Rethinking the Effectiveness of Floor Markings, Machine Guards, and Safety Signage in Shaping Safer Work Environments.

Abstract

This study examines the effectiveness of workplace safety interventions through a qualitative embedded case study conducted in a high-volume manufacturing environment. Focusing on three key interventions: floor markings, machine guards, and safety signage, the research investigates how these measures influence not only hazard control but also worker behavior, perception, and decision-making. The case is situated within a bottling hall setting, where multiple operational risks, including pedestrian–vehicle interactions, machinery hazards, and chemical handling, are present. A key contribution of the study is the development of new internal standards for exclusion zone floor markings in the absence of existing organizational or national guidelines. These bespoke markings, including innovative pacemaker-specific warning zones, represent a novel approach to integrating inclusive and context-specific safety controls directly into the physical workspace. Data were collected through project documentation, visual evidence, structured observations, and implementation records, and analyzed using pattern matching and thematic analysis. The findings indicate that the combined implementation of physical and visual safety interventions produces a synergistic effect, enhancing spatial awareness, reducing risk exposure, and improving engagement with safety practices. Machine guards provided direct hazard control, while floor markings and signage influenced behavioral and situational awareness. Importantly, the study demonstrates that effectiveness is maximized when interventions are integrated and tailored to the operational context rather than applied as isolated compliance and safety measures. The research contributes to occupational safety and offers practical insights for designing adaptive, inclusive, and system-oriented safety management strategies.

Keywords: workplace safety, pacemakers, safety signage, floor marking, machine guards

1. Introduction

Safety at the workplace remains a highly important, but elusive target in contemporary industrial processes [1]. The risk of occupational incidents is high in high-risk manufacturing workplaces characterised by complex machines, high-speed production lines, handling of chemicals, and frequent contact between workers, vehicles, and equipment [2]. Regardless of the considerable improvements in regulatory frameworks, the introduction of international standards, and the extensive adoption of safety management systems, preventable accidents of minor slips, trips, and near-misses to severe machinery-related injuries and lost-time incidents continue to occur in global industries [3]. Such incidents still cause significant human damage, operational disruptions, and economic expenses, and there is still an apparent lack of alignment between official safety policies and real workplace performance [4].

Some of the most frequently implemented safety measures in this type of environment include floor markings, machine guards, and safety signs [5,6]. The controls hold significant places in the Hierarchy of Controls model, as they are engineering and administrative controls aimed at decreasing the exposure to hazard [7]. Floor markings are supposed to provide a visual layout of the work areas, establish safe pedestrian routes, and restrict areas where other people should not go to allow the machinery or vehicles to move [8]. Machine guards are physical barriers that are used to control access to dangerous moving components, and safety signage is used to convey important risk-related information, support operations, and impact the awareness and decision-making of workers [9]. Ideally, all these interventions would work towards orderly and safer working conditions. Practically, however, they are not so effective.

There is an accumulating body of evidence that the effects of floor markings, machine guards, and safety signage are very much dependent on contextual, human, and organisational influences and not necessarily their physical presence [10-12]. Likewise, wear and tear can cause floor markings to become less effective in directing behaviour over time, or habituation can lead to the ignoring of floor markings [13]. Machine guards, even with an engineering purpose, are often bypassed or poorly maintained when they become inconvenient to the production efficiency [14, 15]. Despite being ubiquitous, safety signage has often been criticised as being a cause of signage fatigue or information overload, whereby the workers are desensitized and unresponsive to the messages portrayed on them [16].

Moreover, academic studies have been inclined to consider these interventions separately, with minimal consideration of their interactive and cumulative impacts when done concurrently in the same work system [17-19]. The interaction between the visual signals (floor markings and signage) and the physical obstacles (machine guards) and the impact of this interaction on the cognition and spatial awareness of workers, perception of risks, and their daily decisions is underresearched. Such a gap is especially pronounced in mass production situations where the pressure to produce tends to override the consideration of safety.

This paper addressed these limitations by undertaking a qualitative single embedded case study in the Shield-hall of Diageo, a high-volume beverage production plant. The study critically analyzes the practical efficiency of floor markings, machine guards, and safety signage. One of the key and original aspects of this case is the design of floor markings of exclusion zones between production lines (especially Lines 3 and 4). Looking at the overall lack of internal Diageo standards and the absence of certain British standards that regulate the marking of exclusion zones in such manufacturing facilities, the researcher developed and applied new, specifically Diageo internal standards for these marks. As a practitioner-led innovation that could be adopted by the organisation across the board, this is a change in the direction of generic solutions to contextually-based, site-specific safety engineering.

This research explores not only the question of whether these interventions can decrease hazards at work, but how the design, implementation, contextual integration, and mutual reinforcement of these interventions influence worker behaviour and perception of risk and the safety culture in general by relying on project documentation, rich visual evidence (photographs of measures implemented), and observational data gathered during the project rollout. By so doing, the research aims at closing the gap in evidence-based safety management and provides practical and theoretical information on the circumstances under which floor markings, machine guards, and safety signage can truly make work environments safer and more resilient.

2. Literature Review

2.1 Theoretical Foundations of Safety Interventions in Occupational Settings

The floor markings, machine guards, and signage as safety interventions are traditionally based on a foundational framework within Occupational Health and Safety (OHS), which is the Hierarchy of Controls, which ranks hazard elimination and hazard substitution as the first two measures, then engineering and administrative controls [20]. In this hierarchy, machine guarding is often classified as an engineering control, but floor markings and signage are classified as an administrative or informational control [21]. This categorization implicitly presupposes that the higher-level controls are more effective since they minimize the effects of human behavior.

This deterministic interpretation is, however, being subject to growing criticism in modern scholarship. According to recent research, the success of safety interventions is not necessarily directly determined by their hierarchical positioning but is the result of a complex interaction of physical design, human cognition, and organizational context [14-16]. Socio-technical systems understand safety as an emergent property that is formed by the congruence or incongruence of technical systems and human actors. This is in opposition to the reductionist approach that the automatic application of controls will result in better safety outcomes.

Moreover, behavioral safety theories, such as risk perception and decision-making models, propose that workers are not passively responsive to safety interventions, and that they actively interpret, negotiate, and occasionally resist them [22, 23]. As an example, the schemes based on high levels of compliance of workers can be ineffective when the persons consider the risks to be low or when they put productivity over safety. Equally, even the well-designed interventions may be destroyed by the normalization of deviance, a phenomenon in which unsafe practices are accepted with time.

The other important dimension is associated with safety culture and climate [24]. The empirical data show consistently that the organizations that have a good safety culture, which is defined by leadership commitment, an open line of communication, and the involvement of workers, have a higher probability of achieving better safety outcomes, irrespective of the type of interventions that were used [25]. This implies that the same safety action can have varied results in different organizations, based on the cultural and managerial factors. As a result, the assessment of the effectiveness of safety interventions needs to shift towards the methods that are not technical but include organizational and behavioral aspects.

2.2 Effectiveness of Safety Signage: Beyond Visibility to Cognitive Processing

One of the most prevalent cost-effective interventions in hazard communication in the workplace is safety signage [26]. Signage, based on the communication theory and human factors engineering, is intended to deliver essential information regarding risks, actions that need to be taken, and behaviors that are not allowed [27]. Conventional research studies have paid much attention to maximizing visual attributes like color coding, symbols, and text readability to maximize visibility and understanding [28, 29].

Although these design aspects are significant, the emerging literature points out that visibility is not a sufficient element to guarantee the effectiveness [30, 31]. Cognitive processing is a key factor in the process of perception, interpretation, and behavior of safety signs by individuals. Research shows that there is a significant difference in the level of comprehension among workers, and this is determined by language proficiency, literacy, culture, and experience [32-34]. Consequently, standardized signage is not necessarily universal, especially in multilingual or diverse workforces.

Further, there has been an emergence of the concept of cognitive load in recent studies. Under conditions of saturation of visual stimuli, several signs, operational signals, and environmental distractions, the workers can be subjected to information overload, resulting in selective attention or total disregard of signage [35, 36]. This feature is commonly known as sign fatigue, and it defeats the very purpose of the safety communication systems. Empirical evidence indicates that too much or over-signage may actually lead to less compliance due to a loss of salience of important warnings [17]. The other significant limitation is the gap between awareness and behavior [31-33]. Although workers may know what safety signs mean, this does not in any way translate to safe practices [28]. The literature of behavioral economics and psychology identifies time pressure, normalization of risks, and perceived inconvenience as obstacles to compliance. As an example, employees can intentionally disregard warning indicators when they believe that following them will reduce the speed at which work gets done [23]. More recent studies of high impact also note the importance of organizational context in defining the effect of signage [32-36]. Maintenance (e.g., old or broken signs), placement (visibility in the workflow), and reinforcement (training and supervision) are significant factors. Signage effectiveness, therefore, must not be seen as an absolute property of design but as an ongoing process that is affected by the relations of individuals, environment, and organizational systems.

2.3 Machine Guarding as a Physical Safety Intervention: Evidence and Limitations

The concept of machine guarding has been generally accepted as a fundamental element of engineering control in industrial safety [37]. Guards are supposed to remove or significantly decrease the chance of direct contact injury by creating a physical barrier between workers and parts of the machine that are hazardous [38]. When compared to administrative controls, machine guarding is usually said to be more dependable since it is not based on constant human attention [39]. Research has indicated that well-placed and well-maintained guards can considerably reduce the cases of amputations, cuts, and entanglement injuries [28, 29]. Likewise, guarding compliance is a common focus on regulatory enforcement and safety audits as a key performance indicator [35].

Nevertheless, the literature also shows that there are a variety of practical issues that make this otherwise simple intervention more difficult. Deliberate circumvention of guards or their removal by employees is one of the most serious problems [37]. This is usually motivated by productivity needs, convenient access to service, or perceived inconvenience. In these situations, the presence of guards can give an illusion of safety, as there is a high possibility of exposure to risks [38]. Ineffectiveness is also compromised by maintenance and design constraints. The inadequacy of the design of guards can limit visibility, hinder work processes, or even prevent them from handling the variability in operations, hence workers resist them. Equally, poor maintenance may make guards useless, particularly in severe industrial conditions where wear and tear are usual [21]. Most importantly, a large portion of the current literature assesses machine guarding using safety-related measures like the rate of machines having guards compared to outcome measures like injury rate or behavior change. This is a very narrow focus that restricts the possibility of evaluating real-world effectiveness. Moreover, the interaction between machine guarding and other safety interventions, including signage or training programs, in influencing overall safety performance is also not well explored [15-18].

2.4 Floor Markings and Spatial Safety Cues: An Underexplored Domain

One of the primary, but little-studied elements of workplace safety systems is floor markings. These visual-spatial cues are meant to guide movement, outline the areas of hazards, and support safe behaviors in the physical environments [40]. Uses common include marking pedestrian crossings, separating vehicle paths, defining the storage areas, and defining restricted areas.

Although floor markings are used extensively, there is still a paucity of scholarly focus on this area of safety intervention, compared to other measures. The current literature tends to rely on transportation and urban planning studies, which have demonstrated that road markings can have an effect on the behavior of drivers and can decrease the number of accidents [41]. Although these results are very useful, they cannot be directly applied to the workplace environment, as the complexity of the environment, variability of tasks, and human behavior are different.

The phenomenon of habituation is one of the problems. With time, the workers can be desensitized to the visual cues that are not moving, and this reduces their ability to influence behavior [16-19]. This is particularly inconvenient in areas where markings are not regularly updated, or areas where they are less noticeable due to visual clutter causes them to be less visible. Moreover, the clarity and salience of markings may be greatly influenced by factors like lighting conditions, floor conditions (e.g., dirt, wear), and the spatial layout [5,7,15].

The other limitation is the absence of empirical research on the effect of floor markings on safety outcomes. The majority of available literature is based on anecdotal or observational findings, and little is conducted on the causal impact of these studies. This is especially significant in the light of the growing focus on evidence-based safety management.

Moreover, floor markings are usually introduced as independent interventions without their integration into a larger safety system [31]. This disjointed strategy fails to acknowledge possible synergies with other strategies, like physical barriers and signage [23]. As an example, clear signage can be used as a supplement to floor markings to reach greater understanding and safety, but poorly coordinated interventions may be confusing or unnecessary.

2.5 Toward an Integrated Understanding: Interaction Effects and System Complexity

The main shortcoming of the entire safety literature is the propensity to assess interventions separately, neglecting the fact that real-life workplaces are complex and interrelated. Practically, safety systems are combinations of various interventions working in parallel, which may have an effect of interaction that may be beneficial or detrimental to overall performance [12].

Systematically, the safe results are influenced by the dynamic interaction of the human behavior, physical controls (e.g., machine guards), visual cues (e.g., signage and floor markings), and organizational context [28,29]. An example of this is that the existence of machine guards can minimize the dependence on behavioral cues, whereas signage and floor markings require the concentration of the workers and the way they interpret. These interventions can strengthen one another when well coordinated, but can cause perplexing and conflicting messages or poor performance when poorly coordinated [14].

Recent developments in safety science recommend a move towards systems thinking, where it is important to realize how various aspects of safety systems change in relation to one another. The concepts of resilience engineering and adaptive safety point to the necessity to be flexible, learn, and get better at the continual management of complex risks [13, 16].

Although these theories have been developed, few empirical studies on the effect of interaction have been undertaken. In the majority of research, reductionist methods are still used, and specific intervention is considered in isolation without taking into account the effect of the combination of interventions. This weakness restricts the capacity to formulate the integrated safety measures that are reflective of the contemporary workplace realities.

3. Methodology

3.1 Research Design

The qualitative single embedded case study design [42] was used in this study to investigate the efficacy of floor markings, machine guards, and safety signage in creating safer work settings beyond regulatory standards. The single-case approach was selected due to the possibility to conduct a detailed, contextualised analysis of a modern real-life intervention in the framework of its organisational context in the environment where the lines between the phenomenon and the context are not clearly defined.

The general case refers to the HSE improvement project applied in the bottling hall and the surrounding locations (material store and mezzanine access stairs) of a large beverage production plant owned by Diageo. In this primary case, three embedded units of analysis were studied, namely: (1) exclusion zone floor markings (safe distances), (2) machine guards (slated Div-Inserter safety guard design and prototype), and (3) safety signage (QR codes to SDS access and visibility improvements).

The peculiarities of this case are that the process of development and implementation of the flooring marks in the exclusion areas in the production lines was carried out initially. There were no Diageo standards of marking the exclusion zone internally, and there are no British standards that are specifically applicable to this part of floor marking in such a place. The researcher therefore formulated new internal Diageo rules of marking exclusion zones, which will be incorporated into the organisation in the future. This aspect is addressed as one of the significant innovations in the case study, which makes it possible to analyze how custom, location-specific safety controls can be used to instigate changes that go beyond the traditional safety strategies.

The detailed analysis of each type of intervention was possible, but the embedded design still provided the holistic perception of the overall contribution that each type of intervention makes to the safety culture and behavioural change. Photographs of the measures installed, pre-and post-site conditions, prototypes, as well as the markings of the exclusion zone were all considered as part of the case evidence and were a rich source of contextual and illustrative data.

The inquiry was informed by a pragmatic orientation, which placed more emphasis on practical considerations based on the actual implementation than on generalisation in a purely theoretical manner. The project was conducted according to the natural order of the project, which was the first rollout (approximately January 2026), prototype approval, installation, training, and further compliance audits.

3.2 Case Setting

The case was located in the bottling hall and other supporting areas of the Diageo Shieldhall facility, which is a high-volume production setting with heavy machinery, chemical storage and use under COSHH regulations, forklift and pedestrian traffic, and routine operations. They are common manufacturing risk areas where the standard safety measures like floor markings, machine guards, and signs are widely used but often criticized as safety measures.

The interventions under investigation were:

- Designing new safety guard designs and prototypes of the Div-Inserter, as well as the safe distances and work instructions.
- Development and introduction of floor markings of exclusion areas between production lines (especially Line 3 and 4), organization of material store, and high-visibility tape. These indicators were developed without existing internal or British standards, a new work of the researcher.
- Implementation of improved safety signage, QR code to allow easy access to SDS, and visibility of walkways and stairs.

Other project activities included COSHH assessor training (finished 14th January 2026), reviews of risk assessment, updating of the Sevron substance list, and regular audits to check on compliance and effectiveness.

3.3 Data Collection

The case study data were gathered in a variety of sources to allow triangulation and create a holistic picture of the interventions in their real-world [42]. The main sources were project documentation and archival data, including revised risk assessments, work instructions, COSHH standards rollout documents, Sevron substance list updates, audit reports, meeting notes, and personal records of the researcher on the current status and the plan to be undertaken next. The visual evidence was at the centre of the project and it was comprised of photographs and images taken during the project including the installation of floor markings to identify areas of exclusion, the presence of safety guards, the placement of signage, the design of prototypes, and the identification of marked zones labelled as no-go zones; the images were also used as an evidentiary material as well as to assist in the analysis of the visibility, the usability

Moreover, field notes and structured observations of worker interactions with the new measures in normal operations and audit rounds with special attention to behavioural compliance, bypass, and workability of the exclusion zone markings and other controls were also observed to obtain the required data on the topic. Additional implementation records offer more information about training programs, prototype acceptance, quotes, installation schedules, and how the new internal exclusion zone marking standards were developed step-by-step. All the data were tabularised in a database of case studies, with the chain of evidence being clearly traced between raw materials and the results of analysis. Since the researcher was also closely part of the project, being the chief innovator, especially when it came to the design of the exclusion zone floor markings, reflexive notes were kept throughout the project to increase transparency and help to eliminate any bias.

3.4 Data Analysis

Data analysis used case study analytic strategies offered by [42], which are mainly based on pattern matching and explanation building.

To begin with, in-case analysis of each embedded unit (floor markings/exclusion zones, machine guards, and safety signage) was performed. Each was developed into descriptive narratives that are backed by the visual evidence of the project pictures and records of the official process of setting standards. Cross-unit comparison followed this to look at the interaction of the three interventions in the larger bottling hall environment and the role of the researcher-constructed internal standards of exclusion zones in behaviour change other than safety checklists.

Qualitative aspects (documents, observations, and reflexive notes) were thematically analyzed to determine recurring patterns as per the dimensions of effectiveness: regulatory compliance, actual behavioural modification, worker perceptions of usefulness, barriers to sustained use, and cultural embedding. Special focus was put on the innovation component -

the design of the new internal Diageo standards of marking the exclusion areas where none had existed before.

Interpretation was made by visual data analysis, by evaluating placement, visibility, durability, and real-world interaction, taken in the photographs, with particular attention being paid to the performance of the bespoke markings in the real world.

Competing hypotheses (e.g., training or awareness-only had improved, as opposed to the new physical controls and standards) were explicitly addressed, and they were directly matched with pattern matching with project timelines and audit results.

3.5 Rigour and Trustworthiness

The rigour and credibility of this individual embedded case study were therefore made possible by several strategies that had been put in place within the boundaries of case study research [42]. Triangulation was done through cross-checking various sources of data, such as project documentation, visual evidence through site photographs, structured observations, and implementation records. The lack of existing internal Diageo or British guidelines on the exclusion zone markings and the comprehensive process of creating the new internal standards gave enough contextual data to make transferability to similar high-volume manufacturing environments possible. There was a definite line of evidence that was followed, including the research questions, from the collection of data to the newly found results, which were well documented with the innovative input of the researcher to the floor marking standards.

Furthermore, reflexivity was exercised through being transparent about the dual role of the researcher as a member and a driver of innovations in the project team, especially when it came to designing and implementing the exclusion zone markings; reflexive notes were maintained to differentiate operational decisions and analytic interpretations and to avoid possible bias. Although the limitations inherent to a single-case design, including limited generalisability, are recognised, the amount of contextual information, visual data, and the innovation process described provide high chances of analytical generalisation and theory-making in the case of safety interventions that are not compliance-driven.

3.6 Ethical Considerations

The research was undertaken in the consent of organisational policies on data management and employee involvement. Everything was anonymised on a one-on-one basis, and results are provided in a summary fashion. Project images could only be used in the form of non-identifiable site and equipment images, with proper internal permission for the dissemination of such images in academia. The role of the researcher as the pioneer of the exclusion zone marking standards is clearly stated to ensure academic integrity. This embedded case study methodology offers a very strict, context-based study of the way that floor markings, machine guards, and safety signage work in practice, and the ingeniousness with which the researcher develops new, internal Diageo guidelines on the exclusion zone marking where none were previously available.

4. Results

4.1 Overview of the Case Interventions

This single embedded case study examined three interconnected safety interventions implemented in the bottling hall and associated areas of Diageo's Shieldhall facility as part of a broader HSE improvement project initiated in January 2026. The interventions comprised floor markings for exclusion zones and safe distances, upgraded machine guards, and enhanced safety signage. These measures were introduced to address key operational hazards, including pedestrian–forklift interactions, machinery access risks, and chemical handling under COSHH regulations.

4.1.1 Floor Markings and Exclusion Zones

A central innovation of this HSE project was the development of new internal Diageo standards for floor markings to delineate exclusion zones and safe distances, particularly between production Lines 3 and 4. In the absence of any pre-existing internal Diageo or British standards for such markings, the researcher designed and implemented high-visibility floor tape suitable for warehouse traffic. This included the incorporation of specialised warning tape targeted at pacemaker wearers (see Figure 1). The tape, featuring bold "WARNING" panels and "PACEMAKER WEARERS" text, serves to create clear visual barriers around equipment that may emit electromagnetic fields, thereby protecting workers with active implanted cardiac devices. These bespoke markings go beyond generic spatial organisation by integrating specific health-risk communication directly into the floor environment, enhancing both visibility and inclusivity of the safety controls.

Figure 1. Pacemaker warning tape

4.1.2 Machine Guards

The project included the design, testing, and implementation of an improved safety guard for the Div-Inserter and associated packaging machinery. As shown in Figure 2, a transparent polycarbonate guard was installed on the Bortolin Kemo machine to enclose hazardous moving parts while allowing clear visibility of the packaging process. This engineering control was subjected to testing and validation following prototype approval. The guard incorporates safe distances, interlocks, and ergonomic access features, supported by newly developed work instructions and a reviewed risk assessment. Full guard replacement across all relevant lines remains a key next step in the project plan, aimed at consistently elevating the level of physical protection beyond minimum compliance requirements.

Figure 2. Div-Inserter and associated packaging machinery

4.1.3 Safety Signage

Figure 3 shows a prohibition safety sign affixed to industrial machinery (near electrical or magnetic components, given the visible wiring and stainless-steel housing). Enhanced safety signage was rolled out across the bottling hall, including QR codes for easy access to Safety Data Sheets (SDS), COSHH-related warning signs, and specialised prohibition signs. A notable example is the installation of ISO 7010-compliant signage warning against access for people with active implanted cardiac devices (see Figure 3). This measure addresses potential electromagnetic interference from machinery, reflecting a proactive approach to accommodating diverse worker health profiles beyond standard regulatory requirements.

Figure 3. Safety Signage

4.2 Implementation Process and Challenges

The safety guard intervention followed a structured Plan-Do-Check-Act (PDCA) cycle to ensure systematic development and implementation, as illustrated in Figure 4. In the Plan phase, the project team reviewed the existing safety guard design, conducted a baseline study, defined clear objectives, completed a PUWER review, and scheduled a kick-off meeting. The

Do phase involved Management of Change (MOC) procedures, Equipment Owner Manufacturer (EOM) meetings for modification approval, prototype redesign and testing, and implementation during scheduled production downtime. The new safety guard design was formally established and the prototype was approved following this rigorous process. Subsequent Check and Act phases focused on performance validation, PUWER compliance verification, operator feedback collection, standardisation of the design, updating of Standard Operating Procedures (SOPs) and training materials, and planning of follow-up audits.

Several operational challenges were encountered during implementation. Coordinating modifications with ongoing high-volume production schedules proved difficult, requiring careful alignment of changes with planned downtime windows to minimise disruption to bottling line output. Securing timely approvals through the Management of Change process and Equipment Owner Manufacturer (EOM) meetings involved multiple stakeholders, which occasionally extended timelines. Additionally, ensuring the new guard design balanced enhanced safety with operational efficiency particularly maintaining ease of access for routine maintenance and cleaning required iterative prototype adjustments. Resource constraints, including availability of suitable materials and contractor coordination for full guard replacement across lines, further added complexity. The iterative PDCA approach was instrumental in systematically identifying and mitigating these challenges, ultimately ensuring that the implemented controls met both safety standards and practical production requirements.

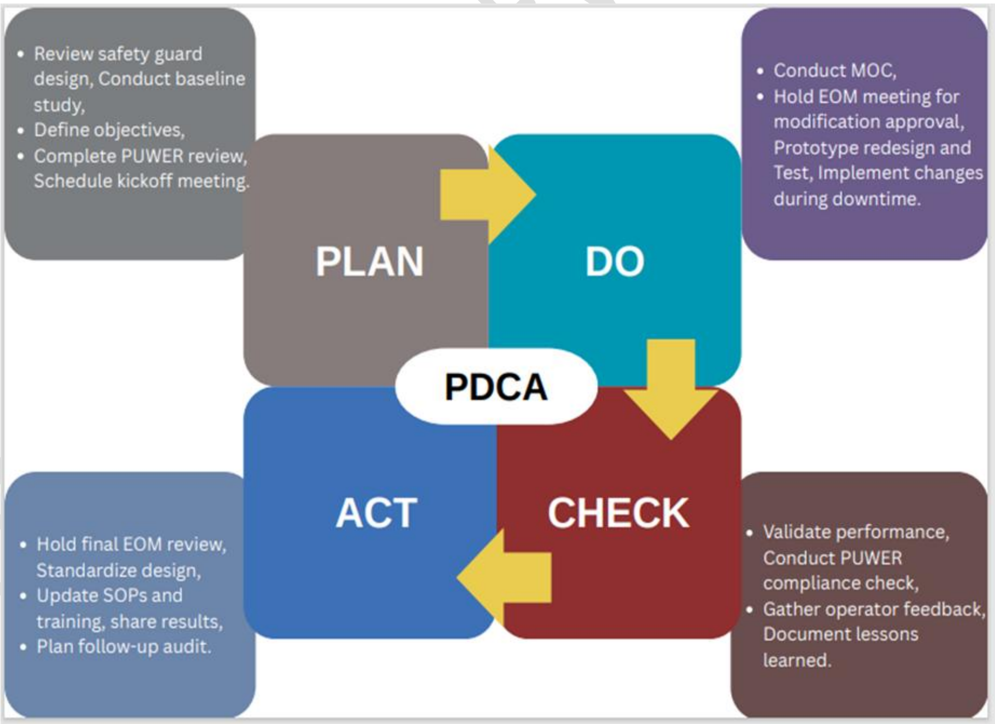

Figure 4. Plan-Do-Check-Act (PDCA) cycle

4.3 Bottling Hall Waste Management

As part of the broader HSE improvement initiative, significant attention was given to streamlining waste management practices in the bottling hall. Prior to the intervention, chemical waste and packaging waste were stored in metal cages in a largely unsorted and overcrowded manner. Figure 5 shows a typical chemical waste cage containing mixed plastic containers and jerry cans with residual liquids, lacking clear segregation or consistent labelling. Similarly, Figure 6 depicts a cardboard waste cage filled with unsorted packaging materials, flattened boxes, and debris. These conditions contributed to increased safety risks, poor housekeeping, and potential compliance gaps with waste regulations. The project achieved Phase 1 completion by designating a site-wide waste area and focusing on identifying waste types with clear signages for better visibility. The implementation of standardised COSHH cabinets (see Figure 4) and enhanced visual management directly supported improved waste segregation. These changes represent an important step toward more organised, safer, and environmentally responsible waste handling practices beyond basic compliance.

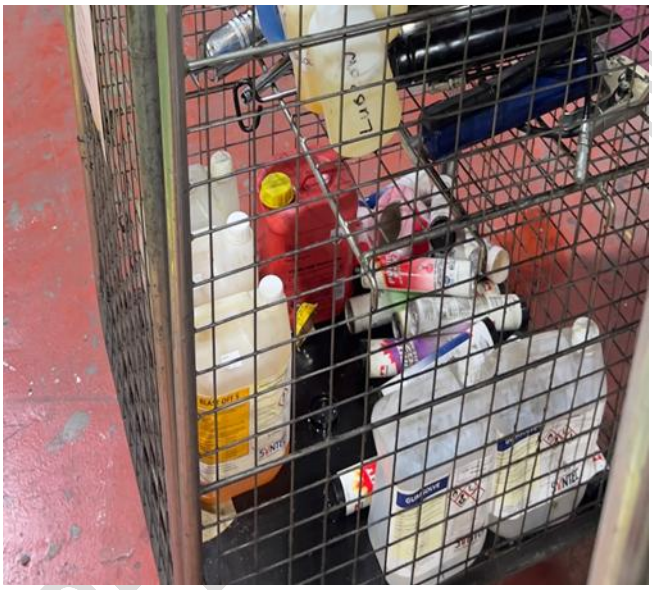

Figure 5. chemical waste cage

Figure 6. Cardboard waste cage

Figure 7 shows a metal grated staircase with bright yellow painted edges and side stringers leading up to a landing area. The yellow high-visibility paint is applied consistently along the nosings (front edges) of each step and along the vertical sides of the staircase structure. Metal handrails are visible on both sides. This photograph depicts the improved visibility treatment applied to stairs in the bottling hall and EBS (Engineered Building Services) area following identification of poor landing visibility that had contributed to a recent first-aid incident. The bright yellow contrasting paint enhances edge definition and depth perception, particularly in areas with potentially low or variable lighting, thereby reducing the risk of missteps or falls.

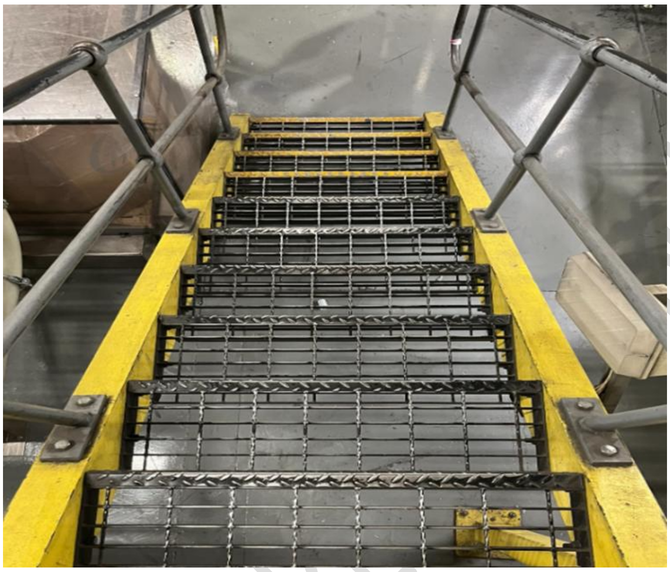

Figure 7. Improved visibility treatment applied to stairs in the bottling hall and Engineered Building Services area

4.5 Observed Outcomes and Effectiveness Indicators

The assessment of the applied safety interventions floor markings, machine guards and improved safety signs showed that there were a variety of visible changes in operational safety, worker behavior and in risk management in the bottling hall in general. Though the interventions are still relatively new and long-term quantitative accident data is not available yet, the combination of qualitative observations, process indicators, safety checks, and operator feedback offers a very solid foundation of the effectiveness evaluation. Significantly, the results do not only indicate the individual contributions of each intervention, but also the summative and reinforcing effects of them in a complex production environment.

4.5.1 Spatial Awareness and Movement Control

Among the most immediate and obvious effects of the interventions was the significant enhancement of the spatial awareness and the movement control throughout the bottling hall. The implementation of easily recognizable floor markings and exclusion zones helped to considerably decrease the level of ambiguity in high-stakes zones, especially the ones where pedestrian traffic collides with the work of forklifts. It was noted that workers tend to move in specific directions more regularly, and less often move disorderly or enter dangerous areas.

The grid-like pattern formed as a result of the markings seemed to act as a visual roadmap, which could easily control the actions of the workers without any active intervention. This is in line with the concept that environmental design can be used to push safer behaviors through the provision of safety cues within the workspace [43]. In addition, the introduction of special signs like pacemaker warning areas increased the scope of the floor markings to the specific risk communication, in addition to the spatial organization. These signs, in addition to raising awareness among vulnerable people, also indicated a wider organizational dedication to inclusive safety measures.

It was also noted however that the effectiveness of these markings would probably rely on the sustained visibility and periodic reinforcement. Wear and tears can lead to the loss of clarity in high-traffic locations with time, and therefore, their behavioral effect might diminish unless there is proper maintenance [38].

Moreover, the application of better machine guarding provided significant gains in direct reduction of hazards. The polycarbonate guards installed successfully surrounded moving components of the Div-Inserter and related equipment and reduced the chances of accidental contact whilst maintaining a view of activity. This safety and usability strike is paramount because over-constricting designs tend to cause non-adherence to or workarounds [35].

According to operators, the perceived risk exposure decreased since operators said they felt more confident when operating near guarded equipment. It is a significant indicator because this perception can affect levels of stress and safe practices [44]. Also, interlocks and ergonomic access features were integrated in such a way that less manual intervention was required in the operation and maintenance processes, which minimized the chances of unsafe behavior.

Although these results were positive, scalability and consistency were also emphasized during the intervention. The entire implementation of all production lines was not done at the moment of observation, which means that the overall efficiency of the intervention will be determined by the standardization of the intervention and its consistent use. Additionally, constant checking will be required so as to prevent bypass and alteration of guards due to pressure during production.

4.5.3 Accessibility and Utilization of Safety Information

The accessibility and usability of the safety information were greatly improved due to the increase in safety signage, especially the incorporation of QR codes that are connected to the Safety Data Sheets (SDS) [45]. The workers could find the relevant chemical handling guidelines in a fast and convenient manner which is a change of passive to more interactive safety communication.

This intervention seemed to make workers more engaged with safety information, with a higher probability to access digital resources when in need instead of using the memory or fixed documentation. Understanding was also enhanced through the use of standardized symbols and explicit visual cues, particularly when there was a diverse workforce, where there could be language barriers [46]. However, signage effectiveness is still conditional upon a number of contextual conditions. Although preliminary results suggest greater attention and attendance, the possibility of decreased engagement as time goes on is also present because of familiarity or information overload. This implies that the signage systems must be reviewed and revised periodically to ensure they remain relevant and effective [24].

4.5.4 Housekeeping and Waste Management Practices

The appearance of standardized COSHH cabinets and the naming of particular waste management zones resulted in the emergence of major changes in the housekeeping procedures. Poor segregation, irregular labeling, and crowded storage were the features of waste handling before the intervention. After implementation, it was observed that the system was more structured and organized, with the identification of substances being clearer and complying better with storage requirements.

The visual management system that used labels, hazard symbols, and QR codes increased the usability and accountability [47]. Employees could find the right places of storage and handling processes, and this minimized the chances of errors and hazardous activities. Also, the better structure led to a cleaner and more organized work environment, which is commonly linked to the minimization of accidents and an increase in efficiency.

Although such advances would be a big advance, their effectiveness in the long term will rely on regular enforcement, frequent audits, and training. In the absence of these supporting measures, there is a probability of going back to previous practices.

4.5.5 Visibility-Related Risks

The use of high-visibility paint on stair edges and structural features was a response to a safety deficiency identified in the past in regard to bad visibility. This comparably straightforward intervention resulted in short-term and observable advantages, such as the improvement of depth perception and edge recognition, especially in locations with unfavorable light sources [18]. Employees noted that they felt much safer and more comfortable when using staircases, and no cases of nearly missing any steps were seen during the assessment period. It implies that even cheap visual improvements can leave a significant impact on the safety results in case they are properly aimed. Nonetheless, like the floor markings, the effectiveness of such visual cues will be highly dependent on their longevity and sustainability in their usage. Their long-term performance can be affected by environmental factors, i.e., wear, dirt, and changes in lighting.[48].

4.5.6 Behavioral and Cultural Indicators of Safety Improvement

The interventions led to a noticeable change in the safety behavior and awareness, in addition to the physical and procedural changes. Employees were more compliant with specific zones, more often involved with safety signs, and more adherent to new procedures. Such shifts in behavior indicate that the interventions not only minimize hazards but also affect the attitudes and behaviors of workers towards risks [39].

Notably, the prominence of the interventions seemed to strengthen the dedication of the management to safety, which is a primary source of favorable safety culture. Workers, when they see actual investments in safety, may improve trust and promote proactive involvement in the safety practices. Simultaneously, certain cases of initial resistance and adaptation difficulties were observed, such as confusion with new layouts and the tendency to leave specific directions. These reactions are normal during the initial phases of change and emphasize the significance of continuous communication, training, and reinforcement to achieve long-term implementation

4.5.7 Integrated Effectiveness and System-Level Impact

One of the insights gained during the observed outcomes is the fact that the effectiveness of interventions was not only additive but synergistic. Although machine guards offered direct physical protection, floor markings and signage had an influence on behavior and awareness to form a multi-layered safety system. This integration covered both physical and cognitive aspects of risk and hence a more holistic approach toward hazard management. The results indicate that the most immediate and sure reduction in risk was with engineering controls (machine guards). The visual interventions (floor markings and signage) were significant in terms of behavior direction and awareness of the situation [49]. Combined action increased total effectiveness by augmenting safety messages through various channels. This system-level view emphasizes the need to develop safety interventions as interrelated units and not as isolated interventions

5. Discussion

One key characteristic of this case study is that practitioner-led innovation plays a central role in shaping safety outcomes. The fact that the researcher was directly engaged in gap identification, solution development, and implementation of new standards also facilitated a degree of responsiveness and sensitivity to the context that is usually lacking in top-down regulation methods. A prominent example of this innovation is the development of new internal Diageo exclusion zone marking standards. Without any official rules or directives, the practitioner-researcher created a system of high-visibility markings that rearranged space, as well as providing a better channel of communication of risk. This shows how practitioners can be knowledge creators, thereby contributing to the development of safety practices as opposed to using existing frameworks.

The pacemaker-focused intervention further supports this. In identifying a risk that has been hitherto not tackled with enough seriousness, electromagnetic exposure to workers with implanted cardiac devices, the study opens a new dimension of safety consideration that includes occupational safety and personal health statuses. This broadens the concept of the conventional boundaries of workplace safety, and it gets closer to the individualized and encompassing risk management strategies.

Theoretically, these results can be used to underpin the increasing importance of bottom-up innovation and reflexive practice in safety management [25]. The development of practical and effective solutions was achieved through the use of iterative approaches like the PDCA cycle, as well as constant observation and adaptation [50]. Nevertheless, to be more generalized, such innovations should be formalized, validated, and incorporated into organizational standards.

Among the most important findings of the present study is the evidence of the interactive and synergistic nature of the effects of numerous safety interventions. In line with arguments against the Hierarchy of Controls, the results indicate that effectiveness is not predetermined by the degree of control but the interactions of interventions within a system [9]. Machine guards were used in this scenario to offer direct physical protection whereas floor markings and signage influenced worker behaviours and awareness. The new exclusion zone signs were especially significant in organizing the movement and strengthening the space, which is equivalent to closing the gap between the physical and mental safety controls. The introduction of pacemaker-specific markings brings another level to this game, introducing the health-specific risk communication into the framework of the safety system. This indicates the potential to combine various forms of interventions physical, visual and informational to deal with multiple layers of risk at the same time. Nevertheless, the results also show that such integration is effective provided that it is carefully designed and coordinated. Redundant or repeated visual stimuli can cause cognitive overload or habituation, making them less effective with time [33]. Thus, the optimal interaction is the result of the balance between visibility, clarity, and usability.

5.4 Theoretical and Practical Implications

The proposed study is a significant addition to the emerging discussion of Occupational Health and Safety in that compliance with regulatory measures alone does not dictate the effectiveness of those measures, but rather their capacity to provide impetus to actual behavior, perception, and decision-making. The results show that operational risks can be handled through context-specific, practitioner-led innovations like designing new exclusion zone marking standards, which can better handle operational risks than generic compliance-based solutions. Specifically, the development of pacemaker-specific warning signs expands the safety beyond the conventional hazard control and provides a more comprehensive and people-centered approach that takes into consideration the various vulnerabilities of workers.

With respect to the Hierarchy of Controls, the research has valuable practical implications as it demonstrates that the success of controls in practice is not only related to their hierarchical location but also to their combination and interaction. Although engineering solutions (like machine guards) provide a direct and trustworthy way to reduce the risk, their effectiveness is boosted when they are combined with carefully planned visual and administrative controls, such as markings on floors and safety signs [45]. This implies that the hierarchy should not be utilized in a strict and linear fashion, but instead the organization should use a more flexible and systems-oriented approach that focuses on the complementary effect that various interventions have on the development of physical safety and worker behavior [16].

Practically speaking, the results provide explicit suggestions to Diageo and other high-volume manufacturing facilities. The new standards of the exclusion zone marks need to be formalized, standardized, and scaled in all the areas of operation to be consistent and sustainable. Besides, organizations are encouraged to think about adopting a more integrated approach to safety design, in which physical controls, visual cues, and informational systems are synchronized to support one another [43]. This is because to ensure that these interventions are effective in the long-term, regular monitoring, maintenance, and periodic updating of the interventions are necessary. In addition, a more comprehensive approach should be promoted to make the workplace safer than required by introducing inclusive safety practices like health-targeted warnings to vulnerable populations of workers [51]. In sum, all these implications imply the significance of innovation, integration, and contextual adaptation in the development of contemporary safety management practices.

5.5 Limitations and Future Research Direction

In spite of providing useful information, this research is limited in a number of ways that are worth mentioning. In the first place, the single embedded case study design restricts the extrapolation of the results to other organisational and operational settings. Although the depth of analysis can be very insightful in its analysis, the findings cannot be necessarily applicable in other industries or contexts unless they are contextually adjusted. Second, the effectiveness assessment relied more on the qualitative observations, process indicators and short-term outcomes than on a longitudinal quantitative measurement like incident rates or near-miss statistics. Consequently, the sustainability and effectiveness of the interventions in the long run is yet to be empirically tested. Third, a dual role of the researcher as a practitioner and investigator also raises the risk of biasing, but it was managed by triangulation and reflexivity, as well as detailed recording of the research process.

These limitations should be addressed in future research through use of multi-case or comparative study designs in various industrial settings to improve on the generalisability. Longitudinal research that included quantitative safety performance indicators would have a better representation of causal relationships between interventions and safety outcomes. Also, more studies are required to investigate the scalability and flexibility of the new exclusion zone marking standards, especially in different operational settings. The interaction effect of various safety interventions, particularly, cognitive and behavioral implication of joint, visual and physical controls also need further exploration. Lastly, the fact that vulnerable groups of workers (e.g., people with medical devices e.g. pacemakers) are included creates a new research opportunity in the area of inclusive and personalized safety interventions in the contemporary workplaces.

6. Conclusion

This research shows that workplace safety interventions can be more effective than those that are designed contextually, behaviorally, and integrated systemically. The study used a qualitative embedded case study, which was carried out on a high-volume manufacturing facility, to investigate the interplay between floor markings, machine guards, and safety signage and its effect on operational safety and worker behavior. The results indicate that the intervention of individuals is effective in the reduction of risks but when they are combined the effect is synergistic and increases cognitive awareness along with physical protection. One of the main contributions of the study is that the new standards of internal exclusion zone marking were developed since no guidelines exist, and practitioner-led innovation is very crucial in counteracting the context-specific risks. The addition of the pacemaker-specific warning signs to occupational safety also broadens the field of occupational safety because it adds inclusive and health-sensitive approaches to the workplace design. These inventions can show how safety interventions can be changed to no longer be a passive compliance tool but a dynamic system that can be used to create safer workplaces.

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