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Driving Safety Performance and Business Resilience in India's Agro and Food-Processing Industries: Integrating Safety Culture, Behaviors-Based Safety and Proactive Risk Management

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Abstract

Food-processing safety depends on more than machinery safeguards, statutory compliance and written procedures. It is also shaped by leadership priorities, worker participation, supervisory practice, reporting climate and everyday decisions at the point of work. Behaviors-Based Safety (BBS) offers a structured means of observing critical behaviors, providing feedback and generating operational learning, but it can become counterproductive when it individualizes blame or substitutes for engineering and process-safety controls. This conceptual review integrates safety-culture theory, BBS principles, occupational-health-and-safety management and food-processing risk into a sector-specific framework for maize-processing industries. A structured narrative review was undertaken using foundational peer-reviewed literature and authoritative guidance relating to safety culture, safety climate, behavioral safety, worker participation, combustible dust, grain handling and ISO 45001. The synthesis identifies distinctive maize-processing risk interfaces across grain receipt, cleaning, wet or dry milling, starch separation, drying, sweetener and sorbitol production, chemical handling, utilities, warehousing and maintenance. The proposed framework places a BBS observation–feedback–learning cycle within six system conditions: leadership and just culture; worker participation and competence; hazard and process knowledge; hierarchy of controls and critical barriers; integration with food-safety and quality behavior; and data-driven continual improvement. The framework argues that safe behavior is an outcome of system design as well as individual action. It therefore requires observations to capture contextual barriers, assign corrective actions to appropriate system owners and verify effectiveness. The paper proposes implementation stages, governance arrangements and balanced leading and lagging indicators suitable for maize-processing facilities. Empirical validation through longitudinal, multi-site and mixed-method research is recommended.

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INTRODUCTION

Occupational safety remains a global development and business-continuity concern. The International Labour Organization estimates that 2.93 million workers die each year from work-related factors, with work-related disease accounting for the majority of the burden (ILO, 2023) [1].

Preventing harm requires reliable technical controls, but experience across high-risk industries

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shows that technology alone cannot determine how hazards are perceived, discussed and managed during routine and abnormal work.

The food-processing sector presents an unusually broad safety interface. Production systems combine moving machinery, conveyors, automated packaging, pressure and steam, chemicals, cleaning and sanitation, mobile equipment, laboratories, refrigeration, boilers, confined spaces and warehousing. In maize processing, this profile is intensified by grain and starch dust, dryers, silos, elevators, milling systems, wet-process chemicals, syrup and sweetener operations, hydrogen in selected derivative processes, and large utility loads. Occupational Safety and Health Administration guidance specifically recognises starch, flour, feed and other food materials as combustible-dust hazards when finely divided particles are dispersed in air with an ignition source and confinement (OSHA, 2005, 2023) [2, 3].

Conventional safety programmes often respond by adding procedures, inspections and training. These are necessary, but their success depends on organisational culture: whether leaders accept production delays for safety, whether supervisors welcome bad news, whether workers can stop work, whether corrective actions are closed, and whether repeated deviations trigger system redesign. Safety culture and BBS are therefore complementary but distinct. Culture concerns shared meaning and organisational priorities; BBS supplies a repeatable observation and feedback mechanism. Neither should be used to displace the hierarchy of controls.

This paper develops a conceptual framework for integrating the two approaches in maize-processing industries. Its contribution is threefold: it translates general safety-culture and BBS theory into a process-specific risk context; it integrates occupational safety with process and food-safety behaviour; and it proposes measurable implementation principles that protect worker participation from blame-oriented misuse.

REVIEW METHOD

A structured narrative-review approach was used because the purpose was conceptual integration rather than estimation of a pooled intervention effect. Literature was selected across four domains: (1) safety culture and climate; (2) BBS and behavioural intervention design; (3) occupational-safety management and worker participation; and (4) maize, grain and food-processing hazards. Foundational articles were combined with recent reviews and authoritative guidance from the ILO, ISO and OSHA. Sources were included when they defined a construct, examined relationships among climate, motivation and behaviour, evaluated behavioural-intervention conditions, or addressed material hazards relevant to maize processing.

The synthesis proceeded in three stages. First, recurring constructs were identified: leadership, just reporting, worker involvement, competence, observation, feedback, reinforcement, system conditions and learning. Second, maize-processing tasks and hazards were mapped to these constructs. Third, the constructs were organised into a multi-layer framework and implementation sequence. The review is conceptual and does not claim exhaustive database coverage or meta-analytic effect estimates.

SAFETY CULTURE: FROM VALUES TO OPERATIONAL PRACTICE

Culture, Climate and Observable Systems

Safety culture is commonly understood as the shared values, assumptions and practices that shape the priority accorded to safety. Safety climate is the more proximal perception of policies, procedures and rewarded behaviour at a particular time. Guldenmund (2000) [4] cautions that the construct is complex, while Cooper (2000) [5] proposes a reciprocal model connecting psychological, behavioural and situational dimensions. This model is particularly useful in manufacturing because it avoids reducing culture either to attitudes or to compliance counts.

Workers infer priorities from daily trade-offs. A policy may declare that safety comes first, but climate is formed by whether supervisors permit isolation, maintenance resources are available, near-miss reporters receive feedback and unsafe production conditions are corrected. Zohar (2010) [6] accordingly

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emphasises enacted priorities. Meta-analytic evidence also links safety knowledge, motivation, climate and behaviour with safety outcomes, while recognising multiple individual and situational influences (Christian et al., 2009) [7].

Reporting, Justice and Learning

A strong culture is not characterised by silence. It creates channels for hazards, weak signals and errors to be reported without fear of arbitrary punishment. Reason's organisational-accident model distinguishes reporting, learning, informed and just-culture properties (Reason, 1997) [8]. Just culture does not mean absence of accountability; it differentiates human error, at-risk choices and reckless disregard, and it examines whether tools, procedures, staffing or incentives made failure more likely.

Leadership and Worker Participation

ISO 45001 places leadership and worker participation at the centre of an occupational-health-and-safety management system. Its risk-based logic connects consultation, hazard identification, competence, operational control, performance evaluation and continual improvement (ISO, 2018) [9]. Participation is substantive when workers influence risk assessment, procedure design, change management and corrective action—not merely attend meetings or sign training sheets.

BEHAVIOUR-BASED SAFETY: CONTRIBUTION AND BOUNDARIES

The Observation–Feedback Cycle

BBS applies behavioural principles to critical work practices. A typical cycle defines observable behaviours, samples work, discusses what was seen, reinforces effective actions, explores barriers to safe work, records information, analyses patterns and verifies corrective actions. Feedback is strongest when it is immediate, respectful, specific and two-way. The observer should ask not only what occurred but what conditions influenced it.

Conditions for Effectiveness

Industry applications indicate that behavioral programmes depend on management commitment, worker ownership, observer credibility, appropriate measures and quality feedback (DePasquale and Geller, 1999) [10]. Participation can increase when observations are separated from disciplinary surveillance and data are used for learning. Conversely, quotas, reward manipulation and public ranking can encourage superficial observations or underreporting.

Common Criticisms and Safeguards

BBS programmes may be criticized when they emphasize individual behaviour without adequately addressing the organizational and system-level factors that influence workplace safety. Worker blaming can overlook issues such as poor equipment design, limited resources, or production demands. Likewise, excessive focus on PPE may divert attention from more effective measures, including hazard elimination, isolation, guarding, and engineering controls. Relying mainly on the number of behavioural observations may also create an activity-count bias, as increased observations do not necessarily indicate reduced risk (Table 1). Furthermore, punitive monitoring can discourage workers from reporting hazards and participating openly in safety initiatives. Behavioural interventions should therefore complement, rather than replace, appropriate engineering and administrative controls. An ethical BBS approach should consider underlying system factors, prioritize effective risk controls, maintain confidentiality and trust, and ensure that corrective actions are directed toward the appropriate organizational level.

MAIZE-PROCESSING RISK CONTEXT

Maize-processing facilities vary by product and technology, but they share connected material, energy and chemical flows. The safety-culture framework must therefore cover routine operation, maintenance, cleaning, start-up, shutdown and abnormal situations. Behavioural observation criteria should be task-specific and validated by operators and maintenance personnel (Table 2).

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Table 1. Design risks and safeguards for an ethical, system-oriented BBS programme.

Common criticism	Potential concern	Recommended safeguard
Worker blaming	Immediate behaviour may reflect defective design, unavailable tools or production pressure.	Record system contributors and assign actions to the owner able to change them.
PPE fixation	Observation programmes may focus on visible personal behaviour while ignoring high-energy hazards.	Prioritise critical controls, isolation, guarding, dust control and mechanical integrity.
Activity-count bias	Large observation numbers do not demonstrate risk reduction.	Measure quality, repeat behaviour, barrier removal and verified closure.
Punitive surveillance	Fear reduces candour and worker participation.	Use peer dialogue, confidentiality, just-culture rules and non-retaliation.
Substitution for engineering	Behavioural compliance cannot compensate for inadequate design.	Apply the hierarchy of controls before administrative and behavioural reinforcement.

Table 2. Maize-processing areas and behaviour–system interfaces.

Process/activity	Main hazards	Key controls/preventive measures
Receiving, unloading and storage	Vehicle movement, falls, grain engulfment, dust, conveyor nip points.	Traffic segregation, access discipline, bin- entry prohibition/permit, housekeeping and alarm response.
Cleaning, conveying and milling	Rotating equipment, belt misalignment, hot bearings, ignition sources, airborne dust.	Guarding, isolation, inspection response, dust containment and hot-work control.
Starch separation and drying	Wet floors, chemicals, centrifuges, steam, pressure, hot surfaces and starch dust.	Line breaking, chemical PPE, machine isolation, leak reporting and dryer/dust barrier verification.
Sweetener and syrup processing	Acids/alkalis, enzymes, heat, pressure, cleaning chemicals and confined vessels.	Dosing control, compatible transfer, permits, sampling safety and emergency readiness.
Sorbitol/hydrogen-related operations	Flammable gas, catalysts, pressure, loss of containment and ignition.	Gas testing, leak response, interlock discipline, management of change and mechanical integrity.
Boilers, utilities and power	Steam, fuel, electricity, water treatment chemicals, noise and heat.	Authorisation, LOTO, alarm response, maintenance quality and contractor control.
Packaging and warehouse	Repetitive motion, forklifts, pallet instability, conveyors and slips.	Pedestrian segregation, speed control, ergonomics and housekeeping.
ETP/ZLD and laboratory	Chemicals, biological exposure, confined space, hot surfaces and glassware.	Chemical compatibility, ventilation, permits, sampling protocols and emergency equipment.

Combustible dust deserves special treatment because safe outcomes depend on both equipment and behaviour. OSHA notes that dispersed combustible material can become explosible under suitable conditions and that food products account for a substantial share of combustible-dust events. Critical barriers include containment, local exhaust, housekeeping methods that do not disperse dust, bearing-temperature and alignment monitoring, ignition-source control, appropriate electrical classification, explosion protection where required and disciplined hot-work management (OSHA, 2005, 2023) [2, 3]. Observations should verify these barriers rather than simply whether workers wear PPE.

Integrated Conceptual Framework

The integrated conceptual framework (Figure 1) illustrates how leadership and just-culture principles, worker participation and competence, hazard and process knowledge, hierarchy of controls, and food-safety and quality behaviours interact through a continuous BBS learning cycle of Define–Observe–Discuss–Act–Verify. These interconnected elements support systematic identification and management of workplace risks while encouraging worker involvement and continuous improvement. The framework ultimately aims to achieve safer work practices, reliable operations, hygienic production, and improved organisational learning and performance.

Layer 1: Leadership and Just Culture

Leaders establish the decision environment through resource allocation, visible field engagement, response to bad news and resolution of production–safety conflicts. Just-culture rules protect good-faith reporting while maintaining proportionate accountability for deliberate high-risk violations. Senior review should focus on barrier health and recurring system causes, not only injury totals.

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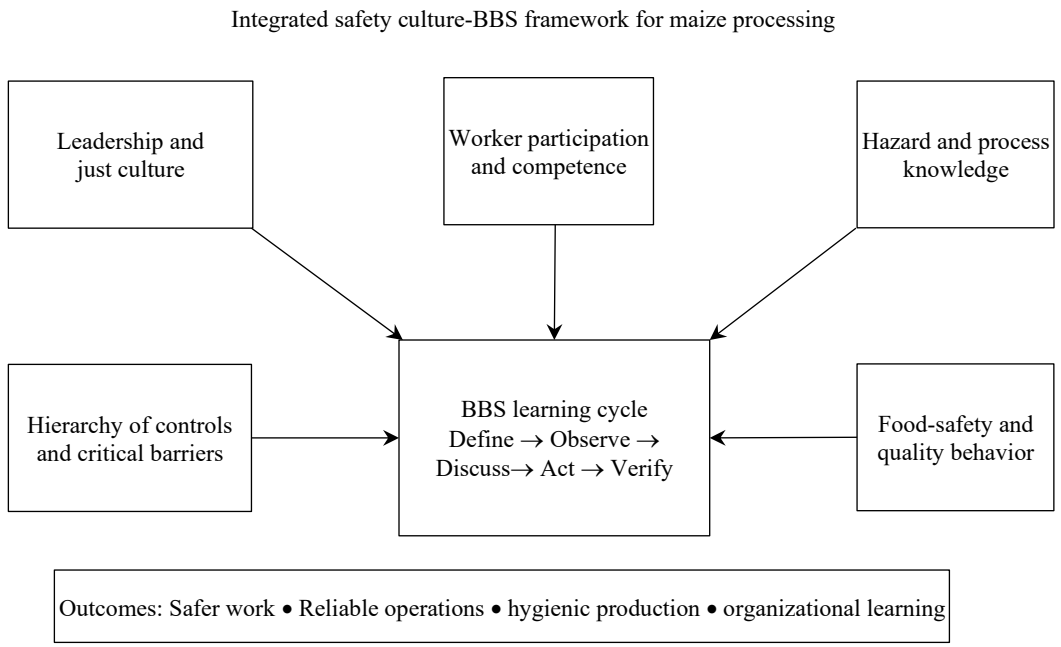


Figure 1. Integrated safety culture–BBS framework for maize-processing industries.
Developed by the authors.

Layer 2: Participation and Competence

Operators, technicians and contractors hold practical knowledge about deviations, workarounds and difficult controls. They should co-design observation criteria and corrective actions. Competence requires demonstrated ability, not attendance alone; assessment should include knowledge, practical performance and supervisor verification in the field.

Layer 3: Hazard and Process Knowledge

The programme must connect personal safety with process-safety knowledge. Participants need to understand energy sources, dust explosion conditions, chemical incompatibility, pressure, loss of containment, alarms, interlocks and escalation pathways. Change management should review new materials, recipes, equipment, automation and maintenance practices for altered risk.

Layer 4: Critical Controls and BBS Learning

The hierarchy of controls determines control selection; BBS then helps verify how administrative and critical human actions perform in practice. Observation data should identify both safe/at-risk behaviour and enabling conditions. Immediate issues are corrected safely, while systemic issues enter a risk-ranked action process with named owners, deadlines and effectiveness checks.

Layer 5: Food-Safety and Quality Integration

Occupational safety, food safety and quality share behavioural foundations: procedure discipline, hygienic practices, maintenance, chemical control, housekeeping, deviation reporting and supervisor response. Research on food-safety culture similarly shows the importance of organisational and human factors (Nyarugwe et al., 2020; Zanin et al., 2022) [11, 12]. Integration reduces mixed messages, provided that occupational high-consequence hazards are not diluted into general compliance checklists.

Layer 6: Learning and Resilience Outcomes

The intended outcome is not merely fewer reported incidents. It is an organisation better able to anticipate, detect, respond and learn. Leading indicators show the condition of controls and participation; lagging indicators show realised loss. Both require exposure denominators, trend analysis and transparent interpretation.

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IMPLEMENTATION MODEL

The six-phase implementation framework begins with diagnosing workplace risks and safety culture, followed by designing behavioural checklists and observation protocols. Pilot testing validates criteria and observer consistency before scaling interventions. Verification assesses data quality and control effectiveness, while continuous learning supports corrective actions, system improvements, and workforce engagement as shown in Table 3 and Appendix A.

Governance Principles

- A cross-functional steering group should include operations, maintenance, engineering, HSE, quality/food safety, human resources and worker/contractor representation.
- Observation data should not be used as an automatic disciplinary score or production incentive.
- High-potential events and failed critical controls should receive greater attention than raw observation volume.
- Workers must have stop-work authority and a reliable escalation route where immediate supervision does not respond.
- Corrective actions should be assigned to the person with authority and resources to change the underlying condition.
- Programme effectiveness should be reviewed at planned intervals and criteria retired or revised as risk changes.

Table 3. Six-phase implementation model.

Phase	Key activities	Expected outputs
1. Diagnose	Map processes and critical risks; review reporting climate; consult workers and contractors.	Baseline culture/climate findings, hazard map and governance charter.
2. Design	Select task-specific critical behaviours and system-condition prompts; define just-culture protections.	Validated checklists, data dictionary, observer protocol and privacy rules.
3. Pilot	Train mixed observers; pilot in one high-risk and one routine area; calibrate feedback.	Inter-rater agreement, worker feedback and revised criteria.
4. Scale	Extend by risk and shift; integrate actions with maintenance, engineering and management of change.	Coverage matrix, action ownership and management dashboard.
5. Verify	Audit data quality, action effectiveness and critical-control health; compare trends.	Verified closure, declining repeat deviations and barrier performance.
6. Learn	Review serious near misses, share learning and redesign weak controls.	Documented system changes and workforce communication.

Table 4. Balanced measurement architecture for the integrated framework.

Indicator	What to measure	Interpretation/keypoint
Participation	Observer diversity, worker suggestions, stop-work use, near-miss reports	More reporting may indicate greater trust, not worse safety.
Observation quality	Task relevance, feedback quality, system factors captured, inter-rater consistency	Observation totals alone are not effectiveness evidence.
Behavior trend	Safe percentage by critical behavior, repeat at-risk rate, sustained improvement	Avoid targets that encourage false “safe” coding.
Critical controls	Isolation verification, dust-control availability, interlock impairment, overdue critical maintenance	Averages can conceal a single failed high-consequence barrier.
Action management	On-time closure, risk-weighted backlog, effectiveness verification, recurrence	Administrative closure is not equivalent to risk removal.
Competence	Pre/post knowledge, practical demonstration, field verification	Attendance measures reach, not competence.
Outcomes	First aid, recordable injury, LTI, fire, explosion, loss of containment and severity potential	Use person-hours and historical trends; avoid zero-injury complacency.

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Measurement Framework

A balanced dashboard should distinguish activity, quality, control health, learning and outcomes. Counts without denominators can be misleading. Facilities should record person-hours, task exposure, department, shift and employee/contractor status where lawful and appropriate (Table 4).

DISCUSSION

The framework reframes BBS as an organizational learning mechanism rather than a worker-correction programme. Its central proposition is that behavior is both an action and information about the system. When a worker bypasses a control, the immediate action matters, but so do accessibility, tool design, time pressure, supervision and prior reinforcement. This is consistent with reciprocal safety-culture theory and the distinction between work as imagined and work as performed (Cooper, 2000; Hale and Borys, 2013) [5, 13].

The maize-processing context demonstrates why this distinction is essential. Some exposures are frequent and visible, such as slips, manual handling and PPE use. Others are less frequent but potentially catastrophic, such as dust deflagration, hydrogen loss of containment, boiler failure or confined-space exposure. A programme optimized for easy-to-count personal behaviors could look successful while critical barriers deteriorate. Risk-weighted observation and process-safety indicators are therefore non-negotiable.

Integration with food-safety culture offers practical benefits. Both domains depend on leadership consistency, competence, procedure use, reporting and corrective action. Joint conversations can strengthen operational discipline. Nevertheless, the consequence pathways differ: a hygienic deviation affects product and consumers, while an energy-isolation failure may immediately threaten workers. Integrated governance should preserve specialist risk assessment and clear accountability.

The framework also responds to ethical concerns. Worker participation is meaningful only when data use is transparent, privacy is respected and reporting does not produce retaliation. BBS should create psychological and operational safety for dialogue. A just culture protects learning while distinguishing honest error from reckless action.

RESEARCH PROPOSITIONS AND FUTURE RESEARCH

The conceptual synthesis generates five propositions for empirical testing:

- *P1:* Leadership consistency and just-reporting climate positively influence participation in BBS and near-miss reporting.
- *P2:* Worker co-design of critical-behavior criteria improves observation validity and corrective-action relevance.
- *P3:* BBS programmes that capture system conditions produce greater reduction in repeat at-risk behaviour than worker-focused programmes.
- *P4:* Integration of BBS with critical-control verification improves process-safety barrier reliability in maize-processing operations.
- *P5:* Coordinated occupational- and food-safety culture practices improve learning and operational reliability when domain-specific critical risks remain visible.

Future studies should use multi-site mixed methods. A longitudinal design could combine validated safety-climate surveys, observation-quality audits, task exposure, person-hours, critical-control performance and incident potential. Interrupted time-series or matched-site designs would support stronger causal inference. Qualitative interviews should examine production pressure, supervisor response, contractor experience and the credibility of feedback. Research should also test whether improvements are sustained after initial programme attention declines.

PRACTICAL IMPLICATIONS

For managers, the framework provides a basis for integrating safety leadership with measurable field learning. For HSE professionals, it cautions against treating behavioral observation as a standalone

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intervention. For operations and engineering, it creates a structured route by which field experience informs design, maintenance and change management. For workers and contractors, it establishes participation, feedback and protection from arbitrary blame as programme requirements rather than optional values.

A facility beginning implementation should first understand its high-consequence scenarios and reporting climate, then pilot a small set of task-specific observations. Rapid expansion before observer calibration and action capacity may generate data without improvement. The pace of observation should be matched by the organization's ability to remove barriers and communicate outcomes.

LIMITATIONS

This is a conceptual narrative review and not a systematic review or meta-analysis. The source selection was purposive, and no formal risk-of-bias scoring was performed. The framework has not yet been validated through primary data in maize-processing facilities. Regulatory references are illustrative and do not replace applicable Indian legislation, site-specific risk assessment or engineering standards. Facility technology, products and organisational context vary; implementation must therefore be adapted rather than copied mechanically.

CONCLUSION

Safety culture and BBS can make a valuable combined contribution to the food-processing sector when they are designed as parts of a wider risk-control system. In maize processing, the combination must address both everyday occupational hazards and low-frequency, high-consequence process events involving dust, flammable gas, pressure, heat, chemicals and stored energy. The proposed framework places leadership, just culture, worker participation, competence and process knowledge around a BBS learning cycle that verifies critical controls and drives system improvement.

The defining principle is that safe behavior cannot be separated from the conditions in which work occurs. Observation should reinforce effective action, reveal barriers, allocate responsibility fairly and verify that corrective measures reduce risk. When aligned with ISO 45001, the hierarchy of controls, process safety and food-safety culture, BBS can support a more informed, participative and resilient maize-processing organization. Empirical testing is now required to evaluate the framework's reliability, transferability and effect on leading and lagging outcomes.

DECLARATIONS

Author Contributions

Shamim A. Rayani, Kaneez Soghra, Yadunath Singh Pal conceptualization, sector-risk interpretation, framework development and manuscript review. Kaneez Soghra: literature organization, management perspective and manuscript review. Final contributions and author order must be confirmed by all authors before submission.

Conflict of Interest

The authors should disclose all employment and professional relationships required by the selected journal. This conceptual paper contains no confidential organizational data and does not represent an employer's official position.

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Data availability

No primary dataset was generated or analyzed. The article synthesizes published literature and publicly available authoritative guidance.

Ethical statement

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The paper does not involve human participants, personal information, clinical intervention or confidential company records. Institutional or journal requirements should nevertheless be checked before submission.

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APPENDIX

Appendix A. Proposed BBS observation record.

Context	Date, time, department, shift, task, employee/contractor category and permit reference where applicable.
Critical behaviour	Task-specific safe/at-risk/not-observed criteria, with the critical risk controlled by each behaviour.
System conditions	Equipment availability, design, procedure clarity, staffing, supervision, workload, environment and competing goals.
Dialogue	Safe behaviour reinforced, concern discussed, worker explanation and agreed immediate action.

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Escalation	Potential severity, critical-control failure, stop-work status and responsible system owner.
Closure	Action, due date, closure evidence, effectiveness verification and recurrence check.

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