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Research Article

The role of human resource management in implementing 'prevention through design' (PtD) strategies to enhance occupational health and safety in the construction industry: A thematic analysis approach

İnşaat sektöründe iş sağlığı ve güvenliğini artırmak için 'tasarım yoluyla önleme' (PtD) stratejilerinin uygulanmasında insan kaynakları yönetiminin rolü: Tematik analiz yaklaşımı

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Abstract

Occupational health and safety (OHS) in the construction industry remains a critical challenge, with high rates of workplace accidents and injuries. Prevention through Design (PtD) offers a proactive approach to mitigating risks by integrating safety considerations at the design phase. However, the role of human resource management (HRM) in facilitating PtD remains underexplored. This study addresses this gap by investigating how HR professionals contribute to the implementation of PtD through strategic planning, training, and cross-functional collaboration. Using a qualitative research design, data were collected from 12 industry experts, including HR managers, safety officers, engineers, and site supervisors. Thematic analysis was conducted using NVivo software, identifying six key themes: HR Involvement in PtD, Training and Competency Development, Cross-Functional Collaboration, Cultural and Organisational Barriers, Safety Culture Impact, and Measuring PtD Effectiveness. The findings reveal that early HR engagement in design planning enhances workforce readiness, training specificity, and the integration of safety culture. Despite these benefits, organisational resistance, hierarchical silos, and the lack of structured evaluation metrics hinder the full adoption of PtD. This study is novel in its focus on HR's strategic role in PtD, offering insights for construction firms, policymakers, and regulatory bodies. The research highlights the need for HR-driven PtD frameworks, improved collaboration mechanisms, and standardised safety assessment models. Future studies should explore longitudinal impacts of HR-led PtD strategies and the role of digital tools such as BIM and VR in safety training. The study contributes to both academia and industry by emphasising the transformational role of HR in designing safer construction environments.

Keywords: Prevention through Design (PtD); Building Information Modelling (BIM); Virtual Reality (VR); Human Resource Management (HRM); Construction Safety

Jel Codes: J28, L74, M12, M53, O33

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Öz

İnşaat sektöründe iş sağlığı ve güvenliği (İSG), iş kazaları ve yaralanma oranlarının yüksekliği nedeniyle kritik bir sorun olmaya devam etmektedir. Tasarım Yoluyla Önleme (Prevention through Design - PtD) yaklaşımı, riskleri azaltmak için güvenlik önlemlerinin tasarım aşamasında entegre edilmesini sağlayarak proaktif bir çözüm sunmaktadır. Ancak, İnsan Kaynakları Yönetimi'nin (İKY) PtD süreçlerini kolaylaştırmadaki rolü literatürde yeterince araştırılmamıştır. Bu çalışma, İKY profesyonellerinin stratejik planlama, eğitim ve disiplinler arası iş birliği yoluyla PtD uygulamalarına nasıl katkı sağladığını inceleyerek bu boşluğu doldurmayı amaçlamaktadır. Çalışmada nitel araştırma tasarımı kullanılmış ve insan kaynakları yöneticileri, iş güvenliği uzmanları, mühendisler ve saha süpervizörlerinden oluşan 12 sektör uzmanından veri toplanmıştır. Veriler, NVivo yazılımı kullanılarak yapılan tematik analizle değerlendirilmiş ve altı ana tema belirlenmiştir: PtD'de İKY Katılımı, Eğitim ve Yetkinlik Geliştirme, Disiplinler Arası İş Birliği, Kültürel ve Kurumsal Engeller, Güvenlik Kültürüne Etki ve PtD Etkinliğinin Ölçülmesi. Bulgular, İKY'nin tasarım planlamasına erken aşamada katılımının iş gücü hazırlığını, eğitimlerin özgünlüğünü ve güvenlik kültürünün entegrasyonunu önemli ölçüde artırdığını göstermektedir. Ancak bu olumlu etkilerin yanı sıra, örgütsel direnç, hiyerarşik bölünmeler ve yapılandırılmış değerlendirme metriklerinin eksikliği, PtD'nin tam anlamıyla benimsenmesini engellemektedir. Bu çalışma, PtD'de İKY'nin stratejik rolüne odaklanması açısından yenilikçi bir yaklaşım sunmakta ve inşaat firmaları, politika yapıcılar ve düzenleyici kurumlar için önemli içgörüler sağlamaktadır. Araştırma, İKY liderliğinde PtD çerçevelerinin geliştirilmesi, iş birliği mekanizmalarının güçlendirilmesi ve standart güvenlik değerlendirme modellerinin oluşturulması gerekliliğini vurgulamaktadır. Gelecekte yapılacak çalışmaların, İKY destekli PtD stratejilerinin uzun vadeli etkilerini ve BIM, VR gibi dijital araçların güvenlik eğitimindeki rolünü araştırması önerilmektedir. Bu çalışma hem akademiye hem de sektöre, İKY'nin daha güvenli inşaat ortamlarının tasarlanmasındaki dönüştürücü rolünü vurgulayarak katkı sağlamaktadır.

Anahtar Kelimeler: Tasarım Yoluyla Önleme (TYÖ); Yapı Bilgi Modellemesi (BIM); Sanal Gerçeklik (VR); İnsan Kaynakları Yönetimi (İKY); İnşaatta İş Sağlığı ve Güvenliği (İSG)

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Introduction

The construction industry remains one of the most hazardous sectors worldwide, consistently recording high rates of occupational injuries, illnesses, and fatalities due to the complex, labour-intensive, and often unpredictable nature of construction work. Workers are frequently exposed to falls from height, machinery accidents, ergonomic strain, and environmental hazards, all of which highlight the urgent need for effective occupational health and safety (OHS) strategies (Segbenya & Yeboah, 2022; Trillo-Cabello, Carrillo-Castrillo & Rubio-Romero, 2021). In response to these persistent risks, the concept of *Prevention through Design* (PtD) has gained momentum as a proactive and systemic strategy. PtD involves the deliberate consideration and elimination of hazards during the design phase of construction projects, thereby reducing the potential for accidents before work begins on-site (Farghaly, Collinge, Mosleh, Manu & Cheung, 2022). By embedding safety into the earliest stages of planning and design, PtD shifts the paradigm from reactive safety management to proactive risk mitigation. Recent studies have emphasised that PtD can significantly improve safety performance, minimise lifecycle costs, and contribute to sustainable construction practices (Khalil, Samsudin & Zainonabidin, 2022; Mohandes & Zhang, 2021).

While considerable attention has been devoted to the technical and regulatory aspects of PtD, the role of human resource management (HRM) in supporting and institutionalising this approach remains underexplored. HRM functions such as recruitment, training, performance evaluation, and policy development are crucial to cultivating a safety culture that supports PtD implementation. Organisations that align HR strategies with safety objectives—through tailored training programs, interdisciplinary collaboration, and employee engagement—are more likely to achieve long-term safety improvements (Melhem, Ateeq, Alzoraiki & Beshr, 2024; Saks, 2022). HR professionals are well-positioned to facilitate cross-functional dialogue between design teams and operational staff, ensure continuous professional development on safety standards, and promote organisational values that prioritise worker well-being. Studies by Chan and Mak (2012) and Lai, Liu, and Ling (2011) have shown that high-performance HR practices are strongly correlated with improved OHS outcomes, particularly when safety is embedded as a performance metric and leadership competency is emphasised.

Despite this potential, there is a noticeable gap in the literature concerning how HRM strategies influence the actual adoption and implementation of PtD in construction projects. While studies have addressed the general contributions of HR to workplace safety, few have directly examined how HR-specific policies, cultural interventions, or training initiatives support the proactive integration of PtD (Obeidat, Sarhan & Qasim, 2023; Park, 2018). Moreover, current research often overlooks the qualitative, context-dependent insights that can be derived from practitioners involved in real-world PtD applications. The absence of empirical, qualitative research capturing the perspectives of HR professionals, safety officers, and design teams leaves unanswered questions about the challenges, enablers, and best practices in HR-led PtD integration.

The motivation for this study stems from both academic and practical needs. Academically, the study addresses a clear gap by investigating the strategic alignment of HRM practices with PtD principles—an area that has not been sufficiently theorised or empirically tested. From a practical standpoint, construction companies are under increasing pressure to reduce workplace accidents, comply with evolving safety regulations, and adopt sustainable project delivery practices. Understanding how HRM can actively contribute to PtD not only supports organisational safety goals but also empowers HR professionals to take a more integrated and strategic role in construction project planning. The study also aims to guide industry leaders in designing HR policies that facilitate the long-term institutionalisation of PtD, thereby enhancing both safety outcomes and organisational performance.

This study, therefore, aims to examine how HRM contributes to the implementation of PtD strategies in the construction industry, using a thematic analysis approach. The research seeks to (1) identify key HRM strategies that facilitate PtD adoption, (2) explore the challenges faced by HR professionals in integrating PtD in construction projects, (3) examine how HR-driven PtD policies impact worker safety culture and engagement, and (4) analyse emerging themes from HR and OHS professionals' perspectives on PtD using NVivo software. In doing so, the study will respond to the need for a more holistic and practice-oriented understanding of the HR-PtD relationship. The research is guided by four core questions: What are the HRM strategies for integrating PtD in construction projects? What are the barriers and challenges in HR-led PtD implementation? How do training programs and HR policies impact worker compliance with PtD principles? And what are the emerging best practices in HR-driven PtD strategies for improving safety? Through the application of qualitative inquiry and thematic analysis, this study aims to generate new insights that bridge the fields of human resource management

and construction safety, thereby contributing to both academic knowledge and the development of practical, actionable safety interventions in high-risk work environments.

Literature review

Occupational health and safety in construction

Occupational health and safety (OHS) has long been recognised as a critical pillar in the construction industry, which remains one of the most hazardous sectors globally due to rapidly changing work environments, complex operations, the use of heavy machinery, and fragmented subcontracting. This risk picture is mirrored in Türkiye, where sectoral analyses using Social Security Institution (SGK) data and national case reviews document persistent accident burdens in construction, highlighting the salience of falls, equipment interfaces, and site organisation as recurrent precursors (Gözüak & Ceylan, 2021; Çüçen & Kurtoğlu, 2024). Framing OHS as a performance lever rather than a compliance burden is therefore essential: evidence from Ghana shows that structured training, open hazard communication, and participatory safety planning are associated with fewer accidents and higher satisfaction and productivity (Segbenya & Yeboah, 2022), a dynamic that resonates with Turkish studies linking safety culture and site practice to safer behaviours (Ayduran & Olcay, 2022; Öngel, 2022).

Risk perception shapes how safety is implemented and enforced. Safety experts' judgments vary based on their experience, education, organisational culture, and project phase, and misalignments between management and frontline views can undermine strategy (Trillo-Cabello et al., 2021). Turkish evidence reinforces this: workers' perspectives point to gaps between formal rules and practical realities on site (Öngel, 2022), while research on safety culture shows that stronger culture levels correlate with safer behaviours, indicating that perceptions are not merely attitudes but actionable predictors of performance (Ayduran & Olcay, 2022). Converting perception into practice also depends on field oversight and equipment conformity; site surveillance and work-equipment controls in the Turkish building sector are emphasised as necessary complements to training and policy, especially where rapid task turnover elevates exposure (Aydoğan & Uçan, 2022).

Institutionalising OHS through management systems further supports sustainable construction practices. A comprehensive synthesis reveals that OHS management systems (OHSMS) reduce accidents, enhance compliance, and improve retention when integrated into the culture and supported by leadership (Kineber, Antwi-Afari, Elghaish, Zamil, Alhusban & Qaralleh, 2023). In the Turkish context, SGK-based statistical analyses provide a baseline for prioritising hazards and evaluating OHSMS performance over time (Çüçen & Kurtoğlu, 2024), while validated instruments for measuring OHS culture offer practical diagnostics for continuous improvement (Olcay, 2021). Together, these tools enable data-driven decision-making—identifying hazards, assessing risks, and monitoring performance—provided they are adequately resourced and applied routinely.

Practical training remains the mechanism that translates policy into day-to-day practice. Transfer of training is highest when content is role-specific, perceived as relevant, and reinforced by supervisors (Pham, Lingard, & Zhang, 2023); conversely, generic or decontextualised modules are often ignored. Turkish studies complement this with modality-level insights: different training methods (e.g., interactive demonstrations, on-the-job coaching) have distinct impacts on behaviour, underscoring the need to tailor delivery to task and learner profiles (Bayrak, Karan, Karakaş, Uçan, Bingöl & Karahan, 2021). Aligning curriculum with site surveillance findings closes the loop between identified risks and the capabilities workers actually build (Aydoğan & Uçan, 2022).

As sustainability imperatives reshape methods, OHS strategies must adapt. A holistic risk-assessment model that integrates environmental and social indicators helps align safety with ESG goals (Mohandes & Zhang, 2021). Research on modular integrated construction (MiC) reveals that crane operations pose unique coordination and space-constraint risks, necessitating tailored protocols and competency-based training (Mohandes, Abdelmageed, Hem, Yoo, Abhayajeewa & Zayed, 2022). In practice, these insights dovetail with Turkish field guidance on equipment and access management, reinforcing the importance of method-specific controls and verified competence (Aydoğan & Uçan, 2022).

Data analytics and digital technologies are expanding the toolkit for prevention and learning. Decision-tree analyses reveal that age, education, and context condition the effectiveness with which workers absorb OHS training, suggesting the need for differentiated pedagogy (Cao, Chen, & Cao, 2021). Vision-based and AI systems enhance hazard detection and compliance auditing in real time, even as privacy, accuracy in complex scenes, and acceptance remain active challenges (Zhang, Shi, & Yang, 2020). Turkish contributions map directly onto this digital turn: IoT applications—such as wearables, sensorized equipment, and real-time analytics—are increasingly interfacing with OHS to anticipate

non-compliance and target interventions, offering a complementary, data-driven layer to training and supervision (Erol & Eraslan, 2024).

Finally, sector-wide reviews chart the move toward integrated, predictive safety systems that leverage BIM and IoT to identify risks preemptively (Sánchez, Peláez & Alís 2017). However, they also warn that many firms—especially in developing contexts—retain reactive and inconsistent approaches (Jaafar, Arifin, Aiyub, Razman, Ishak & Samsurijan, 2018). The knowledge–compliance gap persists where supervision, PPE availability, or site culture falter, underscoring the need for enforcement, regular audits, and HR involvement in cultivating a safety-first mindset (Okoye, Ezeokonkwo, & Ezeokoli, 2016). Collectively, global and Turkish evidence converge on a multidimensional agenda: strengthen safety culture and perception–practice alignment (Ayduran & Olcay, 2022; Öngel, 2022; Olcay, 2021), institutionalize OHS through systems and measurement (Kineber et al., 2023; Çüçen & Kurtoğlu, 2024), tailor and evaluate training for transfer (Pham, Lingard & Zhang, 2023; Bayrak et al., 2021), modernize oversight with field surveillance and equipment controls (Aydoğan & Uçan, 2022), and harness digital tools—including IoT and AI—for proactive risk control (Zhang, Shi & Yang, 2020; Erol & Eraslan, 2024). As the industry evolves toward sustainable, technology-infused delivery, the roles of HR and leadership in embedding these practices into organisational culture and operations become even more vital.

Prevention through design (PtD) and its importance

Prevention through Design (PtD) is the deliberate integration of hazard elimination and risk reduction into the design and redesign of facilities, structures, methods, and equipment across the life cycle of a project, with the objective of "designing out" risks as early as possible and minimising any residual hazards before work begins on site. In contrast to reactive, construction-stage interventions, PtD advances proactive risk anticipation during concept and planning, which improves safety performance, reduces rework, and supports sustainability objectives by preventing incidents at their source. Contemporary reviews underline that digital information technologies—such as Building Information Modeling (BIM), virtual reality, and safety simulations—strengthen PtD by enabling multidisciplinary teams to visualize hazards, compare alternatives, and test "what-if" scenarios before construction; when these tools are embedded in iterative design reviews, design teams' predictive capability improves and reliance on downstream, reactive measures declines (Farghaly et al., 2022).

Successful PtD depends on competent designers and coordinated teams. Evidence on designer competence highlights the importance of safety knowledge, interdisciplinary communication, ethical responsibility, and regulatory literacy; without these competencies, PtD initiatives struggle to translate into measurable reductions in injuries (Che Ibrahim, Belayutham, Manu & Mahamadu, 2021). Evidence from the Malaysian construction context shows that insufficiently structured training and weak integration of safety criteria in design education constrain practice, reinforcing the need for explicit learning outcomes on risk identification, hierarchy-of-controls decision-making, and documentation of residual risks in engineering and architecture programs (Ismail, Che Ibrahim, Belayutham & Mohammad, 2022). Parallel analyses of engineering and architecture curricula indicate where training should occur—within university programs through experiential modules, interdisciplinary projects, and case-based learning—to normalise safety as a first-order design criterion; discussions on integrating PtD into engineering education further argue that institutionalising PtD in curricula will better equip future designers and project managers to incorporate worker protection from the outset (Ismail, S., Che Ibrahim, Belayutham, Mat Isa, Cheung & Manu, 2024; Al-Bayati, Bazzi, Karakhan & Jensen, 2024).

Translating PtD from principle to practice requires governance, leadership, and process discipline across the project life cycle. Studies focused on the U.S. construction industry identify organisational resistance, limited client demand, and misaligned contractual structures as persistent barriers to adoption, emphasising the need for leadership advocacy, regulatory incentives, and clearer demonstrations of PtD's economic and safety value to overcome institutional inertia (Al-Bayati, Jensen, Eiris & Abudayyeh, 2024). Early-stage interventions highlight PtD as foundational to sustainable architectural design, with arguments that integrating PtD in concept development not only improves safety outcomes but also reduces waste, rework, and operational disruptions, thereby contributing to environmental and economic sustainability (Khalil, Samsudin, & Zainonabidin, 2022). Overall, the literature specifies how PtD is implemented and by whom: clients/owners, design leads, constructors, and OHS professionals assume clear responsibilities; staged design reviews apply the hierarchy of controls; and traceable risk information passes from design to procurement, construction, and operations—moving organizations from reactive compliance to proactive, ethically driven prevention (Farghaly et al., 2022; Che Ibrahim et al., 2021; Ismail et al., 2022; Ismail et al., 2024; Al-Bayati et al., 2024; Khalil et al., 2022).

Capacity building is central to answering "who can receive training and where." Beyond entry-level education, organisations should provide role-specific, context-rich training for designers, constructors, and OHS staff that addresses design-embedded risk decisions, constructability, and operations/maintenance access; interview-based evidence shows that such targeted programs outperform generic training (Ismail et al., 2022). These insights align with curricular analyses calling for sustained, programmatic PtD learning in universities and with workplace reinforcement so that knowledge is supported by supervision, resources, and culture (Ismail et al., 2024).

Human Resource Management (HRM) provides the organisational scaffolding that enables PtD and broader safety performance by embedding occupational health and safety (OHS) into strategy, policy design, training, and daily operations. A comprehensive, integrated HR approach—spanning recruitment and onboarding to training, performance evaluation, and leadership development—clarifies where ongoing workforce training occurs inside organisations and helps make safety a shared value rather than a regulatory burden (Melhem et al., 2024). Empirical evidence from small manufacturing shows that HR-driven, job-specific safety education is associated with improved safety awareness and compliance, underscoring that policies alone are insufficient without consistent, well-designed training (Park, 2018). Complementary research on "caring human resource management" demonstrates that when employees perceive genuine organisational care, they report higher engagement, greater psychological safety, and stronger adherence to safety practices, which supports hazard reporting and continuous improvement (Saks, 2022). At the systems level, studies show that treating safety as a performance metric—integrating it into appraisal and recognition—mediates the relationship between high-performance HR practices and organisational outcomes. At the same time, multidisciplinary perspectives argue that HR must collaborate with engineering, operations, and safety to address physical, psychological, and procedural hazards in an integrated way (Chan & Mak, 2012; Burke & Signal, 2010).

Contemporary HR agendas also foreground inclusion, context, and technology. Gender-aware policies—encompassing secure reporting mechanisms, gender-sensitive risk assessments, and anti-harassment training—are identified as essential to creating a safe environment for all workers, particularly in male-dominated sectors such as construction and manufacturing (Khan, 2023). Cross-national comparisons reveal divergent but practical HR-led safety approaches across regulatory regimes—U.S. firms often emphasise decentralised, behaviour-based interventions, while Singaporean firms adopt more formalised, centralised HR frameworks—underscoring the need to tailor practices to local norms while preserving core principles of participation and accountability (Lai, Liu, & Ling, 2011). Within manufacturing, structured HRM practices—clear job design, health-focused recruitment, and periodic safety audits—correlate with improved OHS outcomes and act as both preventive and corrective mechanisms by influencing how risks are anticipated, reported, and addressed (Obeidat, Sarhan, & Qasim, 2023). Emerging IoT-enabled monitoring and analytics further expand HR's capacity to anticipate non-compliance and intervene proactively, providing a complementary, data-driven layer to training and supervision and opening new avenues for continuous safety improvement (Bamidele & Charles, 2021).

Taken together, the literature and field evidence indicate that safer construction is achieved when PtD's design-stage elimination and reduction of hazards is coupled with HRM's strategic integration of safety into people systems, reinforced by leadership and policy frameworks. Effective implementation answers the reviewer's questions by combining a clear definition of PtD, explicit assignment of implementing roles (clients/owners, design leads, constructors, OHS), and clear training pathways located in universities and in organisational HR-led programs, all supported by early, collaborative design routines and infrastructures that measure and reward safety as performance. Addressing current gaps—such as inconsistent institutionalization, cultural resistance, and limited use of standardized leading indicators—requires continued alignment of education, organizational leadership, and regulatory guidance so that prevention becomes the default logic of design and work (Farghaly et al., 2022; Che Ibrahim et al., 2021; Ismail et al., 2022; Ismail et al., 2024; Al-Bayati et al., 2024; Khalil et al., 2022; Melhem et al., 2024; Park, 2018; Saks, 2022; Chan & Mak, 2012; Burke & Signal, 2010; Khan, 2023; Obeidat et al., 2023; Bamidele & Charles, 2021).

Human resource management and workplace safety

Human Resource Management (HRM) plays a pivotal role in shaping workplace safety outcomes by integrating health and safety considerations into organizational strategy, policy design, training, and daily operations, and its formal position in the safety system is as a strategic partner that embeds OHS and PtD expectations across the employee life cycle and coordinates with engineering, operations, and safety to operationalize them (Melhem et al., 2024; Burke & Signal, 2010). Traditionally seen as a support

function, HR has increasingly taken on a strategic role in fostering safe work environments through proactive planning, employee engagement, and compliance enforcement; in practice, this means HR leads the alignment of recruitment, onboarding, training, appraisal, and leadership development with explicit OHS objectives so that safety is treated as a shared value rather than a regulatory burden (Melhem et al., 2024).

The link between HR practices and employee safety behaviour is reinforced through targeted education and training programs; HR's core function is to design, resource, and evaluate job-specific safety education that is continuous and tailored to role risks, ensuring that policies translate into actual behaviour change (Park, 2018). Complementing this, HR is responsible for building a climate of psychological safety—through caring HRM practices, fair procedures, and supportive supervision—so that employees report hazards, comply with protocols, and participate in continuous improvement (Saks, 2022). At the systems level, HR must integrate safety into performance management—setting OHS and PtD-related goals, including them in appraisals, and linking recognition or incentives to leading and lagging indicators—because doing so mediates the relationship between high-performance HR practices and organisational outcomes (Chan & Mak, 2012). These responsibilities are inherently collaborative, and HR's duty is to convene and coordinate with engineering, operations, and safety specialists to address physical, psychological, and procedural hazards within an integrated framework (Burke & Signal, 2010).

With respect to Prevention through Design (PtD), HR's specific duties are to: define and map the PtD competencies required for design-facing roles; embed those competencies and responsibilities (e.g., participation in design-stage risk reviews, documentation of residual risks, and hierarchy-of-controls decision-making) into job descriptions and career paths; resource and schedule PtD training for designers, constructors, and supervisors; and ensure that participation in PtD activities is tracked and evaluated in performance systems (Che Ibrahim et al., 2021; Ismail et al., 2022; Ismail et al., 2024). HR also supports PtD implementation by staffing cross-functional design reviews, integrating lessons learned from site incidents into curricula, and aligning leadership development with PtD expectations so that early-stage risk elimination is rewarded and normalised (Farghaly et al., 2022; Al-Bayati et al., 2024). In sustainability-oriented design contexts, HR's duty extends to ensuring that PtD training and competence development are available during concept and planning phases, where design choices can reduce waste, rework, and operational disruptions, thereby linking safety with environmental and economic outcomes (Khalil, Samsudin, & Zainonabidin, 2022).

Inclusive and context-sensitive practice is part of HR's mandate. HR must implement gender-aware safety policies—such as secure reporting, gender-sensitive risk assessment, and anti-harassment training—to ensure women's safety, particularly in male-dominated sectors, and adapt programs to local regulatory and cultural contexts (Khan, 2023; Lai, Liu, & Ling, 2011). In manufacturing and similar settings, HR's operational duties include maintaining clear job designs, recruiting for health and safety competencies, and running periodic safety audits that function as both preventive and corrective mechanisms for risk anticipation and reporting (Obeidat, Sarhan, & Qasim, 2023). Lastly, HR should steward technology-enabled oversight—deploying IoT wearables, real-time analytics, and AI-assisted dashboards—to monitor compliance, predict incidents, and target interventions, thereby augmenting traditional training and supervision with data-driven decision-making (Bamidele & Charles, 2021).

Taken together, these responsibilities clarify what HR can do, and must do, regarding OHS and PtD: act as a strategic integrator of safety in people systems; own the design, delivery, and evaluation of role-specific training; codify PtD competencies and duties in job architecture and performance management; coordinate cross-functional prevention routines; ensure inclusive, context-appropriate protections; and leverage data and technology for proactive risk control (Melhem et al., 2024).

Thematic analysis in HR and OHS research

Thematic analysis has become a widely accepted and powerful method in qualitative research, particularly in the fields of human resource management (HRM) and occupational health and safety (OHS), where complex, context-dependent, and socially constructed phenomena are often under investigation. As a flexible and iterative technique, thematic analysis enables researchers to identify, analyse, and report patterns (themes) across qualitative datasets, providing deep insight into participants' perceptions, behaviours, and experiences. It is especially well-suited for exploring nuanced processes, such as the implementation of Prevention through Design (PtD), where stakeholder perspectives, organisational dynamics, and contextual factors intersect. The technique facilitates the development of a data-driven understanding of how HR professionals and safety experts conceptualise and operationalise safety-related initiatives.

The applicability of thematic analysis in OHS research is demonstrated by Silalahi, Ryan, Cobb & Houghton (2021), who investigated workplace safety and ergonomic issues in Indonesian food-producing SMEs. Using a thematic analysis approach, the researchers identified recurring challenges, including a lack of standardised procedures, insufficient training, and worker fatigue. Their study revealed how employees' lived experiences shaped their understanding of safety and demonstrated the capacity of thematic analysis to uncover underlying cultural and organisational issues that traditional quantitative methods might overlook. The researchers employed NVivo software to facilitate data coding and manage the large volume of textual data, allowing for a more systematic identification and organisation of themes related to unsafe behaviours, risk perceptions, and ergonomic neglect. This study exemplifies how thematic analysis, supported by digital tools, can distil complex narratives into actionable insights, thereby informing more responsive HR and safety strategies.

In a broader review of occupational health and safety disclosure trends, Podayan and Balakrishnan (2025) utilised topic modelling techniques to extract themes from publicly available reports. While their methodology differed from classical thematic analysis, their findings contribute to the understanding of emerging patterns in how organisations frame and prioritise OHS communication. The study complements thematic approaches by reinforcing the need for qualitative interpretive methods that can capture evolving discourses around safety, particularly in relation to HRM's responsibility for transparent and ethical reporting. Similarly, Tetzlaff, Goggins, Pegoraro, Dorman, Pakalnis & Eger (2021) conducted a retrospective analysis of safety culture by reviewing OHS reports in the mining sector. Through a qualitative lens, they highlighted recurring issues, including weak managerial accountability and underreporting of incidents. Their work illustrates how retrospective thematic analysis can expose systemic weaknesses in safety management systems, many of which intersect directly with HR policies and leadership behaviour.

Mok, Mackenzie, and Thomson (2022) employed narrative thematic analysis to investigate the experiences of HR professionals in managing the career development of ageing workers, a demographic increasingly prevalent in high-risk sectors such as construction and manufacturing. Their study revealed recurring themes of ageism, policy inflexibility, and the need for tailored support programs. While their focus was not directly on safety, the findings have implications for OHS in that an ageing workforce presents unique health and safety challenges—such as reduced physical capacity and higher vulnerability to injury—that HRM must address. This research further demonstrates the versatility of thematic analysis in addressing multifaceted workplace issues that involve both HR policy and employee well-being. Garg (2022) provided another relevant example through a study on OHS competencies among safety professionals in New Zealand. Using qualitative interviews and thematic analysis, Garg identified gaps in practical knowledge, communication skills, and ethical decision-making among practitioners. These findings underscore the significance of HR departments in facilitating ongoing professional development and training, particularly as PtD and other proactive safety strategies gain greater mainstream adoption. The thematic approach enabled a detailed examination of how competencies are understood and developed in practice, providing insight into the workforce readiness required for advanced safety integration efforts.

Finally, Pandey (2024) adopted a systems thinking perspective to reconceptualise traditional OHS principles. Although his study was conceptual in nature, it emphasised the interconnectedness of organisational subsystems, reinforcing the argument that thematic analysis is uniquely equipped to explore such interrelations in real-world settings. The systems view proposed by Pandey aligns well with the objectives of PtD, as both approaches advocate for early intervention and holistic understanding. By enabling researchers to understand how individual, organisational, and structural elements contribute to safety outcomes, thematic analysis provides a robust methodological foundation for examining PtD from a human-centred and organizationally embedded perspective.

In summary, thematic analysis offers a highly suitable methodological framework for exploring the implementation of PtD within the context of HR and OHS. It facilitates the discovery of underlying perceptions, cultural norms, and systemic barriers that shape safety practices. When complemented by tools like NVivo, thematic analysis becomes even more potent in managing large datasets and ensuring analytical rigour. As demonstrated across various studies, this approach is essential for generating practical, grounded, and context-sensitive insights that inform both academic research and workplace interventions in occupational health and safety.

Research gap

Despite the growing body of literature on occupational health and safety (OHS) and the increasing emphasis on proactive design-based approaches such as Prevention through Design (PtD), a significant research gap remains at the intersection of human resource management (HRM) and PtD

implementation in the construction industry. Most existing studies on PtD have primarily focused on technical aspects, designer competencies, and the integration of digital tools or educational frameworks to support hazard mitigation during the design phase. While these contributions have been valuable in advancing the theoretical and practical understanding of PtD, they often overlook the strategic and operational role that HR departments can play in facilitating its adoption within organisations. Specifically, there is a noticeable absence of empirical research examining how HR-led initiatives—such as safety training programs, performance incentives, organisational culture shaping, and cross-functional collaboration—can influence the effective integration of PtD principles on construction sites.

Moreover, the limited studies that do reference HR's involvement in safety typically address general workplace safety practices without explicitly linking them to the early design stages where PtD is most impactful. This lack of attention to HR's potential role in shaping PtD outcomes leaves a conceptual and practical void, particularly in understanding how HR professionals can support design teams, influence managerial decisions, and drive cultural shifts toward prevention-oriented safety mindsets. In addition, much of the existing research in this area tends to adopt quantitative or policy-driven perspectives, which, while valuable, may not fully capture the nuanced, context-specific, and socially constructed nature of HR-led safety strategies in construction settings.

Given the complexity and variability of construction projects, a qualitative approach is essential to understanding how HR practices are operationalised in real-world scenarios and how they interact with other organisational functions to support PtD implementation. Qualitative methods, particularly thematic analysis, offer the depth and flexibility needed to explore these dynamics through the lived experiences of HR professionals, safety officers, and design stakeholders. By focusing on the subjective perceptions, challenges, and strategic actions of those directly involved in safety management, this approach can yield rich insights that are often overlooked in broader surveys or prescriptive policy analyses. Addressing this gap is crucial not only for enhancing the theoretical understanding of PtD but also for informing practical, HR-driven interventions that can lead to safer, more sustainable construction environments.

Methodology

Research approach

This study adopts a qualitative research approach, which is appropriate for exploring complex social processes, perceptions, and organisational behaviours that cannot be easily quantified. Qualitative methods are beneficial for gaining an in-depth understanding of workplace experiences, professional roles, and the contextual factors that influence safety practices in the construction industry (Creswell & Poth, 2018). To systematically analyse the qualitative data collected through semi-structured interviews, Thematic Analysis (TA) was employed. Thematic Analysis is a widely used method for identifying, analysing, and interpreting patterns of meaning (themes) within qualitative data (Braun & Clarke, 2006). It offers flexibility and is suitable for both inductive (data-driven) and deductive (theory-driven) approaches. In this study, TA was employed to investigate the impact of HR practices on the adoption of Prevention through Design (PtD) strategies and to gather the perspectives of professionals working in various roles, including HR, engineering, safety, and project management. To support the analysis process, NVivo software (version 12) was used for data management and coding. NVivo facilitates the organisation of qualitative data, enabling researchers to code interview transcripts, link emerging themes, and visualise patterns across multiple cases (Woolf & Silver, 2018). Its advanced search, query, and visualisation features enhance the rigour and transparency of qualitative analysis, helping to ensure that coding is consistent and grounded in the data.

Data collection methods

This study employed semi-structured interviews as the primary data collection method to explore how Human Resource (HR) strategies support the implementation of Prevention through Design (PtD) in the construction sector. Semi-structured interviews were chosen for their flexibility, enabling the researcher to guide the conversation around key themes while allowing participants to share detailed insights and experiences in their own terms. Interviews were conducted with a purposive sample of professionals from three key roles in construction projects:

- HR professionals are responsible for workforce development, safety training, and compliance.
- Occupational Health and Safety (OHS) managers and safety officers are involved in design reviews, risk mitigation, and safety policy implementation.

- Engineers and site supervisors are engaged in coordinating on-site execution and translating design documents into practice.

This triangulation of perspectives enriched the understanding of how PtD principles are integrated across organisational roles and project stages.

A total of 12 participants were interviewed. Each interview lasted between 45 and 60 minutes and was conducted either face-to-face or via video conferencing, depending on availability and location. All interviews were conducted in a confidential setting, recorded with participant consent, and transcribed verbatim for analysis.

The interviews followed a semi-structured guide composed of open-ended questions designed to explore the following themes:

- Role and responsibilities within the organisation.
- Familiarity with PtD and how it is applied in their projects.
- HR practices that support or hinder PtD implementation.
- Collaboration between HR, design, and safety teams.
- Training programs and worker engagement in safety-related design.
- Challenges and barriers in aligning HR with PtD strategies.
- Observed outcomes and success stories related to HR-led PtD interventions.
- Recommendations for improving HR's contribution to safety through design.

The interview guide was piloted with two professionals to ensure clarity and relevance, and adjustments were made based on their feedback.

Sampling strategy

This study employed a purposive sampling strategy, a common approach in qualitative research that selects information-rich participants with direct experience and insights relevant to the research objectives (Patton, 2015). Participants were selected based on their professional involvement in Human Resource Management (HRM), Occupational Health and Safety (OHS), or design and engineering roles where Prevention through Design (PtD) is applied or influenced. To strengthen the transferability of findings, we explicitly sought maximum variation across organisational and project contexts. Specifically, recruitment targeted variation in company type (e.g., general contractors, design–build firms, specialty subcontractors, client/consultancy), geographic region within Türkiye (e.g., Marmara, Aegean, Central Anatolia, Mediterranean), project type (e.g., residential/commercial building, industrial, infrastructure), typical project scale (small/medium/large, defined below), delivery model (design–bid–build vs. design–build), firm size band (small: <50 employees; medium: 50–249; large: ≥250), and BIM/PtD exposure level (low/medium/high based on routine use in design reviews and site briefings). These contextual descriptors were captured for each participant and are reported in the expanded tables to enable readers to assess the applicability of results to comparable settings.

The goal was to ensure diversity across professional backgrounds while focusing on individuals who could provide in-depth knowledge of how HR strategies interact with design-safety practices in the construction sector. This included those involved in safety training, design implementation, policy-making, workforce development, and on-site supervision. A total of 12 participants were interviewed, representing roles from HR directors and safety officers to site supervisors, project engineers, and BIM coordinators. Their professional fields, educational backgrounds, and years of experience are shown in Table 1. Table 1A adds the requested context—company type, region, project type and scale, delivery model, firm size, and BIM/PtD exposure. To protect confidentiality, company names are not disclosed; regions and project characteristics are reported at an aggregate level.

Consistent with qualitative logic, we do not claim statistical generalizability from this sample. Instead, we provide detailed descriptions of participants and settings, allowing readers to assess the transferability of insights to contexts that share similar organisational profiles, project types, scales, and regional characteristics. This approach aligns the sample's information power with the study aims while addressing the reviewer's request for contextual detail (Patton, 2015).

Table 1: Participant Demographics

Participant ID	Company Type (GC/DB/Sub/Client/ Consult)	Region	Project Type (Bldg/Industrial/Infra)	Typical Project Scale (S/M/L)	Delivery Model	Firm Size Band	BIM/PtD Exposure
P1	General Contractor	Marmara	Bldg	L	Design–Bid–Build	≥250	High
P2	General Contractor	Aegean	Bldg	M	Design–Bid–Build	50–249	Med
P3	General Contractor	Central Anatolia	Infra	L	Design–Bid–Build	≥250	High
P4	Consult	Marmara	Industrial	M	Design–Build	50–249	Med
P5	Consult	Mediterranean	Bldg	M	Design–Build	<50	Med
P6	Consult	Marmara	Bldg	M	Design–Bid–Build	<50	High
P7	General Contractor	Mediterranean	Bldg	M	Design–Bid–Build	50–249	Med
P8	Consult	Marmara	Bldg	L	Design–Build	50–249	High
P9	Consult	Central Anatolia	Industrial	M	Design–Bid–Build	<50	Med
P10	Design–Build firm	Marmara	Bldg	L	Design–Build	≥250	High
P11	General Contractor	Aegean	Bldg	L	Design–Bid–Build	≥250	High
P12	Subcontractor	Aegean	Industrial	M	Design–Build	50–249	High

The diversity of roles and experiences represented in the sample enabled a rich and multidimensional analysis of how HR-led strategies influence the adoption and success of PtD in the construction environment.

Data analysis

The data analysis followed the principles of Thematic Analysis as outlined by Braun and Clarke (2006), supported by the use of NVivo software to ensure a systematic and rigorous process. All interviews were first transcribed verbatim to create accurate textual data for analysis. This was followed by a period of familiarisation, during which the researcher read through the transcripts multiple times to immerse themselves in the data and gain a preliminary understanding of emerging patterns. Initial coding was then carried out in NVivo, where significant segments of the text were assigned codes based on recurring ideas, phrases, and insights relevant to the research objectives. These codes were subsequently organised into broader categories to generate potential themes, capturing patterns of meaning across the dataset. Themes were carefully reviewed and refined to ensure they were coherent, distinct, and accurately reflected the underlying data. Once finalised, each theme was clearly defined and named to encapsulate its core message and relevance to the study. The findings were then reported by structuring the themes and supporting them with illustrative quotes from the participants, enabling a comprehensive and meaningful interpretation of the data.

Ethical considerations

This study adhered to established ethical standards throughout the research process. Before participation, all individuals were provided with a clear explanation of the study's purpose, procedures, and their rights as participants. Informed consent was obtained from each participant, ensuring their voluntary involvement. Anonymity and confidentiality were strictly maintained; all identifying information was removed from transcripts, and participants were assigned codes (e.g., P1, P2) to protect their identities. Data were securely stored and used solely for academic purposes. The research protocol was reviewed and approved by the Institutional Review Board of Istanbul Bilgi University, confirming that the study met ethical requirements for research involving human subjects.

Findings

This section presents the key findings derived from a thematic analysis of the interview data, conducted using NVivo software. Through a systematic coding process, six major themes emerged that reflect how human resource management influences the implementation of Prevention through Design (PtD) strategies in the construction industry. These themes are: HR Involvement in PtD, Training and Competency Development, Cross-Functional Collaboration, Cultural and Organisational

Barriers, Safety Culture Impact, and Measuring PtD Effectiveness. Each theme encompasses multiple subthemes and related codes, which were identified through repeated patterns and conceptual groupings within participant responses. Table 2 summarises the hierarchical structure of the themes and subthemes, providing an overview of the core areas that will be explored in detail in the following sections.

Table 2: Thematic Analysis Summary Table

Theme	Subtheme	Codes
HR Involvement in PtD	Strategic HR Roles	HR manager, HR director, HR business partner, HR specialist, HR department, talent acquisition, workforce planner, HR executive
	Early Involvement	participate, early engagement, included early, initial phase, planning stage, design kickoff, early consultation, initial meetings
	Policy and Leadership	support, lead, initiative, ownership, policy, drive, safety leadership, compliance strategy, HR-led action plan
Training and Competency Development	Customized Training	training program, tailored training, project-specific, design-based training, training content, safety modules, scenario-based learning
	Skill Matching	competency, skills, capability, qualified workforce, readiness, certification, skill audit, training needs analysis
	Learning Culture	learning, continuous development, education, knowledge sharing, upskilling, training culture, peer learning, lifelong learning
Cross-Functional Collaboration	HR-Safety Integration	HR and HSE, joint session, safety meeting, coordination, HR and safety, multi-disciplinary, cross-team briefing, interdepartmental workshop
	Design Coordination	design review, design team, collaborative planning, BIM meetings, design discussion, preconstruction meeting, drawing analysis
	Feedback Mechanisms	worker feedback, loop, survey, input, suggestions, lessons learned, feedback session, team debrief, reflection report
Cultural and Organisational Barriers	Structural Challenges	siloed departments, limited communication, rigid hierarchy, separated functions, narrow scope
	Attitudinal Resistance	resistance to change, traditional mindset, lack of awareness, unwillingness, and reluctance
	Organizational Priorities	cost focus, tight deadlines, limited safety integration, low HR involvement, reactive planning
Safety Culture Impact	Worker Engagement	participation, reporting culture, ownership, safety mindset, proactive attitude
	Trust and Communication	transparency, open dialogue, peer support, feedback channels, inclusive culture
	Leadership Influence	management example, commitment, safety vision, role modelling, safety values
Measuring PtD Effectiveness	Outcome Tracking	incident reports, leading indicators, lagging indicators, safety KPIs, performance metrics
	Evaluation Practices	post-project review, surveys, audits, lessons learned process, trend analysis
	Impact Visibility	results communication, dashboards, progress reports, stakeholder updates, success metrics

Figure 1 illustrates the frequency of coded references for each central theme identified in the thematic analysis conducted using NVivo. The thematic density represents the number of instances where participants discussed topics related to each category, highlighting their prominence in the dataset.

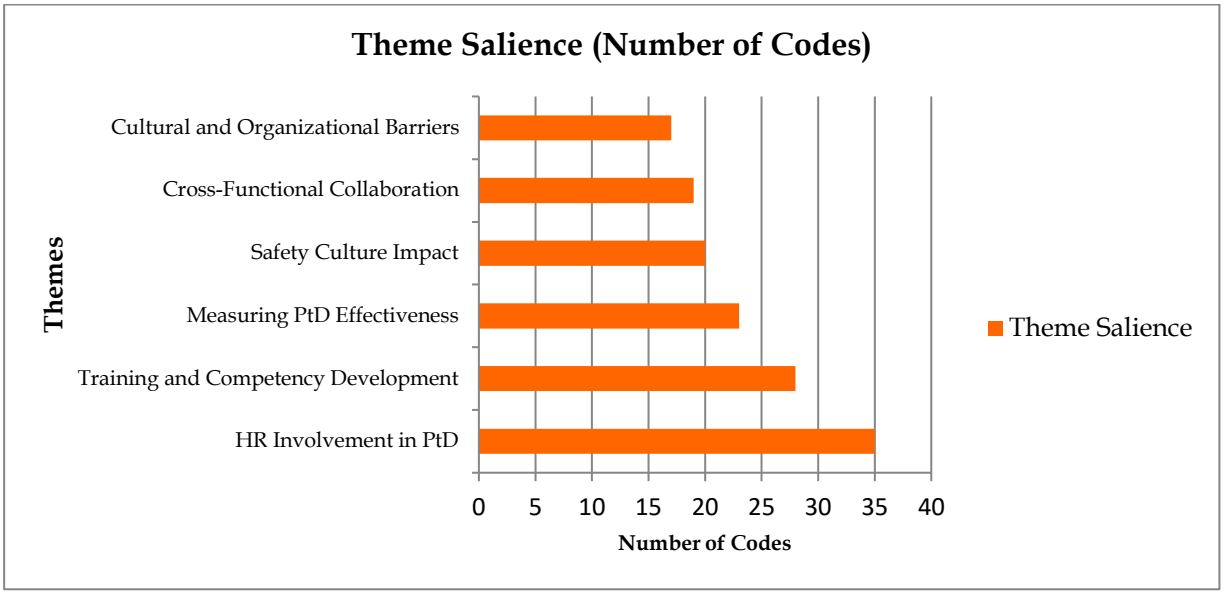

Figure 1: Thematic Salience in HR–PtD Findings

HR Involvement in PtD emerged as the most frequently discussed theme, with 35 coded references, emphasising the strategic role of HR in integrating safety into design processes. Training and Competency Development followed closely with 28 references, reinforcing the importance of targeted safety training aligned with design-based risks. Cross-Functional Collaboration had 19 occurrences, showcasing the value of interdisciplinary teamwork in PtD execution. Meanwhile, Cultural and Organisational Barriers (17 occurrences) highlighted challenges such as resistance to change and hierarchical silos. Safety Culture Impact (20 references) demonstrated how PtD fosters a trust-based, proactive safety culture, and Measuring PtD Effectiveness (23 references) pointed to the need for standardised evaluation frameworks. This figure provides a visual representation of the relative emphasis placed on each theme during the analysis and serves as a foundation for the detailed thematic discussion in the following sections.

HR involvement in PtD

The interviews revealed a strong consensus among participants that Human Resources (HR) departments are increasingly pivotal in the successful implementation of Prevention through Design (PtD) strategies in the construction sector. Rather than functioning solely in administrative or recruitment roles, HR professionals are actively contributing to safety-focused design processes by embedding workforce readiness, training alignment, and behavioural expectations into the earliest phases of project development. This evolving role was highlighted by several participants who stressed the importance of early HR engagement. For example, one HR manager shared, *"We are no longer just onboarding people; we are also helping shape the kind of safety culture that starts with design thinking. HR must sit at the design table"* (P1). This view was echoed by P4, an HR business partner in an engineering firm, who noted that "*Participating in pre-design consultations has allowed us to align human resources strategy with safety-critical roles and job-specific competencies right from the start.*"

Participants described HR's role not as auxiliary but as essential in ensuring that safety policies, workforce constraints, and competency requirements are factored into technical design decisions. This integration of HR and design functions was repeatedly emphasised. As P8 explained, *"We've institutionalised HR's role in design review sessions. It's not an afterthought anymore – it's a structured process where we evaluate how safety, workforce, and training implications are addressed in proposed design plans."* These statements suggest that in more progressive organisations, HR professionals have secured a seat at the design table and contribute actively to shaping safety outcomes even before a project breaks ground.

Moreover, many participants recognised the influence of HR departments in fostering a culture of safety, ownership and leadership across departments. Beyond compliance, HR initiatives were described as shaping attitudes and values related to safety. P12 reflected, *"HR led the development of a safety leadership framework that now guides our design and planning meetings. We don't just assign safety responsibilities – we nurture safety mindsets."* Similarly, P3, a project manager, remarked that *"The sooner HR is involved, the better the workforce is prepared for what's coming in terms of safety expectations. It eliminates confusion and resistance later on."* These comments highlight how HR's influence extends beyond structural duties and encompasses behavioural and cultural dynamics within construction teams.

Finally, several interviewees emphasised that HR professionals can act as bridges between management, design teams, and site personnel, ensuring that the principles of PtD are communicated in a language that resonates across all organisational levels. P9 commented, *"In our case, HR was instrumental in translating complex safety concepts into onboarding content that made sense to everyone, from senior engineers to new apprentices."* This ability to translate, coordinate, and lead reinforces the notion that HR's role in PtD is multifaceted—encompassing strategy, communication, leadership, and compliance.

Training and competency development

Across the interviews, training and competency development emerged as a foundational pillar for the effective implementation of PtD strategies. Participants emphasised that equipping employees with the proper knowledge and skills is essential not only for compliance but also for ensuring that safety is internalised and operationalised throughout the project's lifecycle. Many interviewees described training not as a one-time event, but as a continuous process that must evolve in response to design complexity, project-specific risks, and technological advancements. P6, a safety trainer, noted, *"We used to give general safety training to all new hires, but now we develop targeted modules based on the specific risks identified in the design phase. It's not just about hazard awareness anymore; it's about design-based thinking."*

Tailored, project-specific training was identified as a best practice by several participants, especially in firms where PtD is part of the formal planning process. As P2 explained, *"Our onboarding process includes scenario-based training derived directly from the design review. If the project involves crane work or modular installation, the training reflects that from day one."* This approach ensures that workers are not only aware of potential hazards but are also equipped to respond in ways that align with the design intent and safety protocols. P7, a site supervisor, added, *"What makes a difference is when training is site-specific and conducted before construction begins. People understand how to apply safety concepts when they know why a design was done a certain way."*

Participants also emphasised the importance of competency assessment as a continuous HR–safety collaboration. Several noted that traditional certification was insufficient to evaluate a worker's actual readiness to engage with PtD-sensitive environments. P5, a design engineer, remarked, "Sometimes we get workers who are certified but not ready. That's where HR and safety teams work together to do practical assessments and refreshers based on what's needed for that particular design." The notion of "skill matching" was repeatedly mentioned, with P11 pointing out that "It's not just about having the training record; it's about whether they can execute tasks safely under the conditions the design requires." A key insight from the interviews was the cultural shift surrounding learning and upskilling. Participants described a growing emphasis on creating a "learning culture" that encourages continuous development and collaborative reflection. P4 shared, "We've moved from passive instruction to active learning environments—using simulations, peer feedback, and even digital tools that link design and training dashboards." P10 highlighted the integration of Building Information Modelling (BIM) in training modules, stating, "We use BIM walkthroughs in our sessions to help workers visualise risk and understand how their roles interact with design features like safety rails or load zones." Concretely, teams described 10–15-minute, BIM-enabled pre-task briefings at the start of high-risk activities, where supervisors and a safety lead open the model on a tablet, zoom to "hot spots" (e.g., edges, lift paths, load zones), review the planned sequence and controls, and then ask workers to restate the critical steps and demonstrate the control application before sign-off (Farghaly et al., 2022; Park, 2018). For PtD-critical tasks, HR and safety co-lead competency "check-offs" at the workface: a brief scenario is set from the actual design (e.g., installing guard-anchorage points designed into the facade), the worker executes under observation using the hierarchy of controls, and performance is recorded in the HR system, which automatically schedules a refresher if errors are observed or if task exposure is infrequent (Melhem et al., 2024; Park, 2018). Participants also reported simulation-based micro-sessions—15–30 minutes using desktop VR or screen-based modules—to rehearse unusual lifts, confined-space access designed into the layout, or maintenance routes; these sessions include peer feedback and a short reflection prompt to reinforce psychological safety and help-seeking norms (Saks, 2022; Farghaly et al., 2022). During design reviews, "PtD gates" at 30/60/90% are paired with targeted toolbox briefings for supervisors: designers present the risk-informed option chosen (elimination/substitution where feasible), residual risks are translated into task cards, and supervisors brief crews on what changed in the design and how that affects methods and access (Che Ibrahim et al., 2021; Ismail et al., 2024). Finally, teams described shift-start "Take-5/JSA" briefings that are explicitly tied to the model: the foreman prints or displays a one-page card listing the day's PtD-relevant features (e.g., temporary edge protection locations, engineered lift points) and the expected controls; workers initial the card after a quick teach-back or a practical demonstration (Park, 2018; Melhem et al., 2024).

To sustain these practices, HR's role is to embed the above routines into job design and appraisal (e.g., making successful check-offs and participation in PtD gates part of performance objectives), to map PtD competencies into role profiles for engineers and supervisors, and to provision a learning platform that pushes micro-refreshers triggered by risk exposure, incident trends, or design changes (Melhem et al., 2024; Che Ibrahim et al., 2021; Ismail et al., 2022; Ismail et al., 2024). Safety departments, in turn, curate the scenario library (lift plans, access routes, mock-ups) and co-facilitate the practical assessments, while design teams supply updated BIM views and short clips that show "what good looks like" for the selected methods (Farghaly et al., 2022; Al-Bayati et al., 2024). Where sustainability-linked PtD choices are material (e.g., off-site fabrication to eliminate work-at-height), induction programs are amended to include a module on how those design decisions change site risks and required competencies, reinforcing the connection between safe design, waste reduction, and reliable operations (Khalil, Samsudin, & Zainonabidin, 2022).

Cross-functional collaboration

The interviews consistently revealed that cross-functional collaboration is a critical enabler of successful PtD implementation in construction projects. Participants described collaboration not as an abstract principle, but as a practical, structured process involving continuous communication, shared responsibilities, and alignment between HR professionals, design engineers, safety officers, and operational managers. This integration was considered especially important during the early stages of planning and design. P3, a project manager, stated, *"We don't treat HR and safety as support services. They are integrated into our design coordination meetings from day one, and their input often changes the trajectory of a design decision."* This early and deliberate inclusion ensures that practical, human-centred concerns are integrated into the technical planning of projects.

Several participants emphasised that HR and safety teams are no longer operating in silos but are working together to ensure that workforce planning, training, and safety compliance are all aligned with the evolving design intent. P8 shared, *"It's a collaborative triangle: HR, HSE, and engineering. If one is left out, things fall through the cracks—either you overdesign and under-train, or you train for risks that don't exist."* Such insights highlight the need for a synchronised information flow across departments. P6, who is responsible for safety training, further explained that *"The best results happen when our design and BIM teams give us their layouts early. Then we build our induction and toolbox talks around that content."*

The data also highlighted a growing use of structured platforms—like design coordination meetings, preconstruction workshops, and collaborative software tools—to facilitate ongoing feedback between roles. For example, P10 noted, *"We run design walkthroughs in our BIM sessions, where HR and safety can comment in real time. It makes the model more than just a drawing—it becomes a collaborative decision-making space."* This integration of digital tools and co-review sessions not only enhances technical accuracy but also improves communication and trust between departments.

An extreme emphasis was placed on feedback mechanisms. Participants described how feedback loops between workers and design teams, often mediated by HR or safety officers, were instrumental in identifying overlooked risks or usability issues. P2 shared an example: *"We once installed a new guardrail system based on a designer's spec, but site feedback showed it blocked crane visibility. HR collected that input, looped it back to design, and the solution was revised within days."* This example illustrates how real-time collaboration, facilitated by HR, can lead to dynamic improvements in safety and productivity.

Moreover, cross-functional collaboration was described as contributing to a shared safety culture, where ownership of risk is distributed, and silos are actively broken down. P12 stated, *"There's a visible shift in attitude when HR and safety are treated as co-authors of the design, not just post-design implementers. People feel more responsible, and that translates into safer behaviour."* Similarly, P9 added that "*collaboration builds context. When everyone knows why a safety feature exists, they're more likely to respect it and follow protocols."*

In summary, the findings underscore that cross-functional collaboration in PtD is not simply beneficial but necessary. Through joint planning, active feedback loops, and integrated digital platforms, organisations are creating more responsive, context-sensitive, and safety-driven design processes. HR's bridging role—between workforce needs and design realities—emerges as vital in ensuring that PtD is both technically sound and practically executable on the ground.

Cultural and organisational barriers

While most participants acknowledged the strategic benefits of Prevention through Design (PtD), many also identified persistent cultural and organisational barriers that hinder its full adoption. These challenges are deeply rooted in the hierarchical structures, conventional mindsets, and operational pressures that characterise much of the construction industry. Participants commonly described a

disconnect between safety ideals and actual practices, often driven by rigid organisational systems or resistance to change. For instance, P4 stated, "*You can have all the right policies, but if the senior leadership sees HR and safety as cost centres instead of strategic partners, nothing changes.*" This comment reflects a broader sentiment that structural power dynamics often limit the influence of HR and safety teams in design-related decisions.

One recurring theme was the presence of siloed departments that do not communicate effectively during the design and planning stages. Several interviewees expressed frustration with the lack of integrated processes, where design, HR, and safety teams operate independently rather than collaboratively. P11 noted, "*Everyone works in their lane. The designers focus on technical drawings, and HR is brought in after the fact to handle onboarding. There's no proactive engagement unless the culture supports it.*" This organisational fragmentation contributes to missed opportunities for early safety interventions and undermines the effectiveness of PtD.

Attitudinal resistance also emerged as a significant challenge. Many participants described a persistent "traditional mindset" in construction environments, where speed and cost are prioritised over proactive safety design. As P7 put it, "*Some supervisors still think PtD slows down the process or adds unnecessary steps. Convincing them otherwise is the real battle.*" This reluctance to change often stems from years of working under reactive safety models, where safety measures are implemented after incidents occur, rather than being embedded at the design stage. P2 emphasised this cultural inertia, saying, "*In older firms, people don't question design choices. They build what's on the drawing. Trying to introduce feedback loops or safety design inputs is seen as overcomplicating things.*"

Several participants also cited organisational priorities—such as tight deadlines, budget constraints, and a focus on project delivery—as practical barriers to integrating PtD with HR and safety strategies. P5, a design engineer, noted, "*We're constantly told to cut time and cost. That leaves little room to think about safety in the design. It's always about just getting it done.*" Similarly, P9 reflected on how safety design elements are sometimes excluded during value engineering phases, stating, "*We've had cases where features designed to improve safety were removed because they didn't 'add direct value' – a clear sign of where the priorities lie.*"

In some cases, the lack of clear communication and misalignment of objectives between departments was exacerbated by a hierarchical organisational culture that discourages feedback or alternative viewpoints. P6 highlighted this issue, saying, "*There's often a fear of speaking up. Junior staff or HR officers might see a design risk but won't challenge engineering because of the hierarchy.*" This hesitation can result in latent design risks being carried through into construction phases without mitigation.

In summary, the findings suggest that cultural and organisational barriers—such as rigid hierarchies, departmental silos, traditional mindsets, and misaligned priorities—pose serious obstacles to PtD integration. Overcoming these barriers requires not only structural change but also a cultural shift that repositions HR and safety as integral components of the design process. Without this transformation, the potential of PtD to reduce risk and enhance safety performance remains underutilised.

Safety culture impact

Participants across a range of roles consistently identified safety culture as both a critical outcome and a necessary condition for the successful implementation of PtD. They described how PtD initiatives not only improved tangible safety outcomes but also cultivated shared values, trust, and behavioural alignment around safety practices. PtD was frequently framed as a vehicle for embedding safety thinking into the organisational DNA, moving beyond compliance-based approaches to foster proactive, employee-driven safety cultures. P1 observed, "*When safety is embedded in design, people start seeing it as part of their everyday responsibility – not just something managed by the HSE team.*" This shift in perception—from external enforcement to internal ownership—was echoed by many others.

Several interviewees emphasised that PtD helped drive a more participatory safety culture, where employees at all levels feel empowered to engage in safety discussions. P7 reflected on this, saying, "*When workers see that their input during design reviews has been taken seriously – like changing a ladder angle or relocating a walkway – they become more invested in the safety process.*" This inclusive approach not only enhances the practicality of safety measures but also strengthens employee commitment to safe behaviours. P2, an HSE officer, elaborated further: "*It's no longer top-down. We're seeing more horizontal communication. Teams are more open to raising issues early, and safety isn't an afterthought – it's baked in.*"

Another key dimension of the safety culture discussed by participants was the role of trust and open communication. Several interviewees described how PtD initiatives supported a culture where safety

concerns could be raised without fear of blame or retaliation. P12 explained, *"Designing for safety creates a more transparent work environment. When people know the layout was made with their safety in mind, they feel valued, and that builds trust."* Trust was seen as a foundational component of safety culture—critical not only for communication but for fostering psychological safety and team cohesion on construction sites.

Participants also drew attention to how PtD influenced leadership behaviours, with several suggesting that visible commitment from senior leaders helped reinforce the importance of integrating safety and design. P3 commented, *"When senior management shows up to design review meetings and asks about safety features, it sends a message. It tells the team that this isn't just a compliance checkbox—it's core to how we operate."* P9 similarly emphasised that, *"Our safety culture improved when leadership started discussing safety metrics in design terms. They'd ask, 'Does this design reduce fall risks?' That's a major cultural shift."*

Moreover, the proactive orientation promoted by PtD was seen as instrumental in encouraging forward-thinking safety behaviour. Instead of reacting to incidents, workers and supervisors alike were trained to anticipate and mitigate risks from the outset. P10 reflected, *"We train our teams to look at designs and think, 'What could go wrong here?' That mindset wasn't there before we started doing PtD training."* This anticipatory approach was consistently linked to higher levels of engagement, accountability, and sustained safety performance.

In conclusion, the findings underscore that PtD plays a transformative role in shaping organisational safety culture. By facilitating participatory processes, enhancing trust, promoting leadership visibility, and nurturing proactive risk thinking, PtD initiatives contribute to a more embedded, resilient, and self-sustaining safety culture. Participants viewed this cultural evolution as essential to long-term improvements in both design effectiveness and operational safety outcomes.

Discussion

Summary of key findings

The study revealed that HR involvement is crucial for embedding safety into early design through strategic leadership. At the same time, training and competency development serve as foundational elements in preparing a safety-aware workforce. Cross-functional collaboration, particularly among HR, safety, and design teams, was found to facilitate the effective implementation of PtD through integrated planning and feedback. However, cultural and organisational barriers—such as hierarchical silos, traditional mindsets, and conflicting priorities—were identified as key obstacles to progress. PtD was also shown to positively influence safety culture by promoting trust, participation, and proactive risk engagement. Lastly, the evaluation of PtD effectiveness remained inconsistent, with limited reliance on structured metrics and feedback mechanisms.

Comparison with existing literature

The findings converge with and extend prior work at the HR–OHS–PtD interface while surfacing boundary conditions that temper overly general claims. The strategic involvement of HR in early design phases aligns with evidence that HR-led safety initiatives can enhance performance and project outcomes (Segbenya & Yeboah, 2022). It supports research indicating that expert risk perceptions are influenced by organisational structure and leadership presence (Trillo-Cabello et al., 2021). The present results add specificity: performance gains appear contingent on HR's ability to translate early participation into design-specific competence mapping, scheduling, and verification, rather than relying on generic policy signals alone.

Consistent with Pham et al. (2023), training emerges not as a one-size-fits-all intervention but as a context-bound process tied to the hazards and methods of each project. Interview accounts indicate that certification is an unreliable proxy for readiness in PtD-sensitive tasks, and that scenario-based, design-informed instruction—paired with practical check-offs—better closes the design–execution gap. Turkish studies complement this nuance by showing that training methods differentially affect on-site behaviour (Bayrak et al., 2021) and that safety culture levels are predictive of safe conduct, underscoring the importance of aligning pedagogy with cultural and site realities (Ayduran & Olcay, 2022; Olcay, 2021; Öngel, 2022).

Interdepartmental collaboration and digital enablement are broadly supported in the literature: collaborative platforms and model-based reviews facilitate PtD processes (Farghaly et al., 2022), and designer competence plus multidisciplinary teamwork are central enablers (Che Ibrahim et al., 2021). The present evidence refines this by highlighting workflow integration as the critical success factor: BIM adds safety value primarily when embedded into frontline routines (e.g., toolbox talks, pre-task briefings) rather than confined to coordination meetings. This qualification aligns with technology assessments that highlight both the potential and challenges of AI/IoT solutions—benefits for

visualisation and monitoring, alongside issues of acceptance, data quality, and privacy (Zhang, Shi, & Yang, 2020; Erol & Eraslan, 2024).

The barrier profile also complicates prior accounts. While systemic resistance and limited regulatory pull are established inhibitors in the U.S. context (Al-Bayati et al., 2024), respondents described hierarchical silos, traditional mindsets, and delivery-pressure trade-offs as immediate mechanisms that stall HR's strategic role in design. Regional evidence from Türkiye—persistent accident burdens in construction and the prominence of falls from height in SGK-based analyses—underscores the stakes and the need for earlier, design-stage controls (Gözüak & Ceylan, 2021; Çüçen & Kurtoğlu, 2024). Field studies on surveillance and equipment governance in the Turkish building sector further underscore the need to pair training with method-specific controls and oversight (Aydoğan & Uçan, 2022).

Education and leadership effects are consistent with claims that early safety education and visible leadership can normalise PtD (Ismail et al., 2024). Yet, the interviews suggest that relational practices—such as psychological safety, inclusive briefings, and HR–safety co-ownership of competence—are the proximal levers through which leadership influence materialises on site. This perspective helps reconcile positive policy intentions with variable on-site uptake documented in Turkish settings (Ayduran & Olcay, 2022; Öngel, 2022).

Finally, a measurement gap persists. Reviews call for integrated and predictive systems (Sánchez et al., 2017) and show that system adoption improves outcomes when culturally embedded (Kineber et al., 2023). Still, participants reported limited use of PtD-specific leading indicators—for example, hazard-elimination rates at concept, PtD-gate completion, or competency check-off coverage—relying instead on incidents or informal feedback. Methodological work on training effectiveness also indicates heterogeneous transfer across worker segments (Cao, Chen, & Cao, 2021), implying that indicator sets should be stratified and linked to exposure profiles. Digital infrastructures discussed in the literature (Zhang, Shi, & Yang, 2020; Erol & Eraslan, 2024) provide a feasible path to operationalising such indicators; however, adoption appears uneven without HR stewardship of metrics and incentives.

Implications for practice and industry

The findings of this study present important implications for practitioners across various levels of the construction industry. For human resource professionals, the research highlights a growing need to formalise their role in the design phase of construction projects. Rather than being involved only in recruitment and compliance activities, HR professionals should actively participate in early planning and collaborate with design and safety teams. Their insights into workforce capability, training needs, and organisational behaviour can play a crucial role in shaping design choices that prioritise safety from the outset. Establishing structured mechanisms—such as HR representation in design review boards or PtD committees—can ensure that safety is embedded not only in technical plans but also in workforce strategies.

Construction firms, meanwhile, are encouraged to adopt more integrated operational models that embed HR and safety experts into core design and coordination activities. Tools such as Building Information Modelling (BIM) provide a collaborative platform where multidisciplinary teams can jointly review design scenarios and assess safety implications. Including HR and HSE personnel in BIM coordination meetings enables the translation of technical safety requirements into workforce-friendly procedures and training plans, ensuring that the implementation of PtD is both practical and people-centred.

At the operational level, site supervisors and training coordinators can enhance safety performance by adopting design-informed training modules. Rather than relying solely on general safety inductions, firms should develop training materials based on project-specific hazards identified during the design phase. This allows workers to understand not only what safety procedures are expected but also why they are necessary, reinforcing both comprehension and compliance. Scenario-based training and visualisation tools, such as BIM walkthroughs or VR simulations, can further enhance engagement and contextual understanding.

Leadership also plays a pivotal role in the success of PtD strategies. For management teams, the findings suggest that leadership visibility and advocacy for PtD principles can drive meaningful cultural change. When senior leaders actively participate in design safety discussions and endorse HR-led safety planning initiatives, they signal the strategic importance of safety to the entire organisation. This helps to break down silos and foster a unified approach to safety that transcends departmental boundaries.

Finally, for policymakers and regulatory bodies, the study underscores the urgent need to develop comprehensive guidelines and assessment tools for PtD. While awareness of PtD is growing, its

implementation remains inconsistent across the industry, partly due to the lack of formalised frameworks and accountability structures. Regulatory authorities should consider mandating the integration of safety reviews into design approval processes and supporting the development of standardised metrics to evaluate PtD effectiveness. This will help institutionalise proactive safety planning and align industry practices with evolving international standards.

Measuring PtD effectiveness: Framework and index

To strengthen the practical contribution, Prevention through Design (PtD) effectiveness is specified as a measurable construct composed of four leading dimensions—Design Hazard Control Quality (DHCQ), Process Discipline (PD), Competency Readiness (CR), and Frontline Integration (FI)—together with a lagging outcomes check (Outcomes Impact, OI). Conceptually, DHCQ captures the extent to which hazards are eliminated or reduced at concept and schematic stages and the level of risk carried forward as residual; PD reflects the consistency and timeliness of design-safety reviews and residual-risk closure; CR assesses whether personnel executing PtD-critical tasks possess defined competencies, verified practical ability, and current refreshers; FI evaluates the degree to which safety intent is embedded in frontline routines (for example, BIM-integrated briefings and teach-backs) and whether designed methods are followed in practice. OI is retained as a triangulation layer that tracks injuries and rework specifically within PtD-tagged activities.

Operationalisation utilises a small set of auditable indicators, anchored in routine project artefacts. For DHCQ, the Design Hazard Elimination rate (DHE%) is defined as the number of hazards eliminated or substituted at concept divided by the number of hazards identified at concept, multiplied by 100. Residual risk is summarised as a Residual Risk Index (RRI), calculated as the sum of severity×likelihood for all residual hazards divided by the sum of maximum severity×maximum likelihood for all identified hazards; the index is scaled between 0 and 1, where lower values indicate better control. PD is captured by a PtD Gate Completion Ratio (GCR)—completed design-safety reviews at 30/60/90% divided by planned reviews—and a Residual-Risk Closure Lead Time (RRCLT), the median days from residual-risk registration to closure or formal transfer. CR comprises three coverage measures: Role Coverage (share of PtD-critical roles with competency standards defined in the HR information system), Check-off Coverage (share of workers who have passed a practical, design-specific assessment in the last six months among those assigned to PtD-critical tasks), and Refresher Compliance (share of due design-specific refreshers completed in the period). FI includes BIM Briefing Coverage (share of high-risk tasks executed with a BIM-supported pre-task briefing), Teach-back Pass Rate (share of attendees correctly restating critical steps and controls during the briefing), Method Deviation Rate (observed deviations from the designed method in PtD-tagged tasks per observation; lower is better), and Near-miss Density (near misses in PtD-tagged activities normalized per 200,000 work hours). OI reports the Recordable Incident Rate in PtD-tagged tasks (per 200,000 work hours) and Rework Hours attributable to method/design misalignment (as a fraction of total hours).

Indicator values are compiled from design risk registers and review minutes (DHCQ, PD), HRIS/LMS exports (CR), BIM logs and toolbox-talk records linked to task identifiers plus structured field observations (FI), and safety and cost/time control systems (OI). Leading indicators are calculated monthly and at major design gates (30/60/90%), while lagging outcomes are trended quarterly. To enable aggregation, leading indicators are min–max normalised to a 0–1 scale (beneficial indicators oriented so higher = better; adverse indicators reversed). Dimensional scores are computed as the arithmetic mean of normalised indicators within each dimension. A composite PtD Effectiveness Index (PtD-EI) is then reported as a weighted sum of the four leading dimensions—PtD-EI = 0.30·DHCQ + 0.20·PD + 0.20·CR + 0.20·FI—while OI is displayed separately for validation rather than folded into the index.

Interpretation focuses on decision-relevant thresholds and attribution. For instance, DHE% below approximately 40% or RRI above roughly 0.35 signals inadequate early hazard control and warrants additional elimination/substitution alternatives during concept design. Elevated RRCLT indicates bottlenecks in residual-risk management that should be addressed by reassigning owners or tightening gate criteria. Combinations of sub-scores help localise constraints: a low CR alongside acceptable DHCQ points indicates a people/skills gap; a low FI with a strong CR suggests a workflow-integration problem at the workface. Each indicator is mapped to an accountable owner (Design, HR/Learning, Safety, Site) with predefined corrective actions, thereby linking measurement directly to managerial levers.

Reliability and validity are supported through a definition "lock" (a glossary appended to the manuscript), quarterly audit samples of registers, toolbox logs, and observations, and routine triangulation of leading and lagging signals. Where quantitative pipelines are immature, a temporary maturity rubric (0 = absent to 4 = optimised) may be applied per indicator, to be replaced progressively

by numeric tracking as data capture stabilises. Visual reporting can be standardised using a radar plot of dimensional scores for cross-project comparison and a run chart of PtD-EI over time with an OI overlay on a secondary axis to check directional consistency.

Table 3: PtD Effectiveness Indicators, Definitions, Data Sources, and Frequency

Dimension	Indicator	Definition / Formula	Data Source	Frequency
DHCQ	Design Hazard Elimination (DHE%)	(Hazards eliminated/substituted at concept ÷ hazards identified at concept) × 100	Design risk register	Monthly & at gates
DHCQ	Residual Risk Index (RRI)	Σ(severity×likelihood residual) ÷ Σ(max severity×max likelihood); 0–1, lower = better	Design risk register	Monthly
PD	PtD Gate Completion Ratio (GCR)	Completed design-safety reviews at 30/60/90% ÷ planned reviews	Gate logs/minutes	At gates
PD	Residual-Risk Closure Lead Time (RRCLT)	Median days from residual-risk entry to closure/transfer	Risk log	Monthly
CR	Role Coverage	PtD-critical roles with defined competency standards ÷ total PtD-critical roles	HRIS	Quarterly
CR	Check-off Coverage	Workers with a passed practical assessment in the last 6 months ÷ assigned workers	LMS/HRIS	Monthly
CR	Refresher Compliance	Design-specific refreshers completed ÷ refreshers due	LMS	Monthly
FI	BIM Briefing Coverage	High-risk tasks executed with BIM-supported pre-task briefing ÷ total high-risk tasks	Toolbox/BIM logs	Weekly
FI	Teach-back Pass Rate	Individuals correctly restating critical steps/controls ÷ briefing attendees	Toolbox records	Weekly
FI	Method Deviation Rate	Deviations from designed method in PtD-tagged tasks ÷ observations; lower = better	Field observations	Weekly
FI	Near-miss Density	Near misses in PtD-tagged activities ÷ 200,000 work hours	Safety reports	Monthly
OI (lagging)	Recordable Rate—PtD	Recordables in PtD-tagged tasks ÷ 200,000 work hours	Safety reports	Quarterly
OI (lagging)	Rework Hours—PtD	Rework hours due to method/design misalignment ÷ total hours	Cost/time control	Quarterly

Embedding this framework as a discussion subsection provides a concrete, replicable basis for assessing PtD effectiveness, clarifies ownership of corrective actions, and links design-stage prevention to measurable managerial routines.

Recommendations for future research

Future research should consider conducting sectoral comparisons to examine how the integration of HR-led PtD strategies varies across different types of construction firms, such as those involved in residential versus infrastructure projects. Longitudinal studies are also recommended to assess the sustained impact of HR involvement on safety performance and project outcomes over time. Given the increasing use of digital technologies, further investigation into the role of tools such as Building Information Modelling (BIM) and virtual reality (VR) in facilitating PtD-based training and communication would provide valuable insights. Additionally, there is a need to develop and validate robust evaluation frameworks to measure the effectiveness of PtD, not only in terms of incident reduction but also in shaping organisational safety culture. Lastly, cross-cultural studies could shed light on how national or organisational cultures shape the perception and implementation of HR involvement in PtD, contributing to a more globally informed understanding of best practices.

Conclusion

Findings indicate that Human Resource Management (HRM) functions as a strategic integrator for Prevention through Design (PtD). When recruitment, onboarding, capability building, and performance systems are aligned with design-stage safety decisions, the gap between design intent and site execution narrows. Interview evidence from 12 professionals across HR, safety, and engineering roles points to early HR participation in design coordination, competency mapping, and scheduling of role-specific training as drivers of better PtD decisions and more substantial uptake in the field. PtD in construction is therefore best understood not only as a technical design choice but as an HR-enabled organisational change.

To translate these insights into routine practice, a practical implementation playbook can guide adoption. First, institutionalise PtD governance by naming a design-stage safety lead, formalising 30–60–90% "PtD gates," and maintaining a traceable risk register that flows from design into procurement, pre-task planning, and handover. Second, establish an HR-owned PtD competency framework for design-facing roles (designers, planners, supervisors) and embed it in job descriptions, hiring, promotion, and appraisal. Third, prioritise task- and design-specific training: pair BIM-enabled walkthroughs with brief work-face competency assessments for high-risk tasks; use micro-refreshers triggered by exposure frequency or design changes; and evaluate training transfer through supervisors' routine observations. Fourth, deploy a measurement bundle combining leading and lagging indicators, such as: (i) share of design hazards eliminated at concept; (ii) completion rate of PtD gates and closure time for residual risks; (iii) proportion of workers competency-checked for PtD-critical tasks; (iv) rate of BIM-supported pre-task briefings; and (v) near-miss density in PtD-tagged activities. Alignment with national OHS requirements and professional education should reinforce these routines, including curricula that assess PtD competencies and internships exposing students to design-stage risk decisions.

Context-specific actions can overcome common barriers. Where silos and schedule pressure dominate, mandate joint HR–Safety–Design reviews for methods that alter risk profiles (e.g., modular lifts, complex temporary works). Where certification fails to predict work readiness, implement practical competency evaluations tied to the actual design (e.g., anchor-point installation, access/egress constraints) and schedule automatic refreshers when gaps or infrequent exposure are detected. Where digital tools are available, integrate BIM views into toolbox talks and record attendance plus brief "teach-back" confirmations to strengthen accountability and learning culture. These interventions are low-cost, auditable, and scalable across projects.

Limitations should be acknowledged. The sample (N = 12) supports thematic depth but cannot represent all organisational forms, regions, or delivery models; accounts are self-reported rather than observed; and the inquiry was bounded in time and geography. Future research should employ longitudinal, mixed-methods designs that track the proposed leading indicators across multiple projects, link them to cost, schedule, and injury outcomes, and compare alternative rollout strategies (e.g., phased versus full-bundle). Multi-site studies spanning firm sizes and delivery models (design–bid–build versus design–build) can clarify where HR-enabled PtD routines yield the highest returns. Additional work should assess digital enablers (BIM-driven briefings, VR micro-simulations, and IoT-based exposure signals) for their incremental impact on competency and incident reduction, and examine policy levers (client requirements and contract clauses) that normalise PtD gates and HR-owned competency standards.

Overall, PtD effectiveness depends on treating HR as the owner of the people-side infrastructure for safe design—competencies, training, incentives, and measurement—while designers and constructors steward technical choices and methods. When these responsibilities are synchronised and systematically measured, PtD evolves from a principle to a repeatable routine, improving safety performance, project reliability, and workforce trust.

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