, the choice of which leading metrics are the most effective for an organization is expected to change over time (Kenan and Kadri, 2014b). Traditionally, safety performance has been measured by such metrics as OSHA Recordable Incident Rate (RIR), Days Away/ Restricted/ Job Transfer Rate (DART Rate), Lost Time Case Rate (LTC), Severity Rate (SR), and/or Experience Modification Rating (EMR) on workers' compensation. These metrics provide historical information about some factors of the safety performance measurements, which are now classified as lagging indicators.

$$RIR = \frac{number\ of\ OSHA\ recordable\ cases \times 200{,}000}{number\ of\ employee\ labor\ hours\ worked}$$

$$LTC\ rate = \frac{number\ of\ lost\ time\ cases \times 200{,}000}{number\ of\ employee\ labor\ hours\ worked}$$

$$DART\ rate = \frac{total\ number\ of\ DART\ incidents \times 200{,}000}{number\ of\ employee\ labor\ hours\ worked}$$

$$SR = \frac{total\ number\ lost\ work\ days}{total\ number\ of\ recordable\ incidents}$$

200,000 hours per year is for 100 employees, working 8 hours a day, five days a week, 50 weeks a year.

Later on, using process safety metrics became more popular since they can identify which elements are required, and where they are needed to be improved and evaluate that impacts are occurring. Effective leading and lagging process safety metrics are used to measure existing and future performance. Hale highlights if the indicators are leading or lagging in respect to whether "it leads or lags the occurrence of harm, or at least the loss of control in the scenario leading to harm" (Hale, 2009). The UK oil and gas industry has defined leading and lagging indicators as "something that provides information that helps the user respond to changing circumstances and take actions to achieve desired outcomes or avoid unwanted outcomes while lagging indicators were seen as the outcomes resulting from our actions" (Safety, 2001). The distinction between personal and process safety indicators is much clearer than lead and lag indicators.

7.1 Lagging metrics

Lagging indicators provide an overview of performance and can be used to improve safety management systems that have already failed. Incident data's profile can be measured by absolute indices and normalized numbers, which is the most preferred method to convey incident data appropriately (Wang et al., 2013). For example, one of the lagging indicators for an upstream company is Process Safety Incident Rate. If we assume a company produces both oil and gas, the unit-barrel of oil equivalent would be:

$$BOE = \frac{mcf}{6} + \ barrels\ of\ oil$$

$$Process\ safety\ incidents\ Rate = \frac{total\ process\ safety\ incident \times number\ of\ BOE}{total\ Volume(BOE)\ production}$$

$$DART\ rate\ for\ exploration\ and\ production = \frac{\text{total number of DART incidents} \times \text{BOE}}{total\ volume(BOE)production}$$

These rates can be adopted for drilling and chemical procedures as well. It has been shown that lagging indicators in chemical productions are useful for improving management in assessing process safety performance (Wang et al., 2013).

In fact, lagging indicators measure after the fact and focus on past failures and indicators. Workers' compensation costs, the number of declared community evacuations, and property damages are some other lagging indicators examples.

7.2 Leading metrics

Leading indicators are forward-looking. In other words, they can provide precise information about personnel and process safety such as demands on safety systems and activation of mechanical shutdown system. OECD's guidance document on safety performance indicators in the chemical industry defines leading indicators as "Activities indicators are designed to help identify whether enterprises/organizations are taking actions believed necessary to lower risks" (OECD, 2008). Leading indicators are useful for avoiding mishaps, and improving safety management systems that may fail. Leading indicators are great in gathering information for use in anticipation and developing organization performance (Reiman and Pietikäinen, 2012). Some events that are recognized by lagging indicators and occur repetitively or in certain combinations can serve as leading indicators of more significant events. Hence, if leading indicators are designed accurately and work properly, then lagging indicators will go away automatically (Mannan, 2017). 19 out of 35 companies during a research study on behalf of AIChE introduced some leading indicators that companies are interested in using such as senior leadership time in the field, alarm management, reporting of process safety near misses, number of PHA recommendations (open and closed), Fatigue risk management, and preventive maintenance activities (Kenan and Kadri, 2014b).

Figure 18-Process safety lagging and leading synthesis scale

7.3 Lagging versus leading

Grabowski, Mengolini, and Debarberis claim that lagging indicators are poor predictors of future results. In other words, lagging indicators cannot provide enough information to avoid a future accident (Grabowski et al., 2007; Mengolini and Debarberis, 2008). On the contrary, leading indicators may use historical data, but naturally, they measure factors to predict and prevent future unsafe situations, incidents, or accidents. Applying leading indicators can help to drive safety performance improvement. Many companies recognize the importance in applying leading indicators to assist management in concentrating engagement and efforts of personnel (Kenan and Kadri, 2014a). Different metrics are required to predict future performance, and this is where leading indicators of safety performance can be beneficial. Leading indicators measure component by component of an organization's safety culture (Hinze et al., 2013). When investigations detect one or more hazardous situations, warnings, or high-risk rates in any aspect of a safety process, intervention can be implemented to improve the safety process and prevent any incident from happening.

In a system, both indicators are beneficial; however, there are some differences between their natures and how they can be applied effectively:

1. Type of response: with leading indicators, responses are proactive (perspective) to not to let the incident happen, on the other hand lagging indicators, the responses are reactive

(retrospective) in nature, i.e. the response is made after the accident/incident. Since the incident already happened, the response's purpose is to prevent the occurrence of future incidents.

2. Effect: Lagging indicators are based on past safety performance results. Indeed, they improve safety system management that has already failed. However, it is possible some data or results will not even be recorded. Leading indicators look to improve future safety performance and safety system management that may fail, i.e. missing data is a warning metrics. Below, some examples of process safety performance indicators have provided:

Table 8-Examples of process safety performance indicators

Control	Lagging indicator	Leading indicator
Inspection/ Maintenance	Number of unexpected loss of contaminant incidents due to failure of equipment	Percentage of maintenance actions that have been done on the schedule
Staff capability	How many times the product did not proceed as planned due to staff mistakes	Number of training classes for staff
Communication	Number of times that production has not met the deadline due to lack of communication	Number of post-transfer checks on equipment
Plant change	Number of time equipment or plant went under changes due to undesired outcomes	Percentage or number of changing authorization was given but not implemented yet
Plant design	Number of incidents due to poor design	Number of research for design change
Instrumentation	Number of alarms that are failed	Number of alarms checks
Permit to work	Number of incidents	Percentage of permits that issued
Emergency arrangement	Number of evacuations	Number of real on-site training

Having both lagging and leading indicators is very important as mentioned by the investigation board after BP's Texas City refinery that one of the BP's problem was relying on lag indicators, rather than leading indicators (CSB, 2007a).

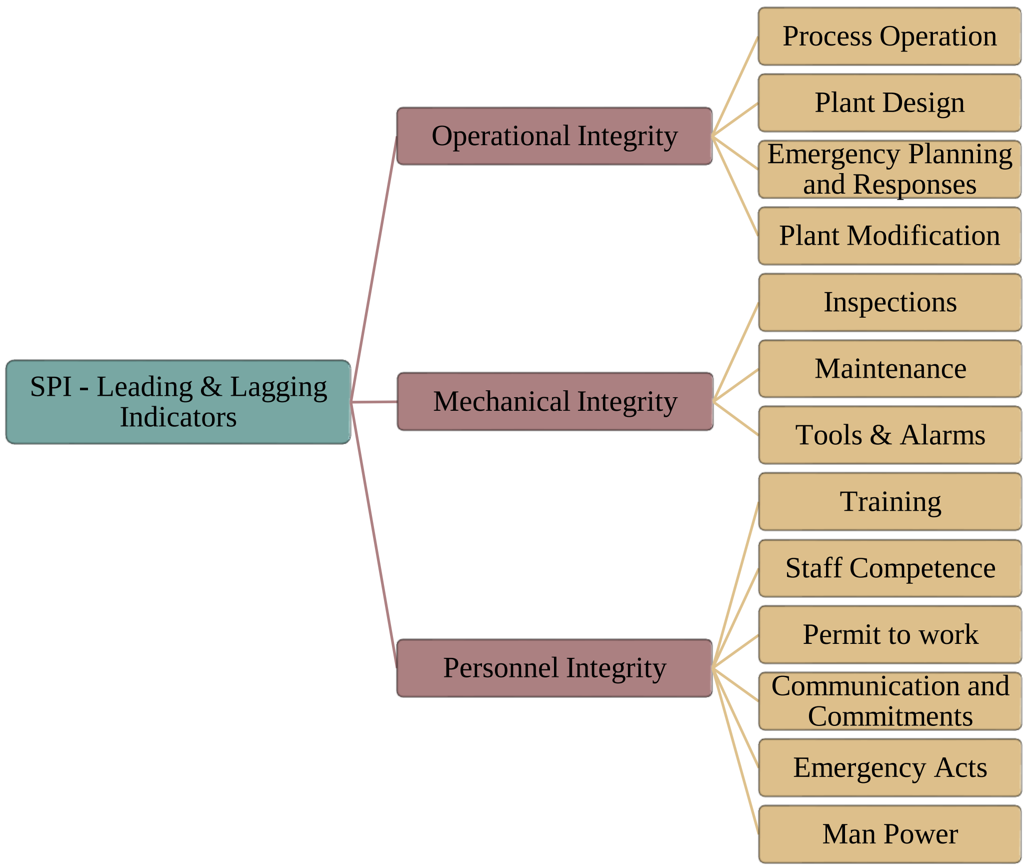

Figure 19-Leading and lagging indicators

7.4 Metrics systems

A good process safety management system will comprise metrics to identify and measure not actual process safety incidents that meet an established reporting threshold, plus metrics to detect lower-severity incidents, near misses, no-loss incidents, and unsafe behaviors. Moreover, a process safety metrics should track the performance of individual system components to ensure it can be a cascade and result in a serious, reportable incident. Process safety incidents are usually caused by coincident of multiple catastrophic failures.

U.K. Health and Safety Executive (HSE) defined the "barrier based" approach, which widely use “Swiss cheese” model to illustrate the relation between consecutive and simultaneous failures.

Each slice of “cheese” represent a barrier and these protective barriers may have weaknesses or “holes.” When these holes align, failure may happen.

On the other hand, Center for Chemical Process Safety (CCPS) and American Petroleum Institute (API) defined "tier-based" approach, which is based on the "safety pyramid."

7.4.1 Safety pyramid

In safety pyramid or any other metric system, the indicators should be objective, few, simple, well defined, capable of being applied consistently across the industry, useful to drive safety performance, and statically valid. As defined by API the pyramid divided into four separate layers but this model does not cover release from pipeline transfer operations outside of the process or storage facility fence line, marine transport operations, and few other circumstances (Keim, 2016):

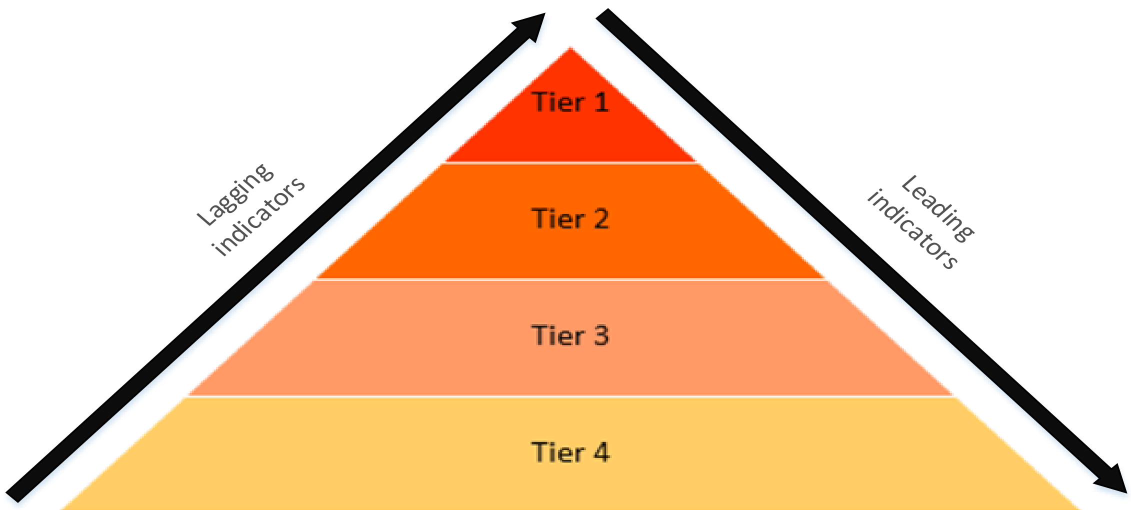

Figure 20-AIChE process metric safety pyramid (CCPS, 2011)

- Tire1-Process Safety Incident- events always start with the loss of primary containment i.e. an unplanned or uncontrolled release of substances from primary containment, including nontoxic and nonflammable substances such as steam, nitrogen or compressed air. This was when the incident happened so this layer can be used as a lagging indicator and learn from incident to not let it happen in the future again. Primary containment is a tank, vessel, pipe, truck or equipment planned to serve as the primary container or used for processing or transferring materials. The unplanned or uncontrolled release of substances from a process should include one or more of the below consequences to be considered as Tier 1 (API RP 754):

    - An employee, contractor or sub-contractor fatality or injury and days away from work
    - A hospital admission and/or fatality of a third-party
    - An officially stated community evacuation or shelter-in-place
    - A fire or explosion that causes $25,000 or more cost in relation to fire and explosion
    - A pressure relief device discharge to the atmosphere whether directly or via a downstream destructive device that results in liquid carryover, discharge to a potentially unsafe location, an on-site shelter-in-place, Public protective measures (e.g., road closure). These events can happen together or individually.
    - A release of material from primary containment of larger than the threshold quantities defined by API RP 754 (API, 2016) in any one-hour period

- Tire 2-Process safety event- can be a lagging indicator and events always start with the loss of primary containment. This layer presents events that did not meet the definition of the incident or have a lesser consequence than process safety incident:

    - No fatality, an employee, contractor or subcontractor recordable injury
    - A fire or explosion resulting in greater than or equal to $2,500 of cost related to fire and explosions
    - A pressure relief device discharge (PRD) to atmosphere whether directly or via a downstream destructive device that results in liquid carryover, and/or discharge to a potentially unsafe location, and/or on-site shelter-in-place, and/or public protective measures (e.g., road closure)
    - A release of material greater than the threshold quantities described in API RP 754 in any one-hour period (API, 2016)

- Tier 3 -near miss- is an unplanned event that there is no significant injury, illness, or damages but had the potential. Many companies have also developed a definition of a process safety near miss. In other words, near miss is an actual event or discovery of a potentially unsafe situation incident. This layer monitors the health of important aspects of the process safety management systems. Failures of safety management systems give a brilliant guide to where needs to be strengthened. This layer can be both lagging and leading indicators since a near miss about to happen or near miss incident which already discovered, so it plays a lagging indicators role. However, many organization using this layer when they have more frequent near miss incidents as an alarm to avoid future disaster which brings up leading indicators definition. Many organizations have discovered that a growing incline in near misses reported, at the beginning after implementation, is a positive sign of improved culture and process safety awareness by the organization (CCPS, 2011). Therefore, it is possible as the near misses reports increase, the number of major incidents decrease. An example of near miss would be the opening of a rupture disc when the pre-determined trigger point is reached. Some acts can be done to understand where there are opportunities for improving a facility's process safety management system such as:

    - Discovery of a failed safety system upon testing
    - Discovery of a defeated safety system
    - Errors of omission and commission (CCPS, 2011)
    - Unexpected equipment condition
    - Physical damage to containment cover

- Tire 4 is operating discipline and management system performance indicators. These indicators measure unsafe behavior or insufficient operating discipline to ensure that safety layers are operating and operating discipline are being maintained. Typically, Tier 4 represent the performance of individual components of barrier system and operating discipline. These indicators reflect activities of the company directly associated with maintaining and improving is risk control barriers. Two examples for tier 4 indicators are training classes, process hazard evaluation completion.

7.4.2 Swiss cheese model

System safety is a well-organized outline for managing the integrity of operational systems and process handling hazardous substances by applying good engineering, operating, and maintenance practices. Therefore, the system safety deals with the prevention and mitigation (control) of risks associated with the procedure, which has the potential to release hazardous materials or energy. Such this incident can cause a fire, explosion, toxic release, injuries, property damage, environment impacts, loss production, and fatality. Process safety incidents mostly caused by cascade events or failures that coincide and collectively result in an incident. This relationship between instantaneous or sequential failures of multiple systems is illustrated by the Swiss cheese model as shown in figure 21, where hazards are controlled by multiple protective barriers that may have weaknesses or holes.

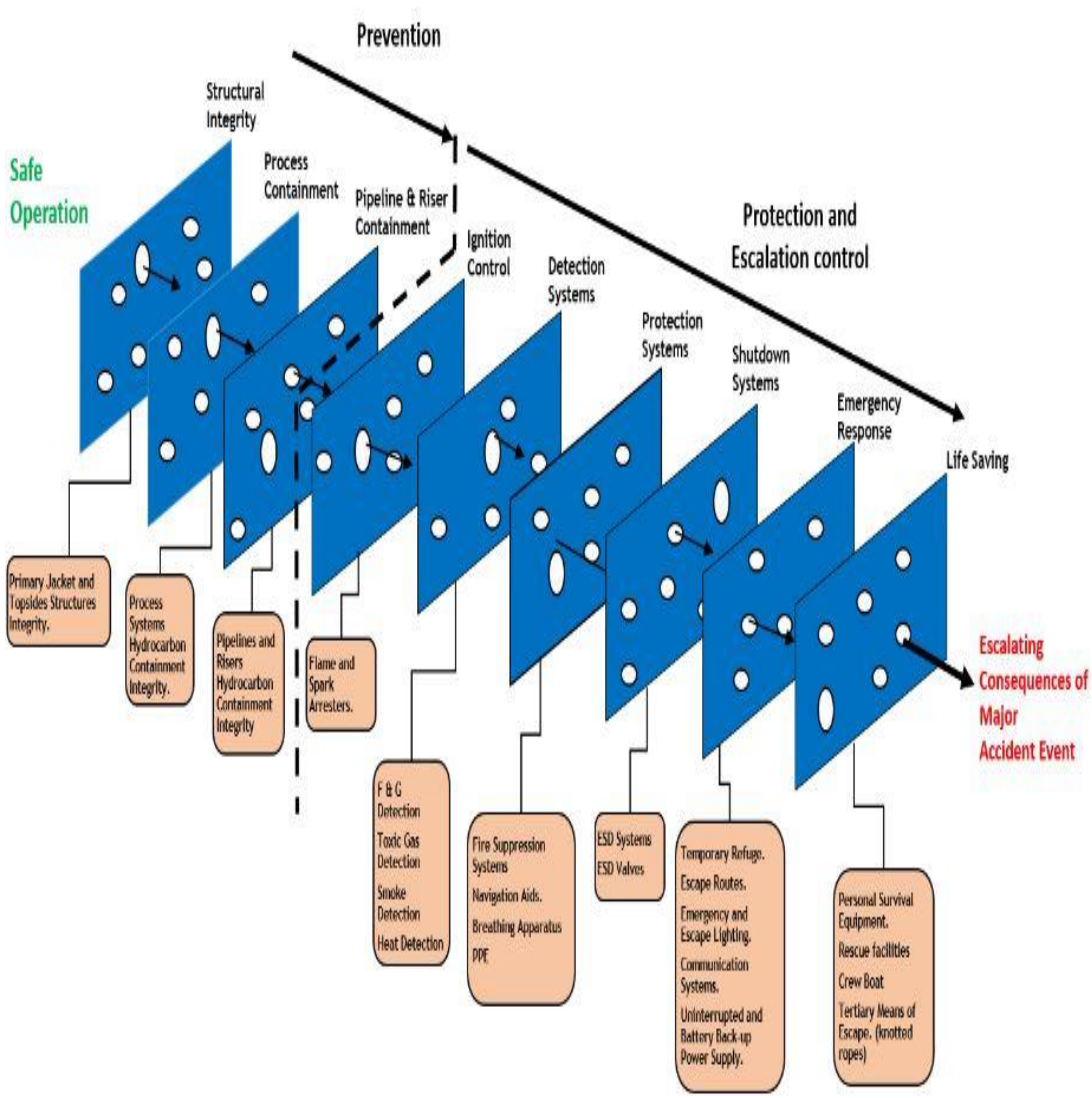

Figure 21-Swiss Cheese model (AIE, 2016)

In the Oxford English Dictionary, a barrier is defined as “a fence or other obstacle that prevents movement or access” (Oxford, 2017). Generally, a barrier blocks a cause-effect pathway leading to the undesired event. In this study, there are two general types of barriers, physical and non-physical or a combination of them to prevent, mitigate, and respond to any incident, accident, or hazard. The prevention function aims at limiting the probability that an incident can happen or reduce the intensity of the accident; for instance, preventing corrosions in pipelines that cause leaking or preventing to let the situation change from controlled to the uncontrolled situation. Pressure valves are a great example for physical preventing-controlling function. Mitigation functions are useful to reduce the loss of life and property and damages to the environment. Responses functions include controlling an event if possible, or to reduce consequences in case of loss of control.

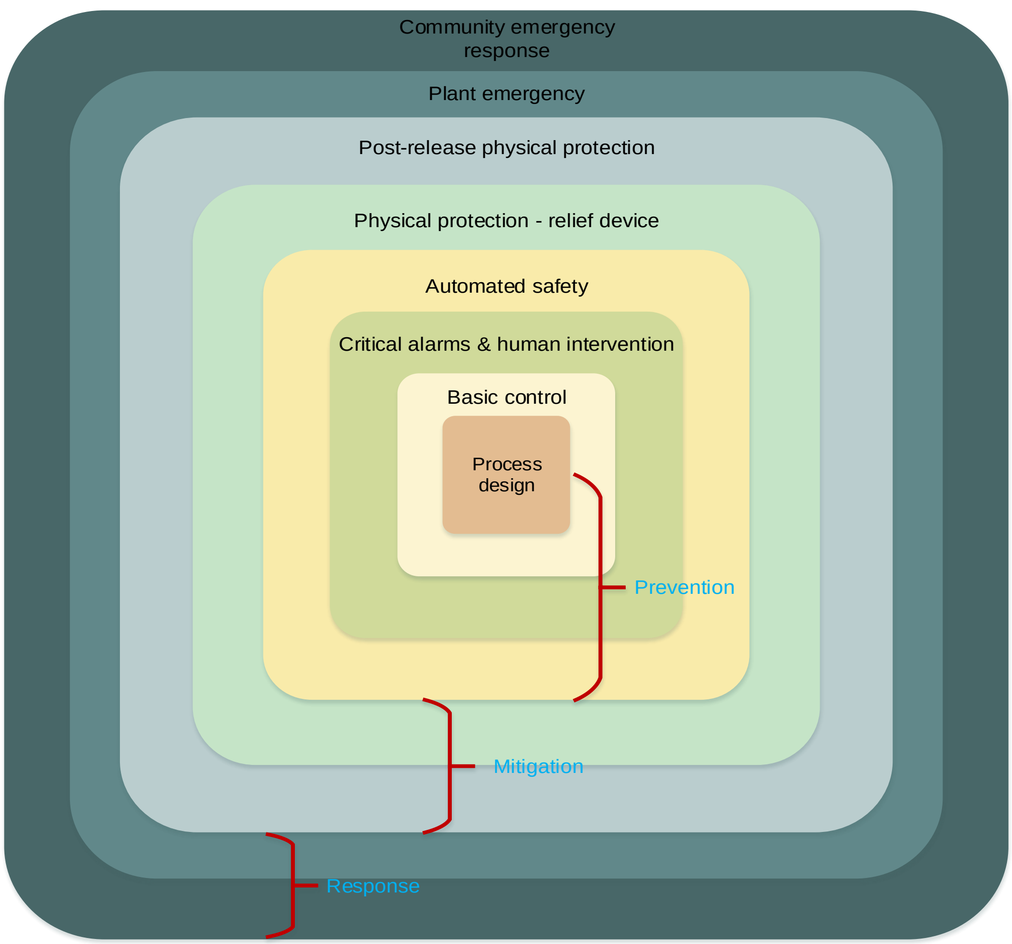

Figure 22-Layers of protection (Hong et al., 2016)

One barrier can have several functions in a system. For instance, safety signs, which are the part of the regulation, but also these signs can send the message that safety is an important factor in this place. These barriers can be preventive or protective means barrier function to intend before the occurrence of an accident or after it has happened. A barrier system may include different types of network elements, e.g., non-physical and physical. In Management Oversight & Risk Tree (MORT), barriers are restricted to flow of energy on the system, where barriers are defined as " the physical and procedural measures to direct energy in wanted channels and control unwanted release" (Johnson, 1980). The European ARAMIS project (Hourtolou and Salvi, 2003b) consists not only physical barriers, control instrumentation, and active safety barriers but also human actions which implement the whole or parts of the safety functions. The safety function is a technical or organizational function to reduce the probability and the consequence of a set of hazards (Harms-Ringdahl, 2000).

Another way to classify the barriers is to distinguish them between passive and active barriers. Passive barriers are always present, and there is no need to activate them such as fire insulations, fences, walls, etc. Activate barriers need a trigger to be activated. So the active barrier follows a consequence of detect, diagnose, and act (Duijm et al., 2004). The active barrier can include different, components such as hardware, software, or a human respond such as sensors.

The oil, gas and process safety industries have been very successful in improving occupational safety but conversely in improving process safety and major incidents performance (Figure 23) (Pitblado and Nelson, 2013). Some level of risk approach has been applied on onshore and offshore. The bow risk model implements the so-called Swiss cheese model of Prof Reason has been widely promoted for both onshore and offshore process safety risk management. Different companies define their barrier system. For example, shell describes a system called Manual of Operations, also known as Summary of Operation Barriers (SOOB), to address necessary barriers for all specific activities (Detman and Groot, 2010). This system derived from risk assessment bowties and constructed by experienced operations staff (Pitblado and Nelson, 2013).

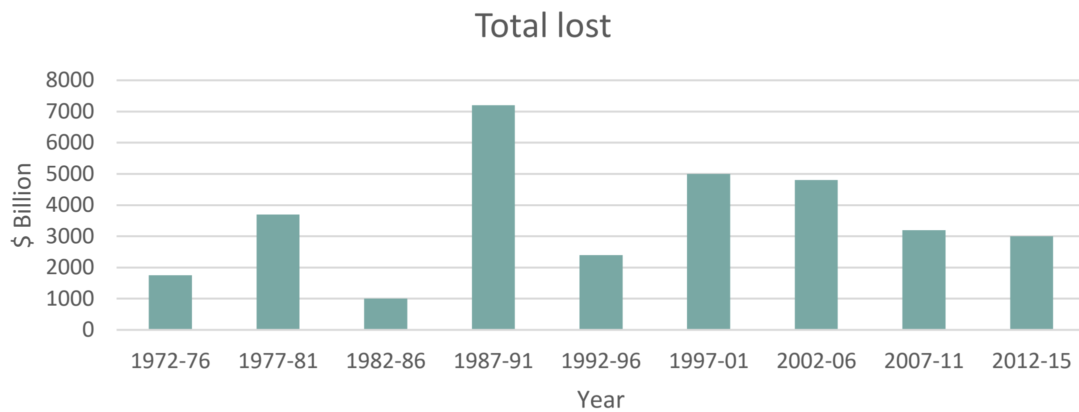

Figure 23-Oil and gas total lost due to accidents from 1972 to 2015 (Marsh, 2016)

Any organization that attempts to improve and sustain process safety performance must clearly establish its performance goals and objectives. Efforts to sustain and improve process safety performance will need tools to measure and evaluate that performance. Process safety metrics provide the data needed to evaluate and monitor performance. Good indicators should have some characteristics, reliable, repeatable, consistent, relevant, comparable, meaningful, timely, easy to use, independent of outside influence, and auditable. 6 main stages needed to implement a process safety measurement system introduced in following (HSE, 2006):

1. Ensure management ownership and establishing implementation team
2. Decide on the scope of the measurement system and establish industry Tier 1 and Tier 2 indicators to assess company performance
3. Identify the risk control systems in place to prevent major incidents. Confirm critical process and in integrity barriers. Decide on the outcomes for each and set a lagging indicator
4. Categorize the critical elements of each risk control system to achieve to outcomes and set leading indicators (select Tier 3 and Tier 4 indicators to monitor critical barriers of facility)
5. Establish collecting data and reporting system, collect quality data, analyze performance and use to set improvement actions
6. Regularly review critical barriers, actions, performance of process safety management system, tolerance, scope of indicators

7.5 The role of leadership in implementing safety indicators

Leadership has a great impact in implementing leading indicators along with fixing issues recognized by lagging indicators. Many of research has considered safety leadership as a lagging indicator such as injury rates and employees exposure rates to hazards (Barling et al., 2002b; Gershon et al., 2000; Vredenburgh, 2002; Zohar, 2002). Wong and his coherets extended the debate regarding the role of trust and safety culture between safety leadership and outcomes (Wong et al., 2016). Safety leadership potentially enables leading indicators (Sinelnikov et al., 2015), when leading indicators receive more attention in management communication and also when managers have superior expertise regarding leading and lagging indicators, it would be easier to take prevention actions through leading indicators in both process and personal safety. Leaders can find the weaknesses in the organization and by guiding the managers, mostly mid-managers, implement correction acts. For instance, a leader by safety questionnaire can evaluate safety culture inside the organization. This is a leading indicator for a leader to improve safety culture. Sometimes lagging indicators may have bad effects on leading indicators (Sheehan et al., 2016) or safety performance. For instance, the lagging indicators' statistics are not showing near miss event to the safety manager. In this case, the leading indicator may not be useful as they supposed to be. Therefore, the leader has more than one indicator in the case of something happened which means the next leading indicators mitigate the consequences. In order to take the most advantages of indications metrics, some components should be considered by leaders and whoever is in charge of monitoring and evaluating safety:

- Understanding the metrics
- Updating leading metrics: metrics that are most useful for an organization may change over time
- Implementing effective change: mechanical or procedure
- Short-time and long-time indication
- Commitment
- Resources
- Training and communication
- Data collection

8. SAFETY CULTURE

Many leaders and researchers have recognized cooperative culture structure acts like glue that holds the organization together and increases the speed of progress. Even OSHA knows that physical compliance with safety requirements alone will not eliminate incidents (Roughton and Mercurio, 2002a). It is an impossible mission for OSHA to write a safety regulation that eliminates every possible or potential hazard in the facility. Therefore, every organization should set a safety culture for the staff to reduce the hazards and risks to the lowest degree. Although no consist universal definition of corporate culture exists (Cooper, 2002), safety culture reflects shared behaviors, beliefs, attitudes and values regarding organizational goals, function, dangers, risks, and the procedure (Mannan et al., 2013). One of the main differences between definitions is how people think or what they do. For instance, not all staff will respond in the same way in any given situation although they may have similar dressing style. Therefore, beliefs, attitudes, and values such as safety will be varied from department to department or even individual to individual in an organization, which is not the way that makes a safe organization. Indeed, many best-in-class organizations may reach to the high safety performance status or zero incident organization through a similar set of elements (Mannan et al., 2013).

Safety culture is a subcomponent of organizations' culture and introduced after Chernobyl disaster (1986) in 1987 by OECD Nuclear Agency (IAEA, 2016). ACSNI human factors study group, HSE (1993) defined the safety culture of an organization as "the product of the individual and group values, attitudes, perception, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management" (HSE, 2002). Turner and his colleges define safety culture as "the set of beliefs, norms, attitudes, roles, social and technical practices that are concerned with minimizing the exposure of employees, managers, customers, and members of the public to conditions considered dangerous or injurious" (Turner et al., 1989). The Confederation of British Industry defined it as " the ideas and beliefs that all members of the organization share about risk, accident and ill health" (CRS, 2016). In fact, Safety culture refers to "how we do" in the organization. In other words, underlying safety attitude of organizations emanates from organization's safety culture. There are many other definitions has been defined, but in all of them, the relationship between the person, behavior, and environment has been emphasized. In other words, by having a good hiring system, more skilled and responsible employees will be hired. This lead to the better safety behavior hence better work environment.

8.1 How to enhance safety culture

One of the focuses in studying organization safety is surveying the distinction between personnel safety and process safety. Personnel safety evaluated by metrics such as OSHA, and SEVESO III Directive incident rates. Loss of containment or hazard identification regarding substances is done by process safety. However, they are both forces by an organization's safety culture, which sets the expectations for both personnel and process safety. In below few components of safety culture and what leaders can do to improve it are discussed:

Figure 24-How to enhance safety culture and the role of leadership

8.1.1 Leadership

Leadership plays a chief role in creating and promoting a sustainable safety culture in order to improve the safety performance of an organization. Leaders' personal commitment to safety and their communication to all members of the organization is very critical since these executive leaders provide the most visible face of the organization to both internal and external audiences. Darren Woods, senior vice president at Exxon Mobil, said, "the culture of safety starts with leadership" (Woods, 2015). There are different methods to help top managers to improve their visibility involvement in the safety issues:

- Aiming at being available
- Being an instance by knowing and following the rules
- Being involved by participating on the workplace health and safety committee
- Getting out to the floor through informal and formal inspections

Leaders and director committees have different responsivities regarding safety in the organization:

- Responsible for health and safety of staff
- Review organization's health and safety performance on specific periodically time
- Responsible for certifying sustained awareness of health and safety issues
- Ensure that organization's policies are matched with regulations and their safety progress is reflecting their priorities
- Ensure they have enough data to evaluate their safety performance
- Do safety culture questionnaires inside the company periodically
- Set a safety culture mission and vision for staff
- Aim at having a single board member as primarily responsible for safety and health oversight
- Ensure that the board and managers sending the same message about the safety and health of staff
- Board continuously qualify managers regarding safety

All authorized leaders must take enough time to allocate resources to ensure that their actions in implementing the organization's effort are obedient to the law and implemented in a way that will not cause harm to staff.

8.1.2 Safety as a core value

In addition to profit and other relevant factors, safety should be considered as the organizations' core value (Burns, 2002; Mannan et al., 2013; NSC, 1999; Wright et al., 1999). As Mary Kay O'Connor Process Safety Center has introduced safety as the second nature (MKOPSC, 2017). Safety is the backbone of the organization. Safety should not be considered as a project or discrete set of duties. Safety is not just a priority since a priority may change with time or with the needs of the organization. safety must be a core value. Value based on Oxford dictionary has defined as: "The regard that something is held to deserve; the importance, worth, or usefulness of something" (Oxford, 2017). In other words, safety is important to leaders, and regardless of changes, safety will be consisted. Chernobyl nuclear disaster happened by violating the plan's attitude and approach toward safety culture (safety operation) (Glendon and Stanton, 2000; Tharaldsen et al., 2009). In an organization, safety should be a core value for both personnel and process safety since just because a company is doing well in personnel safety does not mean that they are doing well in process safety as well. NASA after two shuttle disasters concluded that "while training awareness and incentive programs can result in short-term changes, it is the underlying culture that must be supportive for sustainable improvement in safety to occur" (BST, 2004).

8.1.3 Policy and rules

A new employee start learning about organization's safety culture from the first day on the duty by discussing the safety policies and job hazards in the training courses. In smaller companies may be is easier to explain and understand safety policies through oral statements. However, for any organization policies should be written as a statement and being reviewed by staff frequently. A written declaration does the following:

- Clarifies safety expectation
- Creates continuity and consistency
- Uses as a model or a reference when there are conflicts with other area or between staff
- Supports management's role concerning safety duties

- Causes more encouragement
- Describes the fundamental belief that safety is a core value, not just a priority

Many organizations share their safety culture by posting signs in their facility, which also work as a physical barrier. An important point here is this written statement is not the policy; it is a simple way of communication.

The critical juncture in best-in-class safety culture organization regarding the implementation of the safety policy is constructing consensus support among those most affected by it, mostly front-line workers (Mannan et al., 2013). Another critical point is having adequate staff to support to implement rules inside the organizations and follow the procedures to guarantee policies will survive in a long time. Policy cannot change too frequently since this is against safety culture. Changing policy more frequently will send employees the message that ignoring policies or delaying in implementing them is rational due to their short life.

8.1.4 Commitment

As companies are committed to giving customers high-quality products and services, they undertake to keep the environment clean and safe workplace for staff. Acts speak louder than words. All employees look to leaders and managers. Leaders and managers should have collative "safety spirit," and all employees in the organization must understand, believe, and committed to doing the job safely i.e. all staff should certainly comply with all safety requirements. Leaders should work hard to make an environment in which everyone in the organization stands up for safety. In 1996, Jeff Lipton, CEO of NOVA Chemicals, made everyone committed and set goals for NOVA to reduce the number of uncontrolled process fires to zero as a portion of an effort to mitigate the risk of process incident. The number of uncontrolled process fires has fallen from 65 in 1998 to 6 in 2007 (CCPS, 2009). Kishor argued in his book that commitment is a three-legged stool standing: interest, involvement, and investment (Bhagwati, 2006). Management must be committed to safety, and this commitment should be observable and transparent by providing policies and resources. Continuous communication about safety will increase staffs' commitments.

8.1.5 Safety reporting

Creating an effective reporting culture in an organization, from bottom to top includes frontline staff and site administrators' reports. This such a system can prevent many near misses, incidents, and safety concerns. Ajabnoor suggested that near-miss reporting is the first step to preventing incidents and accidents (Ajabnoor, 2008). Reports work as a feedback system and are excellent indicators. A leader can learn from accidents and incidents, find the roots causes, and not let the same incident happen in future. Besides, just reporting is not enough. Safety departments should disseminate what occurred in the experiences and provide necessary materials and training programs to avoid them in the future. Establishing a standard reporting method based on one of the available standards, such as CCPS or API, is another issue here.

Reporting helps staff to share their vision, best practices, and safety information with one another. Reason explained that an up-to-date culture could only be constructed by reporting culture (Reason, 2000). He mentioned that people do not like to report their mistakes, especially if they scare of the consequences. Therefore, this is the management job to bring the trust and motivate employees to report their mistakes. Giving protection to employees for reporting is one way to solve this issue. The bottom line is any organization that has an effective reporting system for analyzing and developing their training and procedure processes has a better safety culture.

8.1.6 Staff involvement

A success of any business relies on the employees. Bringing safety culture to an organization is not possible without staff's involvement. Creating committees, safety forums, and training classes allow employees to take ownership for safety improvement. Leaders can make staff more involved by making them personally responsible for safety since no one knows the job better than the employees do, and they are the most valuable problem solver as they are the closest to the actions. Krause stated that workers' engagement, who are committed to safety regarding them self and co-workers' actions, is the first line of safety defense (Krause and Henshaw, 2005).

Employees, who aware of hazards that are associated with the facility and the procedures are good sources of ideas for the better preventing process. By reviewing Japanese companies, it found out that there is an approach to employee participation. They used their employees to solve different types of quality- related issues (Roughton and Mercurio, 2002d). Therefore, leaders must take a broader approach on safety participation issues to help to identify and solve safety issues. Employees who participate more will enjoy more of work, and they fill more productive during their shifts. Therefore, they intend to take greater responsibilities for their jobs. In addition, this factor helps to reduce employees turnover (OSHA, 1994, 1995). There are some techniques for encouraging employee involvement:

- Increase their commitment

- Meet with employees in groups or individually if that was possible
- Explain the reasons behind safety policies
- Explaining the objectives that the organizations percussing toward them and how employees get benefits from them
- By explaining how managers need their employees' help with safety efforts
- Ask for employees' suggestions and their work situation (the knowledge that they are taken seriously)
- Leaders and managers try to be more on the floor and motivate employees

8.1.7 Learning culture

Everyone in any organizations should learn the safety process and safety performance. On the one hand, all employees should be able to identify hazardous situations while working. On the contrary, the right leader knows others incidents may happen in their organization, so learning from those events expands organization's process safety management. Jacobsson and Akselsson proposed a six-step method for evaluating learning from incidents (Jacobsson et al., 2011). Statistical studies of numerous incidents show many incidents have similar root causes (Kletz, 1998) so if the leader is not entirely aware of those roots, and/or implement effective rules, and/or hire analysis technique, and/or learned from those incidents, those incidents may happen in their plant again. The 1999 annual report from the European Environment Agency indicates that the trend in incidents proved that several of apparently simple lessons learned from incidents have not yet been appropriately applied in industry's standards (EEA, 1999). Systematic learning means the organization is able to learn from both negative and positive occurrences within their organization as well as other organizations.

Different lessons have been learned from incidents, which can be lagging indicators for any organization. Here are some examples why learning culture is paramount to reduce the hazards in the company. In 1943, wrong design and material selection in LNG tank by East Ohio Gas group, Cleveland, Ohio, killed 131 people and obliterated one square mile of surrounding area (Tassel and Grabowski, 1996). Poor maintenance and inspections resulted in many incidents such as Jilin, China in 2005, Mexico City disaster in 1984, Bunce field explosion in 2005, Port Hudson incident in 1970. Many incidents have occurred due to lack of knowledge of management and operator about hazards associated with chemical process and technologies. In Texas City disaster, the captain was not aware of ammonium nitrate (Yang et al., 2011). A dust explosion happened in the

Imperial Sugar Company caused 14 deaths and injured 38 others, was mainly due to lack of a training program and awareness about explosive dust hazards. Imperial Sugar also did not have a written dust control program or a program for utilizing safe dust removal methods (CSB, 2009a; Yang et al., 2011). In any industry, which deals with hazardous material, inventory and storage design are crucial. For instance, in Mexico City, the amount of stored LPG bottled increased the severity of explosion. Where to install the plant is another lesson that government and cooperates have learned after incidents in nuclear facilities or other accidents/incidents (Mannan, 2012e) like in 1947, the Texas City explosion killed 581 people in a residential area of the city (Mannan, 2012f; Stephens, 1997). In table 9, there are some incidents, which the organizations' and the leaders' failures in learning lessons from the past (Kim et al., 2012; Lutchman et al., 2012; OSHA, 2005).

Table 9-Not learning from dust disasters

Not learning from combustion dust disasters		
Major incidents	Date of incident	Personnel safety impact
Organic dust fire and explosion, Massachusetts	Feb 1999	3 killed, 9 injured
Organic dust fire and explosion, North Carolina	Jan 2003	6 killed, 38 injured
Organic dust fire and explosion, Kentucky	Feb 2003	7 killed, 37 injured
Metal dust fire and explosion, Indiana	Oct 2003	1 killed, 1 injured
Sugar dust explosion and fire, Georgia	Feb 2008	14 killed, 36 injured

There are different practices to improve learning culture:

- Learn from experts through conferences, seminars, etc.
- These lessons should be available to all staff with the organization from employees to contractors
- Making some systematic ways to document learned lessons and review them frequently

8.1.8 Positive staff recognition

An expert leader will give recognitions to employees that have good safety behaviors to motivate others to emulate leader's examples. The leader publicly recognizes the contribution of others, use admiration more often than criticism, offers positive feedback and recognition for good performance and finds ways to celebrate safety accomplishments (Krause, 2004). One way to recognize and accomplish staff is in the meeting, and through communicating with them. Starting with the board of directors, organization leadership at all levels should consistently display concern for and attention to be a great worker at all level of the organization. Leaders by being fair between employees can make them more responsible for following his orders specifically regarding safety aspects. Anyone in the management level should put some time to admire people that doing the right things. To change staff behavior managers should recognize them and then try to make the safety spirit among them.

8.1.9 Trust environment

Mutual trust must exist between management level, employees, and contractors along with culture to improve safety in the organization. Employees should feel that they could report any issue without being punished or blamed. A science of fairness and justice between staff should occur. Having effective communication and work satisfaction can improve trust matters in the organization hence safety culture (Cox et al., 2006). Lewicki and Bunker proposed three types of trust within perfusion working relationships (Lewicki and Bunker, 1994): calculus-based trust, knowledge-based trust, and identification-based trust. Calculus-based trust is based on the promising steadiness of behavior i.e. people will do what they say as they distress the consequences of not doing what they say. In the sense of safety and health, individuals must trust that their colleagues will follow procedures and wear protecting protective equipment during their acts. Knowledge-Based trust is grounded in the other person's predictability. This type of trust depends on data rather than prevention. Knowledge-based trust develops as a function of time. The history of interactions between the parties allows a generalized expectancy about the predictability and trustworthiness of the other party's behavior to makes the knowledge-based trust. Regarding safety management, open and honest communication between key stakeholders provides a sound basis for trust. Identification trust is based upon identification with another person's requests and purposes. At this level, Lewicki and Bunker suggested that "trust exists because the parties effectively understand and appreciate the other's wants; this mutual understanding is developed to the point where they can effectively act for each other" (Lewicki and Bunker, 1994). Regarding safety-related behaviors, employees effectively working in the direction of the same goal of improvements in safety culture hence safety performance to diminish the chance of experiencing an accident, incident, or near miss can demonstrate this type of trust.

8.1.10 Effective communication

Communication can help to build trust, teamwork, and staff's involvement. Providing open lines of communication across the organization is one of the key factors to make a best-in-class safety culture in an organization (Mannan et al., 2013). In a best-in-class safety organization, the communication should have a feedback loop, which means the policies and goals that dictated to the lower body of the organization, should be influenced by the views, and move along the organization. The feedback loop is necessary since by having this system, leaders can ensure that organizational goals and rules are proper and realistic, and managers and workers understand them in the same way (Secretan, 1997).

Once the organization established its policy, the management team should make sure they communicate their policies with the staff. This is one of the things that managers often forget (Roughton and Mercurio, 2002c). Leaders and managers can communicate with employees through words, actions, and examples. Communication by words is mostly based on oral conversations, statement, emails, etc. Communication through actions means the managers provide enough safety equipment to protect employees. Communication by example such as admiring whoever is doing the job safely.

Leaders and managers should have an effective communication about their objective i.e. they should make sure all staff understands what is expected about safety culture. Communicating about hazards, training programs, employees' stresses, employee's visions, etc. are some example of effective communication.

8.1.11 Safety management system

A consist management system is necessary to train leaders and managers as a safety leader, monitor and evaluate the safety performance of the system, and make sure the organization has followed all regulation. SMS is developed to ensure the health and safety of all workers, the environment, and assets. After Texas City, BP incident, it suggested that an effective SMS must extend beyond personal safety and environment dominion to consist of process safety management for continuous improvement (Broadribb, 2006). SMS generally fall into three interrelated categories: people management, supporting process and systems, and facilities and technology.

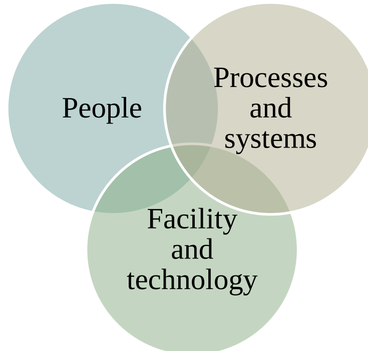

Figure 25-SMS interrelated components

SMS have some direct and indirect effects on the business, which highlighted in table 10.

Table 10-SMS direct and indirect effects on the business

Direct	Indirect
• Fewer Incidents and injuries	• More staff involvement and motivation
• Fewer work-related fatality and disease	• Ability to attract better employees to the company
• Reduce absenteeism	• Greater stakeholder commitment
• Reduce lost time away from work	• More community support and engagement
• Reduce health care cost	• Higher trust environment among management and stakeholders
• Lower employees turn-over	
• Lower operation and production cost	
• Reduction in insurance cost	

Motivating employees have different pros such as increasing the production, the ability to retain talented with the company will increase, and improving trust and commitment. An effective SMS in addition to improving the health and safety of workers, make a framework for achieving all the due diligence necessities for compliance and stewardship (Lutchman et al., 2012).

Markiewicz introduced some of the elements found in every health and safety management system such as OSHA VPP, OHSAS 18001, ILO-OSH, and ANSI/ AIHA Z10 as follow (Markiewicz, 2009):

- Managing leadership and employee involvement
- Planning
- Implementation and operation
- Checking and corrective action
- Management review

These concepts perform well in a continual improvement cycle of "Plan-Do-Check Acts." OH&S Alberta listed eight independent components of a health and safety management system as follow (Alberta, 2015):

- Management Leadership and Organizational Commitment
- Hazard Identification and Assessment
- Hazard Control
- Work Site Inspections
- Worker Competency and Training
- Incident Reporting and Investigation
- Emergency Response Planning
- Program Administration

In any organization, this is the leadership's responsibility to establish or update their SMS to improve the organization culture. Upgrading the SMS is an important act to transmit the organization from regulatory compliance through to world-class safety performance (Lutchman et al., 2012). However, this transmitting is not easy since employees have to change the way that they are accustomed to doing them. Change is multidimensional in nature; a broad process to manage change is required. Maria Darby, vice president at Booz Allen Hamilton, claimed that changing has nine primary disciplines (Darby, 2010):

1. Stakeholder relationship management- managers the skills to map out the multiple layers of stakeholders associated with the proposed changes i.e. managers skillfully address the required and concerns of changes

2. Leading change- who will lead the changes? This is a leader’s ability to articulate a clear and compelling case for changes

3. Change strategy- having a clear plan for changes is very critical, when and how changes will be applied to the organization

4. Communication- it is crucial to involve all stakeholders at all levels of the organization, from leaders to frontiers. Using well-planned and timely communication is a key point to make sure that every person who will affect by the changes has an in-depth understanding of changes and why is taking place

5. Human capital management- Understanding how a change will affect the roles, responsibilities, job descriptions, and numbers of employees is only one of the reasons human capital is essential to a change struggle

6. Learning and training- Training and learning play a major role in the success of change. Training is a tool to learn who has been affected by change to reduce risks, improve their commitment, and it is a chance for effective communication

7. Process and infrastructure- there are different reasons for a change, legislative policy, new technology, market forces, or a new leadership. Any change should be in the context of the organization and its infrastructures

8. Project management- Project management methods, techniques, and skills are central axis to execute change. It is critical to have a strong connection between who are driving changes and who are executing those changes. A goof project management should ensure changes happen within proper time without rushing and violating safety with a reasonable amount of cost

9. Performance management- In the case of safety performance management or any other field of performance management, it is important to use multiple methodologies, but knowing which methods to use and when to use them is invaluable.

Process safety management simply is a tool to eliminate, minimize the impact of the process-related incidents and event, and respond to an incident when it occurred by emergency planning. PSM and RMP form a critical part of SMS in United States of America.

8.1.12 Modern technologies and software

A good leader and manager are open to bringing new needed technologies and software into the company to ensure the safety performance or reduce the hazards. For instance, avoiding additional disassembling procedures by implementing new maintenance sensors. This is a part of organizational and leaders' culture. Being open to changes and new technology is not easy since they cost, and may bring complexity to the system while not all of new technologies are bad. Many beneficial technologies can assist inspection procedures, maintenance, safety matrixes, and other areas inside the organization to save more money and improve the safety performance

8.1.13 Verification and auditing

"Culture is manifest in attitudes and behaviors of workers and can be observed through the visible artifacts" (Winokur and Minnema, 2009). In zero-incident-organization, leaders and managers take benefits from received data through lagging and leading indicators to make the proper changes and improve safety culture in their facility. Committee board use different audit reports, injury rates, maintenance reports, safety climate measurements, inspection reports, employees' safety questionnaires, exposure and release reports, risk assessments result, etc. for further analysis to improve the safety culture. These data have to be organized by different level of managers to be useful. The organization should have an excellent verification and auditing system to gain a useful feedback about their operations' safety. These audits should be reported up all the way to CEO. Mostly in best-in-class culture organization auditing perfumed by a 3rd party (Mannan et al., 2013), these people should be committed to safety culture as well. Auditing helps to identify areas in safety culture that needs to be improved. Scheduling a routine for doing auditing is part of safety culture, which contributes to improving safety culture. The organizational audit standards/protocols should include audits' schedule and how will be performed.

A team or teams are needed to do auditing; how to assemble this team, how to supervise the audit, what need to be audited, how to report findings, and how to document reports are some subjects that organizations auditing protocol should cover. This standard or protocol should be clear for internal use and a third-party use.

These auditing should frequently happen by both internal and a third-party company, and all documents be kept and organized for further investigation. Auditing should be done on finished projects and ongoing project to avoid any near miss incident. The audit report should reflect the safety performance of the organization and give some suggestions to improve it. Some other key goals for safety auditing programs are managing risks effectively, improve compliance, increase awareness and understanding of hazards, enhance public image, provide a guarantee to executive management, and help the facility manager to operate efficiently and safely. Regulations, industry standards, requirements, the best operation performance, and stakeholders will influence audit programs. Choosing the right auditing approach depends on many factors:

- Regulatory environment
- Actual and perceived liabilities of the company
- The culture of the company and leaders
- The performance and capability of the business units
- Safety metrics that have been used in the company
- The safety issues in the organization
- The interest level of public, and stakeholders
- The market’s competition

8.2 Safety climate

Safety climate is another catchword often used interchangeably and in combination with safety culture. While both can use for describing the underlying safety attitudes of and organization, safety climate generally refers to people’s attitude in the organization towards safety (Olive et al., 2006a). In other words, climate is the forefront and culture can be described as the background influences on the organization. As a consequence, safety climate changes more quickly than safety culture i.e. after any event this is the climate of the organization will undergo changes, and the culture needs more time for evolution. In fact, if the necessary times does not give to safety climate to change the safety culture further incidents are inevitable.

Diaz and Cabera claimed that organizational climate is buildup through the interaction of organizational and individual factors (Díaz and Cabrera, 1997) as the organizational framework includes the responsibilities for each individual in the organization. Many studies reported that safety performance would be better as the score of safety climate is higher (Coyle et al., 1995; Díaz and Cabrera, 1997). Safety climate can help to improve areas to improve regarding employees and improve safety performance (Wu et al., 2008; Zohar, 1980). Safety behavior has a direct relation with safety climate and safety performance (Garavan and O'Brien, 2001; Neal and Griffin, 2002b). Therefore, safety climate regarding employees can be divided into five factors, worker involvement, worker autonomy, worker risk perception, worker cohesion, and worker motivation. Those behaviors can include safety violations, incident reporting, accident reporting, and near misses reporting.

8.3 Barriers to safety culture

People have strong patterns of behavior to follow, hence changing their culture is not east, and it takes time (Flynn and Shaw, 2010). It is significant to recognize barriers to achieving long-term cultural shift. Some barriers examples can be related to management styles, which may cause inconsistencies in the right message that has been sent to staff. Lack of strong, effective communication, the level of their caution, and understanding of managers about principles and rules that may interact with safety culture are other issues. Circumstances and bureaucracy may often work against safety culture; sometimes-routine tasks become a casual factor of human performance errors since employees learn to do the steps faster i.e. they start shortcutting steps. Publishing standard textbooks and guidelines are not enough, and an organization should have active plans to achieve safety culture. Effective training programs to train new staff and update all employees every year are critical. Punishing and the awarding system has to be transparent and fair among all employees. Contractors should be trained as same as organization’s employees before starting their duties.

9. ROLE OF DIFFERENT LEVELS OF MANAGEMENT

Leaders', senior managers', and supervisors' behaviors impact subordinate safety performance in various aspects through valuing subordinates, visiting the work sites frequently, participation in workgroups for decision making, and giving effective safety communications. Each manager or leader have some place weight in these aspects. Therefore, everyone in the organization should understand their influence on subordinates. For instance, if an employee reported an unsafe physical condition, a manager who received the report should ensure that the condition is addressed. Every manager should actively participate in training programs; this shows that regardless of managers' responsibilities, safety remains as a core value (Olive et al., 2006b).

Process safety takes account of diverse aspects from developing to monitoring. It would be hard for one person to get all these jobs done accurately. Therefore, a leader should have some people to perform the task precisely. Mostly, process safety roles assist top managers and leaders by supporting safety program, evaluating safety performance via suitable metrics, proposing and helping to improve process safety; hence safety performance (Klein, 2012).

9.1 First-line supervision

First line supervision has been identified as having a critical role in the management of safety (Fleming, 2000; Flin and Yule, 2004). Frontiers are more in-touch plant's employees and have a direct connection with contractors. Therefore, they have the most influence on employees to improve the safety culture and get the job done safely. Moreover, the first-line supervisory role is management's primary interaction with operations personnel in communicating, enforcing their policies, and practicing for effective safety performance. Any organization seeking to establish a strong safety culture needs to ensure that there is an effective first-line supervision practice.

- Ensure work is directed in a way so as guarantee that short-time safety goal and objectives are met
- Ensure that work-plan covers planned measures and strategies to achieve short-term goals
- Help continue enhancement in safety and worker performance

9.2 Senior managers

Senior executives have a vital role in safety performance as their decisions impact day-to-day safety on the plan. Senior executives below the board must be equally committed to safety. Most of the companies convert their data from indicators to meaningful scorecards and senior managers review them to report critical issues to the board members. Hence, senior managers' commitment is essential for implementing a sustainable safety program. Senior directors of operations must fully understand the process, thoroughly identify and evaluate hazards, implement robust controls to prevent accidents, establish mitigation and response plans, audit, and form an emergency acts plans.

Top and mid-level managers are responsible for sustaining the organizational profile regarding new policies, and expressing leadership's commitment to complete and maintain execution. This is a senior manager's job to transmit these new policies to frontiers through personal delivery rather than just posting written rules (Wilpert and Fahlbruch, 2002). Developing and stewarding tools for collecting data and measuring progress about short-term goals and objectives. Moreover, identifying and closing gaps that may prevent achieving short-term safety goals are other important responsibilities that senior managers should perform in any safety position.

Table 11-EPA system management

Position	Primary Responsibility	Changes	Act
Operations Manager	• Developing oversight of operation • On-the-job training • Process Safety Information • On-the- job competency testing • Selecting participation for PHAs • Developing management of change	• New equipment • New process chemistry • New process Parameters • New procedures • Change in process utilization	• Inform head of training • Inform head of maintenance • Inform lead for PHAs • Inform Hazmat team as needed • Inform contractors
Health & safety officer	• Oversee implementation of RMP • Develop accident investigation • Develop employee participation • Plan contractor's evaluation • Track regulation	• New equipment • New process chemistry • New process Parameters • New procedures • Change in process utilization • New regulatory requirements	• Inform all leads off new demands and assign responsibilities • Ensure that everyone is informed of changes and that changes are incorporated into programs as needed

10. WHAT IF AN ACCIDENT HAPPENED IN THE FACILITY?

When incidents occur and the consequences are not mitigate successfully, one of the indicated failures involve ineffective emergency planning and response (EPR)(Abdul Majid et al., 2016). EFR is a significant aspect of the PSM. In CFR 1910.119 (n), the minimum elements of EFR have been explained in handling emergency and small release. Organizations practice different EPR programs, and it has been proved that emergency self-regulatory policies are not an efficient way to improve the EFR due to the many failures in emergency acts such as BP incident or DPS Enterprise chlorine gas release. Another disaster is Piper Alpha incident, which had a very weak emergency response planning as lack of firefighting protections, employee training in responding to emergences, failure of emergency equipment (Broadribb, 2015). Late or weak emergency respond can cause fatality, injury, financial lost and bad reputation.

All leaders and managers should be prepared to respond quickly. There are some factors to evaluate preparation level to respond to an emergency such as having enough people, economic resources, knowledge of procedure, adequate training, etc. All leaders and managers should be trained. When an incident takes place, many things will happen together such as explosions, fires, fatalities, injuries, etc. Therefore, everyone in the facility should have the emergency respond-knowledge and has trained for such these situations. When a disaster happens public will focus on what happened and the way the organization will respond to the media or any other public communication sources. Senior managers should be trained to communicate well with Medias, employees' families, and the government. Lack of communication with the surrounding community is one of the main reason why more people are exposed than necessary (Miehl, 2011). For instance, In BP Gulf of Mexico incident, the poor communication with other closed rigs cased more financial lost (BP, 2010)

Regardless of companies having their own EPR system, incidents are still occurring due to lack of meeting the minimum requirements of PSM Standards. In the U.S., organizations are usually directed by the National Fire Protection Agency (NFPA), Occupational Safety and Health Administration (OSHA) and the Department of Homeland Security for EPR management. The general EPR should address following elements (OSHA, 2017):

- Written and oral emergency action plans
- Fire preventing plans

- Procedures for reporting fires or other emergencies
- Procedures for emergency evacuation, type of evacuation and exit route assignment
- Business specific information
- Communication plan
- Roles and responsibilities
- Alarm systems
- Training
- Review of emergency action plans

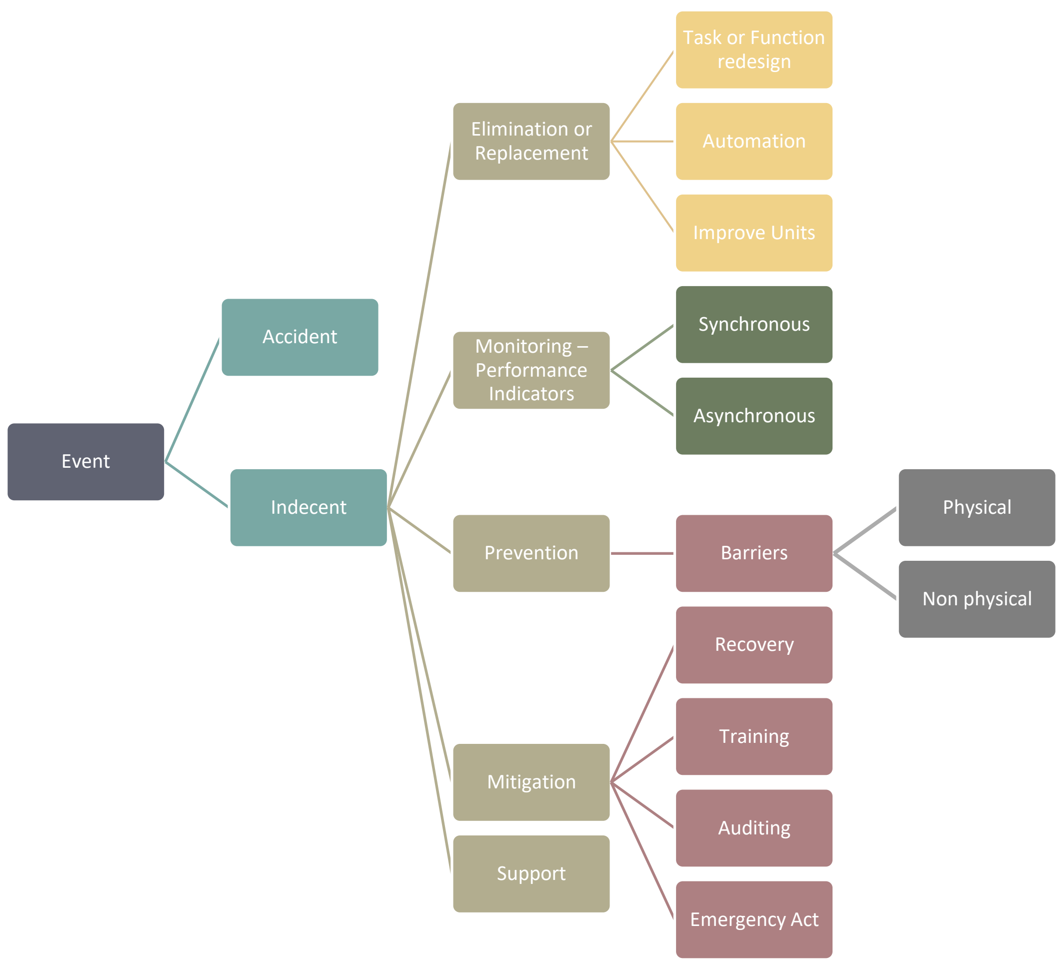

Figure 26-What if an incident happened

11. CONCLUSIONS AND FURTHER STUDY

Every successful organization regarding safety aspects is built on a foundation of essential elements. Leadership has the most impact on safety. Although much has been done to understand the relationship between leadership and safety, much more needs to be done. In addition to reviewing existing safety-related research, this research aimed at introducing more roles that a leader can perform to improve safety in the energy industry. Leaders' and managements' commitment to safety, and their flexibility for applying new technologies and systems, their communication skills, are key components of success.

Leaders, by applying required regulations, educating employees, understanding risk, providing enough resources, defining employees' responsibilities, and implementing proper safety management systems, can guarantee, evaluate, and control process safety and send the safety message to all staff that safety is as important as the production. Leaders', senior managers', and supervisors' behaviors impact subordinate safety performance in various aspects through valuing subordinates, visiting the work sites frequently, participation workgroups for decision making, and giving effective safety communications. All managers and leaders have some place weight in these aspects. Therefore, everyone in the organization should understand their role and influence on subordinates.

Safety is not just a cost. In fact, if a major incident happens the assessed damages, cleanup costs, liability costs, production loss, employees injuries, and fatalities could be dramatically high. In addition to profit and other relevant factors, safety should be considered as the organization's core value. Safety is the backbone of the organization. In fact, safety should not be considered as a project or discrete set of duties. Safety is not just a priority since a priority may change with the time or with needs of the organization. Safety must be a core value.

Occupational Safety and Health Administration (OSHA) promulgated a 14 element regulation for PSM with the purpose of preventing catastrophic release of energy or substances that are hazardous chemicals and avoiding or minimizing the consequences of disasters such as the release of toxins, reactive, flammable, explosive, or a combination of these properties to employees, the community and the environment. Leaders should form and develop process safety management systems in a way to learn from others' incidents and accidents, provide efficient process design, format maintenance systems, be responsible for providing hardware as needed, guarantee safety procedures, and create a safety culture. Many leaders and researchers have recognized organizational culture structure acts like glue that holds the organization together and increases the speed of progress. Even OSHA knows that physical compliance with safety requirements alone will not eliminate incidents. It is an impossible mission for OSHA to write a safety regulation that eliminates every possible or potential hazard in the facility. Therefore, every organization should set a safety culture for the staff to reduce the hazards and risk to the lowest degree. Although no consist universal definition of corporate culture exists, culture reflects shared behaviors, beliefs, attitudes and values regarding organizational goals, function, dangers, risks, and procedure.

Risk and safety are connected both conceptually and logically. The conceptual relation can be described by defining risk and safety. Risk has been defined as the likelihood that something unwanted can happen or as a situation including exposure to danger. Safety likewise defines as the absence of unwanted events, which basically means the absence of risk. Hence, organizations must have such a management system that is able to identify risk, evaluate risk, and have a ready plan to mitigate he risks. Energy companies based on their location and the countries that are operating should adopt the necessary regulations and make a risk management program to prevent, mitigate, and respond to unacceptable risks.

Leaders and managers, by implementing different measuring techniques and safety indicators, can evaluate risks in order to improve safety performance in an organization. Choosing accurate indicators is the key. The objective of hiring matrices must be clear to determine suitable indicators. Both lagging and leading indicators must be applied to learn from past incidents and prevent future incidents. However, the choice of which leading or lagging metrics are the most effective for an organization is expected to change over time.

Safety leadership potentially enables leading indicators. Taking preventative actions through leading indicators in both process and personal safety is easier when leading indicators receive more attention in management communication and also when managers have superior expertise regarding leading and lagging indicators. Leaders can find the weaknesses in the organization and, by guiding the managers - mostly mid-managers - implement correction acts. Improving safety culture is a leading indicator, and becoming a best-in-class safety organization will dramatically help to become a zero-incident-organization.

Some questions came up during this research, which may be good to be researched more. As a system becomes more automated, how can new technologies improve barriers to avoid complexity and also enhance safety

Some questions as guidelines are asked to show the role of leadership and develop safety management system to ensure the safety performance in energy systems to continue this research.

1. How can we improve learning systems and make a practical data base?
2. How can safety culture be evaluated more quantitatively?
3. What are the new metrics that can be defined to improve incident investigation systems and process safety culture?
4. How can we do a better assessment regarding preventing and mitigating risks with hiring quantitatively methods?

Moreover, Emergency respond and plan is not examining by a third party based on regulations. Therefore, how companies can make sure their plan will work in a real situation. Is it required to a third party evaluate the emergency acts?

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