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Non-Digital Method of Process Safety Management (PSM) Compliance, OSHA PSM and EPA RMP Rulemaking Initiatives, and Methodology to Estimate Related Economic Impact on PSM Facilities in the United States of America

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Abstract: Over the years, process safety management (PSM) program development and implementation has benefited the operating facilities in terms of successful avoidance of process safety incidents, and related business losses arising due to equipment damage, production interruption and environmental damage. PSM covered facilities have also reported improved personal injury record through successful implementation of an applicable, regional PSM standard. However, there is still a need to address both the efficiency and effectiveness aspects related to non-digital (manual) PSM program development, implementation, audit, and compliance. There has been continuous reporting of significant process safety incidents even after the promulgation of process safety management regulations both in the United States and globally. The uncertain macroeconomic and political conditions have also forced the governments to allocate less than required fiscal budget to their regional regulatory bodies to address any ongoing operational efficiency concerns in successful enforcement of their PSM regulation. This research paper will investigate and discuss the key issues faced by both the government regulatory bodies and process plant facilities, with the current non-digital (manual) method of PSM implementation, audit, and compliance. Moreover, recent modernization initiatives of safety regulations undertaken by federal regulatory bodies such as OSHA and EPA in the United States are described and discussed in the context of achieving the PSM compliance effectively and efficiently. The paper will also discuss detailed comparison between OSHA's 1992 regulatory impact analysis study and 2023 information collection requirement burden hour and cost estimate and will outline a methodology to estimate the total economic burden of PSM compliance on the existing and future PSM covered facilities in the United States. The methodology to adjust (correct) OSHA's PSM compliance cost estimates are based on accounting key regulatory, industrial, organizational, and economic factors prevalent in the global process plant industry.

Index Terms: Process Safety Management, Compliance, Risk Assessment, Mechanical Integrity, OSHA, Risk Management Program, EPA, Economic Impact, Regulatory Impact Analysis, Process Plants

1. Introduction

Process safety is an important workplace safety aspect globally for all types of process plants and operational facilities. The operational facilities can be hydrocarbon exploration and production categorized as upstream, hydrocarbon refining & petrochemicals categorized as downstream and submarine or cross-country pipelines categorized as midstream. The key difference between occupational and process safety is that occupational safety is a

concept that applies to all types of workplaces while process safety focuses on the unintended release of hazardous and flammable process fluids and subsequent adverse consequences. Process safety affects the workers, operating facilities and the communities living around the operational facilities. Occupational safety, however, focuses only on worker safety in a working (occupational) environment, which may be a process plant.

Governments around the world have promulgated numerous process safety regulations or laws that are meant to provide a solid and comprehensive framework to address and resolve process safety related concerns using a variety of analytical and management techniques. Depending on the region and the government, a particular process safety regulation will include and exclude certain types of process plants or operating facilities. For example, Occupational Safety and Health Administration (OSHA) process safety management (PSM) standard in the United States of America as of February 2024 includes primarily the downstream facilities operating with highly hazardous and flammable chemicals or process fluids of certain threshold quantities. The OSHA PSM [1,2] standard contains 14 elements that implemented together reduces the risk of process safety incidents during the manufacturing, storage, usage, and transportation of hazardous chemicals and flammable fluids.

Similarly, the Bureau of Safety and Environmental Enforcement (BSEE) [3] was established in 2010 to ensure safe and reliable operations of offshore oil and gas facilities in the United States outer continental shelf (OCS). This federal agency created a similar process safety regulation titled Safety and Environmental Management System (SEMS) [4,5] in 2010 based on American Petroleum Institute (API) recommended practice RP-75 titled Safety and Environmental Management System for Offshore Operations and Assets. The SEMS regulation is promulgated under the federal regulation 30 CFR Part 250 Subpart S. This paper will primarily focus on onshore and downstream process plants such as refining, petrochemical, fertilizers, pulp, and paper facilities in the United States.

Another regulatory body in the United States is the Environmental Protection Agency (EPA) which has risk management program (RMP) [6] rule authorized under the 1990 clean air act amendment. The risk management program (RMP), promulgated under the federal regulation 40 CFR 68, has different compliance requirements for program levels 1, 2 and 3 depending on the type of facility, process, and potential risk to the public. Program 3 of the RMP focuses on process plant facilities covered by the OSHA PSM standard and certain other facilities classified under one of ten specified NAICS codes listed in 40 CFR 68.10(d)(1). Another independent federal agency in the United States is Chemical Safety Board (CSB) [7] that investigates the process safety incidents occurring at process plants to determine the root causes. The process plants do not have to be a covered OSHA PSM or EPA RMP facility for CSB to investigate their process safety incidents.

Over the years, process safety management (PSM) program development and implementation has benefited the operating facilities in terms of successful avoidance of process safety incidents, and related business losses arising due to equipment damage, production interruption and environmental damage. PSM covered facilities have also reported improved personal injury record through successful implementation of an applicable, regional PSM standard.

However, there is still a need to address both the efficiency and effectiveness aspects related to non-digital (manual) PSM program development, implementation, audit, and compliance. There has been continuous reporting of significant process safety incidents even after the promulgation of process safety management regulations both in the United States and globally. The uncertain macroeconomic and political conditions have also forced the governments to allocate less than required fiscal budget to their regional regulatory bodies to address any ongoing operational efficiency concerns in successful enforcement of their PSM regulation.

This applied research study investigates the key issues faced by both the government regulatory bodies and process plant facilities, with the current non-digital (manual) method of PSM implementation, audit, and compliance. Moreover, recent modernization initiatives of safety regulations undertaken by federal regulatory bodies such as OSHA and EPA in the United States are described and discussed in the context of achieving the PSM compliance effectively and efficiently.

The paper will also discuss detailed comparison between OSHA's 1992 regulatory impact analysis study and 2023 information collection requirement burden hour and cost estimate and will outline a new methodology to estimate the total economic burden of PSM compliance on the existing and future PSM [1,2] covered facilities in the United States. The methodology to correct OSHA's PSM compliance cost estimates are based on accounting key regulatory, industrial, organizational, and economic factors prevalent in the global process plant industry. The research paper also specifies the idea of an e-governance solution that will potentially eliminate all the efficiency and effectiveness concerns faced by regulatory bodies and process plants in achieving a successful PSM implementation and comprehensive regulatory compliance in the United States. The system design, enterprise architecture and implementation feasibility of the e-governance solution will be examined in future research efforts.

2. Summary of Global Process Safety Management Regulations

This section summarizes the process safety or similar regulations organized country or geographical region wise in its subsections. Major countries and regions such as United States, European Union, United Kingdom, China, India, Australia, and New Zealand are covered under this section.

2.1. United States of America

The Clean Air Act Amendments (CAAA) [8,9] passed in 1990 brought the OSHA PSM, EPA RMP and CSB government standards, programs, and bodies into existence. The CAAA 1990 authorized OSHA to formulate process safety regulations in the form of a standard that was issued under section 304 of the act. The Process Safety Management [1,2] of Highly Hazardous Chemicals (PSM) Regulation was issued in February 1992 under federal regulation 29 CFR 1910.119. PSM regulations primarily apply to hazardous and flammable processes rather than plants except where the exclusion of certain types of facilities are explicitly stated.

OSHA also developed a list of highly hazardous chemicals along with their threshold values as part of CAAA under section 112 of the act. The establishment of the risk management program (RMP) was also authorized under section 112 of the CAAA 1990. The EPA RMP [2,6,8] safety regulation was formulated and issued in 1996 under federal regulation 40 CFR 68. The Chemical Safety Board (CSB) was established in January 1998 as part of CAAA under section 112.

OSHA PSM [1,2] does not cover oil and gas drilling facilities, nuclear energy, federal water treatment, retail, normally unoccupied remote facilities, and transportation. The following are the 14 elements of OSHA PSM standard listed in the code of federal regulation register 29 CFR 1910.

- 29 CFR 1910.119(c) - Employee participation (EP)
- 29 CFR 1910.119(d) - Process Safety Information (PSI)
- 29 CFR 1910.119(e) - Process Hazards Analysis (PHA)
- 29 CFR 1910.119(f) - Operating Procedures (OP)
- 29 CFR 1910.119(g) - Training (TNG)
- 29 CFR 1910.119(h) - Contractor (CON)
- 29 CFR 1910.119(i) - Pre-Startup Safety Review (PSSR)
- 29 CFR 1910.119(j) - Mechanical Integrity (MI)
- 29 CFR 1910.119(k) - Hot Work Permit (HWP)
- 29 CFR 1910.119(l) - Management of Change (MOC)
- 29 CFR 1910.119(m) - Incident Investigation (II)
- 29 CFR 1910.119(n) - Emergency Planning and Response (EPR)
- 29 CFR 1910.119(o) - Compliance Audit (CA)
- 29 CFR 1910.119(p) - Trade Secret (TS)

EPA RMP applies to facilities with quantities of regulated substances above certain specified thresholds. RMP is focused on hazard assessment, emergency response and prevention programs with emphasis on surrounding community and the local environment. Potential release scenarios and adverse consequences on the environment and communities are assessed for a facility along with the development of emergency response and prevention plans as part of RMP.

The Chemical Safety Board (CSB) [7,8,9,10] is a non-regulatory federal agency that investigates the process safety incidents occurring at process plants to determine the root causes. The process plants do not have to be a covered PSM facility for CSB to investigate their process safety incidents. CSB Board members are recommended by the US President and approved by the US Senate. CSB has memorandum of understanding (MoUs) with other federal regulatory agencies such as OSHA and EPA with defined terms of collaboration and specific mechanisms of coordination for investigating a significant process safety incident. CSB publishes the investigation reports and simulation videos of process safety incidents once the investigation is complete.

2.2. European Union

The European Union (EU) and the European Commission were formed in 1992 following the Maastricht Treaty signed by the member EU countries. The European Agency for Safety and Health (EU-OSHA) [9,11] was formed in the year 1996. EU-OSHA collects, analyzes, and shares relevant safety related information, data and analysis reports that can improve health and safety standards of workplaces in the member EU countries.

Process safety related regulatory directives [11,12] issued in the European Union were Seveso I (Directive 82/501/EEC) of 1982, followed by Seveso II (Directive 96/82/EC) of 1996 and Seveso III (Directive 2012/18/EU) of 2012. Seveso regulations require tier classification of facilities based on threshold quantities of hazardous substances. Both upper and lower tier facilities in EU member countries must submit a major accident prevention policy (MAPP) with safety management systems and emergency plans developed for a facility.

June 1989, the EU occupation safety, and health framework directive (Directive 89/391/EEC) [13] was passed. This directive focused on management of safety and health and employer responsibilities such as training, risk assessment.

2.3. United Kingdom

The Health and Safety at Work Act [9,14] was passed by the United Kingdom (UK) government with the royal assent in 1974. The Act led to the formation of a regulatory framework and Health & Safety Commission (HSC) and

Health & Safety Executive (HSE) government bodies. HSC proposes new laws to the UK parliament based on comprehensive research initiatives and HSE assists the HSC in implementing such laws once passed by the UK government. Both HSC and HSE were merged into a single regulatory body in the UK and became Health & Safety Executive (HSE) in 2008.

The United Kingdom passed and implemented the first process safety regulation Control of Industrial Major Accident Hazards Regulation [14,15] (CIMAH) in compliance with the Seveso I (Directive 82/501/EEC) of 1982. CIMAH was replaced with the Control of Major Accident Hazards Regulation [14,16] (COMAH) that was passed in 1999 in compliance with Seveso II (Directive 96/82/EC) of 1996. COMAH is the latest and current process safety regulation in the UK. HSE has regulatory enforcement responsibilities of COMAH over process plant facilities except nuclear establishments in the UK. HSE routinely conducts planned and unannounced inspections and is authorized to issue both monetary and legal penalties to operating process plants for noncompliance.

The UK government also passed the Reporting of Injuries, Diseases and Dangerous Occurrences Regulation [9,14,17] (RIDDOR) in 1985 that warrants operating facilities & companies to report and notify the authorities if an incident takes place on their premises.

2.4. China

China promulgated the State Administration of Work Safety [9,18] (SAWS) government body in 2005. SAWS monitors the implementation of process safety regulations, supervises the local regulatory agencies, and involves in education and training on health and safety. The SAWS passed AQ/T 3034-2010 which is the process safety management (PSM) regulation in China. This 2010 PSM regulation is based on OSHA PSM regulation of the United States with exception of the employee participation and trade secrets elements. China relies on the local agencies to successfully enforce the AQ/T 3034-2010 PSM regulation since it is a large country is hundreds of many process plants.

2.5. India

India passed the Environment Protection Act [9,19] (EPA) in 1986 and amended the EPA Act with the Manufacture, Storage, and Import of Hazardous Chemical Rules [20] (MSIHC) of 1989, and the Chemical Accidents [21] (Emergency Planning, Preparedness and Response) Rules of 1996 following the Bhopal gas tragedy that claimed more than 2000 lives. Additionally, the Major Accident Hazard Control [22] (MAHC) Rules 1997 were added to chapter IV-A of the Factories Act, 1948.

The MSIHC [20] regulations classify the factories (facilities) into different tiers low, middle, and high based on the type of process fluid or material utilized by the facilities. The tier designation sets the requirements for compliance with regulation under authority of the Directorate General, Factory Advice Services and Labor Institutes (DGFASLI). The DGFASLI [22] is under central government and responsible for appointment of state inspectors at the state level. It is not ascertained if there is a framework in place to conduct the routine or unannounced inspections at the facilities across India.

The fundamental requirements for all the tiers in MSIHC [20] are that occupier must identify, notify, and prevent major accidents, and provide workmen with necessary equipment, training, and information. Middle and high tier facilities must have on-site emergency plans, safety reports and audits. The Chemical Accidents [21] (Emergency Planning, Preparedness and Response) Rules warrant the development and submission of both on-site and off-site emergency and risk mitigation (reduction) plans for the chemical manufacturing facilities. The requirements complement the MAHC [22] Rules which are part of the Factories Act, 1948 in chapter IV-A.

2.6. Austrailia & New Zealand

Government of Australia issued a national standard and a national code of practice the Control of Major Hazard Facilities [23,24,25] (COMHF) in 1996 through its National Occupational Health and Safety Commission. This national standard was authorized under the National Occupational Health and Safety Commission Act 1985 (Commonwealth).

The COMHF national standard [24] has advisory and preventive action recommendations that potentially reduce workplace deaths, injuries, and diseases. The national code of practice [25] has specific advisory on acceptable ways for both employers and workers to achieve the goals stated in the COMHF national standard.

The COMHF national standard is not compulsory since states in Australia have the authorities over health and safety laws, but most states have now adopted this national standard to ensure uniformity across commonwealth state and territorial governments. The COMHF national standard is based on Seveso II (Directive 96/82/EC) [11] of 1996 and have similar elements such as hazard identification, risk assessment and control, emergency planning and preparation and submission of safety reports to regional public authorities.

Royal commission under New Zealand government was created in 2010 to address process safety related concerns following the incident of Pike River coal mine which resulted in 29 fatalities. New Zealand government announced that a new health and safety agency WorkSafe New Zealand be established under WorkSafe New Zealand Act [23,26] passed in 2013. New Zealand adopted the Australian model of COMHF (based on Seveso II directive) through a Health and Safety Reform Bill in 2014.

3. Modernization Initiatives of Federal Process Safety & Environmental Protection Regulations in the United States

3.1. Federal PSM Rulemaking Initiatives by OSHA

After the establishment of the federal PSM rule in 1992, OSHA has issued more than 12 directives [27] in the form of national emphasis programs or guidelines for petroleum refining, chemicals and storage facilities, compliance guidelines, enforcement procedures and field manuals. OSHA has also issued more than 250 PSM standard interpretation [27] related documents and more than 30 federal register notices since 1992.

The fire and explosion incident [28] at the ammonium nitrate fertilizer manufacturing facility in Texas on 17th April 2013 claimed 15 lives and injured more than 260 personnel, incurred property damage to more than 150 offsite buildings. The fertilizer company filed for bankruptcy following this incident.

The US President Obama issued an executive order (EO) 13650 in August 2013 titled "Improving Chemical Facility Safety and Security" [29,30,31]. Following this executive order, a working group was formed, and the group identified the following five major thematic areas to fulfill the obligations of various agencies, arising out of EO 13650.

- Strengthening community planning and preparedness
- Enhancing Federal operational coordination
- Improving data management
- Modernizing policies and regulations
- Incorporating stakeholder feedback and developing best practices

Department of Labor and OSHA's biggest PSM standard modernization efforts [32] began with the EO 13650 that required modernizing existing policies and regulations regarding chemical safety for workers. Subsequently, OSHA issued a request for information [32] (RFI) seeking comments on the proposed regulation changes in December 2013. After that, OSHA established a small business advocacy review (SBAR) panel in accordance with the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA). The SBAR panel learnt and addressed the potential issues faced by the small business owners with the proposed PSM regulation changes and issued a final SBREFA or SBAR panel report in 2016. The SBREFA report [32] entailed the feedback, comments, and cost estimates by small entity representatives (SERs) to comply with the proposed changes in the federal PSM regulations.

The executive order (EO) 13990 [33] issued by the US President Biden titled "Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis" also warranted OSHA to consider adding requirements for assessing natural disasters and extreme temperatures scenarios in process hazard analysis (PHA) element of the existing PSM standard.

Table 1. List of Proposed Changes to Federal PSM Regulations due to Executive Orders EO 13650 & EO 13990 [32]

Federal PSM Regulation Subsection & Associated Element	**Proposed Changes in the Federal PSM Regulation Subsections (Elements)**
Subsection (a) Application and Scope	Add oil & gas drilling or servicing operations, resuming coverage of oil and gas exploration and production facilities, add dismantling and disposal of explosives in 29 CFR 1910.109(k) (2,3) leads to PSM coverage
Subsection (b) Definitions	Clarification on the scope / exemption of the retail facilities and atmospheric storage tanks, define the limits of PSM covered process, definition of RAGAGEP & critical equipment, expand definition of process to include reactive chemical hazard
Subsection (j) Mechanical Integrity	Mechanical integrity for all "critical" equipment, Clarifying equipment "deficiencies"
Subsection (c) Employee Participation	Stop work authority and enhanced employee participation
Subsection (d) Process Safety Information	Collecting & assessing reactive hazard data
Subsection (d) Process Safety Information and (j) Mechanical Integrity	Assessing necessary updates to RAGAGEP
Subsection (l) Management of Change	Clarifying management of organizational changes
Subsection (m) Incident Investigation	Root cause analysis, evaluation, and corrective action
Subsection (n) Emergency Planning and Response	Emergency response coordination with local authorities
Subsection (o) Compliance Audits	Third Party (external) audits, written PSM management systems for all elements, periodic mandatory reviews of PSM program
All Elements	Codifying major interpretations
Subsection (e) Process Hazard Analysis	Rationale for PHA recommendations that are not adopted with the management sign-off, require safer technology and alternatives analysis, natural disasters, and extreme temperatures in PSM programs
Appendix A	Addition of specific hazardous chemicals to the list

Federal OSHA conducted a stakeholder meeting [32] with several industry partners, trade organizations and union bodies representatives in October 2022 to discuss the following list of proposed changes to existing PSM regulations. OSHA is yet to finalize the proposed revisions in the PSM rule as of February 2024.

3.2. Federal RMP Rulemaking Initiatives by EPA

After the establishment of EPA RMP regulations in 1996, EPA has undertaken hundreds of rulemaking initiatives [34] and issued small and substantial changes in the original federal EPA RMP regulations. There have been more than 80 notices [34] in the federal register relating to the changes or interpretations of EPA RMP rule as of February 2024 per regulations.gov website that lists all the major updates around rulemaking of federal regulations by all the federal agencies authorized under various United States Code (U.S.C).

Substantial changes in the EPA RMP regulations were issued by EPA following the executive order (EO) 13650 [30,31] as directed by US President Obama. These changes were promulgated in a 2017 EPA RMP amendment [34] and primarily included the additional elements for the prevention program, enhanced emergency planning and response, and information availability provisions. However, EPA received several petitions for reconsidering the 2017 EPA RMP amendment rule and the 2019 reconsideration EPA RMP rule [34] rescinded most of the prevention programs and information availability changes and kept only the revised version of emergency response provision.

The executive order (EO) 13990 [33] issued by US President Biden in 2021 directed the federal agencies to assess the existing regulations with a view to bolster resiliencies of the facilities and related communities to climate change and to prioritize environmental justice for future generations. Subsequently, the EPA proposed the RMP Safer Communities by Chemical Accident Prevention [34,35] (SCCAP) Rule 2022 after holding public listening sessions with the industry stakeholders and distinguished representatives of the public communities. The proposed SCCAP RMP rule also contains the estimated cost and benefit analysis [34,35] for the EPA RMP covered facilities.

The SCCAP RMP rule 2022 proposed the following major changes to various subparts of the EPA RMP regulation in federal register 40 CFR 68 issued in 1996 [34,35].

3.2.1. Prevention Program (Elements) under Subparts C & D

- Mandate natural hazards due to climate change and power loss as necessary scenarios in process hazard analysis or review for program 2 and program 3 facilities.
- Requirement to address facility sitting in process hazard reviews for program 2 and process hazard analysis for program 3 facilities.
- Performing safer technology and alternative analysis (STAA) for facilities classified under North American Industrial Classification System (NAICS) code 324 and 325 located within one mile of another RMP regulated facilities with process classified under NAICS code 324 or 325. STAA is also mandatory for facilities with hydrofluoric acid (HF) alkylation process classified under NAICS code 324.
- Third party compliance audits if RMP facilities experience two reportable RMP incidents within 5 years or one reportable RMP incident for program 3 facilities classified under NAICS code 324 or 325.
- Document justification when hazard analysis recommendations arising out of all the above concerns are not adopted.
- Mandating Root cause failure investigation if a reportable RMP incident or accident occurs.
- Requiring employee participation in process hazard analysis or review, compliance audits and incident investigation recommendations and findings. Stop work procedure in program 3 and develop employee participation plans to add process to anonymously report RMP incidents of process safety or other non-compliance issues.

3.2.2. Emergency Response under Subpart E

- Notification of RMP accidents to the community requiring development of public information procedure about accidental release, release notification data transmission to local emergency response agencies and developing a community notification system for reportable RMP incidents.
- Emergency response field exercises on a 10-year frequency with local emergency response agencies unless the local agencies determine that frequency is not feasible. Mandatory reporting of scope and requirements for such field response exercises.

3.2.3. Information Availability under Subpart H, CFR 68.210

- Requirement of providing the chemical hazard information upon request to residents within 6-mile radius of a facility, in the language requested. This is a new requirement and not present in the current RMP regulation.

3.2.4. Technical Clarification & Regulatory Edits under Subparts A, C & D

- Program 3 facilities to keep the process safety information up to date.
- Consistent requirement of following recognized and generally accepted good engineering practice (RAGAGEP) for facilities under program 2 and program 3. Mandate RAGAGEP review in process hazard analysis.

- Hot work permits to be retained for 5 years.
- Define the storage incident to transportation term and the retail exemption.

The federal agency EPA is yet to finalize the Safer Communities by Chemical Accident Prevention (SCCAP) Rule 2022 as of February 2024.

4. Non-Digital Method of Process Safety Management (PSM) Compliance

The quality of PSM programs at operating facilities, improvement in process safety conditions and related injury records across a nation and subsequent benefits to workmen, facilities, governments and public at large depend on the efficiency and effectiveness of the PSM compliance. PSM program development, implementation, and stewardship at facilities have largely been manual (non-digital) efforts except for a few popular marketplace PSM software(s), that are used by facilities of large conglomerates. Such commercially available PSM software does not communicate seamlessly with the existing information systems at site or with federal OSHA directly, thereby incurring high technology costs to continue maintaining the PSM data for all the 14 elements across numerous databases at facilities.

On the other hand, there has not been any digital solution or technology initiative proposed, developed, or implemented by federal OSHA to enable the covered facilities to submit their PSM compliance reports directly to OSHA, and to conduct compliance audits virtually or minimize physical inspection visits. The information collection requirements for maintaining OSHA PSM compliance are data intensive and warrant manual efforts for the operating facilities stretching the operating expenditure budget in burden hours and labor cost. OSHA uses the Integrated Management Information System (IMIS) on its website to enable listing and viewing of citations and interventions by OSHA applicable to all the federally approved regulatory programs. This has a benefit to users or viewers who wish to perform statistical analysis of OSHA's interventions at worksites across the country.

This section will describe and discuss the key issues faced by PSM covered facilities with the non-digital (manual) method of PSM program implementation and compliance in the United States of America.

4.1. PSM Program Development, Implementation and Industry Best Practices

PSM covered facilities undergo two phases for achieving a complete and successful PSM compliance. The first phase is PSM program development where the PSM team at a facility develops all the required programs, standard operating procedures & implementation manuals required for all the 14 elements stated in the OSHA PSM standard. The second phase is PSM program implementation where the facility PSM staff implements the PSM program by performing PHA, creating or updating PSI data sources, modifying equipment design to rectify MI deficiencies, and adding, removing, or upgrading process hazard controls. There can be considerable overlap between the development and implementation phases of PSM compliance depending on the safety management systems or practices already in-force at a process plant.

Below is the list of all the required document generation, preparation or creation activities required along with specific clauses in the OSHA PSM regulation 29 CFR 1910.119 for all the 14 elements. The industry best practice (IBP) for each of the 14 PSM elements are also listed below.

4.1.1. Employee Participation, 29 CFR 1910.119(c) (1)

Written plan of action outlining engagement responsibilities and procedure for ensuring employee participation and access throughout the development and implementation of all elements in the PSM standard.

4.1.2. Process Safety Information, 29 CFR 1910.119(d) (1,2,3)

Creation of chemical safety data sheets, mechanical datasheets, process flow diagrams, equipment design documents etc. to support process hazard analysis element, if these are not available. IBP is to create a written procedure outlining what and how to compile the hazardous process, technology, and equipment data in prescribed formats for easy standardization and reuse.

4.1.3. Process Hazard Analysis (PHA), 29 CFR 1910.119(e) (1,5,6,7)

Process hazard analysis procedure, report outlining assessment findings for each covered process with resolution timelines in order of process criticality. IBP is to create a corporate procedure (manual) with a chosen PHA methodology, responsible personnel, and their duties during and after PHA process and for resulting recommendations. Predefined PHA formats per chosen methodology and for typical covered process enable standardization and reuse. PHA recommendations such as creating or updating PSI data sources, modifying equipment design to rectify MI deficiencies, and adding, removing, or upgrading process controls to be completed promptly.

4.1.4. Operating Procedures, 29 CFR 1910.119(f) (1,4)

Operating procedure & safe work practice manual for each covered process outlining process safety information during all phases of operation along with safety controls to be created for use and access by both facility and contractor workmen. IBP is to create unit operating manual outlining all the covered and non-covered PSM processes. If there are

any safeguards or controls added or removed, changes be made to this operating manual.

4.1.5. Training, 29 CFR 1910.119(g) (3)

Training manual for each covered process outlining process safety information during all phases of operation along with safety controls for use and access by both facility and contractor workers. IBP is also to create pre-recorded training videos on all aspects of plant operation covering each process and unit in the plant along with necessary quizzes to assess the facility and contractor staff.

4.1.6. Contractors, 29 CFR 1910.119(h) (2,3)

Facility to create and maintain injury, illness, and incident log for contractor staff. Documentation noting two ways sharing of data and process safety related information between facility and contractors. A perimeter security procedure is also created for managing and controlling access of contractors to the facility. IBP is to have a standard operating procedure (SOP) or manual to manage contractors in a PSM facility. The SOP will cover all aspects of perimeter security, training and process safety related communication protocol and necessary documentation procedures.

4.1.7. Pre-startup Safety Review, 29 CFR 1910.119(i)

Pre-start up safety review manual is typically required (although not explicitly stated in regulation) at the facility that outlines the steps required to ensure readiness and compliance with this element before the actual start of the facility. IBP is to create prescribed formats and checklists to conduct comprehensive pre-startup safety review on each process unit in a facility. The format (checklist) be unique to a process unit incorporating the specific process safety information including controls and safeguards, equipment mechanical design, repair, modification, and emergency procedure.

4.1.8. Mechanical Integrity, 29 CFR 1910.119(j) (2,4,5,6)

Plant wide mechanical integrity (MI) manual or SOP for each type of process equipment defined in the regulation. The MI manual contains inspection, testing & preventive maintenance (PM) procedures, the reliability and safe operating limits per process safety information and quality assurance procedure for new construction or major modification (replacement). IBP is that facility maintains the inspection, testing & PM data in information systems such as inspection database management system (IDMS) & computerized maintenance management system (CMMS). Mechanical integrity assessments such as re-rate, repair, and alterations for all types of process equipment to be done in accordance with applicable RAGAGEP.

4.1.9. Hot Work, 29 CFR 1910.119(k)

A hot work permit system or procedure is required at a facility. The procedure will outline the roles, responsibilities and steps required to issue, report, and document the permits for hot work on or near a covered PSM process. IBP is to have a hot work permit system integrated with plant maintenance procedure or system (CMMS). CMMS are equipped to manage hot work, electric work, confined space, and any other special work permit process required in a facility.

4.1.10. Management of Change, 29 CFR 1910.119(l) (1,2)

Plant wide management of change (MOC) manual outlining procedures to document the changes in process fluids (chemicals), equipment design code, operating philosophy, and process control technology. IBP is to have a dedicated MOC system (digital or not) or integrate with plant CMMS that allows easy processing, approval, and recordkeeping of plant MOCs.

4.1.11. Incident Investigation, 29 CFR 1910.119(m) (4,5)

Incident investigation manual or SOP is typically created if not already part of plant mechanical integrity (MI) manual. The procedure outlines responsibilities, criteria to classify the events into process safety incidents, and steps to complete the investigation. IBP is to integrate the incident investigation into plant CMMS that allows easy processing and recordkeeping of incident investigation efforts. Few commercially available CMMS are also equipped with root cause failure analysis (RCFA) module although this is not mandated in the current PSM regulation.

4.1.12. Emergency Planning & Response, 29 CFR 1910.119(n)

Emergency planning & response plan covering the entire plant needs to be created at a PSM facility per 29 CFR 1910.38 which is a standalone regulation for emergency plan. Additionally, PSM covered facilities also include small release scenarios in the plan. IBP is to check if EPA RMP mandated by 40 CFR 68 applies to the facility. The emergency plan can be prepared that meets both the OSHA PSM and EPA RMP requirements.

4.1.13. Compliance Audits, 29 CFR 1910.119(o) (3-5)

A compliance audit procedure or manual is required since there needs to be clear responsibilities defined for facility personnel (including expert consultants) to conduct compliance audit every 3 years. There is mandatory

retention of the two most recent audit reports with all findings and deficiencies of PSM program being resolved. IBP is to thoroughly conduct compliance audits with help of external PSM subject matter expert, if required. Successful PSM programs are evaluated by subject matter experts.

4.1.14. Trade Secrets, 29 CFR 1910.119(p)

Non-disclosure agreements with facility staff and external consultants, to protect confidential business information (trade secrets), be created and retained. Hazard communication regulation 29 CFR 1910.1200(i) (1-12) on trade secrets also applies to this PSM element. IBP is to follow legal and PSM subject matter expert advice to craft the information (data) sharing protocol (procedure) for the facility staff to achieve a successful PSM program.

4.2. Efficiency and Effectiveness Issues due to Non-Digital Method of PSM Compliance

The issues faced by PSM facilities in the development of aforementioned PSM element documents are tabulated in Table 2 along with scope of digitization and digitalization for the PSM document creation phase. All the efficiency and effectiveness issues specified in Table 2 contribute to increased operating expenditure for the facility due to the nature of PSM development and implementation being manual or non-digital.

Digitization is when analog data in the form of verbal information, hard copy document, printed images can be converted to digital format for easy use, sharing and processing. Digitalization is more of a dynamic concept where a manual process or workflow can be transformed into digital process or workflow with tremendous cost savings.

Table 2. Specific Manual Efforts Causing Efficiency & Effectiveness with Non-Digital Method of PSM Compliance

Specific Manual Efforts for each PSM element document Causing Efficiency & Effectiveness Issues due to Non-Digital Method of PSM Compliance	**Scope of Digitization**	**Scope of Digitalization**
Employee Participation Plan		
New PSM facilities (large and small) will require tremendous effort to create this document and integrate it with the rest of the existing management systems or frameworks. Existing PSM facilities going through merger & acquisitions, facing high employee turnover, streamlining corporate wide management systems will require big manual efforts.	Maximum	Maximum
Process Safety Information		
Technical design documents required for conducting process hazard analysis (PHA) or complying with other elements of PSM will need to follow the usual design process following RAGAGEP for creation, if necessary.	Minimum	Minimum
New PSM facilities collecting and extracting process safety information from all the records and compiling these into useful data for process hazard analysis or mechanical integrity review will require a detailed procedure, data repository and prescribed formats for easy standardization and reuse. All of these will be tremendous manual efforts being done for the first time. Existing PSM facilities going through merger & acquisitions, facing high employee turnover, with legacy siloed and disparate data repositories will require big manual efforts to create an enterprise or facility wide view of process safety information data required for PSM compliance.	Maximum	Maximum
Process Hazard Analysis		
New PSM facilities will require a corporate procedure (manual) with a chosen PHA methodology, predefined PHA formats per chosen methodology and for typical covered process enable standardization and reuse. The PHA formats must be consistent with PSI formats for seamless, correct data transfer and tracking of PHA recommendations. Existing PSM facilities will face data normalization and processing issues if the PSI data formats are not aligned with PHA formats. There will be tremendous manual efforts to bridge the gap between PSI and PHA assessment data with possible need for updating corporate PHA procedure (manual).	Maximum	Maximum
Operating Procedures		
New & existing PSM facilities will undertake some manual efforts to make the existing operating procedure & safe work practice manual be aligned with PSM requirements. Most facilities already have unit operating manuals covering safeguards, controls, and other important operational considerations.	Significant	Significant
Training		
New & existing PSM facilities will undertake some manual efforts to create or update the existing facility training manual for each covered process and be aligned with PSM requirements. Updating the operating procedure of a covered process or unit will require manual updating of training manual and videos for that process or unit.	Maximum	Maximum
Contractors		
New & existing PSM facilities will undertake some manual efforts to revise, change or update standard procedure for contractor management. There is typically an information (computerized) system already in place for perimeter security, access, and other contractor management aspects. The manual efforts will most likely be to add process safety related communication protocol into the existing information system or create a separate manual PSI system.	Significant	Significant
Pre-startup Safety Review		

New & existing PSM facilities will undertake some manual efforts to revise, change or update standard commissioning procedure for each PSM covered process and be aligned with PSM requirements. One-time manual effort for creating unique prescribed formats and checklists for each covered PSM process is required. Updating in the process unit operating philosophy may require manual updating of pre-start up safety review procedure, formats, or checklists as applicable.	Maximum	Maximum
Mechanical Integrity		
New PSM facilities will undertake tremendous manual efforts to create mechanical integrity manual for each type of process equipment. Most commercially available IDMS and CMMS might satisfy most of the data gathering and retention requirements of this element. Although, manual effort will be required to make MI data compliance ready at site. Existing PSM facilities will take big efforts in updating MI written procedure or manual if there is a major equipment addition, modification, demolition or repurpose in a PSM covered process unit.	Maximum	Maximum
Hot Work		
New & existing PSM facilities will undertake some manual efforts to revise, change or update the hot work permit system or procedure for each PSM covered process and be aligned with PSM requirements. Most facilities are equipped with CMMS that enable managing and recording hot work permit system.	Minimum	Minimum
Management of Change		
New & existing PSM facilities will undertake some manual efforts to create or update a PSM compliant management of change procedure or manual. Most facilities are equipped with CMMS that enable managing and recording management of change process.	Minimum	Minimum
Incident Investigation		
New & existing PSM facilities will undertake some manual efforts to create or update a PSM compliant incident investigation procedure or manual. Most facilities are equipped with CMMS that enable managing and recordkeeping of incident investigations.	Significant	Significant
Emergency Planning & Response		
New & existing PSM facilities will undertake some manual efforts to create or update a PSM compliant emergency planning and response plan. There is some scope of automation into an existing information system at site.	Significant	Significant
Compliance Audits		
New & existing PSM facilities will undertake some manual efforts to create or update a PSM compliant compliance audit procedure or manual. There is some scope of automation into an existing information system at site.	Significant	Significant
Trade Secrets		
New & existing PSM facilitates that already follow OSHA hazard communication regulation will incur minimal manual efforts to be aligned with PSM regulations. The effort is to craft the information (data) sharing protocol (procedure) for the facility staff.	Minimum	Minimum

4.3. Enterprise (Organizational) Issues affecting PSM Implementation & Compliance

Table 3 highlights the enterprise (organizational) issues that affect the PSM implementation and compliance at a facility, along with most affected PSM elements and related business impact on the PSM covered facilities. The enterprise issues are based on the author's experience of working in the global process plant industries over the last decade.

Table 3. Enterprise (Organizational) Issues affecting PSM Implementation & Compliance

Operational (Management) and Technology Issues
Siloed operations at each facility location. Redundant and unscalable PSI, MI, IDMS, CMMS data repositories at and across facilities. IT infrastructure limitations in network bandwidth, capacity of computing resources.
Inefficient, Short Term and Manual Remedies (Concerns)
Manual work process & decentralized non-digital or indiscriminate use of digital solutions to fill the technology gaps among facility data repositories such as PSI, MI, IDMS, CMMS. Additional and non-value adding manual PSM workload on field personnel maintenance technicians, inspectors, and engineers for PSM data gathering, normalization and processing. Disintegrated, decentralized and non-digital solutions and overdependence on the field personnel for creating an enterprise view of PSM data lead to formation of single points of vulnerability.
Data quality, Stakeholders and Decision-Making Concerns
Low confidence of facility stakeholders in PSM process, data, and related outcomes. Ineffective decision-making regarding cost intensive PHA recommendations such as equipment replacement, adding a process control or upgrading process technology. Deficient preventive maintenance, process controls & less transparent PSM data leading to more process safety or functional failure incidents & deteriorated equipment reliability.
Most affected PSM Elements
Process Safety Information, Process Hazard Analysis, Mechanical Integrity, Compliance Audits Management of Change, Incident Investigation
Related Business Impact on Facilities
Inefficient PSM program leads to high operating and capital expenditures. Ineffective PSM program since no significant improvement in process safety metrics and continued process safety incidents leading to heavy production and reputation losses. Loss of inspection, maintenance, and reliability cost savings through ineffective execution of PHA, MI, II and PSI elements during PSM development or implementation.

5. OSHA's Estimates of Economic Burden on Facilities for PSM Regulatory Compliance

The federal OSHA conducted a regulatory impact and regulatory flexibility analysis (RIA) study [36] in 1992 when the process safety management regulations were promulgated. The study entailed assessing the industry profile (number and types of affected establishments), technological feasibility, cost and benefits of compliance, and other important aspects such as international trade and long-term environmental impact arising out of the OSHA PSM regulation 29 CFR 1910.119.

In 1992, OSHA estimated 24,939 establishments [36], employing more than 2.37 million employees, and 653,000 contract workmen at risk of suffering process safety events due to release of highly hazardous chemicals. OSHA did not include California, New Jersey, and Delaware facilities in this study since these three states already had statutory PSM regulations in 1992.

OSHA's cost model to estimate the labor (man-hours) and cost for initial and ongoing PSM compliance in the 1992 regulatory impact analysis (RIA) study [36] considered the following.

- PSM regulations requiring activities that are unique compared to existing regulatory body safety standards
- Number of affected facilities already practicing safety management system (elements) that fulfill the PSM elements requirements
- Number of affected facilities in each standard industry classification (SIC) or industry segment
- Number, type, and complexity of the PSM covered processes in each standard industry classification (SIC)
- Unit labor and capital costs of achieving compliance with all the PSM elements for each facility

The timeframe for the cost estimate OSHA considered was i) Years 1-5 and ii) Years 6-10 following the issuance year 1992. The per hour labor rates including fringe benefits for engineers, service workers, drafters, production workers and blue-collar supervisors were based on Bureau of Labor Statistics (BLS) employer cost data [36] reported in the year 1990.

The annualized cost (1992 dollars) to achieve PSM compliance for all the affected establishment is reproduced in Table 4 from the regulatory impact analysis report [36] 1992. The inflation adjusted equivalent annualized cost in 2023 dollars is also tabulated in Table 5 using the published consumer price index value from the Bureau of Labor Statistics (BLS).

Table 4. Total and Average Annualized Costs[36] for PSM compliance from RIA Study (Millions of Dollars-1992)

Total Number of Affected Establishments	Total Annualized Costs (Years 1-5)	Total Annualized Costs (Years 6-10)	Average Annualized Cost Per Facility (Years 1-5)	Average Annualized Cost Per Facility (Years 6-10)	Average Annualized Cost Per Facility (Years 1-10)
24,939	888.7	405.8	0.036	0.016	0.052

Table 5. Total and Average Annualized Costs[36] for PSM compliance from RIA Study (Millions of Dollars-2023)

Total Number of Affected Establishments	Total Annualized Costs (Years 1-5)	Total Annualized Costs (Years 6-10)	Average Annualized Cost Per Facility (Years 1-5)	Average Annualized Cost Per Facility (Years 6-10)	Average Annualized Cost Per Facility (Years 1-10)
24,939	1968.8	899.0	0.079	0.036	0.115

Note that benefits of PSM compliance in terms of improved operational efficiencies and reduced production loss due to better process safety records are not considered in Table 4 and 5. The average annualized cost per facility - inflation adjusted from Table 5 will be compared to OSHA's recent burden hours and cost estimate from the information collection report [37] (OSHA-2012-0039-0015) issued January 2023. The January 2023 cost estimates to fulfill the information collection requirements to achieve PSM compliance are produced in Table 6.

In 2023, OSHA followed the EPA's risk management program (RMP) database to estimate the number of affected establishments required for burden and cost calculations for fulfilling the PSM information collection requirements [37] (ICR) by both the existing and new facilities. The EPA RMP database contained 9,131 establishments under program 3 as of March 2022. Again, three states New Jersey, California and Delaware have 870 sites and are covered with similar state regulations that pre-date OSHA federal PSM regulations. These sites are excluded from the 9,131 number of PSM covered processes (establishments). OSHA's internal technical staff then included the facilities not covered by EPA RMP since the threshold quantities and certain hazardous chemicals and flammable fluids listed in PSM standard are different than RMP standard. OSHA further added the explosives and pyrotechnics manufacturing facilities to the estimate of affected establishments in this report. The total number of existing establishments [37] is 8,943 with total estimated processes be 12,072.

OSHA also considered the annual addition and deletion of PSM covered facilities to be 4% based on the EPA RMP actual average number of facilities change over the last 4 years from 2018 to 2021. This led to an estimate of 106 new PSM facilities with 145 associated covered processes. This yields a total of 9,049 facilities [37] with 12,217 processes under the gambit of OSHA PSM regulations.

The January 2023 information collection requirement (ICR) burden hour and cost estimate is based on incremental nature of PSM compliance nationwide. The estimation considered that existing facilities will incur some labor and related costs to continue to retain PSM related data annually to ensure compliance. Moreover, the 106 new facilities and their 145 processes will need a fresh PSM implementation, so their labor and costs are also considered. The wage rate and fringe benefits for the PSM personnel were considered based on the BLS employer costs [37] for employee compensation (March 2022).

Table 6. Estimated Average Annualized Costs for Information Collection for continued PSM compliance for Existing Facilities (Dollars-2023) Itemized by PSM Element & Specific Information Collection Activity [37]

Existing Facility (Respondent) Group	Estimated Number of Facilities (Respondents)	Average Annualized Cost for All Respondents (Facilities)	Average Annualized Cost Per Facility (Respondent)
Updating, Revalidating, and Retaining the Process Hazard Analysis (Paragraphs (e)(6) and (e)(7))			
RMP Program 3 Existing Facilities	1826	$6,877,629	$3767
Lower Technological Complexity Facilities	588	$442,940	$754
Operating Procedures (paragraph (f)(1) to (f)(4))			
RMP Program 3 Existing Facilities	9131	$3,026,488	$332
Lower Technological Complexity Facilities	2941	$194,960	$67
Contractors (paragraphs (h)(2)(i) -(h)(2)(iv), (h)(2)(vi), (h)(3)(iii)), and (h)(3)(v))			
RMP Program 3 Existing Facilities	3001	$5,478,826	$1826
Lower Technological Complexity Facilities	1544	$563,807	$366
Written Procedures, Inspections, and Testing (paragraphs (j)(2) and (j)(4)(iv))			
RMP Program 3 Existing Facilities	9131	$7,245,859	$794
Lower Technological Complexity Facilities	2941	$466,763	$159
Hot Work Permits (paragraph (k)), Management of Change (paragraphs (l)(1), (l)(4), and (l)(5)) Incident Investigations (paragraphs (m)(4) -(m)(7))			
All PSM Facilities	9049	$79,005,057	$8731
Compliance Audits (paragraphs (o)(1) and (o)(3) - (o)(5))			
RMP Program 3 Existing Facilities	2001	$16,136,545	$8065
Lower Technological Complexity Facilities	980	$1,580,592	$1613
Total Average Annualized Cost Range for Existing Facilities		**$121,019,466**	**$23515-$26,474**

The total of average annualized costs ($121,019,466) listed in Table 6 can be subtracted from the OSHA's estimated total value of $125,280,093 from Table 2 in the January 2023 (ICR) burden hour and estimate report [37]. The remaining $4,260,627 attributable to the new 106 PSM facilities will yield annualized cost of PSM compliance coming out to be $40,195 for the new facilities.

Table 7. Comparison of Estimated Annualized PSM Cost [36,37,38] of Compliance Per Facility Between 1992 and 2023

Average Annualized Cost Per Facility (Years 1-5) Inflation Adjusted 2023 from the 1992 RIA Study Report	Average Annualized Cost Per Facility January 2023 (New Facilities) from the 2023 ICR Report	Average Annualized Cost Per Facility (Years 6-10) Inflation Adjusted 2023 from the 1992 RIA Study Report	Average Annualized Cost Per Facility January 2023 (Existing Facilities) from the 2023 ICR Report
$79,753	$40,195	$35,446	$26,474

The January 2023 burden hour and cost estimates by OSHA are smaller compared to the original (1992) and inflation adjusted [38] (2023) cost of compliance estimate by OSHA. Note that OSHA's January 2023 ICR [37] is a burden (hour) and cost estimate to fulfill the information collection requirements (ICR) of PSM regulations and may not reflect the actual labor (hour) and cost incurred by the existing facilities to ensure continued PSM compliance. The annualized PSM cost value for years 1-5, from the 1992 RIA report is considered equivalent to the annualized PSM cost value for the new facilities in the 2023 ICR report. Similarly, the cost estimates for existing facilities in the 2023 ICR report are compared with the 1992 RIA estimates for years 6-10 due to the assumption in 1992 RIA report that the initial PHA and compliance audits be completed in the first five years.

The following paragraphs outline the gaps found in OSHA's January 2023 ICR [37] burden hours and cost estimation released in 2023.

Mechanical integrity related burden hours and related cost are only partially included for both the existing and new PSM programs. Only the written procedures, inspection and testing aspects are covered with 80% discount in labor (hours) for the existing PSM facilities.

Employee participation PSM elements related burden hours and related cost are not included for both the existing and new PSM programs. It is assumed that the burden hours are covered in compliance activities of other PSM elements.

Assumption that the existing PSM facilities will not require the following PSM elements is incorrect. It is because facilities that are considering major process technology or equipment design upgrade, capital expenditure and unit construction are required to conduct compliance related activities for the below stated PSM elements. The associated burden hour and cost are not included in the January 2023 estimation by OSHA.

- Process safety information (PSI) element
- Process hazard analysis (initial) and resolution of identified hazards

Assumption that only 20% of total number of existing facilities will require the following PSM compliance related activities is incorrect. The actual number of facilities requiring effort will depend on the reasons stated in the previous point.

- Reassessment, updating of the past process hazard analysis
- Operating procedures related updates

OSHA estimated only the labor (hours) required for documenting the training records for an assumed percentage of total workforce employed by the total number of PSM establishments.

- Training PSM element estimation did not account labor (hours) for actual training
- Change in training requirements due to reasons stated in a previous point

Assumption that only 50% of total number of existing and new facilities will incur labor (hours) for compliance activities related to Contractor PSM element are not entirely correct. Emergency planning & response PSM element related activities are not considered for existing PSM facilities. Assumption that only 33% of total number of existing facilities will incur labor (hours) for compliance activities related to Compliance Audit PSM element is not entirely correct.

It is noteworthy to compare the estimated labor (hours), potentially be incurred by the new PSM facilities, between 1992 RIA report [36] and 2023 ICR report [37] to realize the impact of the above stated assumptions made by OSHA in the 2023 ICR report for all the PSM elements. The estimation of labor (hours) for each PSM element is documented in Table 3 of the 1992 RIA report [36] and in Table 2 of the 2023 ICR report [37] both issued by OSHA. The basis of comparing labor (hours) estimates is that high complexity processes stated in the 1992 RIA report are equivalent to the RMP program 3 new facilities in the 2023 ICR report.

Table 8. Comparison of Estimated Annualized Labor (Hours) for OSHA PSM Compliance [36,37] (New Facilities)

PSM Element	Labor Category per Federal Bureau of Labor Statistics	Initial & Ongoing Labor [36] (Hours) per 1992 RIA Report	Burden Labor [37] (Hours) per 2023 ICR Report
Employee Participation (c)	Level IV/III Engineers	3	-
	Blue Collar Supervisor	-	-
	Drafter III, Service, Clerical, Production Workers	1	-
	Sub Total	4	-
Process Safety Information (d)	Level IV/III Engineers	152	50
	Blue Collar Supervisor	16	50
	Drafter III, Service, Clerical, Production Workers	40	108
	Total	208	208
Process Hazard Analysis (e)	Level IV/III Engineers	200	122
	Blue Collar Supervisor	-	100
	Drafter III, Typist, Service, Clerical, Production Workers	8	36
	Total	208	258
Operating Procedures (f)	Level IV/III Engineers	255	22
	Blue Collar Supervisor	67	-
	Drafter III, Typist, Service, Clerical, Production Workers	13	-
	Total	139	22
Training (g) Per establishment	Level IV/III Engineers	139	4
	Blue Collar Supervisor	-	-
	Drafter III, Typist, Service, Clerical, Production Workers	-	-
	Total	139	4

Contractors (h)	Level IV/III Engineers	158	50
	Blue Collar Supervisor	33	50
	Drafter III, Typist, Service, Clerical, Production Workers	9	100
	Sub Total	200	200
Pre-Start up Safety Review (i)	Level IV/III/II Engineers	12	-
Mechanical Integrity (j)	Level IV/III/II Engineers	32	8
	Blue Collar Supervisor	13	9
	Drafter III, Typist, Service, Clerical, Production Workers	132	130
	Sub Total	177	147
Hot Work Permit (k)	Level IV/III/II Engineers	5	2
	Blue Collar Supervisor	1	-
	Drafter III, Typist, Service, Clerical, Production Workers	-	-
	Sub Total	6	2
Management of Change (l)	Level IV/III/II Engineers	62	3
	Blue Collar Supervisor	10	-
	Drafter III, Typist, Service, Clerical, Production Workers	10	56
	Sub Total	82	59
Incident Investigation (m)	Level IV/III/II Engineers	32	64
	Blue Collar Supervisor	16	32
	Drafter III, Typist, Service, Clerical, Production Workers	2	4
	Sub Total	50	100
Emergency Planning & Response (n)	Level V/IV/III/II Engineers	47	106
	Blue Collar Supervisor	1	-
	Drafter III, Typist, Service, Clerical, Production Workers	2	-
	Sub Total	50	106
Compliance Audit (o)	Level IV/III/II Engineers	20	-
	Blue Collar Supervisor	8	-
	Drafter III, Typist, Service, Clerical, Production Workers	2	-
	Sub Total	30	-
Grand Total of Annualized Labor (Burden Hours)		1293	1106

The analysis of the compiled data in Table 8 reveals that for employee participation, pre-start up safety reviews and compliance audit elements labor (burden hour) is not considered by OSHA in the January 2023 ICR [37] estimation. It is because OSHA assumed that employee participation activities are covered in other elements for new PSM facilities. Also, OSHA does not anticipate compliance audits for new facilities which is not correct since regulations require an audit every 3 years. The reason for not accounting labor (burden hours) for pre-start up safety review (PSSR) PSM element in the 2023 ICR [37] could not be ascertained. Intuitively, if PSSR is to be conducted for the new facilities or processes to comply with the regulation, the PHA or PSSR facilitator needs to document this activity leading to a qualified information collection requirement for PSM.

Labor (burden hours) for process safety information and contractors PSM elements remain the same between 1992 RIA and 2023 ICR estimation. OSHA estimated more labor (burden hours) in 2023 ICR [37] for incident investigation, emergency response planning and process hazard analysis PSM elements as compared to 1992 RIA [36] estimation leading to the 2023 annualized cost of PSM compliance being $40,195 for new facilities.

The biggest drop in labor (burden hours) is for training PSM element in 2023 ICR [37] because OSHA only accounted for the time (effort) it takes to document a training record and not the actual training hours consumed by the PSM operators and field personnel. The second biggest drop in labor (burden hours) is for operating procedure PSM element in 2023 ICR because OSHA considered only 22 man-hours for this element for the new facilities without any stated assumption or basis.

OSHA anticipated that labor (burden hours) for mechanical integrity, management of change and hot work permit PSM elements will be less in 2023 ICR [37] for the new facilities. It has been 30 years since the original PSM regulations were issued in 1992, and OSHA did not account technological advances in mechanical equipment design, engineering, PHA methodologies, process control, process engineering, and non-destructive or destructive evaluation techniques.

Overall, the estimated total annualized PSM compliance labor (burden hours) for 1992 RIA [36] is 1293 hours and for 2023 ICR [37] is 1106 hours. This denotes a drop of 15% in burden hours if 1992 RIA estimation hours are considered as the base value. Moreover, the comparison and analysis of annualized PSM cost and labor (burden hours) reveals that the 2023 ICR cost estimates are 39% lower for the new PSM facilities and 28% lower for the existing PSM facilities than the original 1992 RIA inflation adjusted (CPI index 2023) estimates.

6. Adjustment (Correction) to OSHA's Cost Estimate for PSM Compliance

There is a need to provide a clear picture of the labor (burden hours) required and potential cost for PSM compliance. OSHA's original 1992 RIA [36] estimate is deemed to be more comprehensive and precise than the January 2023 ICR [37] estimate due to the reasons specified in the previous section. OSHA's 1992 RIA labor (burden hours) and cost estimate adjusted for inflation in 2023 are good starting points but require further correction due to the following key factors and their suggested percentage change over 30 years.

- Modernization of OSHA PSM and EPA RMP standards due to past executive orders EO 13650 & EO 13990, described in the previous section 3
- Industry best practice(s) for process safety management compliance explained in the previous section 4.1
- Enterprise (organizational) issues described in the previous section 4.3
- Technological advances in mechanical design, process engineering, metallurgical compatibility, and non-destructive evaluation (NDE) techniques from 1992 till 2023
- Macroeconomic conditions (consumer price index change) from 1992 till 2023 in the United States

The suggested percentage changes due to the following factors over 30 years are considered conservatively based on author's experience with industry and technological trends over the last decade. The actual cost escalation due to these factors can only be ascertained with an actual survey of all the PSM covered facilities and are expected to be much higher than below suggested percentage changes. Note that regulatory factors are related to modernization of OSHA PSM and EPA RMP standards (programs) due to US presidential orders EO 13650 and EO 13990 on process safety and climate change will incur additional impact on OSHA PSM compliance efforts from 2024 when the PSM and RMP rulemakings are expected to be finalized.

Table 9. Impact of Key Regulatory, Industrial, Technological, Organizational and Economical [38] Factors on Federal OSHA PSM Implementation and Compliance (1992-2023)

Key Factors	Classification	Impact on OSHA PSM Compliance Efforts	Overall Impact on OSHA PSM Cost Estimate	Percentage Change
Modernization of OSHA PSM and EPA RMP Standards due to EO 13650 & EO 13990 from Section 3	Regulatory	Extending PSM coverage to eligible facilities classified under the Crude Petroleum Extraction (211120), Natural Gas Extraction (211130), Drilling Oil and Gas Wells (213111/12) NAICS Codes.	Increase	-
		Rise in manual efforts (labor) for PSM elements that will be revised as part of OSHA PSM rulemaking including atmospheric tanks addition	Increase	15%
Industry Best Practice(s) for PSM Compliance from Section 4.1	Industrial, Technological	Rise in manual efforts (labor) for all PSM elements. Overall increased contractor head-count due to advanced NDEs. Data repository (information system) dependent PSM elements such as MI, PHA, II, PSI, CO will require rigorous technical assessment and field implementation. External subject matter expertise or consulting requirements will increase to meet advanced technological demand for all the specified domains.	Increase	7%
Enterprise (Organizational) Issues from Section 4.3	Technological, Organizational		Increase	15%
Technological Advances in Mechanical, Process, Metallurgical, NDE Techniques (1992-2023)	Technological		Increase	10%
Macroeconomic Conditions (Consumer Price Index Change 1992-2023)	Economical	Rise in wage rate(s) for PSM compliance team personnel	Increase	BLS November 2023 CPI

OSHA's 1992 RIA [36] estimate will be corrected (adjusted) for the above-mentioned groups of factors to arrive at an estimated financial burden (cost) of PSM compliance on facilities annually and the total estimated PSM compliance cost of all the facilities in the United States. All the adjustments are done for a timeframe of 30 years from the year 1992 till 2023 for both the new and existing PSM facilities covered by OSHA PSM regulations.

Note that social, market and political stability factors are not considered for correction (adjustment) due to their inherent non-linear nature and inconsistent financial and organizational impact on the operating facilities in the short term. For example, drastic drop or rise in oil or chemical prices directly impacts the revenue of PSM facilities leading to reduced or enhanced operating and capital expenditure budget which subsequently leads to worsening or remedying the impact of organizational (enterprise) issues discussed in Table 3.

Table 10. PSM Compliance Cost (US Dollars) Corrected (1992-2023) for Industrial, Technological, Organizational and Economical Factors - New Facilities

Average Annualized Cost Per Facility from the Original 1992 RIA Report (1992 Dollars)	$36,000
Inflation (CPI) Adjustment to 2023 Dollars	$43,753
Industrial & Technological Factors Adjustment 7%	$2,520
Technological & Organizational Factors Adjustment 15%	$5,400
Technological Advancement Factors Adjustment 10%	$3,600
Adjusted (Corrected) Average Annualized Cost Per Facility (2023 US Dollars)	$91,273
Average Annual Number of New PSM facilities added to RMP Database per 2023 ICR Report	106
Adjusted (Corrected) Average Annualized Total Cost of PSM Compliance for New Facilities in the United States (US Dollars)	$9,674,938
Estimated Total Number of New PSM facilities added to RMP Database for 2023-2033 Timeframe	1,060
Estimated Total Cost of PSM Compliance for New Facilities in the United States for 2023-2033 Timeframe (US Dollars)	**$96,749,380**

Table 11. PSM Compliance Cost (US Dollars) Corrected (1992-2023) for Industrial, Technological, Organizational and Economical Factors - Existing Facilities

Average Annualized Cost Per Facility from the Original 1992 RIA Report (1992 Dollars)	$16,000
Inflation (CPI) Adjustment to 2023 Dollars	$19,446
Industrial & Technological Factors Adjustment 7%	$1,120
Technological & Organizational Factors Adjustment 15%	$2,400
Technological Advancement Factors Adjustment 10%	$1,600
Adjusted (Corrected) Average Annualized Cost Per Facility (2023 US Dollars)	$40,566
Average Annual Number of Existing PSM facilities in the RMP Database per 2023 ICR Report	8,943
Adjusted (Corrected) Average Annualized Total Cost of PSM Compliance for Existing Facilities in the United States (US Dollars)	$362,781,738
Estimated Total Cost of PSM Compliance for Existing Facilities in the United States for 2023-2033 Timeframe (US Dollars)	**$3,627,817,380**

Table 10 shows that the estimated total financial burden, to comply with PSM regulations, on the 1,060 new facilities would be approximately $96.8 million over the next decade (2023-2033). The estimated total financial burden, per Table 11, on the existing 8,943 facilities would be approximately $3.63 Billion over the next decade (2023-2033). The estimated total PSM compliance costs for all the PSM facilities (across industries) over the next decade (2023-2033) will be approximately $3.74 Billion. The regulatory factors arising out of revised OSHA PSM and EPA RMP rulemaking initiatives are yet to be accounted for.

Expectedly, the regulatory factors specified in Table 9 will further increase the labor (burden hours) and costs to comply with the revised PSM regulations. Table 12 and 13 denote this correction (adjustment) at an assumed rate of 15% due to more stringent rulemaking, scope expansion and consequently increased information collection requirements for ensuring compliance.

Table 12. PSM Compliance Cost Corrected (2024 US Dollars) for Regulatory (PSM and RMP Rulemaking) Factors - New Facilities

Adjusted (Corrected) Average Annualized Cost Per Facility (2023 Dollars)	$91,273
Regulatory (PSM and RMP Rulemaking) Factors Adjustment 15%	$13,691
Adjusted (Corrected) Average Annualized Cost Per Facility Post PSM Rulemaking (2024 US Dollars)	$104,964
Average Annual Number of New PSM facilities added to RMP Database per 2023 ICR Report	106
Adjusted (Corrected) Average Annualized Total Cost of PSM Compliance for New Facilities in the United States (2024 US Dollars)	$11,126,184
Estimated Total Number of New PSM facilities added to RMP Database for 2024-2034 Timeframe	1,060
Estimated Total Cost of PSM Compliance for New Facilities in the United States for 2024-2034 Timeframe (2024 US Dollars)	**$111,261,840**

Table 13. PSM Compliance Cost (US Dollars) Corrected (2024) for Regulatory (PSM and RMP Rulemaking) Factors - Existing Facilities

Adjusted (Corrected) Average Annualized Cost Per Facility (2023 Dollars)	$40,566
Regulatory (PSM and RMP Rulemaking) Factors Adjustment 15%	$6,085
Adjusted (Corrected) Average Annualized Cost Per Facility Post PSM Rulemaking (2024 Dollars)	$46,651
Average Annual Number of Existing PSM facilities in the RMP Database per 2023 ICR Report	8,943
Adjusted (Corrected) Average Annualized Total Cost of PSM Compliance for Existing Facilities in the United States (2024 US Dollars)	$417,199,893
Estimated Total Cost of PSM Compliance for Existing Facilities in the United States for 2024-2034 Timeframe (2024 US Dollars)	**$4,171,998,930**

Note that the EPA RMP rulemaking and the OSHA PSM proposed rules have few overlapping requirements. However, the labor (burden hours) and financial (cost) impact calculated as part of this study are strictly for OSHA PSM compliant facilities which are covered as a subset in EPA RMP program 3 facilities in the United States.

After the proposed OSHA PSM standard revision will be finalized in 2024 and promulgated in federal regulation. The consequent multifold increment in PSM compliance cost is estimated and outlined in Table 12 and 13. Table 12 shows that the estimated total financial burden, to comply with PSM regulations, on the 1,060 new facilities would be approximately $111 million over the next decade (2024-2034). The estimated total financial burden on the existing 8,943 facilities would be approximately $4.17 Billion over the next decade (2024-2034) per Table 13.

OSHA is also contemplating including oil and gas production, drilling, and servicing facilities in the PSM regulations as part of its current standard modernization effort. OSHA utilizes the NAICS [39] codes for industry classification and coverage of facilities. NAICS codes 21120 and 21130 are for crude petroleum and natural gas extraction facilities. Similarly, NAICS codes 213111 and 213112 are for oil and gas drilling and support activities (servicing).

It is assumed that only 15% of such facilities will potentially be covered by the scope expansion in the PSM compliance proposed in the current rulemaking initiative in federal docket OSHA-2013-0020. Table 14 gives the total estimated number of oil and gas production; drilling and servicing facilities be covered under PSM to be 3,855. The PSM compliance scope for oil and gas production, drilling and servicing industry segments are broken down into crude and natural gas extraction, drilling and servicing facilities, and the support activities as described in Table 14 along with relevant and applicable NAICS codes.

Table 14. PSM Compliance Scope Expansion to Oil and Gas Production, Drilling and Servicing Facilities Itemized by relevant NAICS Code [39] per Proposed OSHA PSM Rulemaking

Industry Segment (PSM Rulemaking)	**Industry Title [39]**	**NAICS Code [39]**	**Number of Entities [39]**	**PSM Covered Facilities (15%)**
Oil and Gas Production Facilities	Crude Petroleum Extraction	211120	5,147	772
	Natural Gas Extraction	211130	412	62
Oil and Gas Drilling, Oil and Gas Servicing Facilities	Drilling Oil and Gas Wells	213111	2,201	330
	Support Activities for Oil and Gas Operations	213112	17,939	2,691
Estimated Total Number of New Oil and Gas Production, Drilling and Servicing Facilities in the United States to be Covered per Proposed PSM Rulemaking				3,855

The estimated annualized total cost of PSM compliance for 3,855 oil and gas production, drilling and servicing facilities that will be potentially covered by revised PSM standard would be approximately $405 Million. The total PSM compliance cost would be approximately $4.05 Billion over the next decade (2024-2034) as per Table 15.

Table 15. Estimated PSM Compliance Cost (US Dollars) for Oil and Gas Production, Drilling and Servicing Facilities in the United States

Adjusted (Corrected) Average Annualized Cost Per Facility Post PSM Rulemaking (US Dollars)	$104,964
Estimated Total Number of New Oil and Gas Production, Drilling and Servicing Facilities in the United States to be Covered per Proposed PSM Rulemaking	3,855
Adjusted (Corrected) Average Annualized Total Cost of PSM Compliance for New Oil and Gas Production, Drilling and Servicing Facilities in the United States to be Covered per Proposed PSM Rulemaking (US Dollars)	$404,636,220
Estimated Total Cost of PSM Compliance for New Oil and Gas Production, Drilling and Servicing Facilities in the United States to be Covered per Proposed PSM Rulemaking for 2024-2034 Timeframe (US Dollars)	**$4,046,362,200**

Collectively, the federal OSHA PSM compliance cost for the covered facilities and industries from the year 2024 can be $8.33 Billion over the next decade, considering the standard modernization effort and PSM rulemaking will be finalized in 2024 and enforcement begins immediately across facilities in the United States.

Table 16. Total Economic Burden of PSM Regulatory Compliance on Covered Facilities in the United States

Estimated Total Cost of PSM Compliance for Existing Facilities in the United States for 2024-2034 Timeframe (2024 US Dollars)	$4,171,998,930
Estimated Total Cost of PSM Compliance for New Facilities in the United States for 2024-2034 Timeframe (2024 US Dollars)	$111,261,840
Estimated Total Cost of PSM Compliance for New Oil and Gas Production, Drilling and Servicing Facilities in the United States to be Covered per Proposed PSM Rulemaking for 2024-2034 Timeframe (US Dollars)	$4,046,362,200
The Estimated Total Federal OSHA PSM Compliance Cost for the Covered Facilities and Industries in the United States for 2024-2034 Timeframe (US Dollars)	**$8,329,622,970**

7. OSHA Budget, Enforcement Resources & IT Infrastructure Spending

Department of labor and OSHA have developed their annual requests for appropriation budgets for the FY 2024 and it worth noting that there has been consistently minimal information technology (IT) infrastructure spending under

the budget activity category safety and health statistics for the past 10 annual budgets of OSHA. The safety and health statistics activity category has been allotted only 5-6% of the total annual OSHA budget [40] for the past 5 years. The following table outlines the OSHA annual total budget and safety and health activity category budget for the past 5 years.

Table 17. Summary of Annual Total OSHA [40] and Safety and Health Statistics Activity Budgets (US Dollars in Thousands)

Financial Year	Annual Total OSHA Budget	Budget for Safety and Health Statistics Activity
FY 2020	$581,787	$32,900
FY 2021	$591,787	$32,900
FY 2022	$609,961	$34,500
FY 2023	$632,309	$35,500
FY 2024 (Requested)	$738,668	$43,896

According to the congressional budget (FY 2024) justification report [40], OSHA is currently managing or initiating the following IT infrastructure projects [40] to modernize their enforcement, compliance, and state consultation operations. These projects are for all the rules, programs and standards covered under OSHA and not limited or specific to process safety management (PSM) standard.

- Enhancement of statistical and data analysis capabilities to make the IT infrastructure and data more resilient and secure. For example, OSHA is building a data warehouse that will contain all the historical chemical and material samplings, industrial hygiene, and safety equipment calibration data. This data warehouse will help in statistical trend analysis and long-term data retention.
- FY 2024, OSHA declared its four major technology transformation initiatives listed to support all its federal, state compliance, protection, and emphasis programs.
  - OSHA Data Lake (data availability)
  - eCase Manager (data accessibility)
  - OSHA Intelligence (extrapolation and predictive abilities)
  - OSHA Mobile (accessible on mobile)
- Expansion of OSHA information systems (OIS) to integrate the standalone program specific systems for the following programs into a single system.
  - Voluntary Protection Programs (VPP)
  - OSHA Strategic Partnership Program (OSPP)
  - OSHA Safety Health Response Application (OSHRA)
  - Medical Access Order Program (MAO)
- Modernized compliance workforce initiative focused on specific technology needs such as electronic case file (ECF) processing, acquiring equipment that enables development, issuance, and management of citations on the field. This will require integration of such citation instruments with OSHA's laboratory information management system (LIMS) and will potentially reduce the time between hazard identification by CSHOs on the field and final abatement of such hazards via a due process.
- The interface between the modern laboratory information management system (LIMS) with OSHA's information system (OIS) will continue to be implemented to tackle the efficiency issues in data accessing, processing and use by the field OSHA personnel. For example, a health and safety related complaint filed on OSHA's website will be directly lodged into the e-compliant module of OIS.
- OSHA's injury tracking application (OITA) receives injury and illness information from employers with 20 or more employees annually. The OITA application helps OSHA to track establishments with an elevated day away restricted or transferred (DART) rate.
- OSHA's learning experience platforms (LEP) that enable curating and personalizing various training programs on numerous safety topics for an individual.
- Establishment search engine, and whistleblower complaint form on OSHA's website.
- Voluntary protection programs automated data system (VADS).

OSHA's research and development (R&D) contracts [40] spending has been $0 for the past 5 years. The agency has not allocated budget in any scientific initiative to investigate the feasibility of a digital enforcement or e-governance solution to streamline its functions on a national scale. All the above IT initiatives are in the form of incremental innovations or minor technology upgrades and may not produce a far-reaching efficiency improvement across all the agency functions. OSHA also has not invested in a digital solution that would enable comprehensive compliance with a particular standard, rule or program by a covered facility or workplace. The semi-digital nature of OSHA's program enforcement drowns the covered facilities in huge manual (labor) efforts to comply with, document and manage a particular OSHA program.

Both the Department of Labor (DOL) and OSHA have noted the enforcement resource (staff) constraints in their annual budget reports [40,41] for FY 2024. OSHA noted that it does not have enough resources and personnel to conduct inspections at all the 4 million workplaces covered by Federal OSHA states. OSHA requested approximately

$32 million and 250 full time employees to US Congress in FY 2024 budget [40] to remedy agency's resource constraints. These additional 250 employees will comprise 142 compliance officers, 58 managerial staff and 50 safety technicians. DOL made observation in its FY 2024 annual budget report [41] that the worker protections agencies operating under DOL lost around 14% of their workforce during 2016-2020 period thus being a major hindrance in ensuring continued inspection and effective compliance. OSHA is on the list of agencies which lost major workforce during that four-year period per DOL annual FY 2024 budget report.

OSHA's resource constraints have also been evaluated by major industrial trade associations such as AFL-CIO [42]. AFL stands for American Federation of Labor and CIO stands for Congress of Industrial Organizations. The few noteworthy facts from the 32nd edition of annual death on the job report [42] by AFL-CIO are listed in the Table 18 and 19.

Table 18. Insights from OSHA's Job Safety Enforcement Resource Data [40,42,43]

Financial Year	Annual Budget (Thousand Dollars)	Full Time OSHA Employees (FTE)	Average Number of Establishments (Number)	Budget per Establishment (Dollars)	Establishment Per OSHA FTE
FY 2020	$581,787	1,884	10,487,687	$55.47	5567
FY 2021	$591,787	1,896	10,909,076	$54.25	5887
FY 2022	$609,961	1,951	11,519,312	$52.96	5905
FY 2023	$632,309	2,069	11,537,646	$54.80	5577
FY 2024 (Requested)	$738,668	2,501	11,537,646	$64.03	4614

Table 19. Insights from OSHA's Job Safety Enforcement Resource Data [40,42,43]

Financial Year	Annual Budget (Thousand Dollars)	Full Time OSHA Employees (FTE)	Average Number of Industry Employment (Number)	Budget Per Industry Employment (Dollars)	Industry Employment Per OSHA FTE
FY 2020	$581,787	1,884	139,103,773	$4.18	73,834
FY 2021	$591,787	1,896	143,780,068	$4.16	77,593
FY 2022	$609,961	1,951	150,025,655	$4.07	76,897
FY 2023	$632,309	2,069	150,025,655	$4.22	72,512
FY 2024 (Requested)	$738,668	2,501	150,025,655	$4.93	59,987

Note that the FY 2023 and FY 2024 annual total establishments and employment data is not completely available on BLS [43] website's census of employment and wages database as of December 2023, therefore the missing data for these years are kept same as the previous year BLS data in Table 18 and 19.

There are numerous health and safety compliance rules or programs under the federal agency OSHA, promulgated in several federal regulations. The compilation and analysis of OSHA's past annual budgets, coverage, enforcement resources and IT infrastructure projects reveal that OSHA's budget and resource (personnel) per establishment and industry employment is extremely low. The exact details of the budget and resource (personnel) allocated to the PSM program could not be ascertained from OSHA's published documents. Accordingly, OSHA PSM program will also proportionally face all the challenges arising out of all these limitations. Therefore, it is incumbent on the technological, scientific, and engineering community to craft, design, develop and implement a digital (web-based) solution, for PSM compliance, that will resolve all the above-mentioned enforcement and resource constraints. The web-based digital solution will need to be public (facilities, industries, and community) facing and must also remedy the elevated labor (burden hours) and compliance cost problems for all the PSM covered facilities in the United States.

8. Conclusion

8.1. Summary of Constraints related to Non-Digital Method of PSM Compliance

This applied research study investigated the key issues faced by both the government regulatory bodies and process plant facilities, with the current non-digital (manual) method of PSM implementation and compliance. Recent modernization initiatives of safety regulations undertaken by federal regulatory bodies such as OSHA and EPA in the United States are described and discussed in the context of achieving successful PSM compliance both effectively and efficiently. Additionally, the study included analysis of OSHA's past annual budgets, coverage, enforcement resources and IT infrastructure projects to identify OSHA's budget and resource (personnel) constraints in enforcing and managing an effective and efficient PSM compliance program in the United States.

Below is the concise list of all the constraints, concerns, problems, and issues related to non-digital (existing) method of PSM compliance investigated in this study. The quantification and analysis of impact for each of the below stated constraints is discussed at length in the previous sections of this paper.

PSM covered facilities across United States of America will incur excessive labor (burden hours) and increased compliance cost leading to higher operating expenditure for the facilities due to the following.

- Inclination to follow industry best practice (IBP) guidelines
- Difficulty in surmounting the organizational (enterprise) challenges
- Multidiscipline technological advancements resulting in increased complexity
- Unfavorable macroeconomic changes (consumer price index) over long term
- Major (recent) rulemaking initiatives leading to expansion of the compliance scope, and extension of applicability to three additional industries

OSHA's PSM regulatory body will lose the opportunity to operate at higher efficiency and effectiveness levels for its federal process safety management compliance program due to the following.

- Minimal budget both per establishment and employee
- Minimal enforcement resources both per establishment and employee
- Minimal budget for digital (IT) solutions across the agency and no specific digital solution for process safety management (PSM) program
- Digital (IT) solution initiatives involve only data engineering aspects achieving partial automation in OSHA's internal work process
- No digital (IT) solution initiative to enable the covered facilities achieve either partial or full automation in PSM compliance
- No research and development (R&D) spending or initiatives in the last decade

8.2. Adjusted (Corrected) Economic Burden Estimates for OSHA PSM Compliance

This applied research study also entailed detailed comparison between OSHA's 1992 regulatory impact analysis (RIA) study [36] and 2023 information collection requirement (ICR) burden hour and cost estimate [37]. The paper also outlined a new methodology to estimate the total economic burden of PSM compliance on the existing and future PSM [1,2] covered facilities in the United States. The methodology to correct OSHA's PSM compliance cost estimates included accounting key regulatory, industrial, organizational, and economic factors prevalent in the global process plant industry.

The adjusted (corrected) total federal OSHA PSM compliance cost for the covered facilities and industries in the United States for 2024-2034 timeframe (US Dollars) is approximately $8.33 Billion. The following is the breakup of the adjusted (corrected) estimates of PSM compliance cost, for the United States facilities, over the next decade (2024-2034) based on the assumptions and methodology used in this research study.

- The estimated total cost of PSM compliance for existing facilities in the United States for 2024-2034 timeframe is approximately $4.17 Billion in 2024 US dollars.
- The estimated total cost of PSM compliance for new facilities in the United States for 2024-2034 timeframe is approximately $111.2 Million in 2024 US dollars.
- The estimated total cost of PSM compliance for the new oil and gas production, drilling, and servicing facilities in the United States for 2024-2034 timeframe is approximately $4.05 Billion in 2024 US dollars. The addition of these types of facilities is proposed in the current PSM rulemaking initiative by OSHA.

8.3. Future Research on E-Governance Solution Development

The paper also specified the idea of an e-governance (web-based) solution that will potentially eliminate all the efficiency and effectiveness concerns faced by regulatory bodies and process plants in achieving a successful PSM implementation and comprehensive regulatory compliance in the United States. The web-based digital solution will need to be public (facilities, industries, and community) facing and must also remedy the elevated labor (burden hours) and compliance cost problems for all the PSM covered facilities in the United States. The system design, enterprise architecture and implementation feasibility of the e-governance solution will be examined in future research efforts.

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