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EXAMINING SAFETY BEHAVIORS OF HIGHWAY CONSTRUCTION WORKERS

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ABSTRACT: Highway construction remains one of the most hazardous sectors in the U.S., with safety incidents frequently attributed to behavioral and procedural failures. To enhance compliance, safety incentive and disincentive programs have been implemented across state Departments of Transportation (DOTs), yet their effectiveness varies based on workers' perceptions of fairness, attainability, and relevance. This study examines which elements of these programs highway construction workers find most effective and develops a behavioral safety framework grounded in the Theory of Planned Behavior (TPB). Analysis of safety programs across 50 state DOTs reveals that 32 state DOTs have safety incentive programs, with states like Arizona achieving a 20% reduction in work zone incidents through contractor bonuses, while Missouri's telematics-based enforcement led to a 99.5% decrease in speeding violations. Interviews with six DOT safety managers indicate mixed program effectiveness, with some states transitioning from punitive measures to education-focused models. The framework developed in this study consists of five stages: need identification, worker engagement, program assessment, strategic deployment, and continuous evaluation. Key findings emphasize the importance of financial incentives, real-time monitoring technologies, and continuous training in improving compliance and reducing incidents. This study offers DOTs an adaptable, data-driven framework to foster proactive safety behaviors and achieve sustainable safety improvements in highway construction.

1. INTRODUCTION

The construction industry consistently reports one of the highest rates of workplace injuries and fatalities in the United States, particularly in highway construction, where workers face hazardous conditions such as high-speed traffic, heavy machinery, and unpredictable site environments. Despite ongoing efforts to reduce risks, highway construction workers continue to experience high rates of accidents and fatalities (Census of Fatal Occupational Injuries Summary, 2022). To address these safety concerns, many state Department of Transportation (DOTs) implement safety incentive and disincentive programs, which encourage workers to follow safety protocols by rewarding safe behaviors and penalizing unsafe ones. Research suggests that well-designed incentive programs can enhance safety awareness and compliance (Ahmed & Faheem, 2021). However, their effectiveness varies significantly across different worksites. There is limited research on which specific elements of these programs' workers find most effective in promoting safe behaviors. Without this understanding, programs may struggle to engage workers, resulting in minimal behavioral change and continued safety risks on job sites. Worker perceptions of fairness, attainability, and relevance are critical to the success of safety incentive programs (Bhandari et al., 2019). If workers view a program as unfair or unattainable, they may resist participation, ultimately reducing its

effectiveness. Therefore, it is essential to explore not just the presence of safety incentive programs, but also how workers interact with them, perceive them, and respond to them in practice.

Previous research highlights multiple factors that influence the effectiveness of safety incentive programs for highway construction workers. These include psychological, organizational, motivational, and data-driven elements, each of which plays a distinct role in shaping worker behavior. Intrinsic motivation and autonomy drive long-term behavioral change (Deci & Ryan, 2013). Positive reinforcement is more effective than punitive measures in encouraging compliance (Geller & Geller, 2020). From an organizational perspective, a strong safety climate, clear communication, and management support are essential for fostering trust and engagement in safety programs (Bhandari & Hallowell, 2022; Chen et al., 2021). Psychological contracts between workers and management further reinforce this engagement (Newaz et al., 2019). However, financial incentives alone often fail to sustain long-term safety improvements (Ahmed & Faheem, 2021). A balanced approach, combining financial rewards with personal recognition and intrinsic motivation, proves more effective (Azeez et al., 2019; Maslen & Hopkins, 2014).

In addition to psychological and organizational factors, leadership and data-driven safety management also play crucial roles in ensuring the success of incentive programs. Strong site leadership fosters a safety-first culture. Concurrently, data-driven approaches offer critical insights that refine and optimize safety incentives (Grill & Nielsen, 2019; Liu & Liu, 2022). Additionally, advancements in predictive analytics help identify high-risk behaviors and safety trends (Sohail et al., 2023; Koc et al., 2023). These insights allow for continuous refinement of safety incentive structures, making them more effective in reducing workplace injuries. The integration of active and passive safety indicators further enhances program evaluation, ensuring that incentive programs are empirically guided and continuously refined to improve effectiveness (Alruqi & Hallowell, 2019; Gambatese et al., 2017). This study identifies key elements of safety incentive programs that highway construction workers find most effective, aiming to design worker-centered initiatives that enhance engagement, reduce injuries, and improve site safety.

2. RESEARCH METHOD

This study employs a mixed-method research approach to examine safety behaviors among highway construction workers. The methodology includes a comprehensive literature review, an in-depth analysis of safety programs from all 50 DOTs, and structured interviews with six DOT safety experts. The literature review synthesizes existing research on behavioral safety approaches, safety incentive programs, and risk mitigation strategies in the construction industry. The in-depth analysis evaluates the structure, effectiveness, and variations in incentive and disincentive policies, identifying best practices and gaps. This systematic analysis provides insights into diverse strategies used by DOTs to enhance safety compliance and reduce workplace incidents.

Additionally, interviews with six DOT safety experts provide insights into the real-world implementation and perceived effectiveness of these programs. The interviewees, including safety managers, risk management officers, and program coordinators, offered detailed perspectives on success factors, challenges and recommended improvements for safety initiatives. The collected data were analyzed thematically to identify recurring patterns in program effectiveness, worker engagement, and policy adaptation. By triangulating findings from the literature, program analysis, and expert interviews, this study develops a refined, worker-centered framework to enhance safety behaviors in highway construction zones.

2.1 Literature Review

Psychological factors such as motivation, risk perception, and behavioral reinforcement play a crucial role in shaping safety behaviors among highway construction workers. Intrinsic motivation, driven by autonomy and perceived competence, fosters long-term safety engagement, while extrinsic motivators, such as incentives, often yield temporary compliance (Deci & Ryan, 2013). Risk perception, influenced by past experiences and environmental hazards, significantly impacts workers' decision-making and adherence to safety protocols (Xia et al., 2020). Reinforcement strategies that emphasize positive consequences over punitive measures enhance compliance with safety standards and foster a proactive safety culture (Geller

& Geller, 2020). Additionally, psychological safety—where workers feel comfortable reporting hazards without fear of punishment—strengthens safety commitment and hazard recognition, reducing workplace incidents (Hasanzadeh et al., 2019).

Organizational factors, including safety climate, leadership, and policy implementation, form the foundation for effective safety management in highway construction. A strong safety climate—where management visibly prioritizes safety through consistent communication and enforcement—encourages worker compliance and reduces risk tolerance (Chen et al., 2021). Transformational leadership fosters trust by emphasizing safety as a shared responsibility and motivating workers to adopt safe behaviors (Bhandari & Hallowell, 2022). However, inconsistencies in policy implementation, such as unclear accountability and fragmented communication, can undermine safety initiatives and create gaps in compliance (Newaz et al., 2019). Organizations that promote fairness and worker autonomy achieve higher safety adherence, as employees who perceive equitable treatment and control over their work are more likely to engage in safe behaviors (Jung et al., 2020).

Motivational strategies, including incentives, recognition, and performance-based rewards, are critical in reinforcing safe behaviors. Financial incentives can initially improve compliance, but their effectiveness often diminishes over time unless integrated with intrinsic motivators such as peer recognition and career development opportunities (Ahmed & Faheem, 2021). Training programs that evoke emotional arousal, such as immersive injury simulations, enhance worker engagement and long-term retention of safety knowledge (Bhandari et al., 2019). Additionally, predictive analytics and real-time monitoring systems help identify high-risk behaviors, enabling organizations to refine safety interventions proactively (Koc et al., 2023). Leading indicators, including regular safety training, proactive hazard identification, and near-miss reporting, provide a forward-looking approach to preventing workplace incidents (Hinze et al., 2013). Thus, an integrated framework that combines behavioral reinforcement, leadership support, and technological interventions is essential for sustainable safety improvements in highway construction.

2.2 Analysis of Safety Programs from all 50 State DOTs

The analysis of safety incentive and disincentive programs across all 50 State DOTs highlights the widespread adoption of structured programs to enhance highway construction worker safety. Out of the 50 DOTs reviewed, 32 have formalized programs that integrate financial incentives, training, and enforcement measures, while 18 rely on informal awareness campaigns without structured rewards or penalties. States such as Michigan DOT, Missouri (MoDOT), and Pennsylvania (PennDOT) have long-standing safety initiatives, with Michigan DOT implementing structured recognition programs for over ten years, while MoDOT offers long-term safety awards for employees maintaining injury-free records. Financial incentives have proven effective in states like Arizona (ADOT), where the implementation of contractor bonuses contributed to a 20% reduction in work zone incidents under the Strategic Highway Safety Plan (SHSP). However, in some states, such as Kentucky (KYTC) and Maine (MaineDOT), safety programs remain largely informal, focusing on general awareness without structured rewards or penalties, limiting their long-term effectiveness.

Data analysis reveals that states with well-structured safety incentive programs experience higher compliance rates and improved safety metrics. MoDOT's Good Catch program, for example, encourages proactive safety measures, with recognized employees being featured in internal safety bulletins. In contrast, Georgia DOT (GDOT) has transitioned from punitive measures to a performance-based incentive program that includes rewards such as high-quality safety gear for workers who consistently adhere to safety guidelines. Additionally, financial incentives in states like California (Caltrans) and Texas (TxDOT) have demonstrated effectiveness in reducing workplace injuries by integrating real-time safety monitoring and advanced technology. On the other hand, states that rely primarily on informal safety awareness campaigns without financial motivation tend to have higher rates of underreporting incidents, as observed in MoDOT, which shifted away from team-based incentives due to concerns about hidden injuries.

The findings emphasize the importance of integrating education, incentives, and enforcement into a cohesive safety framework to enhance worker compliance and reduce incidents. Successful models, such as Minnesota's (MnDOT) and PennDOT's, have demonstrated that a structured approach—incorporating

financial incentives, training, and strict safety enforcement—results in higher engagement and improved safety outcomes. However, opportunities remain for improvement, particularly in states with informal programs, which could benefit from adopting structured incentive frameworks. The data suggests that future improvements should focus on increasing financial incentives, integrating real-time safety monitoring technologies, and strengthening worker engagement to enhance program effectiveness further. By adopting these best practices, state DOTs can create safer highway construction environments and improve overall compliance with safety standards.

2.3 Structured Interviews

The interviews were conducted with six state DOTs —Pennsylvania (PennDOT), New Mexico (NMDOT), Michigan DOT, Mississippi DOT, Georgia (GDOT), and Missouri (MoDOT)—to assess safety incentive and disincentive programs. The interview questions placed emphasis on program implementation, challenges, and worker behavior changes across four key areas: program details, perceptions and effectiveness, training and communication, and lessons learned. The study found that DOTs employ a combination of incentive-based and disincentive-based safety programs to encourage compliance with safety regulations. PennDOT and NMDOT have used both incentives and disincentives for over 10 years, while Michigan DOT primarily focuses on disincentive measures due to budget constraints and OSHA guidelines. NMDOT's incentive programs include safety awards, service recognition, and non-monetary rewards such as Carhartt jackets and Yeti mugs for accident-free milestones. For example, PennDOT offers funding for equipment valued between $180,000 and $250,000 as group rewards for meeting safety goals. Meanwhile, MoDOT has observed a 99.5% reduction in speeding violations due to its telematics-based disciplinary measures, indicating that data-driven enforcement strategies can be highly effective in modifying unsafe behaviors.

The effectiveness of safety incentive and disincentive programs varies significantly across the six state DOTs. GDOT reported positive engagement after shifting its focus to rewarding employee participation through safety gear, tools, and regular training incentives. Michigan DOT initially faced challenges with a fear-based compliance model, where workers hid infractions due to fear of penalties, but later improved engagement by transitioning to an educational approach emphasizing safety awareness and training. Mississippi DOT enhanced workplace engagement by raising the criteria for its Safety Excellence Awards, motivating employees to achieve higher safety standards. Conversely, PennDOT experienced challenges due to high employee turnover and the negative perception of its pre-disciplinary conferences (PDCs), which were seen as punitive measures for safety violations. Despite these challenges, DOTs that implemented continuous training, leadership involvement, and regular feedback mechanisms—such as NMDOT and MoDOT—reported improvements in safety culture, increased compliance, and proactive safety behaviors among workers.

Training and communication are critical to the success of safety programs, with several DOTs implementing structured sessions. GDOT conducts monthly flagger training, first aid/CPR sessions, and quarterly fire extinguisher training, ensuring workers are consistently engaged with safety practices. Michigan DOT holds quarterly statewide safety committee meetings and provides training through new employee orientations, annual OSHA updates, and courses from Eastern Michigan University. PennDOT reinforces safety objectives through annual letters from the Secretary of Transportation and monthly safety committee meetings. NMDOT uses administrative directives and annual award ceremonies to communicate safety standards, while Mississippi DOT relies on safety officers and regular maintenance meetings for training and recognition. MoDOT, although lacking formal structured safety program training, communicates objectives through regular department-wide meetings, including new hire orientations and the annual Stand Up for Safety Day. However, Michigan DOT, NMDOT, and MoDOT rely heavily on general safety orientations or external OSHA updates without tailored training specific to their safety incentive programs. Moving forward, enhancing worker feedback mechanisms, increasing the value of safety awards, and refining disciplinary frameworks to emphasize coaching over punishment are essential for improving program sustainability. The study highlights the need for well-structured, balanced safety initiatives that align worker motivation with organizational safety goals, reduce workplace incidents, and foster a proactive safety culture.

2.3.1 Financial Incentives

Financial incentives, as defined within the context of this study, encompass both monetary and non-monetary rewards designed to promote and sustain safe behaviors among highway construction workers. These incentives vary in form, delivery, and eligibility. Cash bonuses, though rare due to OSHA concerns noted by Michigan DOT, may include hypothetical rewards such as $100 per month for no violations. Team-based equipment awards, such as PennDOT's $180,000–$250,000 grants, reward district-level achievement of safety goals. Recognition and leave incentives, like those used by NMDOT and MoDOT, include administrative leave or public acknowledgments in agency communications. Material rewards feature non-cash items like NMDOT's tiered service awards (Yeti mugs at 5 years, Carhartt jackets at 20 years) and GDOT's branded PPE duffel bags. Short-term incentives, used to reinforce consistent safety behavior, include gift cards, tokens, or refreshments (e.g., Gatorades) as seen in NMDOT practices. Long-term service awards, such as MoDOT's 15-year plaques and safety-themed items, honor sustained injury-free performance. Across all categories, compliance conditions are emphasized to ensure OSHA alignment and mitigate underreporting; for example, MoDOT has shifted from team-based to individual incentives to preserve transparency and accountability.

3. FRAMEWORK DEVELOPMENT

3.1 Framework Basis

The framework developed in this study was based on behavioral and planned safety approaches. The Behavioral Safety Approach for Highway Construction Workers is a structured framework designed to improve safety behaviors by addressing psychological, social, and operational factors specific to construction environments. Grounded in the Theory of Planned Behavior (TPB), the framework enhances workers' safety attitudes (belief in the importance of safety), reinforces safety influences (peer support, supervisory expectations, and organizational commitment), and strengthens safety controls (adequate safety equipment, comprehensive training, and safe working conditions). TPB posits that attitudes, social norms, and perceived behavioral control shape individuals' intentions and actions, making it a reliable model for promoting safe behaviors (The Theory of Planned Behavior, 2020). When TPB principles are integrated into structured safety programs—aligning with organizational goals and leveraging real-time safety data—workplace incidents can be reduced by up to 22% (Chen et al., 2021).

3.2 Framework Development

The framework is developed through five key stages. The need identification stage assesses safety challenges by collecting data from DOT safety programs and worker feedback (Newaz et al., 2019). The worker engagement stage fosters participation through incentive-based rewards, training initiatives, and peer accountability measures (Dadi et al., 2023). The program assessment stage evaluates effectiveness using safety audits, behavioral analytics, and feedback loops to measure program impact and identify areas for improvement (Kim et al., 2019). The strategic deployment stage scales safety measures from pilot projects to full district-wide implementation, ensuring adaptability across various construction environments (Muñoz-La Rivera et al., 2021). Finally, the continuous evaluation stage integrates real-time hazard detection and feedback systems, allowing for ongoing refinement and optimization of the framework (Sohail et al., 2023).

To improve clarity, consistency, and implementation efficiency, the research framework for highway construction worker safety was enhanced and streamlined into four stages. Stage 1: Develop & Launch Safety Program combines the initial need assessment, program creation, and worker engagement strategies to ensure a structured and well-communicated safety initiative. Stage 2: Assessment evaluates program effectiveness through safety audits, behavioral analytics, and worker feedback, ensuring that interventions are data-driven and responsive to workforce needs. Stage 3: Deployment scales the safety program from pilot projects to broader district-wide applications, promoting adaptability across varying construction environments. Finally, Stage 4: Evaluation & Implementation focuses on continuous

monitoring, reporting, and lessons learned to refine safety strategies over time. Figure 1 presents this enhanced framework, integrating established DOT practices with behavioral safety principles, such as intrinsic motivation and emotional engagement, to foster sustainable safety behaviors among highway construction workers. This structured approach aligns safety programs with worker psychology, improving long-term compliance and reducing workplace incidents.

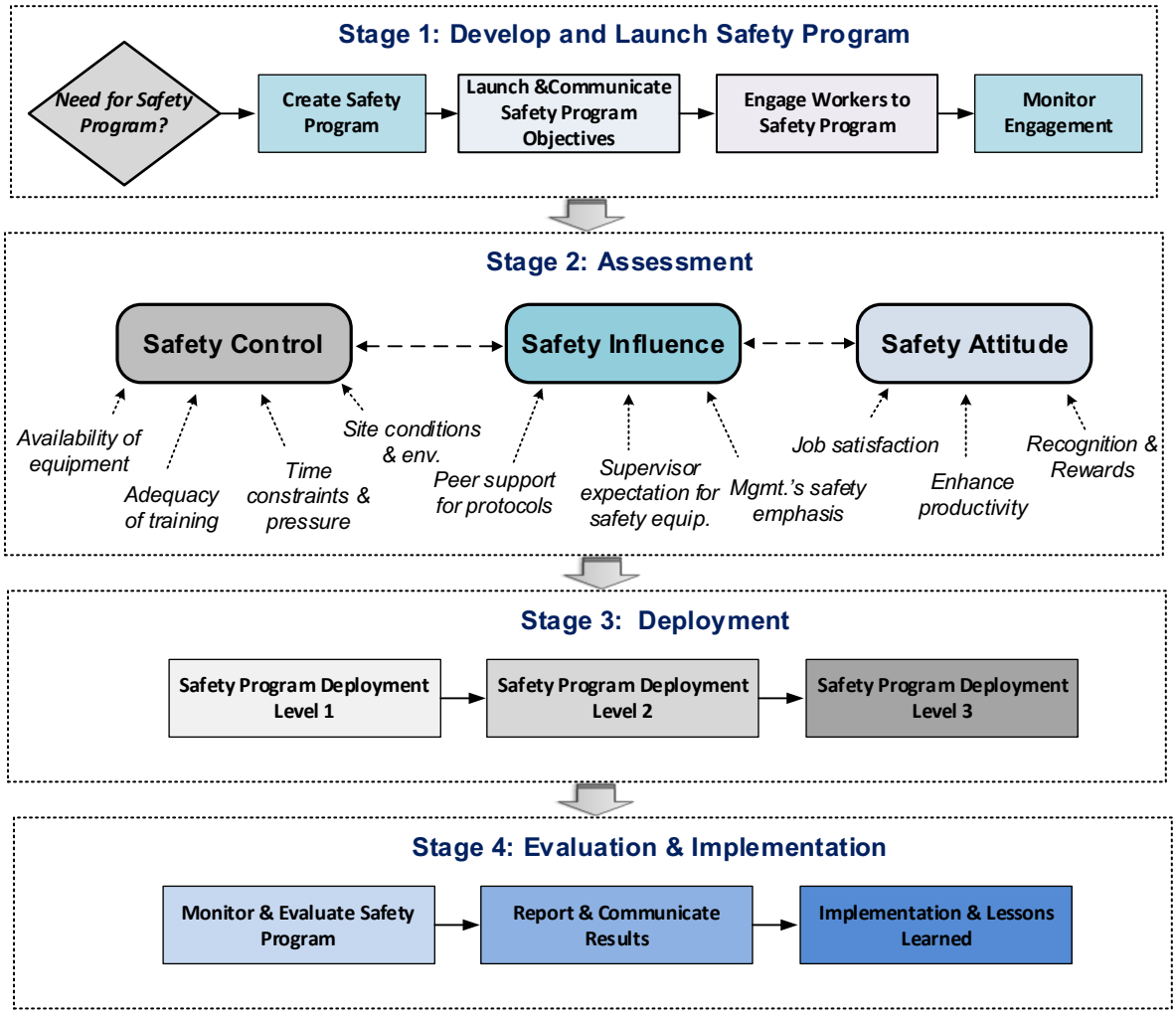

Figure 1: Enhanced Framework for Highway Construction Worker Safety

3.2.1 Stage 1: Develop and Launch Safety Program

Stage 1 establishes the foundation for an effective safety framework through five key components (Figure 1). It begins with identifying the Need for a Safety Program by assessing existing gaps and risks. Next, creating the Safety Program, incorporating structured training, incentives, and compliance measures tailored to workforce needs. The Launch & Communication phase ensures that the program's goals and expectations are clearly conveyed to workers and stakeholders through meetings, training sessions, and visual aids. Worker Engagement then fosters active participation through behavioral safety principles, peer accountability, and incentive-based motivation. Finally, Monitoring Engagement tracks participation and identifies areas for improvement. This structured approach ensures a well-integrated safety framework, setting the stage for assessment and deployment.

3.2.2 Stage 2: Assessment

Stage 2 evaluates the effectiveness of the safety program through three key components: Safety Control, Safety Influence, and Safety Attitude (Figure 1). Safety Control examines external factors that impact compliance, such as the availability of safety equipment, site conditions, time constraints, and work pressure. Safety Influence assesses how supervisors, peer support, and management commitment shape workers' adherence to safety protocols, emphasizing the role of leadership in fostering a safety-driven culture. Safety Attitude focuses on individual perceptions, job satisfaction, and motivation, highlighting how personal beliefs influence safe behaviors. It also considers the impact of recognition and rewards, which reinforce positive safety practices by incentivizing adherence to protocols. Together, these components provide a systematized approach to identifying program strengths and areas for improvement, ensuring continuous enhancement of workplace safety.

3.2.3 Stage 3: Deployment

Stage 3 focuses on implementing the safety program across different project scales through three key components: Safety Program Deployment Level 1, Level 2, and Level 3 (Figure 1). Level 1 begins with pilot projects, where safety measures are tested on a smaller scale to assess feasibility and effectiveness before broader application. Level 2 expands the program to various work environments, including both high-risk and low-risk highway construction sites, ensuring adaptability across different operational conditions. Level 3 represents full-scale deployment, where safety measures are standardized and implemented across all relevant projects within a district or statewide. This tiered deployment strategy allows for gradual refinement, ensuring that lessons learned from earlier stages contribute to optimizing the program. By systematically scaling safety initiatives, this stage enhances consistency, strengthens worker adherence, and ensures long-term integration of safety practices in highway construction projects.

3.2.4 Stage 4: Evaluation & Implementation

Stage 4 ensures the continuous improvement of the safety program through three key components: Monitor & Evaluate Safety Program, Report & Communicate Results, and Implementation & Lessons Learned (Figure 1). Monitoring & Evaluation involves tracking safety performance metrics, analyzing incident reports, and assessing worker compliance to determine the program's effectiveness. Reporting & Communicating Results ensures that findings are shared with key stakeholders, including safety managers, supervisors, and workers, fostering transparency and informed decision-making. Finally, Implementation & Lessons Learned focuses on refining safety initiatives based on evaluation outcomes, addressing identified gaps, and integrating best practices for continuous improvement. This systematized approach helps create a dynamic safety framework that adapts to changing work conditions, enhances worker engagement, and promotes a proactive safety culture in highway construction projects.

3.3 Quantitative Indicators and Metrics for Framework Application

To ensure the Behavioral Safety Approach (BSA) framework is both conceptually robust and operationally effective, a detailed set of quantitative metrics has been integrated into the framework. These metrics, extracted from validation interviews with six state Departments of Transportation (DOTs), offer measurable indicators that align with each of the framework's five core stages. Their inclusion strengthens the framework's practical utility by enabling ongoing monitoring, assessment, and adaptation of safety programs in highway construction environments.

At Stage 1 (Need Identification), the Incident Frequency Rate (IFR)—calculated as OSHA-reportable incidents per 200,000 work hours—serves as a baseline for determining the necessity of launching or revising safety initiatives. Additional lagging indicators, including total injuries, lost-time incidents, and vehicular crashes, support program justification. Stage 2 (Worker Engagement) uses metrics such as Engagement Rate (participation in toolbox talks or training), Participation Index (worker-initiated safety actions such as near-miss reports), and Survey Response Rate to assess safety culture perception. At Stage 3 (Program Assessment), the PPE Compliance Rate tracks job-site adherence to protective

equipment usage, while Behavioral Audit Scores, Incentive Redemption Rates, and Training Completion Rates measure program impact on individual and group behavior. Stage 4 (Strategic Deployment) employs a Safety Program Maturity Index to determine the level of implementation (pilot, district-wide, or statewide), and a Coverage Ratio to assess the geographic or organizational spread of the program. Finally, Stage 5 (Continuous Evaluation) includes Improvement Rate (%) to track trends in incident reduction, Retention of Safe Behavior to evaluate long-term compliance (typically over a 12-month cycle), and the Feedback Implementation Rate to capture how well leadership incorporates worker suggestions into program refinements.

The applicability of these metrics is reinforced by real-world practices from the participating DOTs. For instance, NMDOT ties its five- and 20-year safety milestones—such as branded Yeti mugs and Carhartt jackets—to employee work hours logged without a recordable incident. PennDOT uses performance-based group incentives, awarding between $180,000 and $250,000 in equipment grants to districts meeting safety targets. These examples demonstrate how the proposed metrics are not only theoretically grounded but also actively deployed, making the framework both replicable and adaptable across various jurisdictions.

4. VERIFICATION AND DISCUSSION

The verification of the proposed framework was conducted through an iterative process involving five state DOTs—Missouri (MoDOT), Michigan DOT, Mississippi DOT, Pennsylvania (PennDOT), and New Mexico (NMDOT). The initial framework was presented to each DOT, and the resulting feedback was integrated into the framework at each stage. With every round of feedback, adjustments were incorporated and presented to the next DOT, ensuring continuous improvement and alignment with real-world safety practices. This iterative validation process led to the final Behavioral Safety Approach for Highway Construction Workers, incorporating key refinements like improved assessment metrics and real-time safety monitoring technologies. Successful implementation of the Behavioral Safety Approach requires strong leadership commitment and alignment with existing safety policies (Grill & Nielsen, 2019). Additionally, digital tools like wearable sensors and mobile reporting applications enable real-time hazard detection (Sun et al., 2020), while engagement strategies such as recognition programs, peer feedback, and continuous training foster worker participation and compliance. This structured, adaptable framework enhances safety management strategies and reduces incidents on highway construction sites (Bitar et al., 2022; Ahmed & Faheem, 2021).

The verification process began with MoDOT, which emphasized the importance of balancing safety incentives and disincentives to ensure sustained worker engagement. Feedback from MoDOT highlighted the need to integrate both behavioral and disciplinary measures, leading to refinements in how the framework addressed safety culture and compliance tracking. Next, Michigan DOT provided valuable insights into the structural flow of the framework, suggesting modifications to the decision-making process within the safety program assessment stage. Their recommendations improved clarity in distinguishing between safety program evaluations and decision points, ensuring that DOTs could systematically determine necessary refinements based on real-time data. Additionally, Michigan DOT stressed the importance of replacing the term accidents with incidents to align with modern safety terminology and regulatory standards.

As the framework progressed through validation, Mississippi DOT emphasized the importance of continuous training and education in reinforcing worker safety behaviors. Their input led to the inclusion of structured training cycles and proactive hazard identification strategies. PennDOT further refined the approach by advocating for stronger alignment between safety incentives and existing organizational policies, ensuring that implementation did not conflict with union regulations or established workforce management structures. Finally, NMDOT reinforced the importance of defining the framework as a safety process rather than a safety program, highlighting the need for a dynamic, evolving system rather than a static set of guidelines. This shift emphasized ongoing improvement, real-time data integration, and adaptability to emerging safety challenges. These iterative refinements collectively strengthened the Behavioral Safety Approach for Highway Construction Workers, ensuring its practicality, scalability, and effectiveness in mitigating safety risks across highway construction environments.

4.1 Case Studies: Evidence of Framework in Practice

Validation feedback from New Mexico and Pennsylvania Departments of Transportation provided strong confirmation of the Behavioral Safety Approach (BSA) framework's real-world applicability. New Mexico DOT validated Stages 1 (Need Identification), 2 (Worker Engagement), and 4 (Strategic Deployment), underscoring the importance of an evolving safety model. As their risk manager stated, “A program gets shelved. A process evolves,” emphasizing the need for continuous adaptation rather than static solutions (A. Peinado, personal communication, October 29, 2024). PennDOT demonstrated alignment with Stages 4 (Strategic Deployment) and 5 (Continuous Evaluation) through district-level incentive programs, including equipment grants tied to performance and the integration of over 1,000 worker-generated safety recommendations. “We had 39 near-misses… that’s what we used to push for policy change. You need data to drive reform,” their representative explained, reinforcing the framework’s emphasis on data-driven safety enhancements (D. McArdle, personal communication, October 10, 2024). Both agencies confirmed that the BSA framework functions as a practical, flexible roadmap for institutionalizing worker engagement, management accountability, and long-term safety culture improvements in highway construction environments.

5. CONCLUSIONS

The findings of this study highlight the significance of integrating behavioral, organizational, and data-driven strategies to enhance safety behaviors among highway construction workers. While safety incentive and disincentive programs have been widely implemented, their effectiveness remains variable, largely dependent on worker perceptions, program design, and organizational support. The study's analysis of safety programs across all 50 state DOTs revealed that structured incentive programs, when aligned with organizational goals, can significantly improve compliance rates. Furthermore, insights from interviews with DOT safety experts underscore the importance of balancing incentives with clear communication, leadership commitment, and real-time safety monitoring technologies to ensure sustained worker engagement and participation.

The proposed Behavioral Safety Approach framework, grounded in the Theory of Planned Behavior, provides a structured methodology for improving safety outcomes. The framework consists of five stages: need identification, worker engagement, program assessment, strategic deployment, and continuous evaluation. The integration of predictive analytics, leading safety indicators, and peer-driven accountability mechanisms has been shown to reduce workplace incidents and foster a proactive safety culture. Additionally, the study demonstrates that incentive programs incorporating both financial rewards and intrinsic motivators—such as peer recognition and leadership engagement—are more effective in promoting long-term safety behaviors compared to punitive-only approaches.

This research has several limitations that warrant future research. First, there is a need to conduct case studies to further verify the framework results and suggestions for implementation. Additionally, future research should explore the scalability of this framework across different construction sectors, as well as the long-term impact of real-time safety monitoring technologies on behavioral safety outcomes. By continuously refining safety programs based on worker feedback and emerging safety trends, DOTs and construction organizations can create more adaptive and resilient safety management systems that ensure the well-being of their workforce.

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