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Safety Culture Monitoring: A Management Approach for Assessing Nuclear Safety Culture Health Performance Utilizing Multiple-Criteria Decision Analysis

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SAFETY CULTURE MONITORING:

A MANAGEMENT APPROACH FOR ASSESSING NUCLEAR SAFETY CULTURE HEALTH PERFORMANCE UTILIZING MULTIPLE-CRITERIA DECISION ANALYSIS

by

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ABSTRACT

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James H. Warren, Jr.
Old Dominion University, 2015
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Nuclear power plants are among the most technologically complex of all energy facilities. This complexity reflects the precision needed in design, maintenance and operations to harness the energy of the atom safely, reliably and economically. Nuclear energy thus requires consistent, high levels of organizational performance by the highly skilled professionals who operate and maintain nuclear power plants (Nuclear Energy Institute [NEI], 2014, p. 1).

A key element for achieving consistent, high levels of performance in a nuclear organization is its safety culture. Nuclear safety culture is for an organization what character and personality is for an individual: a feature that is made visible primarily through behaviors and espoused values. Nuclear safety culture is undergoing constant change. It represents the collective behaviors of the organization, which change as the organization and its members change and apply themselves to their daily activities. As problems arise, the organization learns from them. Successes and failures become ingrained in the organization's nuclear safety culture and form the basis on which the organization conducts business. These behaviors are taught to new members of the organization as the correct way to perceive, think, act and feel (NEI, 2014, p. 1).

Nuclear Safety Culture (NSC) is defined as the core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment (Institute of Nuclear Power Operations [INPO], 2012a, p. iv). Thus, nuclear safety culture depends on every employee, from the board of directors, to the control room operator, to the field technician in the switchyard, to the security officers and to contractors on site. That is, nuclear safety culture is affected by everything we say and everything we do. Nuclear safety is a collective responsibility meaning no one in the organization is exempt from the obligation to ensure nuclear safety first (NEI, 2014, p. 1).

Furthermore, NSC is a leadership responsibility. Leaders reinforce safety culture at every opportunity so that the health of safety culture is not taken for granted. Leaders frequently measure the health of safety culture with a focus on trends rather than absolute values. Leaders communicate what constitutes a healthy safety culture and ensure everyone understands his or her role in its promotion. Leaders recognize that safety culture is not all or nothing but is, rather, constantly moving along a continuum. As a result, there is a comfort in discussing safety culture within the organization as well as with outside groups, such as regulatory agencies (INPO, 2012a). That is, NSC like everything else rises and falls based on leadership (Maxwell, 1998).

In order to facilitate a healthy NSC, which is the *sine qua non* of safe nuclear plant operation, the leadership team needs to understand its present health in order to address NSC issues. It has been said “To manage risk, one has first to comprehend it” (Gheorghe, 2005, p. xvii). Equally true, in order to manage the nuclear safety culture of an organization we must first comprehend it.

The goal of this research is to provide an ongoing holistic, objective, transparent and safety-focused process to identify early indications of potential problems linked to culture. The process uses a cross-section of available data (e.g., the corrective action program, performance trends, NRC inspections, industry evaluations, nuclear safety culture assessments, self-assessments, audits, operating experience, workforce issues and employee concerns program and other process inputs). These data are then analyzed utilizing Multiple-criteria Decision Analysis (MCDA) methodology that incorporates belief degrees of the management team leading to insights about its meaning which may lead directly to corrective actions.

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This dissertation is dedicated to the courageous staff at the Japanese Fukushima Daiichi plants who, through tireless personal effort and exceptional resourcefulness, were able to reduce the magnitude of the release of radioactive contamination to the general population and environment from the nuclear reactor fuel that was damaged as a result of a beyond design basis Tsunami. Furthermore, they loyally performed their duties while not knowing what personal loss the Tsunami had caused to their own families. By their professionalism, initiative and loyal devotion to duty, while facing insurmountable odds, these workers modeled the highest regard for the Nuclear Safety Culture.

ACKNOWLEDGMENTS

While credited as the author of this dissertation, the people who have made this research possible deserve a significant portion of that credit.

Dr. Adrian Gheorghe has served as advisor since when we first talked on the phone while he stood under a tree located on the grounds of what later became the new Engineering Systems Building. He is a dedicated mentor that challenges you to take the research to a higher level while simultaneously focusing its scope so as to make it pragmatic.

The other members of this committee have each contributed substantially to the development of this research. It was in a class led by Dr. Pilar Pozos that the epiphany of how to produce a dissertation first occurred. Dr. Ross Anderson has been a long time co-worker and friend in my commercial nuclear power journey from which I learned probabilistic safety analysis and heat transfer and fluid flow within a nuclear reactor. Dr. Charles Daniels continues to challenge me to deepen my understanding of the relationship between leadership and safety culture. Dr. Cuno Künzler has facilitated the broadening of my understanding of the relationship between organizational culture and safety culture.

In addition, the Program Manager and Advisor Dr. Kim Sibson has been an invaluable guide during the complex dissertation journey. She never failed to respond to my questions and swiftly coordinated required activities.

My parents the Reverend James H. Warren, Sr. and Alice Faye Warren instilled in me high ethical standards and encouraged me to never give up on my dreams. They both modeled this by both attending college in their mid thirties while raising four children and my father working at night to financially support the family.

My brothers Charlie Warren, David Warren and sister Marcile Sims deserve my wholehearted thanks as well. They have been a great group of siblings to grow with through life.

Last but not least, after making so many sacrifices during the years working in the Nuclear Power Field, starting in the U.S. Navy and continuing through 32+ years of commercial nuclear power plant operation, I am grateful to my wife Kathy Warren. She is the love of my life; mate of my soul, mother of our children… everything I ever wanted in a wife and best friend!

Thanks also go to our children Jonathan Warren, David Warren, Christabel Snyder, Seth Warren and Joseph Warren for enduring the long hours of inattention necessitated by seemingly endless nights and weekends of study. I am hopeful these efforts serve to provide a good role model for my children and others in never giving up on their dreams!

NOMENCLATURE

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
CAS	Corrective Action System
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
ER	Evidential Reasoning
FR	Federal Register
FY	Fiscal Year
IAEA	International Atomic Energy Agency
IDS	Intelligent Decision System
INPO	Institute for Nuclear Power Operations
IRB	Institutional Review Board
M&S	Modeling and Simulation
MAUT	Multi Attribute Utility Theory
MCDA	Multiple-Criteria Decision Analysis
MCDA	Multi Criteria Decision Analysis
NEI	Nuclear Energy Institute
NRC	U.S. Nuclear Regulatory Commission
NRC	National Research Council
NRR	Office of Nuclear Reactor Regulation
NSC	Nuclear Safety Culture

PRA Probabilistic Risk Assessment

PSA Probabilistic Safety Assessment

QRA Quantitative Risk Assessment

RA Risk Acceptability

ROP Reactor Oversight Process

RPI Responsible Primary Investigator

RR Risk Rewards

SC Safety Culture

SCMP Safety Culture Monitoring Panel

SCRT Safety Culture Review Team

SCPS Safety Culture Policy Statement

SPS Surry Power Station

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Figure Page

Figure Page

CHAPTER 1

1. INTRODUCTION

1.1 Background

Designed, built, and operated to produce electricity, commercial nuclear power plants consist of complex technologies operating in a complex regulatory environment (Wells, 2010). The technical challenges inherent in the design are confronted by economic demands, mainly due to changes in the circumstances of the energy industry (Itoigawa, Wilpert & Fahlbruch, 2005). The nuclear power industry has been challenged by changing circumstances, including governmental pressures to deregulate energy markets, increases in company mergers, organizational cost-saving strategies, and the replacement of aging technical components with newer and more costly technologies (Itoigawa et al., 2005). Competitive business pressures appear to have been compelling the nuclear power industry to improve delivered value and the processes that deliver value, which can affect the NSC through increased risk (Gheorghe, 2006).

Nuclear power is a complex technology for electrical power generation (Wells, 2010). Commercial nuclear power plants consist of redundant systems that force a nuclear reactor shutdown when temperatures and pressures exceed design basis limits (McAvoy & Rosenthal, 2005). These systems are designed to prevent core damage and resultant potential radiological hazards to the surrounding environments. The technical challenges created by a need to ensure safe operations and to prevent the introduction of radioactive materials into the external environment have been a necessary element in the commercial nuclear industry since its beginnings (McAvoy & Rosenthal, 2005).

Researchers have observed that this complex technology is being confronted by additional challenges and demands, including increased competitiveness among nuclear operating companies, intensified cost-saving strategies, and the replacement of original technical components due to natural aging with newer and more costly technologies (Itoigawa et al., 2005).

Although commercial nuclear power plants in the United States (U.S.) historically have had a reasonable record of safe operations (Langston, 2005; U.S. Nuclear Regulatory Commission, 2009), events in the global nuclear industry have influenced conceptualization of nuclear safety cultures. The industry had its first significant safety culture incident in 1979 as a result of an accident at the Three Mile Island Nuclear Power Plant in the United States (Institute of Nuclear Power Operations, 2004). The importance of maintaining strong cultural attributes related to nuclear safety was reinforced after the 1986 event at the Chernobyl Nuclear Power Plant in Ukraine (International Atomic Energy Agency, 1988). According to industry researchers, one critical factor essential to a strong nuclear safety culture was a nuclear business acumen, which included the ability to manage the unique interaction of risks from technology, economics, human factors, and safety in a changing nuclear business environment (Wilpert & Itoigawa, 2001).

Furthermore, when applying processes to improve value and control costs, key organizational factors could be affected, specifically allocation o f resources and work. Corcoran implied that application of improvement processes could affect the nuclear power plant's institutions by which the work organizations perform its activities involved with nuclear safety (Corcoran, 2010).

1.2 Problem

On April 26, 1986, reactor number four at the Ukrainian Chernobyl Nuclear Power Plant exploded resulting in large geographical areas being contaminated, deaths and mass relocation of an entire city population. The Chernobyl Nuclear Power Plant accident provided a watershed event leading to the studies of a nuclear safety culture concept. Researchers developed the concept of a nuclear safety culture in the aftermath of this nuclear accident at the Chernobyl Nuclear Power Plant. However, the industry had its first significant safety culture incident in 1979 as a result of the accident at the Three Mile Island Unit 2 Nuclear Power Plant in the United States. The accident was caused by a combination of personnel errors, design deficiencies, and component failures. In the aftermath of the nuclear accident at the United State (US) Three Mile Island (TMI) Nuclear Plant in 1979 there has been controversy as to whether the commercial use of nuclear power is safe for the generation of electricity (Gheorghe & Muresan, 2011). In fact, this one nuclear accident resulted in a moratorium on new nuclear plant construction for nearly three decades in the United States. Furthermore, this concern for safety was bolstered by the nuclear accident at Russia's Chernobyl Nuclear Plant in 1986 and again recently by the nuclear accidents at the Japanese Fukushima Daiichi Nuclear multi-plant site in 2011 (Gheorghe & Muresan, 2011). What is not widely known, outside of the nuclear industry, is that after the Chernobyl nuclear accident the US nuclear industry along with its civilian governance organization (i.e., the Institute for Nuclear Power Operation or INPO) and its US government regulator (i.e., Nuclear Regulatory Commission or NRC) have worked relentlessly to establish a robust and pervasive nuclear safety culture (NSC).

The NRC defines Nuclear Safety Culture as: "The core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment (NRC-2010-0282, Final Safety Culture Policy Statement, 2011). It is this Nuclear Safety Culture in the US Nuclear Power Plants that has played a significant role in reducing the risk of a nuclear accident as demonstrated by zero nuclear accidents in the US subsequent to TMI.

In order to facilitate a healthy NSC, which is the *sine qua non* of safe nuclear plant operation, the leadership team needs to understand its present health in order to address NSC issues. The volumes of literature on these nuclear accidents; however, has dealt almost exclusively with technical, radiological, and environmental issues. No research was located that studied utilized Multiple-Criteria Decision Analysis Methodology (MCDA) to determine the health performance of a NSC. This research will be conducted to bridge a gap in knowledge and to supplement the body of knowledge with respect to NSC health utilizing a MCDA methodology.

1.3 Purpose

If an excellent NSC is not maintained, then another nuclear accident might occur at a nuclear power plant, utilized for the commercial generation of electricity in the US, which could result in the end of the commercial use of nuclear power to generate electricity in the US.

The health of the NSC is a function of our belief and those beliefs can influence our understanding. In addition, our belief may not always agree with the results of our NSC assessments. Some assessments rely solely on belief in order to qualify or quantify the health of the NSC while others seek to exclude degrees of belief altogether by relying exclusively on objective data. Multiple assessments that seek to assess the health performance of a NSC in a specific organization could vary widely due to being based on tangible data or intangible data (e.g., belief).

Rather than fault the subjectivity of our degrees of belief of the health performance of a NSC, or confuse our objective assessments with personal opinions, it is proposed that we integrate our belief as a unique component of NSC health assessments. Consequently, a MCDA based process is proposed in this dissertation to systematically collect and integrate assessments of NSC in a manner that so that each dimension can be explored uniquely, and such that all components can be aggregated into an overall health assessment in a systematic, transparent, traceable, and reproducible manner.

Consequently, the purpose of this research study is to evaluate NSC health as a function of belief, quantified as degrees of belief, and tangible inputs integrated with MCDA in order to reduce the subjectivity of NSC assessments. Some assessments rely on degrees of belief from subject matter experts (SME) in order to qualify or quantify. Others exclude degrees of belief altogether, relying on objective data, if available. Rather than fault the subjectivity of our belief, or dilute objective assessments with personal opinions, it is logical to embrace our belief of the health performance of a NSC, but isolate and include them as a unique component of the NSC health assessment.

Again, a MCDA based NSC health assessment methodology is proposed by this dissertation to systematically collect and integrate tangible indicators of NSC health along with the intangible of our belief. Combined in a manner that each dimension can be explored uniquely, and such that both components (tangibles and intangibles) can be integrated into an overall Nuclear Safety Culture Health assessment in a consistent and reproducible manner (Figure 1). This NSC health assessment methodology draws from the fields of nuclear engineering, systems engineering, and psychology to develop a model that integrates the intangible of our belief with the various other tangible inputs using Multi-criteria Decision Analysis (MCDA).

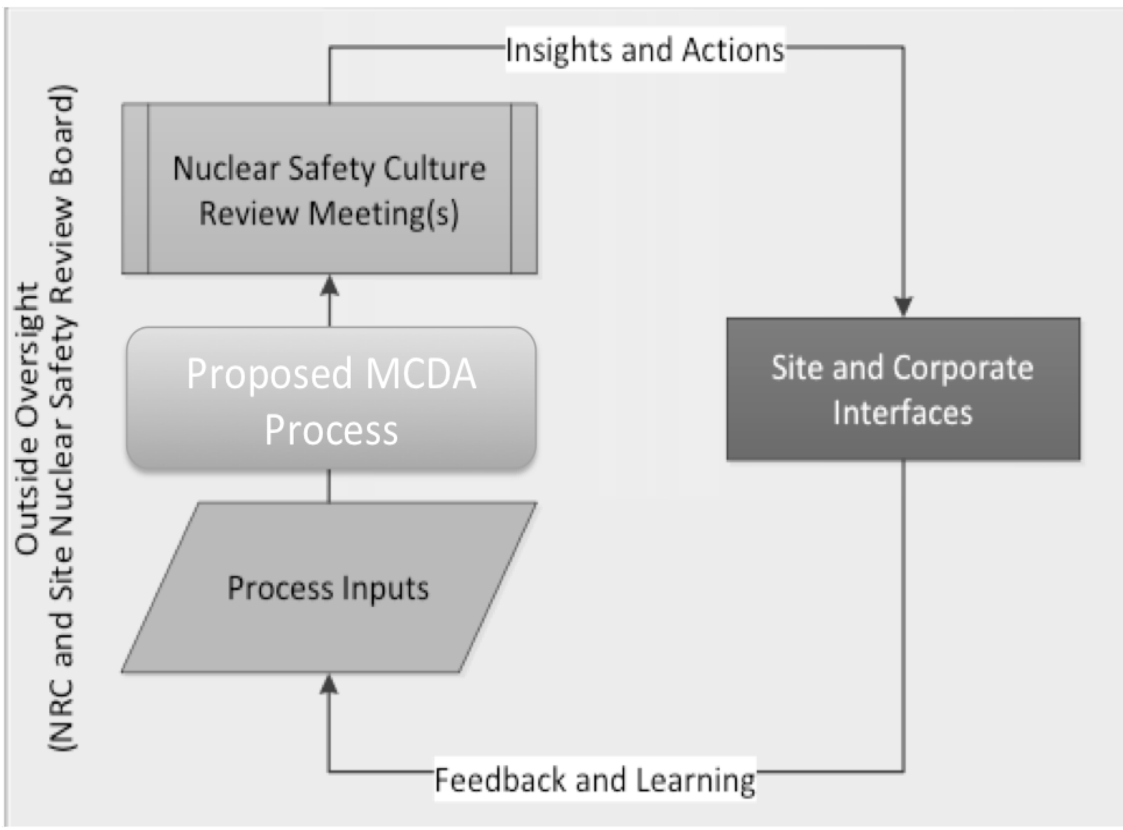


Figure 1. NSC Assessment with Proposed MCDA Process

The NSC Assessment with MCDA Process consists of three phases as illustrated in Figure 2. The first phase is the Deterministic Phase where the process inputs are evaluated and binned. The second phase consists of a Qualitative/Quantitative Survey where upper management's degrees of belief of the health of various NSC scenarios are assessed. The final phase is the assessment integration phase, where the binned process inputs and the assessment of degrees of belief are both assimilated. These phases will be discussed in greater detail in Chapter Four.

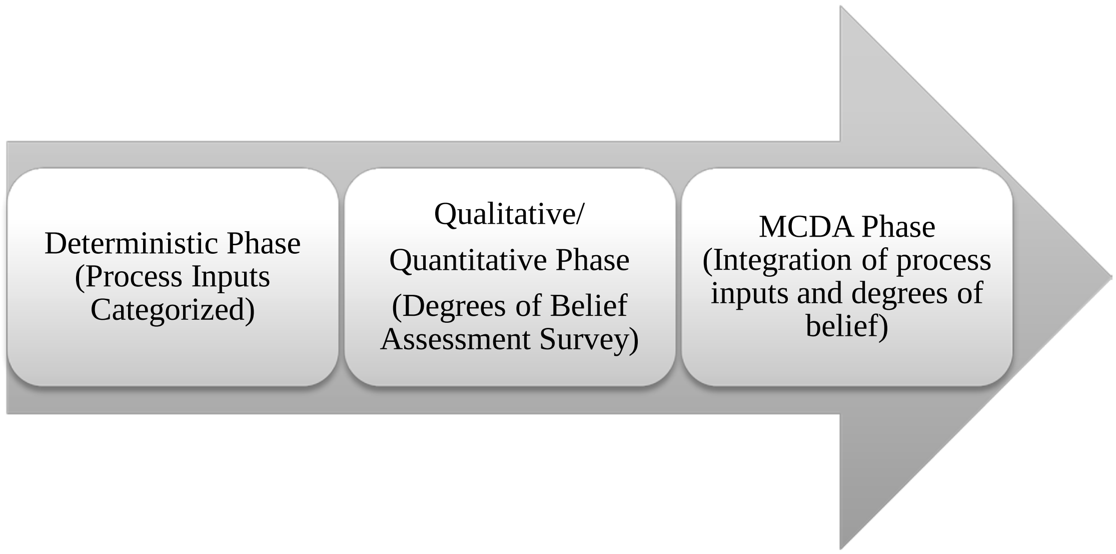


Figure 2. Three Phases of the NSC Assessment with MCDA Process

The purpose of this research, as illustrated in Figure 3, is three-fold. First, it is necessary to determine how to assess the belief of NSC Health for a given scenario. We are less concerned with the degrees of belief data, itself, or even with which method is considered the best way to collect the belief data; rather, we are concerned with integrating degrees of belief data with binned Process Input data. It is assumed that data for the Process Inputs and even degrees of belief could be leveraged from previous assessments, collected as part of the research, or simulated, if necessary, in order to demonstrate the viability of the NSC with MCDA methodology.

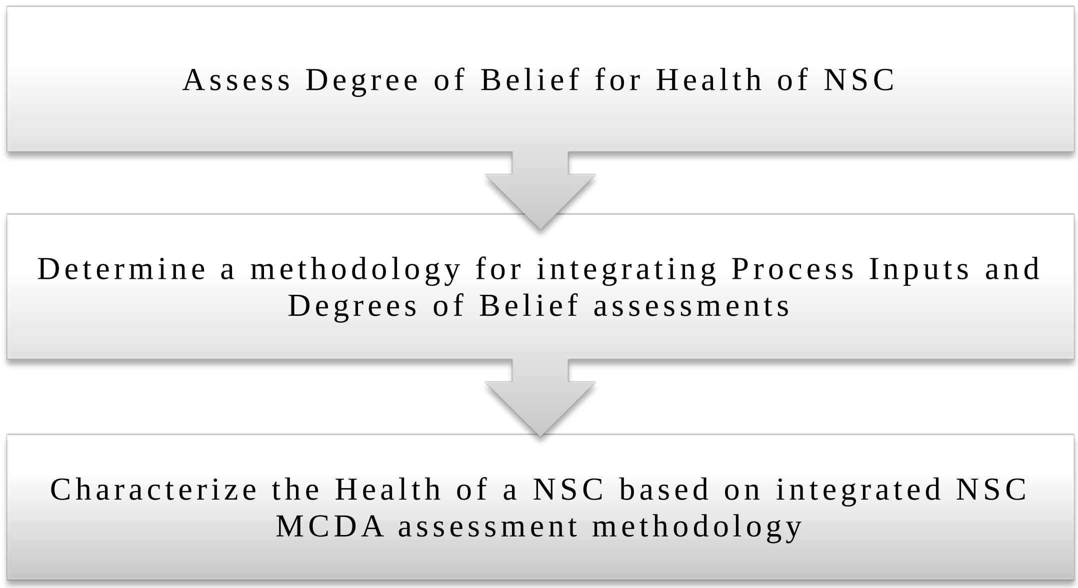


Figure 3. Research Purpose

Next, an integrated NSC with MCDA assessment methodology must be researched. The belief is that the currently accepted NSC Assessment methodology of simply binning and trending the process inputs is inadequate for characterizing health of the NSC and that an integrated model should be explored to incorporate belief into the current health assessment approach. However, precisely how those components of health are integrated must be decided. The improved health assessment integration methodology, based on the binned process inputs and degrees of belief assessments, will be developed and presented. This methodology will systematically integrate both assessments in a meaningful, traceable, and reproducible approach. The end result will be a health indicator of NSC, based on the NSC with MCDA methodology that will assist organizational decision makers in assessing the health performance of an organization's NSC.

1.4 Theoretical Framework

A brief literature review is provided to outline the basic concepts of a nuclear safety culture. It was this review that provides the linkage from nuclear safety culture theory and selection of the Nuclear Energy Institutes model for empirical operationalization. Different methodologies used for analyses of safety cultures are discussed. The need for additional studies in the field of nuclear safety culture health assessment are identified and discussed.

Researchers developed the concept of a nuclear safety culture in the aftermath of a nuclear accident at the Chernobyl Nuclear Power Plant in Ukraine (International Atomic Energy Agency, 1988). On April 26, 1986, reactor number four at the Ukrainian Chernobyl Nuclear Power Plant exploded, which resulted in the top being torn from the reactor and exposing the nuclear core (Medvedev, 1990). Large geographical areas were badly contaminated, dozens of people died, and 336,000 people were evacuated and resettled (Medvedev, 1990). Although the severity of the Chernobyl Nuclear Power Plant accident may have been the catalyst for studies of a nuclear safety culture concept, the industry had its first significant safety culture incident in 1979 as a result of the accident at the Three Mile Island Nuclear Power Plant in the United States (Institute of Nuclear Power Operations, 2004). As explained by Itoigawa, Wilpert and Fahlbruch, the accident at the Three Mile Island Unit 2 Nuclear Power Plant near Middletown, Pennsylvania, resulted in a partial meltdown of the reactor core (Itoigawa, Wilpert, & Fahlbruch, 2005). The researchers determined the accident was caused by a combination of personnel errors, design deficiencies, and component failures. The extensive literature on these two nuclear accidents, however, has dealt almost exclusively with technical, radiological, and environmental issues. Researchers for the International Atomic Energy Agency studied the concept of a nuclear safety culture after the Chernobyl accident and developed common terms, definitions, and methods for assessment (International Atomic Energy Agency [IAEA], 1988). Analysts at the Institute of Nuclear Power Operations studied nuclear power plant events and problems relating to shortfalls in a nuclear safety culture (Institute of Nuclear Power Operations [INPO], 2003; Institute of Nuclear Power Operations [INPO], 2004). Perin (2005) argued that a nuclear power plant culture embodies several different cultures of control based on different methods of risk assessment. For example, the commercial nuclear industry culture is organized around a structured logic of command and control, which requires tradeoffs with a parallel logic of problem identification and diagnosis. The two different intra-cultural logics have not aligned in an environment of intense pressures relative to schedule, electricity output, and reduction of operating costs. Dimensions of a nuclear safety culture may be defined by multiple attributes and measured through multiple methods (Corcoran, 2010; International Atomic Energy Agency [IAEA], 2002). Researchers have typically employed questionnaires and surveys to measure the attributes of leadership; worker and manager attitudes, beliefs, values, and behaviors; and, degrees of beliefs of risk, stress, and decision-making, all of which have some relevance to worker performance and the safety culture (Corcoran, 2010; Findley, 2004; Itoigawa et al., 2005; Reiman, 2007). Other researchers have studied safety culture attitudes, values, and beliefs in other high-risk industries (Bums, 2005; Helrnreich & Merritt, 1998; McDonald, 2006; Reason, 1997). A nuclear safety culture may also be defined by specific observable physical attributes (Corcoran, 2010; Institute of Nuclear Power Operations, 2009). Observations of human actions and physical objects, such as the quality of physical goods and archival records, have been employed in some continuous improvement and safety culture studies (Helmreich & Merritt, 1998; Keating, Olivia, Repenning, Rockart, & Sterman, 1999). Human observations have frequently been used in nuclear power plant studies because the situation and resultant behaviors are not easily predictable (Corcoran, 2010; Institute of Nuclear Power Operations, 2006). Nuclear safety culture researchers have focused on the individual worker's commitment and performance based on attitudes, work approaches, and communication systems (Reason & Hobbs, 2003; Reiman, 2007). Reason and Hobbs (2003) concluded that the most common worker errors at nuclear power plants were caused by failure to do something that should have been done rather than doing something incorrectly. Some nuclear safety culture researchers have studied other dimensions of the complex and dynamic interrelationships within the organizational cultures at nuclear power plants. Findley (2004) and Matthews (2006) found that organizational priorities were not always properly balanced between safety and production and often safety cultures were constrained when production factors became priorities over prevention factors. Reiman (2007) studied the maintenance organizations at three European nuclear power plants and concluded that nuclear safety was affected if the demands of the organizational task were not aligned with the dynamics of the organization's culture. Researchers have stated common parallel underlying extended shutdowns of U.S. nuclear power plants appeared to be the tension between increasing economic and production pressures and diminishing safety culture margins (Institute of

Nuc1ear Power Operations, 2003; Itoigawa et al., 2005). For example, in 1996 the U.S. Nuclear Regulatory Commission directed Northeast Utilities to shut down the three nuclear reactors at the Millstone Nuclear Power Plant in Connecticut. Contributing to the shutdown was diminishing safety culture margins exacerbated by competitive advantage strategies (McAvoy & Rosenthal, 2005). The U.S. Nuclear Regulatory Commission directed closure of the Maine Yankee Nuclear Power Plant in 1997 because of cost cutting measures at the expense of safety considerations (Jackson, 1997). A significant operating event occurred in 2002 at the Davis-Besse Nuclear Power Plant when the reactor pressure vessel head began to leak radioactive coolant (U.S. Nuclear Regulatory Commission, 2002). Analysts at the Institute of Nuclear Power Operations (2002b) concluded a major contributor to this event was a shift in focus at all organizational levels from implementing high safety standards to justifying minimal safety standards. These analysts stated that a reduction in standards resulted from excessive focus on meeting short-term production goals. Within the high-risk industries of aviation and space operations, medical surgery, chemical processing, and offshore drilling, more safety culture studies have been conducted than in the nuclear industry. Researchers have traced various efficiency and cost containment influences as sources of accidents (Columbia Accident Investigation Board, 2003; Helmreich & Merritt, 1998; McDonald, 2006; Vaughan, 1996). Based on the accidents studied, a parallel was evident among increasing production pressures and schedule conflicts and diminishing safety culture margins. Corcoran (2010) stated that the concept of a nuclear safety culture could benefit from more research and reflection.

This research was conducted to bridge a gap in knowledge and to supplement the body of knowledge on health evaluation with respect to nuclear safety cultures.

1.5 Research Questions

The research will seek to address the three questions presented in Figure 4. These questions, and their associated assumptions, are the culmination of an intensive Literature Review (Chapter 2) that highlighted a number of issues and questions that require resolution in the field of Nuclear Safety Culture. The problem statement is reformulated in this section as three questions this research effort attempts to answer. These questions are presented to assist with delineating the scope of this research.

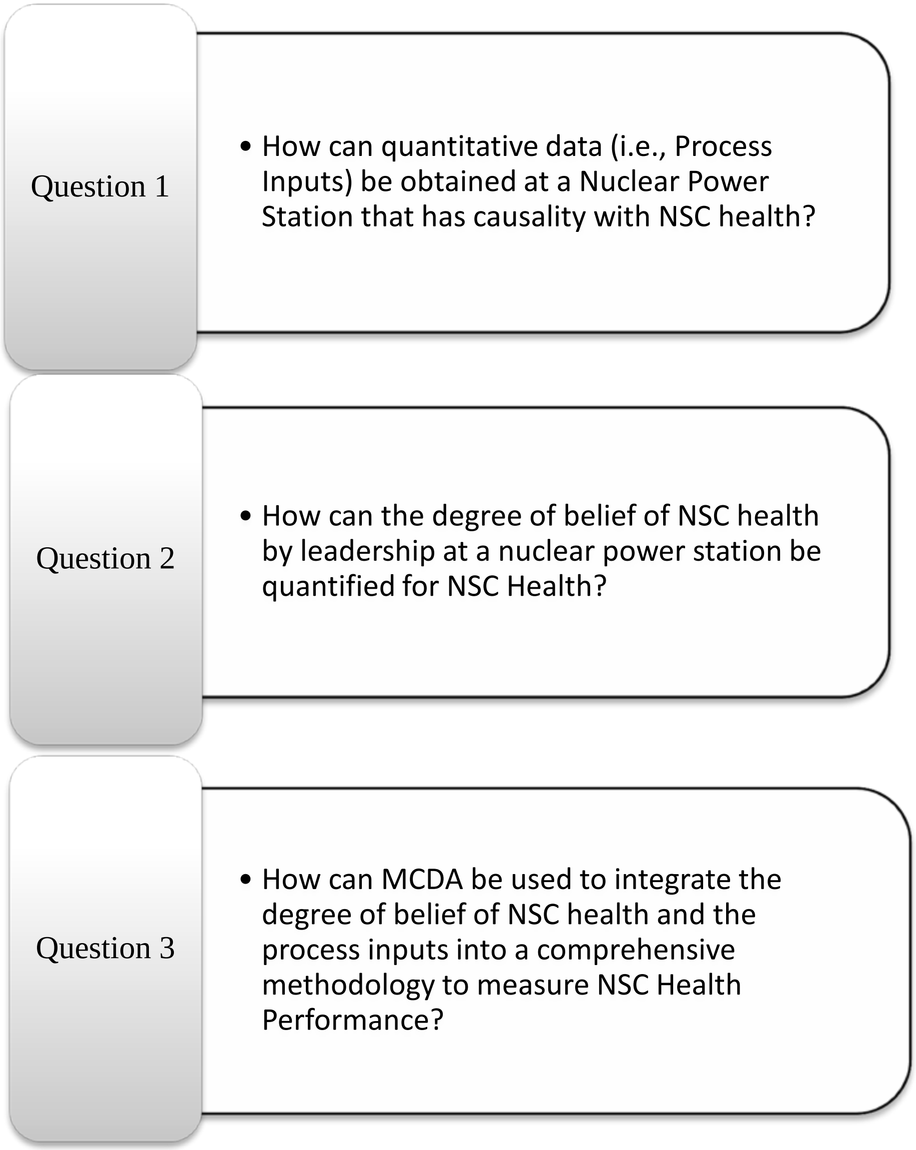


Figure 4. Research Questions

Question 1

How can quantitative data (i.e., Process Inputs) be obtained at a Nuclear Power Station that has causality with NSC health?

Question 2

How can the degrees of belief of NSC health by leadership at a nuclear power station be quantified for NSC Health?

Question 3

How can MCDA be used to integrate the degrees of belief of NSC health and the process inputs into a comprehensive methodology to measure NSC Health Performance?

1.6 Nature of the Study

There are some limitations to this research related to data access or collection, model selections, and technology. A degrees of belief assessment model must be selected that will ultimately produce results compatible with the MCDA model selected. Process Input data and degrees of belief data will need to be leveraged, collected, or simulated, and again those data must be compatible with the selected MCDA model. A MCDA model must be selected from a number of potential options. Finally, the research is constrained by the technology available to conduct the assessments, as well as to integrate the assessments during the third phase of the methodology.

1.7 Significance of the Study

There are two main contributions proposed for this research as illustrated in Figure 5.

First, this research will present a MCDA model for integrating assessments of the binned process inputs data and degrees of belief, incorporating them all into a NSC Health assessment approach.

Second, this research will produce a methodology for deploying the NSC with a MCDA model, to include a means for collecting degrees of belief data for a NSC and then integrating it with the process input data.

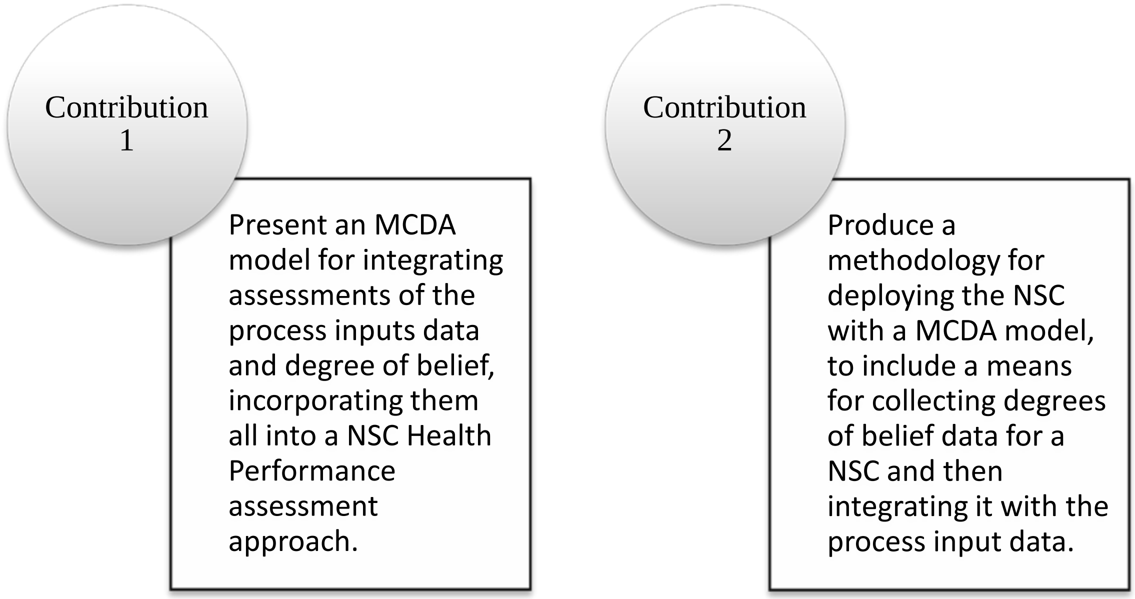


Figure 5. Research Contributions

1.8 Definitions

Many of the following definitions will be discussed in further detail in the Literature Review. However, below is a list of terms and their intended meanings when used throughout this research. Some of these definitions are extracted from the literature. Others are modified from definitions provided in official, government documents. All of these definitions, as they are presented here, reflect the intents and purposes of this research.

Belief: An idea held to be true that may or may not be reflective of reality.

Consequence. Effect of a successful risk scenario on an asset. Consequence is commonly assessed along four factors: human, economic, mission and psychological, but may also include other factors such as impact on the environment; consequence can be measured quantitatively if data exist, but can also be measured qualitatively either along a set of scales or along a single integrated consequence scale for which all consequence factors are considered as a whole.

Credence. Mental acceptance as true or real.

Critical Infrastructure. Government and private systems essential to the operation of our nation in any or all aspects of the lives of its citizens (health, safety, economy, etc.), such as utilities, facilities, pipelines, etc.

Event. Event is defined as an outcome, condition or eventuality that occurred during some activity and resulted in challenges to safe plant operations (Adams, 2007).

Degrees of belief. The subjective interpretation of probability. Probability loosely defined can then be said to be a measure of the degrees of belief (Ramsey, 1978).

Executives. Corporate decision makers who are responsible for setting the long-term strategic goals for the organization; executives develop and implement corporate policies.

High-Risk. High-risk is defined as a hazardous activity or business venture where the risk to human life is an essential part of the operation and a proper balance between production and safety is required (Collins, 2005).

Independent Oversight Organizations. Groups that independently review the performance and direction of the organization.

Individual Contributors. Individuals who operate individually or as members of work groups to accomplish tasks; individual contributors may include leaders when leaders are acting in a nonsupervisory capacity or are accomplishing tasks as members of a work group.

Individuals. All people at all levels of the organization; individuals include all leaders, individual contributors, and supplemental personnel.

Leaders. Individuals who influence, coach, or lead others within the organization and determine the vision, goals, or objectives of their teams; leaders include executives, managers, supervisors, and others who influence individuals in the organization.

Managers. Individuals assigned to managerial positions who control, direct, guide and advise; managers include senior managers, and may include some supervisors.

Multi-criteria Decision Analysis. Multi-criteria decision analysis (MCDA) is a discipline that encompasses mathematics, management, informatics, psychology, social science and economics. Its application is even wider as it can be used to solve any problem where a significant decision needs to be made. These decisions can be either tactical or strategic, depending on the time perspective of the consequences. MCDA methods provide stepping-stones and techniques for finding a compromise solution. They have the distinction of placing the decision maker at the centre of the process. They are not automatable methods that lead to the same solution for every decision maker, but they incorporate subjective information. Subjective information, also known as preference information, is provided by the decision maker, which leads to the compromise solution.

Nuclear Safety Culture. (Previous definition from INPO) Nuclear safety culture is defined as a nuclear organization's values and behaviors - modeled by its leaders and internalized by its members - that serve to make nuclear safety its overriding priority (Institute of Nuclear Power Operations, 2004).

Nuclear Safety Culture (INPO Definition). Nuclear safety culture is defined as the core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment (INPO, 2012a).

Nuclear Safety Culture (NRC Definition). The set of core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment (NRC-2010-0282, Final Safety Culture Policy Statement, 2011).

Nuclear Safety Culture Trait. A pattern of thinking, feeling and behaving such that safety is emphasized over competing priorities.

Organizational Culture. Organizational culture is the shared basic assumptions that are developed in an organization as it learns and copes with problems. The basic assumptions that have worked well enough to be considered valid are taught to new members of the organization as the correct way to perceive, think, act and feel. Culture is the sum total of a group's learning. Culture is for the group what character and personality are for the individual (INPO, 2012a).

Process Inputs. The key data inputs to the nuclear safety culture monitoring process. This data is gathered from various sources (see Section 3.4) including the nuclear power plants' corrective action (incident) reporting systems, excluding proprietary, personal and security safeguards documentary materials. For each input, there are data (e.g., deficiencies, violations, weaknesses, or strengths) that are reviewed in combination with data from other inputs to determine whether there is a nuclear safety culture issue.

Safety Culture Monitoring Panel (SCMP). This consists of key site personnel that meet periodically to review station performance and bin events and trends to the Traits for a Healthy Nuclear Safety Culture. The primary function of the SCMP is to periodically assess nuclear safety culture trends and identify potential trends and/or emergent issues then roll those up to the Safety Culture Review Team. This team consists of a supervisor or individual contributor representative from each of the departments at the power station. Consequently, the members of this team ensure the various sub-culture views at a power station are expressed.

Safety Culture Review Team (SCRT). This is the management team that reviews the results of the SCMP and takes corrective actions to address trends in the safety culture. The primary function of the SCRT is to monitor and promote a healthy nuclear safety culture by conducting a reflective self-critique of information that reflects the health of the Station's safety culture.

Senior Managers. Those managers who are responsible for the execution of business activities, including setting priorities for and monitoring the performance of the organization.

Supervisors. Individuals who provide direction of the day-to-day activities of individual contributors; supervisors may include superintendents, foremen, or work group leads.

Supplemental Personnel. Individuals who accomplish work for but are not employees of the organization; supplemental personnel include short- and long-term contractors and individuals who are not employed by the organization but occasionally perform work related to nuclear safety.

System of Systems. Possess the same definition as systems, but on a larger scale. For a hierarchy of systems, in which systems are components or subsystems of other systems; component systems each have a purpose of their own and would continue to operate even if separated from the overall system. Each component system is managed individually, rather than being managed within the context of the entire system of systems. System of systems often exhibit characteristics of complexity and widespread geographic distribution. The combination of several interdependent CI showing the characteristics of a single system, but lack an overarching management entity (Gheorghe, Masera, & Voeller, 2008; Maier, 1998; Skyttner, 2005).

Systems. Comprised of interrelated or interdependent objects. Systems exhibit holistic properties not necessarily evident at the level of individual objects or subsystems; seek to achieve some final goal or state, and in order to reach this goal they transform inputs into outputs; tend to devolve into entropy without regulation and are typically organized in a hierarchical system of nested subsystems where the subsystems are specialized with different functions within the system. Systems either diverge, in which case it has many ways of achieving a single goal, or converge, where, from an initial state, it could achieve many different goals (Skyttner, 2005).

The Organization. The collective group of all individuals, the reporting structure and the procedures, policies, and practices that individuals use to set goals and make decisions, to accomplish tasks and to implement and maintain a healthy nuclear safety culture.

Threat. The threat of a risk scenario to an asset. The threat of an intentional risk scenario is generally estimated as the likelihood of an attack (that accounts for both the intent and capability of the adversary) being attempted by an adversary. For other risk scenarios, threat is generally estimated as the likelihood that the risk scenario will manifest; however, threat can also be estimated qualitatively as perceived likelihood.

True Belief. An idea held to be true (i.e., a belief) that is reflective of reality.

Vulnerability. Ability of an asset to endure a risk scenario despite physical features, operational attributes, characteristics of design, location, security posture, operation, or any combination thereof that renders an asset open to exploitation or susceptible to a given risk scenario. Vulnerability can be estimated qualitatively, or quantitatively, as the likelihood of a successful risk scenario given the risk scenario is identified, which implies that vulnerability is also related to resilience.

Work Groups. Groups of individuals who work collaboratively to accomplish tasks; work groups may exist at any level of the organization.

1.9 Summary

The technological complexities inherent in nuclear power plants to prevent reactor core damage and potential radiological hazards, while ensuring continual operations to support electricity generation, have been challenged by economic pressures to improve the processes that deliver value by reducing production wastes and operating costs (ltoigawa et al., 2005). Researchers have stated a common parallel underlying extended shutdowns of U.S. Nuclear power plants appeared to be the tension between increasing economic and production pressures and diminishing safety culture margins (Institute of Nuclear Power Operations, 2003; Itoigawa et al., 2005).

The concept of a nuclear safety culture is complex and somewhat difficult to comprehend. In fact, the literature on safety culture has demonstrated that the concept includes many interrelated components and members of many organizations (Itoigawa et al., 2005).

Organizational causes for nuclear power plant events and extended plant shutdowns have been examined in the literature (Itoigawa et al., 2005), and in recent years researchers have conducted studies examining precursors to these organizational causes. These precursors typically have included various dimensions of leadership and organizational behaviors. Several event investigations at U.S. nuclear power plants have uncovered organizational flaws.

Organizational culture and nuclear management researchers have not adequately studied the effect of degrees of belief of risk on the safety culture of a commercial nuclear power plant. The literature on nuclear power plant accidents has dealt almost exclusively with technical, radiological and environmental issues. This research attempted to bridge a gap in knowledge and to supplement the body of knowledge on nuclear safety culture health measurement.

Within the next chapter of this dissertation, a review of organizational culture, relevant safety culture literature and NSC health performance measurement is provided. Since organizational culture and nuclear management literature have not adequately addressed the effect of degrees of belief on a nuclear safety culture, this review included literature in the area of a nuclear safety culture and safety cultures in other high-risk industries, wherein the latter often focused on industrial safety cultures. As such, Chapter 2 has been divided into four subsections of prior studies to assist in comprehension of the material: an overview of organizational culture, a safety culture relative to a nuclear power plant safety culture, current trends in NSC performance measurement and a safety culture relative to other high-risk industries.

CHAPTER 2

2. LITERATURE REVIEW

The foundational basis for this research comes from studies evaluating safety cultures by industry, government and academic organizations. Researchers and theorists have studied organizational culture concepts, staff and budget change processes, and the effects of staff and budget change processes on organizational cultures. Consequently, these topics were considered pertinent for this research. The factors that define and influence any organizational culture have typically been viewed as difficult to quantify and are normally formed over a long process of implementation by members of the organization (Robbins, 2003).

This section has been divided into four subsections of prior studies to assist in comprehension of the material: an overview of organizational culture, a safety culture relative to a nuclear power plant safety culture, current trends in NSC performance measurement and a safety culture relative to other high-risk industries. The high-risk industries studies are not focused on nuclear safety cultures but rather industrial safety cultures. However, there are similarities between an industrial safety culture and a NSC, which will be discussed (Wells, 2010).

2.1 Organizational Culture

There seems to be wide agreement that organizational culture refers to a system of shared meaning. This system of shared meaning is, on closer examination, a set of key characteristics that the organization values. The research suggests that there are seven primary characteristics that, in aggregate, capture the essence of an organization's culture (Robbins, 2003, p. 525).

1. *Innovation and risk taking.* The degree to which employees are encouraged to be innovative and take risks.
2. *Attention to detail.* The degree to which employees are expected to exhibit precision, analysis and attention to detail.
3. *Outcome orientation.* The degree to which management focuses on results or outcomes rather than on the techniques and processes used to achieve those outcomes.
4. *People orientation.* The degree to which management decisions take into consideration the effect of outcomes on people within the organization.
5. *Team orientation.* The degree to which work activities are organized around teams rather than individuals.
6. *Aggressiveness.* The degree to which people are aggressive and competitive rather than easy going.
7. *Stability.* The degree to which organizational activities emphasize maintaining the status quo in contrast to growth.

Each of these characteristics exists on a continuum from low to high. Appraising the organization on these seven characteristics, then, gives a composite picture of an organization's culture. This picture becomes the basis for feelings of shared understanding that members have about the organization, how things are done in it, and the way members are supposed to behave (Robbins, 2003)

Furthermore, organizational culture has been conceptualized as a set of intangible attributes, such as values, beliefs, assumptions, behaviors, degrees of beliefs and norms, synergistically working with tangible attributes, such as customs, traditions, rituals and shared group meanings (Shafritz & Ott, 2001). Some theorists have defined organizational culture as shared meanings that group members assign to organizational concepts and frameworks that are held in common. A definition of this type would include Schein's (2004) assertion that the culture of a group includes patterns of assumptions held in common that the group learned as it matured. Hofstede (n.d.) defined organizational culture as the collective programming of the mind distinguishing the members of one group from another. Others have defined organizational culture as the shared meanings, behaviors, and assumptions aligned with the differences in meanings, behaviors, and assumptions. For instance, Schneider (1990) maintained that shared group behaviors and assumptions that prevail across the work environment would be countered by individual behaviors and assumptions. Other dimensions and attributes for organizational culture have been conceptualized (Wells, 2010). Cameron and Quinn (2006) summarized the works of some culture researchers, specifically the studies conducted by Martin (1992). Martin proposed three dimensions to an organizational culture - integration, differentiation and fragmentation - that supposedly co-exist in all organizations. The integration dimension was similar to Schein's (2004) conceptualization that organizational culture was a set of shared meanings. The differentiation dimension was similar to Schneider's (1990) conceptualization that organizational cultures were defined by the differences and conflicts between subgroups within the organization. The fragmentation dimension was based on the assumption that organizational cultures were ambiguous and unknowable. Cameron and Quinn (2006) argued that culture cannot be described as an attribute of an organization since it was the inherent in the organization itself. Wagner and Hollenbeck (2005) summarized other perspectives and dimensions, including Hofstede's (n.d.) culture dimensions of power distance, uncertainty avoidance, individualism, and masculinity and Ernst's (2001) perspective of an organizational culture grid, wherein people orientation (i.e., participative leadership) and response to the environment were the key cultural dimensions. Kotter and Rathgeber (2005) argued that congruence was a key dimension within organizational cultures. Hofstede (n.d.) documented that organizational cultures differ mainly at the level of practices. Examples of practices included symbols and rituals, process-oriented versus results-oriented perspectives, open systems versus closed systems and tight versus loose controls. According to Hofstede (n.d.), since organizational cultures were rooted in practices, they were somewhat more manageable than national cultures which tended to be rooted in values. Based on additional studies, the cultural dimensions of power distance, uncertainty avoidance, individualism and masculinity were amended to include a fifth dimension of long-term versus short-term orientation (Hofstede & Hofstede, 2004). A long-term orientation indicated values of efficiency, stewardship, and perseverance, with an organizational mindset of safeguarding the organization or group. A short-term orientation indicated values of sustaining tradition, protecting a group's reputation, and meeting obligations (Wells, 2010). Although these two orientations have some relevance to functions within business organizations, application of orientation to business cultural practices was not clear. The classical conceptualization of culture was viewed as a process within a non-equilibrium state and included diagnosis as a key component for understanding an organization's culture and eventually changing the culture to a desired state (Seel, 2000). Seel argued that organizational culture should be considered an emergent result of conversations and negotiations between members of an organization. The implications of this viewpoint were that organizational cultures should be described by participative and collaborative inquiry rather than diagnosis (Wells, 2010). Seel applied Schein's (2004) approaches to organizational culture to the argument - if a culture is co-created by the collective membership of the organization, then these members should jointly inquire into it. In an effort to identify the specific constructs used by researchers to describe the larger concept of organizational culture, Detert, Schroeder, and Mauriel (2000) performed a qualitative content analysis of the literature. The results of the analysis indicated a small number of constructs were common in the majority of existing culture research. These constructs included ideas held within organizations about the basis of truth and rationality, the nature of time and the time horizon, stability relative to change and innovation, orientation to work, isolation relative to cooperation, and orientation and focus (i.e., internal versus external focus). The last construct was of interest from a continuous improvement perspective. It included ideas about whether the organization assumes it controls, or is controlled by, its external environment, wherein the focus would be either on improving processes in the organization or on improving its standing in the industry (Detert et al., 2000). Culture in groups and organizations has been difficult to define in unambiguous terms (Schein, 2004). Cameron and Quinn (2006) maintained that the broadness and inclusiveness of organizational culture have resulted in the many different conceptualizations. As noted by Cameron and Quinn, since the concept is comprised of a set of complex, interrelated, and ambiguous factors, it would be impossible to include every relevant factor when assessing organizational culture. Reason (1997) observed that a continuing controversy among social scientists was whether a culture is something an organization *has* or whether it is something an organization *is*. Reason viewed culture as a hidden force that unified an organization by providing meaning, direction, and mobilization. Although operationally culture has been defined as shared values, beliefs, assumptions, and norms, these concepts are seldom documented yet learned by living in an organization and becoming a part of it (Frick, 2007). Different conceptualizations of organizational culture may have been developed due to differences in actual organizational cultures. As stated by Shafritz and Ott (2001) , each organizational culture is different because what has worked repeatedly for one organization may not for another, which results in changes to basic assumptions. These researchers maintained that an organization's culture is shaped by many factors, including the societal culture in which it resides and its technologies, markets, and competition (Wells, 2010). Further, some organizations have many subcultures that exist in different geographical areas (Shafritz & Ott, 2001). Other factors that shape an organization's culture include the structural foundations of the organization, which may be ordered by the regulatory environment, and the internal integration necessary for group functioning and adaptation to changing environments (Cameron & Quinn, 2006). Schein (2004) maintained that when the intangible aspects of culture are applied to organizations engaged in producing goods and services, the term organizational culture must be broadened to include the tangible aspects of structure and patterning (Schein, 2004). Yukl (2002) stated that structure would be used to stabilize an organization and the organizational structure included systems, processes, policies, rules, and the way the organization functions. According to Schein (2004), patterning and integration would be used to bind the various intangible elements of culture into a coherent whole. Schein viewed patterns as derived from accumulated learning as an organization solves its problems, while integration was viewed as derived from various subcultures, such as professional and national subcultures. Other dimensions have been proposed to classify organizational cultures by types. Schein presented these other dimensions as universal typologies (Schein, 2004). According to Schein, the value of typologies was to provide useful categories for sorting out the complexities of organizational realities. The basic typology focused on assumptions about individual participation and involvement in the organization. The next level of typology focused on assumptions of corporate character and culture. A more difficult typology was described as intraorganizational. Schein (2004) viewed the intraorganizational typology as difficult because work arrangements within many organizations were based on a combination of the work to be done and the occupational reference groups performing the work. Thus, organizational culture includes formal structural relationships and problem solving approaches and informal assumptions and group interconnections (Wagner & Hollenbeck, 2005). Based on the various conceptualizations of organizational culture, a formal definition of organizational culture was developed by Schein (2004) that included the various factors that shape a culture. This definition of organizational culture has been used in the nuclear power industry to conceptualize a nuclear safety culture (Wells, 2010). The culture of an organization was defined as a pattern of shared assumptions that the organization learned as it solved the problems encountered with internal integration of its members and external adaptation to its surroundings. Schein added to this definition that the organization's culture has worked sufficiently well to be considered valid to be taught to new organizational members as the correct way to perceive, think, and feel relative to the problems of integration and adaptation. Schein distinguished between underlying beliefs and espoused values, wherein the values mayor may not be consistent with the beliefs (Schein, 2004). For example, an organization might espouse that quality is the primary objective for its products, but the underlying belief might be that any defects in the products would be marketed anyway at a discounted price. The underlying beliefs of the organization's culture would be the learned responses to problems encountered in the external environment and problems encountered with internal integration (Wells, 2010). Another way of conceptualizing organizational culture is as a composite of interacting subcultures that have specific characteristics and a sense of identification (Wagner & Hollenbeck, 2005). As noted by Wagner and Hollenbeck, subcultures may be classified in several ways, including occupational and professional skills and generational and national diversities. Individuals in the same subcultures would tend to think and act more similarly than would people from other subcultures. These organizational subcultures resulted in diverse networks of meaning yet were homogenous with the organization's overall culture. Cameron and Quinn (2006) identified four major organizational culture types.

The first major culture type described was the hierarchy culture, characterized by a formalized and structured workplace, procedures that govern work people perform, and effective leadership to organize and coordinate. The long-term concerns of hierarchy organizations were viewed as stability, predictability, and efficiency, thus requiring formal rules and policies. The second major culture type - the market culture - evolved as organizations encountered new competitive challenges. The market culture was described as a results-oriented organization, orientated to the external environment instead of internal matters (Wells, 2010). According to Cameron and Quinn, the market organizational culture does not rely on rules and procedures, and has a set of core values focused on competitiveness and productivity. The third major culture type was described as a clan culture, characterized by an emphasis on loyalty and tradition, teamwork, participation, and consensus. The last major culture type was described as an adhocracy culture, characterized by a dynamic, entrepreneurial, and creative workplace. This type organization was viewed as committed to experimentation, innovation, and change. Organizations develop a major culture type dependent on the industry, stage of organizational life cycle, and leadership style (Cameron & Quinn, 2006). Schneider considered organizational cultures strong when all levels of the organization shared the same goals and values (Schneider, 1990). In strong organizational cultures, people throughout the organization at all levels understood what they were supposed to do because a few guiding principles were clearly established (Reason, 1997). Not all organizational cultures, however, would be desirable. Organizational researchers have described a number of negative or dysfunctional cultural dimensions (Hofstede, n.d.; Reason, 1997; Wagner & Hollenbeck, 2005). Dysfunctional dimensions of culture included paranoid, bureaucratic, and political factors. Another type of dysfunctional culture was described as anxiety-avoidance. Although dysfunctional and counter cultural behaviors and practices have been observed wherein organizational cultures were disrupted, Mann (2005) observed that counter cultures typically disrupted other organizational factors as well and the topic was broader in scope than simply culture. Researchers of organizational cultures have discussed actions necessary for maintaining the culture and reshaping or changing the culture (Wells, 2010). Some researchers concluded that organizational cultures were maintained through constancy of business purpose for improvement, unity of organizational members through participation and ownership of work, intimacy among organizational members through sharing, and integrity in work practices (Smith, 2006). Some researchers have considered cultures in any group setting as dynamic - naturally evolving through various kinds of incremental changes (Trice & Beyer, 1993). Trice and Beyer stated that attempts to maintain an organization's culture involved adjustments in ideas, practices, and structures that could be considered changes, yet concluded that true organizational change referred to something more deliberate, drastic, and profound than incremental adjustments in the culture. Trice and Beyer maintained that cultural changes involve a break with the past and continuity in organizational cultures is disrupted. Three different types of culture change efforts in organizations were described - revolutionary efforts to change the cultures of complete organizations, efforts confined to change subunits within organizations, and efforts that are gradual and incremental with the intent to eventually change an entire organization's culture (Trice & Beyer, 1993). Other researchers have considered organizational culture changes as predictable patterns (Cameron & Quinn, 2006). Cameron and Quinn maintained that organizational cultures change as the organization moves through its life cycle stages. According to this theory, in the earliest stages of the organization's life cycle organizations have adhocracy cultures. As the organization matures and develops, the culture evolves into a clan culture, followed by a hierarchy culture and finally a market culture. Although this theory of predictability may be somewhat narrow for high-risk industries such as nuclear power energy, Cameron and Quinn qualified the theory that culture changes in mature organizations (typically those classified as hierarchy cultures) have occurred in less predictable patterns. This theory indicated that culture changes involving hierarchy cultures should be managed consciously. According to Seel (2000), the purpose of describing an organization's culture should be because of some need to change the culture or to determine if the culture needs to be changed. The implications of this viewpoint were that cultural description did not precede cultural change since organizational members participated in describing the culture (Wells, 2010). Seel argued that the process of discovery and inquiry fostered organic change that evolved rather than the classical mandate approach. Yukl (2002) stated that an organization's culture could be influenced by what leaders communicate as priorities, values, and concerns and by the ways leaders react to critical incidents and crises. Organizational leaders also have a role in maintaining and shaping culture by communicating the desired end-state of results (Yukl, 2002). Schein maintained that leaders must first understand the organization's culture before attempting to alter the culture (Schein, 2004). According to Schein, organizational leaders create a group's culture through primary and secondary embedding mechanisms. Primary mechanisms included what leaders measure, how leaders react, how resources are allocated, and how leaders model and coach desired behaviors. Secondary mechanisms included organizational designs, systems, procedures and rituals. Some theorists have argued that the prevailing cultural values would lead organizational members to rely on specific sources of guidance to make sense of what is happening around them, and that reliance on particular sources of guidance would influence the individual and the organization's cultural foundations (Smith, Peterson, & Schwartz, 2002). For instance, organizational actions for improving competitiveness in response to changing business environments and customer demands have resulted in changes to organizational cultures (Smith et al., 2002). Researchers in sociology and psychology have provided other perspectives on organizational cultures. Bochner (2003) discussed the psychological processes that occur between individuals and groups who differ in their cultural backgrounds. The researcher indicated that people working in similar disciplines inhabit a culturally homogeneous space in that they have comparable values, beliefs, and technical languages (Wells, 2010). Bochner contended that the interaction of one culture with another could have potentially adverse reactions. Major change efforts have been shown to help some organizations adapt to changing environments and improve overall performance; however, DeFeo and Barnard (2005) observed that most organizational change initiatives have failed to produce desired results. DeFeo and Barnard maintained that the fundamental flaw in most change strategies was a focus on the change and the results rather than developing an understanding of how the organizational culture would react to the change. Similarly, Kotter (1996) concluded that few organizational change initiatives have successfully helped organizations improve performance. According to Kotter, when improvement initiative changes have not produced the desired results, the interdependence of new practices with existing organizational cultures had not been factored into change plans and the changes were not anchored in the existing organizational culture. Measurement indicators for an organizational culture and changes within an organizational culture have been difficult to establish because the basic defining dimensions of an organizational culture are not directly observable (Schein, 2004). This measurement problem may exist because researchers have concluded that a given organizational culture is defined in the organization's formal structures and processes, symbolic systems, products or services, and actions of the group membership. As observed by Itoigawa, Wilpert and Fahlbruch (2005), based on these defining dimensions, organizational culture cannot be quickly changed at management's desires. These researchers concurred with Schein (2004) that organizational culture is the end-state of a long process of implementation by all group members in which they define and construct their system of meanings. Schein stated that empirical measurement of organizational cultures was difficult because the concept includes shared group rather than individual values, assumptions, and beliefs (Schein, 2004). It can be concluded that organizational culture has been conceptualized in various ways because the culture of an organization has been defined by both mechanistic and organic dimensions and because every organizational culture is different. Empirical measurement of the concept has been difficult for researchers because of these competing dimensions. Researchers have identified that some organizational cultures have been shaped by a distinctive subculture, such as a professional or industrial subculture, due to the nature of the business. Furthermore, an organization's culture has been influenced by other factors, including implementation of processes with the purpose of improving the organization. Organizational cultures can be changed yet some changes have not been as expected (Wells, 2010). Although major change efforts have been shown to help some organizations adapt to changing environments and improve overall performance, many organizational change initiatives have failed to produce desired results when the interdependence of new practices with existing organizational cultures had not been adequately considered (Wells, 2010).

2.2 Nuclear Safety Culture

Since the creation of nuclear technologies during World War II, nuclear industry leaders and regulatory bodies has struggled with the question of how safe is safe enough (Dahlgren, Lederman, Palomo, & Szikszai, 2001). Safety is a common goal for organizations involved in designing, operating, and regulating nuclear installations, yet the concept of safety has not been easy to define (Dahlgren et al., 2001). A general understanding has evolved over time as to what attributes a nuclear power plant should have in order to operate safely (Wells, 2010). Practitioners and researchers; however, continue to develop and understand one key attribute - a nuclear safety culture. The concept of a nuclear safety culture was developed by researchers in the aftermath of a nuclear accident at the Chernobyl Nuclear Power Plant in Ukraine (International Atomic Energy Agency, 1988). On April 26, 1986, reactor number four at the Ukrainian Chernobyl Nuclear Power Plant exploded, which resulted in the top being torn from the reactor and exposing the nuclear core (Medvedev, 1990). Further explosions and the resulting fire sent a plume of highly radioactive fallout into the atmosphere and over an extensive geographical area. Large geographical areas were badly contaminated, dozens of people died, and 336,000 people were evacuated and resettled (Medvedev, 1990). Nuclear industry leaders viewed the accident at the Chernobyl Nuclear Power Plant as a reminder of the risks and hazards of nuclear technology (Medvedev, 1990). Further, this accident showed the importance of maintaining strong cultural attributes related to nuclear safety (IAEA, 1988; Institute of Nuclear Power Operations [INPO], 2004). According to Medvedev (1990), the accident was caused by poor group relationships among plant organizations, weak communications, and pressures to continue with a planned test despite a known flawed design. Kapitza (1993) observed that the safety of any hazardous enterprise is determined by the human factor, such that human attitudes and behaviors have to be factored into every stage of the enterprise, from conception and design to construction and operation. Kapitza maintained that the lack of a nuclear safety culture mindset was the root cause of the Chernobyl accident

Although the severity of the Chernobyl Nuclear Power Plant accident may have been the catalyst for studies of a nuclear safety culture concept, the industry had its first significant safety culture incident in 1979 as a result of the accident at the Three Mile Island Nuclear Power Plant in the United States (Institute of Nuclear Power Operations, 2004). As explained by Itoigawa, Wilpert and Fahlbruch (2005), the accident at the Three Mile Island Unit 2 Nuclear Power Plant near Middletown, Pennsylvania, resulted in a partial meltdown of the reactor core. The researchers determined the accident was caused by a combination of personnel errors, design deficiencies, and component failures. The extensive literature on these two nuclear accidents, however, has dealt almost exclusively with technical, radiological, and environmental issues (Wells, 2010). Researchers for the International Atomic Energy Agency studied the concept of a nuclear safety culture after the Chernobyl accident and developed common terms, definitions, and methods for assessment (International Atomic Energy Agency [IAEA], 1988;

INSAG, 1991). These researchers defined a nuclear safety culture in more holistic terms that included all factors and groups that influence safety at nuclear power plants. Similar to Schein's (2004) definition of organizational culture, the initial nuclear industry definition of nuclear safety culture included the concepts of characteristics and attitudes of both the organizations and the individuals. Some researchers and practitioners have argued that a focus on characteristics and attitudes had confined discussions over nuclear safety culture to the mental-cognitive area of attitudes and noted that attitudes and actions do not correlate well (Wert, 2003; Wilpert & Itoigawa, 2001). Other researchers, most notably at the Institute of Nuclear Power Operations, explored nuclear safety cultures and the various factors affecting the diverse dimensions of a safety culture in order to diagnose the current safety culture at nuclear plants and to establish a common reference framework and common terminology (INPO, 2004). Later conceptualizations of nuclear safety culture included the behaviors and actions that support a desired nuclear safety culture (Institute of Nuclear Power Operations [INPO], 2009). These researchers used industry experiences and data developed by others, often based on nuclear power plant events, to build a body of knowledge that was not previously well defined. As stated by Wilpert and Itoigawa (2001), some theorists have maintained that a safety culture is the organizational culture of industries that are high risk in nature. Some researchers have concluded the concept of nuclear safety culture has not been well defined (Wells, 2010). For instance, Sorensen (2002) concluded that the mechanism by which safety culture affects the safety of nuclear power plant operations was not well established (U.S. Nuclear Regulatory Commission [NRC], 2002). Sorensen observed that statistical evidence linking specific attributes of a safety culture with the safety of nuclear power plant operations was limited. According to Sorensen, these limitations were caused by investigators of nuclear power events constructing new frameworks for each event rather than building on what had been studied previously. Irrespective of the continuing debate about nuclear safety culture, the original concept as defined by the International Atomic Energy Agency (1988; 1999) included a set of critical factors and organizational members that are foundationally important (IAEA, 1988)(International Atomic Energy Agency [IAEA], 1999). Critical factors included training, goals, and policies. One critical factor that has influenced nuclear safety cultures, termed nuclear business acumen, included the ability to manage the unique interaction among technology, economics, human factors, and safety in a changing nuclear business environment (Wells, 2010). In a subsequent study, twelve organizational factors were identified as most important for nuclear safety: external influences, goals and strategies, management functions and overview, resource allocation, human resource management, training, coordination of work, organizational knowledge, proceduralization, organizational culture, organizational learning, and communications (Nuclear Energy Agency [NEA], 1999). Each of these factors was considered to be interrelated, wherein one could influence another. Researchers at the International Atomic Energy Agency stated the organizational membership included several levels, specifically the level of management, the level of individuals, and the extra-organizational level of suppliers and government agencies (IAEA, 1999). Similar to Schein's (2004) definition of organizational culture, membership in a nuclear safety culture was viewed as comprehensive so that a pattern of shared basic assumptions of external adaptation and internal integration could work synergistically to solve common problems, with nuclear safety the overriding priority.

As noted by the International Atomic Energy Agency, nuclear safety is achieved when every member of the group is dedicated to the common goal (INSAG, 1991). In subsequent studies, researchers have identified that a safety culture can be strengthened over time (IAEA, 1998; International Atomic Energy Agency [IAEA], 2002).

Analysts at the Institute of Nuclear Power Operations studied nuclear power plant events and problems relating to shortfalls in a nuclear safety culture (Institute of Nuclear Power Operations [INPO], 2003; Institute of Nuclear Power Operations [INPO], 2004). Perin (2005) argued that a nuclear power plant culture embodies several different cultures of control based on different methods of risk assessment. For example, the commercial nuclear industry culture is organized around a structured logic of command and control which requires tradeoffs with a parallel logic of problem identification and diagnosis (Wells, 2010). The two different intra-cultural logics have not aligned in an environment of intense pressures relative to schedule, electricity output, and reduction of operating costs. Dimensions of a nuclear safety culture may be defined by multiple attributes and measured through multiple methods (Corcoran, 2010; International Atomic Energy Agency [IAEA], 2002). Researchers have typically employed questionnaires and surveys to measure the attributes of leadership; worker and manager attitudes, beliefs, values, and behaviors; and, degrees of beliefs of risk, stress, and decision-making, all of which have some relevance to worker performance and the safety culture (Corcoran, 2010; Findley, 2004; Itoigawa et al., 2005; Reiman, 2007). Other researchers have studied safety culture attitudes, values, and beliefs in other high-risk industries (Bums, 2005; Helrnreich & Merritt, 1998; McDonald, 2006; Reason, 1997). A nuclear safety culture may also be defined by specific observable physical attributes (Corcoran, 2010; Institute of Nuclear

Power Operations, 2009). Observations of human actions and physical objects, such as the quality of physical goods and archival records, have been employed in some continuous improvement and safety culture studies (Helmreich & Merritt, 1998; Keating, Olivia, Repenning, Rockart, & Sterman, 1999). Human observations have frequently been used in nuclear power plant studies because the situation and resultant behaviors are not easily predictable (Corcoran, 2010; Institute of Nuclear Power Operations, 2006). Nuclear safety culture researchers have focused on the individual worker's commitment and performance based on attitudes, work approaches, and communication systems (Reason & Hobbs, 2003; Reiman, 2007). Reason and Hobbs (2003) concluded that the most common worker errors at nuclear power plants were caused by failure to do something that should have been done rather than doing something incorrectly. Some nuclear safety culture researchers have studied other dimensions of the complex and dynamic interrelationships within the organizational cultures at nuclear power plants. Findley (2004) and Matthews (2006) found that organizational priorities were not always properly balanced between safety and production and often safety cultures were constrained when production factors became priorities over prevention factors. Reiman (2007) studied the maintenance organizations at three European nuclear power plants and concluded that nuclear safety was affected if the demands of the organizational task were not aligned with the dynamics of the organization's culture. Researchers have stated common parallel underlying extended shutdowns of U.S. nuclear power plants appeared to be the tension between increasing economic and production pressures and diminishing safety culture margins (Institute of Nuc1ear Power Operations, 2003; Itoigawa et al., 2005). For example, in 1996 the U.S. Nuclear Regulatory Commission directed

Northeast Utilities to shut down the three nuclear reactors at the Millstone Nuclear Power Plant in Connecticut. Contributing to the shutdown was diminishing safety culture margins exacerbated by competitive advantage strategies (McAvoy & Rosenthal, 2005). The U.S. Nuclear Regulatory Commission directed closure of the Maine Yankee Nuclear Power Plant in 1997 because of cost cutting measures at the expense of safety considerations (Jackson, 1997). A significant operating event occurred in 2002 at the Davis - Besse Nuclear Power Plant when the reactor pressure vessel head began to leak radioactive coolant (U.S. Nuclear Regulatory Commission, 2002). Analysts at the Institute of Nuclear Power Operations concluded a major contributor to this event was a shift in focus at all organizational levels from implementing high safety standards to justifying minimal safety standards. These analysts stated that a reduction in standards resulted from excessive focus on meeting short-term production goals. Within the high-risk industries of aviation and space operations, medical surgery, chemical processing, and offshore drilling, more safety culture studies have been conducted than in the nuclear industry (Wells, 2010). Researchers have traced various efficiency and cost containment influences as sources of accidents (Columbia Accident Investigation Board, 2003; Helmreich & Merritt, 1998; McDonald, 2006; Vaughan, 1996). Based on the accidents studied, a parallel was evident among increasing production pressures and schedule conflicts and diminishing safety culture margins. Corcoran (2010) stated that the concept of a nuclear safety culture could benefit from more research and reflection. There has been limited research on the dimensions of a nuclear safety culture when confronted by opposing economic forces. This research was conducted to bridge a gap in knowledge and to supplement the body of knowledge on nuclear safety cultures.

In summary, nuclear safety culture is to an organization what personality is to an individual: an intangible facet that can be seen only through behaviors and espoused values. It is under constant change; it represents the collective behaviors of the organization, which adapt over time as the organization and its members change and apply themselves to their daily activities. As problems are encountered, the organization learns. Successes and failures become ingrained into the organization's nuclear safety culture and form the basis for the means by which the organization does business. These behaviors are taught to new members of the organization as the correct way to perceive, think, act and feel. Nuclear safety is a collective responsibility. No one in the organization is exempt from the obligation to ensure nuclear safety first.

Where organizational culture is the way that people in an organization do things; nuclear safety culture is the way that people in an organization do things with nuclear safety as the overarching priority. Lastly, nuclear safety culture is dependent upon having the necessary framework of an organizational culture that embraces it as the top priority (Wells, 2010).

2.3 Current Trends in Nuclear Safety Culture Performance Measurement

Performance measurement can be defined as: the process of quantifying the efficiency and effectiveness of action; a metric used to quantify the efficiency and/or effectiveness of action or the set of metrics used to quantify both the efficiency and effectiveness of actions (Neely, Mills, Gregory, & Platts, 1995). Operationally, performance measurement refers to the use of a multi-dimensional set of performance measures for the planning and management of a business. This set of measures is multi-dimensional as it includes both financial and non-financial measures, it includes both internal and external measures of performance and it often includes both measures that quantify what has been achieved as well as measures that are used to help predict the future. Furthermore, performance measurement cannot be done in isolation. Performance measurement is only relevant within a reference framework against which the efficiency and effectiveness of action can be judged (Neely, 1998).

The Nuclear Energy Institute (NEI) model for assessing and addressing nuclear safety culture issues places primary responsibility on line management, and in particular, on the site leadership team. The purpose is to provide an objective, transparent and safety-focused process, which uses all of the information available (e.g., corrective action program, performance trends, NRC inspections, industry evaluations, nuclear safety culture assessments, self-assessments, audits, operating experience, employee concerns program, and workforce issues) to provide an early indication of potential problems, develop effective corrective actions and monitor the effectiveness of the actions (Nuclear Energy Institute [NEI], 2010). It utilizes the following critical organizational systems that are critical in supporting increased levels of safety and provides guidance for necessary actions to ensure the health of the nuclear safety culture.

While it is not possible to directly measure culture, and thus there must be some subjectivity, there are tangible aspects of plant conditions, which can be trended to determine if nuclear safety cultural issues contributed to the condition. In addition, process weaknesses, discovered through audits, self-assessments, or inspections, also can provide symptoms of nuclear safety cultural problems. Similarly, the intangible aspects of attitudes and behaviors of site personnel can be assessed through surveys, interviews and the behavioral observations program, etc. (NEI, 2010).

The INPO *Principles for a Strong Nuclear Safety Culture* describes the essential attributes of a healthy nuclear safety culture (Institute of Nuclear Power Operations [INPO], 2004). The INPO *Traits of a Healthy Nuclear Safety Culture* describes the essential traits of a healthy nuclear safety culture (INPO, 2012a; Institute of Nuclear Power Operations [INPO], 2012b). Together they provide a useful framework (i.e., criteria) for assessing and categorizing the data, and in combination, are used to identify potential nuclear safety cultural issues for action. Using a consistent model and terminology throughout the entire process allows clear communication of issues with which the entire site can understand and respond (NEI, 2010).

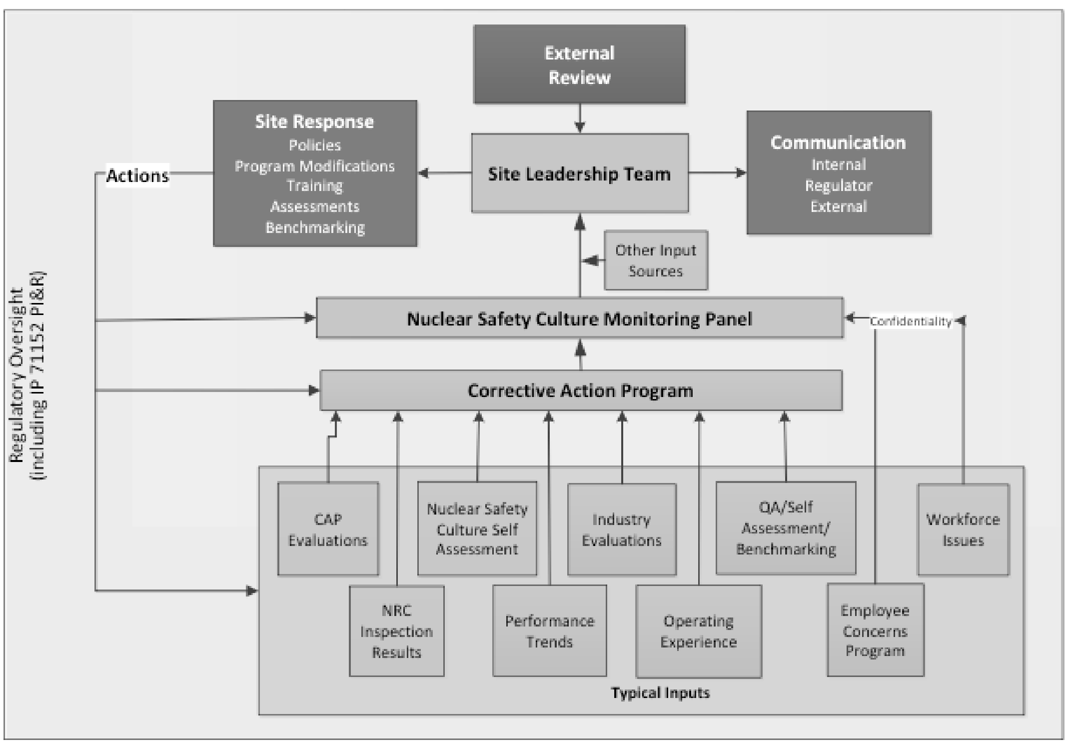


Figure 6. Site Nuclear Safety Culture Process

The following are the key inputs (i.e., the process inputs), accessing both the tangible and intangible; to the NEI nuclear safety culture process as illustrated by Figure 6 (NEI, 2010):

NRC Inspection Results

These include the baseline inspections of plant and processes (especially the problem identification and resolution inspection which also looks at safety conscious work environment and any past nuclear safety culture assessments), supplemental inspections, and event follow-up. If an inspection finding identifies that a nuclear safety culture issue may have caused the deficiency, the station in assessing its nuclear safety culture can use these data. Recurring issues receive careful review to determine if other process inputs are signaling problems in the same area (NEI, 2010).

Nuclear Safety Culture Self-Assessments

INPO SOER 02-4 Recommendation 2 states: Conduct a self-assessment to determine to what degree your organization has a healthy respect for nuclear safety and that nuclear safety is not compromised by production priorities. The self-assessment emphasizes the leadership skills and approaches necessary to achieve and maintain the proper focus on nuclear safety. INPO *Principles for a Strong Nuclear Safety Culture* and INPO *Traits of a Health Nuclear Safety Culture* are the basis for this self-assessment (NEI, 2010).

Industry Evaluations

Evaluations conducted by outside organizations can provide valuable insights. For example, INPO evaluations are conducted approximately every other year, ideally in the alternate year from the nuclear safety culture assessment. Included in the INPO evaluation is an assessment of nuclear safety culture, resulting in a nuclear safety culture assessment of a site almost every year (NEI, 2010).

Operating Experience (OE)

Information from other sites is available from INPO and NRC to improve performance. Any operating experience (OPEX) items tagged as safety culture-related by INPO or NRC are assessed for relevance to the station (NEI, 2010).

QA/Self-Assessment/Benchmarking/Behavioral Observations

Each site performs a variety of self-reviews. These include audits required in the quality assurance programs, department self-assessments, and benchmarking of other sites in the industry (or other industries). It also includes behavioral observations by managers and supervisors in the field (NEI, 2010).

Employee Concerns Program (ECP)

This program provides opportunities to raise issues outside the normal chain of command. ECP issues typically are not entered into the CAP, but ECP trends are considered by the Nuclear Safety Culture Monitoring Panel (NEI, 2010).

Workforce Issues

These include data sources that could reflect concerns within the workforce that may be precursors to nuclear safety culture or safety conscious work environment (SCWE) issues, such as: grievance trends, potential SCWE claims, hostile work environment claims, sexual harassment or peer on peer harassment, industrial safety trends, disciplinary action review board trends, changes in compensation/incentive programs, change management issues and workforce management issues (e.g., staffing, knowledge transfer, or certification issues) (NEI, 2010).

Corrective Action Program (CAP) Evaluations

In addition to being the program that is used to identify, analyze and resolve issues, the CAP is used to identify and evaluate trends across the entire data set of the CAP, for example, by using key words. The data from root cause and apparent cause evaluations also provide insights into potential nuclear safety culture issues and trends. The CAP is the largest single source of potential input to the culture monitoring process. Because the CAP is so comprehensive and encompassing at most sites, it is incumbent on the site to select the subset of CAP evaluations that will be fed into the culture monitoring process. (NEI, 2010).

Site Performance Trends

Each site has a broad suite of indicators to assess performance. These indicators go beyond the NRC performance indicators and assess intermediate outcomes, which, if not corrected, could lead to safety system failures, scrams or events. Trends can be developed in these indicators and the cause of the trend – process or design deficiencies, training, resources, or nuclear safety culture issues – can be examined and corrective action taken. Examples include operator workarounds, control room deficiencies, preventive maintenance deferred, and open positions (NEI, 2010).

The Nuclear Safety Culture Monitoring Panel (SCMP) monitors the process inputs, which are indicative of the health of the organization's nuclear safety culture; to identify strengths and potential concerns that merit additional attention by the organization. The SCMP: collects process inputs for a defined time period; categorizes process inputs; bins the inputs to safety culture attributes; sorts data by principle and performs collegial challenge of aggregated data; looks for long term trends; provides ratings and recommended actions; and reviews status and effectiveness of prior safety culture-related actions.

The Safety Culture Review Team (SCRT) is comprised of the senior-most management personnel onsite charged with the safe operation of a nuclear plant. To promote and monitor the health of the organization's nuclear safety culture, the SCRT periodically (i.e., at least semi-annually) assesses the station against the INPO *Principles for a Strong Nuclear Safety Culture*. This self-critique is intended to be reflective and performed by the SCRT itself in a group setting. During this review, the SCRT examines a variety of information that reflects the health of the organization's work environment to discern trends and early indications of nuclear safety culture challenges. The reports of the Nuclear Safety Culture Monitoring Panel and previous nuclear safety culture assessments, INPO evaluation nuclear safety culture findings, and any insights from the offsite nuclear safety review board (or equivalent) are reviewed by the SCRT prior to the meeting. Although a variety of inputs may be considered during the self-critique, the most valuable insight often comes from the frank discussion of nuclear safety culture based on the SCRT's observations and insights. As the organization's senior leaders, the SCRT possesses broad, diverse backgrounds in managing nuclear power plants and the nuclear professionals that make up the workforce. The SCRT is often able to discern subtle trends and early indications of nuclear safety culture challenges from personal interactions, in-field observations, and other means. The end result is an improved understanding among the members of the SCRT of where their efforts to further improve the station's nuclear safety culture need to be applied.

The SCRT's Nuclear Safety Culture Review is documented using the INPO *Principles for a Strong Nuclear Safety Culture* and INPO *Traits of a Healthy Nuclear Safety Culture* to identify strengths, areas found acceptable, and areas in need of improvement. Follow-up actions are tracked. Strengths and improvement opportunities that are identified are communicated back to the organization to drive desired behaviors and actions for fostering a strong nuclear safety culture. The following (Table 1) provides examples of triggers for action by the SCRT.

Table 1. Recommended Actions

Improvement Opportunity/Weakness	Recommended Action
NSCA weaknesses or negative observations	Enter into CAP
Trends noted in NSCMP and SCRT that do not constitute a significant concern but need to be addressed	Directed training, communication, etc.
A significant immediate indication of declining safety culture performance in a department (e.g., issue with supervisors in the department)	ACE or CCE
A significant immediate indication of declining safety culture performance at the station (e.g., issue with a department manager or senior manager)	ACE, CCE, RCE, or NSCA
An indication of a decline in safety culture over the last two quarters in a functional area (e.g., multiple workforce issues, emotional issues documented in CAP, etc.)	ACE, CCE or RCE
An indication of a declining trend over the last four quarters at the station (e.g., increase in allegations over historic averages, multiple Office of Investigation concerns in an area)	RCE or NSCA
A noticeable difference in a functional area from the remainder of the station culture (e.g., increase in CAP entries that are emotional, survey results indicate a measureable difference from the station norm, etc.)	ACE or RCE
Indications of a return of a previously addressed issue indicating corrective actions were not durable (e.g., return of similar issues to issues addressed two or more years ago and believed corrected)	ACE or RCE
A continuing decline in the culture of a functional area or the station indicating corrective actions are ineffective (e.g., repetitive issues after corrective actions have been completed)	RCE or NSCA
Request from NRC senior management due to their concern over performance (e.g., longstanding plant performance in column three of the action matrix or performance in column four)	Independent or third party NSCA
Recommendation from external safety board to conduct independent or third party assessment	Independent or third party NSCA

ACE = Apparent Cause Evaluation; CCE = Common Cause Evaluation; RCE = Root Cause Evaluation; NSCA = Nuclear Safety Culture Assessment

Few studies of economic effects on a nuclear safety culture could be found in the literature. This despite the documented results of economic pressures and challenged on nuclear power plants. Researchers and analysts have documented regulatory business decisions that indicate economic considerations have contributed to changing conceptualizations of a NSC.

The NRC made official the following Nuclear Safety Culture Statement of Policy by publishing it in the Federal Register on June 14, 2011.

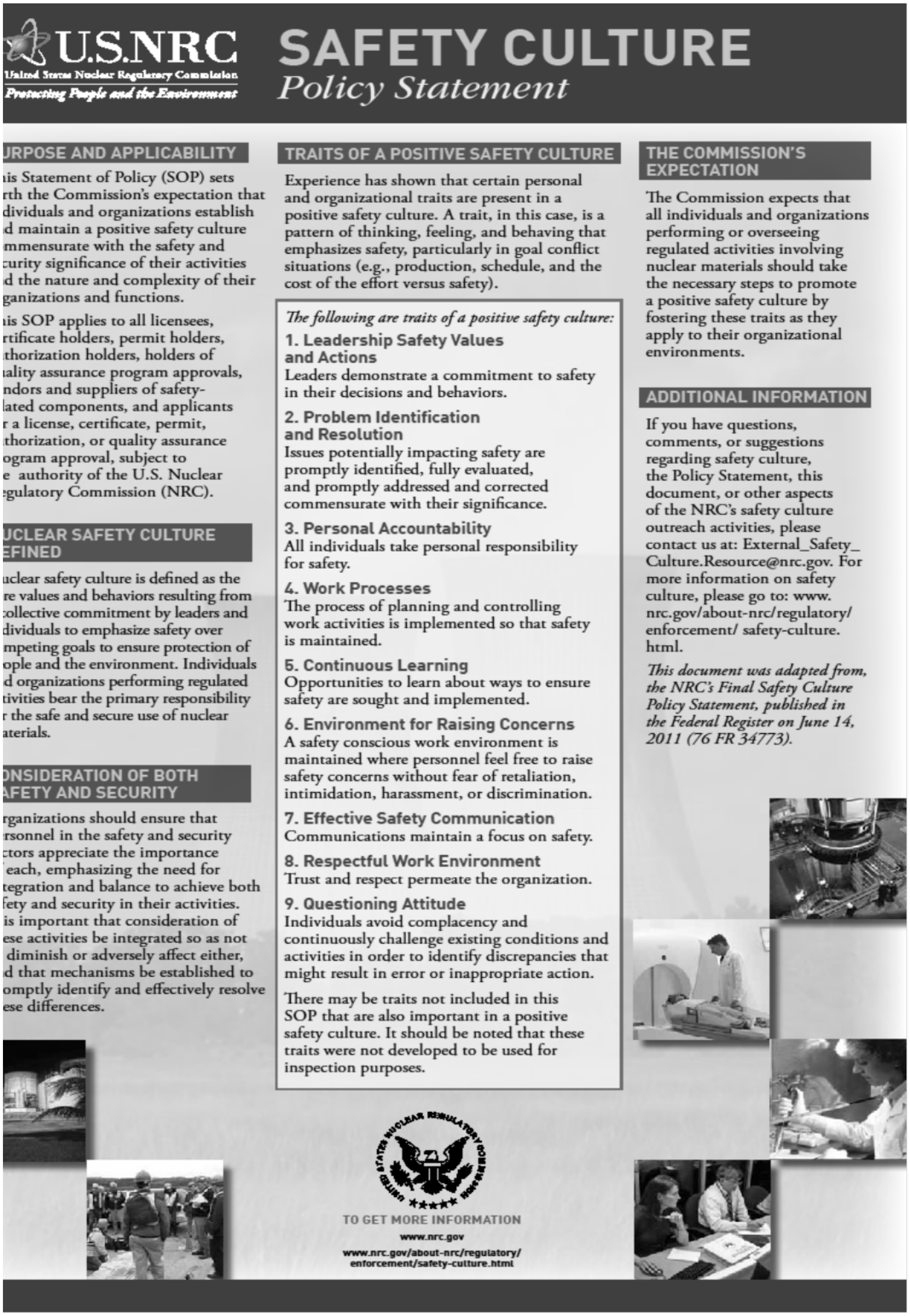
> The purpose of this Statement of Policy is to set forth the Commission's expectation that individuals and organizations establish and maintain a positive safety culture commensurate with the safety and security significance of their activities and the nature and complexity of their organizations and functions. This includes all licensees, certificate holders, permit holders, authorization holders, holders of quality assurance program approvals, vendors and suppliers of safety-related components, and applicants for a license, certificate, permit, authorization, or quality assurance program approval, subject to NRC authority. The Commission encourages the Agreement States, Agreement State licensees and other organizations interested in nuclear safety to support the development and maintenance of a positive safety culture, as articulated in this Statement of Policy. <u>Nuclear Safety Culture is defined as the core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment</u>. Individuals and organizations performing regulated activities bear the primary responsibility for safety and security. The performance of individuals and organizations can be monitored and trended and, therefore, may be used to determine compliance with requirements and commitments and may serve as an indicator of possible problem

areas in an organization's safety culture. The NRC will not monitor or trend values. These will be the organization's responsibility as part of its safety culture program. Organizations should ensure that personnel in the safety and security sectors have an appreciation for the importance of each, emphasizing the need for integration and balance to achieve both safety and security in their activities. Safety and security activities are closely intertwined. While many safety and security activities complement each other, there may be instances in which safety and security interests create competing goals. It is important that consideration of these activities be integrated so as not to diminish or adversely affect either; thus, mechanisms should be established to identify and resolve these differences. A safety culture that accomplishes this would include all nuclear safety and security issues associated with NRC - regulated activities. Experience has shown that certain personal and organizational traits are present in a positive safety culture. A trait, in this case, is a pattern of thinking, feeling, and behaving that emphasizes safety, particularly in goal conflict situations, e.g., production, schedule, and the cost of the effort versus safety. It should be noted that although the term ‘‘security’’ is not expressly included in the following traits, safety and security are the primary pillars of the NRC's regulatory mission. Consequently, consideration of both safety and security issues, commensurate with their significance, is an underlying principle of this Statement of Policy. The following are traits of a positive safety culture: (1) Leadership Safety Values and Actions—Leaders demonstrate a commitment to safety in their decisions and behaviors; (2) Problem Identification and Resolution - Issues potentially impacting safety are promptly identified, fully evaluated, and promptly addressed and corrected commensurate with their significance; (3) Personal Accountability - All individuals take personal responsibility for safety; (4) Work Processes -The process of planning and controlling work activities is implemented so that safety is maintained; (5) Continuous Learning - Opportunities to learn about ways to ensure safety are sought out and implemented; (6) Environment for Raising Concerns - A safety conscious work environment is maintained where personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment, or discrimination; (7) Effective Safety Communication - Communications maintain a focus on safety; (8) Respectful Work Environment - Trust and respect permeate the organization; and (9) Questioning Attitude - Individuals avoid complacency and continuously challenge existing conditions and activities in order to identify discrepancies that might result in error or inappropriate action. There may be traits not included in this Statement of Policy that are also important in a positive safety culture. <u>It should be noted that these traits were not developed to be used for inspection purposes</u>. It is the Commission's expectation that all individuals and organizations, performing or overseeing regulated activities involving nuclear materials, should take the necessary steps to promote a positive safety culture by fostering these traits as they apply to their organizational environments. The Commission recognizes the diversity of these organizations and acknowledges that some organizations have already spent significant time and resources in the development of a positive safety culture. The Commission will take this into consideration as the regulated community addresses the Statement of Policy. (NRC-2010-0282, Final Safety Culture Policy Statement, 2011)

While it is not possible to directly measure culture, without subjectivity, the NRC (Figure 7) and INPO (Figure 8) have adopted the same empiricist trait based framework for measuring the health of a nuclear safety culture. That is, there are tangible aspects of plant conditions that can be trended to determine if nuclear safety cultural issues contributed to the condition. In addition, process weaknesses, discovered through audits, self-assessments, or inspections, also can provide symptoms of nuclear safety cultural problems. Similarly, the intangible aspects of attitudes and behaviors of site personnel can be assessed through surveys, interviews and the behavioral observations program, etc. (NEI, 2010)

The performance of individuals and organizations can be monitored and trended and, therefore, may serve as an indicator of the health of an organization’s safety culture. However, the health of a facility’s safety culture could lie anywhere along a broad continuum, depending on the degree to which the attributes of safety culture are embraced. Even though safety culture is somewhat of an intangible concept, it is possible to determine whether a station tends toward one end of the continuum or the other.

Furthermore, if we could measure nuclear safety culture directly then likely we would have validated theories to state how to exactly create and sustain a healthy nuclear safety culture. However, since we are "looking through a dark mirror" at the reflection of the nuclear safety culture we must be careful to ensure that we are looking at the appropriate secondary indicators, looking at them frequent enough, and with the right metric to understand what they are trying to communicate to us. Hence the evolution from behaviors indicative of a healthy nuclear safety culture to traits as we continue to master the elusive formula that will consistently yield the desired results. If we fail to realize that we are inferring the health of a nuclear safety culture by looking at its outputs then we are already on the road to another black swan nuclear event.



U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

SAFETY CULTURE
Policy Statement

URPOSE AND APPLICABILITY

iis Statement of Policy (SOP) sets rth the Commission's expectation that dividuals and organizations establish d maintain a positive safety culture mmensurate with the safety and curity significance of their activities d the nature and complexity of their ganizations and functions.

iis SOP applies to all licensees, rtificate holders, permit holders, thorization holders, holders of iality assurance program approvals, ndors and suppliers of safety-lated components, and applicants r a license, certificate, permit, thorization, or quality assurance ogram approval, subject to e authority of the U.S. Nuclear gulatory Commission (NRC).

UCLEAR SAFETY CULTURE EFINED

uclear safety culture is defined as the re values and behaviors resulting from collective commitment by leaders and dividuals to emphasize safety over mpeting goals to ensure protection of ople and the environment. Individuals d organizations performing regulated tivities bear the primary responsibility r the safe and secure use of nuclear aterials.

ONSIDERATION OF BOTH AFETY AND SECURITY

rganizations should ensure that rsonnel in the safety and security ctors appreciate the importance each, emphasizing the need for tegration and balance to achieve both fety and security in their activities. is important that consideration of ese activities be integrated so as not diminish or adversely affect either, d that mechanisms be established to omptly identify and effectively resolve ese differences.

TRAITS OF A POSITIVE SAFETY CULTURE

Experience has shown that certain personal and organizational traits are present in a positive safety culture. A trait, in this case, is a pattern of thinking, feeling, and behaving that emphasizes safety, particularly in goal conflict situations (e.g., production, schedule, and the cost of the effort versus safety).

The following are traits of a positive safety culture:

1. Leadership Safety Values and Actions
Leaders demonstrate a commitment to safety in their decisions and behaviors.

2. Problem Identification and Resolution
Issues potentially impacting safety are promptly identified, fully evaluated, and promptly addressed and corrected commensurate with their significance.

3. Personal Accountability
All individuals take personal responsibility for safety.

4. Work Processes
The process of planning and controlling work activities is implemented so that safety is maintained.

5. Continuous Learning
Opportunities to learn about ways to ensure safety are sought and implemented.

6. Environment for Raising Concerns
A safety conscious work environment is maintained where personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment, or discrimination.

7. Effective Safety Communication
Communications maintain a focus on safety.

8. Respectful Work Environment
Trust and respect permeate the organization.

9. Questioning Attitude
Individuals avoid complacency and continuously challenge existing conditions and activities in order to identify discrepancies that might result in error or inappropriate action.

There may be traits not included in this SOP that are also important in a positive safety culture. It should be noted that these traits were not developed to be used for inspection purposes.

THE COMMISSION'S EXPECTATION

The Commission expects that all individuals and organizations performing or overseeing regulated activities involving nuclear materials should take the necessary steps to promote a positive safety culture by fostering these traits as they apply to their organizational environments.

ADDITIONAL INFORMATION

If you have questions, comments, or suggestions regarding safety culture, the Policy Statement, this document, or other aspects of the NRC's safety culture outreach activities, please contact us at: External_Safety_Culture.Resource@nrc.gov. For more information on safety culture, please go to: www.nrc.gov/about-nrc/regulatory/enforcement/ safety-culture.html.

This document was adapted from, the NRC's Final Safety Culture Policy Statement, published in the Federal Register on June 14, 2011 (76 FR 34773).

TO GET MORE INFORMATION
www.nrc.gov
www.nrc.gov/about-nrc/regulatory/enforcement/safety-culture.html

Figure 7. NRC Traits of a Positive Nuclear Safety Culture

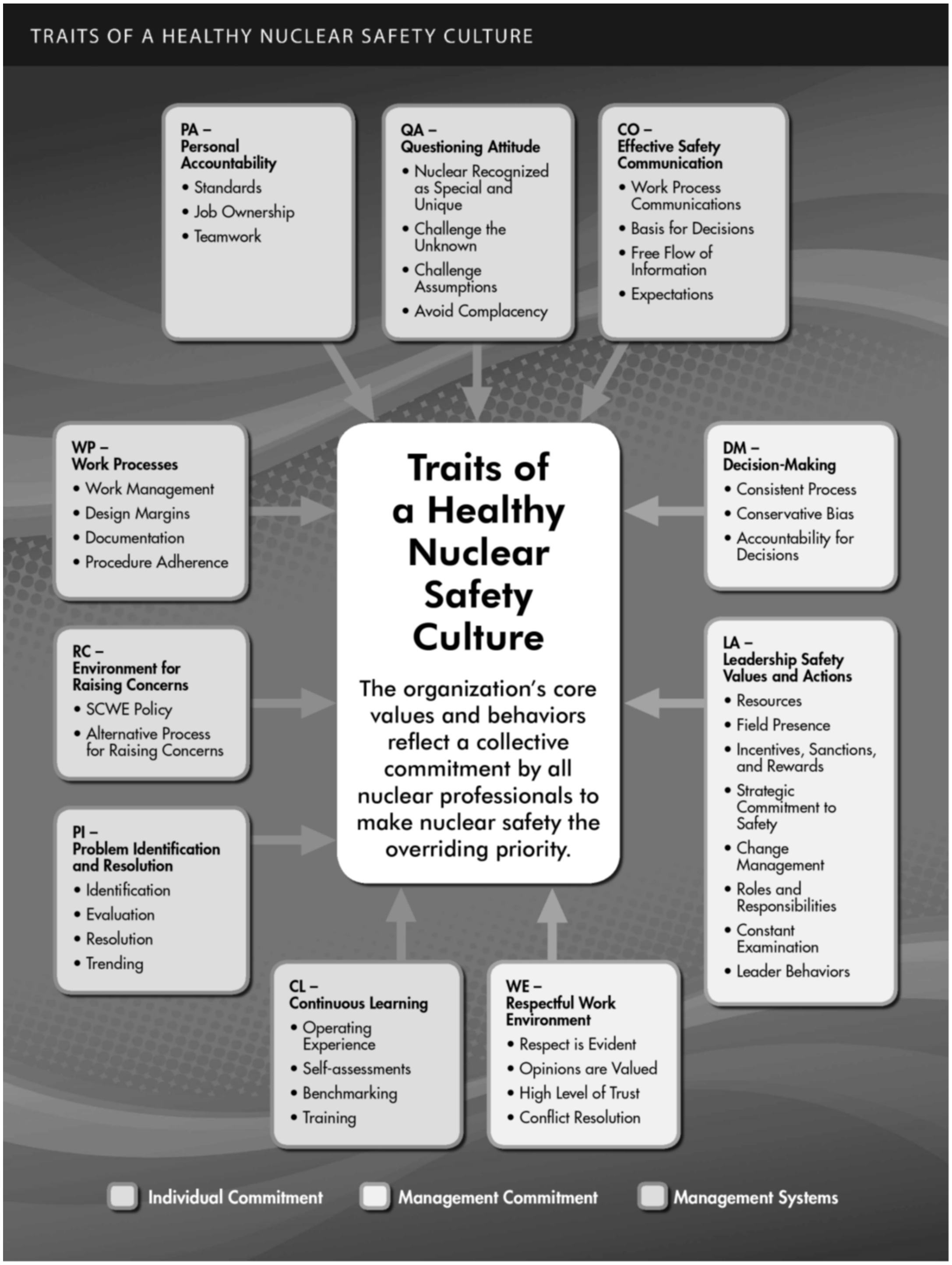


Figure 8. INPO Traits of a Healthy Nuclear Safety Culture

2.4 Other High-Risk Industry Safety Cultures

As defined by the U.S. Occupational Safety and Health Administration (2009), industrial safety cultures included shared beliefs, practices, and attitudes that existed at a business. An organization's safety culture was viewed as the end result of a number of factors, including management and employee norms, assumptions and beliefs, and attitudes; policies and procedures; actions and lack of actions to correct unsafe behaviors; employee training, involvement, and motivation; and production and efficiency factors. According to the U. S. Occupational Safety and Health Administration (2009), peer coaching at all levels and employee awareness of changing conditions and situations at job locations were observed at organizations with strong occupational safety cultures (Wells, 2010).

Researchers in the field of general occupational safety have maintained that safety accidents are typically caused by failure of attitudes, failure of technical training, failure of safety training, or combinations of any of these three causes (Bums, 2005; Roughton and Crutchfield, 2008; Williams, 2002). Bums (2005) stated that the primary focus of industrial safety programs should be on changing employee behaviors and attitudes. Bums maintained that although many researchers have argued that trust was important in modeling safety cultures, attitudes about trust, whether implicit or explicit, were equally important. Roughton and Crutchfield (2008) maintained that fundamental principles for preventing industrial safety accidents included establishing a positive culture where individuals understood job hazards and were not punished for reporting accidents and near misses. According to Roughton and Crutchfield, a positive safety culture included rewarding safe workers, sharing information about accidents and near misses, and assessing the potential hazards of a job while planning the work. Williams (2002) stated that a positive safety culture should start with management behaviors.

Hansen (2006) stated that a strong organizational safety strategy included meaningful measurement, employee participation, shared values, positive recognition, process improvement, continuous improvement, and alignment. According to Hansen, since the work processes contributed to most occupational accidents the safety goals should be challenging yet causing incrementally improving processes. Further, Hansen maintained that safety values should be on the same level as production values and aligned with all organizational members.

Within the complex, high-risk industries of aviation and space operations, medical surgery, chemical processing, and offshore drilling, more safety culture studies have been conducted than in the nuclear industry. Most contemporary researchers have studied the attributes of leadership; worker and manager attitudes, beliefs, values, and behaviors; and, degrees of beliefs of risk, stress, and decision-making, all of which have some relevance to safety cultures (Columbia Accident Investigation Board, 2003; Helmreich & Merritt, 1998; McDonald, 2006; Mearns, Whitaker, & Flin, 2003; Roughton & Crutchfield, 2008; Vaughan, 1996). Various efficiency and cost containment influences have been traced as sources of accidents. Based on the accidents studied, a parallel was evident among increasing economic and production pressures and schedule conflicts and diminishing safety culture margins (Wells, 2010).

Mearns et al. (2003) stated there is little evidence to link weaknesses in safety at the organizational level with individual accidents; however, the researchers noted case studies of major disasters have linked weaknesses in safety culture with organizational accidents. Reason (1997) maintained that work-related values, behaviors, and degrees of beliefs at industrial plants are universal, but are influenced in varying degrees by corporate and organizational cultures. Helmreich and Merritt (1998) compared and contrasted the high - risk industries of aviation and emergency medical operations in the context of organizational, professional, and national cultures. Survey results of physicians and nurses in anesthesia, surgery, and intensive care units were compared with equivalent cockpit crewmembers in commercial aviation. The researchers observed that some organizational events and incidents occurred when organizational focus noticeably shifted from implementing high standards to meeting short-term goals. As implied by Helmreich and Merritt (1998) these short-term goals were often based on resource or economic conditions and were evident in organizational cultures irrespective of the influences by national or professional cultures (Wells, 2010).

The January 26, 1986, Space Shuttle *Challenger* disaster was an organizational accident caused by production influences. Vaughan (1996) concluded that over time production pressures became institutionalized at the National Aeronautics and Space Administration (NASA). It was theorized that a work group culture had evolved wherein technical deviations were normalized when the work groups encountered consistent contributing factors of economic and scheduling pressures.

The February 1, 2003, Space Shuttle *Columbia* disaster was an organizational accident with similar preconditions to the *Challenger* disaster. NASA management had to devise a new business approach when the United States government reduced the national space budget by 40% during the period of 1992 to 2000 (Columbia Accident Investigation Board, 2003). While the intent of the new approach was to improve efficiency and effectiveness, the result was a decrease in resources. Under funding pressure, NASA management began outsourcing much of its work to contractors and simultaneously began reducing the scope of its operational, or institutional, safety program (Columbia Accident Investigation Board, 2003). It was assumed that NASA's ownership of operational safety could be reduced because the contractors would assume the responsibility for safety. Investigators at the Columbia Accident Investigation Board concluded that organizational streamlining and downsizing conveyed an additional message to workers that efficiency was an important goal. Combined with the reductions that decreased the safety focus, efficiency was viewed by employees as more important than safety (Wells, 2010).

Reason (1997) studied safety accidents in aviation, petrochemical, offshore oil, and transportation industries. Reason concluded that significant accidents in some high-risk industries could be repeated in other high-risk industries because of flaws in causal analyses that led to a misguided focus on technical failures rather than organizational weaknesses as learning organizations. Thus, some safety critical organizations had not been effectively solving underlying safety culture problems and, in turn, were not effectively learning from accidents and incidents whether small or large in magnitude. Based on the accidents studied, a parallel was evident between increasing economic and production pressures and diminishing safety culture margins.

According to Reason (1997), the components of a safety culture included an informed culture, a reporting culture, a just culture, a learning culture, and a flexible culture. An informed culture was described as leadership-based, in that those responsible for managing the organizational system had current knowledge about the human, technical, organizational, and environmental factors that determined the safety of the organization as a whole. Reason (1997) maintained that leaders must understand and acknowledge that people were usually not the instigators of accidents or incidents and that they usually inherited bad situations that had been developing over a long period. A reporting culture was described as a climate in which workers were prepared to report their errors and near misses. Reason viewed a just culture as a way of thinking that promoted a questioning attitude, was resistant to complacency, was committed to excellence, and included accountability at all levels of the organization. A learning culture was described as a willingness to draw the right conclusions from its safety information system and to implement major reforms. Reason viewed the last component as a culture where the organization was able to reconfigure itself during times of environmental changes or attacks (Wells, 2010).

Mearns et al. (2003) concluded from studies of offshore oil and gas operations that safety cultures were affected by the convergence of several hazardous factors, including the potential for fire, explosion, and other accidents, work stress, priorities of continuing operations, and the isolation of installations. In the first year of the research, production and schedule pressures were not considered significant contributors to a negative safety culture. In the second year of the research, the researchers found that continued production and schedule pressures had caused these factors to become significant contributors to a negative safety culture.

McDonald (2006) summarized the results from a series of studies concerning aircraft workers. This researcher observed that technicians routinely did not follow procedures, rationalizing their actions by stating they had developed faster, better, and safer ways of performing the tasks than those described in approved procedures. For many of the aircraft companies studied, professional cultures were found to be inconsistent with organizational cultures, leading to inconsistencies between established requirements and the need for flexibility to meet the changing production schedules of the operational environment (McDonald, 2006).

Within the complex, high-risk industries of aviation and space operations, medical surgery, chemical processing, and offshore drilling, contemporary researchers have studied the attributes of leadership; worker and manager attitudes, beliefs, values, and behaviors; and, degrees of beliefs of risk, stress, and decision-making, all of which have some relevance to safety cultures. Researchers have documented that a strong organizational safety strategy should include meaningful measurement, shared values, continuous improvement, and alignment. Although researchers have traced various efficiency and cost containment influences as causes of accidents, none have studied the influence of a continuous improvement process on the respective safety culture. Based on the accidents studied, a parallel was evident among increasing economic and production pressures and schedule conflicts and diminishing safety culture margins (Wells, 2010).

2.5 Summary

From the literature, it can be concluded that an organizational culture has been conceptualized in various ways because both mechanistic and organic dimensions have defined the culture of an organization and because every organizational culture is different (Cameron & Quinn, 2006). Empirical measurement of the concept has been difficult for researchers because of these competing dimensions. Researchers have identified that some organizational cultures have been shaped by influencing factors, including implementation processes with the purpose of improving the organization (Cameron & Quinn, 2006; Schein, 2004). Researchers have identified differing perspectives and frameworks for changing staffing and budget levels to increase return on investment (ROI); however, there has been no common formula (Shafritz & Ott, 2001).

A NSC has been conceptualized in the literature as either a subset of the organizational culture or a unique subculture that resides along with the organizational culture (Wilpert & Itoigawa, 2001). The NSC term is complex and consequently somewhat difficult to understand. Furthermore, the literature on safety culture has demonstrated that the concept includes many interrelated components and members of many organizations (International Atomic Energy Agency, 1999).

It might be expected, due to the interrelationship of economic forces on the operation of a nuclear power plant, that the introduction of a process to improve a plant's ability to create value and contain operating costs would be included in studies of relationships of economic issues to nuclear safety. Despite the significance of reliable production priorities with a focus on cost containment, there has been relatively little research on the various dimensions of a nuclear safety culture when affected by opposing of leadership and organizational behaviors (Wells, 2010).

The literature has examined organizational causes for nuclear power plant events and extended plant shutdowns. In recent years researchers have conducted studies examining precursors to these organizational causes (Itoigawa, 2005). These precursors have typically including various dimensions of leadership and organizational behaviors.

Several event investigations at U.S. nuclear power plants have uncovered organizational flaws (INPO, 2004).

Since the late 1990s, four U.S. nuclear plants have experienced extended shutdowns because of nuclear safety issues (Institute of Nuclear Power Operations, 2004). A major contributor to some extended plant shutdowns was a shift in focus from implementing high safety standards to justifying minimal safety standards, resulting from an excessive focus on meeting short-term production goals (Wells, 2010).

Within other complex, high-risk industries researchers have studied the attributes of leadership; worker and manager attitudes, beliefs, values, and behaviors; and, degrees of beliefs of risk, stress, and decision-making (Columbia Accident Investigation Board, 2003; Helmreich & Merritt, 1998; McDonald, 1999).

Provided within the next chapter of this dissertation are the methods and procedures used to address the research questions. Included in the next chapter are the rationales for the research design and instrumentation used, methods of data analyses, and limitations/delimitations of the research. A discussion of ethical assurances is also included in this chapter.

CHAPTER 3

3. METHODOLOGY

3.1 Research Methods and Design

Research methods supporting safety are typically governed by research paradigms that fall into one of two categories, described as either quantitative or qualitative methods by authors of research design such as Creswell (2005) and Leedy (2013). However, the approach to this study does not exclusively follow either of these traditional methods. According to Leedy (2013), if the research does not fall exclusively into one of the two defined categories of research, it must be a mixed method approach that draws from each of the available methods such that "all aspects substantially contribute to a single, greater whole" (Leedy, 2013, p. 258).

Since this research is not simply a combination of qualitative and quantitative methods; a deeper understanding of the methods applied, the canons associated with those methods, and justification of their use is necessary to build a foundation from which the research can be discussed, critiqued and defended. To that end, the research methods will be described by investigating three divisions of research: the ontological philosophy, the epistemological approach and the mode of reasoning.

Each division of research includes a spectrum along which the research falls, with each end of the respective spectrum labeled to describe its nature. The modes of reasoning fall into either inductive or deductive categories, ontology is described as either positivist or constructivist, and the epistemological position is characterized as either empiricist or rationalist (Siangchokyoo & Sousa-Poza, 2012). These divisions of research may be illustrated in the form of a cube, an example of which is shown illustrated in Figure 9. Note that classic quantitative methods as defined by both Creswell (2005) and Leedy (2013) fall into the lower, left, front portion of the cube, depicted in red, while qualitative methods appear in the upper, right, front portion, depicted in green. In addition to providing an overview of these divisions as a framework for discussion and defense of the selected methods, it also allows deeper insight into the results of this research and perhaps more importantly, the limitations of its conclusions.

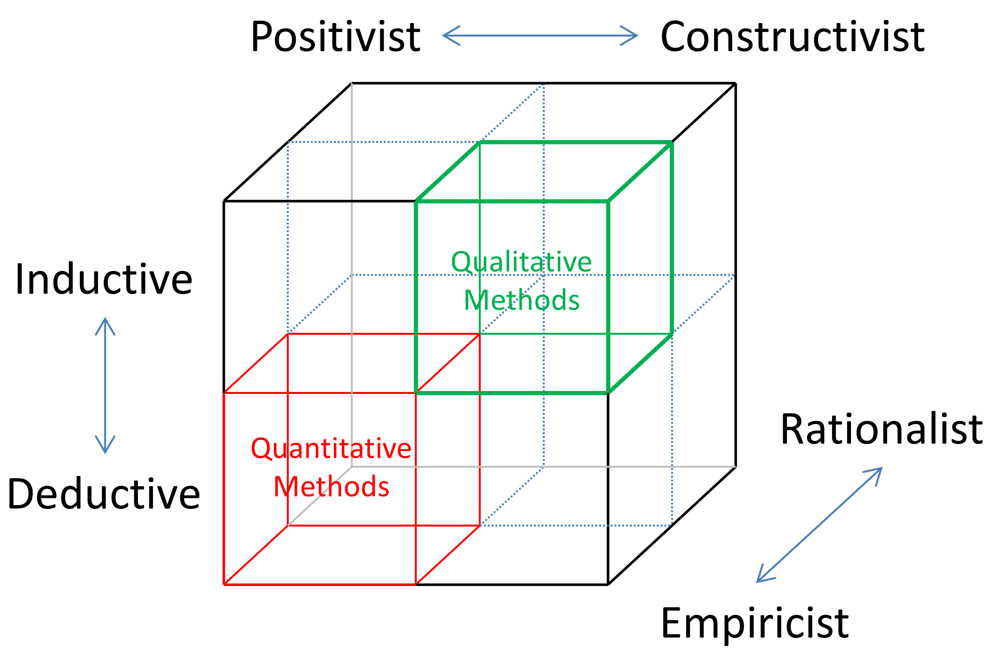


Figure 9. Research Methods Cube with Creswell's (2013) Traditional Methods

This study employs an inductive mode of reasoning. The process of inductive research involves analysis of data, and subsequent abstraction of a methodology for NSC Health Performance measurement through identification of patterns or other features that suggest explanations for its variance. That is, during an inductive research process, knowledge (i.e., ideas) is gained through the researcher's ability to derive meanings out of the information (Siangchokyoo & Sousa-Poza, 2012). This method when juxtaposed with deductive methods that begin with some form of hypothesis and use confirmatory methods to either accept or reject a hypothesis based on results of experimentation. Again, inductive reasoning goes from data to idea where deductive reasoning goes from idea to data (Siangchokyoo & Sousa-Poza, 2012).

In this study, the analyzed data involves thousands of hours of operation of a commercial nuclear power station recorded in data sets. From this large combined data set, consisting of many different operational transients and various leadership decisions trends emerge with regard to health performance of a NSC and these trends can be expressed quantitatively using MCDA methods. Through observation of these data, a generalized methodology may be developed to dynamically measure the health performance of a similar NSC and a model can be developed to express the theory as well as provide a platform from which to extract these measurements.

Another division of research methods is made with regard to its ontological position. Ontology refers to the nature of reality, and there are two possible positions. While Leedy (2013) confines the mind-dependent nature of the constructivists to qualitative methods, he eloquently describes the division in his introduction to qualitative research. He begins by describing the positivist position in which the researcher aims for objectivity, avoiding any influence of the researcher due to impressions or bias. Thus, the positivist in a general sense is represented by a philosophy in which research describes the elements of the real world without need of interpretation – it is mind independent. Results of a positivist approach would be expected to yield objective conclusions, and those should not be significantly different among different researchers who study the topic. The opposing view is a constructivist approach in which the research is formulated through mind-dependent processes, relying on subjective evaluation of reality by participants or the judgment of experts in the field. To quote Leedy (2013), “the [constructivist] researcher is an instrument in much the same way an oscilloscope, sociogram, or rating scale is an instrument” (p. 139). The research proposed for this dissertation is heavily weighted toward a constructivist position in that the process developed through this research is largely based on the interpretation of the data described above. Finally, since the concept of acceptable NSC health is inherently dependent upon human judgment, implying there must be some level of mind-dependent influence, this paper relies primarily on well-established quantitative expressions for acceptable NSC healthy defined by both the NRC and INPO. Once defined, the separation functions developed herein treat NSC health as a dependent variable without further interpretation. Indeed, the value of NSC health modeling lies largely within the expected standardization of the process and uniform application by clients, necessitating a positivist methodology that may be replicated not only by other researchers, but also by practitioners in similar fields.

Finally, research is also influenced by its epistemological approach, a concept that refers to the method by which human beings develop understanding of reality. Once again, the possibilities are divided to describe two ends of a spectrum with one end being referred to as empiricist and the other rationalist in nature. Empiricism suggests that research is accomplished through observation, while rationalism seeks knowledge through reasoning. While a substantial data set has been accumulated and studied in preparation for this research the approach to developing a working NSC health model is largely empiricist in its nature. The observation of nuclear power plants, all of which are equipped with Corrective Action Systems (CAS), allows insight into their respective NSC.

In summary, the research process described in the next section will be accomplished through application of an overall qualitative approach that has been described as a synthetic method and is positioned in the research cube as illustrated in Figure 10 (Siangchokyoo & Sousa-Poza, 2012).

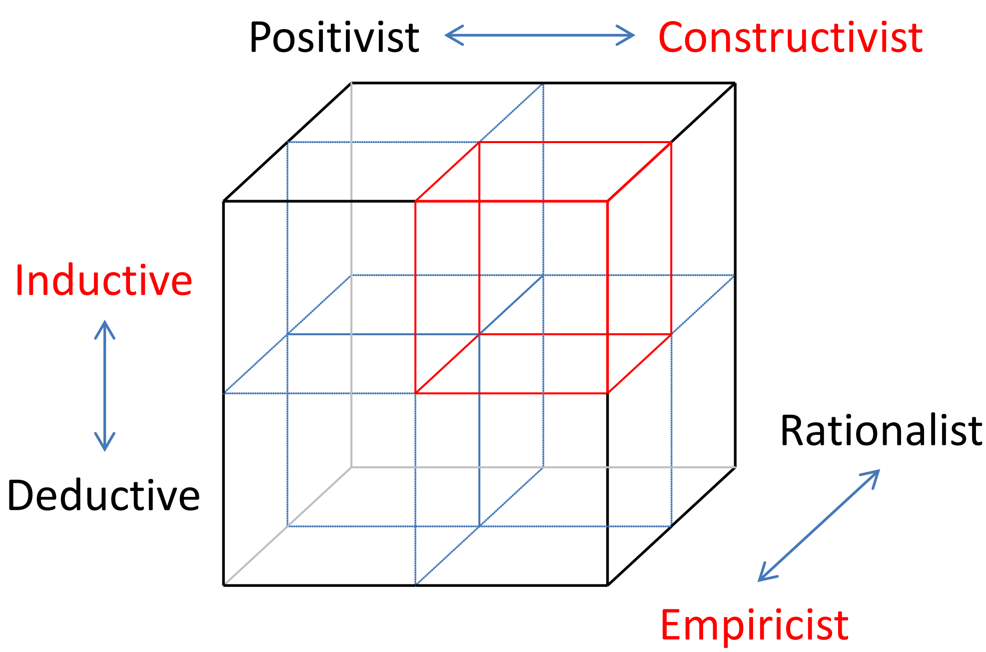


Figure 10. Research Method for Development of Separation Functions

This method is executed by applying an inductive mode of reasoning (i.e., usage of synthesis reasoning to obtain ideas or knowledge) in combination with empiricist (i.e., justification of knowledge through observations) and positivist (i.e., reality is constructed through the mind of the observer) research philosophies (Figure 11) (Siangchokyoo & Sousa-Poza, 2012). The result is the development of a methodology, expressed as a MCDA model that allows management to evaluate NSC health and to make decisions with regard to system capacity necessary to meet demand while maintaining the highest level of NSC health (Bell, 2014).

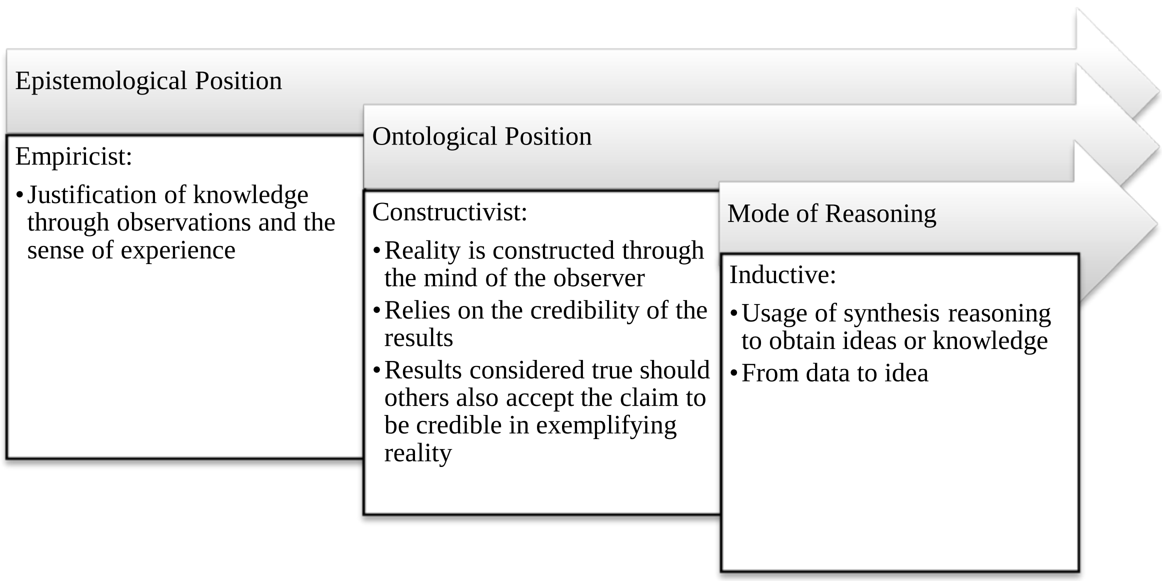


Figure 11. Qualitative Methodology Research Paradigm

3.2 Participants

A survey was administered to members of the Nuclear Safety Culture (NSC) Monitoring Team and Panel at Surry Power Station (SPS) in order to obtain degrees of belief information with respect to NSC Health Performance. Surry Power Station nuclear power plant was selected because the plant leadership had a desire to improve their methodology for NSC health performance assessment. Access to the populations and the plants' corrective action systems were obtained through the plant's leadership team. The researcher had made previous inquiries with the subject nuclear power plant and experienced no difficulties in gaining access to study the plant's systems.

Human subjects were not directly involved in data collection or analysis. Source documentation within the corrective action systems at the plant was analyzed during this study. Although workforce populations were included in the study, they were not considered participants. These workforce members were not specifically selected for this study and did not participate in any part of this study.

3.3 Materials and Instruments

Data (i.e., Process Inputs) for the safety culture indicators were gathered from various sources (see Section 3.4) including the nuclear power plant's corrective action (incident) reporting systems (CAS), excluding proprietary, personal, and security safeguards documentary materials. Approval to use these reporting systems was appropriately obtained (Appendix B). Nuclear power plant CAS are computerized to support collecting, sorting and analyzing performance trends. Instrumentation included a standardized collection of trending criteria and codes, classified by key input types and tabulated in a Microsoft Excel spreadsheet. A standardized coding structure with unique designators (i.e., codes) is utilized by SPS to ensure consistency in the coding process. Use of common trending codes resulted in identification of changes in frequency of occurrence of a given parameter or a change in operational performance levels across a wide range of areas at low detection thresholds (Institute of Nuclear Power Operations [INPO], 2007).

3.4 Operational Definition of Process Inputs

The following are the key process inputs, accessing both the tangible and intangible, to a typical nuclear safety culture process (NEI, 2010):

NRC inspection results

These include the baseline inspections of plant and processes (especially the problem identification and resolution inspection which also looks at safety conscious work environment and any past nuclear safety culture assessments), supplemental inspections, and event follow-up. If an inspection finding identifies that a nuclear safety culture issue may have caused the deficiency, the station in assessing its nuclear safety culture can use this data. Recurring issues receive careful review to determine if other process inputs are signaling problems in the same area (NEI, 2010).

Nuclear Safety Culture Self-Assessments

INPO SOER 02-4 recommendation 2 states: Conduct a self-assessment to determine to what degree your organization has a healthy respect for nuclear safety and that nuclear safety is not compromised by production priorities. The self-assessment emphasizes the leadership skills and approaches necessary to achieve and maintain the proper focus on nuclear safety. INPO *Principles for a Strong Nuclear Safety Culture* and INPO *Traits of a Health Nuclear Safety Culture* are the basis for this self-assessment (NEI, 2010).

Industry Evaluations

Evaluations conducted by outside organizations can provide valuable insights. For example, INPO evaluations are conducted approximately every other year, ideally in the alternate year from the nuclear safety culture assessment. Included in the INPO evaluation is an assessment of nuclear safety culture, resulting in a nuclear safety culture assessment of a site almost every year (NEI, 2010).

Operating Experience (OE)

Information from other sites is available from INPO and NRC to improve performance. Any operating experience (OPEX) items tagged as safety culture-related by INPO or NRC are assessed for relevance to the station (NEI, 2010).

QA/Self-Assessment/Benchmarking/Behavioral Observations

Each site performs a variety of self-reviews. These include audits required in the quality assurance programs, department self-assessments, and benchmarking of other sites in the industry (or other industries). It also includes behavioral observations by managers and supervisors in the field (NEI, 2010).

Employee Concerns Program (ECP)

This program provides opportunities to raise issues outside the normal chain of command. ECP issues typically are not entered into the CAP, but ECP trends are considered by the Nuclear Safety Culture Monitoring Panel (SCMP) (NEI, 2010).

Workforce Issues

These include data sources that could reflect concerns within the workforce that may be precursors to nuclear safety culture or safety conscious work environment (SCWE) issues, such as: grievance trends, potential SCWE claims, hostile work environment claims, sexual harassment or peer on peer harassment, industrial safety trends, disciplinary action review board trends, changes in compensation/incentive programs, change management issues and workforce management issues (e.g., staffing, knowledge transfer, or certification issues) (NEI, 2010).

Corrective Action Program (CAP) Evaluations

In addition to being the program, that is used to identify, analyze and resolve issues, the CAP is used to identify and evaluate trends across the entire data set of the CAP, for example, by using key words. The data from root cause and apparent cause evaluations also provide insights into potential nuclear safety culture issues and trends (NEI, 2010).

Site Performance Trends

Each site has a broad suite of indicators to assess performance. These indicators go beyond the NRC performance indicators and assess intermediate outcomes, which, if not corrected, could lead to safety system failures, scrams (i.e., reactor trips) or other events. Trends can be developed in these indicators and the cause of the trend – process or design deficiencies, training, resources, or nuclear safety culture issues – can be examined and corrective action taken. Examples include operator workarounds, control room deficiencies, preventive maintenance deferred, and open positions (NEI, 2010).

The Nuclear Safety Culture Monitoring Panel (SCMP) monitors the process inputs, which are indicative of the health of the organization's nuclear safety culture; to identify strengths and potential concerns that merit additional attention by the organization. The SCMP collects process inputs for a defined time period; categorizes process inputs; bins the inputs to safety culture attributes; sorts data by principle and performs collegial challenge of aggregated data; looks for long term trends; provides ratings and recommended actions; and reviews status and effectiveness of prior safety culture-related actions.

The Safety Culture Review Team (SCRT) is comprised of the senior-most management personnel onsite charged with the safe operation of a nuclear plant. To promote and monitor the health of the organization's nuclear safety culture, the SCRT periodically (i.e., at least semi-annually) assesses the station against the INPO *Principles for a Strong Nuclear Safety Culture*. This self-critique is intended to be reflective and performed by the SCRT itself in a group setting. During this review, the SCRT examines a variety of information that reflects the health of the organization's work environment to discern trends and early indications of nuclear safety culture challenges. The reports of the Nuclear Safety Culture Monitoring Panel and previous nuclear safety culture assessments, INPO evaluation nuclear safety culture findings, and any insights from the offsite nuclear safety review board (or equivalent) are reviewed by the SCRT prior to the meeting. Although a variety of inputs may be considered during the self-critique, the most valuable insight often comes from the frank discussion of nuclear safety culture based on the SCRT's observations and insights. As the organization's senior leaders, the SCRT possesses broad, diverse backgrounds in managing nuclear power plants and the nuclear professionals that make up the workforce. The SCRT is often able to discern subtle trends and early indications of nuclear safety culture challenges from personal interactions, in-field observations, and other means. The end result is an improved understanding among the members of the SCRT of where their efforts to further improve the station's nuclear safety culture need to be applied.

The SCRT's Nuclear Safety Culture Review is documented using the INPO *Principles for a Strong Nuclear Safety Culture* and INPO *Traits of a Healthy Nuclear Safety Culture* to identify strengths, areas found acceptable, and areas in need of improvement. Follow-up actions are tracked. Strengths and improvement opportunities that are identified are communicated back to the organization to drive desired behaviors and actions for fostering a strong nuclear safety culture.

3.5 Data Collection, Processing and Analysis

Data collection, processing and analysis consist of a number of steps that relate to the three phases of the NSC Assessment with MCDA Process (Figure 2). Including the collection of the process input data in the first phase, selection of the survey instrument to conduct the degrees of belief assessment in the second phase and selection of the MCDA model which will integrate these two in the third, and final, phase. It also covers the research purpose (Figure 3), the research questions (Figure 4), as well as the research contributions (Figure 5). It addresses the research limitations and it details the NSC Assessment with MCDA Process. Finally, the research methodology addresses the sensitivity analyses along with the preliminary verification and validation of the NSC Assessment with MCDA Process. A comprehensive overview of the NSC Assessment with MCDA Process methodology is illustrated in Figure 12.

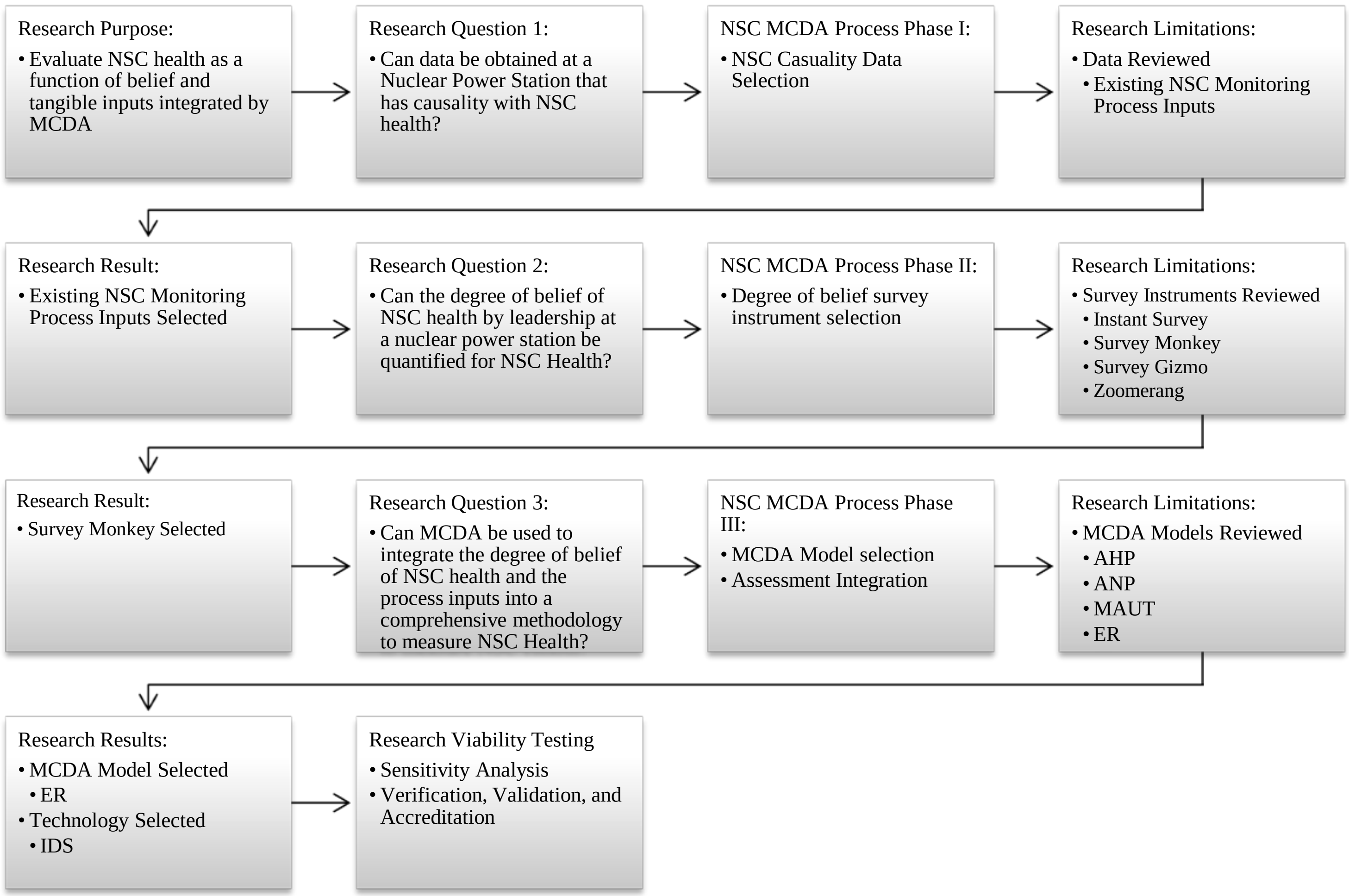


Figure 12. Research Methodology

NSC MCDA Process Phase I

The first phase of this research reviewed and selected the existing Safety Culture Monitoring Panel binning of Process Inputs. This process is conducted in accordance with the Nuclear Energy Institute (NEI) document NEI 09-07, Fostering a Strong Nuclear Safety Culture and the Institute for Nuclear Power Operation (INPO) document INPO 12-012, Traits of a Healthy Nuclear Safety Culture (Nuclear Energy Institute [NEI], 2010)(INPO, 2012a). The traits described in this document are divided into three categories that are similar to the three categories of safety culture found in International Nuclear Safety Advisory Group, *Safety Culture*, (International Nuclear Safety Advisory Group [INSAG], 1991) as illustrated in Figure 13. The categories and their primary traits are as follows:

Individual Commitment to Safety with primary traits of: personal accountability, questioning attitude and effective Safety Communication.

Management Commitment to Safety with primary traits of: leadership safety values and actions, decision-making and respectful work environment.

Management Systems with primary traits of: continuous learning, problem identification and resolution, environment for raising concerns and work processes.

Process Input binning data was obtained for the previous three years from SPS. Based on the common codes for each of the ten indicators for a nuclear safety culture (Section 3.4), appropriate plant incident reports from plant were identified and subsequently evaluated to validate the coding and related trends. The data analysis is expected to provide indication of both positive and adverse trends aligned with the indicators of changes in a nuclear safety culture.

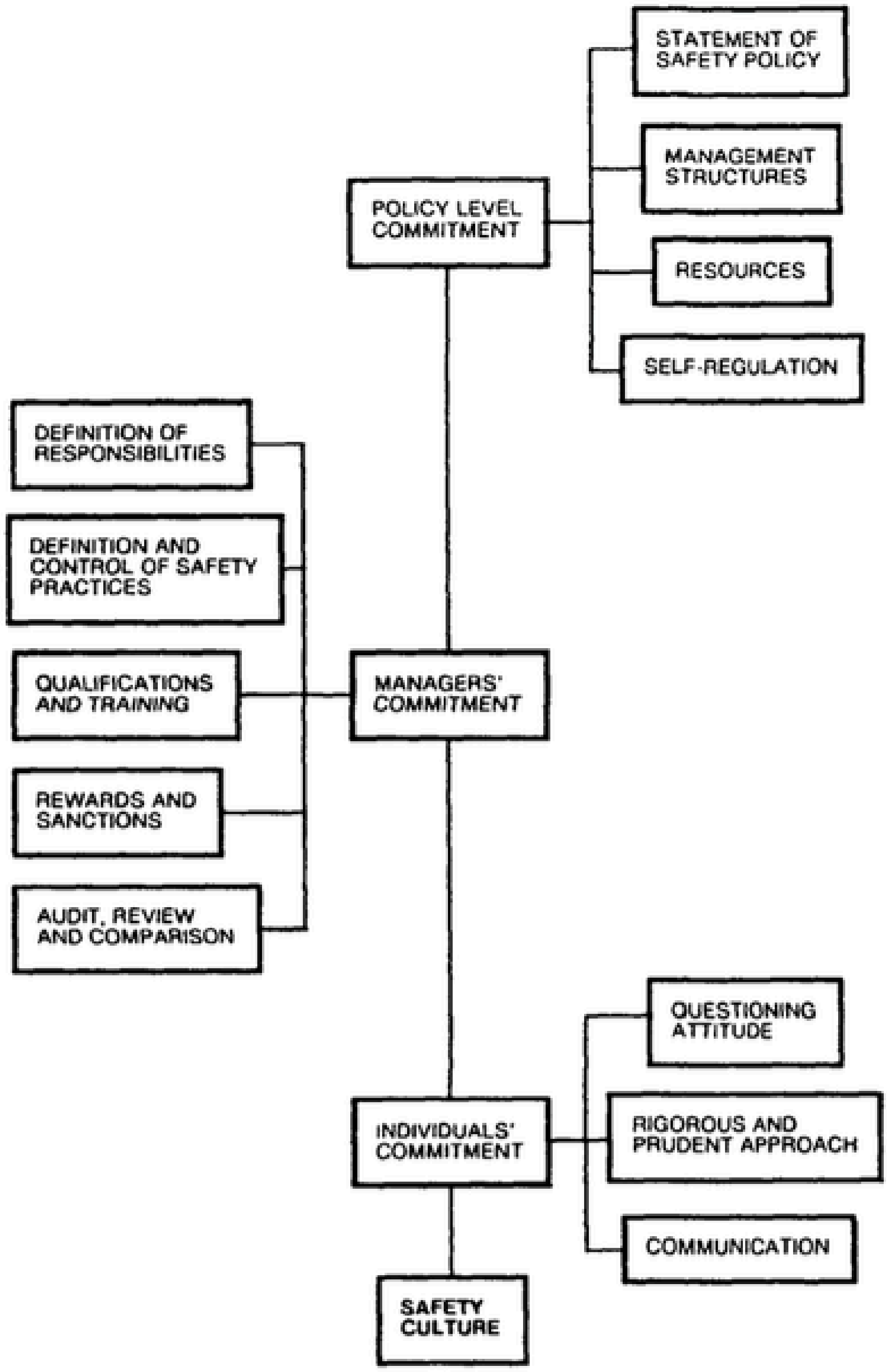


Figure 13. Illustration of the presentation of safety culture

NSC MCDA Process Phase II

The second phase of this research will develop a survey instrument to that will allow the belief (qualitative) of the health performance of a NSC by leadership at a nuclear power station to be quantified in terms of degrees of belief (quantitative). The quantitative technique requires data collection with a field study an example of one of the quantitative methods utilized (Haltiwanger, 2012). Under the umbrella of a field study is the survey that is a means for describing, comparing, or explaining a group's knowledge, attitudes, and behaviors (Fink, 2003). Along the same lines Creswell (2005) states that surveys "provides a quantitative or numeric description of trends, attitudes, or opinions of a population by studying a sample of that population" (p. 153). Surveys provide for high external validity (Bowen, 1995).

Important steps of the survey are setting objectives, designing the survey, preparing a reliable and valid instrument, administering, analyzing, and reporting results (Fink, 2003). The objectives for this survey are developed from the research questions. Survey design considers the type of survey, types of questions asked, survey sampling, sampling methods, sample size, and response rate. Types of surveys are self-administered questionnaires, interviews, structured record reviews, and structured observations. Self-administered questionnaires are surveys in which the individual respondents complete themselves. Of the different types of self-administered questionnaires the web-based survey was chosen. Advantages of a web-based survey included cost, short collection time, and ease of data transfer (De Leeuw, 2008).

Open or closed questions can be asked. In open questions respondents provide answers in their own words. In closed questions respondents choose from a predetermined set of answers. According to Fink, open questions allow respondents to describe the world as they see it and in closed questions respondents answer questions as the surveyor see it (Fink, 2003). Open questions must be interpreted and cataloged, and unless the surveyor is trained in qualitative techniques complexity can arise in comparing and interpreting the results. Closed questions are more difficult to construct but lend themselves better to statistical analysis and interpretation (Fink, 2003). The survey for this research utilizes closed questions.

Answers to closed questions can be nominal, ordinal, or numerical. Nominal answers require respondents to place themselves in a category (i.e. male or female), ordinal answers require respondents to rate the answer (i.e. very positive to very negative), and numerical answers require respondent to give a number (i.e. age). The survey will use ordinal answers to collect data on independent and dependent variables, a mixture of nominal, ordinal, and numerical answers will be used to collect data on moderating variables.

Two sampling methods are probability sampling and nonprobability sampling. In probability sampling all members of the target population have a know probability of being included in the survey. Probability sampling uses random sampling techniques. While in a nonprobability sampling subjects are chosen by judgment and not all members of the target population have a chance of being chosen. The main advantage to nonprobability sampling is convenience and cost, while the main disadvantage is the possibility of selection bias (Fink, 2003). Fink indicates that often nonprobability sampling is appropriate for surveys. For this survey a nonprobability convenience sample will be chosen.

There is a wide range of recommendations for sample size based on total numbers and participants per variable. Hair, Anderson, Tatham, and Black (1998) recommend 15 to 20 observations per independent variable for generalizability, a minimum ratio of 5 to 1, and having at least 50 total observations when performing factor analysis. Gorsuch (1983) repeats the recommendation for a minimum ratio of 5 to 1, while Everitt (1975) recommends the ratio should be at least 10 to 1.

Response and non-response rate must be considered. Both non-response to an entire survey and non-response to individual questions can introduce bias (Fink, 2003). Fink lists identifying larger number of respondents, using surveys that interest the respondents, sending reminders, and following up with non respondents as a few measures to increase response rates (Fink, 2003). The population will be individuals in a nuclear power station culture based environment that are were involved with NSC health governance. Solicitations will be made through e-mail for individuals working in the selected nuclear power station. A flow chart of the proposed survey development process is illustrated in Figure 14.

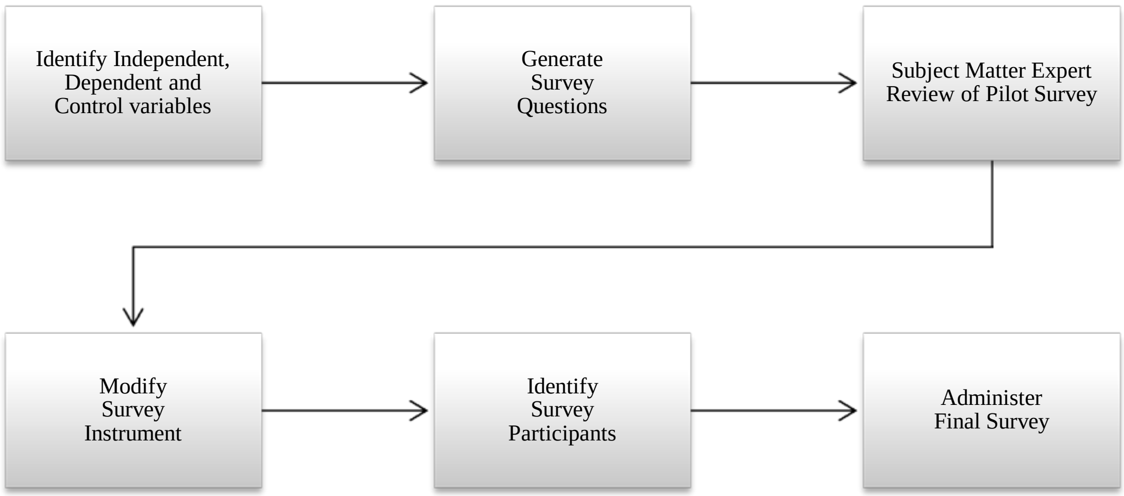


Figure 14. Survey Development

The survey developed is shown in Appendix F. Table 2 lists the questions as they relate to the independent, dependent, and moderating variables.

Table 2. Question Categorization

Question Categorization	
Variable	Questions
Independent Variables	
Complete Integration of NSC into Ops	Intra (5, 10, 15, 20)
Significant Integration of NSC into Ops	Intra (6, 11, 16, 21)
Average Integration of NSC into Ops	Intra (7, 12, 17, 22)
Minimal Integration of NSC into Ops	Intra (8, 13, 18, 23)
Absence of Integration of NSC into Ops	Intra (9, 14, 18, 24)
Dependent Variables	
Individual Commitment to Safety Items binned per Quarter	5, 6, 7, 8, 9
Management Commitment to Safety Items binned per Quarter	10, 11, 12, 13, 14
Management Systems Items binned per Quarter	15, 16, 17, 18, 19
Individual Commitment, Management Commitment and Management Systems Total Items binned per Quarter	20, 21, 22, 23, 24
Moderating Variables	
NSC Monitoring Experience	1
Employee Position	2
Military Nuclear Power Experience	3
Civilian Nuclear Power Experience	4

With respect to survey instruments the following are of particular concern:

Reliability - consistency between the measures of a construct.

Content validity - how well it covers the domain of the concept.

Face validity - how well it appears to measure what it is intended to measure. Validity will be increased by comparison with the existing NSC process.

U*nidimensionality* - how well the indicators represent a single concept?

Internal validity - the extent to which the correlation being tested is between the variables and not an outside factor.

External validity - the extent to which the findings may be generalized.

Nomological validity - the extent to which the constructs relate to each other in a manner consistent with theory (Ahire & Devaraj, 2001).

Reliability is increased in this survey by asking multiple questions for the same factor. Validity is increased in this survey by comparison of results with the existing SPS NSC monitoring process. Reliability and validity were both increased by use of the pilot survey (Haltiwanger, 2012).

This survey instrument only underwent basic statistical analysis partially due to the low maximum response size for one nuclear power station on the order of twelve individuals. While this is a low number for statistical accuracy, it must be recalled that the purpose of this survey is not to prove a hypothesis based on responses as would be performed in deductive research. But rather the survey is an instrument to obtain belief degrees from Subject Matter Experts in NSC at an operating commercial nuclear power station to accomplish the goal of producing a MCDA model for NSC Performance health ranking (i.e., inductive research). See Section 5.2 for recommendations with respect to survey population increase in future research.

NSC MCDA Process Phase III

The third phase of this research will determine a methodology for integrating degrees of belief assessments with the process inputs in a MCDA model, which directly relates to the third assessment integration phase. Four MCDA models: Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Multi Attribute Utility Theory (MAUT) and Evidential Reasoning (ER) will be evaluated for their utility in integrating the binned process inputs and degrees of belief information with the best candidate to be selected for implementation. This final phase (assessment integration) is the most crucial. Many approaches exist that could integrate the Process Input binning and degrees of belief assessments. Based on the goal of this research, the result of this phase of the MCDA methodology must characterize the health of the NSC.

Multi Criteria Decision Analysis Models

The research is dependent upon the MCDA model used to integrate the degrees of belief and the Process Inputs assessments. Options for an integrated NSC Health assessment methodology include AHP, ANP, ER, and MAUT. However, each of these approaches would require complex software with the research; therefore, it is valuable to analyze these different alternatives in order to select the most appropriate MCDA model.

Analytic Hierarchy Process

This hierarchy provides a means for systematically evaluating the complex problem of ranking NSC Health. It also provides a method for quantifying the relative weights of different criteria and factors making it easier to compare incommensurable items (e.g., loss of life versus loss of money). However, AHP is not without criticism.

When ranking alternatives in terms of their attributes, some experts would argue that as new alternatives are added to a problem, the ranking of the old alternatives must not change; in other words, rank reversal should not be permitted. However, as we all have experienced, especially in the realm of commercial nuclear power, new sometimes alternatives do (and should) cause rank reversal. For example, the Fukushima Daiichi beyond design basis tsunami was considered a black swan event, unforeseeable, and forever changing the landscape of NSC assessments. Most AHP software can handle both approaches, either allowing for rank reversal or not, depending on the preference of the user. Furthermore, AHP is sensitive to the hierarchical model proposed. If the model were incomplete, or otherwise inadequate, then all results of the AHP would be questionable. The AHP model would need to be vetted with stakeholders and experts, in the hopes of adequately reflecting the complex decision making problem of integrating degrees of belief of NSC healthy and the tangible process inputs assessments to rank NSC Health Performance.

Analytic Network Process

While both AHP and ANP use pairwise comparisons to measure weights and rank alternatives, there are some fundamental differences between these two approaches (Figure 15). AHP structures a decision problem as a hierarchy with a goal, decision criteria, and alternatives. It also requires independence of all elements in the hierarchy, so the decision criteria must be independent, and the alternatives to be considered must also be independent, not only from each other, but also from the decision criteria. ANP, on the other hand, does not require independence among elements. Often there is interdependence among alternatives and decision criteria, so this is an improvement over

AHP. The way ANP handles this is to structure the decision problem as a network, which might be useful for the purposes of our research as degrees of belief of NSC health and the tangible process inputs are most likely interrelated, not independent.

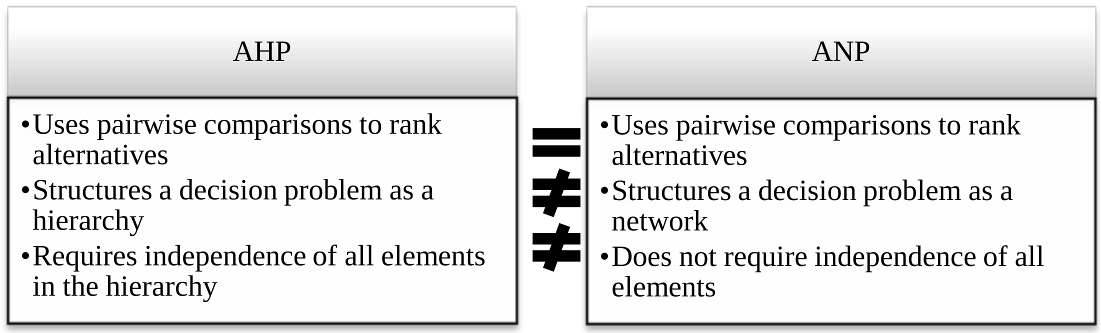


Figure 15. Analytic Hierarchy Process versus Analytic Network Process

Multi Attribute Utility Theory (MAUT)

MAUT builds utility functions for multiple attributes, independently, then combines these utility functions using weighted multi attribute models (additive models are common, but more complicated models exist). Next, the indifference probability between a sure thing and a gamble must be determined. This requires strong assumptions of independence, including (mutual) preferential independence and (mutual) utility independence. Attribute Y is preferentially independent of X if preferences for specific outcomes of Y do not depend on the level of X. For example, say that Y is number of days to complete a job, maybe 5 or 10 days with the cost to perform the job, X, is either $100 or $200. Assume that the cost is $100 no matter what, whether it takes 5 days or 10 days. If we prefer a 5-day time frame, then even if we raise the cost to $200 (again, for both 5 and 10 days), then we would still prefer 5 days. In this case, Y is preferentially independent of X. For mutual preferential independence, we also need X to be preferentially independent of Y, so we need to prefer the lower cost, no matter how many days it takes to perform the job. Utility independence is basically a stronger form of preferential independence. Y is utility independent of X if preferences for uncertain choices involving different levels of Y are independent of the value of X. That is, if there were a 50% chance that Y is 5 days, and a 50% chance that Y is 10 days, then regardless of whether X is fixed at \$100 or \$200, we would still prefer 5 days. For mutual utility independence, then we just need to reverse X and Y and see if the independence still holds. If these assumptions were validated, then we would set up a reference gamble to determine the indifference probability. In our example, the sure thing would be that X is some cost between the best case (X+) and worse case (X-) scenarios ($\$100 \leq X \leq \$200$), and Y would be some duration for the job to be completed. In this case Y+ would be the lesser of the two values, assuming we wish the job to be completed in a shorter period of time, so $Y+ \leq Y \leq Y-$ (or $5 \leq Y \leq 10$). We are interested in the utility, U(X, Y) versus the utility of a gamble. The gamble would have two scenarios based on a chance outcome. There is a best-case scenario, (X+, Y+) or (\$100, 5), which has probability p. There is also a worst-case scenario, (X-, Y-) or (\$200, 10), which has probability 1-p. Then we find p such that we are indifferent between the sure thing and the gamble.

However, these assumptions of independence do not always hold. Without the assumptions of independence, MAUT could become extremely challenging to implement. Furthermore, this model requires significantly more time in order to conduct these reference gambles and determine each respondent's utility. Due to lack of resources, MAUT is not a viable option for this research. In fact, regardless of resources, the model does not lend itself to integrating the types of data available for degrees of belief of NSC healthy and the tangible process indicators of NSC health (Hill, 2012).

Evidential Reasoning

An appealing option for a MCDA NSC integrated assessment methodology is Evidential Reasoning (ER), which deals with problems having both quantitative and qualitative criteria under uncertainty, such as ignorance or randomness (Huynh, Nakamori, Ho, & Murai, 2006). It is used to support decision analyses, assessments, or evaluation activities. It addresses the decision problem using a belief structure to model an assessment with uncertainty, a belief decision matrix to represent a problem under uncertainty, ER algorithms to aggregate criteria for generating distributed assessments, and belief and plausibility functions to generate a utility interval which measures the degree of ignorance.

Both ER and AHP use a hierarchy to model a MCDA problem; however, ER differs from AHP in a several ways. With AHP all of the alternatives comprise the lowest level of the hierarchy, but with ER the alternatives are not included in the hierarchy at all (Xu & Yang, 2001). Further, ER uses a generalized decision matrix where each element of the matrix is an assessment of a given attribute using belief degrees. The decision matrix in AHP merely describes the relative importance of one attribute over another; therefore, “ER can be used to assess an alternative against a set of standards, while AHP can only compare the relative importance between attributes” (Xu & Yang, 2001). Finally, ER aggregates the belief degrees of lower level attributes to higher level attributes gradually, until it achieves an overall score, whereas AHP aggregates average scores based on pairwise comparison (Xu & Yang, 2001). One implication of these differences is that ER can tackle large-scale MCDA problems (without limits on the number of alternatives or attributes). In addition, as new attributes are added, an ER model does not need to be re-evaluated since each attribute is scored for each alternative separately. ER also does not suffer from a common AHP problem known as rank reversal, which can occur when new attributes are added to an AHP model. Perhaps most importantly, ER can handle mixed data, including random and deterministic, qualitative and quantitative, as well as incomplete data for some attributes. Furthermore, ER can incorporate AHP procedures into certain aspects of a model, such as using pairwise comparisons to weight attributes against each other (Xu & Yang, 2001).

MCDA Software Selection Result

While most conventional MCDM methods use a decision matrix for problem modeling, the ER approach uses a belief decision matrix, of which the conventional decision matrix is a special case. In a belief decision matrix, a distribution instead of a single value is used to represent an alternative's performance on an attribute. For example, if a company is assessed to be Excellent on short-term planning and Poor on long-term planning, it would then be described as Average on Planning in a decision matrix, while in a belief decision matrix, this would be a distribution of {[Excellent 50%], [Average, 0], [Poor, 50%]}. A modified Dempster's evidence combination algorithm is used for aggregating the information in the belief decision matrix. The aggregation process is nonlinear, and in essence a probabilistic approach. The outcome of the aggregation is also a distribution, not a single score, of an alternative's performance on the top attribute. However, a score can be calculated from the distribution by adding each assessment grade value weighted by the associated belief degree in the distribution. However the score will normally be different from weighted sum method because the distribution is generated through a nonlinear aggregation process (Xu, McCarthy, & Yang, 2005).

There are two general advantages in employing the ER approach for MCDM. Firstly, it provides a novel belief framework to model and synthesize subjective information. Secondly the ER approach can make full use of different types of data, including subjective judgments, probabilistic data, and incomplete data under weaker assumptions that may undermine other methods such as MAVT. For example, it requires only the satisfaction of value independence condition, which is easy to check and satisfy, in order to apply the ER approach for attribute aggregation, not the stringent preferential independence condition required by the multiple value function theory (MAVT). When there are only a few attributes, it may be manageable to check the satisfaction of the preferential independence conditions. It becomes much more difficult when attribute number increases beyond a handful. Therefore decision scientists normally recommend carefully selecting only a small number of attributes, such as 9 or up to a few tens, when structuring a MCDM problem. In self-assessment, the above general advantages of the ER approach can be transformed into the following three practical advantages. Firstly the belief decision matrix provides flexibilities in question presentation and data collection. Secondly, the ER aggregation process generates more insight information on performance diversities and supports the identification of strengths and weaknesses. Thirdly, the number of attribute (or questions) in the assessment model is much less a concern to the ER approach than to other conventional approaches (Xu et al., 2005).

In conclusion, software for AHP is widely available but can be very expensive. Software for ANP and MAUT are not as common. Consequently, ER is the prudent choice for the NSC MCDA Health Performance research and conveniently, there is free ER software available with limited but sufficient attributes for the research. Furthermore, the ER software can communicate health performance and decisions through graphical data visualizations, making it a logical choice for this research.

3.6 Methodological Assumptions, Limitations and Delimitations

As noted by Schein (2004), the basic defining dimensions of an organizational culture are not directly observable, thus valid indications and measurements of these dimensions are difficult to establish. Although there are a variety of quantitative and qualitative methods available to measure the psychological, behavioral, and situational aspects of safety cultures in high-risk industries, methods to measure work process aspects of safety cultures are limited (Cooper, 2000). As indicated in the review of the literature, various aspects of safety culture have been examined through observations and assessments of management and control records. Employee attitudes, values, and beliefs can be measured by a survey, but only through observations of worker performance or through reviews of event records are the application of these cultural aspects confirmed (Roughton & Mercurio, 2002).

Data gathered from plant event records minimized spatial and respondent behavior limitations and analysis by a single researcher mitigated researcher bias concerns. Gathering data from plant event records is an unobtrusive measurement process and does have a limitation relative to researcher control over the types of data collected (Trochim, 2001). Analysis techniques of content analysis through standardized coding applications were in use at Surry Power Station for Binning the Process inputs that mitigated most other forms of bias. The use of the standardized codes encapsulates human judgment in assigning the codes to power plant event records, which can only be addressed through a qualitative observational study.

History effects at Surry Power Station affected the validity of this study. Organizational changes, including management changes occurred during the data collection period. A limitation of this study is that the research did not consider the effect of organizational changes.

3.7 Ethical Assurances

This research assessed the health of a nuclear safety culture at a commercial nuclear power plant in the United States. Proprietary, personal, and nuclear safeguards information was excluded from the corrective action documents reviewed. Personal and social harm was avoided. Data obtained from nuclear power plant corrective action systems based on trend codes are recorded in such a manner that human subjects cannot be identified directly or through identifiers linked to the subjects. This research was based on the concept of grouped information, for which no identifiable private information was obtained on human subjects. Furthermore, data were not obtained through intervention or interaction with any individuals. This research project did not, therefore, meet the definition of human subject research as specified in the Code of Federal Regulations Title 45, Part 46, and was in compliance with the standards of the Old Dominion University Institutional Review Board (IRB) (Appendix A).

CHAPTER 4

4. RESULTS

This research investigated the ability to integrate survey instrument degrees of belief results and MCDA into a comprehensive methodology to measure NSC Health Performance. The basis of this research was a detailed literature review showing that there is strong interest in maintaining a healthy NSC and that there was a wide gap in the body of knowledge in this area. The literature review went further to identify a specific gap in the body of knowledge for accurately measuring the health performance of a NSC. From the literature review, a conceptual model was formed and research questions were built. A survey was developed, vetted through peer review and distributed. Solicitations for participation were made via the Internet and data were collected. A quantitative data analysis was performed followed by a qualitative interpretation. This degrees of belief data were then utilized in Evidential Reasoning Software to address the questions that are the focus of this research (Figure 16. Three Phases of the NSC Assessment with Evidential Reasoning). The results of this analysis follow.

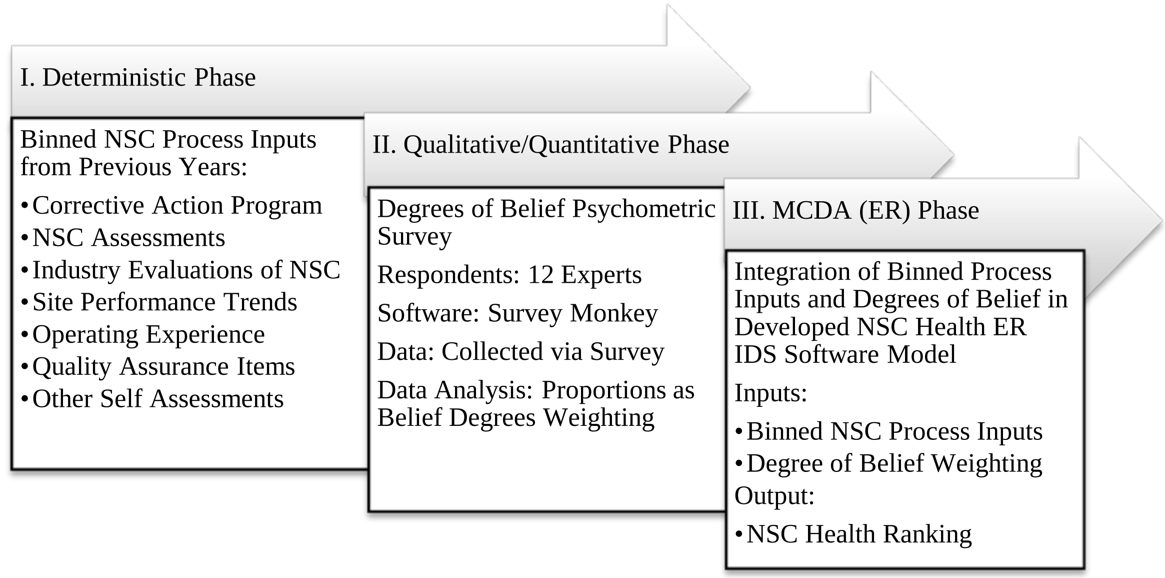


Figure 16. Three Phases of the NSC Assessment with Evidential Reasoning

4.1 Phase I: Binned NSC Process Inputs Results

Nuclear safety culture evolves over time; therefore, it is also appropriate to review any evidence of problems on a frequent, ongoing basis. Personnel and organizational changes, budget challenges, handling of emergent issues, and day-to-day organizational dynamics can have a profound impact on what is viewed as important and hence can influence the behaviors and nuclear safety culture at the plant and across the organization. Many sources of data may indicate a potential nuclear safety culture issue. Examples of such sources include station performance indicators, NRC inspection reports, the corrective action program (CAP), the employee concerns program, audits and quality control inspections, self-assessments, benchmarking, workforce issues, and others identified elsewhere in this document (NEI, 2014).

The CAP is the largest single source of potential input to the culture monitoring process. Important causal investigations are considered for inclusion in the culture monitoring process. The causes and contributors or other latent weaknesses identified are examined for possible safety cultural implications. “Good catches”, CAP trends, anonymous reports, and other CAP feedback are considered for additional insights. In addition, at Surry Power Station (SPS) the CAP process also captures issues that are not adverse to quality. These lower-tier issues are examined for safety culture insights. In general, special consideration is given to CAP entries that appear to be emotionally charged, carry negative tones, or indicate current frustration or dissatisfaction with procedures, processes, resources, or other organizational deficiencies. Special consideration is also given to entries expressing concerns about the ability of the management team to address repetitive or longstanding issues or expressing lack of respect or trust (NEI, 2014).

In addition to CAP data, the following data types are considered high yield inputs important for consideration of cultural implications.

Regulatory Communications – This category includes items that arise from communications with regulatory agencies and are not already in CAP. “Regulatory agencies” include the NRC, other federal regulators (e.g., NERC, EPA), and state and local agencies. The regulatory communications items to capture are those appearing to have safety culture implications.

Assessments – This category includes periodic and ad hoc assessments directly focused on nuclear safety culture behaviors, such as nuclear safety culture assessments

(NSCAs). Other assessments may also be included if they address safety culture behaviors or appear to have other safety culture implications.

Industry Evaluations – This includes evaluations conducted by outside organizations (e.g., INPO, American Nuclear Insurers (ANI), Nuclear Electric Insurance Limited (NEIL)). For example, INPO evaluations are conducted approximately every other year, ideally in the alternate year from the nuclear safety culture assessment. Included in the INPO evaluation is an assessment of nuclear safety culture, resulting in a nuclear safety culture assessment of a site almost every year. These industry evaluations are available to NRC on site and are checked for safety culture implications (NEI, 2014).

The following lower yield data types, that may be less rich in signs of cultural health, are considered on a case-by-case basis.

Operating Experience – Company-internal operating experience (OE) can provide site-specific insights about safety culture behaviors. Nuclear industry OE programs and processes often provide insights that highlight weaknesses in safety culture behaviors. The insights gathered from reviews of internal OE often provide additional detail and perspectives which complement information available in the CAP evaluation of those events. External OE is evaluated to determine if the safety culture behaviors in those events are being exhibited at the site. Comparison of external OE with what the site has learned through its internal OE can help draw attention to the importance and relevance of the site's own safety culture behaviors.

Quality Assurance Items – This category includes items identified through quality assurance audits and/or assessments that have apparent safety culture implications. SPS considers QA items as a potential input for the safety culture monitoring process.

Self-Assessments – This category includes items identified through performance-based self-assessments that appear to have safety culture implications. SPS considers self-assessment items as a potential input for the safety culture monitoring process.

Benchmarking/Observations – This category includes items from the wide variety of benchmarking activities involving other sites, companies, or industries. It also includes observations by managers and supervisors in the field that may provide insights about cultural health.

Site Performance Trends – SPS has a broad suite of indicators to assess performance and are more indicative of individual/organization behaviors and values that support nuclear safety. Trends are developed from these indicators and the cause of the trend – behaviors, process, training, resources, or leadership – is examined for corrective action. Examples include operator work-arounds, control room deficiencies, deferred preventive maintenance, timeliness and effectiveness of corrective action, system health, leadership effectiveness and site staffing, fitness for duty and access authorizations.

Miscellaneous Sources – SPS also considers optional inputs from such sources as: the station oversight organization; plant health reports; vendor-generated nuclear safety culture data such as surveys, audits, and assessments; human performance data such as site or department “clock resets”; and training feedback (NEI, 2014).

The following are other additional low value inputs that come directly to the attention of site senior management and are important in assessing nuclear safety culture, but, due to the sensitive, confidential nature of the information must have all identifying information removed prior to being handled by the nuclear safety culture monitoring panel.

Allegations – These include concerns reported directly to the NRC by site employees and contractors, and NRC requests for information needed for their investigation of allegations.

Workforce Issues - These include data sources that could reflect concerns within the workforce that may be precursors to nuclear safety culture or safety conscious work environment (SCWE) issues, such as: grievance trends, potential SCWE claims, hostile work environment claims, sexual harassment or peer on peer harassment, industrial safety trends, disciplinary action review board trends, changes in compensation /incentive programs, change management issues and workforce management issues (e.g., staffing, knowledge transfer, or certification issues).

Employee Concerns Program (ECP) - This program provides opportunities to raise issues outside the normal chain of command.

These process inputs are then collegiately vetted and binned by the Nuclear Safety Culture Monitoring Panel members into the following ten traits divided into three categories.

I. Individual Commitment to Safety, which includes the following traits:

PA. Personal Accountability

All individuals take personal responsibility for safety. Responsibility and authority for nuclear safety are well defined and clearly understood. Reporting relationships, positional authority, and team responsibilities emphasize the overriding importance of nuclear safety.

QA. Questioning Attitude

Individuals avoid complacency and continuously challenge existing conditions, assumptions, anomalies, and activities in order to identify discrepancies that might result in error or inappropriate action. All employees are watchful for assumptions, values, conditions, or activities that can have an undesirable effect on plant safety.

CO. Safety Communication

Communications maintain a focus on safety. Safety communication is broad and includes plant-level communication, job-related communication, worker-level communication, equipment labeling, operating experience, and documentation. Leaders use formal and informal communication to convey the importance of safety. The flow of information up the organization is seen as important as the flow of information down the organization.

II. Management Commitment to Safety, which includes the following traits:

LA. Leadership Accountability

Leaders demonstrate a commitment to safety in their decisions and behaviors. Executive and senior managers are the leading advocates of nuclear safety and demonstrate their commitment both in word and action. The nuclear safety message is communicated frequently and consistently, occasionally as a stand-alone theme. Leaders throughout the nuclear organization set an example for safety. Corporate policies emphasize overriding importance of nuclear safety.

DM. Decision-Making

Decisions that support or affect nuclear safety are systematic, rigorous, and thorough. Operators are vested with the authority and understand the expectation, when faced with unexpected or uncertain conditions, to place the plant in a safe condition. Senior leaders support and reinforce conservative decisions.

WE. Respectful Work Environment

Trust and respect permeate the organization, creating a respectful work environment. A high level of trust is established in the organization, fostered, in part, through timely and accurate communication. Differing professional opinions are encouraged, discussed, and resolved in a timely manner. Employees are informed of steps taken in response to their concerns.

III. Management Systems, which includes the following traits:

CL. Continuous Learning

Opportunities to continuously learn are valued, sought out, and implemented. Operating experience is highly valued, and the capacity to learn from experience is well developed. Training, self-assessments, and benchmarking are used to stimulate learning and improve performance. Nuclear safety is kept under constant scrutiny through a variety of monitoring techniques, some of which provide an independent “fresh look.”

PI. Problem Identification and Resolution

Issues potentially impacting safety are promptly identified, fully evaluated, and promptly addressed and corrected commensurate with their significance. Identification and resolution of a broad spectrum of problems, including organizational issues, are used to strengthen safety and improve performance.

RC. Environment for Raising Concerns

A safety-conscious work environment (SCWE) is maintained where personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment, or discrimination. The station creates, maintains, and evaluates policies and processes that allow personnel to freely raise concerns.

WP. Work Processes

The process of planning and controlling work activities is implemented so that safety is maintained. Work management is a deliberate process in which work is identified, selected, planned, scheduled, executed, closed, and critiqued. The entire organization is involved in and fully supports the process.

A summary of the SPS quarterly process input binning from the second quarter of 2012 through the first quarter of 2015 is illustrated in Figure 17, Figure 18 , and Figure 19. Example minutes from a Surry Power Station NSCMP meeting are located in Appendix C. The binned process inputs values for the last three rolling years are located in Appendix D (Table 5). Approval to utilize this SPS data was appropriately obtained and is contained in Appendix B.

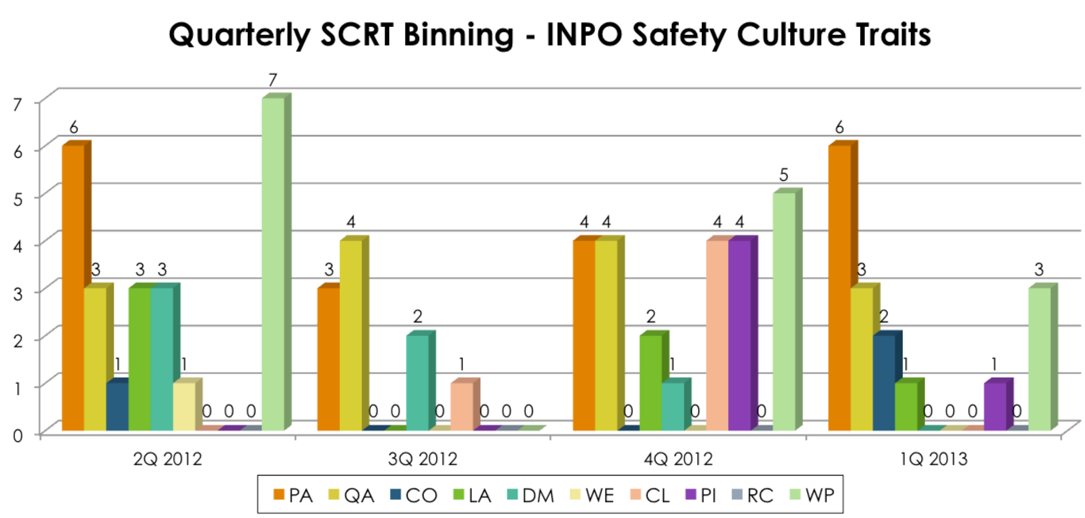


Figure 17. Quarterly Process Inputs Binning 2Q 2012 through 1Q 2013

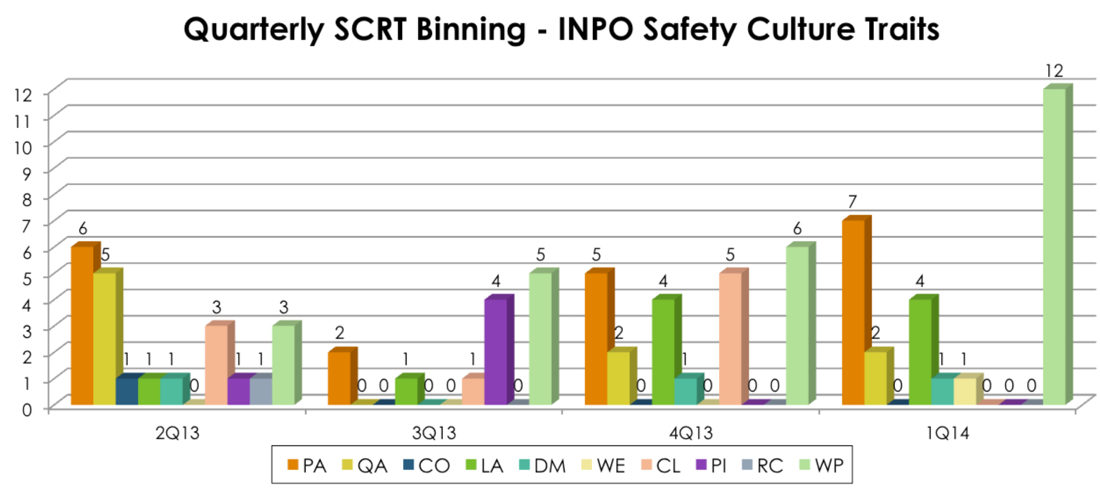


Figure 18. Quarterly Process Inputs Binning 2Q 2013 through 1Q 2014

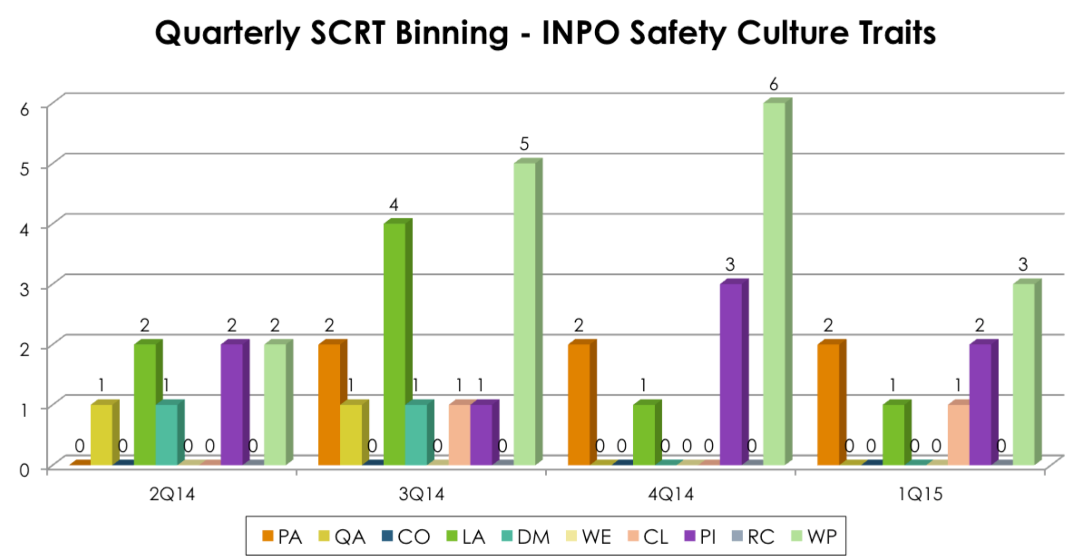


Figure 19. Quarterly Process Inputs Binning 2Q 2014 through 1Q 2015

4.2 Phase II: Degrees of Belief Survey Results

The survey was developed to obtain the degrees of belief, by leadership at a nuclear power station, between binned process input magnitude and NSC health performance. Request for approval was submitted to and granted by the Old Dominion University Institutional Review Board (IRB), Appendix A (p. 172).

The survey was then piloted to a group of subject matter experts. Participation in the survey was voluntary and the participants were informed they could decline to participate in the survey at any point in the process without risk of any adverse implications or effects. The participants of the pilot remained anonymous in the final documentation of results. The pilot survey is shown in Appendix E.

The results of the pilot were quantitatively and qualitatively analyzed. Qualitative analysis was conducted by reviewing the comments section for each question and the comment section for the survey as a whole. The survey instrument was modified using information gained from the quantitative and qualitative analysis.

Various on-line services were investigated as potential vehicles for distribution of the survey. Examples of services investigated were “Instant Survey”, “Survey Gizmo”, “Survey Monkey”, and “Zoomerang”. After evaluating each for cost, ease of survey development, survey types, distribution methods, visual appeal, and how the results were packaged “Survey Monkey” (www.surveymonkey.com) was chosen. The final survey (Appendix F) is, as it appears developed through “Survey Monkey”. All survey responses were anonymous and none of the information could be tracked back to any individual or company, directly or indirectly. To solicit participation a link to the survey was e-mailed by the survey author to twelve individuals that are members of the NSC

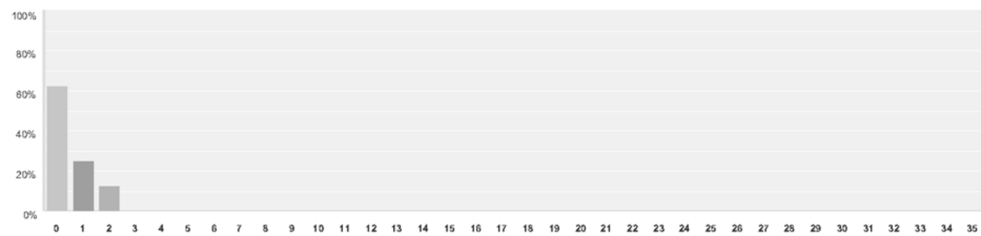
Monitoring Teams at Surry Power Station. These selected individuals had a mean value of 31.5 years of commercial nuclear power experience and with a mean value of 4.13 years experience on a NSC monitoring panel.

There were a total of eight responses and the categorization of the responses is shown in Appendix G: Survey Results (p. 206). While this is a low number for statistical accuracy, it must be recalled that the purpose of the survey was not to prove a hypothesis based on responses as would be performed in deductive research. But rather the survey was an instrument to obtain belief degrees from Subject Matter Experts in NSC at an operating commercial nuclear power station to accomplish the goal of producing a MCDA model for NSC Performance health ranking (i.e., inductive research).

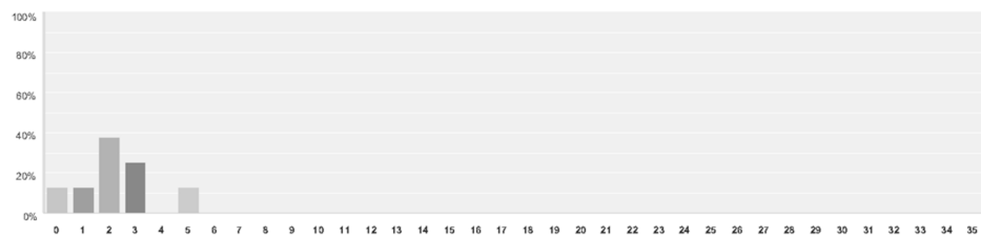
It was known how many individuals were contacted (twelve) and how many responses were received (eight) for a response rate of 66.6%. Additionally, by using a built-in function selection in "Survey Monkey" the respondents were not allowed to partially fill out a survey. All questions for the Independent and Dependent variables had to be answered in order to submit the survey. To help ensure internal validity was maintained it was determined that all questions on each variable be answered in order to complete the survey.

Basic statistical analysis was conducted based on the discussion laid out in the Methodology section of this paper (Section 3). Survey results were obtained from Survey Monkey and are contained in Appendix G (p. 206) and results illustrated by Figure 20, Figure 21, Figure 22, Figure 23, and Figure 24.

Q5 Approximately how many items binned per quarter under Individual Commitment to Safety would indicate complete integration of the Nuclear Safety Culture into normal operations:



Q6 Approximately how many items binned per quarter under Individual Commitment to Safety would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations:



Q7 Approximately how many items binned per quarter under Individual Commitment to Safety would indicate an average level of integration of the Nuclear Safety Culture into normal operations:

Figure 20. Belief Degrees Survey Results (p. 1)

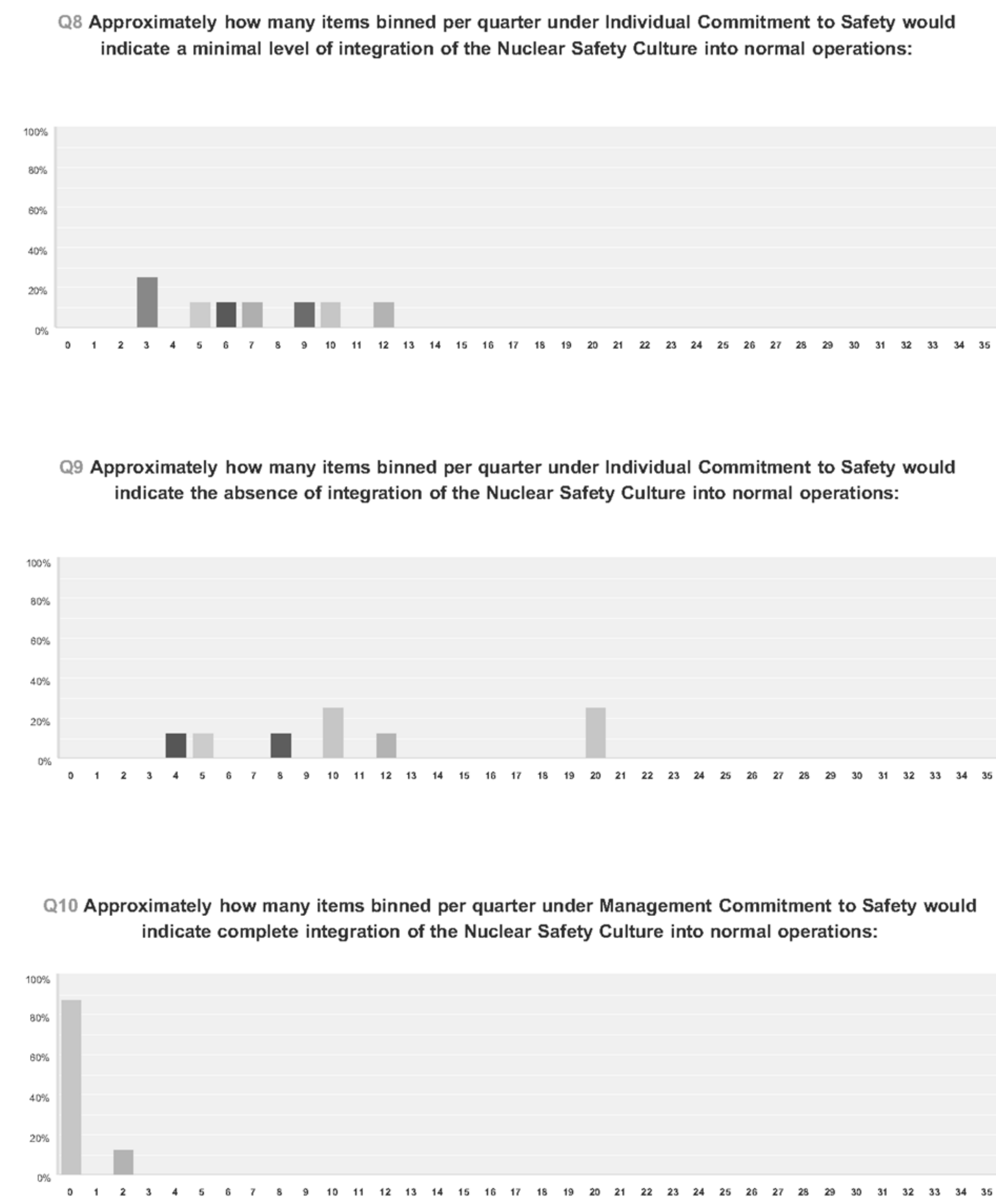
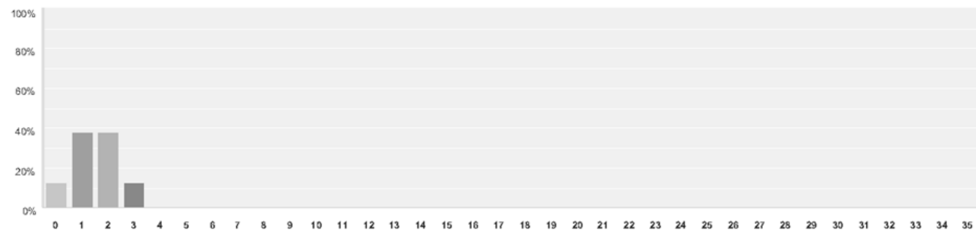
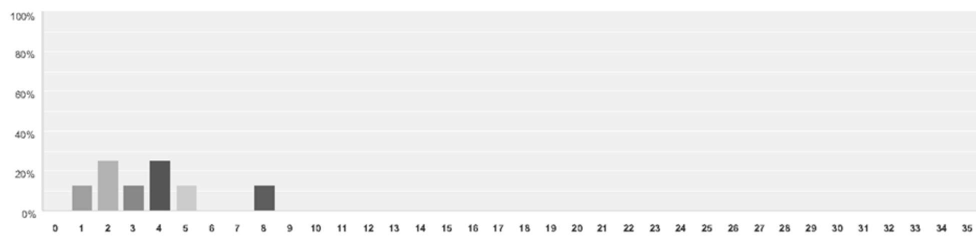


Figure 21. Belief Degrees Survey Results (p. 2)

Q11 Approximately how many items binned per quarter under Management Commitment to Safety would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations:



Q12 Approximately how many items binned per quarter under Management Commitment to Safety would indicate an average level of integration of the Nuclear Safety Culture into normal operations:



Q13 Approximately how many items binned per quarter under Management Commitment to Safety would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations:

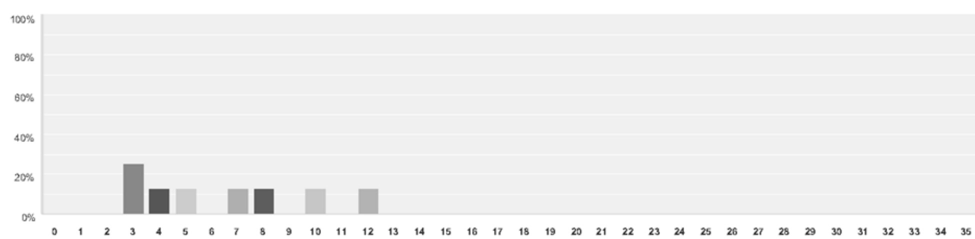
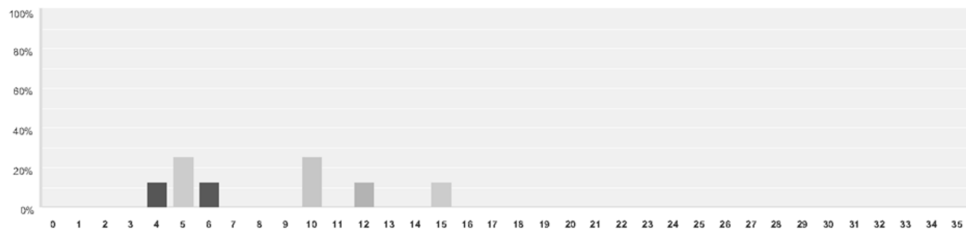
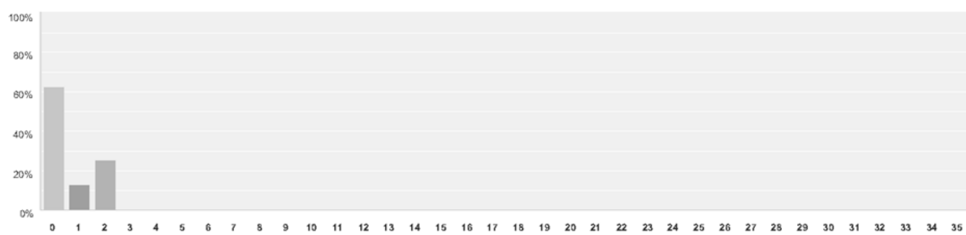


Figure 22. Belief Degrees Survey Results (p. 3)

Q14 Approximately how many items binned per quarter under Management Commitment to Safety would indicate an absence of integration of the Nuclear Safety Culture into normal operations:



Q15 Approximately how many items binned per quarter under Management Systems would indicate complete integration of the Nuclear Safety Culture into normal operations:



Q16 Approximately how many items binned per quarter under Management Systems would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations:

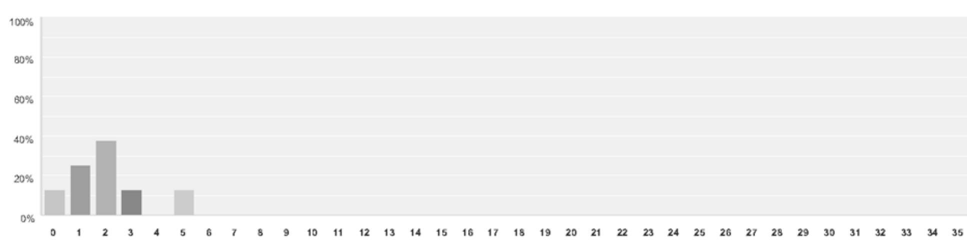
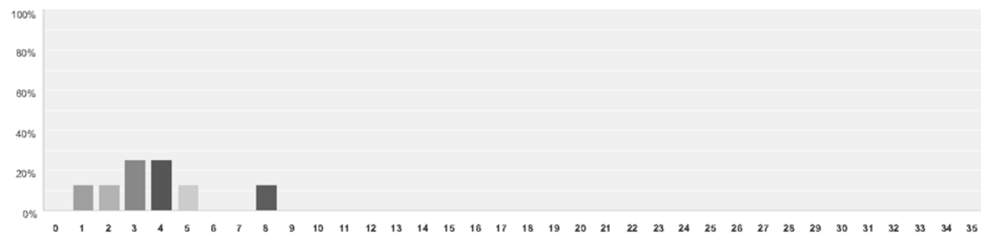
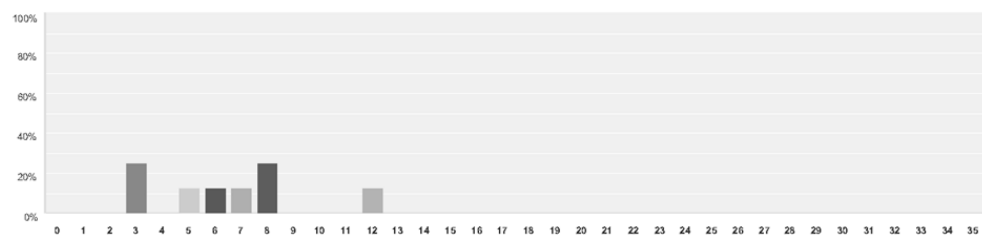


Figure 23. Belief Degrees Survey Results (p. 4)

Q17 Approximately how many items binned per quarter under Management Systems would indicate an average level of integration of the Nuclear Safety Culture into normal operations:



Q18 Approximately how many items binned per quarter under Management Systems would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations:



Q19 Approximately how many items binned per quarter under Management Systems would indicate an absence of integration of the Nuclear Safety Culture into normal operations:

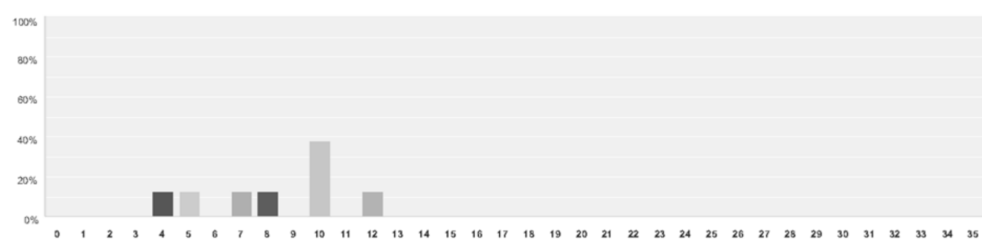


Figure 24. Belief Degrees Survey Results (p. 5)

4.3 Phase III: MCDA (Evidential Reasoning) Model Results

An Evidential Reasoning Model was developed, with Intelligent Decision System (IDS) software (Intelligent Decision System Version 1.2), for the determination of NSC Health utilizing the binned process input data obtained from SPS and the degrees of belief data obtained from the survey conducted at SPS.

This model consists of twelve NSC Health *Alternatives*, which are the past twelve quarters of NSC Process Data Binning results for SPS (i.e., SPS 2012 Q2 through SPS 2015 Q1).

In order to determine the value of the Level 1 NSC Performance *Attribute* for each Quarter of a year *Alternative* there are three Level 2 *Attributes* (Individual Commitment to Safety, Management Commitment to Safety and Management Systems) that receive the binned process input data via ten Level 3 *Attributes* (PA, QA, CO, LA, DM, WE, CL, PI, RC, WP). The model also utilizes weighting to determine the contribution of the Level 2 and 3 Attributes to the Level 1 Attribute, utilities to determine the relationship between the binned process input data and the *Child Attributes* and two sets of belief degrees. One is used to relate the grades of *Child* and *Father Attributes*, the other to determine the beliefs held for the process input data selected within each *Child Attribute* for each *Alternative*.

While this model is relatively simple, it is extensible and could easily address additional layers of complexity from an increase in the number of *Alternatives* under study, to a more complex description of the father and child *Attributes* (e.g., adding additional sub-categories or *Child Attributes* to each of the ten NSC Traits).

The utility of ER, and the IDS software for implementing ER, is its simple structure, which can be organized into many combinations of *Attributes* and *Alternatives* making it easy to implement, but capable of handling complex problems without overcomplicating them.

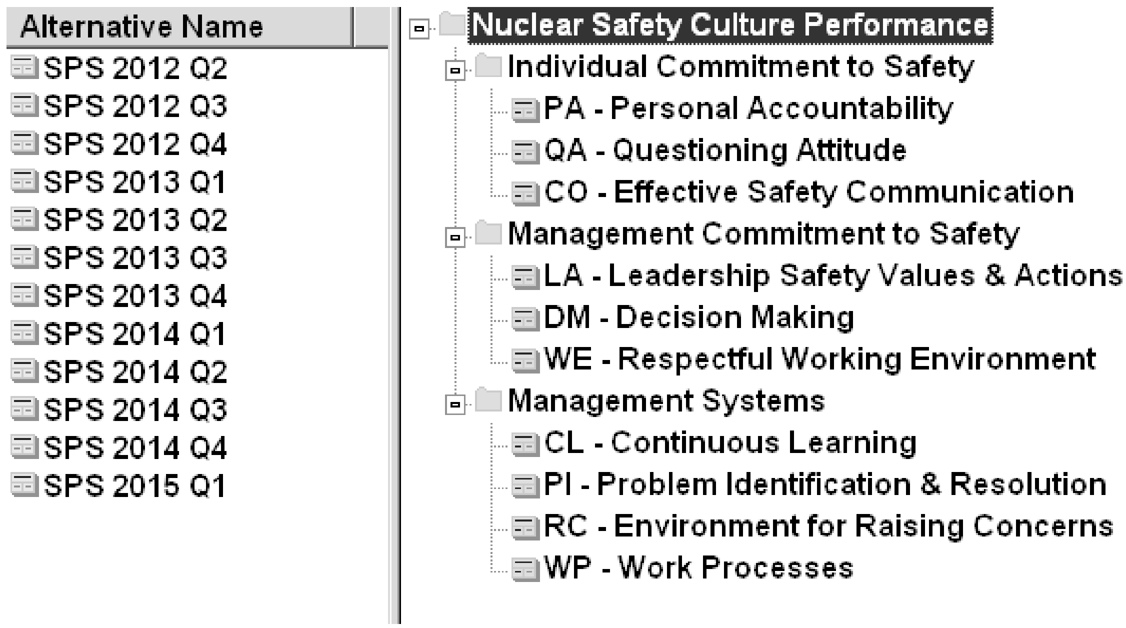


Figure 25. IDS NSC Model (List-Tree View)

An example of how this model appears in the IDS Software List-Tree View is shown in Figure 25. In the IDS model display window, users can opt to select **View > Dialog Box View** to see a more visual version of the model (Figure 26).

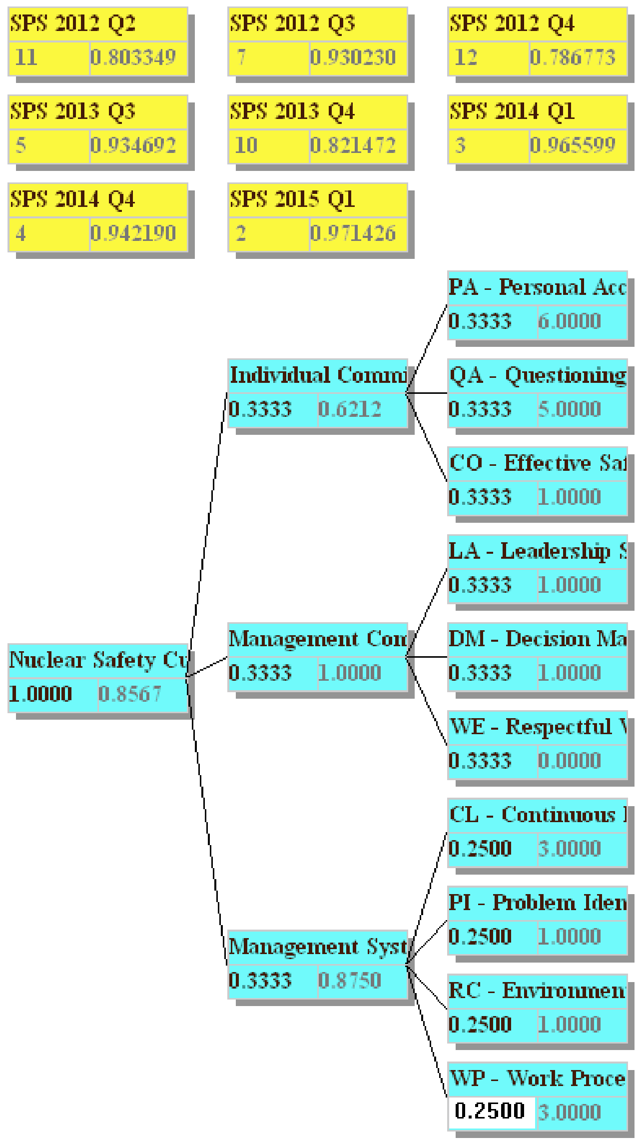


Figure 26. IDS NSC Model (Dialog Box View)

The yellow colored boxes hold the information for Alternatives, including the Alternative name at the top, the ranking in the bottom left and the utility value in the bottom right. The cyan colored boxes are used for inputting and displaying information for Attributes: the Attribute name is at the top, the weight of the Attribute in the bottom left and the value of the Attribute (in case of a quantitative attribute) or average utility value of the attribute (in case of an qualitative one) in the bottom right.

Each of the Level 3 Attributes (PA, QA, CO, LA, DM, WE, CL, PI, RC, WP) was defined in IDS as quantitative; however, ER can integrate both qualitative and quantitative data, and IDS provides that option when defining attributes. For example, if the attribute is defined as quantitative, then the user can also decide whether it is a certain or uncertain attribute. This is useful for defining stochastic quantitative attributes, which could be random variables with some underlying distribution, may be difficult to assess, or could suffer from missing data. The steps to program uncertainty information in IDS ER are illustrated in Figure 27, Figure 28, and Figure 29.

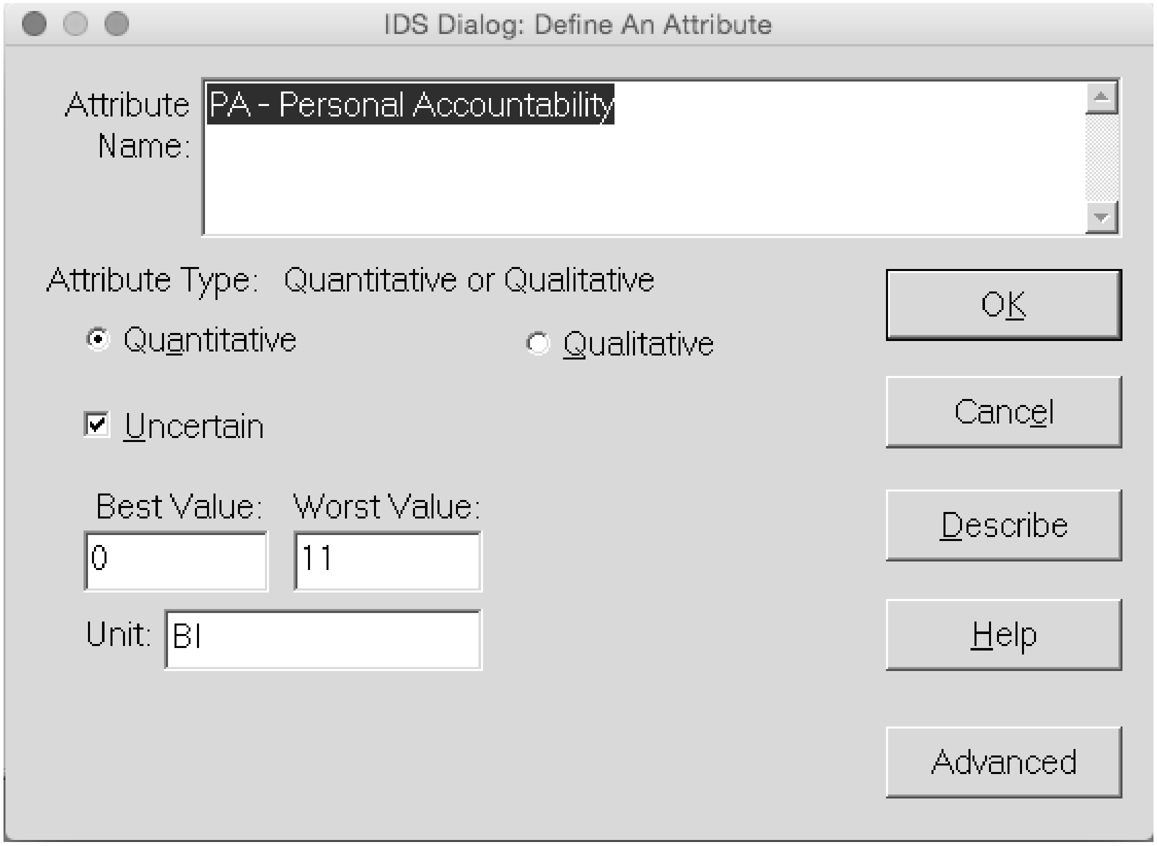


Figure 27. Programming Uncertainty in IDS ER (Step 1)

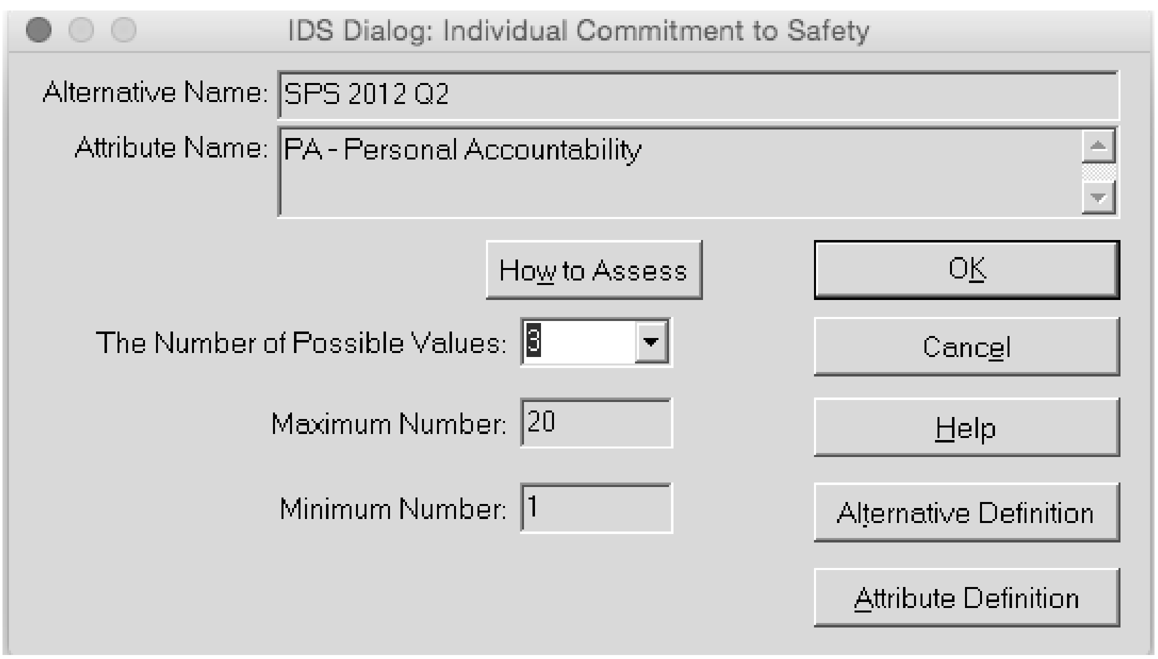


Figure 28. Programming Uncertainty in IDS ER (Step 2)

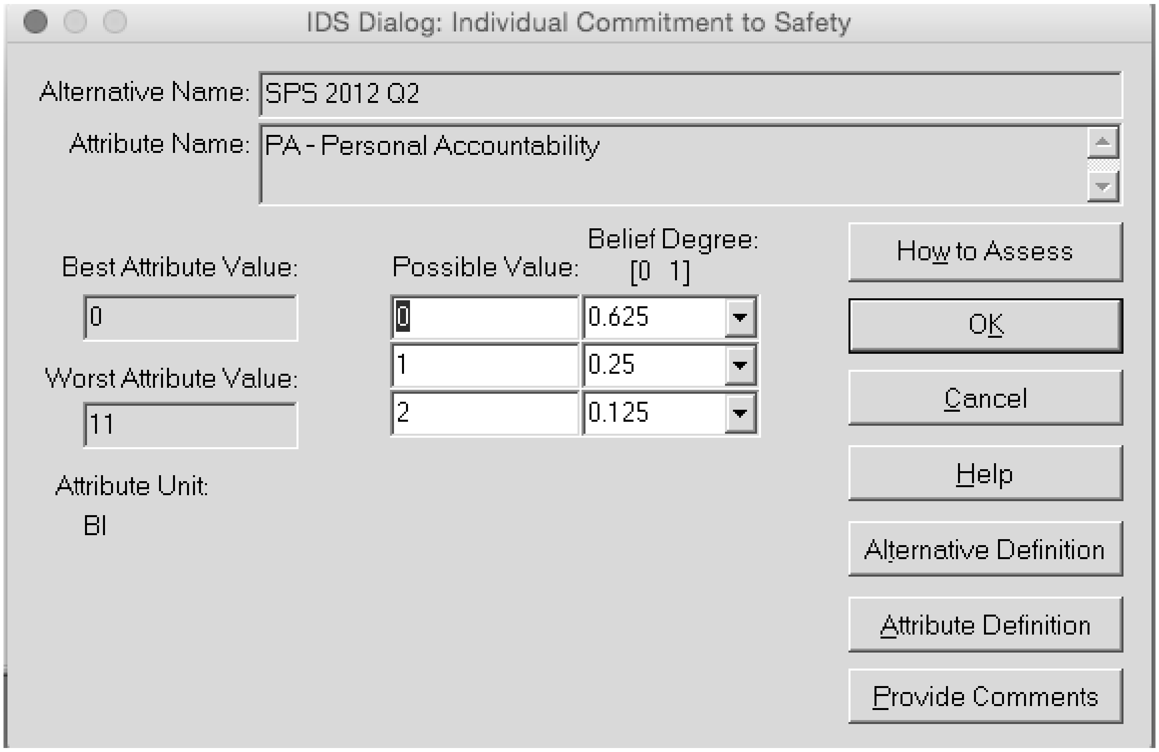


Figure 29. Programming Uncertainty in IDS ER (Step 3)

Utilities for the Level 1 or overall attribute (NSC Performance) were assigned to these grades (from a linguistic set of Absent Integration of NSC into Operations, Minimal Integration of NSC into Operations, Average Integration of NSC into Operations, Significant Integration of NSC into Operations, and Complete Integration of NSC into Operations) as shown in Table 3. The utilities were chosen arbitrarily, but during future research, how to assess and incorporate the utilities of those providing inputs for the ER model could be explored. These values could easily be revised in future iterations of the model. For the purposes of this dissertation, Complete Integration of NSC into Operations would be ideal and thus would receive a Utility of 1. The remaining grades were ranked accordingly with utilities juxtaposed to probabilities not necessarily summing to 1.

Table 3. Grades and Utilities

Grade	Utility [0,1]
Absent Integration of NSC into Operations	0
Minimal Integration of NSC into Operations	.25
Average Integration of NSC into Operations	.5
Significant Integration of NSC into Operations	.75
Complete Integration of NSC into Operations	1

To relate father and child attributes, the following belief degrees were used for each child (PA, QA, CO, LA, DM, WE, CL, PI, RC, WP). These values could also be adjusted easily in future iterations of the model. For example, future research could conduct a survey for each of the respective child attributes (PA, QA, CO, LA, DM, WE, CL, PI, RC, WP) with the results entered as belief degrees father grade of Absent, Minimal, Average, Significant or Complete. However, in the interest of keeping this model simple, belief degrees were assigned at this level (i.e., for the Level 3 child to Level 2 father attributes) using the identity matrix **(**Table **4**). The belief degrees that relate these father and child grades are not the same belief degrees that were selected by respondents during data collection via survey when they chose the grade (i.e., Absent, Minimal, Average, Significant or Complete) they deemed appropriate for the Level 2 child to Level 1 father attributes.

Table 4. Belief Degrees for Relating Father and Child Grades

Father Grade/ Child Grade	Absent	Minimal	Average	Significant	Complete
Absent	1	0	0	0	0
Minimal	0	1	0	0	0
Average	0	0	1	0	0
Significant	0	0	0	1	0
Complete	0	0	0	0	1

Weights are then used to relate the child attributes to the father attribute. This can be done using visual scoring or using a pairwise comparison of attributes. Again, future versions of the model could work with respondents or subject matter experts to complete the pairwise comparison approach provided with the IDS software, which is basically an AHP approach for weighting the child attributes. However, for this study the visual scoring approach was utilized with **normalized** selected to ensure the weights added to 1, and the weights as equal (i.e., .33, .33 and .33) (Figure 30).

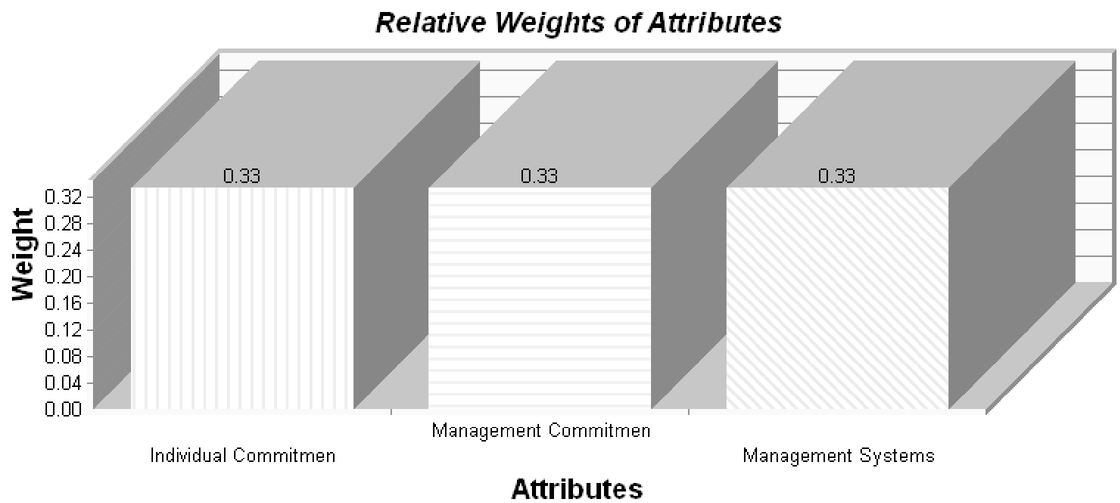


Figure 30. Attribute Weights Using Visual Scoring

Using the binned process inputs for the last three rolling years (PA, QA, CO, LA, DM, WE, CL, PI, RC, WP) (Appendix D Table 5), the IDS model can now rank the twelve Alternatives (Quarterly NSC Performance) based on the attributes, grades, and associated utilities, belief degrees, and weights. The user can select Report > Graph Ranking within IDS to obtain the overall ranking of alternatives on NSC Performance, the level 1 father attribute (Figure 31). The user can also select **Report > Visual Comparison** to see further breakdowns of the first five alternatives across the level 1 father attribute and its three child attributes (Figure 32).

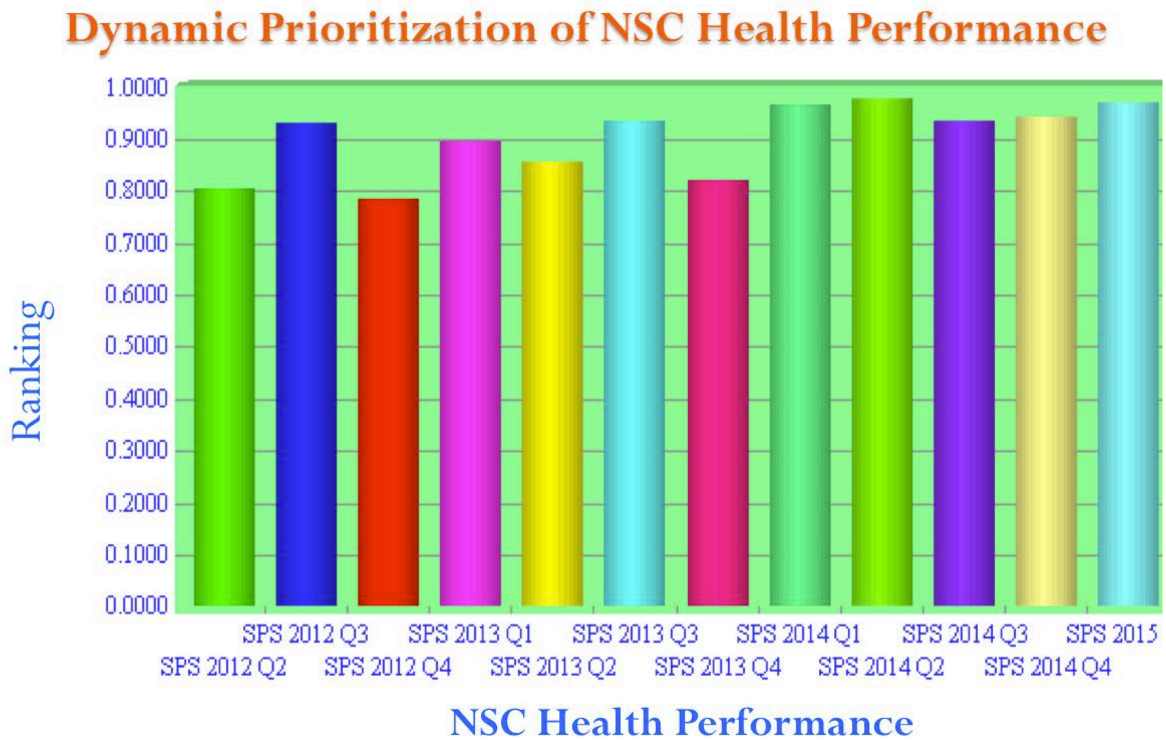


Figure 31. Dynamic Prioritization of NSC Health Performance

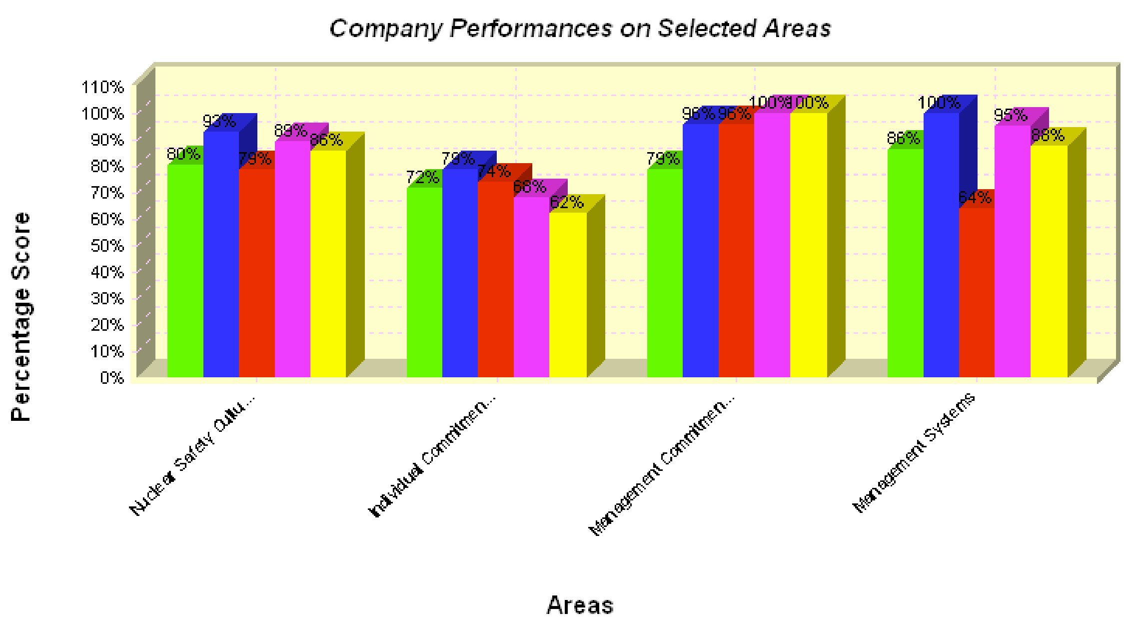


Figure 32. Alternative Performances Across Child Attributes

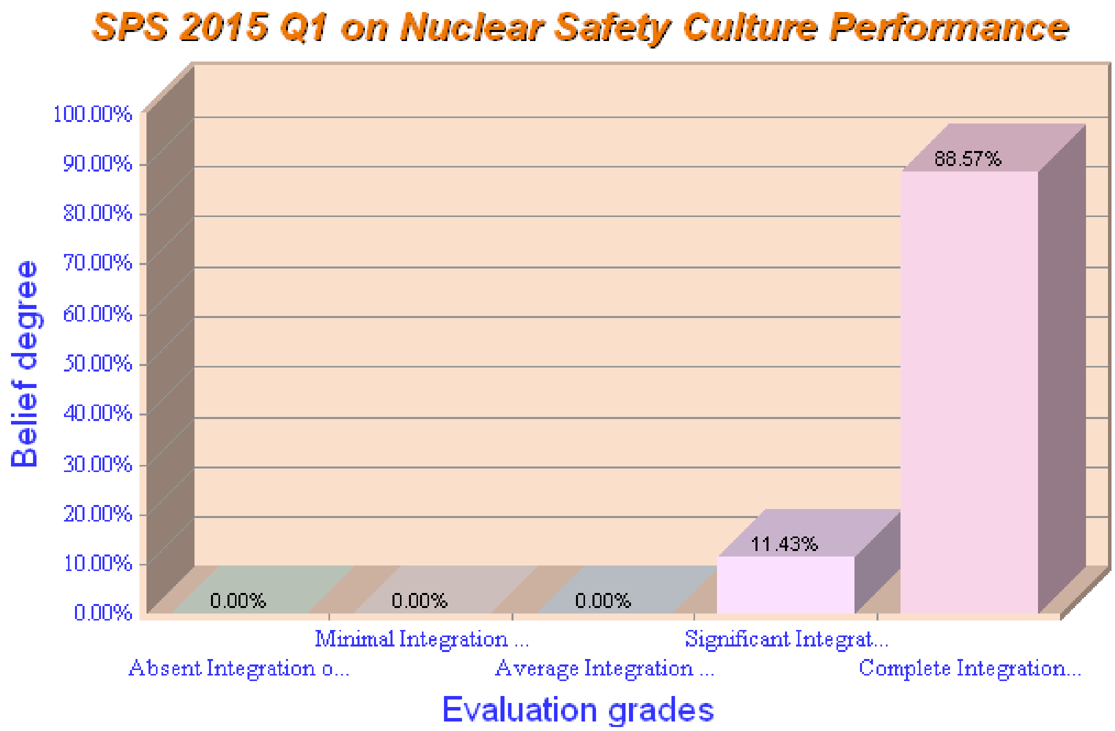


Figure 33. SPS 2015 Q1 on Nuclear Safety Culture Performance

Figure 33 can be obtained by highlighting the alternative of interest, then selecting **Report > Graph Belief Degree > Att at Alt**, where the last selection means, "Attribute at Alternative". That is, whichever combination of attribute and alternative are highlighted at the time this report is run will be used to create the chart. This chart shows the breakdown of grades for SPS 2015 Q1 NSC Performance (with the lowest overall risk in the model for which degrees of belief was weighted lower than the other attributes) at the father attribute level (NSC Performance). This gives an overall distribution of the calculated grades and belief degrees for NSC Performance (level 1 attribute), based on the grades and belief degrees for the level 2 child attributes (Individual Commitment to Safety, Management Commitment to Safety and Management Systems). The individual level 2 attributes can also create similar charts to explore belief degrees using level 3 child attributes (PA, QA, CO, LA, DM, WE, CL, PI, RC, WP).

Another informative chart that is available in IDS is the radar plot. By plotting the values of all of the child attributes, alongside the father attribute, it is easy to see which of the child attributes might be driving the overall NSC Performance score. In IDS, users can select **Report > Visual Comparison**, then select the **Tool Bar** button to obtain a menu of options. One of the options is an icon displaying the type of chart selected, and by selecting it; users see a drop-down list of chart types, including the radar plot. The default view of this chart is three-dimensional, however, clicking the icon that looks like a set of three-dimensional glasses will recalibrate the view to two dimensions. Because we are exploring twelve alternatives, it may be difficult to compare them all on the same radar plot. However, by highlighting alternatives and using the **Select One**, **Select Group**, **Select All**, **Deselect**, and **Draw** buttons we are able to explore alternatives individually (Figure 34, Figure 35, Figure 36).

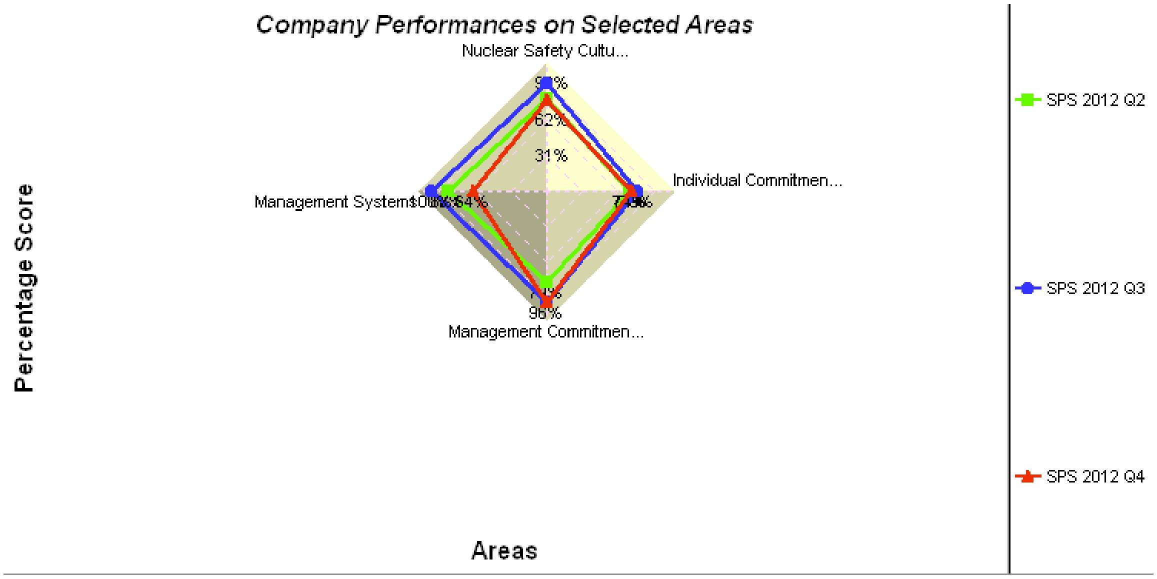


Figure 34. Example NSC Health Performance and Categories Radar Plot

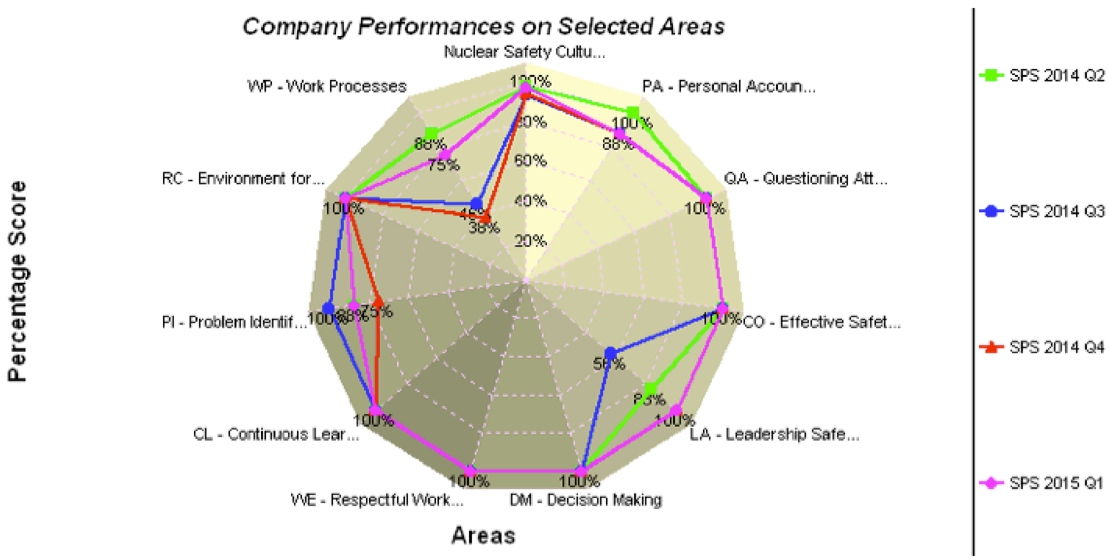


Figure 35. Example NSC Health Performance and Traits Radar Plot 4 Qtr's

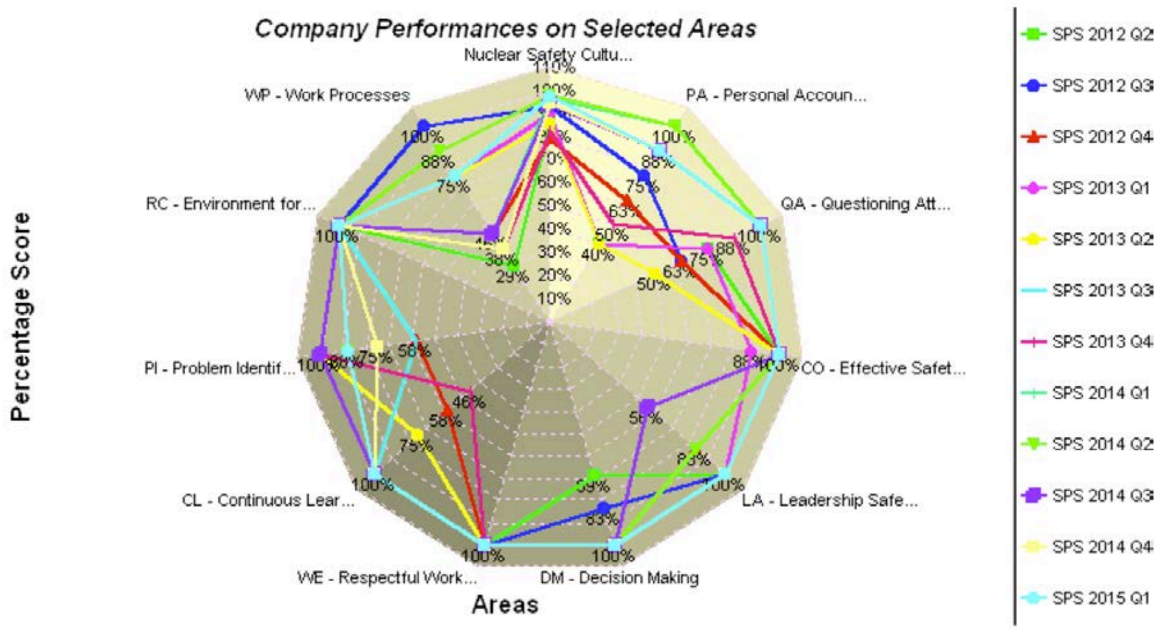


Figure 36. Example NSC Health Performance and Traits Radar Plot 12 Qtr's

Sensitivity Analysis

IDS offers built-in sensitivity analyses. Figure 37 displays a trade-off analysis chart, found under **Sensitivity > Trade-Off Analysis**, which shows the overall NSC Performance for the twelve alternatives compared with Individual Commitment to Safety.

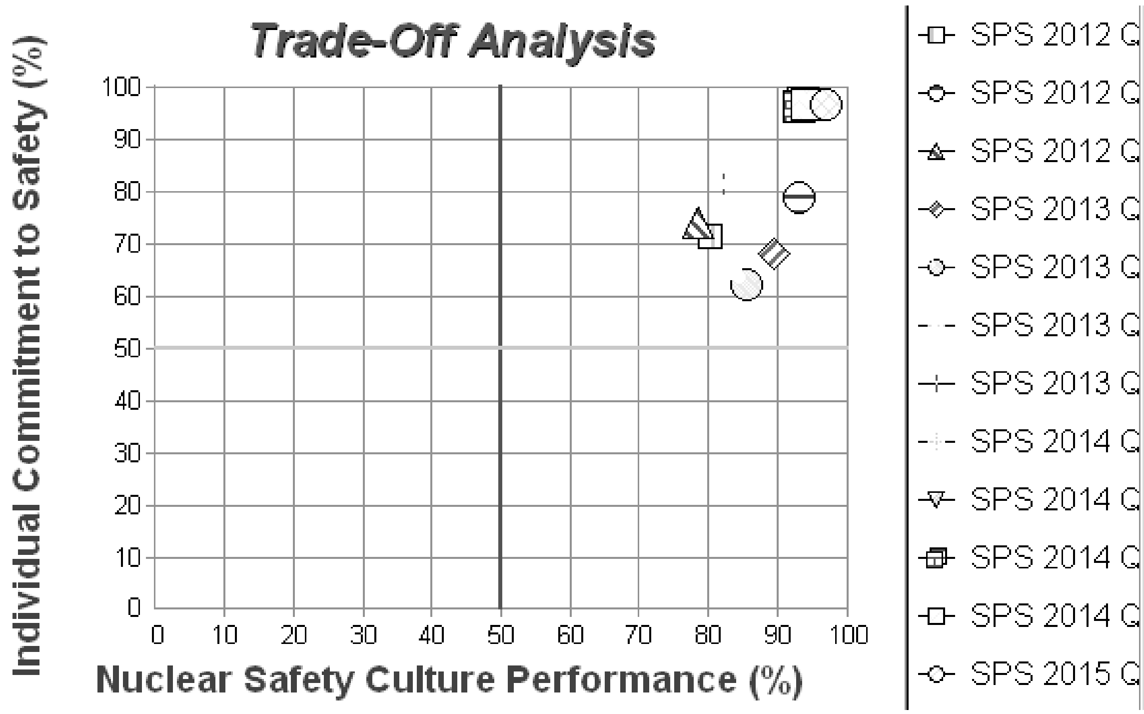


Figure 37. Individual Commitment to Safety and NSC Perf. Trade-Off Analysis

Figure 38 displays overall NSC Performance for the twelve alternatives compared with Management Commitment to Safety.

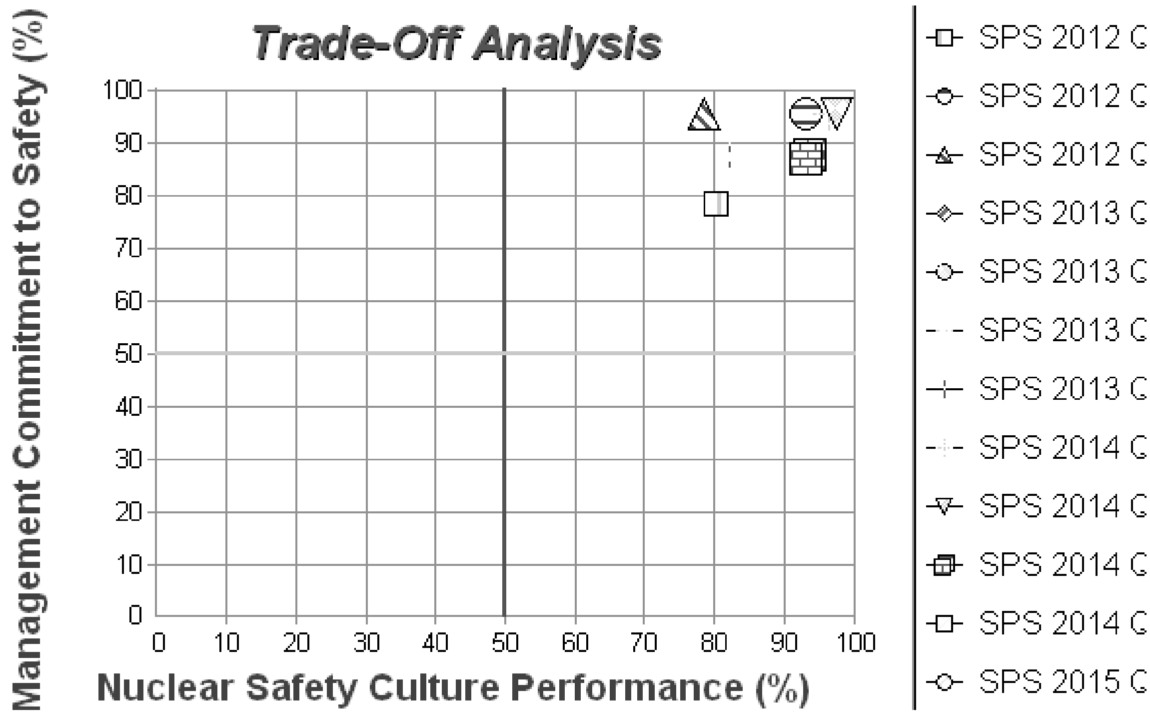


Figure 38. Management Commitment to Safety and NSC Perf. Trade-Off Analysis

Figure 39 displays overall NSC Performance for the twelve alternatives compared with Management Systems.

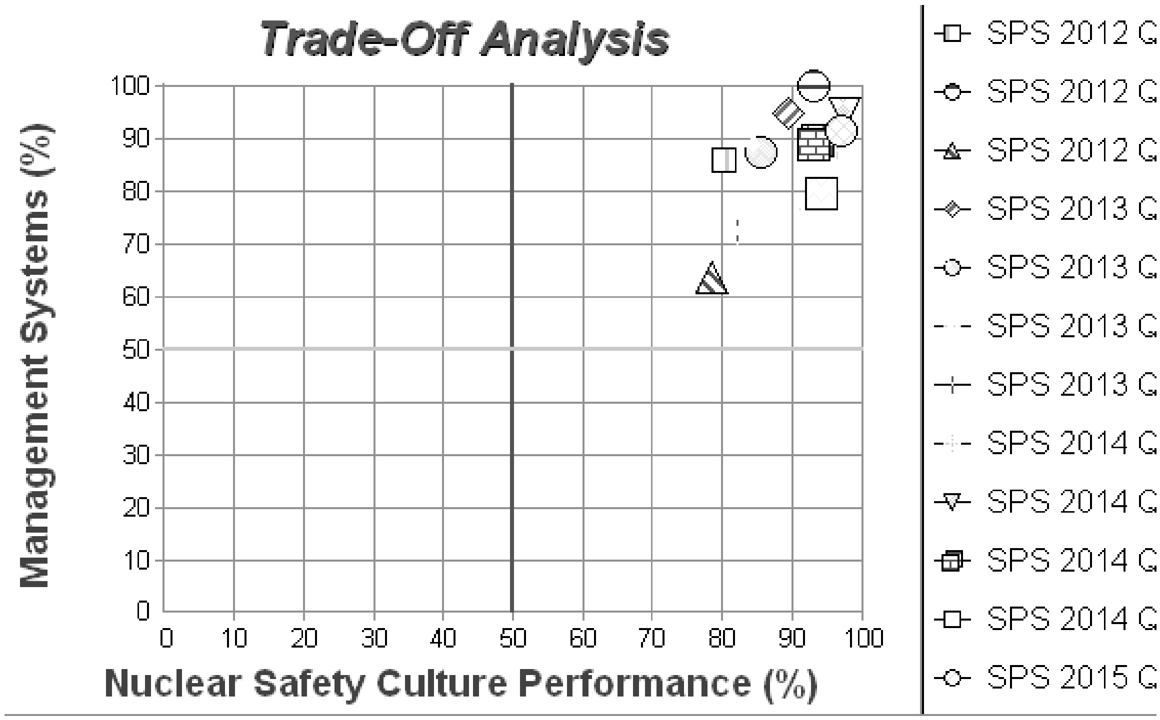


Figure 39. Management Systems and NSC Performance Trade-Off Analysis

IDS can produce sensitivity analyses based on the weighting of individual attributes, which look at the overall father attribute ranking, or the rank change, of alternatives. Users can select the attribute for which they wish to perform sensitivity analyses (e.g., Individual Commitment to Safety), then click **Sensitivity** > **Change Weight**. This brings up a dialog box where the user can select which alternatives to explore (e.g., SPS 2012 Q2 through Q4). Initially presented are the weights originally input for the model as shown in Figure 40. By selecting **Ranking**, users can manually adjust the weights of the child attributes to see how that affects the overall ranking of alternatives. Weights do not remain normalized automatically; consequently, weights for the child attributes were selected that summed to 1 (Figure 41). Adjusting the weights of the child attributes, we can see how that affects the overall risk scores for the father attribute across each of the alternatives.

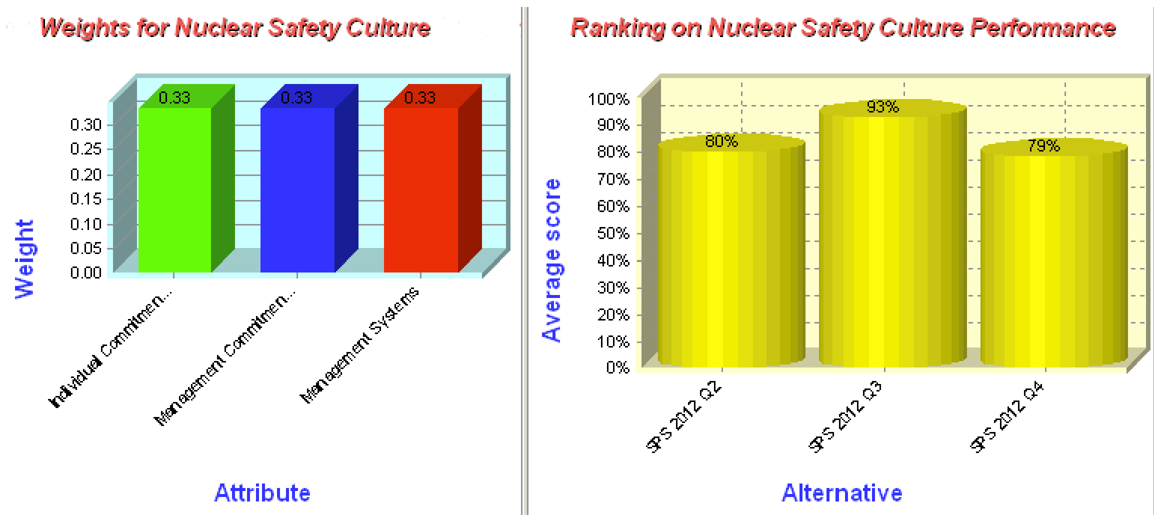


Figure 40. Child Attributes on Ranking (Original)

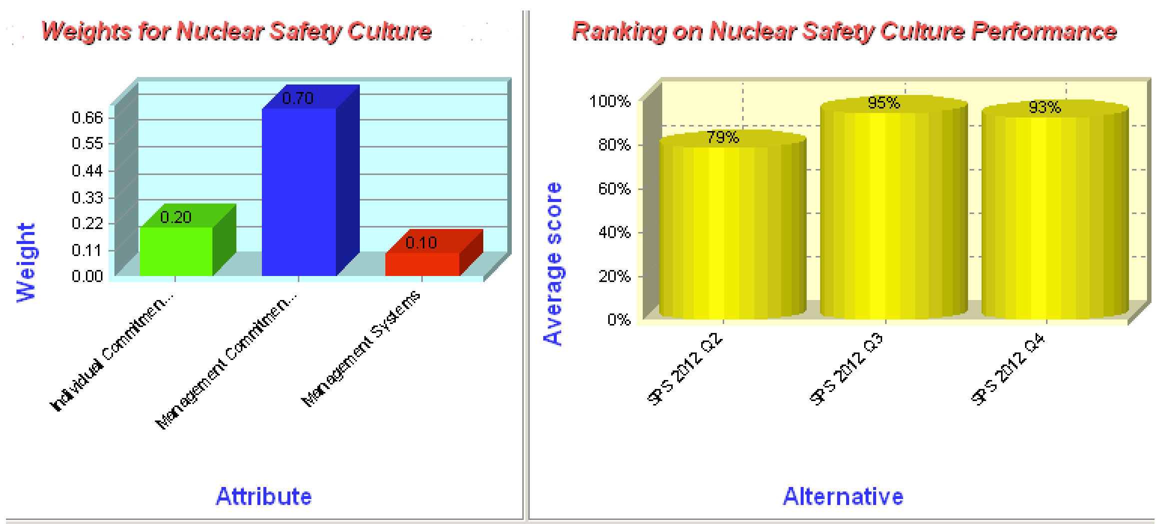


Figure 41. Child Attributes on Ranking (Manually Adjusted)

Alternately, by selecting **Rank Change**, we can produce a more controlled sensitivity analysis on individual child attributes. The graphic given in Figure 42 displays the overall NSC Performance scores for the first three alternatives as the weight of the Individual Commitment to Safety attribute is varied from 0 through 1. It is interesting to note that the overall score for each alternative varies with the weight of the Individual Commitment to Safety attribute, but it is not a linear relationship. All of the selected alternatives increase as the weight of Individual commitment to safety increases.

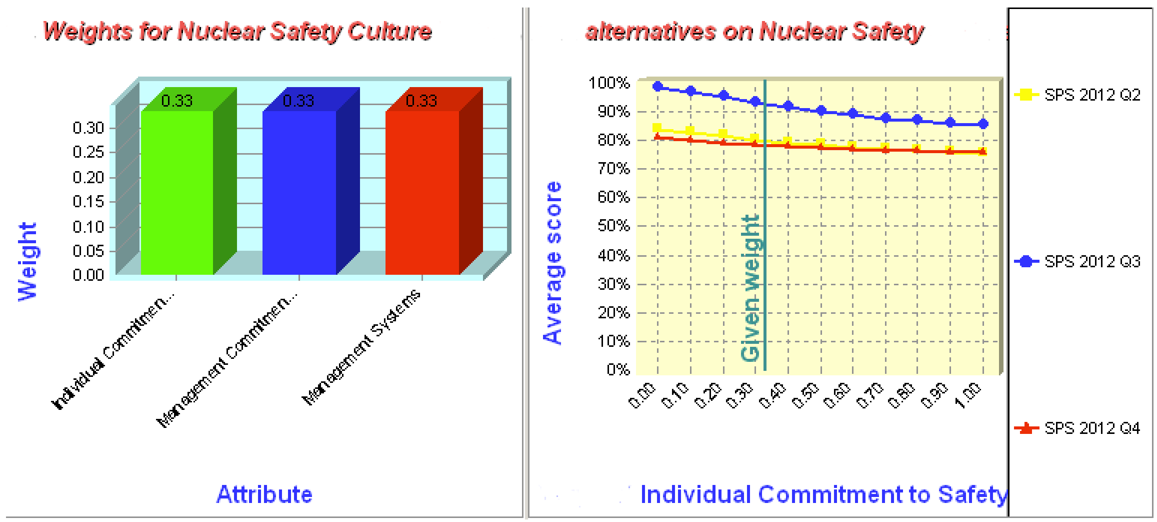


Figure 42. Sensitivity Analysis of Individual Commitment to Safety

The graphic given in Figure 43 displays the overall NSC Performance scores for the first three alternatives as the weight of the Management Commitment to safety attribute is varied from 0 through 1. It is interesting to note that the overall score for the majority of the alternatives vary with the weight of the Management Commitment to Safety attribute, but it is not a linear relationship. Furthermore, while the majority of the NSC Performance scores increase as the weight of Management Commitment to safety increases, SPS 2012 Q2 does not change.

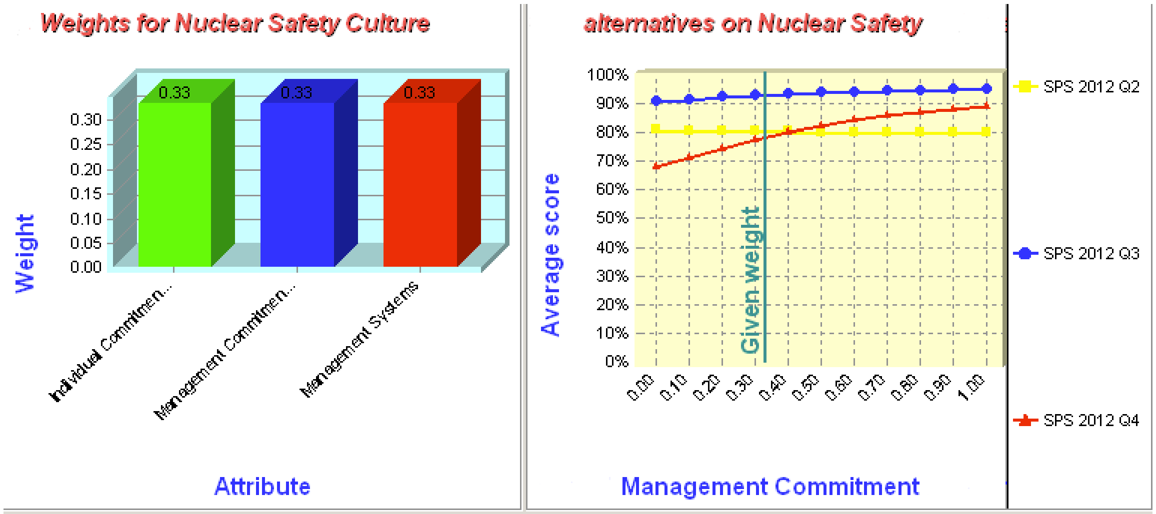


Figure 43. Sensitivity Analysis of Management Commitment to Safety

The graphic given in Figure 44 displays the overall NSC Performance scores for the first three alternatives as the weight of the Management Systems attribute is varied from 0 through 1. It is interesting to note that the overall score for the first three alternatives vary with the weight of the Management Systems attribute, but it is not a linear relationship. Furthermore, while the majority of the NSC Performance scores increase as the weight of Management Commitment to safety increases, SPS 2012 Q4 demonstrates a negative correlation.

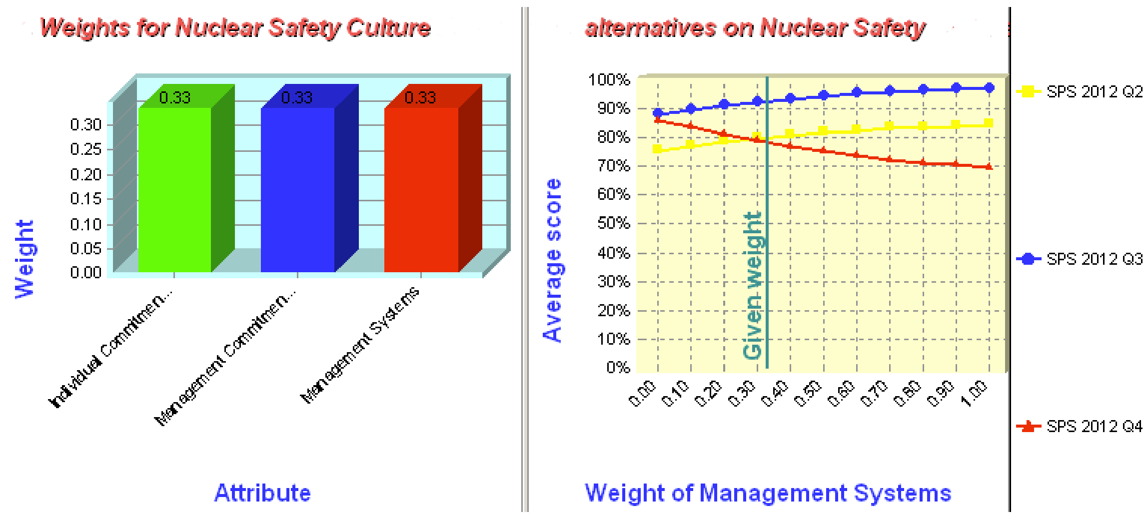


Figure 44. Sensitivity Analysis of Management Systems

IDS can also produce sensitivity analyses of belief degrees based on adjusting the child attribute weights. From the same dialog box, the user simply selects **Belief Degree**.

This shows the belief degrees for the degrees of belief attribute related to the grades (our linguistic set) based on the weights input for the child attributes (PA, QA, CO, LA, DM, WE, CL, PI, RC, WP). Notice as the child attributes are adjusted up and down the belief degree values of the father attributes change proportionally (Figure 45, Figure 46). Future research could be conducted to better understand if the weighting of the child attributes should be adjusted.

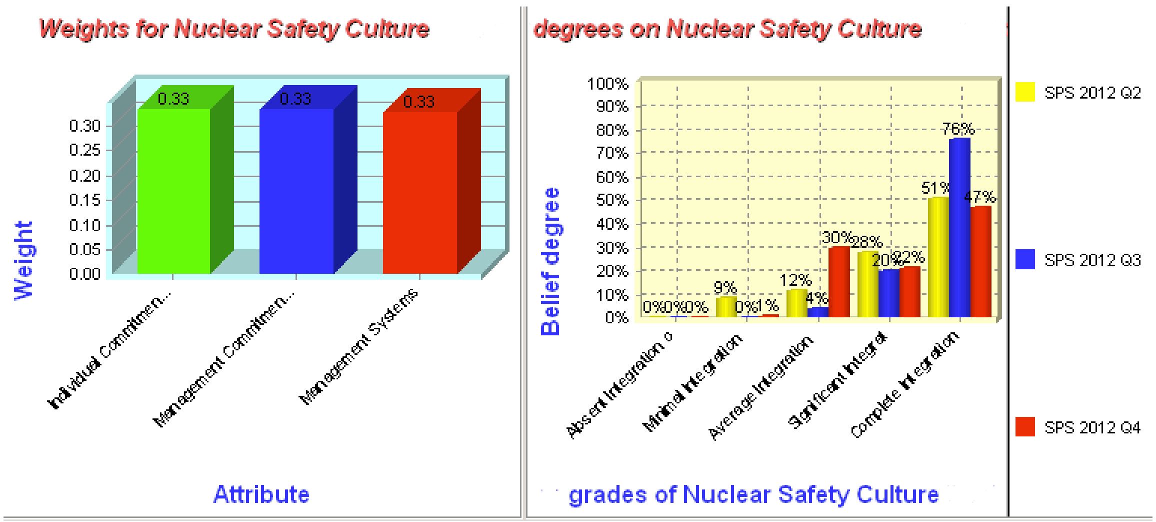


Figure 45. Child Attributes on Belief Degrees (Original)

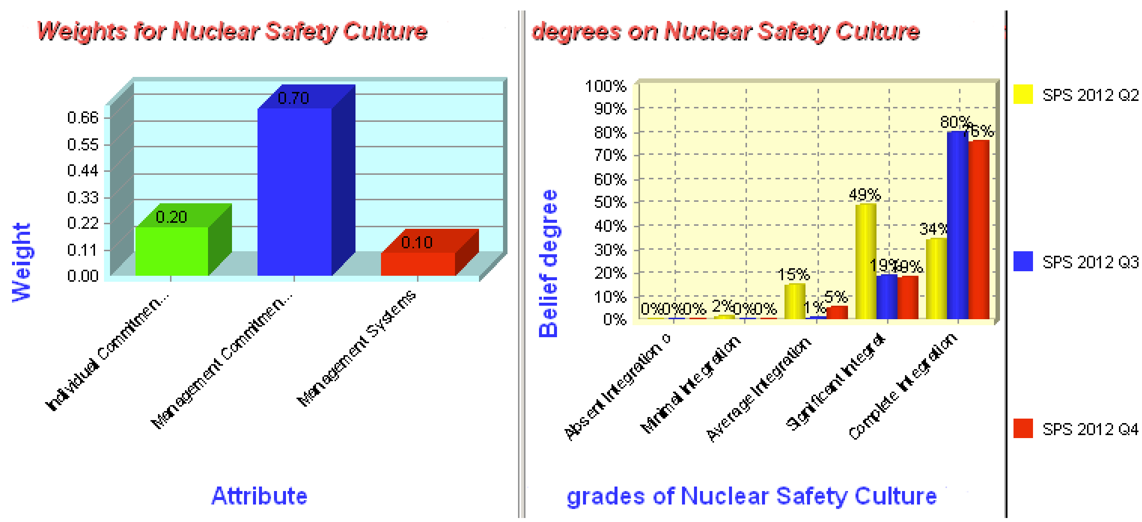


Figure 46. Child Attributes on Belief Degrees (Manually Adjusted)

IDS can also produce sensitivity analyses based on the data, itself. Users can select **Sensitivity > Change Input Data**, which brings up a dialog box that produces two side-by-side graphs (Figure 47). The first graph displays the Process Input or Score for each grade (from the SPS data) for a selected alternative. SPS 2012 Q2 was selected, which received the lowest number of binned process inputs (lower being worse).

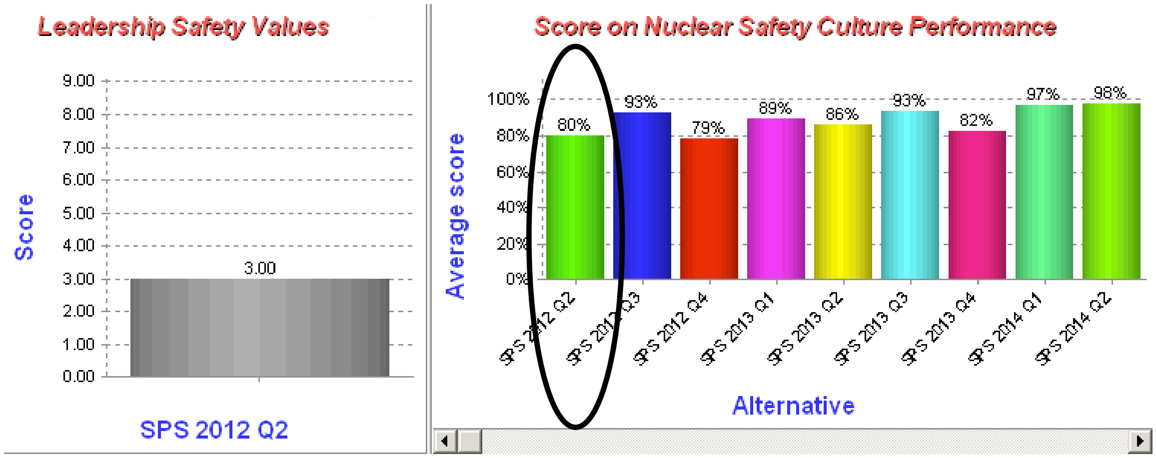


Figure 47. Input Data (Original)

The second graph displays the Process Input Score for SPS 2012 Q2 adjusted down and its affect upon the NSC Performance for the respective time period. Other alternatives (i.e., SPS process input data for a selected time period) or any of the other attributes (i.e., PA, QA, CO, LA, DM, WE, CL, PI, RC, WP) can also be explored as desired. Although we did not drastically alter the score from the original value, we still see a marked change in the overall NSC Performance score 2012 Q2, which increased from 80% to 85% (Figure 48).

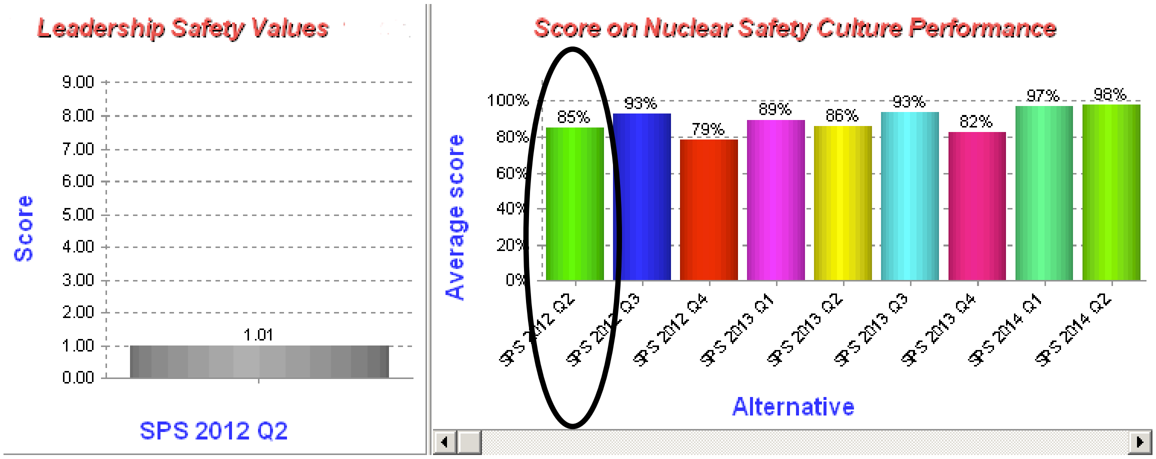


Figure 48. Input Data (Adjusted)

Verification, Validation, and Accreditation

In addition to the data that were collected from the process input binning and belief degrees survey there are also data required for the MCDA model selected. For example, the IDS software used to implement ER requires values such as weights, utilities, and belief degrees in order to describe the model. These values have nothing to do with the actual assessment data, but rather are used to define the way in which the assessment data will be integrated using the MCDA model. While future research may expand on the in NSC Performance methodology to include approaches for determining these values, we have assigned these values as necessary in order to complete the testing of the NSC Performance methodology. Sensitivity analyses were conducted to determine the impact of some of these selected values on the ER model. Further, a preliminary verification and validation of the assessment integration model selected for the NSC Performance methodology was also performed and is presented in the following paragraphs. However, a more thorough Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A) will be necessary in the future.

M&S VV&A is crucial to the development and deployment of a model or simulation, especially if it is to be accepted and employed by stakeholders for decision-making with respect to NSC performance (Macal, 2005). For example, the Department of Defense released instructions for VV&A of M&S (Department of Defense [DoD], 2009) and many other agencies have developed their own standards.

The DoD official definitions of M&S and VV&A are provided in Figure 49 (DoD, 2009).

Model	a physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process.
Simulation	a method for implementing a model over time.
Verification	the process of determining that a model or simulation implementation and its associated data accurately accurately represent the developer's conceptual description and specifications.
Validation	the process of determining the degree to which the model or simulation and its associated data are an accurate representation of the real world from the perspective of the intended uses.
Accreditation	the official certification that a model or simulation and its associated data are acceptable to use for a specific purpose.

Figure 49. DoD Verification, Validation, and Accreditation Definitions

NSC Performance Model Verification

Verification ensures that a model or simulation is programmed and implemented correctly. That is, the model should be free from errors, bugs, accidental omissions, misapplications of the model, misapplications of the software, and invalid implementations of any algorithms (Macal, 2005). Verification is the process of determining whether a model is consistent from concept to requirements, including a review of the model's capabilities and the specifications associated with each capability. It is important to understand that no model can ever be completely verified, so the result of model verification is not a verified model, but rather a model that has passed all verification tests. For the purposes of the NSC Performance Model, verifying the model relies upon verifying the NSC Performance assessment integration method selected for the third phase of this methodology, so ideally we would verify the ER model deployed using IDS. Therefore, the verification plan addresses the following three questions (Figure 50.

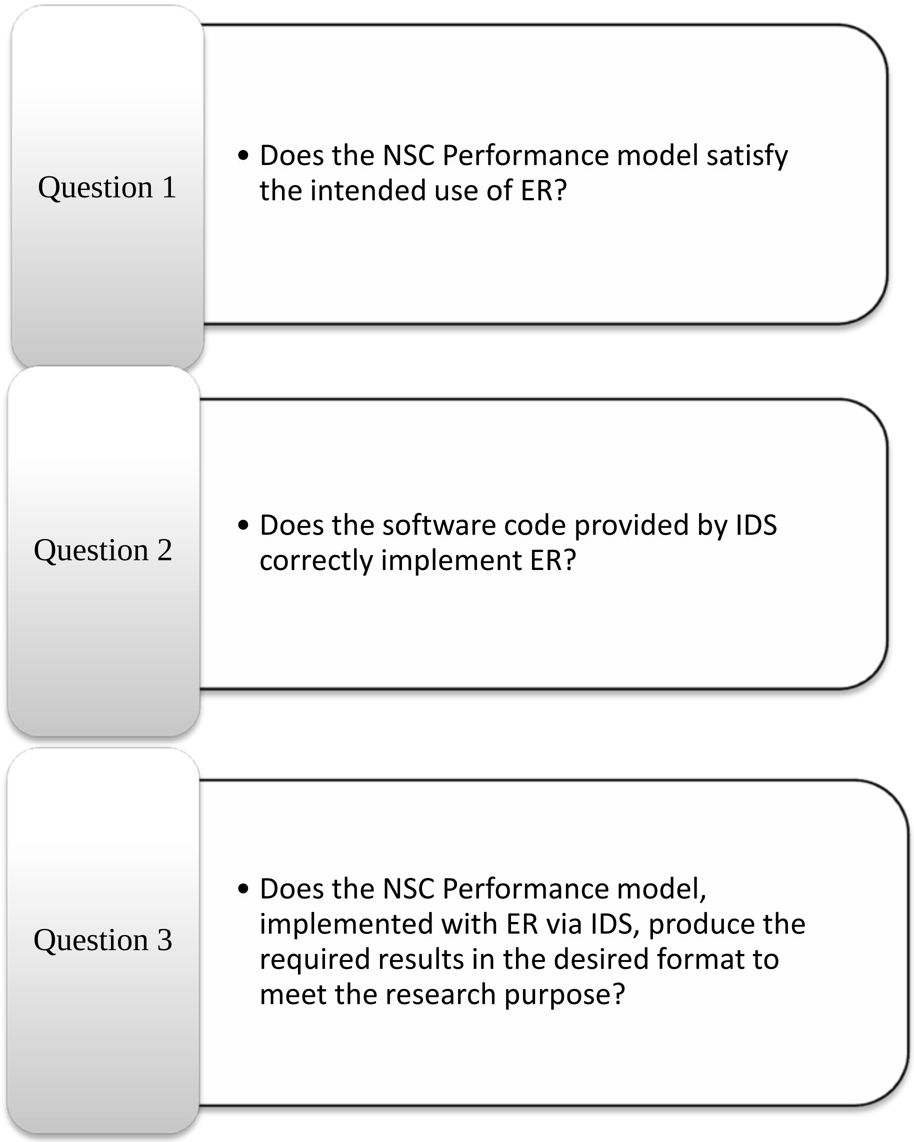


Figure 50. Model Verification Questions

Question 1

Does the NSC Performance model satisfy the intended use of ER?

In an effort to accommodate MCDA problems prone to uncertainties and subjectivity, ER was devised, developed, and implemented via IDS by Yang, along with his collaborators (Xu & Yang, 2001). ER and IDS are now used in many areas, such as supply chain management, design decision support, risk and safety analysis, quality management, and government policy consultations (Xu et al., 2005). ER uses a set of attributes, weights, utilities, and belief degrees to assess and rank a series of alternatives. This approach lends itself nicely to the complex problem of NSC Performance in an operating nuclear power station which consists of a number of attributes (PA, QA, CO, LA, DM, WE, CL, PI, RC, WP), and also offers a series of alternatives in need of ranking (Quarterly Process Input binning). ER is used to support decision analyses, assessments, or evaluation activities. The NSC Performance Model would also be used to support decision-making, specifically for corrective or preventive measures for degrading NSC Performance indication. Consequently, the challenge of ranking NSC Performance based on a set of attributes (PA, QA, CO, LA, DM, WE, CL, PI, RC, WP) is certainly an appropriate application of ER.

Question 2

Does the software code provided by IDS correctly implement ER?

Many MCDA problems inevitably deal with information under uncertainty, and that is especially true when dealing with Safety Cultures with their tangible and intangible inputs. ER provides an alternative way of handling such information systematically and consistently. ER is a powerful MCDA approach based on a recursive algorithm that essentially aggregates information nonlinearly. ER has been compared to other MCDA approaches, such as MAUT, Saaty's left eigenvector method, Belton's normalized left eigenvector procedure, and Johnson's right eigenvector procedure (J.-B. Yang, 1999). The results of those comparisons produced comparable rankings of alternatives. IDS has also been compared to AHP, and while both use a hierarchical structure to model MCDA problems, there are some distinctions (Xu & Yang, 2001). For example, ER alternatives are not part of the hierarchy like they are in AHP. AHP uses a decision matrix whereas ER uses a generalized decision matrix that incorporates belief degrees (which are not employed in AHP); also, AHP uses average scores from pairwise comparisons to aggregate data, but ER aggregates the belief degrees in a progressive manner from lower level attributes to high level attributes. Because of these distinctions, IDS (the software implementation of ER) can: manage large and complex MCDA problems; assess new alternatives independently; produce consistent rakings of alternatives even after new ones are added; create a distributed assessment of alternatives in addition to a ranking of those alternatives; assess an alternative against standards or criteria (AHP can only compare the relative importance of alternatives between attributes); handle mixed data models (with both qualitative and quantitative data, as well as random and deterministic data, under uncertainty); and lastly, IDS can optionally utilize AHP as one of its weighting approaches for attributes (Xu & Yang, 2001).

The detailed problem description, basic evaluation framework, algorithms, axioms, and theorems utilized by ER have been presented in detail (J.-B. Yang & Xu, 2002) and demonstrate that the ER approach and IDS have sound theoretical foundations. ER has undergone mathematical proofs (J.-B. Yang, 1999) and the mechanics of ER along with the results of ER deployed via IDS have been presented in a number of peer-reviewed journals and conferences (Sonmez, Yang, & Holt, 2001; Wang, Yang, & Sen, 1996; Xu, 2004; Xu & Yang, 1999, 2003, 2005; Xu, Yang, & Wang, 2005; J.-B. Yang, 1999; J.-B. Yang & Xu, 2002, 2004; J. B. Yang, Dale, & Siow, 2001). Furthermore, there is an example for which ER, using IDS, was used in the fields of corporate quality management to produce a European Foundation for Quality Management (EFQM) self assessment (Siow, Yang, & Dale, 2001). This example offers a degree of face validity for the methodology, the model, as well as the software code, all of which translates to our research as the NSC Performance Methodology leverages IDS to implement an integrated safety culture health assessment based on the binned process inputs and degrees of belief used to rank the NSC health alternatives, which is a valid application of ER. Furthermore, as evidenced by the sensitivity analyses provided earlier, as well as the model validations that will be provided in the next section, it has been demonstrated that the model behaves logically, which implies that the software code is free from mathematical errors.

Question 3

Does the NSC Performance model, implemented with ER via IDS, produce the required results in the desired format to meet the research purpose?

The research purpose requires that the output of the NSC Performance model provide a ranked assessment of NSC Health (Figure 3). ER is an MCDA approach, which, like other MCDA approaches such as AHP, produces a ranked list of alternatives as its output. The IDS software implementation of ER thus also produces a ranked list of alternatives. The SPS Process Input Binning Data was designated as alternatives in the NSC Performance model. The Traits of a Healthy NSC were designated as attributes in the model, and assigned NSC Performance as the overall father attribute. The model has been provided with sufficient information (including attribute weights, utilities, and belief degrees) to relate father and child attributes, as well as to relate our data (from the process input binning and degrees of belief survey) to the attributes and alternatives. The output of our model is, indeed, a ranked list of NSC Performance based on an integrated NSC health assessment and thus adequately meets the needs of this research.

NSC Performance Model Validation

Validation ensures that the model is useful (Macal, 2005). That is, the model should address the correct problem and provide accurate information about the system or phenomenon being modeled. Validation could also consist of a series of challenges designed to purposefully address any doubts about the application of the model, in which case, similar to verification, the results of validation do not necessarily produce a validated model, but rather a model that has passed all validation tests (or perhaps a model that has failed some tests, but may be able to pass them in the future after additional model improvements have been made). Validation of complex models involves demonstrating that the model has the appropriate underlying relationships to permit an acceptable representation of the real world. The validation plan addresses the following three questions (Figure 51).

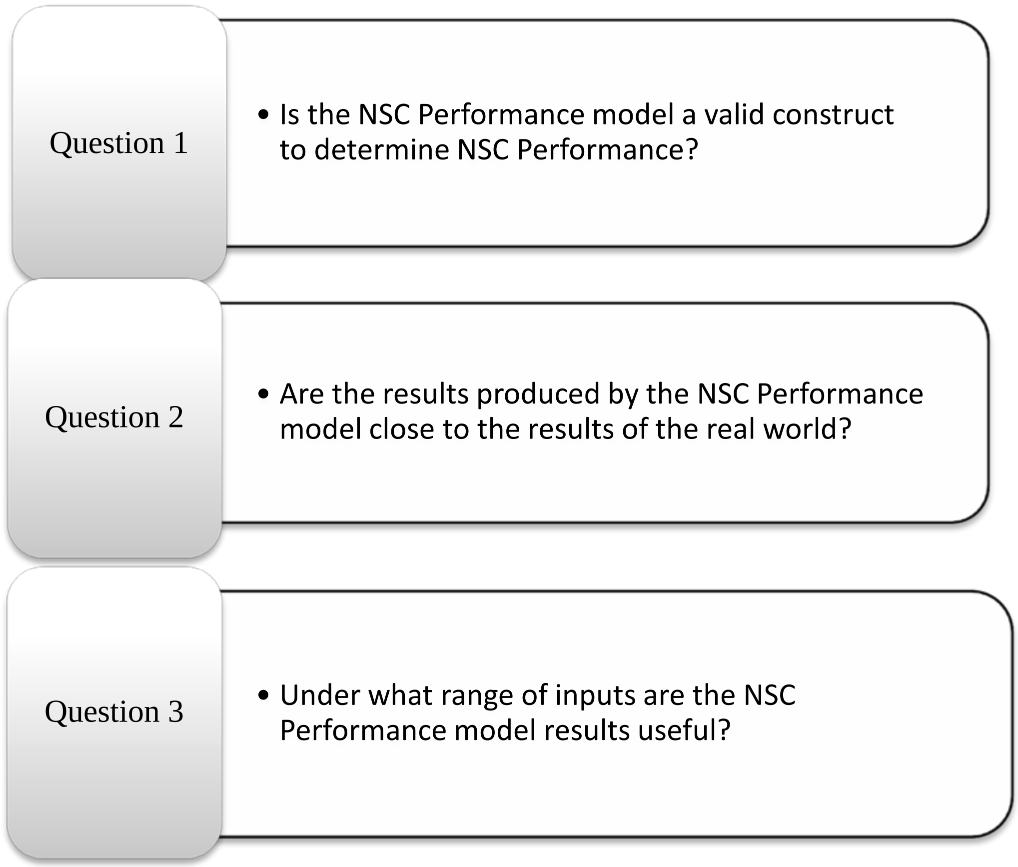


Figure 51. Model Validation Questions

Question 1

Is the NSC Performance model a valid construct to determine NSC Performance?

Typically, validation requires that a newly proposed model be compared to some existing reference model. However, no such model for NSC Performance was located during the extensive literature review. Consequently, we will instead explore whether the model constructed for NSC Performance is understandable with reasonable results. This validation depends on the purpose of the model and its intended use, so it is valuable to understand why we are using a model in the first place. In the case of the NSC

Performance model, we are modeling NSC health as a function of the traits of a healthy NSC, in order to make qualitative or quantitative predictions about the future. That is, to quantify a NSC's health performance based on the integrated performance assessment value (produced by the NSC Performance model). In addition, the model is also used to gain insight into how degrees of belief affect the ranking of NSC performance. The NSC Performance model uses ER that allows us to explore all ten traits or attributes of NSC performance (PA, QA, CO, LA, DM, WE, CL, PI, RC, WP), as well as to explore how those attributes interact, depending on the weights, utilities, and belief degrees supplied for the model. The presently utilized NEI NSC model utilizes these same attributes. The introduction of degrees of belief is now obvious after conducting this research, so the NSC Performance model appears to be a valid construct.

Face validation is another technique for validating a model or simulation. Essentially, face validation determines whether a model or simulation appears to measure a certain criterion. It is often conducted via peer reviews accompanied by surveys or interviews to seek the opinions of subject matter experts regarding the model or simulation. ER and IDS have undergone extensive face validation by presenting the methodology, mathematics, and software implementation in numerous peer-reviewed journals and conference proceedings (Huynh et al., 2006; Wang, Yang, & Sen, 1996; Yang, Dale, & Slow, 2010. Therefore, any model, which correctly implements ER and IDS, can claim some level of transitive face validation.

Question 2

Are the results produced by the NSC Performance model close to the results of the real world?

In addition, comparing model predictions to historical data via benchmarking and sensitivity analysis can also validate new models. For example, the maritime security assessment that leverages ER and IDS validates its model with benchmarking and sensitivity analysis (Yang, Wang, Bonsall, & Fang, 2009). Sensitivity analyses of the NSC Performance model has been successfully conducted as stated previously in this chapter. A benchmarking study was conducted by obtaining the subjective grading from the existing process input binning from the Safety Culture Review Team (SCRT). These results were then compared to the results achieved with the new model (our NSC Performance model), based on the same data. The resulting grading from the SCRT and the NSC Performance model were found to have fidelity with one another.

Question 3

Under what range of inputs are the NSC Performance model results useful?

A sensitivity analysis to explore different input settings of the NSC Performance model has already been performed. The NSC Performance model has been compared to the current SCRT process with fidelity. Consequently, a better understanding of the effects of weights for the degrees of belief attribute on the overall father attribute of NSC Performance has been gained. The sensitivity of the belief degrees to the selected weights has been determined. How changing the input data impacts the degrees of belief score has been explored. Nevertheless, additional sensitivity analysis can be conducted to further validate the NSC Performance model.

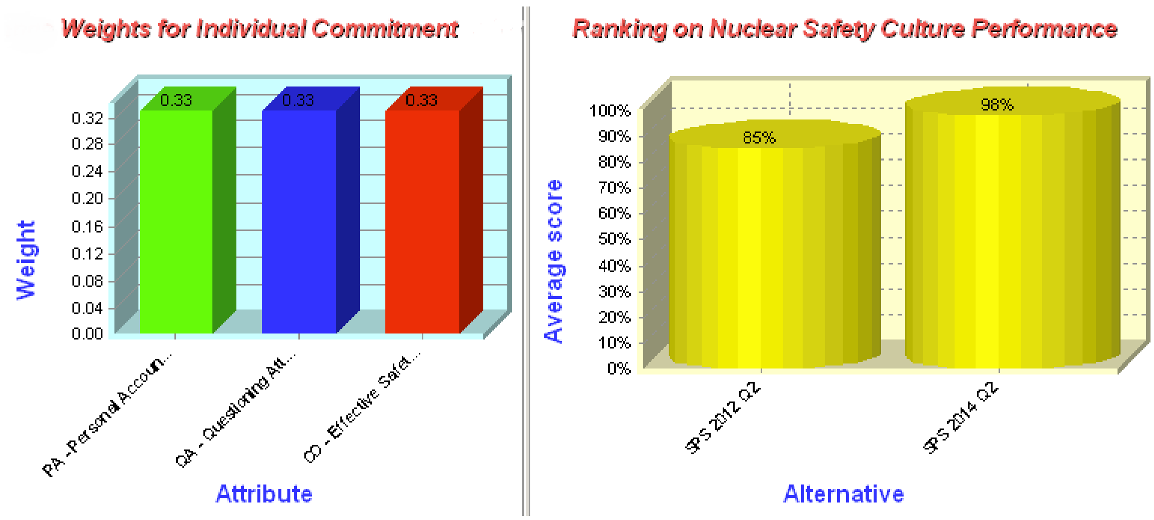


Figure 52. Attribute Weights Using Visual Scoring (Equal Weights Model)

The output of the NSC Performance model (the ranked NSC Performance) should change depending on the weights selected for the child attributes. Consequently, extreme-weighting cases will be explored to test the validity of the model by ensuring that the results align with our assumptions and expectations. From Appendix D, we know that PA had the highest number of binned process inputs in 2Q 2012 (PA received an equally high value in 1Q 2013 and 3Q 2013 as well but for the sake of simplicity 2Q 2012 will be utilized) and a zero value in 2Q 2014. Consequently, if the value of PA is changed it is expected that 2Q 2012 would be affected; however, 2Q 2014 would not be affected as shown in Figure 52, Figure 53 and Figure 54.

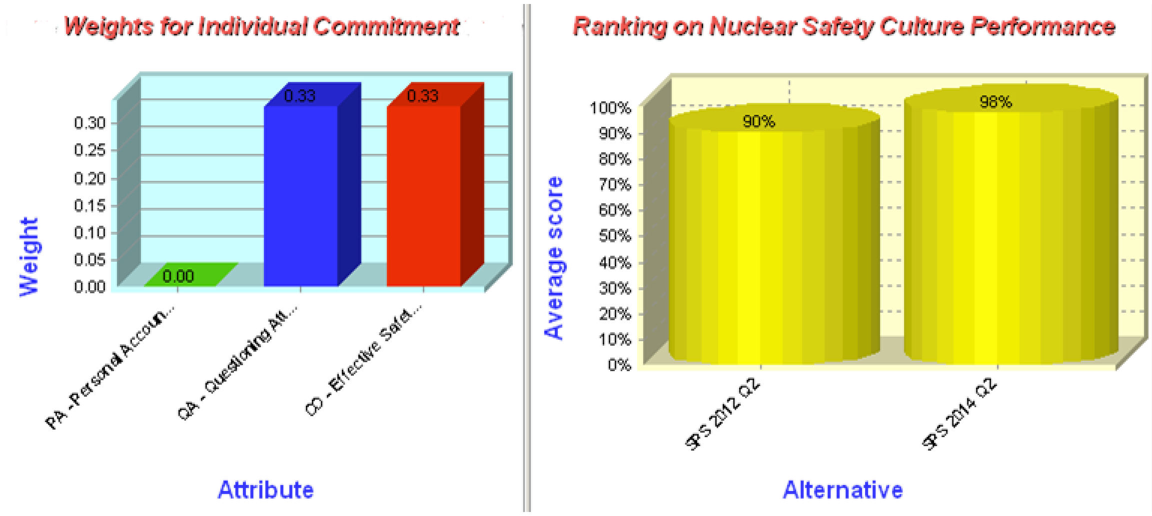


Figure 53. Minimum PA Weighting

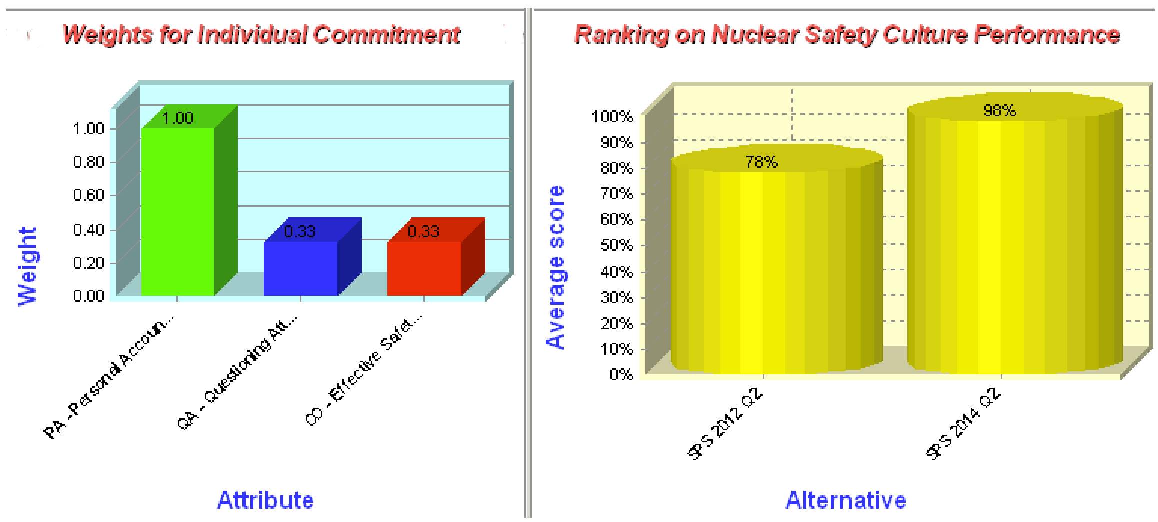


Figure 54. Maximum PA Weighting

This weight testing is then completed for the remaining attributes to verify fidelity and utility of range with respect to the binned process inputs.

NSC Performance Model Accreditation

Accreditation is the final step in a full M&S VV&A process. Accreditation is used to approve a model or simulation that has demonstrated that it can be employed successfully and that its results would be beneficial to the decision-making process. The entire VV&A process, but especially accreditation, would require close work with the stakeholders or agency that would be interested in employing the model or simulation. For the purposes of our research, we would initially look to market the NSC Performance model to the commercial nuclear industry, and perhaps later share the approach with other agencies (e.g., INPO, WANO, IAEA). However, direct interaction with the nuclear industry regarding the NSC Performance model has been extremely limited. It is easy to see how the quick visual analyses, sensitivity analyses, and preliminary verification and validation of the model would be valuable once the NSC Performance model is deployed in vivo with actual data and stakeholders reviewing the results to inform their decisions. Future research would be necessary to better understand the sensitivity of the model to the selected weights, utilities, and belief degrees selected for the model, but it is easy to see how IDS could be useful in producing these analyses. Further, these sensitivity analyses would be invaluable for communicating with participants and stakeholders in a NSC Performance model integrated assessment. As evidenced by this preliminary model testing, the NSC Performance model has the potential to integrate degrees of beliefs of subject matter experts with binned process input data using an ER model.

In summary, it has been demonstrated that an integrated assessment methodology, based on ER, can be employed to integrate the binned process inputs and degrees of belief assessments. Furthermore, this methodology systematically integrates these data in a meaningful, traceable, and reproducible approach, and provides a ranked NSC Performance list as its output.

CHAPTER 5

5. CONCLUSIONS AND RECOMMENDATIONS

This section discusses the summary of the findings, limitations and recommendations for future research. This section will also explain the relevance of this research to academia and the implications to engineering managers.

5.1 Implications

The implications to academia are to expand the current body of knowledge in the area of nuclear safety culture health evaluation. The literature review has expanded the body of knowledge by highlighting relevant research literature, and exploring common themes, and identifying new conceptual models. The literature review also exposed the considerable gap in the current body of knowledge. The research presented in this paper furthers our understanding on the causal relationship between the process inputs and NSC health utilizing MCDA. This research provides several avenues to expand and bolster this area of study.

The implication to the engineering and project managers is to provide a better functional understanding of the relationship between process inputs and NSC utilizing MCDA in an operating commercial nuclear power station.

This research also identified areas of the NSC that had higher significant correlations. This information better equips the manager when deciding on what areas to focus on and perhaps most of all allows the manager to have a better actionable insight on the relationships and interactions between the process inputs and the NSC Health.

5.2 Recommendations

There are several important limitations that will be discussed in this section. The sample size, while technically acceptable, was low. Eight respondents answered the survey. A larger sample size in the range of hundreds would make the results more generalizable. The sample size included only one nuclear power station. It is possible that there is bias in the study to one particular industry (i.e., US commercial nuclear power stations). Future research should account for other industrial safety cultures. The survey was self-administered and while self-administered surveys are accepted as a standard measurement tool, self-assessment raises concerns of source biases.

Other important areas for future research are the correlations established between aspects of the process inputs and NSC Health. Research in the specific area of how best practices in NSC Health are documented, socialized, and disseminated both within and without a nuclear power station would bolster the research presented here.

5.3 Conclusions

A literature review on the performance of a nuclear safety culture in an operating commercial nuclear power station environment was conducted. From the review it was established that there was a large gap in the body of knowledge. A conceptual model was built, research explored and research questions posed.

It has been established that quantitative data in the form of Process Inputs, that have causality with NSC health, at a nuclear power station can be obtained (Question 1). That the degrees of belief of NSC health by leadership at a nuclear power station can be quantified for NSC health via a survey (Question 2). That MCDA can be utilized to integrate the degrees of belief of NSC health and the process inputs into a comprehensive methodology to dynamically evaluate NSC Health Performance (Question 3) (Figure 55. NSC Assessment Model with MCDA and Figure 56. NSC Assessment Model with MCDA (Simplified View). This research has provided a more objective living NSC management tool that provides a management team with NSC health changes dynamically. This can lead to thoughtful discussion and cognitive analysis by the site leadership team as to the reason for any changes in the health the NSC.

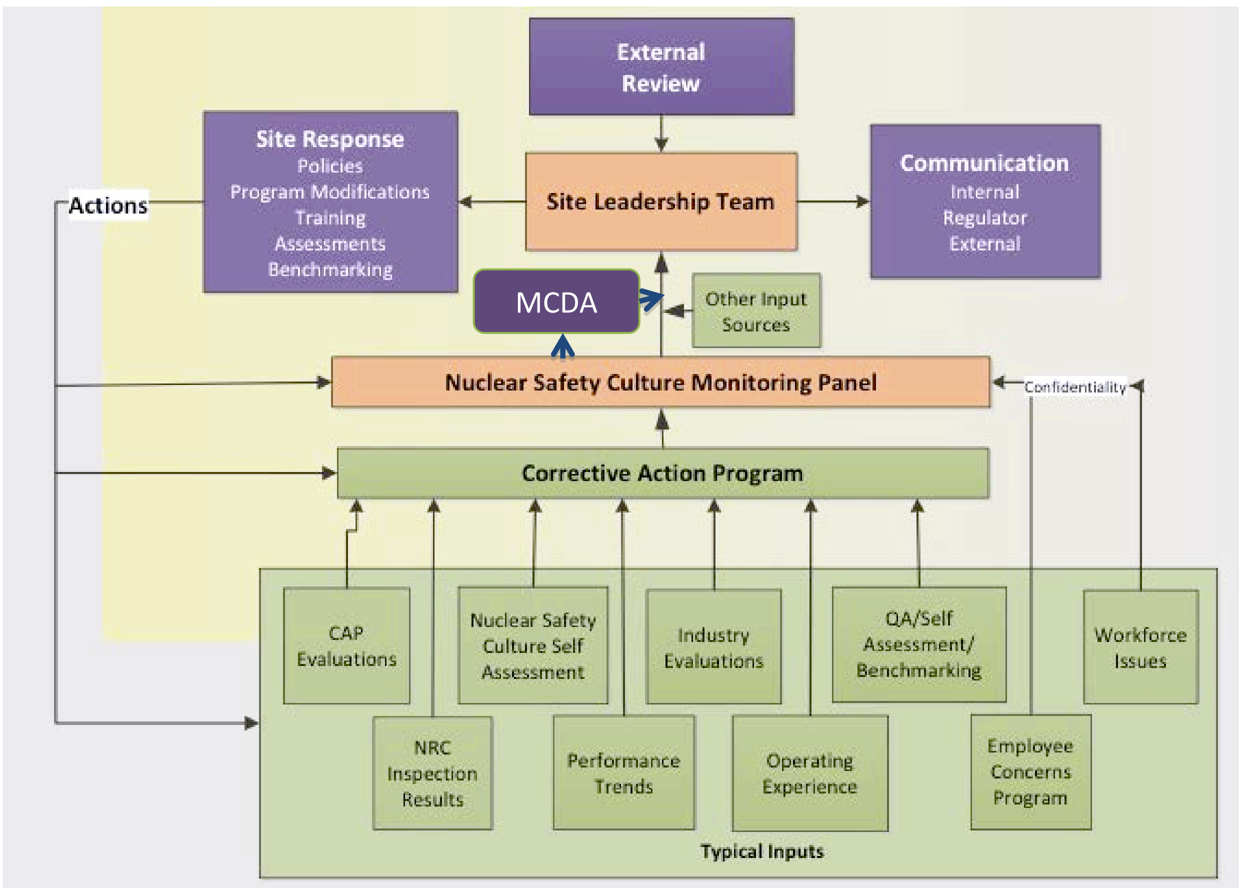


Figure 55. NSC Assessment Model with MCDA

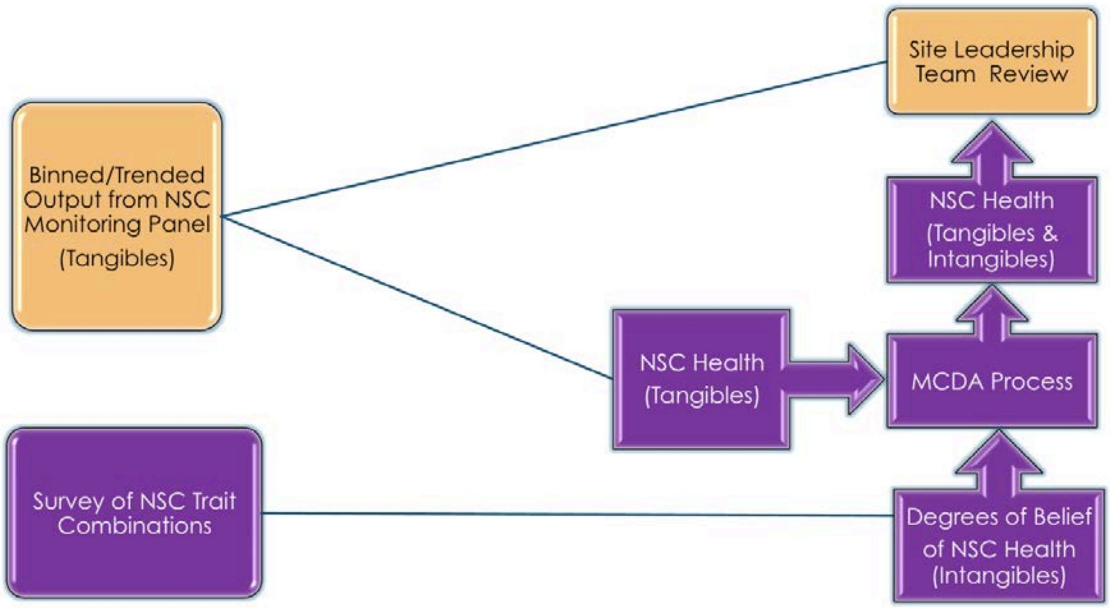


Figure 56. NSC Assessment Model with MCDA (Simplified View)

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APPENDICES

APPENDIX A: ODU INSTITUTIONAL REVIEW BOARD APPROVAL

OLD DOMINION UNIVERSITY

aaalac INTERNATIONAL
PROUDLY, AN AAALAC ACCREDITED PROGRAM

OFFICE OF THE VICE PRESIDENT FOR RESEARCH

Physical Address
4111 Monarch Way, Suite 203
Norfolk, Virginia 23508
Mailing Address
Office of Research
1 Old Dominion University
Norfolk, Virginia 23529
Phone(757) 683-3460
Fax(757) 683-5902

DATE:	July 17, 2015
TO:	Adrian Gheorghe, Ph.D.
FROM:	Old Dominion University Engineering Human Subjects Review Committee
PROJECT TITLE:	[756415-4] ASSESSING THE HEALTH OF AN ORGANIZATIONS SAFETY CULTURE UTILIZING MULTIPLE-CRITERIA DECISION ANALYSIS
REFERENCE #:	
SUBMISSION TYPE:	Revision
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	ENGN-15-08
REVIEW CATEGORY:	Exemption category # *6.2*

Thank you for your submission of Revision materials for this project. The Old Dominion University Engineering Human Subjects Review Committee has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations.

We will retain a copy of this correspondence within our records.

If you have any questions, please contact Stacie Ringleb at 757-683-6363 or sringleb@odu.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Old Dominion University Engineering Human Subjects Review Committee's records.

APPENDIX B: DOMINION'S SURRY POWER STATION APPROVAL

Dominion Generation
5570 Hog Island Road, Surry, VA 23883

Dominion

May 4, 2015

Dr. Adrian V. Gheorghe
Department Chair
Department of Engineering Management & Systems Engineering
Old Dominion University
2101 Engineering Systems Building
Norfolk, VA 23529

RE: Letter of Approval to Conduct Research at Surry Power Station

Dear Dr. Gheorghe:

Dominion will work with James H. Warren, Jr. to provide the necessary data and information for the completion of the dissertation: *Assessing the Health of an Organization's Safety Culture Utilizing Multiple-Criteria Decision Analysis*. Specifically, this includes authorization to send an anonymous survey to Surry Power Station personnel associated with the Safety Culture Monitoring Program and to allow use of Safety Culture Monitoring Panel process input and output binning data from 2012 through 2015.

We understand that the dissertation will be available in the public domain and therefore proprietary information, if any, will be masked in a meaningful and scientific way to preserve the scientific contribution of the dissertation findings without compromising the integrity of the information provided by Dominion.

Sincerely,

Larry Lane
Site Vice President
Surry Power Station
5570 Hog Island Road
757-365-2001
Larry.Lane@dom.com

APPENDIX C: SURRY POWER STATION SCMP MINUTES (EXAMPLE)

Surry Safety Culture Monitoring Panel

February 24, 2015

Period Reviewed: October 1 to December 31, 2014 (4Q 2014)

Chairperson: (Supervisor-Organizational Effectiveness T/A)

Members: (Maintenance), (NSS), (RP), (Protection Services), (O&P), (Licensing), (Training).

Non-Members: None.

Summary: A quorum of qualified SCMP participants was confirmed to be in attendance and the meeting was called to order at 1300.

One Root Cause Evaluation and one Apparent Cause Evaluation were performed during the fourth quarter of 2014. These and other required materials were reviewed and binned in accordance with LI-AA-1002 (Rev 4), *Safety Culture Review*, section 3.4, Conduct of SCMP Meetings. The results of this binning activity are recommendations for the Safety Culture Review Team (SCRT) to consider during their quarterly meeting.

Four of the ten Nuclear Safety Culture (NSC) traits were selected during the binning activity, distributed as follow:

Six items were binned to Work Processes. Three items were binned to WP.3 (Documentation), and three were binned to WP.4 (Procedure Adherence).

Three items were binned to Problem Identification and Resolution, with two items binned to PI.2 (Evaluation) and one item binned to PI.3 (Resolution).

Two items were binned to Personal Accountability, with both binned to PA.2 (Job Ownership).

One item was binned to Leadership Safety Values and Actions under LA.5 (Change Management).

Positive NSC traits were recommended for Questioning Attitude (four instances), as described in the attached binning matrix.

The SCMP determined there were no emergent station issues that signaled a decline in station Nuclear Safety Culture focus (ref. LI-AA-1002, 3.4.2.d) or required immediate attention or action. No other actions were assigned and the meeting was adjourned.

CORRECTIVE ACTION PROGRAM / PERFORMANCE IMPROVEMENT

Root Cause Evaluations (Level 1 and 2)	Trait(s)	SCMP Recommendation(s)	SCRT Comments
<u>RCE 1128 – Surry Unit 2 Trip:</u> Unit 2 experienced an automatic reactor trip from 100% power. Following the reactor trip troubleshooting determined the source of the trip was a spurious opening of the 'B' reactor trip breaker. **Root Cause**: Relay terminal screws were tightened "hand tight" (qualitative) resulting in inconsistent torque applied to terminal screws. This inconsistency is the result of a lack of quantitative standards for terminal screw tightness.	**WP.3**	<u>Procedure adherence, (a)</u>: *"Plant activities are governed by comprehensive, high-quality programs, processes, and procedures."* The procedure did not include the torque value for the relay terminal screws.	
Apparent Cause Evaluations (Level 1 and 2)	**Trait(s)**	**SCMP Recommendation(s)**	**SCRT Comments**
<u>ACE 19845 – Evaluate the cause of EDG No. 1 circuit breaker 15H3 remote trip and breaker-closed indication failure during performance of 1-OPT-EG-001</u>: The EDG #1 circuit breaker, 01-EP-BKR-15H3 EG1 panel breaker-closed indication, became lit after the breaker opened during the performance of 1-OPT-EG-001 and subsequent tests of the remote trip capability from the EG1 panel failed to trip open the breaker. This ACE will determine the most likely cause for the failure of conductor 15H3PT1 of cable 1H3PH12. **Apparent Cause**: The EDG No. 1 output circuit breaker control circuit cable 1H3PH12 conductor 15H3PT1 failed open. The most likely apparent cause of the failed conductor is mechanical failure of the conductor due to post installation stressors. These stressors are characterized as forces created by sharp bends at conduit and penetration entrances and exits, as well as proximity to cable tray edges and cable tray cover edges. This apparent cause was previously identified by ACE019381 after adjacent cables 1H3PH11 and 1EG89 from the same cable bundle experienced similar failures.	**PI.2** **PI.3**	<u>Evaluation, (d)</u>: *"Extent of condition and extent of cause evaluations are completed in a timely manner, commensurate with the safety significance of the issue."* Extent of condition evaluation was insufficient. <u>Resolution, (e)</u>: *"Corrective actions prevent the recurrence of significant conditions adverse to quality."* Corrective actions did not prevent recurrence.	

CAP Trend Report – 4Q 2014 – New Potential Adverse Trends	Trait(s)	SCMP Recommendation(s)	SCRT Comments
From the trending of condition report trend codes, cause evaluation codes, and INPO PO&C codes, Emergency Planning (CR flag trending) and Engineering Fundamentals (PO&C Code) were identified as potential adverse trends. **CR570073**: Submitted for Emergency Planning (CR flag trending)	**Carry to 2Q2015**	Recommend reviewing after CA is complete (2Q2015 SCMP) to determine if trend exists.	

CR570074: Submitted for Engineering Fundamentals (PO&C Code) CA response: There were 3 CRs, in the 4th quarter 2014, with the Primary INPO criteria Hot Button, "EN.1 - Engineering Fundamentals (INPO 12-013)." CR 570074 is currently being reviewed by engineering. CRs 563897 & 563876 were determined by engineering to be department HU clock resets. These two CRs were also binned in the Nov 2014 DSEM presentation as Engineering HU Fundamental issues and aggregated on the Technical Conscience Bubble Chart for the current INPO cycle. The Technical Conscience Bubble Chart for Dec 2014 shows a negative trend in Engineering Fundamentals for the current INPO cycle. Actions to improve engineering performance include plans for additional classroom training for Independent Review & Verification Practices.	**No NSC concerns**	SCMP determined this event not to be a nuclear safety culture concern.	
Nuclear Oversight: New AFIs, Issues, and Audit Findings	**Trait(s)**	**SCMP Recommendation(s)**	**SCRT Comments**
AFI 14-007S – Configuration Control: In some cases, operators performing plant activities failed to verify proper component positions or maintain positive control of components. This has resulted in the start of a bearing cooling pump without a suction source, operation of a circulating water pump without its associated screen in service, and inadequate isolation of a train of the low head safety injection system during maintenance.	**WP.4**	Procedure adherence, (d): *"Individuals manipulate plant equipment only when appropriately authorized and directed by approved plant procedures or work instructions."* Work was not always conducted in accordance with	

	PA.2	procedures/work orders. <u>Job ownership, (c):</u> *"Individuals take ownership for the preparation and execution of assigned work activities"* was selected as all examples may not have been driven by procedures/work orders.	
<u>AFI 14-010-NBU – SBO Outage Preparation</u>: In some cases, elements of Fleet GaRD MA-AA-DQT-1001, Diesel Quality Team, were not implemented effectively during the planning of SBO outages at all three sites in July 2014. Management oversight and intrusiveness into the quality of the milestone deliverables and enforcement of accountability was lacking in some instances. In addition, inconsistent procedure knowledge and adherence was also noted across the fleet. Contributing to this, expectations of the new NBU diesel improvement initiative have not been effectively communicated from the site leadership team to key station stakeholders.	**WP.4** **LA.5**	<u>Procedure adherence, (a):</u> Individuals did not follow procedures. <u>Change management (e):</u> Managers did not *"communicate the effects of impending changes."*	
<u>Finding 14-07-01MNS</u>: Storage Practices utilized for Level D items have not been effective in preventing contaminates from entering.	**PA.2**	<u>Job ownership (c):</u> Individuals did not *"take ownership for the preparation and execution of assigned work activities"* and stored the items improperly.	
<u>Finding 14-07-03CMNS</u>: The basis for selection of Critical Characteristics for Commercial Grade Item Evaluations is not being consistently documented.	**WP.3** **WP.4**	<u>Documentation (b):</u> Design documentation, procedures, and work packages were not *"complete, thorough, accurate, and current."*	

		<u>Procedure adherence (e):</u> Individuals did not *"ensure the statuses of work activities were properly documented."*	
<u>**Finding 14-08-02MNS**</u>: National Academy Nuclear Training (NANT) accreditation records are not identified by procedure as QA records and are not being retained as required.	**NO NSC concerns**	SCMP determined this legacy event not to be a nuclear safety culture concern.	
<u>**Finding 14-10-01MS**</u>: Qualification requirements for personnel to perform concrete and grout activities has not been developed and implemented at Millstone and Surry.	**WP.3**	<u>Documentation, (a):</u> These activities are not *"governed by a comprehensive, high-quality program, process, or procedure."*	
Station Management Review Meeting (SMRM) Open Items and Trends	**Trait(s)**	**SCMP Recommendation(s)**	**SCRT Comments**
NO new GAPS, Performance Improvement items, or trends were noted during SMRM held 11/12/14.	**N/A**	None.	None.

SAA32611: Validate training (PAPII) for FME controls issue. **SAA32612:** Provide a list and feedback to the Site VP, acting Plant Manager and Director of Eng on the Deficient Critical Work Backlog (Non-outage) **SAA32614:** Revise the Performance Measures and Goals for the GE on the packing program **SAA32615:** Ensure making additions to the RCS are to the top of VCT for controlling H2 concentration during reactor startups is proceduralized. **SAA32616:** Licensing evaluate strategy for readiness for big inspections. **SAA32617:** Verify oversight of critical valve packing is planned for the upcoming outage	**No NSC concerns**	SCMP determined none of these SAA/Action Items were nuclear safety culture concerns.	

SAA32618: Benchmark Calvert Cliffs on their elimination of TIG welding in FW heaters as a method to help with chemistry control of the secondary. **SAA32619:** Determine how lessons learned from NAPS red KPI on circuit breakers was or was not shared with Surry and why Surry's same KPI is green **SAA32620:** During benchmarking on configuration control, include review of configuration control KPIs			
NNOE containing safety culture flag	**Trait(s)**	**SCMP Recommendation(s)**	**SCRT Comments**
None this quarter.	**N/A**	None.	
CRs flagged as "Significant Abnormal Unexplained Conditions"	**Trait(s)**	**SCMP Recommendation(s)**	**SCRT Comments**
None this quarter.	**N/A**	None.	
Results from Nuclear Safety Culture Assessments, Self-Assessments, Benchmarking and Industry Assessments, INPO/WANO AFIs and PDs	**Trait(s)**	**SCMP Recommendation(s)**	**SCRT Comments**
None this quarter.	**N/A**	None.	
Human Performance "Good Catches"	**Trait(s)**	**SCMP Recommendation(s)**	**SCRT Comments**
During a cursory review of a design change (DC) that was not even assigned to him, [Engineer] identified that the Current Transformers (CTs) for use in 4160 volt switchgear were left open-circuited. This condition would have resulted in a catastrophic failure (i.e., explosion) inside the 4kV switchgear and possible arc flash that could have led to personal injury or death and a likely loss of the entire 4kV bus. This DC had been fully reviewed by the preparing architect firm and the owner's review completed by Dominion prior to [Engineer] identifying the concern. It was only the extra effort by [Engineer] that prevented this potentially very serious consequence.	**POSITIVE for QA**		

While walking down a JPM with an initial License Class Trainee, an operator assigned to the Condensate Polishing Water Treatment crew, discovered a discrepancy in the actuating solenoid alignment for the unit 2 Emergency Switchgear room Halon fire protection system. The system is designed to pump in two stages when fire is detected, the second stage 5 minutes after the first. He noticed that the actuating solenoids were arranged such that the second stage bottle for Zone 2 would dump along with the first stage bottles, thus negating the second actuation for that zone. He brought this to the attention of shift supervision, Safety & Loss Prevention and Engineering, and it was confirmed that this sequence could not positively ensure that the required Halon concentration would be maintained in the space for the desired duration. This rendered Unit 2 Emergency Switchgear Room Halon system non-functional. This Operator's knowledge of plant systems, his concern over the functionality of an installed fire protection system, and his desire to ensure the proper response to a deviating condition are prime examples of the 'K', 'N' and 'H' in the station's THINK Human Performance model.	**POSITIVE for QA**		
As part of Watchstation Rounds, [Operator] identified that the slinger ring for the outboard motor bearing of 1-BC-P-1B was not rotating. She submitted a CR and identified the abnormality to Shift Supervision, which allowed for the proper research and questions to be asked. 1-BC-P-1A had previously been secured due to an upcoming scheduled work package; however, due to [the Operator's] diligence on Watchstation Rounds, the organization decided to place 1-BC-P-1A in service again to allow for investigation/repair of 1-BC-P-1B before removing 1-BC-P-1A from service. Her attention to detail helped to prevent what could have been a potential Reactor Trip due to loss of Bearing Cooling.	**POSITIVE for QA**		
During verification of the tag out for the 50 Ton Chiller, the crew went to verify that the component was de-energized and found unexpected voltages. The crew contacted their supervisor and Engineering for resolution to the problem. This attention to detail and verification process of a protective barrier shows the proper method to ensure each person's safety. This reflects highly upon the	**POSITIVE for QA**		

crew and the organization as a whole.			

ENGINEERING

Red or Yellow KPI ERI (6.2) "Age of Red and Yellow Systems" window	Trait(s)	SCMP Recommendation(s)	SCRT Comments
SURR01/SURR02, 4Q2014: The age of R/Y System Health Reports > 18 months: EDG 30 months (10 quarters). One point lost for one system (EDG) being Red / Yellow for greater than to 18 months.	**No NSC concerns**	SCMP determined this event not to be a nuclear safety culture concern.	

LICENSING

NRC Quarterly Reports and new inspection findings:	Trait(s)	SCMP Recommendation(s)	SCRT Comments
<u>Fourth Quarter 2014 NRC Integrated Inspection Report</u>: An NRC-identified, non-cited violation (NCV) of Surry Technical Specification (TS) 6.4, Unit Operating Procedures and Programs, Section A.7 was identified because Surry procedure 0-ECM-1801-01, "Westinghouse Type BF – BFD – or NBFD65NR Relay Replacement" did not include a torque value for the reactor protection system (RPS) relay terminal screws to a field wiring connection. Subsequently, Unit 2 tripped on October 13, 2014, when a field wire connection became loose from the terminal end of a RPS trip relay and caused a reactor trip breaker to open. The issue was documented in Surry's corrective action program (CAP) as condition report (CR) 561820.	**PI.2**	While this issue was covered in the RCE binned previously, PI.2 (Identification) was added because the NRC inspection NCV was issued after the RCE was complete. Evaluation, (H): "Cause analyses identify and understand the bases for decisions that contributed to issues."	
MSRC Action Items	**Trait(s)**	**SCMP Recommendation(s)**	**SCRT Comments**
None this quarter.	**N/A**	None.	

OPERATIONS

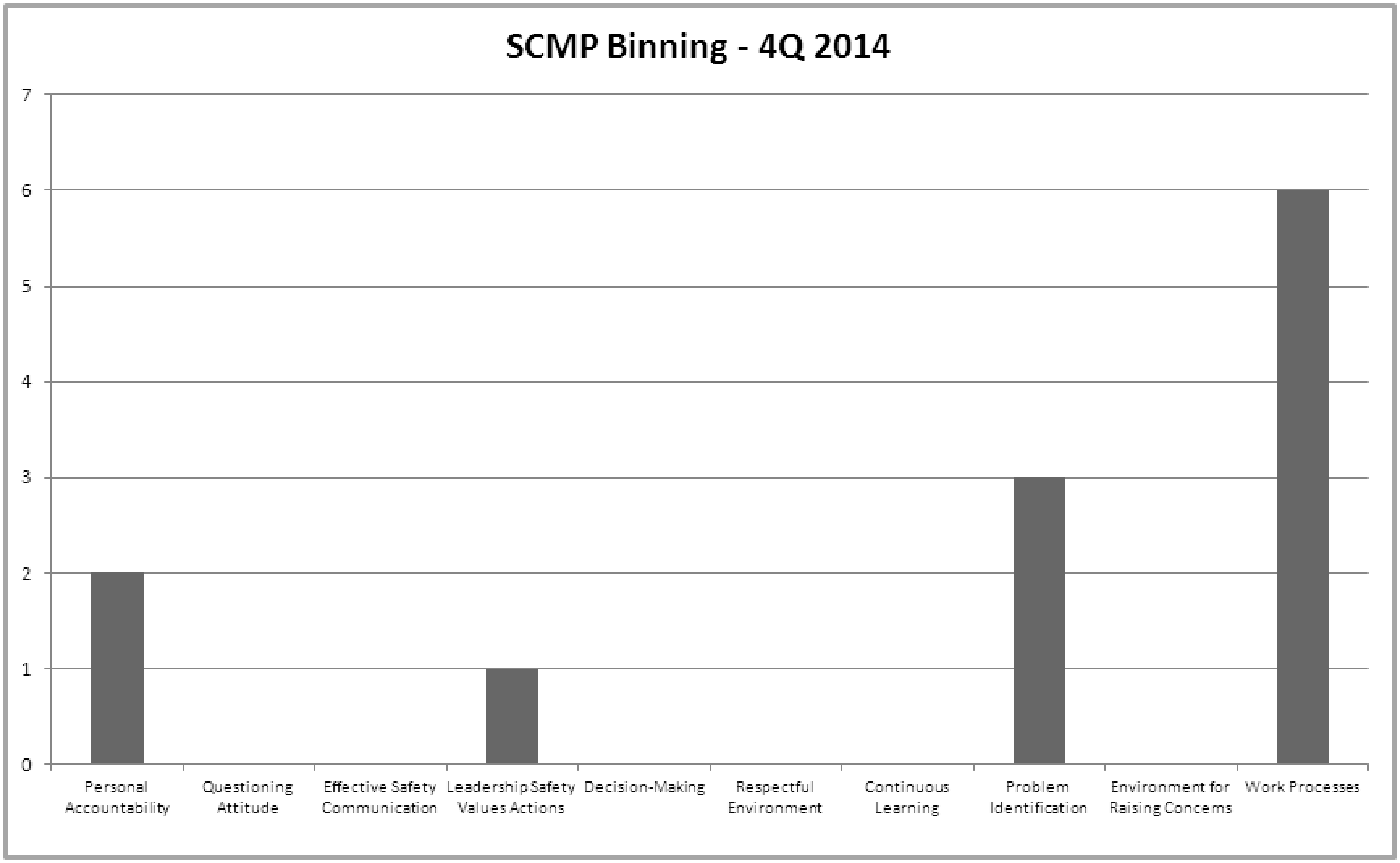
NEW Operator Work-Arounds and/or Burdens	Trait(s)	SCMP Recommendation(s)	SCRT Comments
<u>Operator Burden – U1/2 LLIS</u>: Biological fouling of trash racks, travelling screen failure when swapping CW pumps, VP LCV performance, 1-VS-F-47 in manual.	**NO NSC concerns**	SCMP determined this not to be a nuclear safety culture concern.	

HUMAN RESOURCES & EMPLOYEE CONCERNS (for SCRT review only)

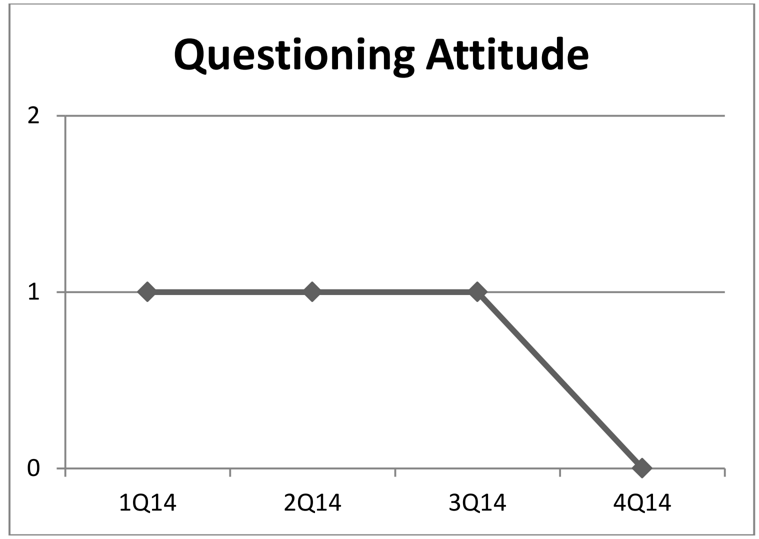
Human Resources	Trait(s)	SCMP Recommendation(s)	SCRT Comments
NO INPUT FOR SCMP – SCRT review only			
Generic ECP or SCWE issues	**Trait(s)**	**SCMP Recommendation(s)**	**SCRT Comments**
NO INPUT FOR SCMP – SCRT review only			
Results of Culture or Organizational Effectiveness Surveys (PI-AA-100-1009)	**Trait(s)**	**SCMP Recommendation(s)**	**SCRT Comments**
NO INPUT FOR SCMP – SCRT review only			

OTHER ITEMS FOR REVIEW

Other concerns identified by the members including identification of any emergent issues	Trait(s)	SCMP Recommendation(s)	SCRT Comments
None identified.			


SCMP Binning - 4Q 2014
7
6
5
4
3
2
1
0
Personal Accountability
Questioning Attitude
Effective Safety Communication
Leadership Safety Values Actions
Decision-Making
Respectful Environment
Continuous Learning
Problem Identification
Environment for Raising Concerns
Work Processes


Personal Accountability
3
2
1
0
1Q14
2Q14
3Q14
4Q14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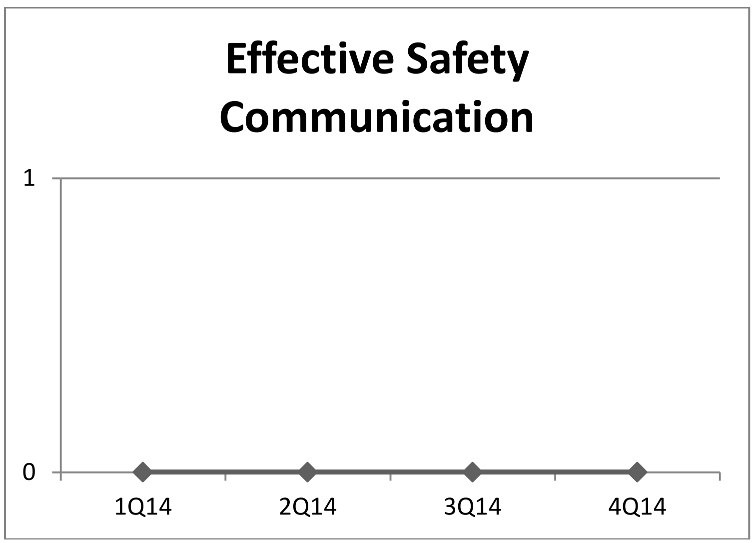
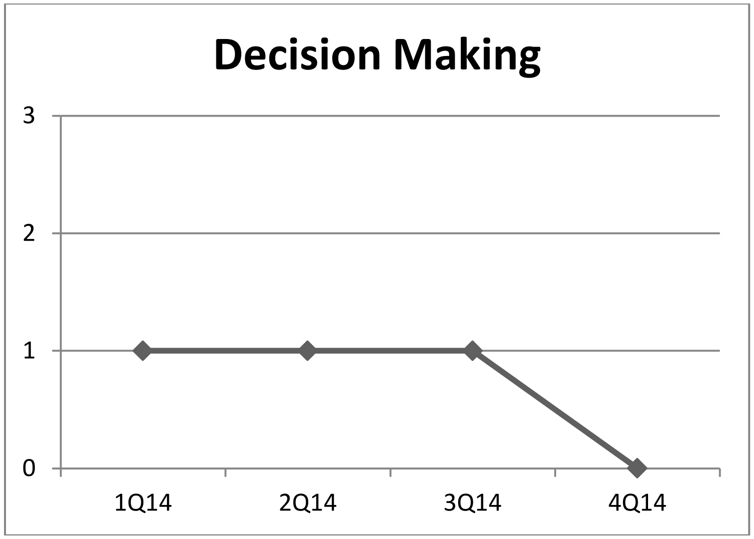
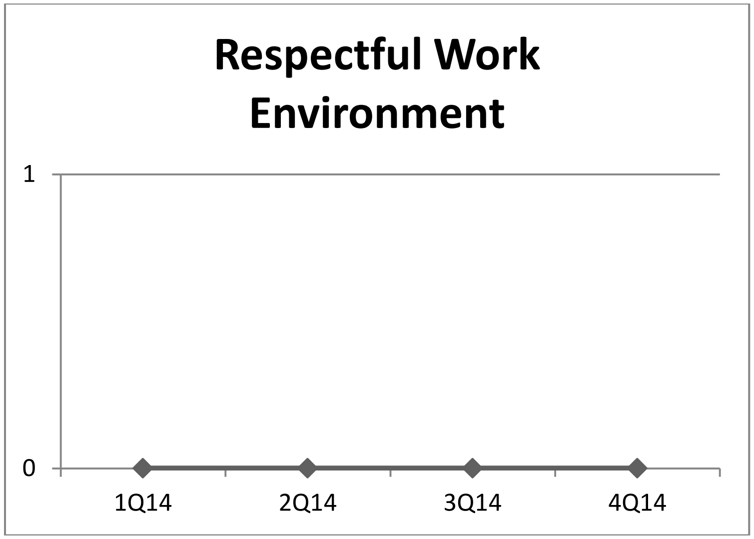
1
0
1Q14
2Q14
3Q14
4Q14


Effective Safety Communication
1
0
1Q14
2Q14
3Q14
4Q14


Leadership Safety Values & Actions
5
4
3
2
1
0
1Q14
2Q14
3Q14
4Q14


Decision Making
3
2
1
0
1Q14
2Q14
3Q14
4Q14


Respectful Work Environment
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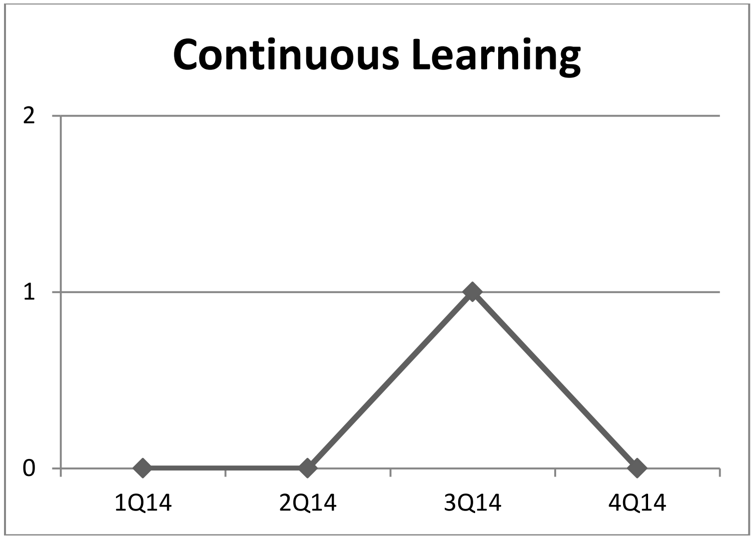
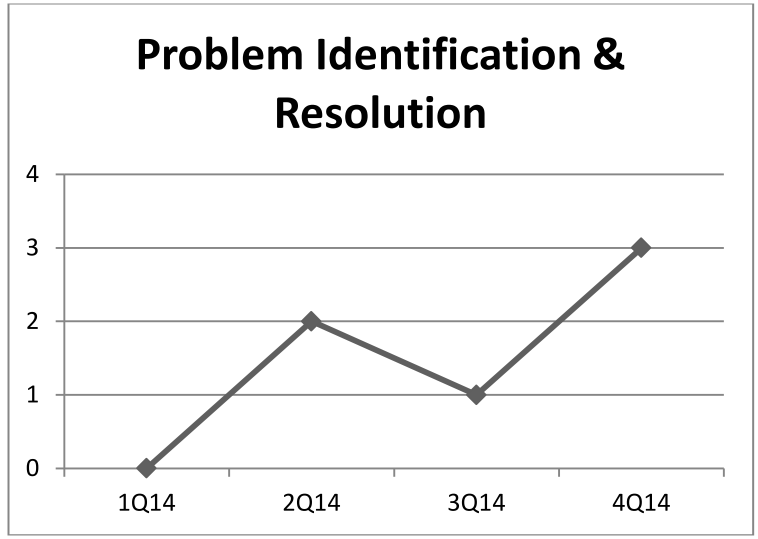
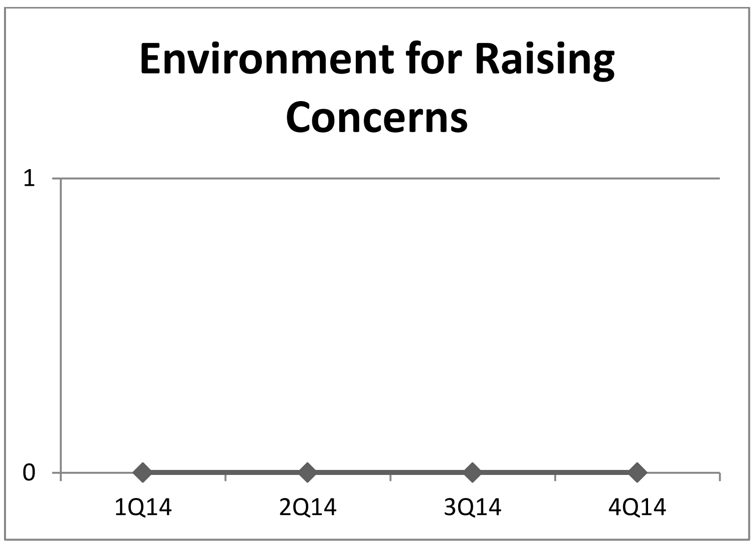
0
1Q14
2Q14
3Q14
4Q14


Continuous Learning
2
1
0
1Q14
2Q14
3Q14
4Q14


Problem Identification & Resolution
4
3
2
1
0
1Q14
2Q14
3Q14
4Q14


Environment for Raising Concerns
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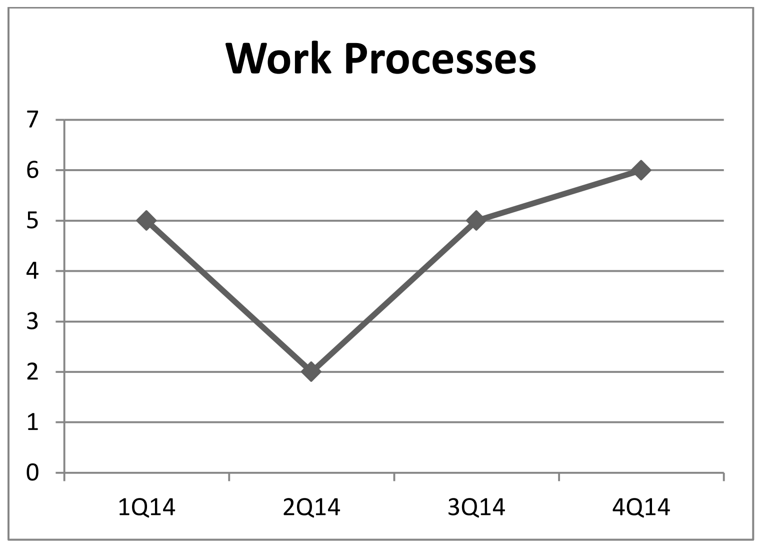
0
1Q14
2Q14
3Q14
4Q14


Work Processes
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6
5
4
3
2
1
0
1Q14
2Q14
3Q14
4Q14

APPENDIX D: NSCMP PROCESS INPUT BINNING RESULTS

Table 5. SPS NSCMP Process Input Binning Data

	Personal Accountability	Questioning Attitude	Effective Safety Communication	Leadership Safety Values & Actions	Decision Making	Respectful Work Environment	Continuous Learning	Problem Identification & Resolution	Environment for Raising Concerns	Work Processes
Quarter	**PA**	**QA**	**CO**	**LA**	**DM**	**WE**	**CL**	**PI**	**RC**	**WP**
2Q 2012	6	3	1	3	3	1	0	0	0	7
3Q 2012	3	4	0	0	2	0	1	0	0	0
4Q 2012	4	4	0	2	1	0	4	4	0	5
1Q 2013	6	3	2	1	0	0	0	1	0	3
2Q 2013	6	5	1	1	1	0	3	1	1	3
3Q 2013	2	0	0	1	0	0	1	4	0	5
4Q 2013	5	2	0	4	1	0	5	0	0	6
1Q 2014	1	1	0	2	1	0	0	0	0	5
2Q 2014	0	1	0	2	1	0	0	2	0	2
3Q 2014	2	1	0	4	1	0	1	1	0	5
4Q 2014	2	0	0	1	0	0	0	3	0	6
1Q 2015	2	0	0	1	0	0	1	2	0	3
AVG	3.3	2.0	0.3	1.8	0.9	0.1	1.3	1.5	0.1	4.2

APPENDIX E: PILOT SURVEY

This pilot survey will be used to validate the proposed survey questions. The full survey is attached. It is not necessary to answer the actual survey questions. Please read through the question and answer the review section for that particular question. The review section contains 5 columns. For the first 4 columns, please place an "X" in the box(s) that are most appropriate. Each question has a place for comments on that question in the last column labeled "Recommendations/Assessment". Additionally, at the end of the survey there is a general comments section. This section can be used to address the survey in general or specific survey questions. If commenting on survey questions please refer to the survey question number. The survey will be revised based on the inputs from the pilot survey responses and posted on an on-line survey service. The survey will be sent out to multiple individuals in multiple organizations that work in a nuclear power station environment. Thank you for your time and expertise.

[redacted]

SURVEY

The information being requested will help academics and companies better understand health of a nuclear safety culture in a nuclear power station environment. Analysis of the results will be based on a combination of survey participants and cannot be traced back to any one individual, event, or company. Individual responses will remain anonymous and will not be reported to any person or entity. Individual responses will not be traced back to any one individual, event, or company. Participation in this survey is voluntary, with no penalties or reprisals for not participating or completing the survey. Please read through the definitions prior to starting the survey and refer back to the definitions as needed.

Definitions:

Nuclear Safety Culture:
The core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment.

Safety Culture Monitoring Panel (SCMP):
Consists of key site personnel that meet periodically to review station performance and bin events and trends to the Traits for a Healthy Nuclear Safety Culture. The primary function of the SCMP is to periodically assess nuclear safety culture trends and identify potential trends and/or emergent issues then roll those up to the Safety Culture Review Team.

Nuclear Safety Monitoring Panel (NSCMP) Binning:

The NSCMP reviews the inputs most indicative of the health of the nuclear safety culture (e.g., Corrective Action Program, Regulatory Communications, Self Assessments, etc.) to identify potential concerns that merit additional attention by the organization. These inputs are then binned in one or more of the Traits of a Healthy Nuclear Safety Culture.

Safety Culture Review Team (SCRT):
This is the management team that reviews the results of the SCMP and takes corrective actions to address trends in the safety culture. The primary function of the SCRT is to monitor and promote a healthy nuclear safety culture by conducting a reflective self-critique of information that reflects the health of the Station's safety culture.

1. My years of experience as a member of a Nuclear Safety Culture Review Team and/or Nuclear Safety Culture Monitoring Panel?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 1:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

2. My position at this power station would most accurately be classified as?

	Drop down menu with: Manager or above, Supervisor (Titled) or Non-management.				

Review of Question 2:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

3. My years of experience working in Military Nuclear Power Plants?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 3:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

4. My years of experience working in Commercial Nuclear Power Plants?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 4:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

Individual Commitment to Safety: includes –
PA. Personal Accountability
All individuals take personal responsibility for safety. Responsibility and authority for nuclear safety are well defined and clearly understood. Reporting relationships, positional authority, and team responsibilities emphasize the overriding importance of nuclear safety.

QA. Questioning Attitude
Individuals avoid complacency and continuously challenge existing conditions, assumptions, anomalies, and activities in order to identify discrepancies that might result in error or inappropriate action. All employees are watchful for assumptions, values, conditions, or activities that can have an undesirable effect on plant safety.
CO. Safety Communication
Communications maintain a focus on safety. Safety communication is broad and includes plant-level communication, job-related communication, worker-level communication, equipment labeling, operating experience, and documentation. Leaders use formal and informal communication to convey the importance of safety. The flow of information up the organization is seen as important as the flow of information down the organization.

Management Commitment to Safety includes:
LA. Leadership Accountability
Leaders demonstrate a commitment to safety in their decisions and behaviors. Executive and senior managers are the leading advocates of nuclear safety and demonstrate their commitment both in word and action. The nuclear safety message is communicated frequently and consistently, occasionally as a stand-alone theme. Leaders throughout the nuclear organization set an example for safety. Corporate policies emphasize overriding importance of nuclear safety.
DM. Decision-Making
Decisions that support or affect nuclear safety are systematic, rigorous, and thorough. Operators are vested with the authority and understand the expectation, when faced with unexpected or uncertain conditions, to place the plant in a safe condition. Senior leaders support and reinforce conservative decisions.
WE. Respectful Work Environment
Trust and respect permeate the organization, creating a respectful work environment. A high level of trust is established in the organization, fostered, in part, through timely and accurate communication. Differing professional opinions are encouraged, discussed, and resolved in a timely manner. Employees are informed of steps taken in response to their concerns.

Management Systems includes:
CL. Continuous Learning
Opportunities to continuously learn are valued, sought out, and implemented. Operating experience is highly valued, and the capacity to learn from experience is well developed. Training, self-assessments, and benchmarking are used to stimulate learning and improve performance. Nuclear safety is kept under constant scrutiny through a variety of monitoring techniques, some of which provide an independent "fresh look."
PI. Problem Identification and Resolution
Issues potentially impacting safety are promptly identified, fully evaluated, and promptly addressed and corrected commensurate with their significance. Identification and resolution of a broad spectrum of problems, including organizational issues, are used to strengthen safety and improve performance.
RC. Environment for Raising Concerns

A safety-conscious work environment (SCWE) is maintained where personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment, or discrimination. The station creates, maintains, and evaluates policies and processes that allow personnel to freely raise concerns.

WP. Work Processes

The process of planning and controlling work activities is implemented so that safety is maintained. Work management is a deliberate process in which work is identified, selected, planned, scheduled, executed, closed, and critiqued. The entire organization is involved in and fully supports the process.

All questions pertain to an operating nuclear power station that has no emergent conditions present.

Individual Commitment to Safety

5. Approximately how many items binned under Individual Commitment to Safety would indicate complete integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 5:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

6. Approximately how many items binned under Individual Commitment to Safety would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 6:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

7. Approximately how many items binned under Individual Commitment to Safety would indicate an average level of integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 7:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

8. Approximately how many items binned under Individual Commitment to Safety would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 8:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

9. Approximately how many items binned under Individual Commitment to Safety would indicate the absence of integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 9:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

10. Approximately how many items binned under Management Commitment to Safety would indicate complete integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 10:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

11. Approximately how many items binned under Management Commitment to Safety would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 11:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

12. Approximately how many items binned under Management Commitment to Safety would indicate an average level of integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 12:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

13. Approximately how many items binned under Management Commitment to Safety would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 13:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

14. Approximately how many items binned under Management Commitment to Safety would indicate an absence of integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 14:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

15. Approximately how many items binned under Management Systems would indicate complete integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 15:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

16. Approximately how many items binned under Management Systems would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 16:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

17. Approximately how many items binned under Management Systems would indicate an average level of integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 17:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

18. Approximately how many items binned under Management Systems would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+

Review of Question 18:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

19. Approximately how many items binned under Management Systems would indicate an absence of integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 19:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

20. Approximately how many total items binned under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate complete integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 20:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

21. Approximately how many total items binned under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 21:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

22. Approximately how many total items binned under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate an average level of integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 22:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

23. Approximately how many total items binned under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 23:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

24. Approximately how many total items binned under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate an absence of integration of the Nuclear Safety Culture into normal operations?

	Drop down menu with: 0,1,2,3….48,49,50+				

Review of Question 24:

Question is clear/under standable	Question is NOT clear/understandable	Question relates to Nuclear Safety Culture Performance	Recommendations/ Assessment

GENERAL COMMENTS ON THE SURVEY:

APPENDIX F: FINAL SURVEY

Nuclear Safety Culture (NSC) Trait Questionnaire

1. NSC Trait Binning vs NSC Health Degree of Belief Survey

Purpose: The purpose of this survey is to help academics and companies to more objectively assess the health of a nuclear safety culture in a nuclear power station environment.

Anonymity: Individual responses will remain anonymous and will not be reported to any person or entity. Individual responses will not be traced back to any one individual, event, or company. Analysis of the results will be based on a combination of survey participants and cannot be traced back to any one individual, event, or company.

Agreement to Participate: Participation in this survey is voluntary, with no penalties or reprisals for not participating or completing the survey. By selecting the "Next" button below you are agreeing to participate in this survey.

Nuclear Safety Culture (NSC) Trait Questionnaire

2. Definitions

Please read through the definitions prior to starting the survey and refer back to the definitions as needed.

Definitions:

Nuclear Safety Culture:
The core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment.

Safety Culture Monitoring Panel (SCMP):
Consists of key site personnel that meet periodically to review station performance and bin events and trends to the Traits for a Healthy Nuclear Safety Culture. The primary function of the SCMP is to periodically assess nuclear safety culture trends and identify potential trends and/or emergent issues then roll those up to the Safety Culture Review Team.

Nuclear Safety Monitoring Panel (NSCMP) Binning:
The NSCMP reviews the inputs most indicative of the health of the nuclear safety culture (e.g., Corrective Action Program, Regulatory Communications, Self Assessments, etc.) to identify potential concerns that merit additional attention by the organization. These inputs are then binned in one or more of the Traits of a Healthy Nuclear Safety Culture.

Safety Culture Review Team (SCRT):
This is the management team that reviews the results of the SCMP and takes corrective actions to address trends in the safety culture. The primary function of the SCRT is to monitor and promote a

healthy nuclear safety culture by conducting a reflective self-critique of information that reflects the health of the Station's safety culture.

1. My position at this power station would most accurately be classified as?

Manager, Supervisor, Non-management

* 2. My years of experience as a member of a Nuclear Safety Culture Review Team and/or Nuclear Safety Culture Monitoring Panel:

0-50

* 3. My years of experience working in Military Nuclear Power Plants:

0-50

* 4. My years of experience working in Commercial Nuclear Power Plants:

0-50

Nuclear Safety Culture (NSC) Trait Questionnaire

3. Individual Commitment to Safety

Please read the following terms and descriptions that are the primary traits of the*Individual Commitment to Safety* category and then answer the questions for this section:

PA. Personal Accountability
All individuals take personal responsibility for safety. Responsibility and authority for nuclear safety are well defined and clearly understood. Reporting relationships, positional authority, and team responsibilities emphasize the overriding importance of nuclear safety.

QA. Questioning Attitude
Individuals avoid complacency and continuously challenge existing conditions, assumptions, anomalies, and activities in order to identify discrepancies that might result in error or inappropriate action. All employees are watchful for assumptions, values, conditions, or activities that can have an undesirable effect on plant safety.

CO. Safety Communication
Communications maintain a focus on safety. Safety communication is broad and includes plant-level communication, job-related communication, worker-level communication, equipment labeling, operating experience, and documentation. Leaders use formal and informal communication to convey the importance of safety. The flow of information up the organization is seen as important as the flow of information down the organization.

* 5. Approximately how many items binned per quarter under Individual Commitment to Safety would indicate complete integration of the Nuclear Safety Culture into normal operations:

0-50

* 6. Approximately how many items binned per quarter under Individual Commitment to Safety would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations:

0-50

* 7. Approximately how many items binned per quarter under Individual Commitment to Safety would indicate an average level of integration of the Nuclear Safety Culture into normal operations:

0-50

* 8. Approximately how many items binned per quarter under Individual Commitment to Safety would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations:

0-50

* 9. Approximately how many items binned per quarter under Individual Commitment to Safety would indicate the absence of integration of the Nuclear Safety Culture into normal operations:

0-50

Nuclear Safety Culture (NSC) Trait Questionnaire

4. Management Commitment to Safety

Please read the following terms and descriptions that are the primary traits of the*Management Commitment to Safety* category and then answer the questions for this section:

LA. Leadership Accountability
Leaders demonstrate a commitment to safety in their decisions and behaviors. Executive and senior managers are the leading advocates of nuclear safety and demonstrate their commitment both in word and action. The nuclear safety message is communicated frequently and consistently, occasionally as a stand-alone theme. Leaders throughout the nuclear organization set an example for safety. Corporate policies emphasize overriding importance of nuclear safety.

DM. Decision-Making
Decisions that support or affect nuclear safety are systematic, rigorous, and thorough. Operators are vested with the authority and understand the expectation, when faced with unexpected or uncertain conditions, to place the plant in a safe condition. Senior leaders support and reinforce conservative decisions.

WE. Respectful Work Environment
Trust and respect permeate the organization, creating a respectful work environment. A high level of trust is established in the organization, fostered, in part, through timely and accurate communication. Differing professional opinions are encouraged, discussed, and resolved in a timely manner. Employees are informed of steps taken in response to their concerns.

* 10. Approximately how many items binned per quarter under Management Commitment to Safety would indicate complete integration of the Nuclear Safety Culture into normal operations:

0-50

* 11. Approximately how many items binned per quarter under Management Commitment to Safety would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations:

0-50

* 12. Approximately how many items binned per quarter under Management Commitment to Safety would indicate an average level of integration of the Nuclear Safety Culture into normal operations:

0-50

* 13. Approximately how many items binned per quarter under Management Commitment to Safety would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations:

0-50

* 14. Approximately how many items binned per quarter under Management Commitment to Safety would indicate an absence of integration of the Nuclear Safety Culture into normal operations:

0-50

Nuclear Safety Culture (NSC) Trait Questionnaire

5. Management Systems

Please read the following terms and descriptions that are the primary traits of the*Management Systems* category and then answer the questions for this section:

CL. Continuous Learning
Opportunities to continuously learn are valued, sought out, and implemented. Operating experience is highly valued, and the capacity to learn from experience is well developed. Training, self-assessments, and benchmarking are used to stimulate learning and improve performance. Nuclear safety is kept under constant scrutiny through a variety of monitoring techniques, some of which provide an independent "fresh look."

PI. Problem Identification and Resolution
Issues potentially impacting safety are promptly identified, fully evaluated, and promptly addressed and corrected commensurate with their significance. Identification and resolution of a broad spectrum of problems, including organizational issues, are used to strengthen safety and improve performance.

RC. Environment for Raising Concerns
A safety-conscious work environment (SCWE) is maintained where personnel feel free to raise safety

concerns without fear of retaliation, intimidation, harassment, or discrimination. The station creates, maintains, and evaluates policies and processes that allow personnel to freely raise concerns.

WP. Work Processes
The process of planning and controlling work activities is implemented so that safety is maintained. Work management is a deliberate process in which work is identified, selected, planned, scheduled, executed, closed, and critiqued. The entire organization is involved in and fully supports the process.

* 15. Approximately how many items binned per quarter under Management Systems would indicate complete integration of the Nuclear Safety Culture into normal operations:

0-50

* 16. Approximately how many items binned per quarter under Management Systems would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations:

0-50

* 17. Approximately how many items binned per quarter under Management Systems would indicate an average level of integration of the Nuclear Safety Culture into normal operations:

0-50

* 18. Approximately how many items binned per quarter under Management Systems would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations:

0-50

* 19. Approximately how many items binned per quarter under Management Systems would indicate an absence of integration of the Nuclear Safety Culture into normal operations:

0-50

Nuclear Safety Culture (NSC) Trait Questionnaire

6. Individual Commitment to Safety, Management Commitment to Safety and Management Systems

Please answer the questions for this section based on the terms and descriptions from the previous sections:

* 20. Approximately how many total items binned per quarter under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate complete integration of the Nuclear Safety Culture into normal operations:

0-50

* 21. Approximately how many total items binned per quarter under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations:

0-50

* 22. Approximately how many total items binned per quarter under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate an average level of integration of the Nuclear Safety Culture into normal operations:

0-50

* 23. Approximately how many total items binned per quarter under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations:

0-50

* 24. Approximately how many total items binned per quarter under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate an absence of integration of the Nuclear Safety Culture into normal operations:

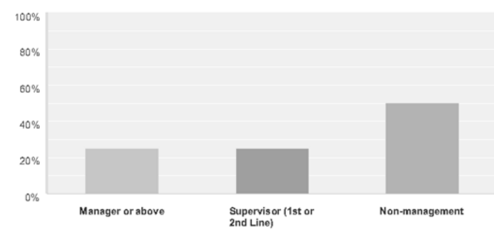
0-50

APPENDIX G: SURVEY RESULTS

Nuclear Safety Culture (NSC) Trait Questionnaire SurveyMonkey

Q1 My position at this power station would most accurately be classified as?

Answered: 8 Skipped: 0

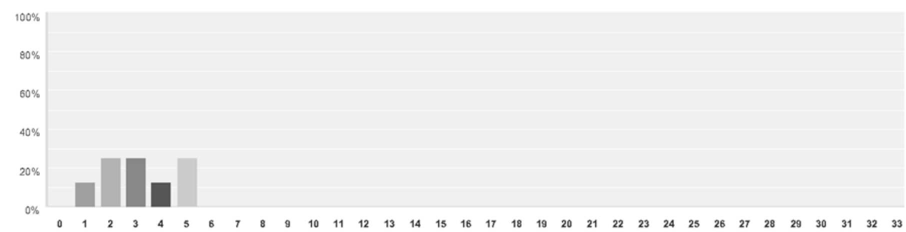


Answer Choices	Responses	
Manager or above (1)	25.00%	2
Supervisor (1st or 2nd Line) (2)	25.00%	2
Non-management (3)	50.00%	4
Total		**8**

Basic Statistics				
Minimum 1.00	Maximum 3.00	Median 2.50	Mean 2.25	Standard Deviation 0.83

Q2 My years of experience as a member of a Nuclear Safety Culture Review Team and/or Nuclear Safety Culture Monitoring Panel:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	12.50%	1
2 (3)	25.00%	2
3 (4)	25.00%	2
4 (5)	12.50%	1
5 (6)	25.00%	2
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0

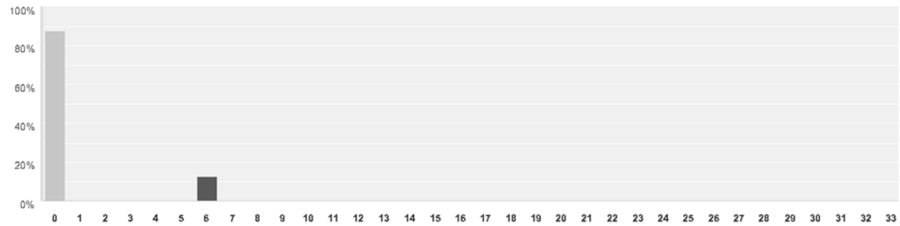
12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
2.00	6.00	4.00	4.13	1.36

Q3 My years of experience working in Military Nuclear Power Plants:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	87.50%	7
1 (2)	0.00%	0
2 (3)	0.00%	0
3 (4)	0.00%	0
4 (5)	0.00%	0
5 (6)	0.00%	0
6 (7)	12.50%	1
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0
12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0

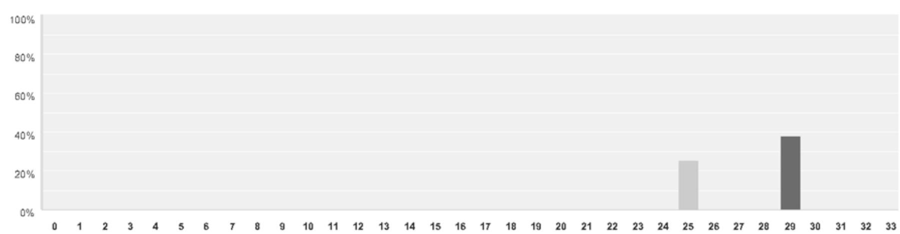
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
1.00	7.00	1.00	1.75	1.98

Q4 My years of experience working in Commercial Nuclear Power Plants:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	0.00%	0
2 (3)	0.00%	0
3 (4)	0.00%	0
4 (5)	0.00%	0
5 (6)	0.00%	0
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0
12 (13)	0.00%	0

13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	25.00%	2
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	37.50%	3
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	12.50%	1
35 (36)	12.50%	1
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	12.50%	1
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

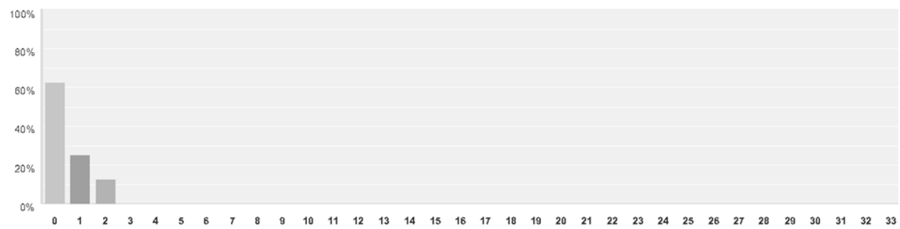
Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
26.00	39.00	30.00	31.50	4.42

Q5 Approximately how many items binned per quarter under Individual Commitment to Safety would indicate complete integration of the Nuclear Safety Culture into normal

operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	62.50%	5
1 (2)	25.00%	2
2 (3)	12.50%	1
3 (4)	0.00%	0
4 (5)	0.00%	0
5 (6)	0.00%	0
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0
12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0

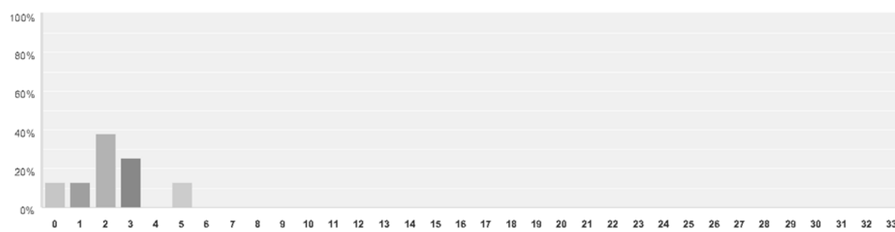
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
1.00	3.00	1.00	1.50	0.71

Q6 Approximately how many items binned per quarter under Individual Commitment to Safety would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	12.50%	1
1 (2)	12.50%	1
2 (3)	37.50%	3
3 (4)	25.00%	2
4 (5)	0.00%	0
5 (6)	12.50%	1
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0

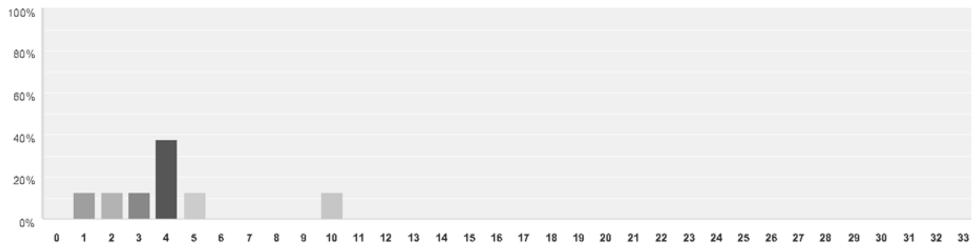
10 (11)	0.00%	0
11 (12)	0.00%	0
12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
1.00	6.00	3.00	3.25	1.39

Q7 Approximately how many items binned per quarter under Individual Commitment to Safety would indicate an average level of integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	12.50%	1
2 (3)	12.50%	1
3 (4)	12.50%	1
4 (5)	37.50%	3
5 (6)	12.50%	1
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0
10 (11)	12.50%	1
11 (12)	0.00%	0
12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0

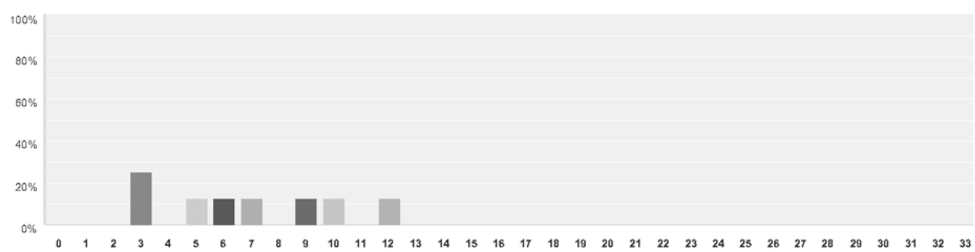
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
2.00	11.00	5.00	5.13	2.52

Q8 Approximately how many items binned per quarter under Individual Commitment to Safety would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	0.00%	0
2 (3)	0.00%	0
3 (4)	25.00%	2
4 (5)	0.00%	0
5 (6)	12.50%	1

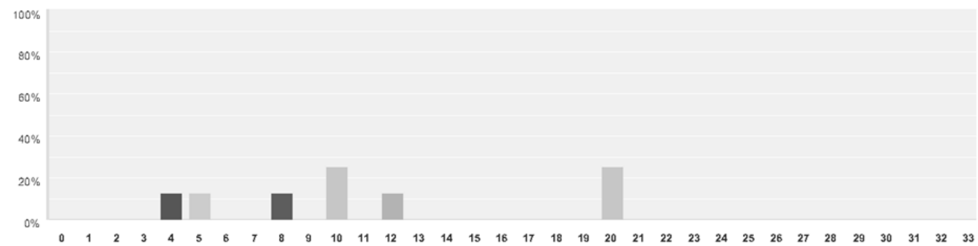
6 (7)	12.50%	1
7 (8)	12.50%	1
8 (9)	0.00%	0
9 (10)	12.50%	1
10 (11)	12.50%	1
11 (12)	0.00%	0
12 (13)	12.50%	1
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0

Total	8

Basic Statistics				
Minimum 4.00	Maximum 13.00	Median 7.50	Mean 7.88	Standard Deviation 3.06

Q9 Approximately how many items binned per quarter under Individual Commitment to Safety would indicate the absence of integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	0.00%	0
2 (3)	0.00%	0
3 (4)	0.00%	0
4 (5)	12.50%	1
5 (6)	12.50%	1
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	12.50%	1
9 (10)	0.00%	0
10 (11)	25.00%	2
11 (12)	0.00%	0
12 (13)	12.50%	1
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	25.00%	2
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0

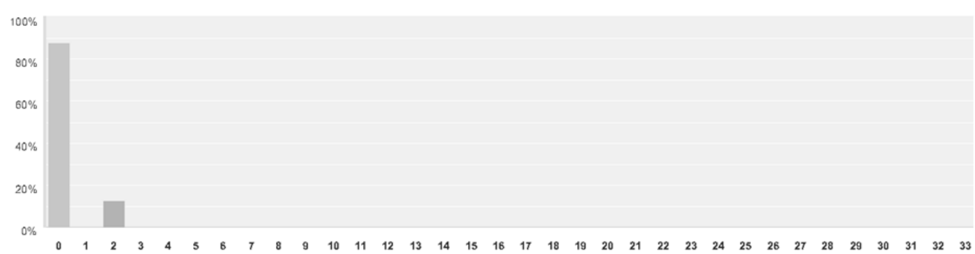
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
5.00	21.00	11.00	12.13	5.69

Q10 Approximately how many items binned per quarter under Management Commitment to Safety would indicate complete integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	87.50%	7
1 (2)	0.00%	0
2 (3)	12.50%	1

3 (4)	0.00%	0
4 (5)	0.00%	0
5 (6)	0.00%	0
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0
12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0

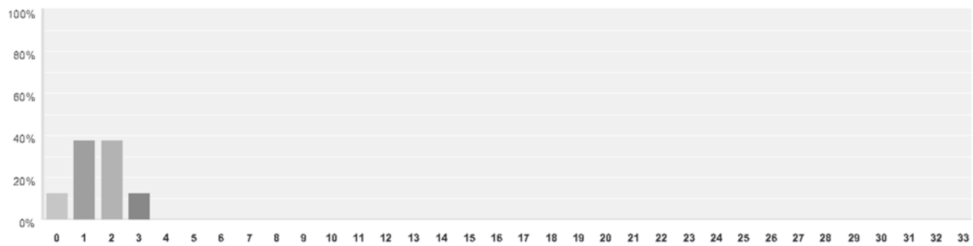
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
1.00	3.00	1.00	1.25	0.66

Q11 Approximately how many items binned per quarter under Management Commitment to Safety would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	12.50%	1
1 (2)	37.50%	3
2 (3)	37.50%	3
3 (4)	12.50%	1
4 (5)	0.00%	0
5 (6)	0.00%	0
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0
12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0

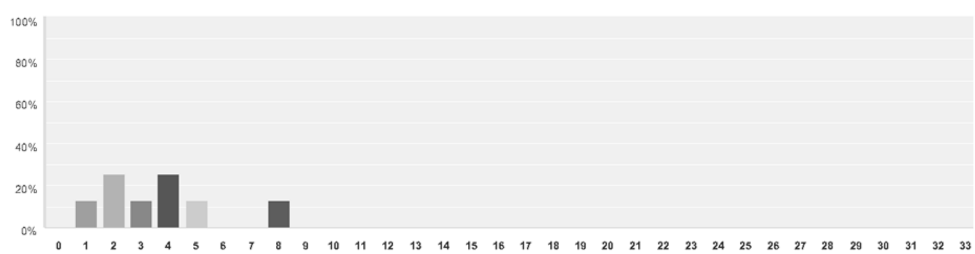
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
1.00	4.00	2.50	2.50	0.87

Q12 Approximately how many items binned per quarter under Management Commitment to Safety would indicate an average level of integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



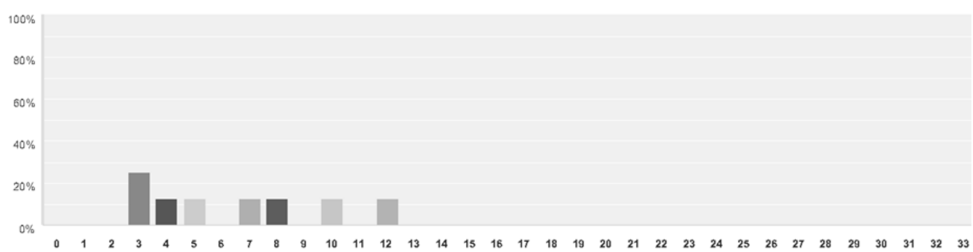
Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	12.50%	1
2 (3)	25.00%	2
3 (4)	12.50%	1
4 (5)	25.00%	2
5 (6)	12.50%	1
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	12.50%	1
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0
12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0

44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics				
Minimum 2.00	**Maximum** 9.00	**Median** 4.50	**Mean** 4.63	**Standard Deviation** 2.06

Q13 Approximately how many items binned per quarter under Management Commitment to Safety would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	0.00%	0
2 (3)	0.00%	0
3 (4)	25.00%	2
4 (5)	12.50%	1
5 (6)	12.50%	1
6 (7)	0.00%	0
7 (8)	12.50%	1
8 (9)	12.50%	1
9 (10)	0.00%	0
10 (11)	12.50%	1
11 (12)	0.00%	0
12 (13)	12.50%	1
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0

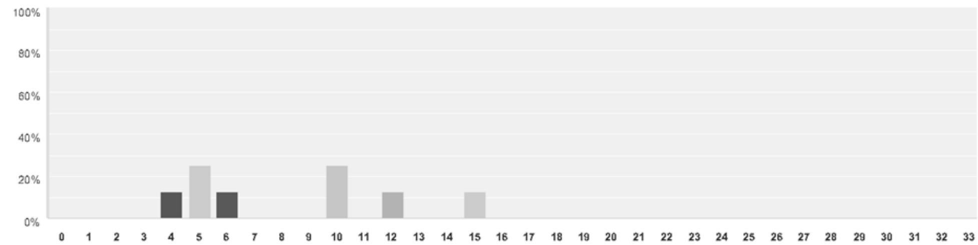
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
4.00	13.00	7.00	7.50	3.12

Q14 Approximately how many items binned per quarter under Management Commitment to Safety would indicate an absence of integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	0.00%	0
2 (3)	0.00%	0
3 (4)	0.00%	0
4 (5)	12.50%	1
5 (6)	25.00%	2
6 (7)	12.50%	1
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0
10 (11)	25.00%	2
11 (12)	0.00%	0
12 (13)	12.50%	1
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	12.50%	1
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0

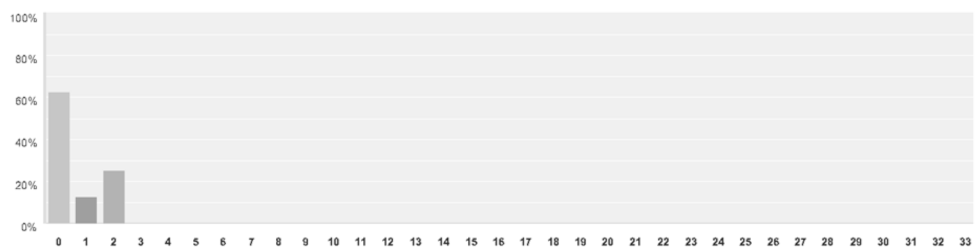
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
5.00	16.00	9.00	9.38	3.71

Q15 Approximately how many items binned per quarter under Management Systems would indicate complete integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	62.50%	5
1 (2)	12.50%	1
2 (3)	25.00%	2
3 (4)	0.00%	0
4 (5)	0.00%	0
5 (6)	0.00%	0
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0

12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

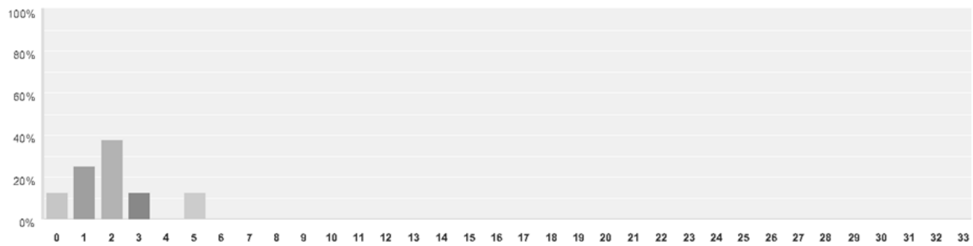
Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
1.00	3.00	1.00	1.63	0.86

Q16 Approximately how many items binned per quarter under Management Systems would indicate significant integration but

not complete integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	12.50%	1
1 (2)	25.00%	2
2 (3)	37.50%	3
3 (4)	12.50%	1
4 (5)	0.00%	0
5 (6)	12.50%	1
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0
12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0

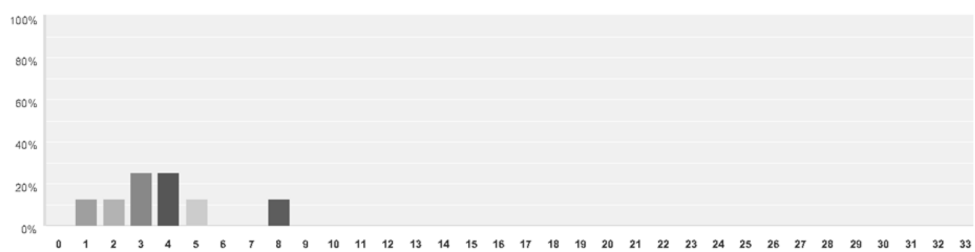
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
1.00	6.00	3.00	3.00	1.41

Q17 Approximately how many items binned per quarter under Management Systems would indicate an average level of integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	12.50%	1
2 (3)	12.50%	1
3 (4)	25.00%	2
4 (5)	25.00%	2
5 (6)	12.50%	1
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	12.50%	1

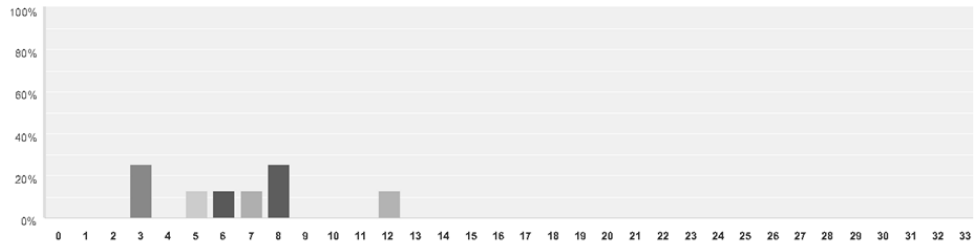
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0
12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
2.00	9.00	4.50	4.75	1.98

Q18 Approximately how many items binned per quarter under Management Systems would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	0.00%	0
2 (3)	0.00%	0
3 (4)	25.00%	2
4 (5)	0.00%	0
5 (6)	12.50%	1
6 (7)	12.50%	1
7 (8)	12.50%	1
8 (9)	25.00%	2
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0
12 (13)	12.50%	1
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0

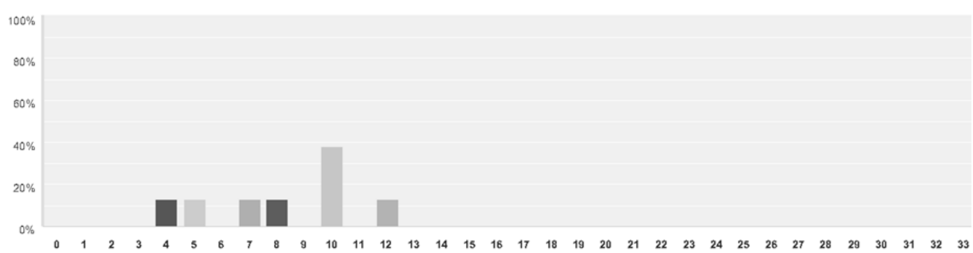
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
4.00	13.00	7.50	7.50	2.78

Q19 Approximately how many items binned per quarter under Management Systems would indicate an absence of integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



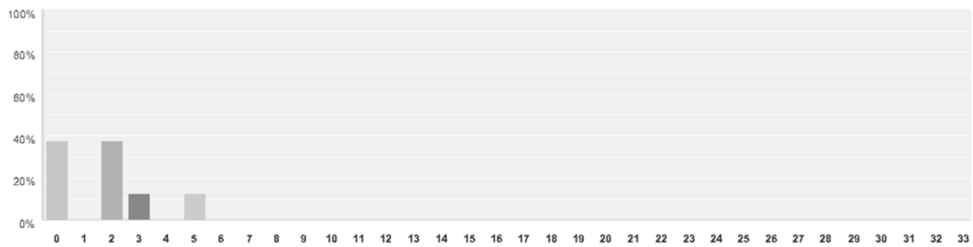
Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	0.00%	0
2 (3)	0.00%	0
3 (4)	0.00%	0
4 (5)	12.50%	1
5 (6)	12.50%	1
6 (7)	0.00%	0

7 (8)	12.50%	1
8 (9)	12.50%	1
9 (10)	0.00%	0
10 (11)	37.50%	3
11 (12)	0.00%	0
12 (13)	12.50%	1
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics				
Minimum 5.00	Maximum 13.00	Median 10.00	Mean 9.25	Standard Deviation 2.59

Q20 Approximately how many total items binned per quarter under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate complete integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	37.50%	3
1 (2)	0.00%	0
2 (3)	37.50%	3
3 (4)	12.50%	1
4 (5)	0.00%	0
5 (6)	12.50%	1
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0
12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0

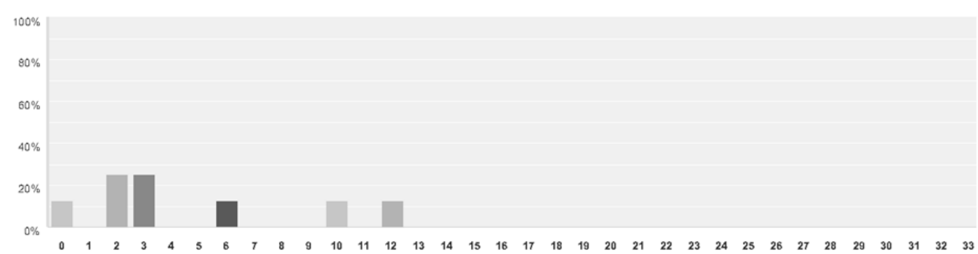
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
1.00	6.00	3.00	2.75	1.64

Q21 Approximately how many total items binned per quarter under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate significant integration but not complete integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses

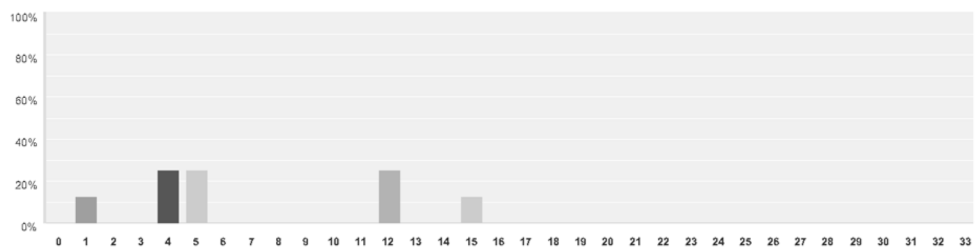
0 (1)	12.50%	1
1 (2)	0.00%	0
2 (3)	25.00%	2
3 (4)	25.00%	2
4 (5)	0.00%	0
5 (6)	0.00%	0
6 (7)	12.50%	1
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0
10 (11)	12.50%	1
11 (12)	0.00%	0
12 (13)	12.50%	1
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0

45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics				
Minimum 1.00	Maximum 13.00	Median 4.00	Mean 5.75	Standard Deviation 3.96

Q22 Approximately how many total items binned per quarter under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate an average level of integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	12.50%	1
2 (3)	0.00%	0
3 (4)	0.00%	0
4 (5)	25.00%	2
5 (6)	25.00%	2
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	0.00%	0
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0
12 (13)	25.00%	2
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	12.50%	1
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0

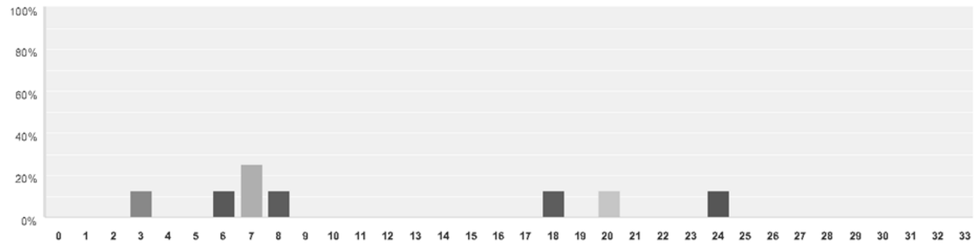
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	0.00%	0
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
2.00	16.00	6.00	8.25	4.68

Q23 Approximately how many total items binned per quarter under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate a minimal level of integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



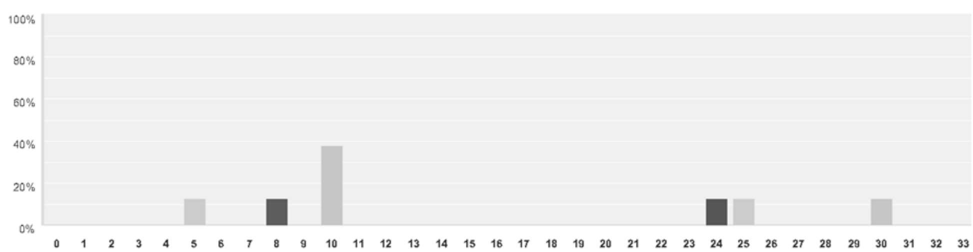
Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	0.00%	0
2 (3)	0.00%	0
3 (4)	12.50%	1
4 (5)	0.00%	0
5 (6)	0.00%	0
6 (7)	12.50%	1
7 (8)	25.00%	2
8 (9)	12.50%	1
9 (10)	0.00%	0
10 (11)	0.00%	0
11 (12)	0.00%	0
12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	12.50%	1
19 (20)	0.00%	0
20 (21)	12.50%	1
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	12.50%	1
25 (26)	0.00%	0
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	0.00%	0
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0

36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics				
Minimum 4.00	**Maximum** 25.00	**Median** 8.50	**Mean** 12.63	**Standard Deviation** 7.30

Q24 Approximately how many total items binned per quarter under Individual Commitment to Safety, Management Commitment to Safety and Management Systems would indicate an absence of integration of the Nuclear Safety Culture into normal operations:

Answered: 8 Skipped: 0



Answer Choices	Responses	
0 (1)	0.00%	0
1 (2)	0.00%	0
2 (3)	0.00%	0
3 (4)	0.00%	0
4 (5)	0.00%	0
5 (6)	12.50%	1
6 (7)	0.00%	0
7 (8)	0.00%	0
8 (9)	12.50%	1
9 (10)	0.00%	0
10 (11)	37.50%	3

11 (12)	0.00%	0
12 (13)	0.00%	0
13 (14)	0.00%	0
14 (15)	0.00%	0
15 (16)	0.00%	0
16 (17)	0.00%	0
17 (18)	0.00%	0
18 (19)	0.00%	0
19 (20)	0.00%	0
20 (21)	0.00%	0
21 (22)	0.00%	0
22 (23)	0.00%	0
23 (24)	0.00%	0
24 (25)	12.50%	1
25 (26)	12.50%	1
26 (27)	0.00%	0
27 (28)	0.00%	0
28 (29)	0.00%	0
29 (30)	0.00%	0
30 (31)	12.50%	1
31 (32)	0.00%	0
32 (33)	0.00%	0
33 (34)	0.00%	0
34 (35)	0.00%	0
35 (36)	0.00%	0
36 (37)	0.00%	0
37 (38)	0.00%	0
38 (39)	0.00%	0
39 (40)	0.00%	0
40 (41)	0.00%	0
41 (42)	0.00%	0
42 (43)	0.00%	0
43 (44)	0.00%	0
44 (45)	0.00%	0
45 (46)	0.00%	0
46 (47)	0.00%	0
47 (48)	0.00%	0
48 (49)	0.00%	0
49 (50)	0.00%	0
50 (51)	0.00%	0
Total		**8**

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
6.00	31.00	11.00	16.25	8.87

VITA

Education
- Old Dominion University, 2015, Major: Engineering Management, Degree: Ph.D.
- Liberty University, 2007, Major: Leadership, Degree: M.B.A.
- Excelsior College, 2003, Major: Technology (E/I T), Degree: B.S.

Licensures and Certifications
- Professional Engineer License (PE) (VA)
- Senior Reactor Operator (SRO) Certification (Surry Power Station)
- National Academy for Nuclear Training (NANT) Instructor Certification

Honors and Awards
- Institute for Nuclear Power Operations (INPO) Strength Awards 2003 and 2008
- Training Top Industry Practice (TIP) Award, Nuclear Energy Institute (NEI) 2003.
- Training Excellence Award, American Nuclear Society (ANS), April 1995
- U.S. Navy Commendation Medal, Secretary of the Navy, Department of the Navy

Association Memberships
- American Society for Engineering Management (ASEM) January 2014 to Present
- Golden Key International Honour Society (ODU/VCU Chapters) 2008 to Present
- The American Legion 2000 to Present
- International Society of Automation (ISA) (Senior Member) 1986 to Present

Professional Experience

2004 – Present, Project Manager/Supervisor/Engineer – Surry Power Station.

Teaching Experience

1986 - 2004, Instructor and Chair, I&C and Licensed Operator Requalification Programs, National Academy for Nuclear Training (SPS Branch)

Military Experience

1977 - 1983, Reactor Plant Operator/Technical Advisor/Supervisor - USN, *Protected Veteran Status*.

Published Papers
- Simulation Provides Insight and Training at Surry Nuclear Power Station, Visual Solutions Inc. December 12, 2000
- Computer-based simulations that provide dynamic analysis of process control fundamentals. The Nuclear Professional, INPO October 23, 1996

Conference Presentations

Multi-Criteria Analysis Investigation for Seismic Modifications in Nuclear Power Plants. The 6th International Conference of Management and Industrial Engineering October 31, 2013 Authors: James H. Warren, Jr. P.E., Adrian Gheorghe