CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

The primary goal of effective safety programs is excellent performance. This is accomplished through a strong and continued commitment by everyone in an organization to achieve zero injuries, zero significant harmful events and zero environmental harm. Other program goals also come into play such as “no one gets hurt,” positive rather than negative business impact, and employees striving to be good corporate citizens and community members. Many companies have achieved sustained excellent performance while some have not. Even good companies with strong safety programs sometimes have lapses. The reality is that people make mistakes and equipment can fail unexpectedly. Human error can be anticipated and prevented, or possible effects mitigated. Equipment can be designed appropriately and maintained correctly, and potential failures can be anticipated and safeguarded. Ultimately, excellent safety performance requires continuous focus, dedication and perseverance by management and employees who take purposeful actions to implement, improve and sustain effective safety practices (Klein, 2021). While prioritizing safety management in the construction industry is crucial, findings from Agyekum *et al* (2022), Adebiyi (2020), Gong *et al*, (2021) and Rivera *et al* (2021), indicates that numerous companies may not give due attention to safety concerns.

Despite numerous instances of successful manufacturing safety initiatives, many companies remain hesitant, viewing such efforts as potential cost escalations and time-consuming endeavors. There is growing recognition that in order to further improve safety performance, attention needs to be given beyond the immediate working conditions and worker actions (Gambatese and Al-Omari, 2016).

A better definition of performance relates to executing safety program requirements and systems with the intent of achieving program goals and objectives. Program goals should include Prevention of serious injuries and incidents and Use of other leading and lagging indicators to measure the functioning and effectiveness of safety program activities to provide early warning of possible problems.

Like medical professionals who routinely measure vital signs such as blood pressure and cholesterol for early warning of potential health problems, appropriate goals and metrics should be established, monitored and responded to by accountable facility personnel to monitor overall injury and safety program performance.

The importance of this study which is to compare safety performance systems in organizations cannot therefore be over emphasized.

1.2 Statement of the Problem

Safety management is commonly defined as the application of a set of principles, framework, various processes and measures aimed at averting accidents, injuries and associated repercussions stemming from the utilization of a facility or a product. Thus, the safety of any organization is a priority choice of any management decision to offer the best safety system to all concerned. Obviously, safety management system comes with a very high premium and yet the implementation of safety precautions nose – dive with little or no credibility.

OHS vulnerability refers to the situations in which workers are exposed to hazards in combination with inadequate protection to protect them from these hazards, with protections including OHS policies and procedures, awareness of OHS rights and responsibilities (Yanar *et al*., 2018), or a workplace culture that encourages worker participation in safety (Smith et al., 2020). According to the Expert Advisory Panel on Occupational Health and Safety of 2015, vulnerable workers have greater exposure to health and safety hazards than most workers and lack the power to alter those conditions.

Inadequate protection of workers exposed to hazards are at greater risk of injury and illness, and also, supervisor activities have been associated with injury risk (Premji and Smith, 2013). Yanar *et al.* (2019) claimed in their study that lack of supervisor assistance and OHS vulnerability in the workplace alone progressed the likelihood of physical injuries. In connection, the result of crude and adjusted models revealed that workers with a supportive supervisor were at less risk, unlike workers experiencing both OHS vulnerability and a lack of supervisor, which has at least 3.5 times higher risk of physical injury. It implies that the presence of a supportive supervisor would influence the risk level of the workers.

In this study, we introduce an experimental design technique known as the Central Composite Design (CCD) with five coded levels and four factors that would give a functional relationship with the proposed global regression method for adequate fitting of the data as generated from the compiled questionnaire. Thereafter, a single response optimization is performed to minimize the Squared – Distance from Target (SDT). Lastly,

a computer application will be applied for model validation on the regression method to further justify the results obtained from the predictive response for selected oil companies.
Safety management is complicated due to the complex "nature" of the workplace. Several factors related to workplace safety have been identified, including risk management and site management, organizational intricacy and combinations of these factors linked to safety performance.

Numerous work-related accidents and injuries continue to occur. Traditional methods, unfortunately, have become stagnant because they overlook market dynamics.
Despite recent technological advancements, the persistent risk to workers remains a pressing societal issue. Often, companies only acknowledge the need to address worker risks after an accident has transpired.
Some key question of Safety Performance includes:

i. What is the current level of performance?
ii. Is performance trending better, about the same, or worse?
iii. How can performance be improved?

1.3 Aim and Objectives of the Study

The aim of this study is to propose a predictive method via the use of experimental design technique for safety management system using computer application for model adequacy check.

The objectives are as follows:

i. To design a questionnaire for selected oil companies in Nigeria.
ii. To design an experiment using CCD
iii. To examine an appropriate global regression method for predicting the response generated from (i).
iv. To provide goodness-of-fit statistics and loss function for model adequacy check.
v. To validate the results of the global regression method through the use of computer application program.

1.4 Scope of the Study

This study focuses on a comparative evaluation of safety performance systems in both local and multinational oil companies operating in Nigeria.

1.5 Limitations of the Study

In the course of this work the following limitations were encountered:

i. Getting adequate data for the evaluation was a difficult task due to some reservations on the part of the respondents.

ii. Valuable literature review on this area was scanty as little research have been conducted in this regard.

iii. Time forms a major constraint as research of this magnitude require time for full implementation to be possible.

1.6 Significance of the Study

This study is a comparative evaluation of safety performance systems, and it is relevant to stakeholders in the safety industry because it enables the relevant regulatory agencies have informed knowledge of the performance of an organization's safety precautional mechanisms.

CHAPTER TWO

LITERATURE REVIEW

2.1 Safety Concern in Manufacturing Industry

Despite many success stories of manufacturing safety, many organizations still see safety as costly and time consuming. The primary issue may stem from the reliance on lagging indicators instead of proactive leading indicators. In Adebiyi's (2020) research, he introduced a comprehensive model for determining the most effective safety strategy. This model combined elements of combinatorial theory and cost benefit analysis to create a function that measured monetary savings and losses in terms of prevention value and prevention strategy costs. Adebiyi collected data for his model through documentation, interviews and structured questionnaire focusing on Before-And-After safety program records from a Tobacco company. The data spanned from 1993 to 2001(pre-safety) and 2002 to 2008 (safety period). Through this analysis, three combinatorial alternatives (A, B, C) were identified, resulting in 4, 6 and 4 respective safety strategies. These strategies incorporated elements such as PPE (Personal Protective Equipment) and Training. During a nine-year period of the pre-safety program, a total of 724 accidents were recorded, while during a seven-year period of the safety program, 163 accidents were reported. Notably, the strategy involving six prevention activities (alternative B) yielded the most favorable results, except for the year 2004. Overall, Adebiyi's study serves as a valuable resource for planning and implementing successful safety programs, highlighting the importance of utilizing leading indicators to enhance workplace safety.

Adebiyi *et al* (2018) developed a mathematical model for the evaluation of profitability of safety and health program in Tobacco industry in Nigeria. A cost function monetary savings/loss in terms of accidents and health incidences preventions, was developed. Accidents and health incidences for both pre – safety period and safety program period data were collected. Four classes of accidents were identified as fatal, serious, minor and trivial wounds with their costs determined as N2,455,750, N221,275, N26,780, and N2,000, respectively. Also, seven health incidences were identified as hearing issues, back pain/ache, leg pain/ache, chest pain/ache, neck pain/ache, eye issue and headache with their costs determined as N18,176, N22,987, N8,354, N17,296, N33,305, N14,432 and N12,842, respectively. Accident prevention program had monetary savings of N40.1 million while about N9.7 million were lost on health incidences annually. The results showed that the safety program performance indices range from 5.78% in 2002.

2.2 Safety Concern in Aviation Industry

Safety has been established in maintaining and improving the productivity level of the aviation industry with derivable benefits in terms of wealth and reputation. Despite high investments in aviation, safety is generally recognized as an incurred cost, leading to a compliance approach. Akinyemi and Adebiyi (2019) introduced predictive models designed to assess investment strategies for enhancing runway safety and to forecast the overall performance of the aviation system. These models are built using a System Dynamics approach employing stock and flow diagrams to represent the complex relationship within the system. To make these models accessible, an interactive computer program was developed using the Java programming language. The models incorporated a set of dynamic equations capable of predicting various aspects of runway safety, including accident occurrences, prevention measures, monetary savings or losses, and the breakeven point for safety programs. Two critical parameters, the effectiveness of runway safety interventions and the level of budget implementation, were used to regulate the behavior of the runway safety system. To validate the models, relevant data were obtained from the Federal Aviation Authority in Nigeria. In total, twenty-nine different quantities related to runway safety were identified and incorporated into the models. The dynamic equations for runway accident prevention and monetary outcomes exhibited exponential growth, while the number of actual runway accidents showed exponential decay. The results of the simulation demonstrated that the models closely aligned with real-life situations, revealing no significant differences. This suggests that these models can be valuable tools for effectively and efficiently managing the behavior and performance of runway safety programs in aviation.

The substantial surge in aviation activity and air traffic witnessed over recent decades has given raise to multiple public health concerns. Among these concerns, a paramount issue is runway safety, coupled with the escalating demand for accident-free airports. Apart from the evident threat to human lives, runway accidents often result in severe environmental and pollution related consequences. In a study conducted by Yousef *et al*, (2020) an innovative three-tiered approach was employed to evaluate the risks associated with runways. This approach considered accident probability, geographical factors, and the potential outcome of accidents utilizing advanced statistical techniques. The research put forward original models for implementing these three stages of assessment within the context of Iran. Data pertaining to runway excursion accidents were gathered from various countries with comparable air accident rates. These proposed models provide engineers

with the means to conduct precise evaluations of accident probabilities and safety assessments for airports. In cases of operational airports, they offer the capability to assess existing runways and, if deemed necessary, take measures to eliminate obstacles in close proximity to the runways. Furthermore, these models can be utilized for preliminary assessments when developing existing airports or constructing new runways.

2.3 Safety in Petroleum Industry

Ali *et al* (2022) conducted an assessment of the efficacy of a safety management system (SMS) within a liquefied natural gas company. They employed a 5-point Likert questionnaire which encompassed questions ranging from "strongly disagree to strongly agree". These questions were utilized to gauge employee's perception regarding the impact of the safety management system within the organization. Additionally, the OHSAS (Occupational Health and Safety Assessment Series) 18001 internal audit checklist was used to gauge compliance level with SMS requirements. Secondary data were gathered from document and safety reports related to the case study. The collected data underwent analysis, including descriptive statistics, t-test and row and column contingency table to examine the relationship between safety performance and compliance. The findings regarding SMS compliance were as follows: General requirements, 91%; Health and Safety Policy, 95%; Planning, 93%, Implementation and Operation, 98%; Audit, 98%; and Management Review, 93%. The overall average level of compliance was 95%. A total of 100 respondents participated in the questionnaire, 64 males and 36 females; as well as 68 technical personnel and 32 non-technical respondents. The descriptive analysis of employees' perception yielded the following results: Safety satisfaction and feedback, 4.113; Training and competence, 4.182; Safety reporting and investigation, 4.212; Work Duties/Pressure, 3.989; Management commitment, 4.098; Safety communication, 4.171; and Emergency response and planning, 4.126. A t-test revealed no significant difference in perception between males and females, as well as between technical and non-technical employees with $p > 0.05$. The relationship between safety compliance and safety performance was evaluated using a row-and-column contingency table which indicated a significant difference between the two. Consequently, the study concluded that the SMS would continuously enhance safety performance and emphasized the critical importance of the safety management system. While safety practices have evolved over time and become a matter of common sense in numerous industries, the study contends that adherence to SMS requirements is pivotal for achieving sustained, continuous improvement in safety

performance. As such, the study encourages organizations to consider safety management system certification.

2.4 Safety in Engineering Industry

Managing safety in the construction industry poses challenges due to the intricate "nature" of the sector. Winge *et al* (2019) identified various elements influencing safety management, encompassing safety management factors (such as risk and site management), contextual factors (including organizational complexity) and combinations of these components linked to safety outcomes. To examine safety management and safety performance, twelve construction projects were chosen for comparison. An analytical framework was devised drawing upon prior research, regulations, and standards to precisely define each management factor. Qualitative comparative analysis (QCA) was utilized to generate case-specific insights, perform inter-case comparisons, and establish associations between the factors and safety performance. The data collection and analysis encompassed included construction planning documents, reports from OHS-inspections, safety indicators, and interviews with project leaders and OHS experts. The study findings revealed the following key points: (a) projects with high safety performance tended to exhibit higher average scores across the twelve safety management factors compared to those with lower safety performance; (b) high safety performance could be achieved in projects characterized by both high and low construction complexity and organizational complexity. However, these factors introduced complexities in coordinating project participants and operations; (c) high safety performance was attainable despite relatively subpar performance in many safety management factors; (d) eight safety management factors were deemed "essential" for achieving high safety performance. These factors encompassed roles and responsibilities, project management, OHS management and integration, safety climate, learning, site management, staff management, and operative risk management. Notably, site management, operative risk management, and staff management were the three factors most strongly connected with safety performance. This research underscores the significance of comprehending the interplay of key safety management factors, contextual elements, and their combinations in achieving high safety performance in construction projects.

Safety management programs (SMPs) are crafted to reduce the risk of workplace injuries and foster a secure working environment. In a study by Dele *et al* (2020) the correlation between contractors' SMPs and the perceived safety climate and safety behaviors of workers in small and medium-sized construction subcontracting firms was scrutinized.

Subcontractor SMP scores were assigned based on 18 safety-related elements encompassing both organizational and project-level aspects, which were drawn from the subcontractors' documented safety programs and interview responses. Workers partook in surveys to convey their assessment of their contractor's safety climate and the safety conduct of their colleagues, teams, and themselves. The investigation employed Spearman correlation analysis and hierarchical linear regression models (HLM) to explore the links between SMP scores and safety climate and behavior evaluations. The study, encompassing 78 subcontractors engaged in sizable commercial construction projects, unveiled notable variations in SMP scores among small, medium, and large subcontractors ($p < 0.001$), mainly attributed to specific safety management practices. However, the research disclosed only modest association between SMP factors and safety climate ratings reported by 746 workers employed by these subcontractors ($\beta = 0.09$, $p = 0.04$ as per HLM). Notably, no discernible variations were observed in worker reported safety climate and safety behaviors with respect to contractor size. This underscores that SMPs offered limited predictive capacity for subcontractors' safety climate assessments. Nonetheless, significant disparities were evident in the quality and substance of SMPs based on the size of the employing organizations.

Over the past few decades there has been a notable reduction in workspace injuries and fatalities in the UK construction industry, primarily due to advancements in occupational health and safety (OHS) management systems. Nevertheless, safety performance has seemingly reached a plateau, prompting the need for further enhancements in OHS management systems. OHS expertise is a multifaceted domain encompassing both implicit and explicit components, deeply rooted in ongoing practices. There is a pressing need for institutionalization and the seamless transfer of knowledge within and between organizations throughout the construction supply chains to mitigate OHS risks and foster a cultural shift. Duryan *et al* (2020) elucidated the factors facilitating the transfer of OHS knowledge within and between organizations participating in construction projects. The research employed an interpretative approach to account for the tacit facets of knowledge transfer and application. Thematic analysis augmented by a cognitive mapping technique, was employed to unravel the intricate connections among the concepts conveyed by the respondents. The findings unveiled inconsistency in OHS practices across construction organizations and underscored the paramount importance of cultivating a positive safety culture. Such a culture is instrumental in promoting the transfer of insights gleaned from good practices, incidents, near misses and failures, not only between individual projects

but also from projects to overarching programs and across the entire supply chain. Furthermore, the study recognized that governmental health and safety regulations, norms and guidelines often fail to encompass all safety concerns specific to diverse work environments and contextual work settings. Consequently, the OHS system should encourage employees to report near misses, incidents and failures within a 'no-blame' framework and facilitate the implementation of appropriate corrective measures.

The construction industry plays a significant role in contributing to the economy and development globally. During the process of construction, various hazards coupled with the unique nature of the industry contribute to high fatality rates. Jaafar *et al* (2020) have identified four primary factors encompassing human, worksite, management, and external elements, that contribute to occupational accidents and illnesses. External and management elements are the underlying causes contributing to occupational safety and health (OSH), while human and worksite elements are more apparent causes of occupational accidents and illnesses. An effective OSH management approach is required to contain all hazards at construction sites. An approach to OSH management constructed by elements of policy, process, personnel, and incentive developed in previous work was explored.

2.5 Occupational Safety in Engineering Firm

In August 2014, Zimbabwe introduced the National Occupational Safety and Health Policy (ZNOSHP) with the overarching goal of eradicating workplace accidents, injuries, diseases, and fatalities while advancing the cause of Occupational Safety and Health (OSH). Mkungunugwa *et al*, (2022) delved into the factors, both at the individual- and organizational-levels, influencing the implementation of ZNOSHP. The study involved data collection from 309 employees situated in the Willowvale industrial area in Harare, Zimbabwe. The investigation harnessed negative binomial regression models to investigate the determinants of ZNOSHP's implementation. After adjustment, several factors emerged as noteworthy participant's familiarity with ZNOSHP (Incidence Rate Ratio, IRR = 1.32; 95% Confidence Interval, CI: 1.19-1.46; $p \leq 0.001$), production department (IRR = 1.13; 95% CI: 1.03-1.26; $p \leq 0.05$), company years of operation (IRR = 1.33; 95% CI: 1.21-1.46; $p \leq 0.001$), participants who identified several implementation barriers (IRR = 1.12; 95% CI: 1.01-1.25; $p \leq 0.001$), and agricultural industry were associated with higher rates of ZNOSHP's implementation. This research unearthed both individual- and organizational-level determinants of implementation of OSH standards with positive correlation observed. To ensure adherence to safety measures, it is

imperative that strategies for policy implementation, enforcement, and follow-up are thoughtfully devised and put into action.

The construction industry continues to be a focal point of safety concerns, leading to sustained interest in research pertaining to occupational safety and health (OSH) regulations. Prior research has highlighted that OSH regulations exert a direct influence on performance and indirectly by heightening awareness of these regulations. Furthermore, investigations have underscored the impact of OSH regulations on both innovation and corporate safety. However, the precise relationship between OSH regulation and innovation remains somewhat elusive, as our comprehension of the connection between the perception of OSH regulation and innovation remains incomplete. In a study conducted by Shin and Kim (2021), the innovation efficiency of companies in the Korean construction industry was evaluated using data envelopment analysis (DEA). Additionally. The study delved into the interplay between innovation efficiency and companies' perceptions of OSH regulations. The findings indicate that companies with a positively view of OSH regulations tend to exhibit higher levels of innovation compared to those with a less favorable perspective. This study further corroborates variations in innovation efficiency contingent up on the perception of OSH regulations through bootstrap DEA analysis. The outcomes of this research offer valuable insights for shaping effective strategies aimed at fostering innovation within the construction industry, with implications for both government policies and practical implementation within firms.

Johansson *et al* (2019) conducted a study that aimed to shed light on various aspects the of occupational safety and associated risks while also identifying areas in which research is yet to be explored. Their investigation encompassed the analysis of 146 articles sourced from scientific journals, predominantly focused on the construction industry across regions including Europe, Canada, USA, Australia, and Japan. The research findings were categorized into 11 distinct areas: accident statistics; individual factors; legislation and regulations; ethical considerations; risk management; leadership, management, organization; competence; safety design; cost-benefit calculations; programs and models; and technical solutions. Notably, the research landscape primarily featured contributions from researchers and government bodies, with the construction industry primarily serving as the subject of the research rather than an active participant. Significant gaps were identified in the research, particularly in the domain of integrated systems involving subcontractors and a dearth of research with sociological perspectives on accidents. Furthermore, only a limited number of studies have incorporated a gender perspective on

safety into the examination of safety in the construction sector, indicating the need for more extensive exploration in this area. Despite some cultural disparities the initiatives aimed at enhancing safety in the construction industry have generally yielded positive outcomes, with researchers presenting similar results regardless of the country or region under investigation.

Total Worker Health (TWH), an initiative of the U.S. National Institute for Occupational Safety and Health, encompasses policies, programs, and practices that amalgamate safeguarding against work-related health and safety hazards with the promotion of efforts to enhance worker well-being. Its noteworthy that interventions rooted in the TWH framework yield swifter advancements in workplace health in comparison to standalone wellness programs. However, the available evidence pertaining to the obstacles and enablers influencing the adoption, implementation, and long-term sustainability of TWH programs is rather limited. Dissemination and implementation (D&I) science, a field dedicated to exploring methodologies and strategies for bridging the chasm between public health research and practical application, can serve as an asset in addressing these factors, spanning system-level, setting-specific and worker-centric dimensions. D&I science offers a means to amplify the adoption, impact, and continuity of TWH initiatives. Harden (2021) leveraged a comprehensive synthesis of the existing D&I science literature to furnish TWH researchers and practitioners with: (1) an overview of D&I science; (2) a plain language explanation of key concepts in D&I science; (3) a case study example of moving a TWH intervention down the research-to-practice pipeline; and (4) a discussion of future opportunities for conducting D&I science in complex and dynamic workplace settings to increase worker safety, health, and well-being.

2.6 Current State of Safety Trend in Engineering

The construction industry is acknowledged for its high-risk nature, marked by a frequent occurrence of safety incidents and worker injuries. This study undertook a systematic and quantitative examination of the existing body of research by employing a social network analysis approach. Its aim was to discern the present states and anticipate future trends concerning the occupational safety of construction workers. A comprehensive set of 250 peer-reviewed articles was amassed for an exhaustive exploration of safety concerns within the construction industry. Utilizing tools such as VOS viewer and CitNetExplorer, a social network analysis was executed to scrutinize the interconnection among authors, keywords, and citations within these articles. This analytical process facilitated the creation of a knowledge structure map using main path analysis (MPA) for the assembled

papers, a task executed with the aid of Pajek. In congruence with the outcomes of the social network analysis, the study delineated five distinct research clusters and identified six overarching keyword themes, each corresponding to the collaborative history of researchers and the correlation among keywords featured in the papers. Moreover, core papers were pinpointed through main path analysis, signifying their pivotal role as the primary reference points and foundational pillars within the respective research domains. Drawing upon these research findings, the study imparted valuable implications and insights concerning the current status of research and forthcoming research trajectories. These insights serve as a valuable resource of scholars aiding in the formulation of targeted developmental plans aimed at advancing occupational safety within the construction industry.

2.7 Factors Affecting Safety in Engineering Firm

Rivera *et al* (2021) have noted that the construction industry, by virtue of its activities, environmental conditions, and operational dynamics, is characterized by elevated rates of accidents. In response to this, various initiatives have emerged with the objective of curbing these statistics. These initiatives predominantly revolve around the adoption of novel methodologies and technologies for the management of safety in construction. Therefore, it becomes imperative to comprehend the pivotal factors that would influence over safety within construction projects (fSCPs). To channel efforts effectively, this study conducted a systematic literature review following the PRISMA methodology. The review identified, expounded upon and categorized a total of 100 factors that exert an impact on construction safety. This endeavor represents a significant contribution by furnishing a comprehensive overarching framework, consolidating prior research endeavors that often focused on specific geographic regions or case specific scenarios. These previous studies may have overlooked factors or provided insufficient granularity in their classifications. Moreover, they often lacked a comprehensive perspective on how and where these factors intersect with various facets of construction projects. The 100 factors identified are systematically described and categorized based on the dimensions and facets of the project in which they manifest their influence. Additionally, these factors are differentiated as either immediate influences or originating determinants that contribute to accident occurrences. This compilation, along with its detailed descriptions and categorizations, stand as a pivotal contribution. It holds the potential to enhance the structured formulation of safety measures and serves as a foundation resource for the development of training materials and awareness initiatives aimed at fostering a robust safety culture within organizations.

Safe behavior and work conditions are a major concern in construction projects. However, accidents occur due to system failures, not a single factor such as unsafe behavior or condition. Construction safety should be investigated by a systematic view capable of illustrating the complex nature of accidents. The present research aims to detect and categorize behavior patterns recurring in construction safety management continuously. In order to attain the goals of this study, an approach combining content analysis and the ground theory method (GTM) was employed. A thorough examination was conducted on a corpus of 90 articles, spanning various regions worldwide, to delve into the determinants that impact safety within construction projects. Furthermore, 20 interviews were carried out, engaging individuals possessing extensive expertise in the realm of construction health and safety. The data collection process yielded four distinct archetypes encompassing factors such as delay in design, number of subcontractors, cost and safety of project, and supervisors and safety. Each archetype is completely discussed at different steps of dynamic complexity, behavior over time, and the leverage point to show how to deal with the archetype (Mohammadi, 2018).

2.8 Safety Performance in Engineering Firm

The construction industry grapples with subpar safety performance primarily stemming from a twofold issue; insufficient safety investment by contractors and inefficient safety supervision by the government because of the information gap between the two sides. The primary objective of this study is to introduce a novel approach for enhancing the efficiency of safety investment supervision while analyzing the decision-making dynamics among relevant stakeholders operating within this new framework. To achieve this goal, the study establishes a safety investment information system tailored to bridge the information divide between the government and contractors for construction projects in China and further develops a dynamic safety investment supervision mechanism based on this. Evolutionary game theory is used to describe the decision-making interactions among stakeholders under the current static supervision mechanism and the dynamic supervision mechanism proposed in this research. Furthermore, the study employs system dynamics to simulate the evolutionary game progression. It examines the and supervision outcomes and equilibrium states associated with various supervision mechanisms. The findings indicate that the suggested safety investment information system holds the potential to facilitate the shift from a static to dynamic supervision paradigm. Also, the analysis reveals that within the current static penalty framework, there is no existence of an evolutionarily stable strategy. Conversely, the dynamic supervision mechanism, which

correlates penalties with the probability of contractors' engaging in unlawful behavior, effectively curtails fluctuations within the evolutionary game model. Over time, it fosters the stabilization of strategy choices among participants, ultimately leading to an equilibrium state. These results underscore the efficacy of the proposed dynamic supervision mechanism in bolstering supervision efficiency. This study not only enriches the discourse on safety supervision policymaking but also offers practical insights for enhancing supervision efficiency in real-world scenarios (Gong *et al*, 2021).

2.9 Game Theory Study and Safety in Engineering Firm

Ning*et al*, (2022) recognized that achieving effective supervision for ensuring the safety behavior of front-line workers is a challenging endeavor when enterprises and frontline workers are not actively engaged. In the absence of such active involvement, government supervision faces limitations, including information dilution due to vertical management approaches and constrained resources. Consequently, there is a pressing need to shift from passive oversight to active control, wherein enterprises and workers actively participate in safety supervision. In order to address these issues, this study introduces a fusion of the entity responsibility mechanism and the third-party participation mechanism, integrating them with government supervision. This integrated approach is utilized to dissect the decision-making processes of both government entities and enterprises regarding safety behavior supervision. An evolutionary game model was constructed to delineate the decision-making dynamics between the government and construction enterprises operating under the influence of these two mechanisms. Furthermore, a simulation is conducted to elucidate the factors that influence the effective implementation of these mechanisms. The findings underscore the beneficial impact of both mechanisms on government supervision, with the third-party participation mechanism demonstrating superior effectiveness. The successful implementation of these mechanisms is contingent on several factors, including punitive measures, subsidies, and associated costs. Importantly, each mechanism displays distinct sensitivities to these influencing factors. This study contributes by presenting a theoretical framework aimed at enhancing the government supervision mechanism. It lays the foundation for informed decision-making between government bodies and construction enterprises. thereby enriching management practices and guiding the practical execution of supervision protocols.

2.10 Towards Improving Safety in Engineering Firm

The available evidence underscores the prevalence of work-related accidents and injuries within the realm of construction projects. In response, governments have implemented an

array of administrative measures in recent years with the intent of diminishing casualties. However, these conventional approaches have encountered a roadblock, primarily due to their disregard for market dynamic. Consequently, there arises a pressing need for innovative measures to address these challenges. In this context, Pi *et al* (2019) have introduced a novel perspective on safety performance (SP) tailored to the construction projects in China. They proposed the development of a safety information system, a concept born out of collaborative brainstorming sessions aimed at bolstering safety oversight within the construction industry. This system, in turn, disseminates rating information to the public, and contractors with subpar performance find themselves on a blacklist that exerts influence over their economic activities. Recognizing the inherent limitations of both government entities and various contractors, this study undertakes the construction of a judicious evolutionary game model. This model serves to substantiate the viability of the safety information system. The analysis results show that there is not a single set of evolutionarily stable strategies (ESSs), due to the variability of circumstances, which can lead to different ESSs. Nevertheless, the efficacy of applying the safety information system (the blacklist) in the construction industry is demonstrated through reduced government safety supervision cost and simultaneous improvements in construction safety.

2.11 Accident Prevention in Engineering Firm

Workers in the construction industry are constantly exposed to dangers during work that can lead to death or disability. Despite recent advances in construction technology, the presence of these risks for workers has become an unresolved social issue. Typically, companies tend to acknowledge the necessity of risk mitigation for workers only in the aftermath of accidents. This has sparked a growing demand for the development of new safety technologies and policy recommendations to safeguard workers during construction and related activities. However, it is essential to recognize that the optimal solution lies not in merely reacting accidents but in preventing them. Achieving this goal requires proactive commitment from companies. In order to work towards such preventive solutions, Korea has undertaken an initiative to access construction companies' efforts in preventing industrial accidents voluntarily without relying on legal mandates or coercion. In their work, Kang *et al* (2021) proposed a direction for enhancing the effectiveness of the system implemented by the Korea Occupational Safety and Health Agency. The process involves a comprehensive evaluation of the systems intricacies and an analysis of the evaluation results to gauge its efficiency and rationality. Subsequently, steps for refinement are

delineated. Furthermore, the study introduces an evaluation model that factors in the size of the company under evaluation and the level of safety and health. The model's validity is substantiated through a survey involving construction workers. Ultimately, the research outlines a strategy to incentivize the voluntary participation of construction companies within this system and underscores the supervisory authority's role in this endeavor.

2.12 Safety and Climate Adaptation in Engineering Firm

The frequency and intensity of extreme climate events are increasing all around the world and this is due to climate change. In light of the impending impacts of climate change, it is imperative to adopt climate adaptation strategies as reliance solely on mitigation measures proves insufficient to avert severe consequences. However, the path to climate adaptation is far from straightforward, as it grapples with a complex interplay of diverse and conflicting interests, along with the presence of epistemological (or scientific) uncertainties, rooted in scientific knowledge. In order to ensure its efficacy, active engagement of stakeholders and citizens in the adaptation policy cycle emerges as a fundamental prerequisite.

While safety climate is widely acknowledged as a valuable precursor of safety performance, research on safety climate within the Canadian construction sector has been relatively limited. It is essential to recognize that safety climate may exhibit geographical variations, underscoring the need to investigate how this concept is conceptualized and employed to enhance safety outcome in different regions. Concurrently, growing attention has been directed towards job related stress in the construction industry. Earlier studies have postulated that individual resilience could potentially correlate with enhanced safety performance and serve as a coping mechanism for employees in managing stress. Regrettably, there exists a dearth of empirical research endeavors aimed at scrutinizing this hypothesis.

Chen *et al* (2017) investigated the functions of safety climate and individual resilience concerning safety performance and job-related stress within the context of the Canadian construction sector. The study was grounded on data collected from 837 surveys administered in Ontario over the span of one year, commencing in June 2015 and concluded in June 2016. The researchers employed Structural equation modeling (SEM) techniques to scrutinize the influence of individual resilience and safety climate on both physical safety outcomes and psychological stress experienced by construction workers. The outcome of the study unveiled that safety climate exhibited not only a direct impact

on safety performance among construction workers but also exerted an indirect influence on their psychological stress levels. Furthermore, the research divulged that individual resilience exerted a direct mitigating effect on psychological stress, yet it did not bear any influence on physical safety outcomes. These findings underscore the significance of both organizational and individual factors in shaping individual safety performance and contributing to psychological well-being.

2.13 Engineering Firm and Safety Performance Measurement

Although complexity and resilience are key inter-related characteristics of construction projects, little is known on how to monitor these characteristics and their implications for safety management. This research delves into the role of Safety Performance Measurement Systems (SPMS) in monitoring and comprehending the factors contributing to complexity and resilience in the construction domain. The study is underpinned by three empirical investigations conducted within construction projects, with two of them situated in Chile and one in Brazil. Within these studies two primary instruments were employed: (i) the Technical, Organizational and Environmental (TOE) framework, directed at complexity assessment; and (ii) the Resilience Assessment Grid (RAG), geared towards resilience evaluation. Through these enquiries, opportunities for enhancing existing SPMS were pinpointed. Furthermore, a set of guidelines emerged, serving as a blueprint for the development of SPMS. Additionally, a model was formulated to elucidate the interconnections among the principal constructs encapsulated by these guidelines (Peñaloza *et al*, 2020).

Safety professionals play a pivotal role in making decisions related to project safety and risk assessment within the construction industry. Their perceptions of safety risk directly influence the reliability of risk assessments. Typically, safety professionals tend to heavily rely on their own past experiences, leading to subjective risk assessment decisions devoid of a systematic approach. Therefore, a solid grasp of the fundamental principles of risk assessment is essential. Fung *et al* (2012) conducted qualitative analysis to delve into safety professionals' beliefs about risk assessment and their outlook on the subject. This encompassed their recognitions of potential accident causes, the extent to which they differentiated risk levels among various trades, acknowledgement of different types of accidents, and the interplay of these factors with safety performance in terms of accident rates.

Additionally, the study addressed shortcomings in current risk assessment practices. Drawing from their findings and the historical accident data from 15 large-scaled construction projects in 3-year average, the researchers developed a quantitative risk evaluation model. This model prioritizes risk levels across different trades and identifies causes of various types of on-site accidents.

The proposed model known as Q (2) REM serves as a valuable supplementary guide for construction safety professionals in risk assessment. It assists them in identifying potential on site risk specific to different trades through safety trainings and education thereby raising safety awareness. Q (2) REM offers clear insights into potential accident causes corresponding to different types of accident by trade, enabling safety professionals and relevant stakeholders to devise effective accident prevention measures based on priority of the risk levels. In light of the dynamic nature of construction work and its associated environmental factors, the industry experiences high accident rates. Numerous initiatives aimed at reducing these incidents have emerged, focusing on the adoption of novel methodologies and technologies for safety management.

Hence, it becomes imperative to comprehensively understand the key factors influencing safety in construction projects (fSCPs) to concentrate efforts on these elements. Rivera *et al* (2021) conducted a systematic literature review following the PRISMA methodology, identifying, describing, and categorizing 100 factors that impact construction safety. This endeavor contributes significantly by providing a holistic framework that unifies prior studies, transcending specific geographic contexts or case studies. Notably, it addresses factors that had hitherto been overlooked or inadequately disaggregated. Furthermore, the classifications are oriented towards elucidating where and how these factors influence various dimensions of construction projects. These factors, along with their detailed descriptions and categorizations, serve as a crucial resource for enhancing the systematic development of safety measures and creating training and awareness materials that foster a robust safety climate within organizations.

2.14 Impact of Covid-19 On Health and Safety in the Construction Sector

The construction industry has experienced significant disruptions due to the impact of COVID-19, necessitating a continuous emphasis on safety and risk management while maintaining project timelines. The guidelines for addressing COVID-19 should be implemented in a manner that aligns with established working practices and project demands. Nevertheless, there exists a potential gap in knowledge regarding the practical

feasibility and consequences of enforcing COVID-19 measures within construction. This challenge is compounded by factors such as the transient nature of construction projects and intricate working arrangements. This paper provides an analysis of ensuring safety in construction during and after the COVID-19 era, addressing the human factors challenges and the practical aspects of implementing COVID-19 protocols. It is evident that while there is comprehensive guidance on risk management, there is still uncertainty about the most effective ways to put this guidance into practice. Additionally, caution must be exercised to ensure that the implementing of these guidance does not compromise overall safety, which is further strained by the increased pressures stemming from COVID-19 related project delivery challenges. Nevertheless, there may be opportunities to enhance safety practices through heightened awareness of health, hygiene, and safety risk. Notably, the role of safety leadership which is essential for the secure implementation of COVID-19 protocols, is often overlooked in guidance documents. The key takeaway is that COVID-19 measures should be seamlessly integrated into and promoted within the broader context of risk management. This approach accounts for varying safety priorities, rather than solely concentrating on COVID-19, and leverages the effectiveness of COVID-19 mitigations by incorporating them into existing safety processes (Stiles *et al*, 2021).

2.15 Management of Safety in Engineering Industry

Resilience engineering has been advocated as an alternative to the management of safety over the last decade in many domains. Nevertheless, devising a system for quantifying and analyzing the resilience capabilities of emergency departments (EDs) poses a substantial challenge. This research endeavors to transform Hollnagel's resilience assessment grid (RAG) into a customized version known as ED-RAG to enhance resilience management within EDs. Chuang et al., (2020) approach encompassed three key phases:

1.) Translating: Hollnagel's RAG into a Chinese version, and subsequently creating a tailored set of ED- RAG queries tailored specifically to ED settings.

2.) Testing and refining these customized question sets to attain a satisfactory level of validity for practical application.

3.) Developing a fresh rating scale and scoring methodology. The evaluation criteria for the ED-RAG questionnaire adopted the modified three-tier scoring system introduced by Bloom and Fischer. The field test was conducted in a private regional hospital. The fifth iteration of the ED-RAG questionnaire demonstrated acceptability following the field test.

It includes three sets of open-ended questions relating to the potential to respond, monitor, and anticipate, along with a set of structured questions concerning the potential to learn. In total, it comprises 38 questions corresponding to 32 focus areas. The introduction of a new 4-level rating scale and an innovative scaling method enhance the validity of score conversion and facilitates effective communication among team members and across various investigations. This final version is designed to facilitate interviews lasting approximately 2 hours (Chuang *et al*., 2020).

Creating an occupational health and safety management system (OHS MS) is a crucial step in establishing a systematic approach for enhancing health and safety standards. It is widely recognized that the construction industry experiences numerous accidents and injuries, with a significant portion of these incidents happening within small and medium-sized enterprises (SMEs). In their work, Gunduz and Laitinen (2017) introduced a quantitative indexing method for OHS MS and demonstrated its practical application within real SMEs. The study discussed the promising outcomes of this approach.

2.16 Safety and Multicriteria Decision Making Tool in Engineering Firm

Gunduz and Khader (2020) delved into the challenging environment of the construction industry, recognized for its inherent riskiness due to the complex interplay of labor, machinery, accelerated activities, and overlaps. This complex scenario often leads to accidents and fatalities, which, in turn, result in added expenses and project delays, affecting all stakeholders negatively. In order to plan effectively, it becomes imperative to identify and assess hazards, understanding their implications for building safety. The process of categorizing security risks is intricate, as these risks are interconnected, and existing literature lacks an exploration of these interdependencies and their associated occurrence frequencies. In order to address this gap, this research adopted a two-pronged approach, combining the frequency-adjusted importance index with the Analytical Network Process (ANP) tool. This combined approach facilitated the exploration of 14 interconnections among hazards, alongside their respective frequencies, as ascertained through a survey distributed to 106 professionals within the construction industry. The principal contribution of this study lies in its ability to identify and prioritize potential risks within the construction sector, considering their interrelationships and the frequency of their occurrence. This research marks the pioneering effort in the existing literature to integrate the frequency-adjusted importance index and the ANP tool comprehensively. The outcomes derived from the importance index served as the foundation for the pairwise

comparisons within the ANP model. Drawing insights from the model, the study furnishes recommendations tailored to industry professionals for their consideration and implementation.

2.17 Assessment of Safety in Engineering Firm

In spite of the concerted efforts exerted, there has been no substantial reduction in the frequency of accidents within the construction industry. This lack of progress can be attributed to the unique challenges associated with the nature of work in this sector, where conducting hazard analysis and implementing safety measures proves to be considerably more intricate compared to other industries. In order to address these persistent issues, it becomes imperative to adopt a comprehensive approach towards hazard analysis. This approach should concentrate on the specific activities through which a given work task is carried out, as these activities exhibit distinct categories of hazards, each associated with varying levels of risk. The research introduces a methodology that melds the principles of quality function deployment (QFD) with the analytical network process techniques to establish connections between work activities, potential hazardous incidents, and their respective consequences. This integrated approach enhances the decision-making process, simultaneously reducing the uncertainty inherent in qualitative assessment criteria. The outcomes of this study contribute to expanding our understanding of the applicability of QFD in safety-related research, thereby offering a foundation for its utilization in future investigations (Fargnoli *et al*., 2020).

2.18 Inter Dependency of Safety Measures in Engineering Firm

The presumption that safety risks within construction projects exist independently creates a fragile foundation for conducting risk assessments, potentially leading to biased management strategies. Therefore, it is crucial to gain an understanding of the interconnections among hazards in the context of construction safety risk assessment. In their study, Pin-Chao et al. (2020) introduced a hybrid approach, blending qualitative and quantitative methods, to elucidate these hazard associations. Utilizing the hazard network model applied to an elevator installation scenario, they identified distinctive traits of the hazard network and pinpointed critical hazard categories based on these associations. The primary findings of their research include;

(a) The topology of the hazard network is characterized by an exceptionally sparse distribution of hazard associations, with a limited number of central elements and highly cohesive interrelations.

(b) Effective risk management should prioritize a range of hazard mitigation strategies rather than relying solely on causal relationships.

(c) Human error leading to a wrong sequence emerges as the most pivotal factor influencing various hazards. These conclusions enrich the existing body of knowledge by shedding light on the distinctive features of hazard interdependencies (Pin-Chao *et al.,* 2020).

2.19 Environmental Impact on Engineering Safety

Unsafe conduct stands out as a primary contributor to accidents, with the working conditions exerting a significant influence on such behaviors. However, the existing body of research has paid limited attention to the intricate mechanisms underlying the manifestation of unsafe behaviors due to environmental constraints. The primary objective of this investigation is to elucidate these mechanisms through the application of cognitive work analysis (CWA), as illustrated in a case study centered on elevator installation. The choice of elevator installation as the subject of study stems from the fact that this task involves working at elevated heights, with falls from such heights being a leading cause of fatalities among construction workers. The research adopts a mixed-methods approach, encompassing three distinct stages of research methodology. This comprehensive approach dissects various aspects, including the specifics of the work environment, the decision-making processes of the workers, the strategies they employ in response to environmental conditions, and the development of a conceptual model encapsulating worker behaviors. Together, these components provide a detailed exposition of the intricate interplay between the environment and behavior. Implementing CWA within the construction industry, it becomes feasible to readily pinpoint environmental constraints and formulate targeted engineering recommendations to enhance safety (Yanqing *et al*.,2019).

2.20 Safety and Unsafe Behavior in Engineering Industry

Unsafe behaviors among construction workers rank as a primary catalyst for accidents occurring at construction sites. Research focused on understanding and mitigating these unsafe behaviors has garnered significant attention due to its potential to curtail accident rates. However, there remains a notable gap in the literature—a systematic review of this subject has yet to be conducted, impeding a comprehensive grasp of construction workers unsafe behaviors by stakeholders. To address this gap, Meng *et al*. (2022) undertook an investigation utilizing literature sourced from the Web of Science.

In the initial phase, the study performed a descriptive analysis, examining variables such as publication year, quantity, publishing institution, and keywords associated with them literature. Subsequently, three key research themes were identified and explored: them factors influencing construction workers unsafe behaviors, the mechanisms underlying the formation of these behaviors, and the proactive measures for controlling them. Furthermore, the study introduced a research framework and put forth future avenues for research inquiry. The research findings serve to enhance stakeholders comprehension of the factors at play, the mechanisms at work, and the strategies for preventing construction workers unsafe behaviors, ultimately guiding future research in this domain.

Recognizing the significance of safety education and training for employees in ensuring construction site safety and bolstering employees safety awareness, it is imperative to adapt traditional safety education and training approaches to meet the evolving demands of safety production in today's context. Existing literature underscores that workers unsafe behaviors result from a combination of individual cognitive processes and their interactions with colleagues. In light of this, Ye *et al*. (2020) introduced an Agent-Based Modeling (ABM) approach that delves into the social cognitive processes of construction workers as influenced by their interactions with managers, coworkers, and foremen. This model was deployed to investigate the causes of cognitive failures leading to workers unsafe behavior and the impact of social groups and organizational factors on these behaviors. The findings reveal that;

1.) Workers unsafe behaviors diminish gradually as they interact with managers, foremen, and coworkers.
2.) Foremen wield substantial influence in reducing workers unsafe behaviors, with their role as exemplars holding significant sway.
3.) Cognitive failures in the social cognitive processes of construction workers are multifactorial and can be rectified within established social norms.
4.) Among the various social organizational factors, social identity exerts the most pronounced influence in curbing workers unsafe behaviors, with proactive measures proving more effective than reactive ones in this regard (Ye et al., 2020).

2.21 Machine Learning and Engineering Safety

To effectively minimize elevator safety accidents, big data technology is combined with deep learning technology based on the Spark platform. This research commences by

introducing relevant theories pertaining to elevator safety monitoring technology, specifically focusing on big data technology and deep learning technology. Subsequently, it proceeds to identify the various fault types that may arise during the operation of an elevator, culminating in the development of a finite state machine (FSM) model. Within this framework, a method for elevator fault monitoring, rooted in the Spark platform, is proposed and denoted as the finite state machine (FSM) approach. Additionally, the research encompasses an evaluation of the outcomes associated with elevator safety fault monitoring. Furthermore, leveraging the capabilities of deep learning, the study constructs an elevator fault warning model and assesses its performance in terms of early warning capabilities. The findings underscore the study's capacity to achieve real-time and efficient monitoring of elevator operation states, coupled with its ability to ascertain the specific fault type by correlating abnormal operation states with corresponding faults. The study's effectiveness in enhancing elevator safety monitoring efficiency is evaluated based on three key metrics: mutual information, accuracy, and false positives. When juxtaposed with alternative algorithms, the proposed FSM algorithm stands out, boasting the highest mutual information value (0.1337), the utmost accuracy (0.9899), the lowest false positive rate (0.0624), and the most minimal false negative rate (0.1126). Similarly, in comparison to alternative models, the elevator fault warning model introduced in this research exhibits the lowest root mean-square error (RMSE) value (0.0201), the highest accuracy (0.9834), the lowest Loss value (0.0012), and the swiftest convergence time (88.2608 seconds). These outcomes collectively affirm the feasibility of both the elevator safety monitoring system and the elevator fault warning model. In essence, this study charts a promising path=toward enhancing elevator safety monitoring efficiency in China, laying the foundation for future developments in this domain (Jie and Hu, 2020).

2.22 Prediction of Safety Risk Assessment in Engineering Firm

Occupational Health and Safety (OHS)-related injuries are vexing problems for construction projects in developing countries, mostly due to poor managerial-, governmental-, and technical safety-related issues. While some examinations have explored occupational health and safety (OHS) matters in developing nations, the existing body of research in this domain remains rather limited. A review of the available literature underscores the potential of introducing a predictive assessment framework employing machine learning techniques, which could substantially enrich this field. Remarkably, within the Malaysian context, despite the persistent expansion of the construction sector, there has been a noticeable absence of studies concentrated on evaluating OHS conditions

for workers actively engaged in construction endeavors. Addressing these existing voids, this paper introduces the Ensemble Predictive Safety Risk Assessment Model (EPSRAM) as a potent tool for evaluating OHS risks associated with construction site workers. EPSRAM, as developed in this research, relies on the amalgamation of neural networks and fuzzy inference systems. To illustrate the effectiveness of EPSRAM, the model is applied to various construction projects in Malaysia. This paper makes noteworthy contributions to the field by;

1.) Identifying prominent safety risks with the potential for significant impact.
2.) Isolating pivotal factors influencing safety assessments for construction workers.
3.) Accurately forecasting the magnitude of recognized safety risks.
4.) Suggesting evaluation strategies applicable to the identified risks. The study highlights how EPSRAM can furnish safety professionals and inspectors, who are committed to the well-being of workers, with invaluable insights, ultimately contributing to an improved working environment for construction crew members (Sadeghi, 2020).

2.23 Workplace Hazards In Petroleum Industry

Workplace dangers hold the potential to exert a considerable impact on both the physical and mental well-being of employees, consequently diminishing an organization's safety effectiveness. Importantly, the significance of psychosocial hazards is gaining recognition as a critical element necessitating attention for the welfare of both individuals and the organization. This study aimed to introduce and subject to statistical scrutiny a concise theoretical framework, rooted in leadership, organizational communication, work environment, and psychosocial hazards, within the context of Malaysia's upstream oil and gas sector. The framework underwent testing involving 380 workers in the Malaysian upstream oil and gas industry. Subsequently, the gathered data were subjected to analysis employing partial least squares and structural equation modeling (PLS-SEM). The results of the study unveiled a noteworthy revelation – in the Malaysian oil and gas domain, leadership, communication, and the work environment exhibited an adverse relationship with psychosocial hazards. This inverse correlation between the predictors and psychosocial hazards, specifically pertaining to job expectations, control, role, and interpersonal relationships, opens up new avenues for further investigation. The study also discusses the potential utility of these findings in tracking the well-being of employees over time and devising targeted interventions.

2.24 Towards Safety Inspection in Engineering Firm

While government-led safety inspections play a pivotal role in accident prevention, there exists a notable dearth of comprehensive understanding concerning their outcomes and the underlying processes that drive them. To bridge this gap in knowledge, this research employs a systems thinking (ST) perspective as a framework for gaining deeper insights into safety inspections conducted at construction sites. The study encompasses an examination of thirteen case studies involving sites where prohibited activities were identified, shedding light on how four key attributes of systems thinking were applied during the inspection process. Tarcisio (2016) research served as the foundation for this investigation, and the sources of evidence encompassed participant observation, direct on-site observations, scrutiny of pertinent documents, and interviews. This research identifies two complementary approaches, grounded in systems thinking, for acquiring insights into safety inspections;

1.) The study design itself must align with the principles of systems thinking, ensuring a holistic and systemic perspective.

2.) Data collection and subsequent analysis should prioritize the examination of various elements, including the individuals involved in the inspections, their interactions, the constraints and opportunities influencing their actions, the outcomes of these interactions, and the recommendations aimed at shaping future interactions (Tarcisio, 2016).

2.25 Safety in Mechanical Engineering

Mechanical engineering encompasses a wide-ranging domain encompassing the conception, construction, and testing of mechanical contrivances such as engines and tools. Engineers engage in devising solutions to engineering challenges and then proceed to formulate detailed blueprints for the machinery. Subsequently, they embark on the creation of prototypes and supervise the entire production and manufacturing process culminating in the final product. While a significant portion of a mechanical engineer’s tasks unfolds within the confines of an office, involving computer-based work, they also dedicate time to on-site assignments. These assignments expose them to a spectrum of occupational hazards, including sharp tools, conveyor systems, potentially perilous machinery, and hazardous chemicals, particularly during troubleshooting and the execution of mechanical safety inspections. Irrespective of their role, all employees, including mechanical engineers, bear the responsibility of maintaining clean work environments devoid of avoidable risks. It is imperative to promptly address any debris

and maintain unobstructed walkways. When dealing with hoses, elevating them above workers or covering them with crossover planks is essential. Moreover, any spills must be expeditiously cleaned up. Furthermore, ensuring unimpeded access to emergency exits and fire alarms is indispensable for workplace safety (Malone, 2022).

2.26 Safety in Food Processing Plants

Employees working within food processing facilities face potential risks of injuries stemming from falls and equipment-related cuts. These workplaces expose workers to a multitude of hazards, including but not limited to knife lacerations, slip-and-fall incidents, and the potential for exposure to infectious diseases and hazardous chemicals. To mitigate these risks and foster a secure working milieu, regulations mandated by the Occupational Safety and Health Administration (OSHA) play a pivotal role. Adherence to these regulations by both the plant management and its workforce is imperative, as it not only ensures a safe environment but also helps evade potential fines. Workers have a responsibility to abide by these regulations in order to sustain a secure workplace. This entails routine inspections of the equipment they operate and the immediate cleanup of any spills, encompassing water, to forestall slip-and-fall accidents. Additionally, provisions necessitate the availability of hand-washing facilities in proximity to all workers who handle potentially hazardous substances like ammonia or deal with potentially infectious materials such as raw meat. Furthermore, employers bear the obligation of furnishing safety training to empower workers with an awareness of potential hazards within the plant and equip them with the knowledge needed to prevent injuries and illnesses (Malone, 2022).

2.27 Mine Safety Performance

This study focused its research on the assessment of mine safety performance and the associated regulatory framework. It employed various facets such as human factors, mechanical equipment, management systems, environmental factors, and technological elements as indices to gauge the state of mine safety (Chen, 2022). Additionally, it considered accident losses and the frequency rate of disabling incidents as evaluative indices for mine safety performance. In order to establish criteria for safety performance classification, the research employed a combination of influence index range and evaluation indices. Subsequently, the values of safety performance influence indices were discretized. Employing these classification criteria, the study identified the classical and node domains for classifying safety performance evaluation indices. In conjunction with

the weighting assigned to each safety performance evaluation index, the study calculated the correlation degree for each mine's safety performance assessment. This process facilitated the comprehensive evaluation of mine safety performance and the construction of a decision system for mine safety performance assessment. Furthermore, by applying dominance-based rough set theory, the research scrutinized the laws governing mine safety performance evaluation decisions. To enhance the reliability of these laws, an efficient concept lattice reduction technique was introduced, aimed at reducing the attributes within the decision system. An illustrative example reveals that the utilization of the concept lattice for reduction yielded 84 concepts in the Hasse diagram, with 24 being distinguishable. The decision system involved 8 conditional attributes, generating 255 power sets under these attributes. After eliminating redundant attributes, 148 reducible sets remained, among which 4 emerged as optimal reducible sets characterized by two conditional attributes. These results underscore the efficacy of the proposed methodology in analyzing the patterns and principles governing mine safety performance, ultimately contributing to advancements in mine safety practices.

2.28 Factors Influencing the Performance of Safety Programmes in Construction Industry

While prioritizing safety management in construction is paramount, existing literature (Agyekum *et al.,* 2022) highlights a deficiency in safety considerations, particularly in many developing nations. This research delves into the myriad factors influencing the effectiveness of safety management programs within the Ghanaian Construction Industry. The study's objectives aimed to identify the safety components integrated into construction firms safety initiatives and pinpoint the factors detrimentally impacting the execution of these elements. In the pursuit of objectivity, a quantitative survey was administered to safety managers hailing from 60 D1 building construction firms situated in the Kumasi and Greater Accra regions of Ghana. The questionnaire encompassed three sections, encompassing respondent profiles, an assessment of safety components embedded within the firms safety initiatives, and an evaluation of factors impeding the performance of these safety elements. Following a comprehensive literature review, participants were tasked with rating 13 elements and 17 factors using a Likert scale. Subsequent data analysis was conducted utilizing the Statistical Package for Social Sciences (SPSS) Version 22. The analysis encompassed assessments of construct reliability, mean scores, modes, and standard deviations. The research outcomes divulged the presence of all 13 elements within the safety initiatives of the firms. Notable elements

included deployment of safety managers on-site, development of comprehensive written safety and health plans, implementation of project-specific training and regular safety meetings, provision of safety and health orientation training, and involvement of employees in safety and evaluation. Additionally, the study's findings underscored the adverse influence of 16 out of the 17 identified factors on the firms safety programs. These factors encompassed issues such as inadequate communication regarding safety initiatives, insufficient self-protection awareness among workers, contractors overlooking safety due to project schedule time pressures, suboptimal personal attitudes toward safety, and ineffective laws and a lack of enforcement. The insights garnered from this survey hold relevance for construction practitioners aiming to enhance the safety performance of their respective firms.

2.29 Safety and Health at Work

Machida, (2012) focused on the importance of national reporting of occupational accidents and diseases and how it can be improved, as well as data collection systems and how the data can be evaluated and analyzed. All over the world it is widely accepted that there is a huge economic benefit to be gained from improved safety and health in the workplace and a reduction in occupational accidents and diseases. In order to achieve this benefit, there is a need for a better knowledge of the true situation of safety and health in the workplace at the enterprise, industry and national levels in order to take the right decisions. Effective risk assessment and control at the workplace require accurate and reliable accident and disease data. Published national statistics and experience gained all over the world show that national systems for reporting, data collection and analysis are often very poor and do not reflect the real safety and health situation in the country because accidents and diseases are reported more or less by chance. The reasons for this unsatisfactory situation are varied: sometimes the country lacks a functioning social system, which is necessary for effective reporting and preventive action. Sometimes there is a lack of knowledge about the prerequisites and how to develop an effective system. Sometimes there is a lack of understanding that effective reporting is not simply bureaucracy but delivers the basis for many political decisions that developing economies need to make.

Machida's (2020) report underscores the imperative need for an enhanced and efficient national framework dedicated to the reporting, data compilation, and analysis of occupational mishaps and ailments. The document illuminates the vital link between effective reporting mechanisms and the implementation of preventive strategies. It delves

into the economic facets associated with targeted prevention strategies, underscoring the pivotal role of dependable data in this context. Practical recommendations for establishing a new system or enhancing an existing one are provided, drawing insights from the well-established German system of statutory accident insurance. The report meticulously outlines the requisite definitions and categorizations for occupational accidents and diseases, mandating their incorporation into national legislation. Fundamental principles, including active involvement of social partners and the creation of a unified integrated system for managing occupational incidents and diseases, are elucidated. The development of standardized tools such as report forms and coding systems is explored, with reference to best practices gleaned from long-standing systems. Subsequently, the report expounds on the prerequisites and mechanisms indispensable for the operation of a robust reporting system, encompassing a comprehensive overview of data sources and responsible stakeholders engaged in data reporting. The paper also elucidates the pivotal components necessary for the data analysis process. Moreover, it engages in an extensive discourse regarding the utility of dependable data on occupational accidents and diseases for various stakeholders, including employers, employees, industries, competent authorities, and other concerned parties vested in enhancing workplace safety and health. Finally, the report concludes by underscoring the significance of extending the reporting system's coverage to encompass traditionally excluded worker categories, notably those in small and micro enterprises and the formal economy.

2.30 Safety Management in 2022

Over the past couple of years, occupational health and safety has garnered an unprecedented level of attention. Practitioners in this domain have grappled with the challenges posed by a global pandemic. The constant flux between stringent safety measures and tentative returns to normalcy has not only heightened the burden on managers but also accentuated their daily efforts, earning them a newfound appreciation. These insights emerge as significant findings from the Safety Management Trend Report, an annual publication by Quentic, a prominent provider of software as a service solutions encompassing health, safety, environmental, sustainability, and quality management. In the preparation of its trend forecast, Quentic (2022) scrutinized the enduring impact of these developments on professionals and the broader field. Furthermore, the Safety Management Trend Report delves into the discussion of how overarching factors such as environmental, social, and corporate governance (ESG) criteria, coupled with the pervasive influence of

digitalization, will continue to mold the landscape of occupational health and safety moving forward.

2.31 SUMMARY OF LITERATURE REVIEW

AUTHORS	Title	METHODOLOGY	GOAL	STRENGTH/FINDINGS	WEAKNESS
Adebiyi (2020)	**Safety concern in manufacturing industry**	He used documentations, interviews and structured questionnaire to collect information.	To develop a monetary saving / loss function in terms of value of preventions and cost of prevention strategy.	The study provides a leading resource for planning successful safety programme.	Accident within the industry not reported to Organization for Safety in Workplace.
Yousefi, Y., Karballaeezadeh, N. and Moazami, D. (2020). (2020)	**Safety concern in aviation industry**	A three-step approach was used for runway risk assessment considering probability, location, and consequences of accidents through advanced statistical methods.	Increase airport safety	The proposed models can be used for preliminary evaluation of developing existing airports and the construction of new runways.	Accidents not reported to Organization for Safety in Workplace.
Ali, P. O., Wyse, M. E., Odeniyi, K. O, Oludele, O. E. , Ejomafuvwe, E., John, A and Faremi, O. B. (2022).	**Safety in petroleum industry**	Evaluation of the effectiveness of safety management system (SMS) in a liquefied natural gas company with a 5-point Likert questionnaire system in the organization.	Increase safety in petroleum industry	The study was of the opinion that effective safety management system will continuously improve performance.	Safety is an in house affair

AUTHORS	Title	METHODOLOGY	GOAL	STRENGTH/FINDINGS	WEAKNESS
Winge, S. ,Albrechtsen, E. and Arnesen, J. (2019).	**Safety in engineering industry**	They employed qualitative comparative analysis (QCA) to produce case knowledge, compare the cases, and identify connections between the factors and safety performance	Improve safety in engineering industry	Specified factors necessary for high safety performance	Safety performance is not reported to Organization for safety in Workplace.
Shin and Kim (2021), Johansson, J., Berglund, L, Johansson, M, Nygren, M., Rask, K., Samuelson, B. and Magnus Stenberg, M. (2019).	**Occupational safety in engineering firm**	Presented research that highlights the areas of occupational safety and risk.	To eliminate occupational accidents.	They identified several implementation barriers and made recommendations for improvement.	Occupational safety issues not reported outside the organization.
Rivera, F. M., Mora-Serrano, J. and Oñate, E. (2021). Mohammadi, (2018)	**Factors affecting safety in engineering firm**	Systematic literature review.	Highlight importance of safety.	They detected and categorized behavioral patterns recurring in construction safety.	No authority to enforce safety, safety not reported to organization for safety.

AUTHORS	Title	METHODOLOGY	GOAL	STRENGTH/FINDINGS	WEAKNESS
Gong, S., XinGao, X., Li, Z. and Chen, L.(2021).	**Safety performance in engineering firm**	The use of evolutionary game theory to describe the decision-making and supervision mechanism.	Improvement of workers safety	The results reveal that the proposed safety investment information system could facilitate the transition of the supervision mode from static to dynamic.	Safety not reported outside the firm.
Pi. Z., Gao, X., Chen, L. and Liu, J. (2019).	**Towards improving safety in engineering firm**	Development of a perspective of safety performance (SP) for construction projects by using several brainstorming sessions to strengthen the safety supervision of participants in the construction industry.	Improvement of work safety	Proposed private sector involvement in matters related to safety performance.	Safety concern is an internal affair.
Kang, S., Min, S., Won, D., Kang, Y. and Kim, S. (2021)	**Accident prevention in engineering firm**	They proposed an effective improvement direction for the system implemented by the Korea Occupational Safety and Health Agency.	Safety improvement	Proposed an effective safety policy model by encouraging companies' voluntary efforts to prevent accidents in engineering firms and raise the level of potential safety and health awareness.	Safety is an internal affair in engineering firms.

AUTHORS	Title	METHODOLOGY	GOAL	STRENGTH/FINDINGS	WEAKNESS
Fargnoli, M., Lombardi, M. and Guadagno, F. (2020).	**Assessment of safety in engineering firm**	Employed a comprehensive approach for hazard analysis focusing on the activities in which a working task is articulated.	Improve workers safety	The results achieved can augment knowledge on the usability of Quality Function Deployment in safety research, providing a basis for its application for further studies.	Users of such information cannot access them.
Machida (2012)	**Safety and health at work**	Focused on the importance of national reporting of occupational accidents and diseases and how it can be improved, as well as data collection systems and how the data can be evaluated and analyzed. .	Improving health in workplace.	Proposed solution for effective national safety reporting system.	National systems for reporting, data collection and analysis are often very poor and do not reflect the real safety and health situation.
Quentic (2022)	**Safety management**	Looked at the extent to which health, safety, environment, sustainability and quality management will continue to influence professionals and their work at large.	Improve safety in workplace.	Discusses how strategic influences such as environmental, social and corporate governance (ESG) criteria and digitalization will shape occupational health and safety in the future.	Safety not reported outside organization.

CHAPTER THREE
METHODOLOGY

3.1 Software Methodology

Software development methodology refers to structured processes involved when working on a project. It is a framework that is used to structure, plan, and control the process development of an information system. In this study, we adopted the Waterfall development method. The waterfall method is a rigid linear model that consists of sequential phases (requirements, design, implementation, verification, maintenance) focusing on distinct goals. Each phase must be 100% complete before the next phase can start. There's usually no process for going back to modify the project or direction.

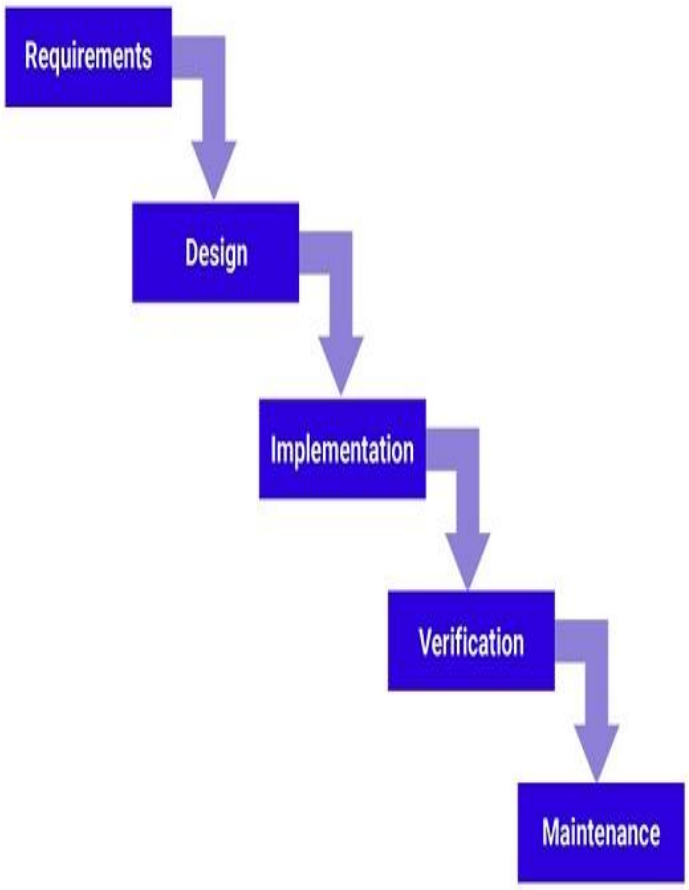


Figure 3.1: Waterfall model

The linear nature of the waterfall development method makes it easy to understand and manage projects with clear objectives and stable requirements. Less experienced project managers and project teams, as well as teams whose composition changes frequently may benefit the most from using the waterfall development methodology.

3.2 Method of Data Gathering

The method of data gathering that was adopted for the research work is survey (quantitative). It was to generate primary data from staff of four (4) oil companies operating in Nigeria to answer the research questions. Two (2) of the four (4) oil companies are indigenous oil companies and the other two (2) are foreign oil companies operating in the shores of Nigeria. The staffs selected for this research were picked at random from various departments of the companies (it was not limited to those staff working in safety department alone). They were assured that their names and the names of their companies will not be mentioned in this research work before some of them agreed to be part of the survey.

The research instrument we adopted for data gathering is a questionnaire consists of a set of restricted questions for respondent to make choices. The questions include company's safety: whether safety related training is provided for those working in hazardous environment, provision of safety equipment (personal protective equipment), whether managers discuss safety issues with workers on sight of operation and as well as whether workers in critically safer environment actually complied with safety regulations. The questionnaires consist of a five-point (Likert scale) in which the different options are assigned numerical value from 5 to 1. With the help of the questionnaires, we were able to gather relevant information concerning safety of work force in the oil and gas industry.

3.3 Analysis of the Present System

The process of safety management in the organizations selected for this study include:

i. Workers undergo training on accident prevention and are provided with the required safety equipment.
ii. The companies have policies on safety in place. Their site managers usually encourage them to think safety during the performance of their duties.
iii. The companies also require employees to report directly to their immediate supervisor to file a report.
iv. Issues of safety are dealt with as soon as they occur.
v. Workers have site managers who are specialists in safety matters and give them regular briefings of safety in workplace.

The Gap

The gap identified in the literature review include the fact that though the individual companies have safety department and support their staff with training and relevant

workplace equipment (Personal Protection Equipment) to ensure their safety, information on safety issues are not reported to outside bodies such as the Organization for the regulation of safety practices in workplace. When safety issues are reported to such bodies, they will take a holistic approach by training and sharing ideas with other related companies on how best to handle such safety issues. Such bodies when fully informed about accident in different workplaces will collate such data and use it to the benefit to all the stakeholders in the various industries.

3.4 Architecture of the Present System

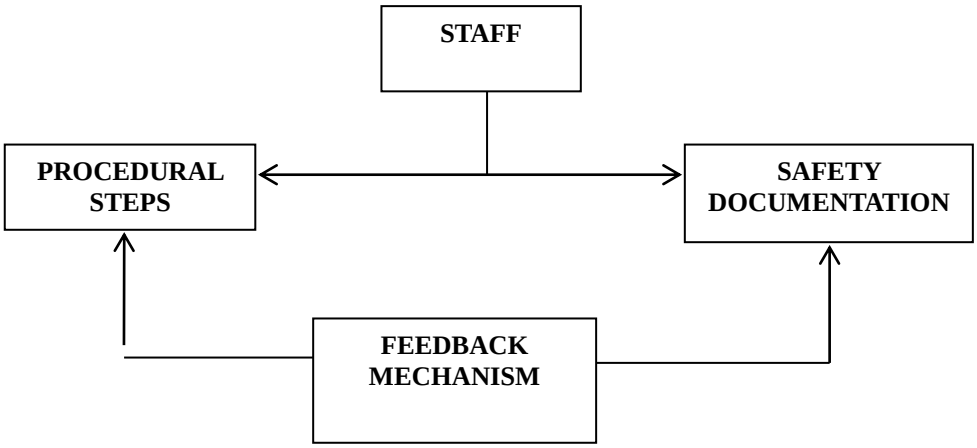


Figure 3.2: Architecture of the Present System

Staff: This is the entire workforce of the organization and they are expected to carry out their job functions in line with the company's laid down procedures and policies. There is the saying that "safety is everyone's business" and as such the entire staff and even visitor's and contractors are expected to work safely in the company's premises.

Procedural Steps: There are laid down procedures and policies that guide workers on how to carry out specific jobs in a particular environment. If a worker deviates from these procedures and policies in the course of executing his/her job, he/she is deemed to be working unsafely.

Safety Documentation: Safety is majorly about proper documentation and keeping of records, you simply cannot claim to practice safety without documentation and record keeping. For instance, all jobs carried out in a company's premises are expected to be documented with the use of a PTW (Permit To Work) system. This permit to work is duly signed by these involved in the job as well as the safety officer on ground to ensure the job is done according to the company's policies and procedures.

Feedback Mechanism: There is an independent, non-governmental, international organization that develops standards to ensure the quality, safety and efficiency of products,

services and system in organizations known as ISO (International Organization for Standardization). It usually goes to inspect the safety practices, procedures, company policies and documentation of companies before they are standardized to be recognized internationally. Obtaining these standards give oil companies and as well as other companies an edge over their peers in the business environment.

3.5 Problem with the Present System

In the multinational organizations sampled for this study, safety is integrated in their day-to-day work environment. They have a recommended mode of reporting safety issues. Reporting on safety incidents in the companies sampled for this study is an in-house affair. The degree to which each of them are involved in safety programs for their staff varies. There is no comparative analysis of how they performed individually as it concerns safety. Also, safety is not usually reported outside the organization. Organizations concerned with safety do not have offices in these companies and it is the information the companies make available to such body that enables the said organization to determine their level of compliance with safety matters. This situation makes it very difficult for the safety organization to determine their level of compliance on safety issues and the aspects of safety that needs improvement. Without reliable data regarding to workplace hazards it is difficult to effectively focus inspection and compliance efforts on the most hazardous workplaces.

3.6 Analysis of the Proposed System

The proposed system is a web-based analysis of safety of multinational and national co-operations operating in oil and gas sector in Nigeria. Data was collected with the use of questionnaire which required the respondents to respond to safety issues. The data were analyzed and grouped together according to the performance of the various companies as it relates to accident reporting, provision of training, companies' policy on accident, provision of safety instructions by managers at the site of operation and workers compliance with safety precaution. The average performance of safety in the aforementioned areas were computed and inputted into a web application that has been designed to do comparative analysis of safety issues in the said companies. The comparison was based on the overall performance, performance in training, performance in provision of personal protective equipment, performance in workers compliance as well as performance on company's policy on safety. With the said web application, it is possible to determine which company performed best in all the various aspects of safety in the workplace.

3.6.1 Benefits of the Proposed System

Information on accidents in workplace is very critical especially in the provision of training and equipment to forestall the reoccurrence of similar accidents in future. Every organization is bound to fulfill the compliance related to the health and safety of the employees and every individual associated with it. This is not specified to any particular industry, but some industries are at higher risk because of their sensitive production processes that involve risky tasks to be performed by the employees. Those organizations that do not comply with the regulations toward them by the state on health and safety are at higher risk compared with other organizations. This may result in loss of lives and health hazards to the people working there.

Oil and gas safety also hinge on the industry's resolve to support product stewardship to deliver safe products that champion safety. Implementing safety measures is just the beginning but monitoring safety improvements become quintessential to supplementing oil and gas safety management.

Safety in Oil and Gas industries can be enhanced with the provision of appropriate data. This will enable the users of such information to be strategic in their planning and for the good image of the companies concerned. Where data is not available it becomes very difficult to plan and workers safety cannot be assured especially in Oil and Gas where safety precaution is very important.

3.7 Architecture of the proposed system

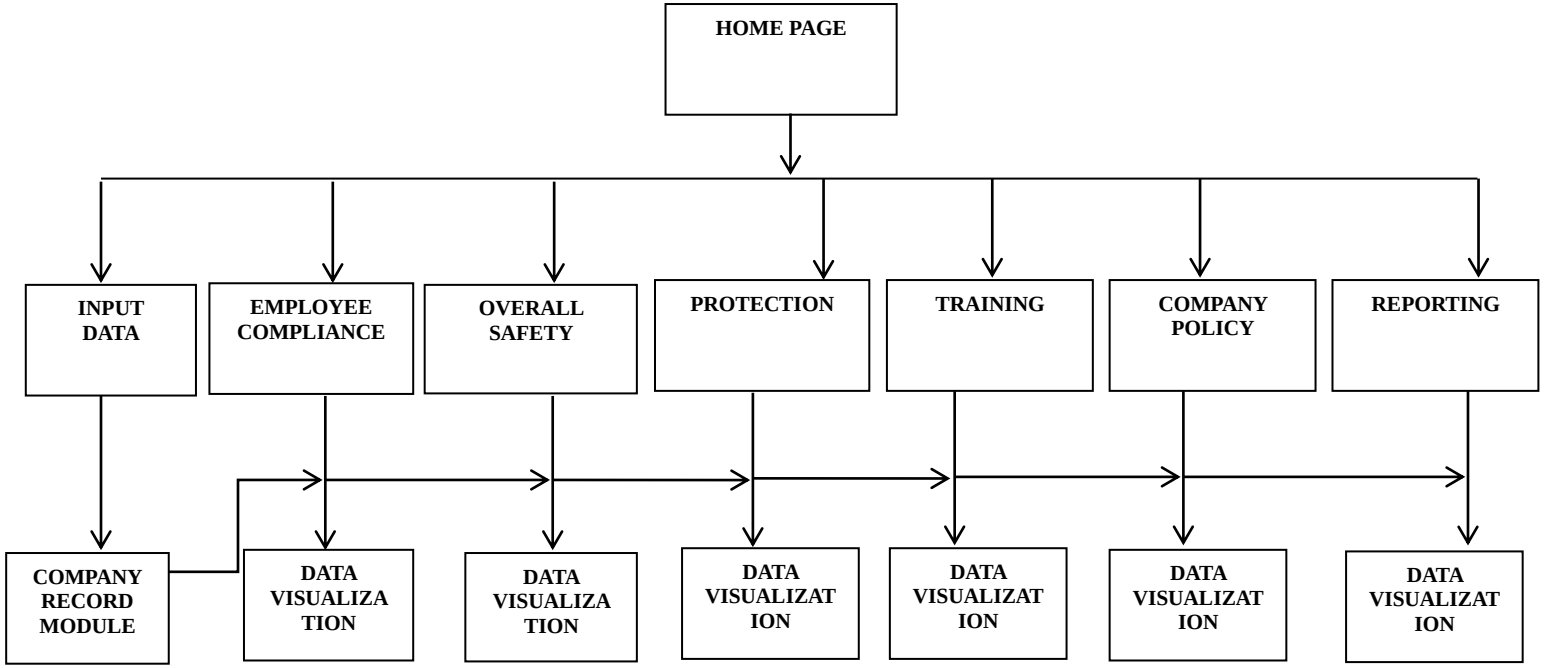


Figure 3.3: Architecture of the proposed system

Operational Procedure

The operational procedure for the usability of the software developed for safety performance is as follows:

Step i: Download and install XAMPP 3.x msi or higher version.

Step ii. Lunch XAMPP, start Apache and MySQL



Figure 3.4: XAMPP control panel

In figure 3.4 Apache and MySQL have been activated and are up and running after clicking on start.

Step iii. Create a folder inside htdocs and name it safety. Copy and paste all the codes for the application including index. php into the safety folder. Step iv. Lunch the safety application using the following URL. 127.0.0.1/safety and press enter key. Then control is transferred to the home page.



Figure 3.5: Home page of the safety application.

The home page of the safety application (figure 3.5) consists of menu such as input data, employee compliance, overall safety, protection, training, company policy and reporting.

Step v. Input data interface

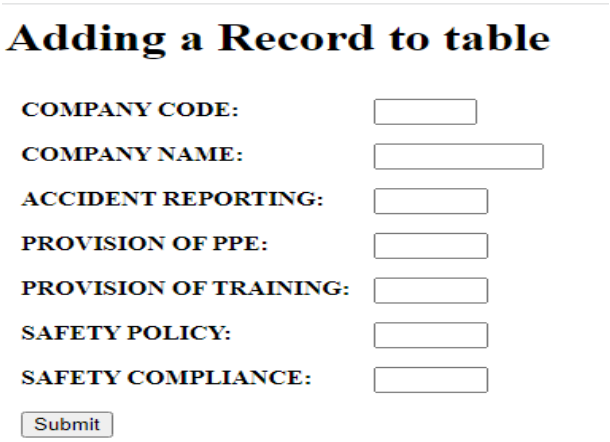


Figure 3.6: Input data interface

Figure 3.6 represents the user interface for data entry. This will be activated by clicking on input data. Company code is usually numeric, while company name takes the form of COY1 or COY 2 etc. The actual company name is not required for security reasons. Reporting, protection, training, policy and compliance performance are real numbers based on the performance of the companies.

Table 3.1: Employee compliance output

Step vi. Employee Compliance

Employee compliance on Accident prevention Petroleum industry

COY CODE	NAME	REPORTING	PROTECTION	TRAINING	POLICY	COMPLIANCE	TOTAL
4	COY 4	4.6	4.2	4	4.6	4.1	21.5
1	COY 1	3.9	4.2	4.3	3.9	3.5	19.8
3	COY 3	3.7	3.7	4.1	3.8	3.4	18.7
2	COY 2	4	4.2	4	4.2	3.2	19.6

In order to access employee safety compliance, click on employee compliance and transferred to the employee compliance web page. In the said web page, the safety performance rating was ordered in accordance with employee performance. The companies sampled for this study were ordered accordingly.

Table 3.2: Overall safety performance

vii. Overall performance

Overal Safety performance in Oil and Gas Industry

COY CODE	NAME	REPORTING	PROTECTION	TRAINING	POLICY	COMPLIANCE	TOTAL
4	COY 4	4.6	4.2	4	4.6	4.1	21.5
1	COY 1	3.9	4.2	4.3	3.9	3.5	19.8
2	COY 2	4	4.2	4	4.2	3.2	19.6
3	COY 3	3.7	3.7	4.1	3.8	3.4	18.7

Return to home page

Table 3.2: represent the overall performance of companies in oil and gas sampled for this study. The data in the table records were ordered according to total. Company 4 (COY4) performed best while company 3 (COY3) is trailing behind other companies.

Table 3.3: Output of performance on safety equipment

Step viii: Performance on protective equipment

Povision of Personal Protective Equipment

COY CODE	NAME	REPORTING	PROTECTION	TRAINING	POLICY	COMPLIANCE	TOTAL
1	COY 1	3.9	4.2	4.3	3.9	3.5	19.8
4	COY 4	4.6	4.2	4	4.6	4.1	21.5
2	COY 2	4	4.2	4	4.2	3.2	19.6
3	COY 3	3.7	3.7	4.1	3.8	3.4	18.7

Table 3.3 shows the output on performance of the companies selected for this study in terms of their performance concerning provision of safety equipment. The result can be accessed by clicking on protection on the menu. From the result company 1 performed the same way as company 2 and company 4 while company 3 did not perform well in this regard.

Table 3.4: Output of performance on reporting

Step ix Accident reporting

Accident Reporting in Petroleum industry

COY CODE	NAME	REPORTING	PROTECTION	TRAINING	POLICY	COMPLIANCE	TOTAL
4	COY 4	4.6	4.2	4	4.6	4.1	21.5
2	COY 2	4	4.2	4	4.2	3.2	19.6
1	COY 1	3.9	4.2	4.3	3.9	3.5	19.8
3	COY 3	3.7	3.7	4.1	3.8	3.4	18.7

Table 3.4 shows the output on performance of the companies selected for this study in terms of accident reporting. The result can be accessed by clicking on reporting on the menu. From the result company 4 performed well in this regard. Company 4 performed more than other companies while company 3 performed below other companies.

Table 3.5: Output of performance on policy implementation of accident prevention

Step x. Company policy on accident prevention

Good policy implementation on Accident prevention Petroleum industry

COY CODE	NAME	REPORTING	PROTECTION	TRAINING	POLICY	COMPLIANCE	TOTAL
4	COY 4	4.6	4.2	4	4.6	4.1	21.5
2	COY 2	4	4.2	4	4.2	3.2	19.6
1	COY 1	3.9	4.2	4.3	3.9	3.5	19.8
3	COY 3	3.7	3.7	4.1	3.8	3.4	18.7

Table 3.5 shows the output on performance of the companies selected for this study in terms of policy implementation on accident safety. The result can be accessed by clicking on company's policy on the menu. From the result company 4 performed well in this regard compared to other companies.

3.8 Design of the Proposed System

Experimental design or Design of experiments (DOE) is referred to as a sequential development of statistics gathering using experimental and statistical methods to find the optimum factors and levels for a particular problem either for industrial measurement or for research purposes. Nair *et al*. (2014) and Yeniay, (2014) defined RSM (Response Surface Methodology) as statistical technique applied by industrial statistician and engineers for empirical model building, with the aim of optimizing the response variables which are influenced by several operating factors.

RSM is suitable for optimizing the response variable $\boldsymbol{y}$ as a function of several explanatory variables ($x_{i1}, x_{i2}, \ldots, x_{ik}$) which can be modeled as:

$$y_i = f(x_{i1}, x_{i2}, \ldots, x_{ik}) + \varepsilon_i, i = 1,2, \ldots, n \quad (1)$$

where ε_i is the error term and assumed to satisfy the homoscedasticity property with mean zero and constant variance$\boldsymbol{\sigma^2}$property. The surface represented by $f(x_{i1}, x_{i2}, \ldots, x_{ik})$ is termed a response surface (Wan and Birch, 2011).

3.8.1 Global (Fixed) Bandwidth

The bandwidth is the most crucial parameter in nonparametric regression and estimation procedure because the choice selected determines the shape of the fitted curve, see (Nair *et al*. (2014); Yeniay, (2014)). If $b_{ij} = b$ for all i and all j, we say that smoothing in the LLR model is done using fixed bandwidth or a global bandwidth given as:

$$b_{ij} = b \tag{2}$$

where, $0 < b_{ij} \leq 1$,.

3.8.2 Single Response Optimization Problem

In a study that involves a single response, the optimization of the fitted response is targeted to identify the settings of the explanatory variables that will maximize or minimize the fitted response (see Pickle, 2008). But, in situations where it is required for the process or product to meet a given production target, the optimization criterion is based on the constrained maximization of the estimated Squared Distance from Target, (SDT), given as:

$$\text{Maximize} \quad \widehat{SDT} = (\hat{y}(\boldsymbol{x}) - T)^2 \tag{3}$$
$$s.t\ \boldsymbol{x} \epsilon\ \varphi.$$

where φ is the design space for the study, T denotes the target value set by the researcher, $\hat{y}(\boldsymbol{x})$ is the estimated response at the settings $\boldsymbol{x}$ of the explanatory variables (Najafi *et al*., 2011).

3.8.3 The Local Linear Regression Model (LLR)

The LLR model is a nonparametric regression version of the weighted least squares model, also see (Mays *et al*., 2001; Hardle *et al*., (2005)). The LLR estimate, $\hat{y}_i^{(LLR)}$ of y_i, is given as:

$$\hat{y}_i^{(LLR)} = \tilde{\boldsymbol{x}}_i(\tilde{\boldsymbol{X}}^T \boldsymbol{W}_i \tilde{\boldsymbol{X}})^{-1} \tilde{\boldsymbol{X}}^T \boldsymbol{W}_i \boldsymbol{y} = \boldsymbol{h}_i^{(LLR)} \boldsymbol{y}, \tag{4}$$

where $\tilde{\boldsymbol{x}}_i$ is the i^{th} row of the LLR model matrix $\tilde{\boldsymbol{X}} = \boldsymbol{X}^{LLR}$ given as:

$$\tilde{\boldsymbol{X}} = \begin{bmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1k} \\ 1 & x_{21} & x_{22} & \cdots & x_{2k} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & x_{n1} & x_{n2} & \cdots & x_{nk} \end{bmatrix}_{n \times (k+1)},$$

where $x_{ij}, i = 1,2,\ldots,n, j = 1,2,\ldots,k,$ denotes the value of the j^{th} explanatory variable in the i^{th} data point, $\boldsymbol{W}_i$ is a $n \times n$ diagonal weights matrix given as:

$$\boldsymbol{W}_i = \begin{bmatrix} w_{i1} & 0 & \cdots & 0 \\ 0 & w_{i2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & w_{in} \end{bmatrix}_{n \times n}$$

3.8.4 Experimental Design Tool

In the application of RSM, the explanatory variables are usually more than one. Hence, the drive for a suitable choice of coded levels to be considered for the explanatory variables are important as it can affect model accuracy or precision. The design of experiment phase gives credence for an appropriate design that can adequately and substantially estimate the relationship that exist between the response and one or more explanatory variables. Often applied DOEs in RSM include: 2^k full factorial design, 3^k full factorial design, and the

Central Composite Design (CCD). Thus, the five coded levels for the design of experiment are given in Table 1.

Table 3.6: Coded stages and range for the design of experiments

Factors or Input parameters	Symbol	Coded Levels				
		-2(-α)	-1(Low)	0(Medium)	1(High)	2(+α)

In Table 3.6, we have four factors for a single response problem with the number of experimental run generated from a CCD which can be expressed by a mathematical equation given as:

$$CCD = 2^k + 2k + \eta_k \quad (1)$$

where 2^k is the full factorial design, $2k$ axial points (star points) and η_k at least kth central point.

3.8.5 Output Design

Table 3.7: Overall Safety performance in Oil and Gas Industry

Coy Code	Name	Reporting	Protection	Training	Policy	Compliance	Total
N1	COY 1	Xxx	Xxx	Xxx	Xxx	xxx	xxx
N2	COY 2	Xxx	Xxx	Xxx	Xxx	xxx	xxx
N3	COY 3	Xxx	Xxx	Xxx	Xxx	xxx	xxx
N4	COY 4	Xxx	Xxx	Xxx	Xxx	xxx	xxx

Table 3.7 shows the output form design of the web application for safety performance in oil and gas industry. The fields in the report include company code referred to as N1, N2, N3, and N4. COY1, COY2, COY3 and COY4 are the names of the multinational oil cooperation operating in Nigeria sampled for this study. The names of the companies were not indicated because we did not get permission from the authorities of the companies to carry out safety performance in their companies.

the basis for the development of a web application for the evaluation of safety performance with respect to the companies selected for this study.

The second field which is reporting indicates the average performance in terms of accident reporting. When accidents occur it is reported? A five Likert scale was used to measure the performance of the various companies and the average was shown under reporting. Protection refers to the availability of appropriate protective equipment for workers in the oil and gas sector in the four companies sampled for this study.

Training, policy and compliance talk about provision of adequate safety training for the workforce, company's policy on safety as well as workers compliance on safety measure laid down in the companies.

3.8.6 Input Form Design

Table 3.8: Structure Of Safety Database Table

Sn	Field	Meaning	Data type	Width	Decimal
1	Coycode	Company code	Integer	4	Nil
2	Coyname	Company name	Character	20	
3	Accrep	Accident reporting	Numeric	6	2
4	PPE	Availability of personal protection equipment	Numeric	6	2
5	Training	Training on accident prevention for workers	Numeric	6	2
6	Sfpolicy	Company's safety policy	Numeric	6	2
7	Comply	Workers compliance with safety procedure in workplace	Numeric	6	2
8	sumtot	Sum total of average performance concerning safety	Numeric	6	2

The structure of database table for safety in workplace is as shown in table 3.8 The table shows the code for the various fields, the meaning of the data type, the width as well as the decimal places where applicable.

3.9 Architecture of Safety Procedure Based on the Elements of Training Cycle

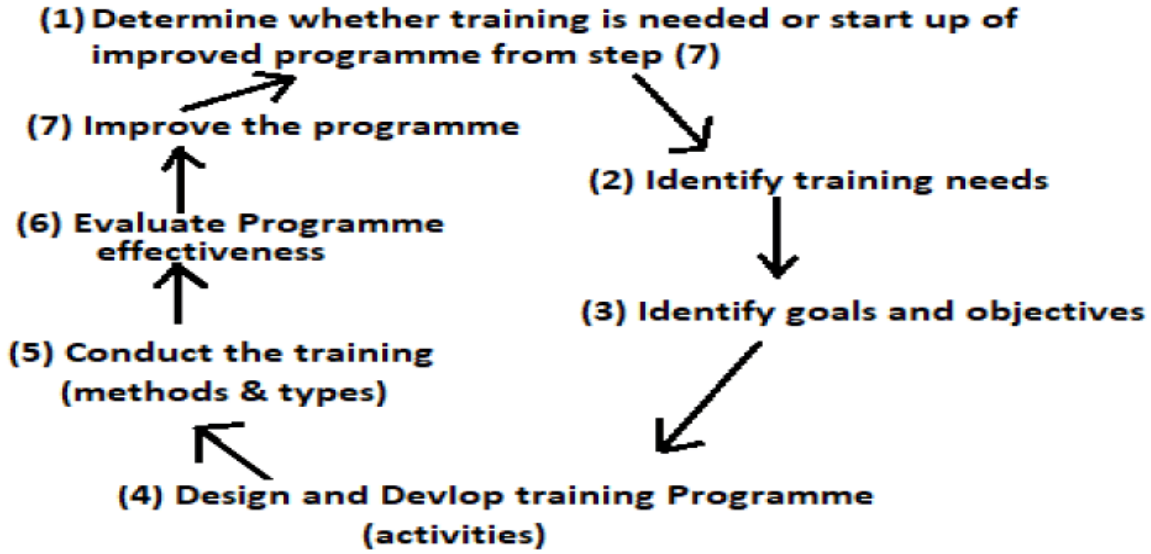


Figure 3.7: Architecture of Safety Procedure Based on the Elements of Training Cycle (Ranjan, 2018)

The proposed system evaluates how well the companies selected for this study complied with safety procedure. The said safety procedure is based on the elements of training cycle (Ranjan, 2018) which is consistent with Occupational Safety and Health Administration (OSHA) training guidelines. The basic element of any safety training program shows them in a cyclic order. The training cycle are as follows:

Determine if training is needed: The first step is to determine whether a problem can be solved by training. All skill deficiencies are not solvable through training and some other tool may be required. This step includes need of any improved (revised) training programme.

Identify training needs: Analyze the worker's duties and what he or she needs to perform the job more skillfully and safely.

Identify goals and objectives: A list of Specific job knowledge and skill deficiency derived from step 2, will tell employers what workers should do, do better or stop doing.

Design & Develop training programme: After listing precise objectives and goals, learning (training) activities must be identified and described. Type of training will be decided based on the training resources available to the employer, the kind of knowledge or skills to be learned end whether the learning should be oriented towards physical skill or mental attitudes.

Conduct the training: Now the training programme should be conducted by (a) providing overviews of the material to be learned and (b) relating each specific item of knowledge or skill to the worker's goals, interests or experience to be learned.

Evaluate programme effectiveness: By knowing trainee's opinion, supervisor's observation, workplace improvement, hazard reduction, performance improvement etc., it should be checked whether the training has accomplished its goals.

Improve the programme : Based on feedback from the workers, supervisors etc., and from evaluation and observing the gap, the training programme should be improved (revised) as per need.

Assessment of Training Needs: architecture of safety procedure based on the elements of training cycle as shown in figure 3.2 formed.

3.10 Current Model for Accident Safety Management



Figure 3.8: The current model for accident management

Source: Sparkman (2022)

The current model for accident management (figure 3.8) consist of training of workers, hazard control, ongoing worksite inspection, incident investigation, program administration review, emergency response planning and hazard identification. All these functions are done internally without the involvement of outside bodies who are users of accident information. Such outside bodies include organization of safety in work place. They have a great role to play in ensuring safety in a special way for workers because of the numerous data on safety at their disposal. A situation in which accident in work place is dealt with internally without bringing in other relevant stakeholders in accident management may not be very helpful for accident management in workplace.



Figure 3.9: The proposed model

3.11 The Updated Model

In the proposed model as stated in figure 3.9, accident management is dealt with both internally and externally by ensuring proper reporting of accident to the relevant stakeholders outside workplace. The users of such information have a role to play in monitoring to ensure compliance and training in order to guide against the reoccurrence of similar cases of accidents in workplace. This is the aspect that was not covered in the present model. In the present model, cases of safety reporting are dealt with internally without the involvement of the relevant stakeholders concerned with hazard management in workplace.

3.12 Functionality of the System

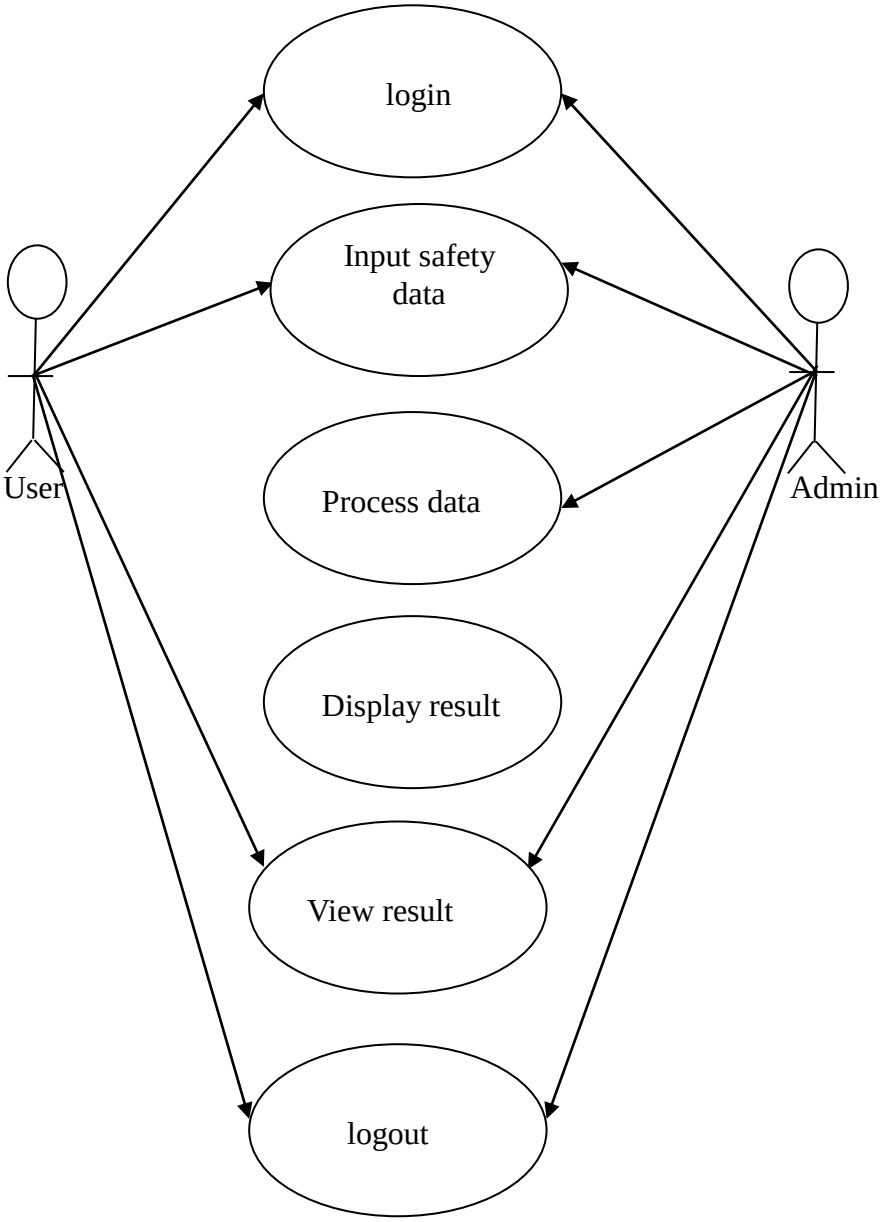


Figure 3.10: Use Case diagrams for safety management

Figure 3.10 represents the functionality of the safety management system. The user has limited role to carry out such as logging into the system and input data obtained from analysis of questionnaire. He also has the privilege to view the result of the output and then logout. The admin has total control of the system. He logs into the system, input data, process such data and display the result for the users concerning the performance of companies on safety in workplace.

3.13 Screen Display of the Proposed System

Table 3.9: Screen display of hazard reporting

Employee compliance on Accident prevention Petroleum industry

COY CODE	NAME	REPORTING	PROTECTION	TRAINING	POLICY	COMPLIANCE	TOTAL
4	COY 4	4.6	4.2	4	4.6	4.1	21.5
1	COY 1	3.9	4.2	4.3	3.9	3.5	19.8
3	COY 3	3.7	3.7	4.1	3.8	3.4	18.7
2	COY 2	4	4.2	4	4.2	3.2	19.6

The screen display for hazard reporting consists of companies and their performance in terms of hazard reporting. The result of the performance is displayed according to the different category of hazard. In table 3.9, the result of employee compliance of accident prevention was analyzed. Company 4 top the list while company 2 performed least compared with other multinational co-operations. The performance 4 was judged from the responses from the questionnaire from the respondents in that particular company. Same also applied to other companies. The result was arranged in order of performance.

CHAPTER FOUR

IMPLEMENTATION AND DISCUSSION

The program is implemented via the use of a questionnaire, design of experiment (DOE) and an appropriate regression method that would best fit the raw response from the different oil companies.

4.1 Data Generated From Questionnaire

The data was generated from questionnaire given to ten (10) each randomly selected staff of four (4) oil companies operating in Nigeria and from the respective experimental factors $x_1, x_2, \ldots, x_4$.

Tables 4.1 – 4.4 represent the coded levels and experimental factors for NPDC, IDSL, BGP and SHELL actual responses generated from distributed questionnaire.

Table 4.1: Experimental coded level for RSM data **NPDC**

Exptal. Run	X_1	X_2	X_3	X_4	Actual Response for NPDC
1	0	0	0	0	10
2	0	0	0	0	10
3	-1	1	1	1	10
4	-1	1	-1	1	10
5	-1	1	1	-1	10
6	-1	1	-1	-1	10
7	1	1	-1	1	10
8	1	1	-1	-1	10
9	1	-1	1	1	9
10	1	-1	-1	1	9
11	1	-1	1	-1	11
12	1	1	1	-1	9
13	1	1	1	1	11
14	-1	-1	1	-1	10
15	0	0	0	0	8
16	1	-1	-1	-1	10
17	0	0	0	0	10
18	-1	-1	1	1	10
19	-1	-1	-1	-1	10
20	-1	-1	-1	1	10
21	0	0	2	0	10
22	0	-2	0	0	10
23	2	0	0	0	10
24	0	0	-2	0	10
25	0	0	0	-2	10
26	0	2	0	0	10
27	0	0	0	0	10
28	0	0	0	0	10
29	-2	0	0	0	10
30	0	0	0	2	10

Table 4.2: Experimental coded level for RSM data IDSL

Exptal. Run	X_1	X_2	X_3	X_4	Actual Response for IDSL
1	0	0	0	0	10
2	0	0	0	0	10
3	-1	1	1	1	11
4	-1	1	-1	1	10
5	-1	1	1	-1	10
6	-1	1	-1	-1	10
7	1	1	-1	1	9
8	1	1	-1	-1	10
9	1	-1	1	1	10
10	1	-1	-1	1	9
11	1	-1	1	-1	10
12	1	1	1	-1	12
13	1	1	1	1	8
14	-1	-1	1	-1	10
15	0	0	0	0	10
16	1	-1	-1	-1	10
17	0	0	0	0	10
18	-1	-1	1	1	11
19	-1	-1	-1	-1	10
20	-1	-1	-1	1	10
21	0	0	2	0	9
22	0	-2	0	0	10
23	2	0	0	0	11
24	0	0	-2	0	10
25	0	0	0	-2	9
26	0	2	0	0	10
27	0	0	0	0	10
28	0	0	0	0	10
29	-2	0	0	0	10
30	0	0	0	2	10

Table 4.3: Experimental coded level for RSM data BGP

Exptal. Run	X_1	X_2	X_3	X_4	Actual Response for BGP
1	0	0	0	0	10
2	0	0	0	0	9
3	-1	1	1	1	11
4	-1	1	-1	1	10
5	-1	1	1	-1	10
6	-1	1	-1	-1	10
7	1	1	-1	1	10
8	1	1	-1	-1	10
9	1	-1	1	1	10
10	1	-1	-1	1	9
11	1	-1	1	-1	10
12	1	1	1	-1	11
13	1	1	1	1	10
14	-1	-1	1	-1	9
15	0	0	0	0	11
16	1	-1	-1	-1	10
17	0	0	0	0	9
18	-1	-1	1	1	10
19	-1	-1	-1	-1	10
20	-1	-1	-1	1	10
21	0	0	2	0	10
22	0	-2	0	0	10
23	2	0	0	0	10
24	0	0	-2	0	10
25	0	0	0	-2	11
26	0	2	0	0	9
27	0	0	0	0	9
28	0	0	0	0	10
29	-2	0	0	0	10
30	0	0	0	2	10

Table 4.4: Experimental coded level for RSM data SHLL

Exptal. Run	X_1	X_2	X_3	X_4	Actual Response for SHELL
1	0	0	0	0	9
2	0	0	0	0	11
3	-1	1	1	1	10
4	-1	1	-1	1	10
5	-1	1	1	-1	10
6	-1	1	-1	-1	10
7	1	1	-1	1	10
8	1	1	-1	-1	11
9	1	-1	1	1	9
10	1	-1	-1	1	10
11	1	-1	1	-1	10
12	1	1	1	-1	10
13	1	1	1	1	10
14	-1	-1	1	-1	10
15	0	0	0	0	10
16	1	-1	-1	-1	10
17	0	0	0	0	10
18	-1	-1	1	1	10
19	-1	-1	-1	-1	9
20	-1	-1	-1	1	10
21	0	0	2	0	9
22	0	-2	0	0	10
23	2	0	0	0	10
24	0	0	-2	0	10
25	0	0	0	-2	10
26	0	2	0	0	10
27	0	0	0	0	10
28	0	0	0	0	10
29	-2	0	0	0	10
30	0	0	0	2	10

4.2 Transformation of Data from Central Composite Design (CCD)TO RSM

For the nonparametric regression techniques in RSM, the values of the explanatory variables are coded to lie between 0 and 1. The data collected via a Central Composite Design (CCD) is transformed by a mathematical relation:

$$x_{new} = \frac{Min(x_{old}) - x_o}{(Min(x_{old}) - Max(x_{old}))} \quad (1)$$

where the transformed value is x_{new}, x_0 is the target value that needed to be transformed in the vector containing the old coded value, represented as x_{old}, Min (x_{old}) and $Max(x_{old})$ are the minimum and maximum values in the vector x_{old} respectively, see (He *et al*., (2012)).The natural or coded variables in Tables 3- 5 can be transformed to explanatory variables in Tables6 - 9 using equation (1).

Target points for the four coded variables that needed to be transformed for location 4 are given below:

Target points x_0: $-1, 1, -1, 1; Min(x_{old})$: $-2, -2, -2, -2;\ Max(x_{old})$: $2, 2, 2, 2$

$$x_{new} = \frac{Min(x_{old}) - x_0}{(Min(x_{old}) - Max(x_{old}))}$$

$$Explanatory\ variable\ x_1:\ x_{41} = \frac{-2-(-1)}{((-2)-(2))} = 0.2500$$

$$Explanatory\ variable x_2:\ x_{42} = \frac{-2-(1)}{((-2)-(2))} = 0.7500$$

$$Explanatory\ variable x_3:\ x_{43} = \frac{-2-(-1)}{((-2)-(2))} = 0.2500$$

$$Explanatory\ variable x_4:\ x_{44} = \frac{-2-(1)}{((-2)-(2))} = 0.7500$$

Target points needed to be transformed for location 23 under the coded variables are given below:

Target points x_0: $2, 0, 0, 0, 0; Min(x_{old})$: $-2, -2, -2, -2;\ Max(x_{old})$: $2, 2, 2, 2$

$$x_{new} = \frac{Min(x_{old}) - x_0}{(Min(x_{old}) - Max(x_{old}))}$$

$$Explanatory\ variable\ x_1:\ x_{23,1} = \frac{-2-(2)}{((-2)-(2))} = 1.0000$$

$$Explanatory\ variable x_2:\ x_{23,2} = \frac{-2-(0)}{((-2)-(2))} = 0.5000$$

$$Explanatory\ variable x_3:\ x_{23,3} = \frac{-2-(0)}{((-2)-(2))} = 0.5000$$

$$Explanatory\ variable x_4:\ x_{23,4} = \frac{-2-(0)}{((-2)-(2))} = 0.5000$$

Repeating the process up to location 30, then we obtain the entries for explanatory variablesx_1,x_2,x_3 and x_4 respectively in Tables 5 – 8 (NPDC, IDSL, BGP and SHELL) representing transformed RSM data that needed to lie between zero and one inclusively.

4.2.1 Transformation RSM for NPDC

Table 4.5: Transformed experimental coded level for RSM data NPDC

Exptal. Run	X_1	X_2	X_3	X_4	Actual Response for NPDC
1	0.5000	0.5000	0.5000	0.5000	10
2	0.5000	0.5000	0.5000	0.5000	10
3	0.2500	0.7500	0.7500	0.7500	10
4	0.2500	0.7500	0.2500	0.7500	10
5	0.2500	0.7500	0.7500	0.2500	10
6	0.2500	0.7500	0.2500	0.2500	10
7	0.7500	0.7500	0.2500	0.7500	10
8	0.7500	0.7500	0.2500	0.2500	10
9	0.7500	0.2500	0.7500	0.7500	9
10	0.7500	0.2500	0.2500	0.7500	9
11	0.7500	0.2500	0.7500	0.2500	11
12	0.7500	0.7500	0.7500	0.2500	9
13	0.7500	0.7500	0.7500	0.7500	11
14	0.2500	0.2500	0.7500	0.2500	10
15	0.5000	0.5000	0.5000	0.5000	8
16	0.7500	0.2500	0.2500	0.2500	10
17	0.5000	0.5000	0.5000	0.5000	10
18	0.2500	0.2500	0.7500	0.7500	10
19	0.2500	0.2500	0.2500	0.2500	10
20	0.2500	0.2500	0.2500	0.7500	10
21	0.5000	0.5000	1.0000	0.5000	10
22	0.5000	0.0000	0.5000	0.5000	10
23	1.0000	0.5000	0.5000	0.5000	10
24	0.5000	0.5000	0.0000	0.5000	10
25	0.5000	0.5000	0.5000	0.0000	10
26	0.5000	1.0000	0.5000	0.5000	10
27	0.5000	0.5000	0.5000	0.5000	10
28	0.5000	0.5000	0.5000	0.5000	10
29	0.0000	0.5000	0.5000	0.5000	10
30	0.5000	0.5000	0.5000	1.0000	10

4.2.2 Transformation RSM For IDSL

Table 4.6: Transformed experimental coded level for RSM data IDSL

Exptal. Run	X_1	X_2	X_3	X_4	Actual Response for IDSL
1	0.5000	0.5000	0.5000	0.5000	10
2	0.5000	0.5000	0.5000	0.5000	10
3	0.2500	0.7500	0.7500	0.7500	11
4	0.2500	0.7500	0.2500	0.7500	10
5	0.2500	0.7500	0.7500	0.2500	10
6	0.2500	0.7500	0.2500	0.2500	10
7	0.7500	0.7500	0.2500	0.7500	9
8	0.7500	0.7500	0.2500	0.2500	10
9	0.7500	0.2500	0.7500	0.7500	10
10	0.7500	0.2500	0.2500	0.7500	9
11	0.7500	0.2500	0.7500	0.2500	10
12	0.7500	0.7500	0.7500	0.2500	12
13	0.7500	0.7500	0.7500	0.7500	8
14	0.2500	0.2500	0.7500	0.2500	10
15	0.5000	0.5000	0.5000	0.5000	10
16	0.7500	0.2500	0.2500	0.2500	10
17	0.5000	0.5000	0.5000	0.5000	10
18	0.2500	0.2500	0.7500	0.7500	11
19	0.2500	0.2500	0.2500	0.2500	10
20	0.2500	0.2500	0.2500	0.7500	10
21	0.5000	0.5000	1.0000	0.5000	9
22	0.5000	0.0000	0.5000	0.5000	10
23	1.0000	0.5000	0.5000	0.5000	11
24	0.5000	0.5000	0.0000	0.5000	10
25	0.5000	0.5000	0.5000	0.0000	9
26	0.5000	1.0000	0.5000	0.5000	10
27	0.5000	0.5000	0.5000	0.5000	10
28	0.5000	0.5000	0.5000	0.5000	10
29	0.0000	0.5000	0.5000	0.5000	10
30	0.5000	0.5000	0.5000	1.0000	10

4.2.3 Transformation RSM for BGP

Table 4.7: Transformed experimental coded level for RSM data BGP

Exptal. Run	X_1	X_2	X_3	X_4	Actual Response for BGP
1	0.5000	0.5000	0.5000	0.5000	10
2	0.5000	0.5000	0.5000	0.5000	9
3	0.2500	0.7500	0.7500	0.7500	11
4	0.2500	0.7500	0.2500	0.7500	10
5	0.2500	0.7500	0.7500	0.2500	10
6	0.2500	0.7500	0.2500	0.2500	10
7	0.7500	0.7500	0.2500	0.7500	10
8	0.7500	0.7500	0.2500	0.2500	10
9	0.7500	0.2500	0.7500	0.7500	10
10	0.7500	0.2500	0.2500	0.7500	9
11	0.7500	0.2500	0.7500	0.2500	10
12	0.7500	0.7500	0.7500	0.2500	11
13	0.7500	0.7500	0.7500	0.7500	10
14	0.2500	0.2500	0.7500	0.2500	9
15	0.5000	0.5000	0.5000	0.5000	11
16	0.7500	0.2500	0.2500	0.2500	10
17	0.5000	0.5000	0.5000	0.5000	9
18	0.2500	0.2500	0.7500	0.7500	10
19	0.2500	0.2500	0.2500	0.2500	10
20	0.2500	0.2500	0.2500	0.7500	10
21	0.5000	0.5000	1.0000	0.5000	10
22	0.5000	0.0000	0.5000	0.5000	10
23	1.0000	0.5000	0.5000	0.5000	10
24	0.5000	0.5000	0.0000	0.5000	10
25	0.5000	0.5000	0.5000	0.0000	11
26	0.5000	1.0000	0.5000	0.5000	9
27	0.5000	0.5000	0.5000	0.5000	9
28	0.5000	0.5000	0.5000	0.5000	10
29	0.0000	0.5000	0.5000	0.5000	10
30	0.5000	0.5000	0.5000	1.0000	10

4.2.4 Transformation RSM for Shell

Table 4.8: Transformed experimental coded level for RSM data SHELL

Exptal. Run	X_1	X_2	X_3	X_4	Actual Response for SHELL
1	0.5000	0.5000	0.5000	0.5000	9
2	0.5000	0.5000	0.5000	0.5000	11
3	0.2500	0.7500	0.7500	0.7500	10
4	0.2500	0.7500	0.2500	0.7500	10
5	0.2500	0.7500	0.7500	0.2500	10
6	0.2500	0.7500	0.2500	0.2500	10
7	0.7500	0.7500	0.2500	0.7500	10
8	0.7500	0.7500	0.2500	0.2500	11
9	0.7500	0.2500	0.7500	0.7500	9
10	0.7500	0.2500	0.2500	0.7500	10
11	0.7500	0.2500	0.7500	0.2500	10
12	0.7500	0.7500	0.7500	0.2500	10
13	0.7500	0.7500	0.7500	0.7500	10
14	0.2500	0.2500	0.7500	0.2500	10
15	0.5000	0.5000	0.5000	0.5000	10
16	0.7500	0.2500	0.2500	0.2500	10
17	0.5000	0.5000	0.5000	0.5000	10
18	0.2500	0.2500	0.7500	0.7500	10
19	0.2500	0.2500	0.2500	0.2500	9
20	0.2500	0.2500	0.2500	0.7500	10
21	0.5000	0.5000	1.0000	0.5000	9
22	0.5000	0.0000	0.5000	0.5000	10
23	1.0000	0.5000	0.5000	0.5000	10
24	0.5000	0.5000	0.0000	0.5000	10
25	0.5000	0.5000	0.5000	0.0000	10
26	0.5000	1.0000	0.5000	0.5000	10
27	0.5000	0.5000	0.5000	0.5000	10
28	0.5000	0.5000	0.5000	0.5000	10
29	0.0000	0.5000	0.5000	0.5000	10
30	0.5000	0.5000	0.5000	1.0000	10

4.3 Local Linear Regression Predicted Results For NPDC and IDSL

In Table 4.9, four explanatory variables, actual responses for NPDC and IDSL, and their respective predicted responses so obtained from the Local Linear regression (LLR) model with fixed bandwidths.

Table 4.9: Actual and Predictive Responses for NPDC and IDSL

Exp. Run	x_1	x_2	x_3	x_4	$y_{ACT}(1)$ NPDC	$y_{PRE}(1)$ NPDC	$y_{ACT}(2)$ IDSL	$y_{PRE}(2)$ IDSL
1	0.2500	0.2500	0.2500	0.2500	10	9.8937	10	9.9992
2	0.7500	0.2500	0.2500	0.2500	10	9.9109	10	9.9981
3	0.2500	0.7500	0.2500	0.2500	10	10.1265	11	10.9974
4	0.7500	0.7500	0.2500	0.2500	10	9.9001	10	10.0018
5	0.2500	0.2500	0.7500	0.2500	10	10.1202	10	9.9969
6	0.7500	0.2500	0.7500	0.2500	10	10.0015	10	9.9996
7	0.2500	0.7500	0.7500	0.2500	10	9.7859	9	9.0010
8	0.7500	0.7500	0.7500	0.2500	10	10.0187	10	9.9995
9	0.2500	0.2500	0.2500	0.7500	9	9.1568	10	10.0003
10	0.7500	0.2500	0.2500	0.7500	9	9.1203	9	9.0023
11	0.2500	0.7500	0.2500	0.7500	11	10.8060	10	10.0017
12	0.7500	0.7500	0.2500	0.7500	9	9.1445	12	11.9974
13	0.2500	0.2500	0.7500	0.7500	11	10.8183	8	8.0039
14	0.7500	0.2500	0.7500	0.7500	10	9.9997	10	10.0008
15	0.2500	0.7500	0.7500	0.7500	8	8.3139	10	9.9994
16	0.7500	0.7500	0.7500	0.7500	10	9.9631	10	10.0010
17	0.0000	0.5000	0.5000	0.5000	10	9.9822	10	9.9998
18	1.0000	0.5000	0.5000	0.5000	10	9.9642	11	10.9997
19	0.5000	0.0000	0.5000	0.5000	10	9.9822	10	9.9997
20	0.5000	1.0000	0.5000	0.5000	10	9.9642	10	10.0002
21	0.5000	0.5000	0.0000	0.5000	10	9.9642	9	9.0005
22	0.5000	0.5000	1.0000	0.5000	10	9.9822	10	9.9997
23	0.5000	0.5000	0.5000	0.5000	10	9.9795	11	9.9999
24	0.5000	0.5000	0.5000	0.5000	10	9.9795	10	9.9999
25	0.5000	0.5000	0.5000	0.0000	10	10.0212	9	9.5007
26	0.5000	0.5000	0.5000	1.0000	10	9.9379	10	10.4991
27	0.5000	0.5000	0.5000	0.5000	10	9.9795	10	9.9999
28	0.5000	0.5000	0.5000	0.5000	10	9.9795	10	9.9999
29	0.5000	0.5000	0.5000	0.5000	10	9.9795	10	9.9999
30	0.5000	0.5000	0.5000	0.5000	10	9.9795	10	9.9999

4.4 Local Linear Regression Predicted Results ForBgp And Shell

In Table 4.10, four explanatory variables, actual responses for BGP and SHELL, and their respective predicted responses so obtained from the Local Linear regression (LLR) model with fixed bandwidths.

Table 4.10: Actual and Predictive Responses for BGP and SHELL

`	x_1	x_2	x_3	x_4	y_{ACT} BGP	$y_{PRE}(3)$ BGP	y_{ACT} SHELL	$y_{PRE}(4)$ SHELL
1	0.2500	0.2500	0.2500	0.2500	10	10.0012	9	9.0020
2	0.7500	0.2500	0.2500	0.2500	9	9.0018	11	10.9659
3	0.2500	0.7500	0.2500	0.2500	11	10.9995	10	9.9961
4	0.7500	0.7500	0.2500	0.2500	10	10.0025	10	9.9995
5	0.2500	0.2500	0.7500	0.2500	10	10.0011	10	9.9961
6	0.7500	0.2500	0.7500	0.2500	10	10.0001	10	9.9995
7	0.2500	0.7500	0.7500	0.2500	10	10.0024	10	10.0014
8	0.7500	0.7500	0.7500	0.2500	10	10.0013	11	10.9731
9	0.2500	0.2500	0.2500	0.7500	10	9.9985	9	8.9998
10	0.7500	0.2500	0.2500	0.7500	9	8.9992	10	10.0126
11	0.2500	0.7500	0.2500	0.7500	10	9.9998	10	9.9961
12	0.7500	0.7500	0.2500	0.7500	11	10.9971	10	9.9951
13	0.2500	0.2500	0.7500	0.7500	10	9.9985	10	9.9961
14	0.7500	0.2500	0.7500	0.7500	9	9.0003	10	9.9951
15	0.2500	0.7500	0.7500	0.7500	11	10.9969	10	9.9992
16	0.7500	0.7500	0.7500	0.7500	10	9.9988	10	10.0197
17	0.0000	0.5000	0.5000	0.5000	9	9.0006	10	9.9951
18	1.0000	0.5000	0.5000	0.5000	10	9.9999	10	10.0049
19	0.5000	0.0000	0.5000	0.5000	10	9.9998	9	9.0073
20	0.5000	1.0000	0.5000	0.5000	10	10.0003	10	10.0024
21	0.5000	0.5000	0.0000	0.5000	10	10.0000	9	9.0073
22	0.5000	0.5000	1.0000	0.5000	10	10.0000	10	10.0024
23	0.5000	0.5000	0.5000	0.5000	10	9.8752	10	9.9994
24	0.5000	0.5000	0.5000	0.5000	10	9.8752	10	9.9994
25	0.5000	0.5000	0.5000	0.0000	11	10.8738	10	10.0046
26	0.5000	0.5000	0.5000	1.0000	9	8.8765	10	9.9943
27	0.5000	0.5000	0.5000	0.5000	9	9.8752	10	9.9994
28	0.5000	0.5000	0.5000	0.5000	10	9.8752	10	9.9994
29	0.5000	0.5000	0.5000	0.5000	10	9.8752	10	9.9994
30	0.5000	0.5000	0.5000	0.5000	10	10.0012	10	9.9994

4.5 Local Linear Regression Residual Results For Npdc, Idsl, BgpAnd Shell

Table 4.11 gives the respective residual errors obtained between the actual and the predicted responses for NPDC, IDSL, BGP and SHELL.

Table 4.11: Residual Responses for NPDC, IDSL, BGP and SHELL on the LLR_{FB}

Exp. Run	y_{RES} NPDC	y_{RES} IDSL	y_{RES} BGP	y_{RES} SHELL
1	0.1063	0.0008	-0.0012	-0.0020
2	0.0891	0.0019	-0.0018	0.0341
3	-0.1265	0.0026	0.0005	0.0039
4	0.0999	-0.0018	-0.0025	0.0005
5	-0.1202	0.0031	-0.0011	0.0039
6	-0.0015	0.0004	-0.0001	0.0005
7	0.2141	-0.0010	-0.0024	-0.0014
8	-0.0187	0.0005	-0.0013	0.0269
9	-0.1568	-0.0003	0.0015	0.0002
10	-0.1203	-0.0023	0.0008	-0.0126
11	0.1940	-0.0017	0.0002	0.0039
12	-0.1445	0.0026	0.0029	0.0049
13	0.1817	-0.0039	0.0015	0.0039
14	0.0003	-0.0008	-0.0003	0.0049
15	-0.3139	0.0006	0.0031	0.0008
16	0.0369	-0.0010	0.0012	-0.0197
17	0.0178	0.0002	-0.0006	0.0049
18	0.0358	0.0003	0.0001	-0.0049
19	0.0178	0.0003	0.0002	-0.0073
20	0.0358	-0.0002	-0.0003	-0.0024
21	0.0358	-0.0005	-0.0000	-0.0073
22	0.0178	0.0003	-0.0000	-0.0024
23	0.0205	1.0001	0.1248	0.0006
24	0.0205	0.0001	0.1248	0.0006
25	-0.0212	-0.5007	0.1262	-0.0046
26	0.0621	-0.4991	0.1235	0.0057
27	0.0205	0.0001	-0.8752	0.0006
28	0.0205	0.0001	0.1248	0.0006
29	0.0205	0.0001	0.1248	0.0006
30	0.0205	0.0001	0.1248	0.0006

4.6 Local Linear Regression Goodness-of-Fit Results for NPDC, IDSL, BGP and Shell

Table 4.12 shows the goodness-of-fit statistics for NPDC, IDSL, BGP and SHELL onthe LLR_{FB} for which the SHELL on LLR_{FB} outperformed the NPDC, IDSL and BGP in terms of

the results obtained and IDSL safety management system has the poorest performance statistics. Obviously, SHELL safety management system is the best among the four oil companies considered in this study.

Table 4.12: Model Goodness-of-Fits Statistics NPDC, IDSL, BGP and SHELL on the LLR_{FB}

Response	Model	*DF*	*PRESS***	*PRESS*	*SSE*	*MSE*	R^2(%)	R^2_{Adj} (%)
$y\ LLR_{FB}$	*NPDC*	8.9826	0.5167	17.0118	0.3479	0.0387	96.00	87.09
	IDSL	6.0306	1.1140	31.2180	1.5001	0.2487	89.98	51.80
	BGP	6.0306	0.8040	22.6146	0.8750	0.1451	91.13	57.35
	SHELL	6.5322	0.1672	5.2699	0.0028	0.000425	99.96	99.79

4.7 Local Linear Regression Combined Residual Plots for NPDC, IDSL, BGP and Shell

LC V-

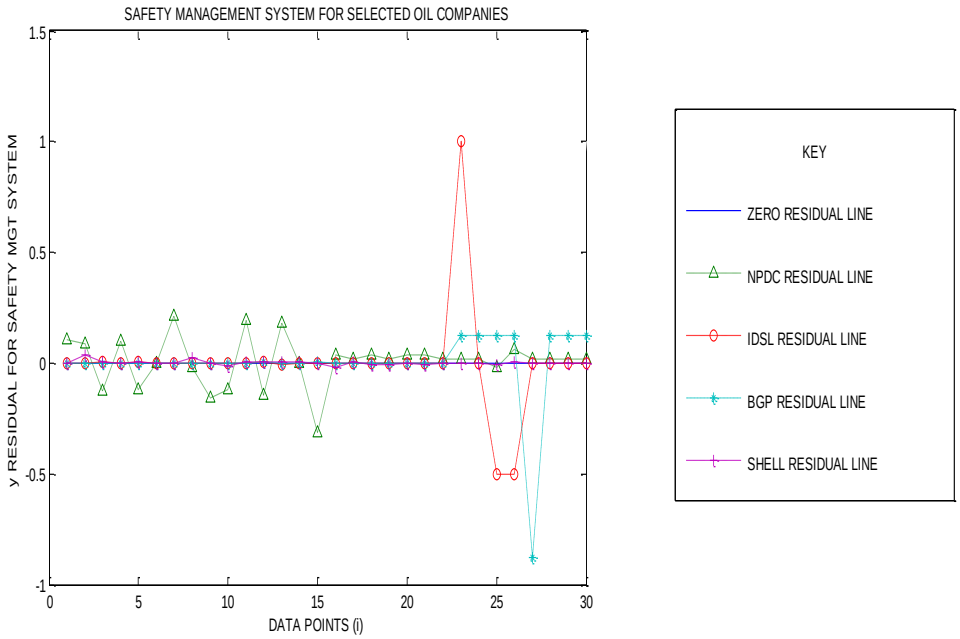


Figure 4.1: NPDC, IDSL, BGP and SHELL residuals deviation from the zero residual line.

In Figure 4.1, is a display of errors associated with four different safety management system with SHELL residual error is closest to the zero residual line, with NPDC the second, BGP the third and IDSL with the poorest to the zero residual line.

4.8 Local Linear Regression Residual Plot For NPDC

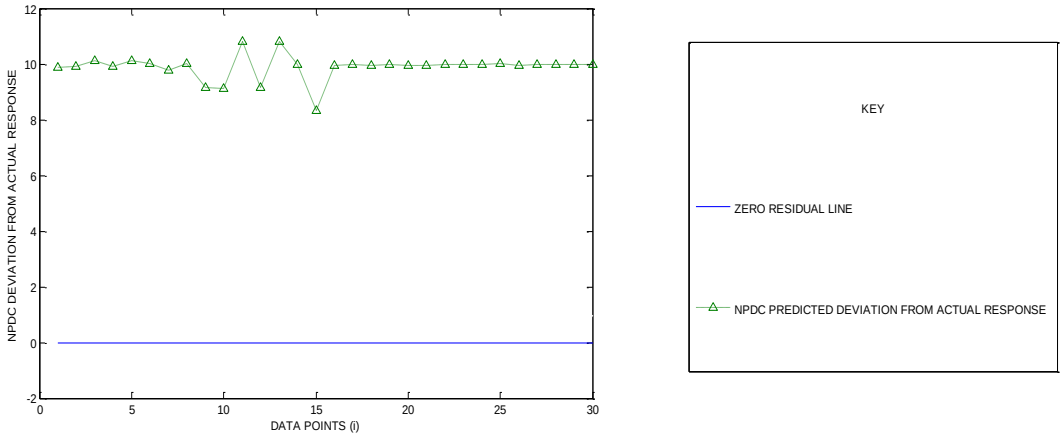


Figure 4.2: NPDC predicted deviation from zero residual line.

4.9 Local Linear Regression Residual Plot for IDSL

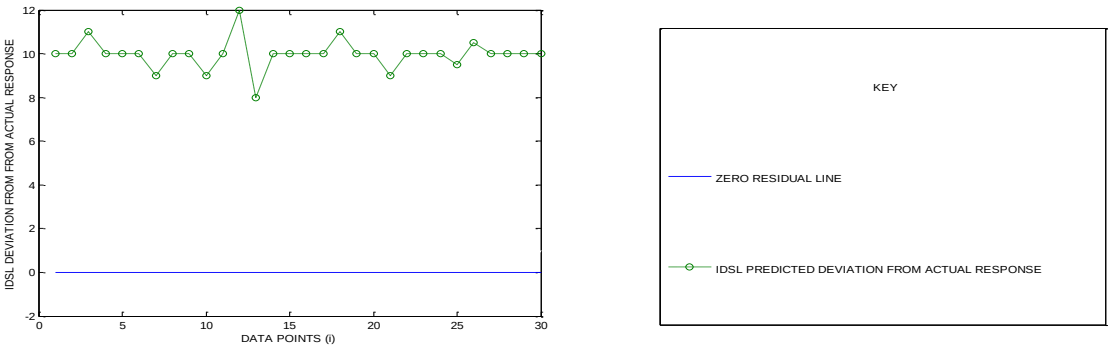


Figure 4.3: IDSL predicted deviation from zero residual line.

4.10 Local Linear Regression Residual Plot for BGP

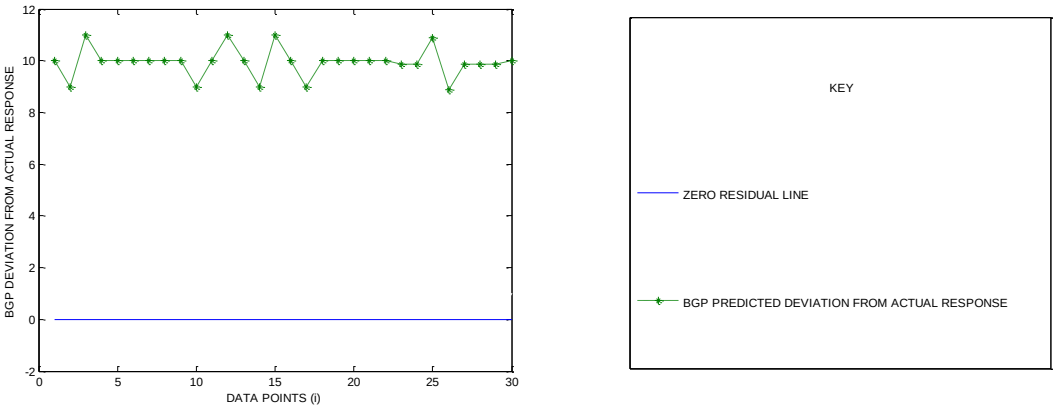


Figure 4.4: BGP predicted deviation from zero residual line.

4.11 Local Linear Regression Residual Plot for Shell

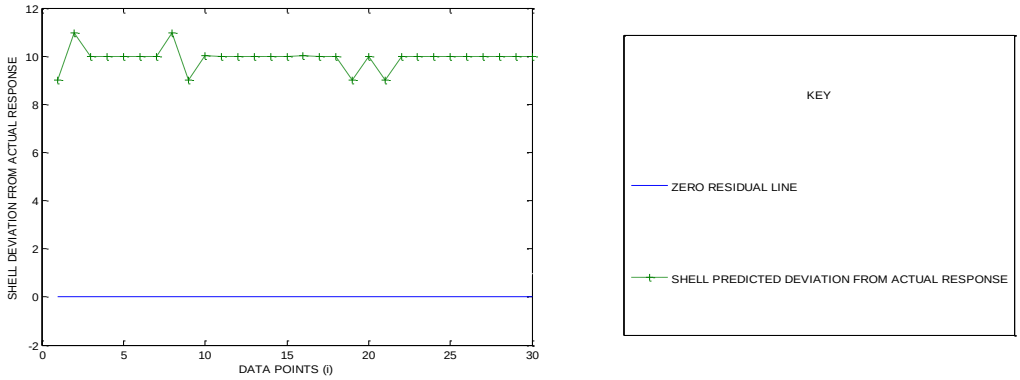


Figure 4.5: SHELL predicted deviation from zero residual line.

In Fig. 4.1 – 4.4, SHELL management system has more straight dotted points signifying the best safety management system over NPDC, BGP and IDSL safety management system. Whereas NPDC is the second best with more straight dotted points over BGP and IDSL safety management system. Again, this confirmed that SHELL performed better in terms of safety management system.

4.12 Optimization Results for NPDC, IDSL, BGP and SHELL

Table 4.13: Desirability function (Optimization Results) forNPDC, IDSL, BGP and SHELL on the LLR_{FB}

Response	**Model**	Optimization for $yMAX$	Actual $yMAX$
$y\ LLR_{FB}$	*NPDC*	10.5184	11.0000
	IDSL	9.5878	12.0000
	BGP	10.2110	11.0000
	SHELL	10.6565	11.0000

Table 4.13 is the optimal solution based on the Squared Distance from Target value for NPDC, IDSL, BGP and SHELL safety management system with NPDC optimization value of y =10.5184 and actual value of y= 11.0000; IDSL safety management system with IDSL optimization value of y = 9.5878 and actual value of y= 12.0000; BGP safety management system with BGP optimization value y = 10.2110 and actual value y= 11.0000; SHELL safety management system with SHELL optimization value of y = 10.6565 and actual value of y= 11.0000. Therefore, SHELL management system optimizes the squared – distance from target better with$yMax$ of 10.6565.

4.13 Surface Plots Showing Maximum Desirability ForNPDC, IDSL, BGP and Shell

Surface Plot for NPDC Maximum Desirability Result

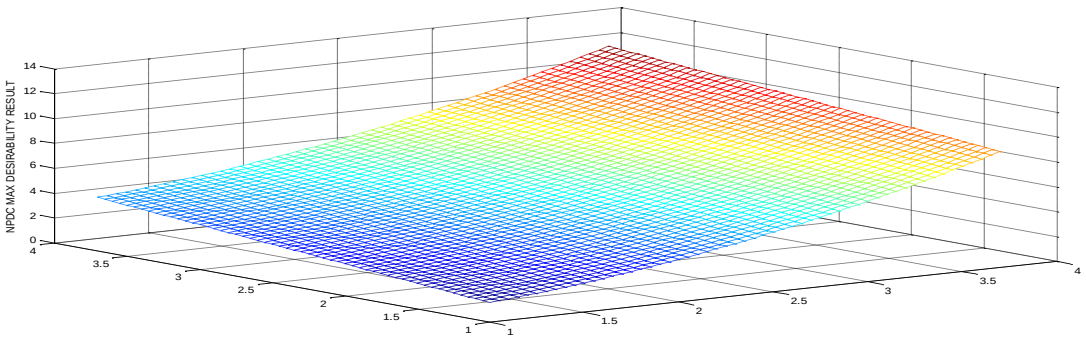


Figure 4.6: Surface plot for NPDC desirability function with Max. value of 10.5184

Surface Plot for IDSL Maximum Desirability Result

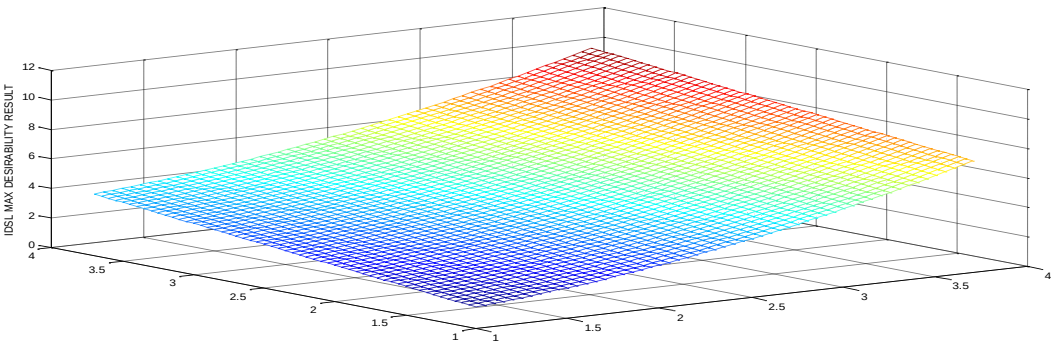


Fig. 4.7: Surface plot for IDSL desirability function with Max. value of 9.5878

Surface Plot for Bgp Maximum Desirability Result

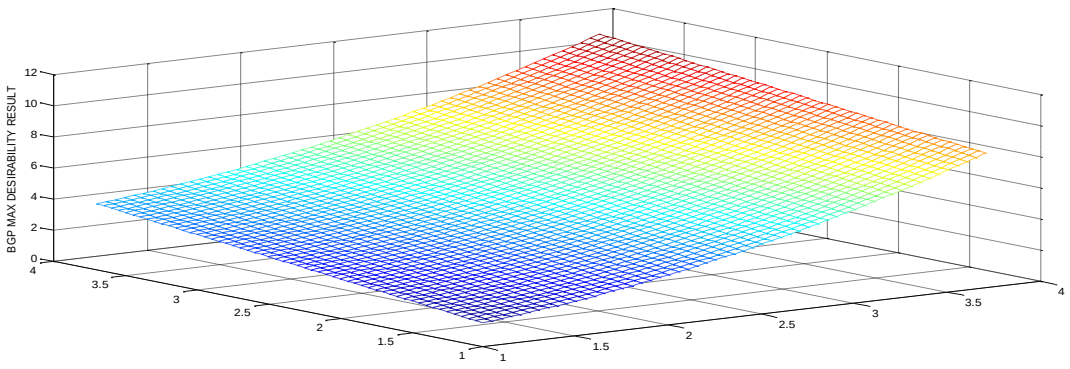


Figure 4.8: Surface plot for BGP desirability function with Max. value of 10.2110

Surface Plot for Shell Maximum Desirability Result

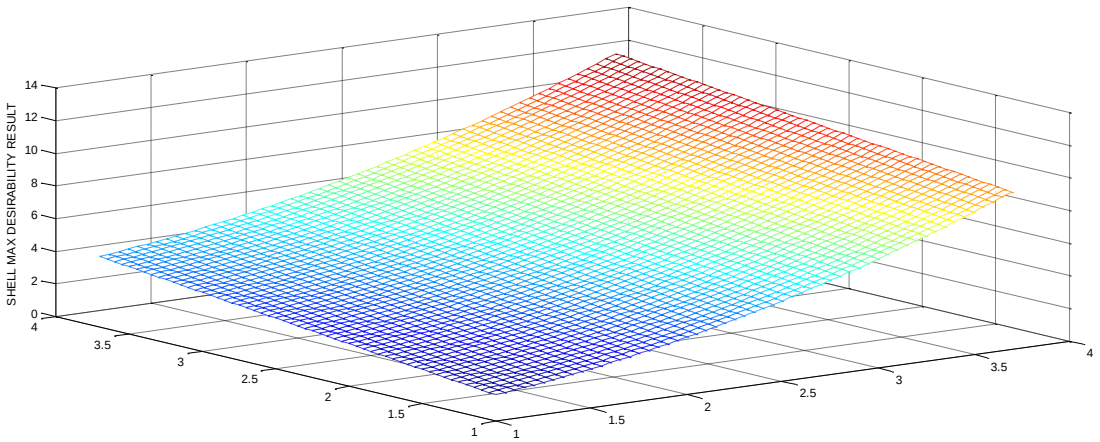


Figure 4.9: Surface plot for SHELL desirability function with Max. value of 10.6565

The linear nature of the waterfall development method makes it easy to understand and manage projects with clear objectives and stable requirements. Less experienced project managers and project teams, as well as teams whose composition changes frequently may benefit the most from using the waterfall development methodology.

4.14 Development Language Used

The development language used is PHP/MySQL. The program consists of a home page that is hyperlinked to several pages that carried out specific functions such as input data, show result for different company's safety performance including:

i. Employee Compliance with company policy on safety.
ii. Company's policy on safety.
iii. Provision of Personal Protective Equipment.
iv. Staff Training on safety.
v. Overall performance on safety.

4.15 Justification of Programming Language Used

PHP is a very popular general-purpose scripting language which is mainly suited for web development. The following are some of the advantages of PHP.

i. **Platform Independence**: PHP is supported by mostly all the operating systems like Windows, Unix, Linux, etc. Advanced PHP applications can be easily deployed on any platform. It can be integrated with other applications and data quickly, and there is no need for rebuilding. It saves a lot of effort and expenses.

ii. **Open source and dynamic Library support**: Another benefit of using the PHP Hyper Preprocessor script which has been developed and maintained by a team of PHP developers. This helps to create a support community, an additional library. PHP additionally has high-performance workflow modules, and several modules available in PHP include Graphics and PDF.

iii. Organized: PHP has been around for about 21 years. During this time, many developers worked on the app to improve app usage. Most bugs are discovered over the years, and bugs are quickly resolved by a team of developers. PHP is now very stable.

iv. **Free Availability:** PHP is an open-source web language, that is why it is completely free. There is no cost involved in purchasing expensive licenses or software. It can work efficiently with different databases, such as Apache, MySQL, and PostgreSQL. The cost of building a website using PHP is small.

v. **Database:** PHP is easily linked to the database and makes communication secure with data. It has in-built modules which can be connected to the database easily. PHP and its database connection solve the purpose of developing web applications. Reduce the time to connect to the data management system. Many details can be integrated with PHP.

vi. **Easy to understand and code:** The PHP framework is mainly used to make web application development easy and automatically coded. The creation of a PHP framework view controller enables the code to be easily stored and used. MVC architecture facilitates the separation of a separate module file.

vii. **Gives Web Developer More Control:** Compared to other languages, PHP allows the website builder to have more control. Long, complex documents override some programming languages, but this is not the case for PHP. Some simple lines of code are enough. Also, PHP allows tags and, thus, website builders can add and mix HTML tags, making the content more authoritative. Developers do not have to worry about putting codes in the right place when using PHP, as written between tags. Therefore, functions and systems do not need to be written in any order, as long as they are marked.

viii. **Easy integration and consistency**: PHP is compatible with most applications. It can smoothly run on different platforms, including UNIX, Solaris, and Linux. Since it can be integrated without effort and other technologies, such as Java, existing software does not need to be upgraded. This saves time and money.

Another development language used in the course of this work is mat lab. The programming environment was used to analyze, create and test the data gotten from the questionnaires to serve as a confirmation of the results we had in the previous program. Below are some of the advantages of MATLAB:

i. MATLAB complier: by converting MATLAB application into a p-code that is machine independent and then, at runtime, interpreting the p-code instruction, MATLAB is able to be flexible and independent of platforms.

There is a different MATLAB complier available with the help of this complier, MATLAB programs can be turned into genuine executable that execute more quickly than interpreted code.

ii. Ease of use: the program can be used to execute lengthy prewritten programs or as a scratchpad to evaluate command-line inputted phrases. Applications can be created, modified and debugged with the MATLAB debugger and built-in integrated development environment. The language is ideal for quick prototyping of new apps because it is so simple to use.

iii. Device-independent plotting: the imaging and basic plotting instructions in MATLAB are numerous. Any kind of graphical output device offered by the machine running MATLAB can display the plots and images. This feature elevates MATLAB to the level of a superior technical data visualization tool.

iv. Platform independence: MATLAB runs on a variety of computers so it offers a high degree of platform freedom. Linus, various UNIX versions, Macintosh, windows 2000/xp/vista, and other operating systems all support the language application created on my platform will function fully on any other platform and data files created for any platform can ostensibly be read on any other platform. As a result, when the demands of the user change, programs created in MATLAB can switch to new platforms.

v. Graphic user interference: a programs graphic user interface can be created interactively by a programmer using a tool found in MATLAB. With this capacity, a programmer can created sophisticated data-analysis Algorithms that relatively inexperienced people can utilize.

vi. Predefined function: a sizable predefined functions library include with MATLAB offers tried and true answers to mainly common technical problems. Your job will be considerably more comfortable thanks to the hundreds of different service that are already include in the MATLAB programming language.

4.16 Operational Procedure

The operational procedure for the usability of the software developed for safety performance is as follows:

Step i: Download and install XAMPP 3.x msi or higher version.

Step ii. Lunch XAMPP, start Apache and MySQL

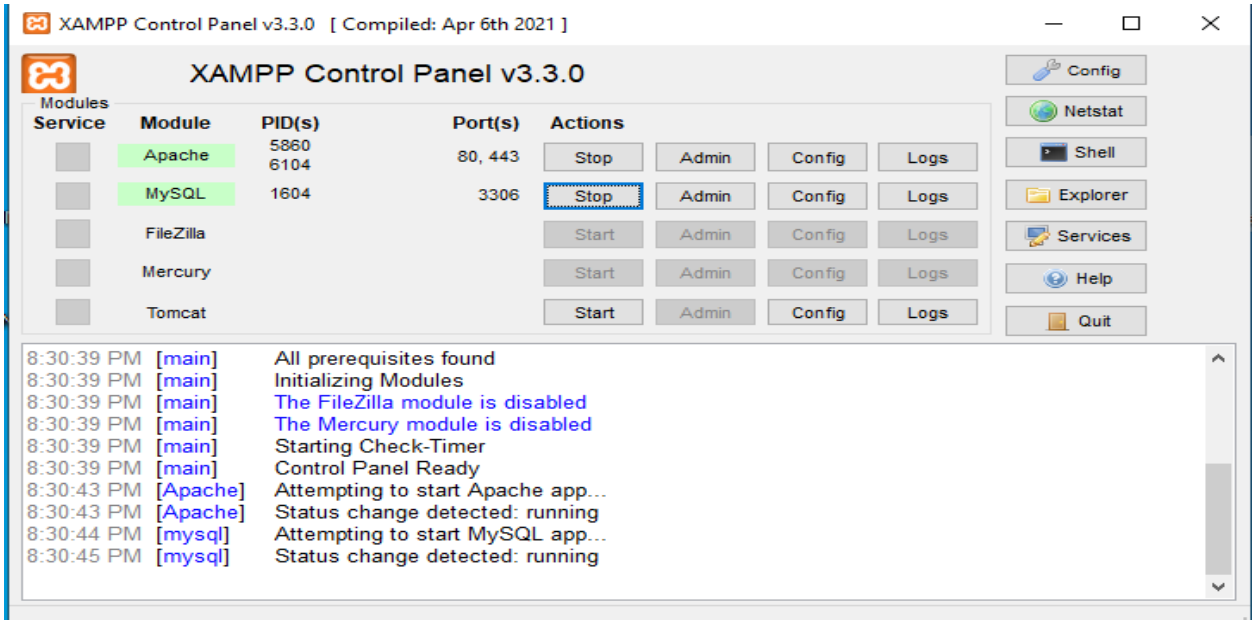


Figure 4.10: XAMPP control panel

In figure 4.10 Apache and MySQL have been activated and are up and running after clicking on start.

Step iii. Create a folder inside htdocs and name it safety. Copy and paste all the codes for the application including index.php into the safety folder.

Step iv. Lunch the safety application using the following URL. 127.0.0.1/safety and press enter key. Then control is transferred to the home page.



Figure 4.11:Home page of the safety application.

The home page of the safety application (figure 4.11) consists of menu such as input data, employee compliance, overall performance, protection and training.

Step v. Input data interface



Figure 4.12: Input data interface

Figure 4.12 represents the user interface for data entry. This will be activated by clicking on input data. Company code is usually numeric, while company name takes the form of COY1 or COY 2 etc. The actual company name is not required for security reasons. Reporting, protection, training, policy and compliance performance are real numbers based on the performance of the companies.

Step vi. Employee Compliance

Employee compliance on Accident prevention Petroleum industry

COY CODE	NAME	REPORTING	PROTECTION	TRAINING	POLICY	COMPLIANCE	TOTAL
4	COY 4	4.6	4.2	4	4.6	4.1	21.5
1	COY 1	3.9	4.2	4.3	3.9	3.5	19.8
3	COY 3	3.7	3.7	4.1	3.8	3.4	18.7
2	COY 2	4	4.2	4	4.2	3.2	19.6

Figure 4.13: Employee compliance output.

In order to access employee safety compliance, click on employee compliance and transferred to the employee compliance web page. In the said web page, the safety performance rating was ordered in accordance with employee performance. The companies sampled for this study were ordered accordingly.

vii. Overall performance

Overal Safety performance in Oil and Gas Industry

COY CODE	NAME	REPORTING	PROTECTION	TRAINING	POLICY	COMPLIANCE	TOTAL
4	COY 4	4.6	4.2	4	4.6	4.1	21.5
1	COY 1	3.9	4.2	4.3	3.9	3.5	19.8
2	COY 2	4	4.2	4	4.2	3.2	19.6
3	COY 3	3.7	3.7	4.1	3.8	3.4	18.7

Return to home page

Figure 4.14: Overall safety performance

Figure 4.14: represent the overall performance of companies in oil and gas sampled for this study. The data in the table records were ordered according to total. Company 4 (COY4) performed best while company 3 (COY3) is trailing behind other companies.

Step viii: Performance on protective equipment

Povision of Personal Protective Equipment

COY CODE	NAME	REPORTING	PROTECTION	TRAINING	POLICY	COMPLIANCE	TOTAL
1	COY 1	3.9	4.2	4.3	3.9	3.5	19.8
4	COY 4	4.6	4.2	4	4.6	4.1	21.5
2	COY 2	4	4.2	4	4.2	3.2	19.6
3	COY 3	3.7	3.7	4.1	3.8	3.4	18.7

Figure 4.15: Output of performance on safety equipment.

Figure 15 shows the output on performance of the companies selected for this study in terms of their performance concerning provision of safety equipment. The result can be accessed by clicking on protection on the menu. From the result company 1 performed the same way as company 2 and company 4 while company 3 did not perform well in this regard.

Step ix Accident reporting

Accident Reporting in Petroleum industry

COY CODE	NAME	REPORTING	PROTECTION	TRAINING	POLICY	COMPLIANCE	TOTAL
4	COY 4	4.6	4.2	4	4.6	4.1	21.5
2	COY 2	4	4.2	4	4.2	3.2	19.6
1	COY 1	3.9	4.2	4.3	3.9	3.5	19.8
3	COY 3	3.7	3.7	4.1	3.8	3.4	18.7

Figure 4.16: Output of performance on reporting.

Figure 4.16 shows the output on performance of the companies selected for this study in terms of accident reporting. The result can be accessed by clicking on reporting on the menu.

From the result company 4 performed well in this regard. Company 4 performed more than other companies while company 3 performed below other companies.

Step x. Company policy on accident prevention

Good policy implementation on Accident prevention Petroleum industry

COY CODE	NAME	REPORTING	PROTECTION	TRAINING	POLICY	COMPLIANCE	TOTAL
4	COY 4	4.6	4.2	4	4.6	4.1	21.5
2	COY 2	4	4.2	4	4.2	3.2	19.6
1	COY 1	3.9	4.2	4.3	3.9	3.5	19.8
3	COY 3	3.7	3.7	4.1	3.8	3.4	18.7

Figure 4.17: Output of performance on policy implementation of accident prevention

Figure 4.17 shows the output on performance of the companies selected for this study in terms of policy implementation on accident safety. The result can be accessed by clicking on company's policy on the menu. From the result company 4 performed well in this regard compared to other companies.

4.17 Software testing

Table 4.14Test Plan

Test Case type	Description	Test step	Expected result	Status
Lunch application	The user uses the url to invoke the web application	Click on web browser and google 127.0.0.1/safety	Control is transferred to safety home	Pass
Input a new record	Input company code and the performance indicators for different safety outcome	Click on input data from the homepage menu	Control is transferred to the input user interface	Pass
View result	Click on the different category of output result	Control is transferred to the appropriate result output web page	The safety performance is displayed in order of performance	Pass

A Test Plan (table 4.14) is a detailed document that describes the test strategy, objectives, schedule, estimation, deliverables, and resources required to perform testing for a software product. In this study, the Test Plan helps us determine the effort needed to validate the quality of the application under test. The test plan also serves as a blueprint to conduct software testing activities.

CHAPTER FIVE

SUMMARY CONCLUSION AND RECOMMENDATION

5.1 Summary

As given in Table 4.13, the goodness-of-fit statistics for NPDC, IDSL, BGP and SHELL on the LLR_{FB} $(Fixed\ bandwidth\ on\ Local\ Linear\ Regression)$ model for which the SHELL oil company on LLR_{FB} outperformed the NPDC, IDSL and BGP in terms of the results obtained and IDSL safety management system has the poorest performance statistics. Obviously, SHELL safety management system is the best among the four oil companies considered in this study. Hence, the maximization of the individual desirability functions as given in Table 4.14 and Figures 4.6, 4.7, 4.8 and 4.9 shows the shapes of the different colour variation in the surface plots representing individual desirability of the optimization criteria for NPDC, IDSL, BGP and SHELL on the LLR_{FB}respectively. In Figure 4.9, the individual desirability function for LLR_{AB} is 10.6565as against the optimization results of 10.5184, 9.5878 and 10.2110for NPDC, IDSL and BGP oil companies.

In this study, a web-based application was developed for accident management. The data used for the development of the web application were obtained from questionnaire administered to selected multinational cooperation involved in the exploration and exploitation of oil and gas in Nigeria. The web application showed the performance of the various companies in terms of their overall performance in accident management, provision of protective equipment for workers, training, company policy, accident reporting and workers compliance with accident prevention procedure. In the past it was not possible to make such comparative analysis of safety performance in the said industries.

5.2 Conclusion

The stages in RSM are namely, experimental design phase, modeling phase of the fitted regression model and the optimization phase with the goal to find setting of the operating factors that optimize responses in relation to safety management system among the four different oil companies considered in this study. In the optimization processes such as safety management system and in the industries, this procedure is known as process or product qualification (Anderson-Cook and Prewitt, 2005).

In this study, we have shown that the data or response was generated from administered questionnaire and the coded levels and factors via DOE and how the data generated were transformed via the use of CCD to RSM data in terms of the factors that needed to be in the interval of zero's and one's. In other to obtain optimal regression results, a fixed bandwidth applied to the local linear regression (LLR with fixed bandwidth) model was introduced for adequate smoothing of the data for RSM. Obviously, the SHELL oil company that utilized the LLR with fixed bandwidth outperformed the NPDC, IDSL and BGP oil companies in terms of regression results and for a squared distance from target optimization in other to maximize safety precautions engaged for a single response problem.

Obtaining data for comparative analysis of safety in oil and gas industry is a challenging task. The report obtained will assist the users of such information to persuade company management to continue to improve safety measures in areas where they have not performed well compared to other companies.

5.3 Recommendations

The following recommendations have been made to assist the relevant stakeholders improve workplace safety in the multinational co-operations selected for this study.

i. Management should continue with the safety measures in place and make improvement where it is deemed necessary.

ii. Management should do more to ensure that data concerning safety is made available to users of such information in order to improve the overall employee safety.

iii. Organizations concerned with monitoring compliance with safety should be on ground in multinational co-operations to ensure compliance with safety procedure in the said companies.

iv. Government should enact the enabling legal measure to make it mandatory for multinational co-operation operating in Nigeria to make information about safety in their organization available to users of such information for the purpose of strategic planning to avert accidents in workplace.

5.4 Further Study

This study should be expanded to include other companies operating in Nigeria with a view of getting a holistic performance of safety performance in as many industries as possible.

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APPENDIX A : REGRESSION CODES AND RESULTS FOR NPDC, IDSL, BGP AND SHELL

NPDC Safety Management

```
function PRESS_DOUBLE_STAR= my_Nikky1A_y2LLR_fiXed_bandwidth_April_2023(b)
warning ('off','all')
e=2.7183;
x1=[0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500
0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.0000 1.0000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x2=[0.2500 0.2500 0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.2500 0.2500
0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.5000 0.5000 0.0000 1.0000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x3=[0.2500 0.2500 0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.2500 0.2500
0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.0000 1.0000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x4=[0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.7500 0.7500
0.7500 0.7500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.0000 1.0000 0.5000 0.5000 0.5000 0.5000]';
y2=[10 10 10 10 10 10 10 10 9 9 11 9 11 10 8 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10]';
n=length(x1);
const=ones(n,1);
X11=[const x1 x2 x3 x4];
k=rank(X11)-1;
ymean=mean(y2);
SSM=sum((y2-ymean).^2);
%%%%%%%%%%preallocate dimensions for arrays
y2LLR_max=zeros(n,1);y2LLRcv=zeros(n,1);a=zeros(n,1);y2LLR=zeros(n,1);
%%%%%%%%%%get maximum SSE
b_max=999999999;
for i=1:n;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
w1max_LLR=((1/e).^(((x1-x1(i))./b_max).^2)).*((1/e).^(((x2-
x2(i))./b_max).^2)).*((1/e).^(((x3-x3(i))./b_max).^2)).*((1/e).^(((x4-
x4(i))./b_max).^2)); % normal kernel for max SSE;
WWmax_LLR=sum(w1max_LLR);
kerweight_max_LLR=w1max_LLR./WWmax_LLR;
Wmax_LLR=diag(kerweight_max_LLR);
HatLLR_max=X11(i,:)*((X11'*Wmax_LLR*X11)\(X11'*Wmax_LLR)); % ith row of the
n by n LLR hat matrix;
y2LLR_max(i)=HatLLR_max*y2;    % LLR estimate of the response vector y2;
end
SSEmax=sum((y2-y2LLR_max).^2);
%b=0.2600;
for i=1:n;
w1_LLR=((1/e).^(((x1-x1(i))/b).^2)).*((1/e).^(((x2-
x2(i))/b).^2)).*((1/e).^(((x3-x3(i))/b).^2)).*((1/e).^(((x4-
x4(i))./b_max).^2));  % normal kernel for max SSE;
WW_LLR=sum(w1_LLR);
kerweight_LLR=w1_LLR./WW_LLR;
%%%%%%%%%%begin leave-one-out regression procedure
kerweight_LLR(i,:)=[];
y2(i,:)=[];
X11(i,:)=[];
W_LLR=diag(kerweight_LLR);
a2=(X11'*W_LLR*X11)\X11'*W_LLR*y2;
%%%%%%%%%%restore original dimensions of arrays
kerweight_LLR=w1_LLR./WW_LLR;
X11=[const x1 x2 x3 x4];
```

```
y2=[10 10 10 10 10 10 10 10 9 9 11 9 11 10 8 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10]';
%%%%%%%%%get leave-one-out estimates of responses
y2LLRcv(i)=X11(i,:)*a2;
%%%%%%%%%get estimates of responses
W_LLR=diag(kerweight_LLR);
HLLR=X11(i,:)*((X11'*W_LLR*X11)\(X11'*W_LLR));
a(i)=HLLR(1,i);
y2LLR(i)=HLLR*y2;
end
PRESS=sum((y2-y2LLRcv).^2),
SSEb=sum((y2-y2LLR).^2),
mse=SSEb/(n-sum(a)),
Rsqr=1-(SSEb/SSM),
Rsqr_adj=1-((SSEb*(n-1))/((n-sum(a))*SSM)),
df=n-sum(a),
PRESS_DOUBLE_STAR=PRESS/((n-sum(a))+(n-k-1)*(SSEmax-SSEb)/SSEmax),
r2LLR=y2-y2LLR,y2LLR,
```

```
PRESS =

   17.0118


SSEb =

    0.3479


mse =

    0.0387


Rsqr =

    0.9600


Rsqr_adj =

    0.8709


df =

    8.9826


PRESS_DOUBLE_STAR =

    0.5167


r2LLR =

    0.1063
    0.0891
   -0.1265
    0.0999
   -0.1202
   -0.0015
```

```
    0.2141
   -0.0187
   -0.1568
   -0.1203
    0.1940
   -0.1445
    0.1817
    0.0003
   -0.3139
    0.0369
    0.0178
    0.0358
    0.0178
    0.0358
    0.0358
    0.0178
    0.0205
    0.0205
   -0.0212
    0.0621
    0.0205
    0.0205
    0.0205
    0.0205


y2LLR =

    9.8937
    9.9109
   10.1265
    9.9001
   10.1202
   10.0015
    9.7859
   10.0187
    9.1568
    9.1203
   10.8060
    9.1445
   10.8183
    9.9997
    8.3139
    9.9631
    9.9822
    9.9642
    9.9822
    9.9642
    9.9642
    9.9822
    9.9795
    9.9795
   10.0212
    9.9379
    9.9795
    9.9795
    9.9795
    9.9795


ans =

    0.5167
```

```
function PRESS_DOUBLE_STAR= my_Nikky2_y2LLR_fiXed_bandwidth_April_2023(b)
warning ('off','all')
e=2.7183;
x1=[0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500
0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.0000 1.0000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x2=[0.2500 0.2500 0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.2500 0.2500
0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.5000 0.5000 0.0000 1.0000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x3=[0.2500 0.2500 0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.2500 0.2500
0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.0000 1.0000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x4=[0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.7500 0.7500
0.7500 0.7500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.0000 1.0000 0.5000 0.5000 0.5000 0.5000]';
y2=[10 10 11 10 10 10 9 10 10 9 10 12 8 10 10 10 10 11 10 10 9 10 11 10 9
10 10 10 10 10]';
n=length(x1);
const=ones(n,1);
X11=[const x1 x2 x3 x4];
k=rank(X11)-1;
ymean=mean(y2);
SSM=sum((y2-ymean).^2);
%%%%%%%%%%preallocate dimensions for arrays
y2LLR_max=zeros(n,1);y2LLRcv=zeros(n,1);a=zeros(n,1);y2LLR=zeros(n,1);
%%%%%%%%%%get maximum SSE
b_max=999999999;
for i=1:n;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
w1max_LLR=((1/e).^(((x1-x1(i))./b_max).^2)).*((1/e).^(((x2-
x2(i))./b_max).^2)).*((1/e).^(((x3-x3(i))./b_max).^2)).*((1/e).^(((x4-
x4(i))./b_max).^2)); % normal kernel for max SSE;
WWmax_LLR=sum(w1max_LLR);
kerweight_max_LLR=w1max_LLR./WWmax_LLR;
Wmax_LLR=diag(kerweight_max_LLR);
HatLLR_max=X11(i,:)*((X11'*Wmax_LLR*X11)\(X11'*Wmax_LLR)); % ith row of the
n by n LLR hat matrix;
y2LLR_max(i)=HatLLR_max*y2;    % LLR estimate of the response vector y2;
end
SSEmax=sum((y2-y2LLR_max).^2);
%b=0.1600;
for i=1:n;
w1_LLR=((1/e).^(((x1-x1(i))/b).^2)).*((1/e).^(((x2-
x2(i))/b).^2)).*((1/e).^(((x3-x3(i))/b).^2)).*((1/e).^(((x4-
x4(i))./b_max).^2));  % normal kernel for max SSE;
WW_LLR=sum(w1_LLR);
kerweight_LLR=w1_LLR./WW_LLR;
%%%%%%%%%%begin leave-one-out regression procedure
kerweight_LLR(i,:)=[];
y2(i,:)=[];
X11(i,:)=[];
W_LLR=diag(kerweight_LLR);
a2=(X11'*W_LLR*X11)\X11'*W_LLR*y2;
%%%%%%%%%%restore original dimensions of arrays
kerweight_LLR=w1_LLR./WW_LLR;
X11=[const x1 x2 x3 x4];
y2=[10 10 11 10 10 10 9 10 10 9 10 12 8 10 10 10 10 11 10 10 9 10 11 10 9
10 10 10 10 10]';
```

```
%%%%%%%%%get leave-one-out estimates of responses
y2LLRcv(i)=X11(i,:)*a2;
%%%%%%%%%get estimates of responses
W_LLR=diag(kerweight_LLR);
HLLR=X11(i,:)*((X11'*W_LLR*X11)\(X11'*W_LLR));
a(i)=HLLR(1,i);
y2LLR(i)=HLLR*y2;
end
PRESS=sum((y2-y2LLRcv).^2),
SSEb=sum((y2-y2LLR).^2),
mse=SSEb/(n-sum(a)),
Rsqr=1-(SSEb/SSM),
Rsqr_adj=1-((SSEb*(n-1))/((n-sum(a))*SSM)),
df=n-sum(a),
PRESS_DOUBLE_STAR=PRESS/((n-sum(a))+(n-k-1)*(SSEmax-SSEb)/SSEmax),
r2LLR=y2-y2LLR,y2LLR,
```

```
PRESS =

   31.2180


SSEb =

    1.5001


mse =

    0.2487


Rsqr =

    0.8998


Rsqr_adj =

    0.5180


df =

    6.0306


PRESS_DOUBLE_STAR =

    1.1140


r2LLR =

    0.0008
    0.0019
    0.0026
   -0.0018
    0.0031
    0.0004
   -0.0010
    0.0005
   -0.0003
```

```
   -0.0023
   -0.0017
    0.0026
   -0.0039
   -0.0008
    0.0006
   -0.0010
    0.0002
    0.0003
    0.0003
   -0.0002
   -0.0005
    0.0003
    1.0001
    0.0001
   -0.5007
   -0.4991
    0.0001
    0.0001
    0.0001
    0.0001


y2LLR =

    9.9992
    9.9981
   10.9974
   10.0018
    9.9969
    9.9996
    9.0010
    9.9995
   10.0003
    9.0023
   10.0017
   11.9974
    8.0039
   10.0008
    9.9994
   10.0010
    9.9998
   10.9997
    9.9997
   10.0002
    9.0005
    9.9997
    9.9999
    9.9999
    9.5007
   10.4991
    9.9999
    9.9999
    9.9999
    9.9999


ans =

    1.1140
```

BGP SAFETY MANAGEMENT

```
function PRESS_DOUBLE_STAR=
my_Nikky3BGP_y2LLR_fiXed_bandwidth_April_2023(b)
warning ('off','all')
e=2.7183;
x1=[0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500
0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.0000 1.0000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x2=[0.2500 0.2500 0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.2500 0.2500
0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.5000 0.5000 0.0000 1.0000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x3=[0.2500 0.2500 0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.2500 0.2500
0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.0000 1.0000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x4=[0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.7500 0.7500
0.7500 0.7500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.0000 1.0000 0.5000 0.5000 0.5000 0.5000]';
y2=[10 9 11 10 10 10 10 10 10 9 10 11 10 9 11 10 9 10 10 10 10 10 10 10 11
9 9 10 10 10]';
n=length(x1);
const=ones(n,1);
X11=[const x1 x2 x3 x4];
k=rank(X11)-1;
ymean=mean(y2);
SSM=sum((y2-ymean).^2);
%%%%%%%%%%preallocate dimensions for arrays
y2LLR_max=zeros(n,1);y2LLRcv=zeros(n,1);a=zeros(n,1);y2LLR=zeros(n,1);
%%%%%%%%%%get maximum SSE
b_max=999999999;
for i=1:n;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
w1max_LLR=((1/e).^(((x1-x1(i))./b_max).^2)).*((1/e).^(((x2-
x2(i))./b_max).^2)).*((1/e).^(((x3-x3(i))./b_max).^2)).*((1/e).^(((x4-
x4(i))./b_max).^2)); % normal kernel for max SSE;
WWmax_LLR=sum(w1max_LLR);
kerweight_max_LLR=w1max_LLR./WWmax_LLR;
Wmax_LLR=diag(kerweight_max_LLR);
HatLLR_max=X11(i,:)*((X11'*Wmax_LLR*X11)\(X11'*Wmax_LLR)); % ith row of the
n by n LLR hat matrix;
y2LLR_max(i)=HatLLR_max*y2;    % LLR estimate of the response vector y2;
end
SSEmax=sum((y2-y2LLR_max).^2);
%b=0.2600;
for i=1:n;
w1_LLR=((1/e).^(((x1-x1(i))/b).^2)).*((1/e).^(((x2-
x2(i))/b).^2)).*((1/e).^(((x3-x3(i))/b).^2)).*((1/e).^(((x4-
x4(i))./b_max).^2));  % normal kernel for max SSE;
WW_LLR=sum(w1_LLR);
kerweight_LLR=w1_LLR./WW_LLR;
%%%%%%%%%%begin leave-one-out regression procedure
kerweight_LLR(i,:)=[];
y2(i,:)=[];
X11(i,:)=[];
W_LLR=diag(kerweight_LLR);
a2=(X11'*W_LLR*X11)\X11'*W_LLR*y2;
%%%%%%%%%%restore original dimensions of arrays
kerweight_LLR=w1_LLR./WW_LLR;
X11=[const x1 x2 x3 x4];
```

```
y2=[10 9 11 10 10 10 10 10 10 9 10 11 10 9 11 10 9 10 10 10 10 10 10 10 11
9 9 10 10 10]';
%%%%%%%%%get leave-one-out estimates of responses
y2LLRcv(i)=X11(i,:)*a2;
%%%%%%%%%get estimates of responses
W_LLR=diag(kerweight_LLR);
HLLR=X11(i,:)*((X11'*W_LLR*X11)\(X11'*W_LLR));
a(i)=HLLR(1,i);
y2LLR(i)=HLLR*y2;
end
PRESS=sum((y2-y2LLRcv).^2),
SSEb=sum((y2-y2LLR).^2),
mse=SSEb/(n-sum(a)),
Rsqr=1-(SSEb/SSM),
Rsqr_adj=1-((SSEb*(n-1))/((n-sum(a))*SSM)),
df=n-sum(a),
PRESS_DOUBLE_STAR=PRESS/((n-sum(a))+(n-k-1)*(SSEmax-SSEb)/SSEmax),
r2LLR=y2-y2LLR,y2LLR,
```

```
PRESS =

   22.6146


SSEb =

    0.8750


mse =

    0.1451


Rsqr =

    0.9113


Rsqr_adj =

    0.5735


df =

    6.0306


PRESS_DOUBLE_STAR =

    0.8040


r2LLR =

   -0.0012
   -0.0018
    0.0005
   -0.0025
   -0.0011
   -0.0001
   -0.0024
```

```
   -0.0013
    0.0015
    0.0008
    0.0002
    0.0029
    0.0015
   -0.0003
    0.0031
    0.0012
   -0.0006
    0.0001
    0.0002
   -0.0003
   -0.0000
   -0.0000
    0.1248
    0.1248
    0.1262
    0.1235
   -0.8752
    0.1248
    0.1248
    0.1248


y2LLR =

   10.0012
    9.0018
   10.9995
   10.0025
   10.0011
   10.0001
   10.0024
   10.0013
    9.9985
    8.9992
    9.9998
   10.9971
    9.9985
    9.0003
   10.9969
    9.9988
    9.0006
    9.9999
    9.9998
   10.0003
   10.0000
   10.0000
    9.8752
    9.8752
   10.8738
    8.8765
    9.8752
    9.8752
    9.8752
    9.8752


ans =

    0.8040
```

SHELL SAFETY MANAGEMENT

```
function PRESS_DOUBLE_STAR=
my_Nikky4SHEL_y2LLR_fiXed_bandwidth_April_2023(b)
warning ('off','all')
e=2.7183;
x1=[0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500
0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.0000 1.0000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x2=[0.2500 0.2500 0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.2500 0.2500
0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.5000 0.5000 0.0000 1.0000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x3=[0.2500 0.2500 0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.2500 0.2500
0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.0000 1.0000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x4=[0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.7500 0.7500
0.7500 0.7500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.0000 1.0000 0.5000 0.5000 0.5000 0.5000]';
y2=[9 11 10 10 10 10 10 11 9 10 10 10 10 10 10 10 10 10 9 10 9 10 10 10 10
10 10 10 10 10]';
n=length(x1);
const=ones(n,1);
X11=[const x1 x2 x3 x4];
k=rank(X11)-1;
ymean=mean(y2);
SSM=sum((y2-ymean).^2);
%%%%%%%%%%preallocate dimensions for arrays
y2LLR_max=zeros(n,1);y2LLRcv=zeros(n,1);a=zeros(n,1);y2LLR=zeros(n,1);
%%%%%%%%%%get maximum SSE
b_max=999999999;
for i=1:n;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
w1max_LLR=((1/e).^(((x1-x1(i))./b_max).^2)).*((1/e).^(((x2-
x2(i))./b_max).^2)).*((1/e).^(((x3-x3(i))./b_max).^2)).*((1/e).^(((x4-
x4(i))./b_max).^2)); % normal kernel for max SSE;
WWmax_LLR=sum(w1max_LLR);
kerweight_max_LLR=w1max_LLR./WWmax_LLR;
Wmax_LLR=diag(kerweight_max_LLR);
HatLLR_max=X11(i,:)*((X11'*Wmax_LLR*X11)\(X11'*Wmax_LLR)); % ith row of the
n by n LLR hat matrix;
y2LLR_max(i)=HatLLR_max*y2;    % LLR estimate of the response vector y2;
end
SSEmax=sum((y2-y2LLR_max).^2);
b=0.2028848042224932;
for i=1:n;
w1_LLR=((1/e).^(((x1-x1(i))/b).^2)).*((1/e).^(((x2-
x2(i))/b).^2)).*((1/e).^(((x3-x3(i))/b).^2)).*((1/e).^(((x4-
x4(i))./b_max).^2));  % normal kernel for max SSE;
WW_LLR=sum(w1_LLR);
kerweight_LLR=w1_LLR./WW_LLR;
%%%%%%%%%%begin leave-one-out regression procedure
kerweight_LLR(i,:)=[];
y2(i,:)=[];
X11(i,:)=[];
W_LLR=diag(kerweight_LLR);
a2=(X11'*W_LLR*X11)\X11'*W_LLR*y2;
%%%%%%%%%restore original dimensions of arrays
kerweight_LLR=w1_LLR./WW_LLR;
X11=[const x1 x2 x3 x4];
y2=[9 11 10 10 10 10 10 11 9 10 10 10 10 10 10 10 10 10 9 10 9 10 10 10 10
10 10 10 10 10]';
%%%%%%%%%get leave-one-out estimates of responses
```

```
y2LLRcv(i)=X11(i,:)*a2;
%%%%%%%%%get estimates of responses
W_LLR=diag(kerweight_LLR);
HLLR=X11(i,:)*((X11'*W_LLR*X11)\(X11'*W_LLR));
a(i)=HLLR(1,i);
y2LLR(i)=HLLR*y2;
end
PRESS=sum((y2-y2LLRcv).^2),
SSEb=sum((y2-y2LLR).^2),
mse=SSEb/(n-sum(a)),
Rsqr=1-(SSEb/SSM),
Rsqr_adj=1-((SSEb*(n-1))/((n-sum(a))*SSM)),
df=n-sum(a),
PRESS_DOUBLE_STAR=PRESS/((n-sum(a))+(n-k-1)*(SSEmax-SSEb)/SSEmax),
r2LLR=y2-y2LLR,y2LLR,
```

```
PRESS =

    5.2699


SSEb =

    0.0028


mse =

0.00042472


Rsqr =

    0.9995

Rsqr_adj =

    0.9979

df =

    6.5322

PRESS_DOUBLE_STAR =

    0.1672


r2LLR =

   -0.0020
    0.0341
    0.0039
    0.0005
    0.0039
    0.0005
   -0.0014
    0.0269
    0.0002
   -0.0126
    0.0039
    0.0049
    0.0039
```

```
    0.0049
    0.0008
   -0.0197
    0.0049
   -0.0049
   -0.0073
   -0.0024
   -0.0073
   -0.0024
    0.0006
    0.0006
   -0.0046
    0.0057
    0.0006
    0.0006
    0.0006
    0.0006


y2LLR =

    9.0020
   10.9659
    9.9961
    9.9995
    9.9961
    9.9995
   10.0014
   10.9731
    8.9998
   10.0126
    9.9961
    9.9951
    9.9961
    9.9951
    9.9992
   10.0197
    9.9951
   10.0049
    9.0073
   10.0024
    9.0073
   10.0024
    9.9994
    9.9994
   10.0046
    9.9943
    9.9994
    9.9994
    9.9994
    9.9994


ans =

    0.1672
```

APPENDIX B: NPDC, IDSL, BGP AND SHELL CODES FOR RESIDUAL PLOT

1.

```
function my_Nikky_Residual_Safety_Mgt_graph_April_2023
yaxis=[-0.8752 -0.5007 -0.4991 -0.3139 -0.1568 -0.1445 -0.1265 -0.1203 -
0.1202 -0.0212 -0.001 -0.001 -0.0001 -0.0001 0 0.0001 0.0002 0.0003 0.0004
0.0005 0.0006 0.0007 0.0008 0.0009 0.0010 0.002 0.003 0.005 0.009 1];
xaxis=[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
27 28 29 30];
r=[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];
rNPDC=[0.1063 0.0891 -0.1265 0.0999 -0.1202 -0.0015 0.2141 -0.0187 -0.1568
-0.1203 0.1940 -0.1445 0.1817 0.0003 -0.3139 0.0369 0.0178 0.0358 0.0178
0.0358 0.0358 0.0178 0.0205 0.0205 -0.0212 0.0621 0.0205 0.0205 0.0205
0.0205];
rIDSL=[0.0008 0.0019 0.0026 -0.0018 0.0031 0.0004 -0.0010 0.0005 -0.0003 -
0.0023 -0.0017 0.0026 -0.0039 -0.0008 0.0006 -0.0010 0.0002 0.0003 0.0003 -
0.0002 -0.0005 0.0003 1.0001 0.0001 -0.5007 -0.4991 0.0001 0.0001 0.0001
0.0001];
rBGP=[-0.0012 -0.0018 0.0005 -0.0025 -0.0011 -0.0001 -0.0024 -0.0013 0.0015
0.0008 0.0002 0.0029 0.0015 -0.0003 0.0031 0.0012 -0.0006 0.0001 0.0002 -
0.0003 0.0000 0.0000 0.1248 0.1248 0.1262 0.1235 -0.8752 0.1248 0.1248
0.1248];
rSHELL=[-0.0020 0.0341 0.0039 0.0005 0.0039 0.0005 -0.0014 0.0269 0.0002 -
0.0126 0.0039 0.0049 0.0039 0.0049 0.0008 -0.0197 0.0049 -0.0049 -0.0073 -
0.0024 -0.0073 -0.0024 0.0006 0.0006 -0.0046 0.0057 0.0006 0.0006 0.0006
0.0006];
subplot(2,4,1),
plot(xaxis,yaxis,'w',xaxis,r,'-
',xaxis,rNPDC,'^',xaxis,rIDSL,'o',xaxis,rBGP,'*',xaxis,rSHELL,'+');
```

2.

```
function my_Nikky_NPDC_Deviation_from_Actual_Safety_Mgt_graph_April_2023
yaxis=[-0.8752 -0.5007 -0.4991 -0.3139 -0.1568 -0.1445 -0.1265 -0.1203 -
0.1202 -0.0212 -0.001 -0.001 -0.0001 -0.0001 0 0.0001 0.0002 0.0003 0.0004
0.0005 0.0006 0.0007 0.0008 0.0009 0.0010 0.002 0.003 0.005 0.009 1];
xaxis=[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
27 28 29 30];
r=[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];
rNPDC=[9.8937 9.9109 10.1265 9.9001 10.1202 10.0015 9.7859 10.0187 9.1568
9.1203 10.8060 9.1445 10.8183 9.9997 8.3139 9.9631 9.9822 9.9642 9.9822
9.9642 9.9642 9.9822 9.9795 9.9795 10.0212 9.9379 9.9795 9.9795 9.9795
9.9795];
subplot(2,2,1),
plot(xaxis,yaxis,'w',xaxis,r,'-',xaxis,rNPDC,'^');
```

3.

```
function my_Nikky_IDSL_Deviation_from_Actual_Safety_Mgt_graph_April_2023
yaxis=[-0.8752 -0.5007 -0.4991 -0.3139 -0.1568 -0.1445 -0.1265 -0.1203 -
0.1202 -0.0212 -0.001 -0.001 -0.0001 -0.0001 0 0.0001 0.0002 0.0003 0.0004
0.0005 0.0006 0.0007 0.0008 0.0009 0.0010 0.002 0.003 0.005 0.009 1];
xaxis=[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
27 28 29 30];
r=[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];
rIDSL=[9.9992 9.9981 10.9974 10.0018 9.9969 9.9996 9.0010 9.9995 10.0003
9.0023 10.0017 11.9974 8.0039 10.0008 9.9994 10.0010 9.9998 10.9997 9.9997
10.0002 9.0005 9.9997 9.9999 9.9999 9.5007 10.4991 9.9999 9.9999 9.9999
9.9999];
subplot(2,2,1),
plot(xaxis,yaxis,'w',xaxis,r,'-',xaxis,rIDSL,'o');
```

4.

```
function my_Nikky_BGP_Deviation_from_Actual_Safety_Mgt_graph_April_2023
yaxis=[-0.8752 -0.5007 -0.4991 -0.3139 -0.1568 -0.1445 -0.1265 -0.1203 -
0.1202 -0.0212 -0.001 -0.001 -0.0001 -0.0001 0 0.0001 0.0002 0.0003 0.0004
0.0005 0.0006 0.0007 0.0008 0.0009 0.0010 0.002 0.003 0.005 0.009 1];
xaxis=[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
27 28 29 30];
r=[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];
rBGP=[10.0012 9.0018 10.9995 10.0025 10.0011 10.0001 10.0024 10.0013 9.9985
8.9992 9.9998 10.9971 9.9985 9.0003 10.9969 9.9988 9.0006 9.9999 9.9998
10.0003 10.0000 10.0000 9.8752 9.8752 10.8738 8.8765 9.8752 9.8752 9.8752
10.0012];
subplot(2,2,1),
plot(xaxis,yaxis,'w',xaxis,r,'-',xaxis,rBGP,'*');
```

5.

```
function my_Nikky_SHELL_Deviation_from_Actual_Safety_Mgt_graph_April_2023
yaxis=[-0.8752 -0.5007 -0.4991 -0.3139 -0.1568 -0.1445 -0.1265 -0.1203 -
0.1202 -0.0212 -0.001 -0.001 -0.0001 -0.0001 0 0.0001 0.0002 0.0003 0.0004
0.0005 0.0006 0.0007 0.0008 0.0009 0.0010 0.002 0.003 0.005 0.009 1];
xaxis=[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
27 28 29 30];
r=[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];
rSHELL=[9.0020 10.9659 9.9961 9.9995 9.9961 9.9995 10.0014 10.9731 8.9998
10.0126 9.9961 9.9951 9.9961 9.9951 9.9992 10.0197 9.9951 10.0049 9.0073
10.0024 9.0073 10.0024 9.9994 9.9994 10.0046 9.9943 9.9994 9.9994 9.9994
9.9994];
subplot(2,2,1),
plot(xaxis,yaxis,'w',xaxis,r,'-',xaxis,rSHELL,'+');
```

APPENDIX C: CODES FOR DESIRABILITY FUNCTION

1.

```
function D=my_Nikky_NPDC_Desirability_Safety_Mgt_System_April_2023(X)
%X(1) % GA code representing one of the values of x1 in {x:x?R,0?x?1}
%X(2) % GA code representing one of the values of x2 in {x:x?R,0?x?1}
%X(3) % GA code representing one of the values of x3 in {x:x?R,0?x?1}
%X(4) % GA code representing one of the values of x4 in {x:x?R,0?x?1}
%X=[X(1) X(2) X(3) X(4)]; % GA code for set of values of X(1), X(2), X(3) &
X(4)
%X=[];
e=2.7183;
% get raw data
x1=[0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500
0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.0000 1.0000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x2=[0.2500 0.2500 0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.2500 0.2500
0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.5000 0.5000 0.0000 1.0000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x3=[0.2500 0.2500 0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.2500 0.2500
0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.0000 1.0000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x4=[0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.7500 0.7500
0.7500 0.7500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.0000 1.0000 0.5000 0.5000 0.5000 0.5000]';
y1=[10 10 10 10 10 10 10 10 9 9 11 9 11 10 8 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10]';
n=length(x1);const=ones(n,1);
% LLR model matrix
X1=[const x1 x2 x3 x4];
%empty vectors for storing predicted responses
y1LLR=zeros(n,1);
% lower limit of process requirement for each response
b1_LLR=0.2600;
%%%%%%%%%%%%%%%%%%%%%%%%
for i=1:n;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
w1_LLR=((1/e).^(((x1(i)-X(1))./b1_LLR).^2)).*((1/e).^(((x2(i)-
X(2))./b1_LLR).^2)).*((1/e).^(((x3(i)-
X(3))./b1_LLR).^2)).*((1/e).^(((x4(i)-X(4))./b1_LLR).^2));  % mormal
product kernel for max SSE;
WW_LLR=sum(w1_LLR);
kerweight_LLR=w1_LLR./WW_LLR;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
W_LLR=diag(kerweight_LLR);
%%%%%%%%%%%%%%%%%%%%%%%%
A1=[1 X(1) X(2) X(3) X(4)];
HLLR=A1*((X1'*W_LLR*X1)\(X1'*W_LLR));%ith row of n by n LLR Hat mat
y1LLR(i)=HLLR*y1;   % predicted response for the ith local mixing parameter
end
y1max=-max(y1LLR),   % code for getting settings of explanatory variables
% that maximizes response via the Genetic Algorithm
[y1max i]=max(y1LLR),                % code for getting the location of
max predicted response
X(1),X(2),X(3),X(4),
```

```
DESIRABILITY FOR NPDC
y1max =

  -10.5184
```

```
y1max =

   10.5184


i =

     1
```

2.

```
function D=my_Nikky_IDSL_Desirability_Safety_Mgt_System_April_2023(X)
%X(1) % GA code representing one of the values of x1 in {x:x?R,0?x?1}
%X(2) % GA code representing one of the values of x2 in {x:x?R,0?x?1}
%X(3) % GA code representing one of the values of x3 in {x:x?R,0?x?1}
%X(4) % GA code representing one of the values of x4 in {x:x?R,0?x?1}
%X=[X(1) X(2) X(3) X(4)]; % GA code for set of values of X(1), X(2), X(3) &
X(4)
%X=[];
e=2.7183;
% get raw data
x1=[0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500
0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.0000 1.0000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x2=[0.2500 0.2500 0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.2500 0.2500
0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.5000 0.5000 0.0000 1.0000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x3=[0.2500 0.2500 0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.2500 0.2500
0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.0000 1.0000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x4=[0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.7500 0.7500
0.7500 0.7500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.0000 1.0000 0.5000 0.5000 0.5000 0.5000]';
y1=[10 10 11 10 10 10 9 10 10 9 10 12 8 10 10 10 10 11 10 10 9 10 11 10 9
10 10 10 10 10]';
n=length(x1);const=ones(n,1);
% LLR model matrix
X1=[const x1 x2 x3 x4];
%empty vectors for storing predicted responses
y1LLR=zeros(n,1);
% lower limit of process requirement for each response
b1_LLR=0.1600;
%%%%%%%%%%%%%%%%%%%%%%%%
for i=1:n;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
w1_LLR=((1/e).^(((x1(i)-X(1))./b1_LLR).^2)).*((1/e).^(((x2(i)-
X(2))./b1_LLR).^2)).*((1/e).^(((x3(i)-
X(3))./b1_LLR).^2)).*((1/e).^(((x4(i)-X(4))./b1_LLR).^2));  % mormal
product kernel for max SSE;
WW_LLR=sum(w1_LLR);
kerweight_LLR=w1_LLR./WW_LLR;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
W_LLR=diag(kerweight_LLR);
%%%%%%%%%%%%%%%%%%%%%%%%
A1=[1 X(1) X(2) X(3) X(4)];
HLLR=A1*((X1'*W_LLR*X1)\(X1'*W_LLR));%ith row of n by n LLR Hat mat
y1LLR(i)=HLLR*y1;   % predicted response for the ith local mixing parameter
end
y1max=-max(y1LLR),   % code for getting settings of explanatory variables
% that maximizes response via the Genetic Algorithm
[y1max i]=max(y1LLR),                  % code for getting the location of
max predicted response
%X(1),X(2),X(3),X(4),
```

```
DESIRABILITY FOR IDSL
y1max =

   -9.5878


y1max =

    9.5878


i =

     1
```

3.

```
function D=my_Nikky_BGP_Desirability_Safety_Mgt_System_April_2023(X)
%X(1) % GA code representing one of the values of x1 in {x:x?R,0?x?1}
%X(2) % GA code representing one of the values of x2 in {x:x?R,0?x?1}
%X(3) % GA code representing one of the values of x3 in {x:x?R,0?x?1}
%X(4) % GA code representing one of the values of x4 in {x:x?R,0?x?1}
%X=[X(1) X(2) X(3) X(4)]; % GA code for set of values of X(1), X(2), X(3) &
X(4)
%X=[];
e=2.7183;
% get raw data
x1=[0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500
0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.0000 1.0000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x2=[0.2500 0.2500 0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.2500 0.2500
0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.5000 0.5000 0.0000 1.0000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x3=[0.2500 0.2500 0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.2500 0.2500
0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.0000 1.0000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x4=[0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.7500 0.7500
0.7500 0.7500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.0000 1.0000 0.5000 0.5000 0.5000 0.5000]';
y1=[10 9 11 10 10 10 10 10 10 9 10 11 10 9 11 10 9 10 10 10 10 10 10 10 11
9 9 10 10 10]';
n=length(x1);const=ones(n,1);
% LLR model matrix
X1=[const x1 x2 x3 x4];
%empty vectors for storing predicted responses
y1LLR=zeros(n,1);
% lower limit of process requirement for each response
b1_LLR=0.2600;
%%%%%%%%%%%%%%%%%%%%%%%%%
for i=1:n;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
w1_LLR=((1/e).^(((x1(i)-X(1))./b1_LLR).^2)).*((1/e).^(((x2(i)-
X(2))./b1_LLR).^2)).*((1/e).^(((x3(i)-
X(3))./b1_LLR).^2)).*((1/e).^(((x4(i)-X(4))./b1_LLR).^2));  % mormal
product kernel for max SSE;
WW_LLR=sum(w1_LLR);
kerweight_LLR=w1_LLR./WW_LLR;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
W_LLR=diag(kerweight_LLR);
%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
A1=[1 X(1) X(2) X(3) X(4)];
HLLR=A1*((X1'*W_LLR*X1)\(X1'*W_LLR));%ith row of n by n LLR Hat mat
y1LLR(i)=HLLR*y1;   % predicted response for the ith local mixing parameter
end
y1max=-max(y1LLR),   % code for getting settings of explanatory variables
% that maximizes response via the Genetic Algorithm
[y1max i]=max(y1LLR),                  % code for getting the location of
max predicted response
%X(1),X(2),X(3),X(4),

DESIRABILITY FOR BGP

y1max =

  -10.2110


y1max =

   10.2110


i =

     1
```

4.

```
function D=my_Nikky_SHELL_Desirability_Safety_Mgt_System_April_2023(X)
%X(1) % GA code representing one of the values of x1 in {x:x?R,0?x?1}
%X(2) % GA code representing one of the values of x2 in {x:x?R,0?x?1}
%X(3) % GA code representing one of the values of x3 in {x:x?R,0?x?1}
%X(4) % GA code representing one of the values of x4 in {x:x?R,0?x?1}
%X=[X(1) X(2) X(3) X(4)]; % GA code for set of values of X(1), X(2), X(3) &
X(4)
%X=[];
e=2.7183;
% get raw data
x1=[0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.2500 0.7500
0.2500 0.7500 0.2500 0.7500 0.2500 0.7500 0.0000 1.0000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x2=[0.2500 0.2500 0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.2500 0.2500
0.7500 0.7500 0.2500 0.2500 0.7500 0.7500 0.5000 0.5000 0.0000 1.0000
0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x3=[0.2500 0.2500 0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.2500 0.2500
0.2500 0.2500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.0000 1.0000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000 0.5000]';
x4=[0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.2500 0.7500 0.7500
0.7500 0.7500 0.7500 0.7500 0.7500 0.7500 0.5000 0.5000 0.5000 0.5000
0.5000 0.5000 0.5000 0.5000 0.0000 1.0000 0.5000 0.5000 0.5000 0.5000]';
y1=[9 11 10 10 10 10 10 11 9 10 10 10 10 10 10 10 10 10 9 10 9 10 10 10 10
10 10 10 10 10]';
n=length(x1);const=ones(n,1);
% LLR model matrix
X1=[const x1 x2 x3 x4];
%empty vectors for storing predicted responses
y1LLR=zeros(n,1);
% lower limit of process requirement for each response
b1_LLR=0.2028848042224932;
%%%%%%%%%%%%%%%%%%%%%%%%%
for i=1:n;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
w1_LLR=((1/e).^(((x1(i)-X(1))./b1_LLR).^2)).*((1/e).^(((x2(i)-
X(2))./b1_LLR).^2)).*((1/e).^(((x3(i)-
X(3))./b1_LLR).^2)).*((1/e).^(((x4(i)-X(4))./b1_LLR).^2));  % mormal
product kernel for max SSE;
WW_LLR=sum(w1_LLR);
kerweight_LLR=w1_LLR./WW_LLR;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
W_LLR=diag(kerweight_LLR);
%%%%%%%%%%%%%%%%%%%%%%%%
A1=[1 X(1) X(2) X(3) X(4)];
HLLR=A1*((X1'*W_LLR*X1)\(X1'*W_LLR));%ith row of n by n LLR Hat mat
y1LLR(i)=HLLR*y1;   % predicted response for the ith local mixing parameter
end
y1max=-max(y1LLR),   % code for getting settings of explanatory variables
% that maximizes response via the Genetic Algorithm
[y1max i]=max(y1LLR),                  % code for getting the location of
max predicted response
%X(1),X(2),X(3),X(4),

DESIRABILITY FOR SHELL

y1max =

  -10.6565


y1max =

   10.6565


i =

     1
```

APPENDIX D: CODES FOR SURFACE PLOT

1. SURFACE PLOT FOR NPDC DESIRABILITY

```
>> % creates meshgrids X and Y of same size
[X,Y]=meshgrid(1:.05:3.7);
% Initialize Z as of same size of X
Z=0.61*X.^2+Y;
% Plot the mesh plot with X,Y,Z of linestyle='--'
% We can change surface properties of using variable s
s=mesh(X,Y,Z,'LineStyle','--')
```

2. SURFACE PLOT FOR IDSL DESIRABILITY

```
>> % creates meshgrids X and Y of same size
[X,Y]=meshgrid(1:.05:3.7);
% Initialize Z as of same size of X
Z=0.48*X.^2+Y;
% Plot the mesh plot with X,Y,Z of linestyle='--'
% We can change surface properties of using variable s
s=mesh(X,Y,Z,'LineStyle','--')
```

3. SURFACE PLOT FOR BGP DESIRABILITY

```
>> % creates meshgrids X and Y of same size
[X,Y]=meshgrid(1:.05:3.7);
% Initialize Z as of same size of X
Z=0.56*X.^2+Y;
% Plot the mesh plot with X,Y,Z of linestyle='--'
% We can change surface properties of using variable s
s=mesh(X,Y,Z,'LineStyle','--')
```

4. SURFACE PLOT FOR SHELL DESIRABILITY

```
>> % creates meshgrids X and Y of same size
[X,Y]=meshgrid(1:.05:3.7);
% Initialize Z as of same size of X
Z=0.63*X.^2+Y;
% Plot the mesh plot with X,Y,Z of linestyle='--'
% We can change surface properties of using variable s
s=mesh(X,Y,Z,'LineStyle','--')
```

APPENDIX E: SOURCE CODE

Home page

```
//Index.php
<html>
<head>
<style>
html, body{
	margin: 0px;
}
div#nav{
	background-color: #7a9;
}
a{
	display: inline-block;
	padding: 5px;
	text-decoration: none;
	color: white;
	background-color: #7a9;
}

</style>
</head>

<body>
<div id="nav">
<a href = "inputform.php">INPUT DATA    </a>
<a href = "complianceoutput.php">EMPLOYEE COMPLIANCE   </a>
<a href = "Overaloutput.php">OVERALL SAFETY   </a>
<a href = "ppeoutput.php">PROTECTION    </a>
<a href = "trainingoutput.php">TRAINING    </a>
<a href = "policyoutput.php">COMPANY POLICY   </a>
<a href = "reportingoutput.php">REPORTING</a>
</div>
<imgsrc = "download.jpg" style="width:1366px;height:636px"/>
</body>
</html>
```

Adding records to database table obtained from form input

```
//Addrecprd.php
<?php
if ((!$_POST["coycode"]) ||
(!$_POST["coyname"])   ||
(!$_POST["accrep"])    ||
(!$_POST["ppe"])       ||
(!$_POST["training"])  ||
(!$_POST["sfpolicy"])  ||
(!$_POST["comply"]))
{
header("Location: http://127.0.0.1/safety/inputrec1.php");
exit;
```

```
}
$sql = "INSERT INTO coysf (coycode,coyname,accrep,ppe,training,sfpolicy,comply)
VALUES ('$_POST[coycode]', '$_POST[coyname]', '$_POST[accrep]', '$_POST[ppe]',
'$_POST[training]', '$_POST[sfpolicy]', '$_POST[comply]')";

// create connection; substitute your own information
$conn =mysqli_connect("localhost","root","","coysafe") or die (mysql_error());

// execute SQL query and get result
$sql_result = mysqli_query($conn,$sql,) ;
if ($sql_result){
echo("Update successful");
}
?>
```

Staff compliance output code

```
<h2>Employee compliance on Accident prevention Petroleum industry</h2>
<?php
$sql = "SELECT coycode,coyname,accrep,ppe,training,sfpolicy,comply,sumtot
FROM coysf ORDER BY comply DESC ";

// create connection; substitute your own information
$conn =mysqli_connect("localhost","root","","coysafe") or die (mysql_error());

// execute SQL query and get result
$sql_result = mysqli_query($conn,$sql,) ;

// start results formatting
echo "<TABLE BORDER=1>
<TR>
<TH>COY CODE</TH>
<TH>NAME</TH>
<TH>REPORTING</TH>
<TH>PROTECTION</TH>
<TH>TRAINING</TH>
<TH>POLICY</TH>
<TH>COMPLIANCE</TH>
<TH>TOTAL</TH>

</TR>";
// format results by row
while ($row = mysqli_fetch_array($sql_result)) {
$code   = $row["coycode"];
$name   = $row["coyname"];
$rep    = $row["accrep"];
$ppe    = $row["ppe"];
$train  = $row["training"];
$policy = $row["sfpolicy"];
$com    = $row["comply"];
$tot    = $row["sumtot"];
echo "<TR>
```

```
        <TD>$code</TD>
        <TD>$name</TD>
        <TD>$rep</TD>
        <TD>$ppe</TD>
        <TD>$train</TD>
        <TD>$policy</TD>
        <TD>$com</TD>
        <TD align=right>$tot</TD>
</TR>";
}
echo "</TABLE>";
?>

Input data code
<h1>Adding a Record to       table</h1>
<FORM method="POST" action="addrecord.php">
<table cellspacing=5 cellpadding=5>
<tr>
<td valign=top><strong>COMPANY CODE:</strong></td>
<td valign=top><INPUT type="text" name="coycode"
size=4 maxlength=4></td>
</tr>
<tr>
<td valign=top><strong>COMPANY NAME:</strong></td>
<td valign=top><INPUT type="text" name="coyname"
size=10 maxlength=10></td>
</tr>
<tr>
<td valign=top><strong>ACCIDENT REPORTING:</strong></td>
<td valign=top><INPUT type="text" name="accrep"
size=5 maxlength=5></td>
</tr>
<tr>
<td valign=top><strong>PROVISION OF PPE:</strong></td>
<td valign=top><INPUT type="text" name="ppe"
size=5 maxlength=5></td>
</tr>
<tr>
<td valign=top><strong>PROVISION OF TRAINING:</strong></td>
<td valign=top><INPUT type="text" name="training"
size=5 maxlength=5></td>
</tr>
<tr>
<td valign=top><strong>SAFETY POLICY:</strong></td>
<td valign=top><INPUT type="text" name="sfpolicy"
size=5 maxlength=5></td>
</tr>
<tr>
<td valign=top><strong>SAFETY COMPLIANCE:</strong></td>
<td valign=top><INPUT type="text" name="comply"
size=5 maxlength=5></td>
</tr>
```

```
<tr>
<tdalign=left colspan=2><INPUT type="submit" value="Submit"></td>
</tr>
</table>
</FORM>
```

Code for overall performance

```
<h2>Overal Safety performance in Oil and Gas Industry</h2><?php
$sql = "SELECT coycode,coyname,accrep,ppe,training,sfpolicy,comply,sumtot
FROM coysf ORDER BY sumtot DESC ";

// create connection; substitute your own information
$conn =mysqli_connect("localhost","root","","coysafe") or die (mysql_error());

// execute SQL query and get result
$sql_result = mysqli_query($conn,$sql,) ;

// start results formatting
echo "<TABLE BORDER=1>
<TR>
<TH>COY CODE</TH>
<TH>NAME</TH>
<TH>REPORTING</TH>
<TH>PROTECTION</TH>
<TH>TRAINING</TH>
<TH>POLICY</TH>
<TH>COMPLIANCE</TH>
<TH>TOTAL</TH>

</TR>";
// format results by row
while ($row = mysqli_fetch_array($sql_result)) {
$code   = $row["coycode"];
$name   = $row["coyname"];
$rep    = $row["accrep"];
$ppe    = $row["ppe"];
$train  = $row["training"];
$policy = $row["sfpolicy"];
$com    = $row["comply"];
$tot    = $row["sumtot"];
echo "<TR>
          <TD>$code</TD>
          <TD>$name</TD>
          <TD>$rep</TD>
          <TD>$ppe</TD>
          <TD>$train</TD>
          <TD>$policy</TD>
          <TD>$com</TD>
          <TD align=right>$tot</TD>
</TR>";
}
```

```
echo "</TABLE>";
?>
<a href = "index.php">Return to home page</a>

Codes for policy performance
<h2>Good policy implementation on Accident prevention Petroleum industry</h2>
<?php
$sql = "SELECT coycode,coyname,accrep,ppe,training,sfpolicy,comply,sumtot
FROM coysf ORDER BY sfpolicy DESC ";

// create connection; substitute your own information
$conn =mysqli_connect("localhost","root","","coysafe") or die (mysql_error());

// execute SQL query and get result
$sql_result = mysqli_query($conn,$sql,) ;

// start results formatting
echo "<TABLE BORDER=1>
<TR>
<TH>COY CODE</TH>
<TH>NAME</TH>
<TH>REPORTING</TH>
<TH>PROTECTION</TH>
<TH>TRAINING</TH>
<TH>POLICY</TH>
<TH>COMPLIANCE</TH>
<TH>TOTAL</TH>

</TR>";
// format results by row
while ($row = mysqli_fetch_array($sql_result)) {
$code   = $row["coycode"];
$name   = $row["coyname"];
$rep    = $row["accrep"];
$ppe    = $row["ppe"];
$train  = $row["training"];
$policy = $row["sfpolicy"];
$com    = $row["comply"];
$tot    = $row["sumtot"];
echo "<TR>
          <TD>$code</TD>
          <TD>$name</TD>
          <TD>$rep</TD>
          <TD>$ppe</TD>
          <TD>$train</TD>
          <TD>$policy</TD>
          <TD>$com</TD>
          <TD align=right>$tot</TD>
</TR>";
}
echo "</TABLE>";
?>
```

Codes for protective equipment performance

```
<h2>Povision of Personal Protective Equipment</h2>
<?php
$sql = "SELECT coycode,coyname,accrep,ppe,training,sfpolicy,comply,sumtot
FROM coysf ORDER BY ppe DESC ";

// create connection; substitute your own information
$conn =mysqli_connect("localhost","root","","coysafe") or die (mysql_error());

// execute SQL query and get result
$sql_result = mysqli_query($conn,$sql,) ;

// start results formatting
echo "<TABLE BORDER=1>
<TR>
<TH>COY CODE</TH>
<TH>NAME</TH>
<TH>REPORTING</TH>
<TH>PROTECTION</TH>
<TH>TRAINING</TH>
<TH>POLICY</TH>
<TH>COMPLIANCE</TH>
<TH>TOTAL</TH>

</TR>";
// format results by row
while ($row = mysqli_fetch_array($sql_result)) {
$code   = $row["coycode"];
$name   = $row["coyname"];
$rep    = $row["accrep"];
$ppe    = $row["ppe"];
$train  = $row["training"];
$policy = $row["sfpolicy"];
$com    = $row["comply"];
$tot    = $row["sumtot"];
echo "<TR>
          <TD>$code</TD>
          <TD>$name</TD>
          <TD>$rep</TD>
          <TD>$ppe</TD>
          <TD>$train</TD>
          <TD>$policy</TD>
          <TD>$com</TD>
          <TD align=right>$tot</TD>
</TR>";
}
echo "</TABLE>";
?>
```

Reporting output performance

```
<h2>Accident Reporting in Petroleum industry</h2>
<?php
$sql = "SELECT coycode,coyname,accrep,ppe,training,sfpolicy,comply,sumtot
FROM coysf ORDER BY accrep DESC ";

// create connection; substitute your own information
$conn =mysqli_connect("localhost","root","","coysafe") or die (mysql_error());

// execute SQL query and get result
$sql_result = mysqli_query($conn,$sql,) ;

// start results formatting
echo "<TABLE BORDER=1>
<TR>
<TH>COY CODE</TH>
<TH>NAME</TH>
<TH>REPORTING</TH>
<TH>PROTECTION</TH>
<TH>TRAINING</TH>
<TH>POLICY</TH>
<TH>COMPLIANCE</TH>
<TH>TOTAL</TH>

</TR>";
// format results by row
while ($row = mysqli_fetch_array($sql_result)) {
$code   = $row["coycode"];
$name   = $row["coyname"];
$rep    = $row["accrep"];
$ppe    = $row["ppe"];
$train  = $row["training"];
$policy = $row["sfpolicy"];
$com    = $row["comply"];
$tot    = $row["sumtot"];
echo "<TR>
          <TD>$code</TD>
          <TD>$name</TD>
          <TD>$rep</TD>
          <TD>$ppe</TD>
          <TD>$train</TD>
          <TD>$policy</TD>
          <TD>$com</TD>
          <TD align=right>$tot</TD>
</TR>";
}
echo "</TABLE>";
?>
```

Codes for reporting training performance

```
<h2>Training on Accident prevention Petroleum industry</h2>
<?php
```

```
$sql = "SELECT coycode,coyname,accrep,ppe,training,sfpolicy,comply,sumtot
FROM coysf ORDER BY ppe DESC ";

// create connection; substitute your own information
$conn =mysqli_connect("localhost","root","","coysafe") or die (mysql_error());

// execute SQL query and get result
$sql_result = mysqli_query($conn,$sql,) ;

// start results formatting
echo "<TABLE BORDER=1>
<TR>
<TH>COY CODE</TH>
<TH>NAME</TH>
<TH>REPORTING</TH>
<TH>PROTECTION</TH>
<TH>TRAINING</TH>
<TH>POLICY</TH>
<TH>COMPLIANCE</TH>
<TH>TOTAL</TH>

</TR>";
// format results by row
while ($row = mysqli_fetch_array($sql_result)) {
$code   = $row["coycode"];
$name   = $row["coyname"];
$rep    = $row["accrep"];
$ppe    = $row["ppe"];
$train  = $row["training"];
$policy = $row["sfpolicy"];
$com    = $row["comply"];
$tot    = $row["sumtot"];
echo "<TR>
          <TD>$code</TD>
          <TD>$name</TD>
          <TD>$rep</TD>
          <TD>$ppe</TD>
          <TD>$train</TD>
          <TD>$policy</TD>
          <TD>$com</TD>
          <TD align=right>$tot</TD>
</TR>";
}
echo "</TABLE>";
?>
```

Background image of home page


Safety Guidelines for
OIL INDUSTRY

APPENDIX: F: QUESTIONNAIRES FOR IDSL, SHELL, NPDC AND BGP