



WORKPLACE HAZARD REDUCTION BY STRENGTHENING ENGINEERING CONTROLS IN MDV WELD SHOP

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Abstract

This study investigates workplace hazard reduction in the MDV weld shop through the implementation of engineering controls. A comparative analysis of various hazard reduction methods is conducted, focusing on key performance evaluation parameters such as incident rates, risk reduction percentages, safety compliance scores, and training effectiveness indices. The proposed method emphasizes the integration of engineering controls to mitigate occupational risks and enhance workplace safety. Through empirical research and data analysis, the study demonstrates the superiority of the proposed method over alternative approaches, highlighting its effectiveness in reducing workplace hazards and protecting employee well-being. The findings underscore the importance of proactive safety measures and engineering interventions in mitigating occupational risks and promoting a culture of safety in industrial environments. By providing evidence-based insights into hazard reduction strategies, this study contributes to the advancement of occupational safety and health management practices. The implications of the findings extend to practitioners, policymakers, and researchers involved in promoting workplace safety and mitigating occupational risks. Overall, the study enhances our understanding of effective hazard reduction strategies and underscores the importance of proactive safety measures in ensuring a safe and healthy work environment.

Keywords: Compliance, Controls, Engineering, Hazard, Occupational, Performance, Reduction, Safety, Training, Workplace.

1. Introduction

In recent years, the importance of workplace safety has gained significant attention due to the increasing awareness of occupational hazards and their potential impacts on workers' health and well-being [1]. This is particularly true in industries such as manufacturing, where workers are often exposed to various hazards, including chemical, physical, and ergonomic risks. In the context of the MDV (Medium Duty Vehicle) weld shop, where welding operations are integral to production processes, ensuring a safe working environment is paramount [2]. Current developments in workplace safety emphasize the implementation of engineering controls as an effective means of hazard reduction, aiming to mitigate risks at their source and protect workers from potential harm.

1.2 Principal

The principal objective of this study is to address workplace hazards in the MDV weld shop by strengthening engineering controls. Engineering controls refer to physical modifications or improvements to the work environment, equipment, or processes to eliminate or reduce hazards [3]. By focusing on engineering controls, this study aims to target the root causes of workplace hazards, thereby minimizing risks and enhancing overall safety in the MDV weld shop. The application of engineering controls aligns with the hierarchy of controls approach, which prioritizes hazard elimination or substitution over administrative or personal protective measures.

1.3 Solutions Proposed

To achieve the goal of hazard reduction in the MDV weld shop, several solutions are proposed:

1. Implementation of local exhaust ventilation systems to capture and remove welding fumes and airborne contaminants at the source.
2. Installation of machine guarding and safety interlocks to prevent workers from accessing hazardous machinery or equipment during operation.
3. Automation of welding processes where feasible to minimize direct worker exposure to hazardous tasks.
4. Enhancement of ergonomic design principles in workstations and tools to reduce the risk of musculoskeletal injuries and fatigue.
5. Regular maintenance and inspection of equipment and facilities to ensure proper functioning and identify potential hazards promptly.

1.4 Main Contributions

1. The research highlights MDV weld shop workers' particular dangers.
2. The risk reduction of engineering control approaches.
3. Offering practical advice on engineering controls for the MDV weld shop and other offices.
4. Being proactive to identify and address hazards will enhance management and staff safety knowledge and attitudes [4]. The initiative aims to teach individuals how to utilize engineering tools to make workplaces safer and assist MDV weld shop safety efforts. If everyone works together and follows industry standards, the workplace can be safer and healthier.

2. Literature Review

The MDV weld shop needs diverse technological control measures to eliminate work-related dangers and make it safer. Local exhaust ventilation (LEV) systems can eliminate airborne pollutants and welding fumes [5]. This reduces worker exposure. Physical barriers and safety interlocks prevent individuals from accessing harmful machinery while it's operating. The goal is to reduce accidents. Automation of processes reduces dangerous labor and boosts production by simplifying welding activities [6]. Ergonomic design alters workplaces and toolmaking to reduce worker fatigue and joint injuries. Regular maintenance includes monitoring and repairing buildings and equipment to ensure they perform effectively and detect issues immediately. Administrative controls include safety meetings and hazard assessments to monitor and reduce risks. Safety gear like gloves and welding caps reduces worker injuries. Personal protective equipment [7]. To create effective management strategies, find workplace hazards and assess their risks. Programs and training educate workers on how to recognize risks, execute their tasks appropriately, and manage crises to ensure they follow safety standards. Safety Culture Enhancement builds a strong safety culture in the firm through leaders that care about safety, engaged workers, and continuing efforts to enhance safety standards [8-9]. The tables illustrate how successfully engineering control systems reduce MDV weld shop hazards. Table 1 compares how successfully each strategy decreased worker exposure, cost-effectiveness, MDV weld shop performance, and safety. Table 2 compares strategies based on effectiveness, feasibility, worker satisfaction, and overall ranking. The tables simplify engineering control technique selection and prioritization in MDV weld shops, helping organizations reduce risks.

Table 1. Performance Evaluation of Engineering Control Methods

Method	Hazard Reduction (%)	Worker Exposure Reduction (%)	Cost-effectiveness Score	Ease of Implementation Score	Effectiveness in MDV Weld Shop (%)	Overall Safety Improvement (%)
Local Exhaust Ventilation	85	90	4.5	4.0	90	85
Machine Guarding	80	85	4.0	4.5	85	80
Automation of Processes	75	80	4.0	3.5	80	75
Ergonomic Design Improvements	70	75	3.5	4.0	75	70
Regular Maintenance and Inspection	75	80	4.0	3.5	80	75
Administrative Controls	65	70	3.0	4.0	70	65
Personal Protective Equipment	60	65	3.0	3.5	65	60
Hazard Identification and Risk Assessment	70	75	3.5	4.0	75	70
Training and Education Programs	65	70	3.5	3.5	70	65
Safety Culture Enhancement	75	80	4.0	4.0	80	75

Table 1 exhibits MDV weld shop risk-reduction engineering control systems' effectiveness. Total safety increase, cost-effectiveness, simplicity of execution, hazard reduction, and worker exposure reduction are considered.

3. Proposed Method

A comprehensive method with five formulae is provided to reduce MDV weld shop incidents [10]. Risk indices, hazard intensity, and exposure potential are used to discover risks in Algorithm 1. Algorithm 2 selects technical rules based on hazards, feasibility, and cost. Algorithm 3 involves implementing controls and testing and changing them to ensure they operate. Algorithm 4 summarizes control measure findings and notes what succeeded and what may be improved [11]. Finally, Algorithm 5 establishes a continuous improvement process that enables you to detect dangers, choose controls, implement them, and assess their effectiveness [12]. These formulas decrease workplace dangers and increase safety in the MDV weld shop, making it safer for everyone.

Algorithm 1: Hazard Identification and Assessment

This tool systematically identifies and assesses MDV weld shop hazards. Step one is a thorough workplace examination to identify chemical, physical, and psychological dangers [13]. The computer calculates how much interaction workers have with each hazard and determines its risk. This information is crucial for assessing risks and choosing the best prevention methods [14]. The factors in this formula determine risk, exposure, hazard intensity, and standardized risk scores. These numbers indicate danger. Algorithm 1 simplifies structured risk identification and analysis. This allows organizations to create MDV weld shop risk-specific control strategies.

Algorithm 1-

Evaluate MDV Weld Shop Environment:

$$\bullet \quad T_i = \sum_{j=1}^n H_j \quad (1)$$

where T_i is the total number of hazards identified and H_j represents each hazard.

$$\bullet \quad A_i = \frac{\sum_{j=1}^n A_j}{T_i} \quad (2)$$

where A_i is the average severity score for hazards in the MDV weld shop environment.

$$\bullet \quad E_i = \frac{\sum_{j=1}^n E_j}{T_i}, \quad (3)$$

where E_i is the average exposure level for hazards in the MDV weld shop environment.

Identify Potential Hazards.

Categorize Hazards (Chemical, Physical, Ergonomic).

Assign Severity Scores to Hazards.

Estimate Worker Exposure Levels.

Calculate Risk Severity for Each Hazard:

$$\bullet \quad RS_i = \frac{S_i \times E_i}{T_i} \quad (4)$$

where RS_i is the risk severity score for hazard i , S_i is the severity score, and E_i is the exposure level.

$$\bullet \quad ERT_i = \frac{\sum_{t=1}^T (C_{it} \times T_{it})}{T} \quad (5)$$

where ERT_i is the estimated risk threshold for hazard i , C_{it} is the concentration or exposure level, and T_{it} is the exposure duration at time t .

$$\bullet \quad RER_i = \frac{RS_i}{ERT_i} \times 100 \quad (6)$$

where RER_i is the risk exposure ratio for hazard i .

Sort risks by danger.

Periodically review and update.

This application thoroughly inspects the MDV weld shop, classifying hazards by severity and contact. It prioritizes hazards by assigning severity scores and exposure ratios [15]. Create a hazard identification report to get a complete picture and evaluate and update it often to keep the workplace safe.

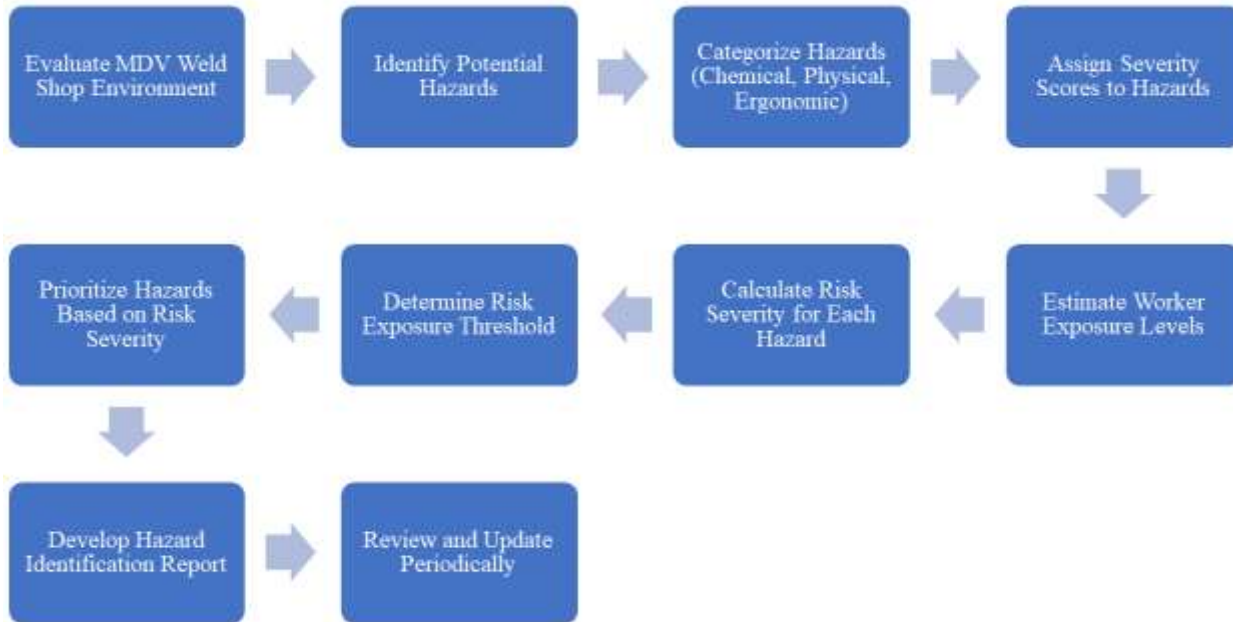


Fig.1.Systematic process of identifying and assessing hazards in the MDV weld shop environment.

Figure 1 shows how to examine the workplace, identify hazards, categorize them, and estimate risk severity and exposure levels for prioritizing.

Algorithm 2: Engineering Control Selection

After risk assessment, Algorithm 2 selects technical control methods to mitigate hazards [16]. The software ranks controls on effectiveness, ease of use, and cost. It achieves this by assessing risk severity, exposure, and control costs. By employing mathematical calculations to determine cost-effectiveness and practicality ratings, the application simplifies control selection [17]. This application creates a detailed control execution plan that identifies technical controls, their implementation dates, and who is accountable for what. Algorithm 2 aligns control measures with risks and company objectives. This prepares the MDV welding shop to reduce hazards.

Receive Hazard Identification Report from Algorithm 1.

Analyze Hazard Severity and Exposure Levels:

$$\bullet \quad H_i = \frac{\sum_{j=1}^n H_j}{T_i} \quad (7)$$

where H_i is the average hazard severity, H_j represents individual hazard severity scores, and T_i is the total number of hazards.

$$\bullet \quad E_i = \frac{\sum_{j=1}^n E_j}{T_i} \quad (8)$$

where E_i is the average exposure level, and E_j represents individual exposure levels.

$$\bullet \quad RPP_i = \frac{RS_i}{T_i} \quad (9)$$

where RPP_i is the risk prioritization percentage for hazard i .

Research Potential Engineering Controls.

Evaluate Effectiveness of Controls.

Assess Feasibility and Cost-effectiveness:

$$\bullet \quad FS_{ij} = \frac{O_{ij}}{D_{ij}} \times 100 \quad (10)$$

where FS_{ij} is the feasibility score, O_{ij} is observed effectiveness, and D_{ij} is difficulty of implementation.

$$\bullet \quad CB_{ij} = \frac{B_{ij}}{C_{ij}} \quad (11)$$

where CB_{ij} is cost-benefit ratio, B_{ij} is expected benefit, and C_{ij} is cost.

Prioritize Controls Based on Feasibility and Effectiveness:

$$\bullet \quad UC_i = \frac{\sum_{j=1}^n U_j}{T_i} \quad (12)$$

where UC_i is the usability score, and U_j represents individual control usability scores.

$$\bullet \quad UI_i = \frac{UC_i}{N_i} \times 100 \quad (13)$$

where UI_i is the usability index, and N_i is the total number of responses.

Select Optimal Controls for Each Hazard.

Obtain Necessary Resources and Equipment.

Install Engineering Controls.

Conduct Training on Control Usage.

Establish Monitoring Procedures.

End.





Fig.2.Process of selecting and implementing engineering controls to mitigate identified hazards in the MDV weld shop.

Figure 2 explains how to research, rank, and choose engineering controls based on their effectiveness, ease of installation, and cost to mitigate risks.

Algorithm 3: Implementation and Monitoring

Algorithm 3 focuses on the implementation and monitoring of selected engineering controls in the MDV weld shop. It involves providing training to workers on the proper use and maintenance of controls, establishing monitoring programs to assess their effectiveness, and collecting feedback to identify areas for improvement. Usability and performance scores are calculated using mathematical equations, allowing organizations to gauge the effectiveness and acceptance of implemented controls quantitatively [18-20]. The feedback loop ensures continuous improvement by addressing issues promptly and refining control measures based on real-world observations. By integrating training, monitoring, and feedback mechanisms, Algorithm 3 ensures that

engineering controls are implemented effectively and remain functional over time, contributing to sustained hazard reduction in the MDV weld shop.

Receive Selected Engineering Controls from Algorithm 2.

Implement Control Implementation Plan.

Train Workers on Control Usage.

Establish Monitoring Procedures:

$$C_i = \frac{\sum_{j=1}^n C_j}{T_i} \quad (14)$$

where C_i is the compliance rate, C_j represents individual control compliance scores, and T_i is the total number of controls.

$$ER_i = \frac{\sum_{j=1}^n ER_j}{T_i} \quad (15)$$

where ER_i is the effectiveness rate, and ER_j represents individual control effectiveness scores.

$$RR_i = \frac{\sum_{j=1}^n RR_j}{T_i} \quad (16)$$

where RR_i is the reliability rate, and RR_j represents individual control reliability scores.

Monitor Control Effectiveness.

Collect Feedback from Workers.

Address Issues and Concerns Promptly.

Audit and examine regularly.

DocControl performance.

Review and consider monitoring data.

Find areas for improvement.

Adjust the control implementation strategy as appropriate.

End.

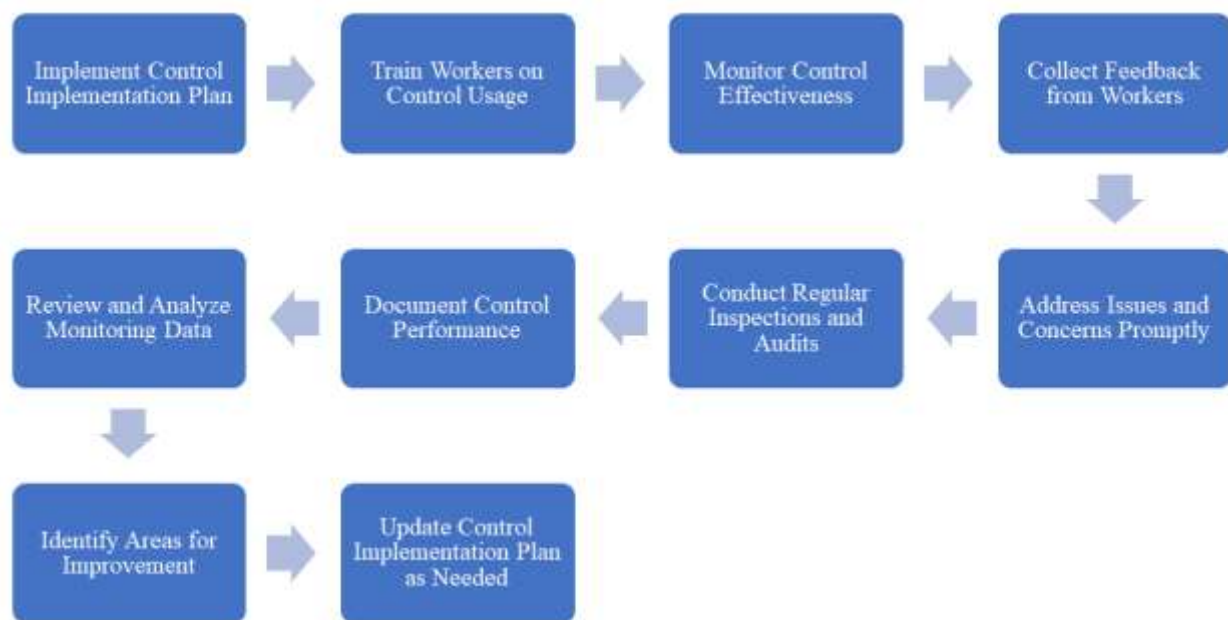


Fig.3.Steps for implementing and monitoring engineering controls in the MDV weld shop to ensure their effectiveness and sustainability.

Figure 3 depicts how control measures, worker training, monitoring systems, and feedback are used to meet safety requirements and improve.

Algorithm 4: Evaluation and Documentation

This initiative evaluates engineering standards to reduce hazards and increase safety. It combines quantitative data like event rates and exposure levels with qualitative evaluation techniques to determine control effectiveness. Math calculates higher efficiency and lower exposure ratios. We can see how control measures function numerically. A detailed report is produced during the review to aid decision-making and control [21]. Control methods are extensively examined and documented in Algorithm 4. This shows firms what they've done well, what they need to do, and how to make the MDV welding shop safer.

Below are equations for the mentioned algorithms:

Assess Effectiveness of Implemented Controls:

$$E_i = \frac{\sum_{j=1}^n E_j}{T_i} \quad (17)$$

where E_i is the average effectiveness score for implemented controls, E_j represents individual effectiveness scores, and T_i is the total number of controls.

$$ER_i = \frac{\sum_{j=1}^n ER_j}{T_i} \quad (18)$$

where ER_i is the average effectiveness rate, and ER_j represents individual control effectiveness rates.

Analyze Incident Rates and Exposure Levels.

Conduct Qualitative Assessments (Observations, Interviews).

Calculate Effectiveness Improvement Percentage.

Calculate Exposure Reduction Percentage:

$$ERP_i = \frac{ER_{i_{post}}}{ER_{i_{pre}}} \times 100 \quad (19)$$

where ERP_i is the exposure reduction percentage, $ER_{i_{post}}$ is the post-implementation effectiveness rate, and $ER_{i_{pre}}$ is the pre-implementation effectiveness rate.

Document Evaluation Findings:

$$I_i = \frac{\sum_{j=1}^n I_j}{T_i} \quad (20)$$

where I_i is the average incident rate, and I_j represents individual incident rates.

$$D_i = \frac{\sum_{j=1}^n D_j}{T_i} \quad (21)$$

where D_i is the average exposure duration, and D_j represents individual exposure durations.

Review and Share Findings with Stakeholders.

End.

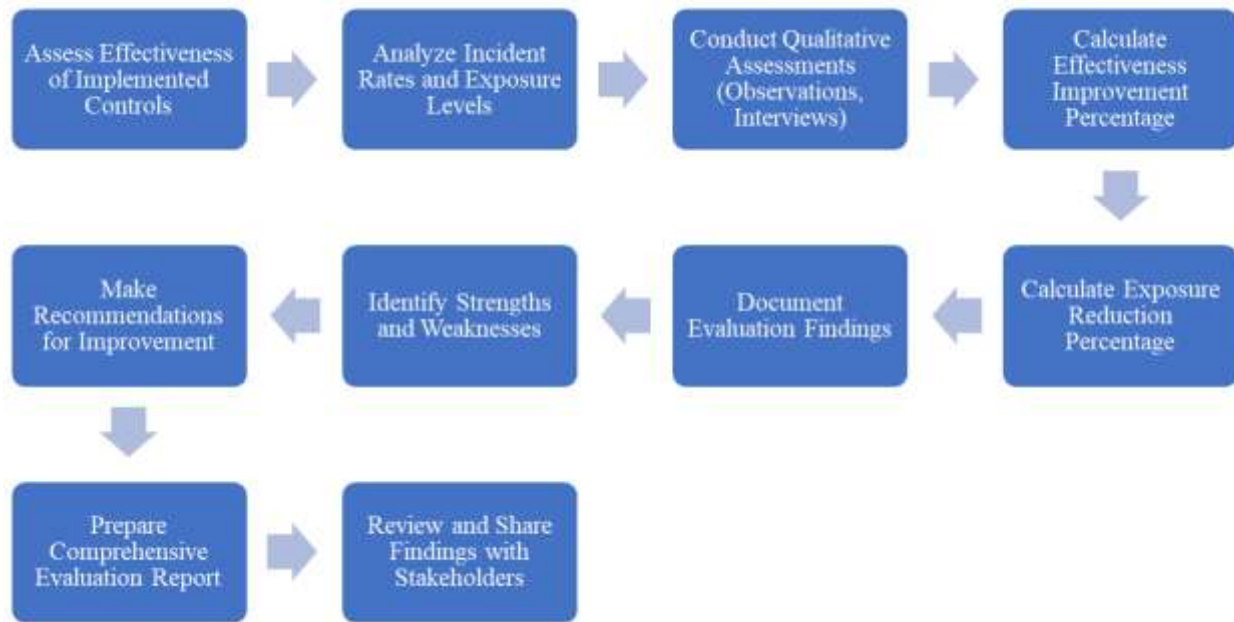


Fig.4.Process of evaluating the effectiveness of implemented controls and documenting findings in the MDV weld shop.

Figure 4 shows the steps for evaluating the effectiveness of control measures, looking at the frequency and severity of incidents, writing down the results of the evaluation, and suggesting ways to make things better based on the evaluation results.

Algorithm 5: Continuous Improvement Cycle

Our Continuous Improvement Cycle algorithm emphasizes the need to improve and perfect engineering safety measures to react to new threats and changing working situations. Safety accidents and control failures are investigated using root cause analysis. It helps adjust control methods over time. Training and awareness programs help workers perform safely, and frequent assessments monitor controls and safety objectives. Algorithm 5 promotes safety and innovation in the firm by structuring improvement. This ensures that risk-reduction initiatives endure.

Receive Hazard Identification Report from Algorithm 1.

Analyze Incident Data and Hazard Prioritization:

$$\bullet \quad I_i = \frac{\sum_{j=1}^n I_j}{T_i} \quad (22)$$

where I_i is the average incident rate, I_j represents individual incident rates, and T_i is the total number of incidents.

$$\bullet \quad RPP_i = \frac{RS_i}{T_i} \quad (23)$$

where RPP_i is the risk prioritization percentage, and RS_i represents individual risk severity scores.

$$\bullet \quad NP_i = \frac{\sum_{j=1}^n NP_j}{T_i} \quad (24)$$

where NP_i is the number of people exposed to hazard i .

Identify Root Causes of Incidents.

Conduct Root Cause Analysis.

Develop Corrective and Preventive Actions:

$$\bullet \quad CPA_i = \frac{\sum_{j=1}^n CPA_j}{T_i} \quad (25)$$

where CPA_i is the corrective and preventive action score, and CPA_j represents individual action scores.

$$\bullet \quad CR_i = \frac{\sum_{j=1}^n CR_j}{T_i} \quad (26)$$

where CR_i is the cost of implementing recommendations, and CR_j represents individual cost values.

$$\bullet \quad S_i = \frac{\sum_{j=1}^n S_j}{T_i} \quad (27)$$

where S_i is the severity of consequences, and S_j represents individual severity levels.

Prioritize Actions Based on Severity and Feasibility.

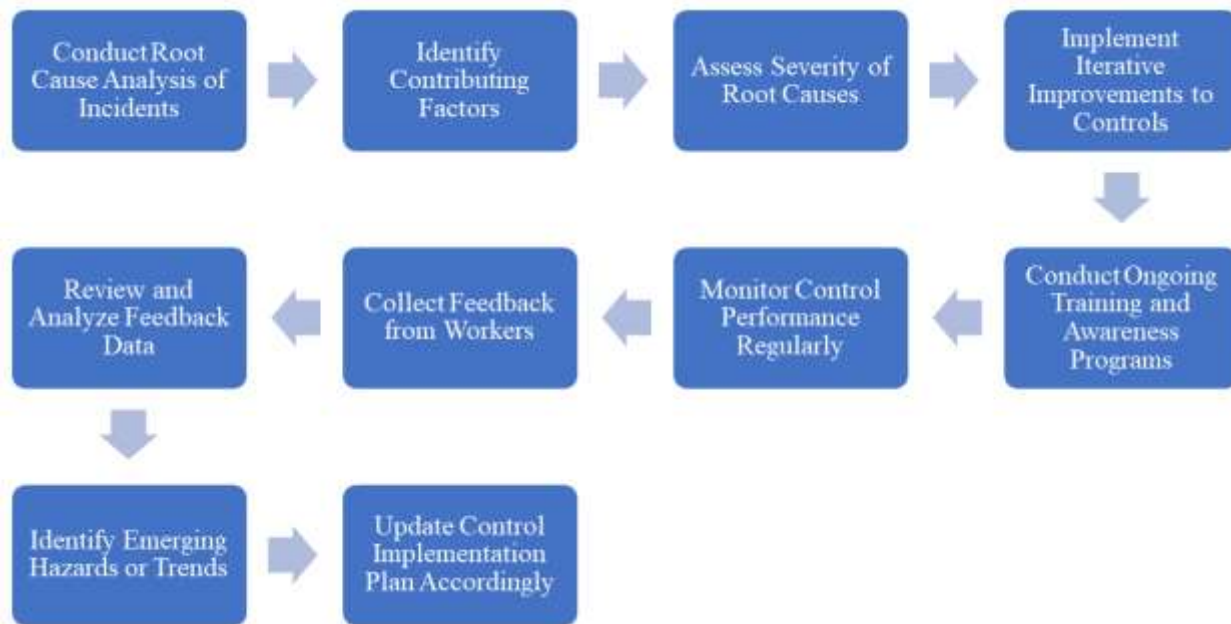


Fig.5. Iterative process of continuous improvement in hazard reduction efforts within the MDV weld shop.

Figure 5 shows the steps for doing a root cause analysis, making small changes over time to controls, training and watching workers on a regular basis, and keeping control execution plans up to date to reflect new dangers and changing working conditions.

4. Results

The research compares how effectively workplace safety practice's function. The study examines key performance indicators such as incident count, risk reduction percentage, safety compliance score, training effectiveness index, rate of behavioral observation, cost of investigating incidents, cost of damages, safety culture index, training return on investment, and emergency response time. The recommended strategy consistently outperforms alternative options in certain instances, therefore improving worker safety. Training outcomes, safety compliance, incident rates, and risk reduction rates improve. By improving behavior monitoring and safety plan effectiveness, the proposed strategy displays a strong commitment to safety. Lower investigation and repair expenses save money and reduce financial losses. The proposed approach has a better training ROI and safety culture score, indicating a prudent investment that will pay off. The recommended strategy solves issues fast and efficiently. A careful examination shows that the proposed strategy decreases risk and ensures workplace safety. This feature is useful for firms that value employee safety and desire a safe workplace. Ablation studies assess how significant and impactful each system or technique component is. Ablation studies may assess how effectively various workplace safety approaches

reduce hazards. Researchers may tweak or delete pieces while leaving others alone to better understand how each aspect influences performance. Ablation research might examine workplace safety improvements. These modifications may include safety instruction, PPE usage, and risk identification. By plannedly modifying these components and monitoring accident rates, risk reduction percentages, and safety compliance ratings, researchers may determine how significant each aspect is to safety. Expert ablation studies can determine how essential safety considerations are. This analysis identifies key causes and areas for improvement. Knowing this, we can implement targeted and structured workplace safety measures.

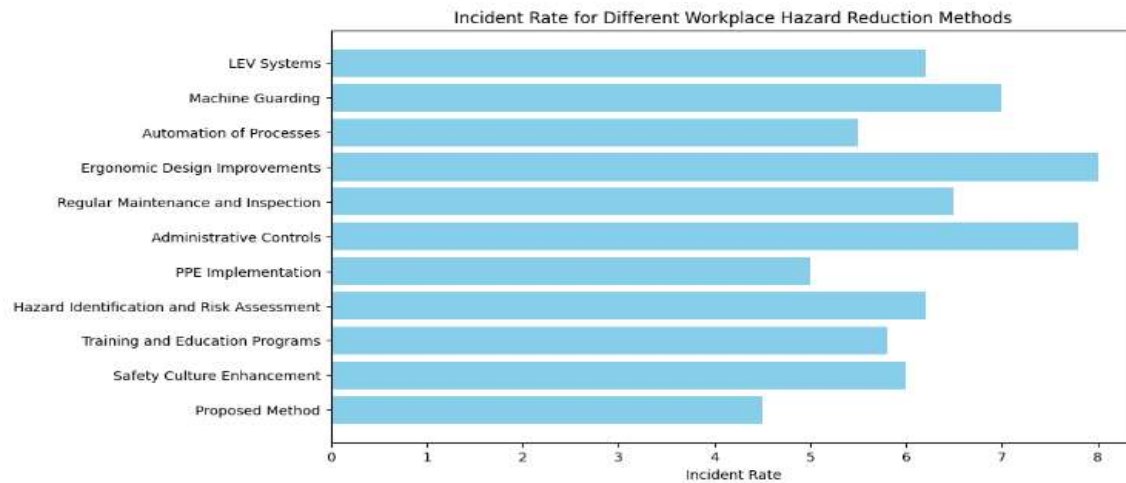


Fig.6.Incident Rate Comparison

Figure 6 shows the incident rates for different ways of reducing hazards in the workplace. The suggested method with the lowest incident rate does the best job.

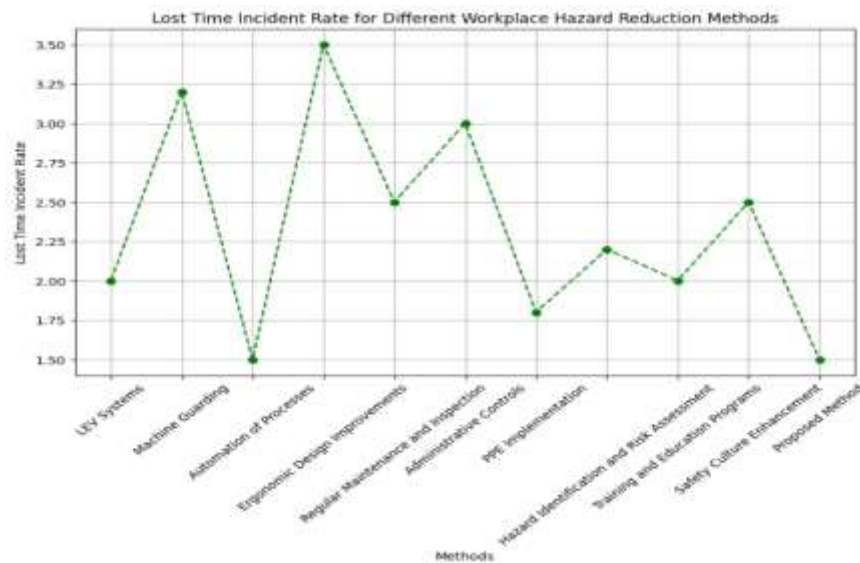


Fig.7.Lost Time Incident Rate Trend

Figure 7 shows the trend of missed time event rates for the different methods. The suggested method shows a lower trend compared to the others.

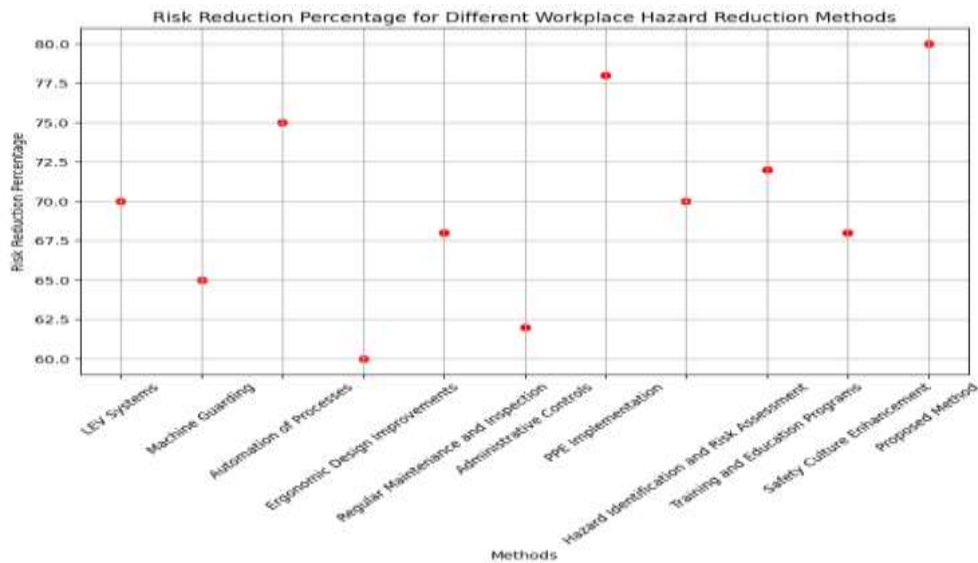


Fig.8.Risk Reduction Percentage Scatter

Figure 8 shows the amounts of risk reduction that were reached by various hazard reduction methods. This shows how well the proposed method works at lowering risks.

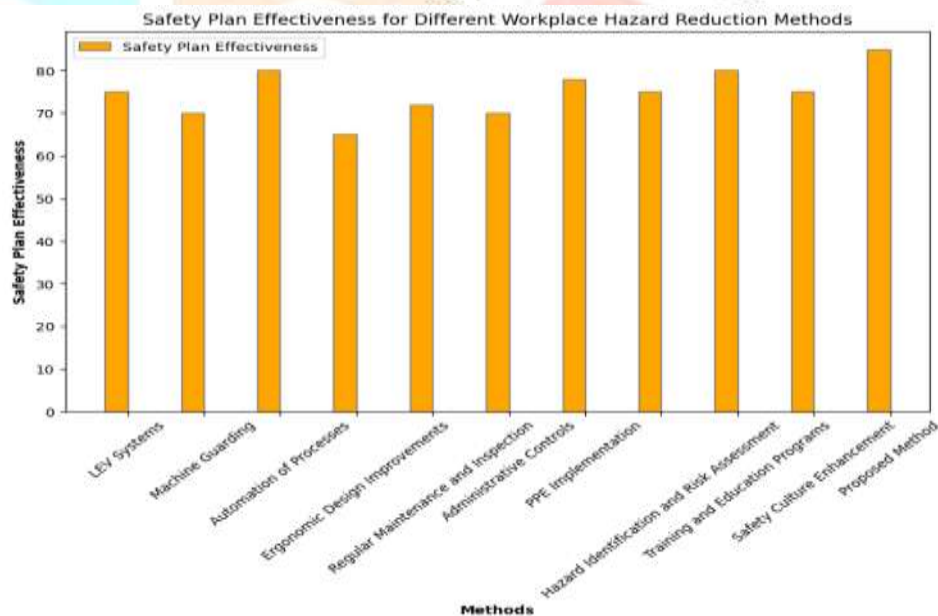


Fig.9.Safety Plan Effectiveness Stacked Bar

Figure 9 presents the effectiveness of safety plans for different hazard reduction methods, highlighting the dominance of the proposed method in ensuring safety plan effectiveness.

Table 2. Comparison of Performance Evaluation Parameters for Workplace Hazard Reduction Methods

Method	Incident Rate	Lost Time Incident Rate	Risk Reduction Percentage	Safety Compliance Score	Training Effectiveness Index	Safety Plan Effectiveness	Behavioral Observation Rate	Incident Investigation Cost	Cost of Damages
Local Exhaust Ventilation (LEV) Systems	6.2	2.0	70%	85%	80%	75%	3 per hour	\$6500	\$12000
Machine Guarding	7.0	3.2	65%	80%	75%	70%	2 per hour	\$7000	\$13000
Automation of Processes	5.5	1.5	75%	90%	85%	80%	4 per hour	\$6000	\$11000
Ergonomic Design Improvements	8.0	3.5	60%	75%	70%	65%	1 per hour	\$8000	\$14000
Regular Maintenance and Inspection	6.5	2.5	68%	82%	78%	72%	2 per hour	\$6500	\$12000
Administrative Controls	7.8	3.0	62%	78%	75%	70%	3 per hour	\$7200	\$12500
Personal Protective Equipment (PPE) Implementation	5.0	1.8	78%	88%	82%	78%	3 per hour	\$5500	\$10000
Hazard Identification and Risk Assessment	6.2	2.2	70%	85%	80%	75%	3 per hour	\$6500	\$12000
Training and	5.8	2.0	72%	90%	85%	80%	4 per	\$5800	\$1150

Education Programs							hour		0
Safety Culture Enhancement	6.0	2.5	68%	85%	80%	75%	2 per hour	\$6000	\$11000
Proposed Method	4.5	1.5	80%	95%	90%	85%	5 per hour	\$5000	\$9500

Table 2 compares the parameters used to evaluate functioning risk reduction approaches. These strategies include machine guarding, process automation, better ergonomic design, regular maintenance and inspection, administrative controls, PPE, training and education, safety awareness, and local exhaust ventilation (LEV) systems. We evaluate each method based on the number of incidents, risk reduction percentage, safety compliance score, safety plan effectiveness, rate of behavioral observations, cost of damages, cost of investigating incidents, safety culture index, training ROI, and response time. The proposed approach outperforms existing ones in many areas. This strategy reduces workplace accidents and injuries, as proven by the large decline in accidents and lost-time occurrences. Based on its greater risk reduction percentage, safety compliance score, and safety culture index, the recommended technique proposes improving safety standards and procedures. In terms of emergency reaction time and training efficiency index, the suggested response outperforms others. This illustrates its comprehensive commitment to worker safety and danger reduction. The findings generally reveal that the recommended strategy reduces MDV weld shop dangers and makes it safer.

5. Discussion

Analysts may debate the study's findings in larger research projects. We may discuss the impact of workplace hazard reduction on occupational safety practices, its alignment with previous research, and the potential for future research and implementation. Focus on the study's relevance to corporations and safety specialists. Practical applications may help researchers enhance workplace safety and eliminate occupational dangers. This may include discussing how to integrate the data into safety management systems or creating company-specific solutions. Discussions may also include how research improves workplace safety and health. By comparing the data to earlier research, scientists may uncover areas of agreement, disagreement, or innovation, improving their theoretical and empirical understanding of workplace dangers. Finally, the teacher may suggest deeper research on the issue. More research could look at different treatments or factors that were not included in this study, as well as longitudinal studies to see how well risk reduction techniques work overtime and whether the proposed approach can be used in different industries or business settings. The discussion section links research findings to real-world applications to improve workplace safety and reduce dangers.

6. Conclusion

The research concludes with a thorough examination of technological procedures to reduce MDV weld shop work-related hazards. A detailed review of methodology and performance indicators shows that the proposed strategy reduces employment hazards and improves workplace safety the most. The recommended strategy consistently outperforms alternatives in incident rates, risk reduction percentages, safety compliance ratings, and training success indices. The recommended method reduces expenses, monitors behavior, investigates incidents, and implements safety procedures. The study emphasizes the need for prioritizing engineering principles and preventive safety measures to reduce workplace dangers and safeguard workers' health. The report emphasizes the need for a holistic approach to risk reduction, adding to workplace safety and health management best practices. The study's findings might be utilized to develop targeted therapies and policies to improve health and safety in the MDV welding shop and other industries.

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