Prioritizing engineering designs and safety guidelines over personal safety equipment (PPE) utilization in achieving hazards prevention and occupational safety in Nigeria

[1]Akintoye, Oluyemi Ayorinde, [2]Ubong, Edet Harrison, [3]Asuquo Edung Etim, [4]Akintoye, Taiwo Adesola, [5]Agbo, Yvonne Nkan, [6]Ekumankama, Destiny Chidinma

[1]Department of Environmental Management, Faculty of Environmental Sciences, University of Calabar, Calabar, Nigeria, https://orcid.org/0000-0002-9597-7361, Email: oluyemi.akintiye@unical.edu.ng
[2]Nigeria Erosion and Watershed Management Project, Uyo Akwa Ibom State, https://orcid.org/0009-0002-3423-0384
[3]Department of Environmental Education, University of Calabar, Nigeria https://orcid.org/0000-0002-8352-5034
[4]Department of Special Education, Faculty of Education, University of Calabar, Nigeria https://orcid.org/0009-0008-9355-1157
[5]Department of Environmental Management, Faculty of Environmental Sciences, University of Calabar, Calabar, Nigeria,
[6]Department of Environmental Management, Faculty of Environmental Sciences, University of Calabar, Calabar, Nigeria,

Abstracts

Occupational health and safety (OHS) has traditionally emphasized the use of personal protective equipment (PPE) as a frontline defense against workplace hazards. However, modern safety philosophy and regulatory frameworks increasingly advocate for higher-order control strategies, such as engineering design modifications and the implementation of robust company policies. This article explores the rationale for prioritizing engineering solutions and organizational controls over PPE in hazard prevention. Drawing from empirical studies, safety engineering principles, and international safety standards, the paper argues that reliance on PPE is often reactive and insufficient, especially in high-risk environments. The article presents a conceptual framework highlighting the hierarchy of controls and demonstrates how proactive safety design and policy enforcement can significantly reduce occupational risks. Recommendations are made for safety managers, engineers, and policymakers to reorient prevention strategies toward sustainable, systems-based approaches that minimize human error and improve overall safety culture. The article concludes that while PPE remains a vital component of occupational safety, it should serve as a last line of defense rather than the primary safeguard.

Keywords: Personal Safety Equipment (PPE), Engineering Design, Safety Guidelines, Hazards Prevention, Occupational Health and Safety

Introduction

Occupational health and safety (OHS) is an essential pillar of workplace sustainability and human well-being. Across various industries, ranging from manufacturing and mining to construction and energy, workplace hazards continue to result in injuries, illnesses, and fatalities. In response, many organizations have implemented protective measures, the most visible and commonly used being personal protective equipment (PPE). However, despite widespread adoption, reliance on PPE has shown to be insufficient in preventing many types of workplace incidents. The limitations of PPE are well documented, especially when used as a standalone strategy for hazard control (Bahn, 2013; Okorie, Emeka, & Ezeokafor, 2020)

A more sustainable and effective approach to occupational hazard prevention lies in prioritizing engineering design and the formulation of robust company policies. These higher-order controls emphasize the elimination or substantial reduction of hazards at their source, rather than merely shielding workers from exposure. This paper contends that engineering controls and institutional policies should be placed at the core of occupational health and safety strategies, with PPE serving as a supplementary or last-resort measure. This perspective aligns with globally accepted safety models, including the Hierarchy of Controls developed by the National Institute for Occupational Safety and Health (NIOSH), which ranks hazard control methods in terms of effectiveness, from elimination to substitution, engineering controls, administrative controls, and finally, PPE (NIOSH, 2015).

In many workplaces, however, the emphasis remains on the use of PPE. This preference is driven by several factors, including cost considerations, regulatory compliance checklists, and a misplaced sense of safety assurance. The reality is that PPE effectiveness is highly dependent on human behavior—correct selection, proper usage, and consistent maintenance. Such dependencies introduce room for human error, fatigue, and non-compliance (Velásquez, Benavides & Rojas, 2021). On the contrary, engineering design solutions such as automated machinery, hazard enclosures, ergonomic workstations, and noise-dampening systems function independently of human variability, making them more reliable in the long term. Company policies and safety cultures further reinforce the importance of systemic thinking in hazard management. Policies that mandate regular risk assessments, enforce hazard elimination strategies, promote worker participation, and integrate safety in design processes contribute significantly to accident reduction (Hale & Borys, 2013). When these policies are institutionalized and enforced with leadership commitment, they form the backbone of organizational resilience against occupational risks.

This article takes a comprehensive look at the limitations of PPE-centric safety approaches and advocates for a paradigm shift toward engineering design and policy enforcement in occupational safety strategies. Through a review of scholarly literature, safety models, and real-world case studies, the article builds a conceptual and practical framework that supports this shift. It aims to influence safety professionals, engineers, and policymakers to prioritize systemic interventions that eliminate hazards at their source rather than relying on defensive mechanisms after exposure. Ultimately, occupational safety should not be reactive but proactive, built into the core of work environments through thoughtful design and intelligent policy. As organizations worldwide strive toward sustainability and resilience, embracing this shift is not only prudent but necessary.

Historical Context of Personal Protective Equipment (PPE) Usage

Personal Protective Equipment (PPE) has long been considered a fundamental element in workplace safety. Its origins date back to the early industrial era when rapid mechanization introduced new occupational risks, including chemical exposure, mechanical injuries, and noise pollution (Geller, 2001). Early safety efforts were often rudimentary, but with the advent of regulatory frameworks in the 20th century, such as the Occupational Safety and Health Act (1970) in the United States, PPE became a mandatory compliance item in most industrial settings. Despite its ubiquity, PPE was never intended to be the first line of defense against hazards. The Hierarchy of Controls, a model endorsed by NIOSH and widely accepted across occupational health literature, places PPE at the bottom tier, which is less effective than elimination, substitution, engineering, and administrative controls (NIOSH, 2015). Yet, in many developing countries and even some advanced economies, PPE remains the most commonly implemented safety measure. Studies suggest this is due to its relatively low cost and ease of deployment, despite its limitations in effectiveness (Zhou et al., 2008).

Limitations of PPE-Centric Safety Approaches

PPE primarily serves as a barrier between the worker and the hazard. However, its effectiveness depends heavily on consistent and proper use. Behavioral inconsistencies, discomfort, equipment degradation, and lack of training often compromise its protective function (Okorie, Emeka, & Ezeokafor, 2020). Workers may fail to wear PPE properly due to high temperatures, limited mobility, or simple neglect. This human factor risk makes PPE a fragile line of defense. Additionally, PPE does not eliminate the hazard; it merely attempts to shield the worker. For example, a worker wearing earplugs in a high-decibel environment is still exposed to noise pollution, which can degrade hearing over time if the PPE is inadequate or improperly used. According to Velásquez et al. (2021), over 60% of reported workplace injuries in small-scale industries involved cases where PPE was available but improperly used.

Engineering Design as a Proactive Safety Strategy

Engineering design interventions aim to eliminate or isolate hazards through structural and mechanical solutions. These controls reduce reliance on human compliance and provide more consistent protection. For example, designing quieter machinery or enclosing hazardous processes reduces worker exposure without requiring behavioral change (Wulff, Brand & Ernst, 2015). Engineering controls are considered more sustainable than PPE because they integrate safety into the core of operational systems. Research in the manufacturing and oil and gas industries shows that workplaces adopting engineering interventions experience significantly fewer incident rates compared to PPE-dependent settings (Chi et al., 2009). Moreover, automation, robotics, and ergonomic redesigns are increasingly being used to reduce physical and cognitive strain on workers (Zhao et al., 2020). One notable example is the use of lockout/tag-out (LOTO) systems in industrial maintenance procedures. These systems prevent accidental energization of equipment, thereby eliminating the hazard entirely—an outcome PPE cannot achieve (OSHA, 2020).

Company Policies and Organizational Controls

Beyond physical interventions, organizational policies play a pivotal role in shaping workplace safety. Safety policies govern behavior, set standards for compliance, and institutionalize accountability mechanisms. Effective policies support regular risk assessments, safety training, and incident reporting systems, thereby creating a safety-conscious culture (Reason, 1997). ISO 45001:2018, the global standard for occupational health and safety management systems, emphasizes the importance of organizational commitment, worker participation, and continuous improvement in safety performance. This standard prioritizes hazard elimination and process safety over PPE reliance, advocating for a strategic integration of safety into management systems (ISO, 2018). A study by Hale and Borys (2013) demonstrates that companies with clear, enforced safety policies had significantly lower injury rates, even in high-risk industries. These findings support the idea that safety is a function of organizational systems, not individual behavior alone. Policies that enforce maintenance schedules, limit exposure times, and embed safety reviews into operational procedures reduce risks at a systemic level.

Comparative Effectiveness of PPE, Engineering and Policy Interventions

Numerous studies support the superiority of engineering and administrative controls over PPE. In a meta-analysis of industrial safety interventions, Cohen and Colligan (1998) found that workplaces implementing engineering redesigns and safety policies reported 40–60% fewer incidents than those relying predominantly on PPE. Similarly, research in the construction sector revealed that risk mitigation through scaffolding redesigns and traffic flow changes had a far greater impact than simply requiring high-visibility vests or hard hats (Lingard et al., 2010). In healthcare, where exposure to infectious agents is a concern, administrative policies such as patient triage protocols, ventilation system upgrades, and workflow redesign have been more effective in infection control than PPE alone (MacIntyre, Seale, Dung, Hien, Nga, Chughtai, Rahman, Dwyer, and Wang 2015). These comparative findings reinforce the need for a paradigm shift in OHS from reactive to proactive systems-based approaches.

Global best practices and regulatory standards

Globally, leading occupational safety institutions have moved toward engineering and organizational approaches. The European Union's Framework Directive on Safety and Health at Work (89/391/EEC) mandates employers to avoid risks at the source and adapt work to the individual, reinforcing the principle of proactive hazard elimination (European Commission, 1989). In the U.S., OSHA encourages the use of engineering controls wherever feasible and offers grant incentives for companies that adopt such strategies (OSHA, 2020). Meanwhile, in Japan, the "Zero Accidents Campaign" promotes safety-by-design as a core element of its national safety strategy (Shikdar & Sawaqed, 2004). These global movements illustrate a broad consensus that while PPE has its place, lasting safety outcomes require investment in upstream interventions.

Conceptual Framework

A strong conceptual framework is essential in understanding the shift from reliance on personal protective equipment (PPE) to a more sustainable and proactive approach that prioritizes engineering controls and company policies. This framework is grounded in occupational safety theory, systems thinking, and the well-established Hierarchy of Controls model.

The Hierarchy of Controls

At the core of this framework is the Hierarchy of Controls, developed by the National Institute for Occupational Safety and Health (NIOSH), which prioritizes hazard control strategies based on their effectiveness. In table 1, five levels of control are shown:-

Table 1: Five levels of control

S/N	TERMINOLOGY	ACTION
1	Elimination	Physically remove the hazard
2	Substitution	Replace the hazard with a safer alternative
3	Engineering Controls	Isolate people from the hazard
4	Administrative Controls	Change the way people work
5	PPE	Protect the worker with equipment

Source: National Institute for Occupational Safety and Health (NIOSH), 2015

This hierarchy suggests that PPE should be considered only when other, more effective interventions are not feasible (NIOSH, 2015). By structuring interventions according to this model, organizations can reduce dependence on human behavior and instead design safety into the system.

Systems Theory and Organizational Safety

Systems theory posits that safety is a function of the entire operational environment, not isolated actions or equipment. According to Rasmussen's Risk Management Framework (1997), workplace accidents occur not merely due to human error but due to systemic failures at different organizational levels, management decisions, supervisory roles, and frontline operations. This framework supports the integration of engineering design and policy development as part of a holistic safety system. When safety is embedded in organizational processes—through equipment design, workflow engineering, and regulatory policies—hazards are minimized at their origin, rather than relying on workers to compensate through behavior.

Safety Culture and the Swiss Cheese Model

The Swiss Cheese Model of accident causation (Reason, 1997) further explains how multiple layers of defense—technological, organizational, and human—interact to prevent or allow failures. Each layer has inherent "holes" (i.e., weaknesses), but when multiple weak layers align (e.g., poorly designed machinery, lax safety policies, and improper PPE use), accidents occur. The model underscores why PPE, the final layer of defense, should never be relied upon in isolation. Instead, upstream measures such as engineering design and company-wide policies are necessary to plug systemic gaps before they reach the worker level.

Behavioral and Cognitive Psychology in Safety

The human factor is often the weakest link in PPE-reliant safety strategies. Cognitive psychology has shown that repetitive tasks, physical discomfort, and mental fatigue reduce compliance with PPE protocols (Neal & Griffin, 2006). Additionally, risk perception studies indicate that workers may overestimate the protection offered by PPE and thus engage in riskier behavior, a phenomenon known as risk compensation (Fuller, 2005). This psychological insight supports a shift toward controls that do not require constant human input or vigilance, such as engineering barriers or automated hazard-detection systems.

Integrative Conceptual Model

The proposed conceptual model for this article integrates the above theories into a three-tiered framework:

Tier 1: Design-Level Controls

Includes elimination, substitution, and engineering controls embedded into equipment, facility layout, and task design. These are proactive and highly reliable.

Tier 2: Organizational Policies and Procedures

Encompasses administrative controls, safety protocols, employee training, and safety audits. These are semi-reliable and rely on managerial oversight.

Tier 3: Residual Risk Management via PPE

Represents the final defense line, useful only when hazards cannot be eliminated or adequately controlled by upstream methods.

This model advocates for an inverted approach to hazard control: beginning with the elimination or reduction of hazards before considering protective measures. It shifts the safety narrative from "protecting workers from hazards" to "designing hazards out of the workplace. Figure 1: presents the Three-Tier Conceptual Framework, as proposed by this study. This pyramid mirrors the traditional hierarchy of controls but emphasize the integration of systemic thinking.

Engineering works allow for accident prevention efforts to be made during design and construction, or after observation of accident prevention flaws during plant operations. Policies and guidelines can also become necessary tools, in the second tier, while PPE and behavioral controls are in the third tier of the accident prevention and control pyramid, as suggested in this article.

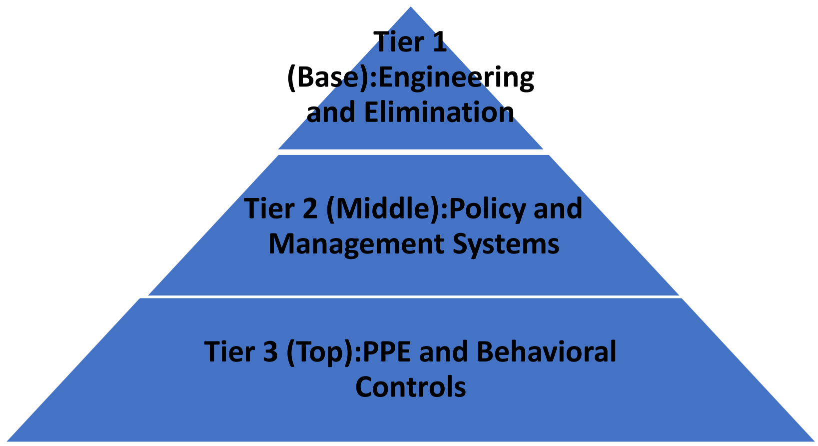

Figure 1: Three-Tier Conceptual Framework for Occupational Accident Prevention
Source: Proposed by this Article (2025)

PPE as a reactive strategy: The case of limited protection

Personal Protective Equipment (PPE), though widely used, is inherently reactive. It addresses the symptom of hazardous environments rather than the cause. In industries such as construction, mining, and chemical processing, PPE merely acts as a shield once the worker is already exposed to risk. The inefficacy of PPE has been documented in various sectors. For instance, studies from Nigeria's small-scale manufacturing sector show that over 45% of workers experience injuries despite using PPE, largely due to equipment fatigue, improper use, or lack of adequate training (Okorie, Emeka, & Ezeokafor, 2020).

Further, PPE does not function in isolation—it demands strict compliance, regular replacement, and situational appropriateness. In hot climates or strenuous work, workers often remove PPE due to discomfort, reducing its effectiveness. Consequently, an over-reliance on PPE places the burden of safety on the individual worker, rather than on the system, process, or management structure.

Engineering controls: Designing hazards out of the system

Engineering interventions eliminate or isolate hazards before workers are even exposed. These controls include noise enclosures, dust extraction systems, fail-safe machinery, ergonomic designs, and robotics. In the oil and gas sector, for example, automated valve shutoff systems reduce the need for human interaction with high-pressure pipelines, a function PPE cannot match. A study by Chi et al. (2009) in the construction industry found that the use of design-based fall-prevention measures (e.g., guardrails, walkways) reduced fatalities by over 60%, while PPE alone reduced fall injuries by less than 30%. Similarly, in the food processing industry, installing machine interlocks and blade guards decreased amputation rates more effectively than requiring cut-resistant gloves (Zhao et al., 2020). Engineering designs, when built into the operational architecture, eliminate human inconsistency. Once installed, they require minimal behavior change, thereby creating a safer work environment by default rather than by discretion.

The role of company policies in embedding safety

Policy-level interventions support safety by codifying standards and embedding risk management practices into organizational culture. Comprehensive safety policies address training, hazard reporting, equipment maintenance, and work-rest cycles. ISO 45001:2018 encourages organizations to create dynamic systems that identify, evaluate, and eliminate hazards through a

Plan-Do-Check-Act (PDCA) framework. For example, Shell Nigeria has implemented an integrated health and safety policy that emphasizes hazard elimination through early-stage project design, contractor safety compliance, and digital reporting tools. As a result, Shell has seen a consistent decline in Lost Time Incidents (LTI) across its upstream operations (Shell Annual Report, 2022). Similarly, Dangote Cement adopted a company-wide “No Shortcut to Safety” policy, including mandatory risk assessments before task initiation. This policy, enforced with real-time monitoring and a feedback loop, has been credited with reducing major incidents at its Obajana and Gboko plants by 40% over five years (HSE Nigeria Report, 2021). Policies also encourage employee participation and safety ownership. When workers are empowered to halt operations due to safety concerns—without fear of retaliation—it reinforces a culture where safety is systemic, not superficial.

Integration of engineering and policy for maximum effect

The most effective occupational health strategies do not treat engineering and policy in isolation. Instead, they integrate both into a cohesive risk management system. For instance, consider a factory that redesigns its assembly line to minimize lifting (engineering) and mandates quarterly ergonomic training (policy). This dual approach not only eliminates hazards but ensures continuous worker education and monitoring. The construction industry’s Design for Safety (DfS) initiative illustrates this integrated model. By involving engineers, safety officers, and project managers in pre-construction planning, hazards are anticipated and eliminated through design. Supported by administrative policies—like mandatory safety briefings and checklists—the result is a proactive safety net that goes far beyond PPE mandates (Lingard et al., 2010).

Ethical and legal implications of PPE-only approaches

Over-reliance on PPE also raises ethical and legal questions. Employers have a duty of care that includes providing a safe working environment, not just supplying protective gear. Regulatory bodies such as OSHA and the International Labour Organization (ILO) emphasize the employer's responsibility to eliminate hazards as a priority (ILO Convention No. 155). Failing to implement systemic safety solutions, when they are technically and economically feasible, could be interpreted as negligence. Courts in countries like Canada and the UK have held companies liable for preventable accidents when engineering solutions were ignored in favor of cheaper PPE alternatives (Hale & Borys, 2013).

Real-world examples with lessons from industrial giants

There are real examples and lessons from well-established global giants. These include, but are not limited to:-

(i) Toyota Production System (Japan): Toyota’s focus on ergonomic workstations and automation in car manufacturing led to a sharp decline in repetitive strain injuries. Safety is integrated into every task cycle, reducing reliance on PPE (Shikdar & Sawaqed, 2004).

(ii) BHP Billiton (Australia): In its mining operations, BHP uses autonomous trucks and remotely operated drilling systems. The result: minimized human exposure to geological hazards, leading to fewer PPE-related injuries (BHP HSE Report, 2020).

(iii) Lafarge Africa: Integrated engineering controls in cement kilns and clinker cooling zones have reduced worker heat exposure significantly. Combined with heat-exposure policies, PPE now functions as a backup—not the frontline.

Addressing barriers to implementation

Despite its proven benefits, engineering redesign is often underutilized due to initial capital costs, lack of technical expertise, or short-term productivity pressures. However, cost-benefit analyses often reveal that long-term savings from injury reduction, lower insurance premiums, and improved productivity outweigh upfront expenses (Cohen & Colligan, 1998). Governments and organizations can facilitate vital transitions by offering tax incentives, technical training, and regulatory frameworks that reward hazard elimination over hazard accommodation.

Argument Structure and Analytical Discussion

PPE as a Reactive Strategy: The Case of Limited Protection

Personal Protective Equipment (PPE), though widely used, is inherently reactive. It addresses the symptom of hazardous environments rather than the cause. In industries such as construction, mining, and chemical processing, PPE merely acts as a shield once the worker is already exposed to risk. The inefficacy of PPE has been documented in various sectors. For instance, studies from Nigeria's small-scale manufacturing sector show that over 45% of workers experience injuries despite using PPE, largely due to equipment fatigue, improper use, or lack of adequate training (Okorie, Emeka, & Ezeokafor, 2020). Further, PPE does not function in isolation—it demands strict compliance, regular replacement, and situational appropriateness. In hot climates or strenuous work, workers often remove PPE due to discomfort, reducing its effectiveness. Consequently, an over-reliance on PPE places the burden of safety on the individual worker, rather than on the system, process, or management structure.

Engineering Controls: Designing Hazards Out of the System

Engineering interventions eliminate or isolate hazards before workers are even exposed. These controls include noise enclosures, dust extraction systems, fail-safe machinery, ergonomic designs, and robotics. In the oil and gas sector, for example, automated valve shutoff systems reduce the need for human interaction with high-pressure pipelines, a function PPE cannot match. A study by Chi, Chang & Ting (2009) in the construction industry found that the use of design-based fall-prevention measures (e.g., guardrails, walkways) reduced fatalities by over 60%, while PPE alone reduced fall injuries by less than 30%. Similarly, in the food processing industry, installing machine interlocks and blade guards decreased amputation rates more effectively than requiring cut-resistant gloves (Zhao et al., 2020). Engineering designs, when built into the operational architecture, eliminate human inconsistency. Once installed, they require minimal behavior change, thereby creating a safer work environment by default rather than by discretion.

The Role of Company Policies in Embedding Safety

Policy-level interventions support safety by codifying standards and embedding risk management practices into organizational culture. Comprehensive safety policies address training, hazard reporting, equipment maintenance, and work-rest cycles. ISO 45001:2018 encourages organizations to create dynamic systems that identify, evaluate, and eliminate hazards through a Plan-Do-Check-Act (PDCA) framework. With companies like Dangote Investments, delving into food production, automobile manufacturing, cement making, petroleum refinery, and so on, the importance of this insight, embedded in company safety policies and operations can not be overemphasized in Nigeria. These strides in multi-focused and diverse investment strategies are being closely emulated by dozens of other Nigerian agencies, Including BUA Cement, Bua foods Ltd, Guiness Nigeria, Coca Cola Nigeria, Nestle Nigeria, Nigeria Breweries, NASCON Allied

Industries, BAGCO supper Bags, Niger Mills, Shell Petroleum Development Company among so many. Consequently, there is a dire need for insightful planning of industrial safety, without strategic PPE adherence.

For example, Shell Nigeria has implemented an integrated health and safety policy that emphasizes hazard elimination through early-stage project design, contractor safety compliance, and digital reporting tools. As a result, Shell has seen a consistent decline in Lost Time Incidents (LTI) across its upstream operations (Shell Annual Report, 2022). Similarly, Dangote Cement adopted a company-wide “No Shortcut to Safety” policy, including mandatory risk assessments before task initiation. This policy, enforced with real-time monitoring and a feedback loop, has been credited with reducing major incidents at its Obajana and Gboko plants by 40% over five years (HSE Nigeria Report, 2021). Policies also encourage employee participation and safety ownership. When workers are empowered to halt operations due to safety concerns, without fear of retaliation—it reinforces a culture where safety is systemic, not superficial.

Comparative Analysis of PPE vs. Systemic Interventions

Table 2: displays a comparative analysis of the effectiveness of PPE and systemic approach. The information in this table reflects that while PPE is the easiest to implement, it is the least reliable. Engineering and administrative controls, though costlier at inception, yield higher returns in long-term safety and operational efficiency.

Table 2: Comparative analysis PPE and systemic approach

Intervention Type	Dependence on Human Behavior	Effectiveness in Long-Term Risk Reduction	Initial Cost	Sustainability	Example
Personal Protective Equipment (PPE)	High	Low to moderate	Low	Low	Hard hats, Gloves
Engineering Controls	Low	High	High	High	Guard rails, exhaustion ventilation
Administrative Controls & Policies	Moderate	Moderate to high	Moderate	Moderate	Safety audits, Shift rotations

Source: Proposed for this article (2025)

Integration of engineering and policy for maximum effect

The most effective occupational health strategies do not treat engineering and policy in isolation. Instead, they integrate both into a cohesive risk management system. For instance, consider a factory that redesigns its assembly line to minimize lifting (engineering) and mandates quarterly ergonomic training (policy). This dual approach not only eliminates hazards but ensures continuous worker education and monitoring. The construction industry’s Design for Safety (DfS) initiative illustrates this integrated model. By involving engineers, safety officers, and project managers in pre-construction planning, hazards are anticipated and eliminated through design. Supported by administrative policies—like mandatory safety briefings and checklists—the result is a proactive safety net that goes far beyond PPE mandates (Lingard et al., 2010).

Ethical and legal implications of PPE-only approaches

Over-reliance on PPE also raises ethical and legal questions. Employers have a duty of care that includes providing a safe working environment, not just supplying protective gear. Regulatory bodies such as OSHA and the International Labour Organization (ILO) emphasize the employer's responsibility to eliminate hazards as a priority (ILO Convention No. 155). Also, non -adherence to this approach could result in avoidable, legal cases and payment of massive damages, compensations and legal fees. In present Nigeria, laws and edicts are being reviewed and new technicalities, and previously excluded dimensions being inserted. These could become stumbling stones to national and multi-national corporations, which have not been properly guided, and unable to avoid these problems. Failing to implement systemic safety solutions, when they are technically and economically feasible, could be interpreted as negligence. Courts in countries like Canada and the UK have held companies liable for preventable accidents when engineering solutions were ignored in favor of cheaper PPE alternatives (Hale & Borys, 2013).

Real-world examples: Lessons from industrial leaders

Toyota Production System (Japan): Toyota's focus on ergonomic workstations and automation in car manufacturing led to a sharp decline in repetitive strain injuries. Safety is integrated into every task cycle, reducing reliance on PPE (Shikdar & Sawaqed, 2004). BHP Billiton (Australia)In its mining operations, BHP uses autonomous trucks and remotely operated drilling systems. The result: minimized human exposure to geological hazards, leading to fewer PPE-related injuries (BHP HSE Report, 2020). Lafarge Africa, which has established itself in Nigeria, is known to depend on integrated engineering controls in cement kilns and clinker cooling zones have reduced worker heat exposure significantly. Combined with heat-exposure policies, PPE now functions as a backup, and not the frontline, in their manufacturing processes.

Addressing barriers to implementation

Despite its proven benefits, engineering redesign is often underutilized due to initial capital costs, lack of technical expertise, or short-term productivity pressures. However, cost-benefit analyses often reveal that long-term savings from injury reduction, lower insurance premiums, and improved productivity outweigh upfront expenses (Cohen & Colligan, 1998). Governments and organizations can facilitate transitions by offering tax incentives, technical training, and regulatory frameworks that reward hazard elimination over hazard accommodation.

Implications and recommendations

For an article like this, there is a need for the provision of insights into the implications of these as well as to provide useable recommendations.

Practical Implications for Industries

The shift from PPE-centric approaches to systems-based safety strategies has significant implications for how organizations structure their occupational health programs. Industries that continue to rely primarily on PPE face increased operational risks, regulatory scrutiny, and financial liabilities. Emphasizing engineering designs and company policies:

(i) Reduces incident rates and costly workplace disruptions. Improves productivity, as safer systems require less downtime for training, inspections, and investigations.

(ii) Builds corporate reputation, showing commitment to proactive risk management rather than reactive compliance.

(iii) Supports sustainability, as systemic controls are long-lasting and reduce waste generated from disposable PPE.

(iv) Organizations should therefore embed safety into design phases, task planning, and policy drafting. Rather than purchasing new PPE annually, the same funds could be invested in hazard elimination strategies that permanently improve working conditions.

Policy Implications for Regulatory Bodies

(i) Policymakers and regulatory bodies such as the Federal Ministry of Labour and Employment (Nigeria), OSHA, and ILO must take leadership roles in redefining safety expectations. Recommendations include:

(ii) Revising existing regulations to prioritize hazard elimination and engineering controls as mandatory, not optional.

(iii) Incentivizing innovation in workplace design through tax credits, research grants, or compliance rating systems.

(iv) Expanding enforcement protocols to assess how well employers have minimized risks upstream, not just provided PPE.

(v) Publishing sector-specific guidelines that identify common hazards and recommend engineering alternatives.

(vi) Furthermore, labour inspectors should be trained to evaluate the design philosophy of a workplace, not just the presence of PPE.

Strategic recommendations for employers

(i) Conduct Hazard Identification and Risk Assessments (HIRA) with a focus on elimination and substitution.

(ii) Collaborate with engineers and process designers during the planning and retrofitting of workstations and tools.

(iii) Create multidisciplinary safety teams involving safety officers, managers, engineers, and frontline workers.

(iv) Develop comprehensive company safety policies that integrate behavioral safety, engineering changes, and organizational accountability.

(v) Monitor effectiveness through metrics such as near-miss reports, absenteeism, equipment malfunctions, and feedback loops.

(vi) Engage employees through safety culture initiatives, suggestion programs, and recognition schemes for innovation.

Educational and Research Implications

There is a pressing need for academic programs in engineering, occupational health, and industrial safety to include hazard control design as part of their curriculum. Research institutions can: Partner with industries to pilot design-focused interventions and develop case studies showing ROI from engineering safety investments. It is very important to study behavioral economics to understand resistance to design changes. It's also important to document indigenous engineering innovations in countries like Nigeria that creatively address workplace hazards with minimal resources. This approach aligns with the United Nations' Sustainable Development Goal 8, which promotes decent work and economic growth through safer, more productive environments.

Social justice and ethical considerations

Systemic approaches also address social inequities in occupational health. In many low-income settings, workers have limited access to effective PPE and training. By eliminating hazards at their source, employers protect the most vulnerable workers—those who often lack bargaining power to demand safer conditions. Thus, ethically, it is unjust to expect workers to bear the brunt of systemic failures by depending solely on PPE. As Reason (1997) and Hale & Borys (2013) argue, safety must be seen as a design and management responsibility, not a personal burden.

The future of occupational safety

The future of workplace safety lies in smart technologies, automated systems, and data-driven decision-making. Artificial intelligence, IoT sensors, and predictive maintenance are already being used in developed nations to anticipate hazards and respond before incidents occur. Countries like Nigeria can leapfrog into these innovations by adopting low-cost, scalable engineering solutions (e.g., solar-powered dust extractors, ergonomic hand tools) and supporting policies that foster a culture of prevention.

Conclusion

The ongoing reliance on Personal Protective Equipment as the frontline defense in occupational health and hazard prevention is no longer sufficient. As industries grow more complex and workers face a wider range of risks, a paradigm shift is required, one that places greater emphasis on engineering design and organizational policies. Engineering controls proactively eliminate hazards, while company policies ensure systemic accountability and long-term safety culture. PPE, though still useful, should serve as a last line of defense, not the foundation of workplace safety. By rethinking our approach to occupational health, from compliance-driven to design-driven industries can achieve sustainable safety outcomes that protect workers, enhance productivity, and uphold ethical standards. Regulatory agencies, employers, and academic institutions must collaborate to embed this shift in both practice and policy. Only then can we move from a culture of injury management to one of hazard prevention, by design, not by default.

References

Bahn, S. (2013). Workplace hazard identification: What do workers in mining know? Journal of Health, Safety and Environment, 29(1), 1–9.

Chi, C. F., Chang, T. C., & Ting, H. I. (2009). Accident patterns and prevention measures for fatal occupational falls in the construction industry. Applied Ergonomics, 36(4), 391–400.

Cohen, H. H., & Colligan, M. J. (1998). Assessing occupational safety and health training. Journal of Safety Research, 29(3), 121–143.

European Commission (1989). Directive 89/391/EEC – Framework Directive on Safety and Health at Work. https://osha.europa.eu

Fuller, R. (2005). Towards a theoretical understanding of risk compensation: Safety, danger, and behavior. Safety Science, 43(9), 703–722.

Geller, E. S. (2001). The psychology of safety handbook. CRC Press.

Hale, A. R., & Borys, D. (2013). Working to rule or working safely? Part 2. Safety Science, 55, 222–231.

Hale, A., & Borys, D. (2013). Working to rule or working safely? Part 2: The management of safety rules and procedures. Safety Science, 55, 222–231.

ISO (2018). ISO 45001: Occupational Health and Safety Management Systems – Requirements with Guidance for Use.

Lingard, H., Cooke, T., & Blismas, N. (2010). Do perceptions match reality? A comparison of employees' perceptions of the effectiveness of health and safety management systems. Construction Management and Economics, 28(4), 433–446.

MacIntyre, C. Raina, Seale, Holly, Dung, Tran Tinh, Hien, Nguyen Phuong, Nga, Pham Thi, Chughtai, Abrar Ahmad, Rahman, Baki Billah, Dwyer, Dominic ., & Wang, Quanyi. (2015). The efficacy of medical masks and respirators against respiratory virus transmission. *International Journal of Infectious Diseases*, *26*, 91–95. https://doi.org/10.1016/j.ijid.2014.12.027

Neal, A., & Griffin, M. A. (2006). A study of the lagged relationships among safety climate, safety motivation, and accidents at the individual and group level. Journal of Applied Psychology, 91(4), 946–953.

NIOSH (2015). Hierarchy of Controls. Centers for Disease Control and Prevention. https://www.cdc.gov/niosh/topics/hierarchy/default.html

Okorie, U., Emeka, O., & Ezeokafor, C. (2020). Personal protective equipment usage and its limitations in Nigerian industries. African Journal of Occupational Safety, 8(2), 45–56.

OSHA (2020). Lockout/Tagout Fact Sheet. https://www.osha.gov

Rasmussen, J. (1997). Risk management in a dynamic society: A modelling problem. Safety Science, 27(2–3), 183–213.

Reason, J. (1997). Managing the Risks of Organization. Argument Structure and Analytical Discussions, Ashgate Publishing.

Shikdar, A. A., & Sawaqed, N. M. (2004). Worker productivity, and occupational health and safety issues in selected industries. Computers & Industrial Engineering, 47(1), 173–189.

Velásquez, J. D., Benavides, J. I., & Rojas, L. E. (2021). Compliance with PPE use and occupational risks in small-scale industries. Safety and Health at Work, 12(3), 311–318.

Wulff, I. A., Brand, R., & Ernst, G. (2015). Engineering controls in the workplace: A systematic review. Journal of Occupational Health, 57(2), 151–160.

Zhao, J., Wang, Y., & Chen, X. (2020). Ergonomic risk assessment in the automotive industry. Human Factors and Ergonomics in Manufacturing, 30(3), 207–217.

Zhou, Q., Fang, D., & Wang, X. (2008). A method to identify strategies for the improvement of human safety behavior. Safety Science, 46(10), 1406–1420.