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Organizational variation in safety observation practices and their relationship to accidents: A three-year multi-site study

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A R T I C L E I N F O

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A B S T R A C T

Introduction: Safety observations are widely used as proactive tools in safety management, yet their relationship with accident outcomes remains unclear. *Method:* This study examines safety observation practices and their association with total recordable injuries (TRIs) across seven production units within the same industrial organization during 2023–2025. Safety observations were normalized as observations per 100 working hours and accident occurrence was measured using TRI rates. *Results:* The results reveal substantial variation among production units in both observation activity and accident occurrence. Temporal analysis shows a recurring pattern in which observation reporting declines during mid-year and increases toward the end of the year. Correlation analysis indicates no consistent linear relationship between observation activity and TRI levels across units. *Conclusions:* The findings suggest that safety observation frequency alone does not function as a direct predictor of accident occurrence. Instead, observation activity appears to reflect broader organizational factors such as reporting practices, safety engagement, and local safety management processes. *Practical applications*: The study highlights the importance of interpreting safety observation metrics within their organizational context when assessing safety performance.

1. Introduction

Safety observations have become a central component of modern safety management systems and are widely promoted as leading indicators intended to identify hazards, reinforce safe behaviors, and support proactive risk control. In many industrial organizations, observation activity is interpreted not only as a technical reporting practice but also as a reflection of deeper organizational characteristics such as safety climate, leadership commitment, and employee engagement. Recent research emphasizes that observation systems function as part of a broader organizational information infrastructure, both shaping and being shaped by reporting culture, psychological safety, and managerial responsiveness (Hollnagel, 2018; Le Coze, 2019; Rae et al., 2018).

Despite their widespread adoption, the empirical relationship between safety observations and accident outcomes remains theoretically contested and practically ambiguous. Observation systems are frequently assumed to function as early warning mechanisms; however, empirical evidence supporting their predictive value is mixed. Reporting behavior has been shown to depend strongly on psychological safety and trust (Newman et al., 2017; Frazier et al., 2017), as well as on the usability of reporting systems and perceived management support (Zohar & Polachek, 2014). These factors influence not only the quantity of observations but also their content, quality, and distribution across organizational levels. Consequently, observation data may reflect underlying cultural and organizational conditions rather than functioning as a straightforward leading indicator of accident risk.

The literature also highlights the complexity of linking leading indicators to lagging safety outcomes. Several studies suggest that leading indicators often correlate only weakly with accident rates due to low base rates, reporting biases, and reverse causality, where accidents themselves may trigger increased reporting activity (Reiman & Pietikäinen, 2012; Hale, 2009). Other studies emphasize that observation frequency alone provides limited explanatory power unless observation quality, follow-up actions, and organizational learning processes are also considered (Rae & Provan, 2019; van der Beek & Schraagen, 2015). These insights underscore the need for empirical studies examining how observation practices vary across units operating under comparable organizational conditions and how such variation relates to accident

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occurrence when exposure is controlled.

Despite increasing interest in leading indicators, relatively few studies have systematically analyzed safety observation patterns across multiple operational units within the same organization. Even fewer studies have examined temporal variation in observation activity or explored how unit-level differences in reporting behavior relate to accident outcomes. This gap is particularly relevant for large industrial organizations where observation metrics are frequently incorporated into performance dashboards and managerial decision-making processes.

The present study addresses this gap by analyzing three years of monthly safety observation and accident data from seven production units within the same industrial organization. The units operate under comparable processes, risk profiles, and safety management systems, providing an opportunity to examine unit-level variation under relatively controlled organizational conditions. Using normalized observation and accident rates, descriptive time-series analysis, and cross-unit comparisons, the study investigates how observation practices differ among units, how these patterns evolve over time, and how they relate to total recordable injuries (TRIs).

The study addresses three research questions:

1) How do the number, type, and temporal patterns of safety observations differ among production units, and what do these differences reveal about unit-level safety practices?
2) What is the association between safety observation activity and accident occurrence when normalized by working hours?
3) To what extent might unit-specific differences in observation activity and accident outcomes reflect structural, organizational, or cultural factors?

By addressing these questions, the study contributes to ongoing debates concerning the interpretation and validity of safety observation metrics. Rather than treating observation frequency as a direct predictor of accidents, the analysis conceptualizes observation practices as part of a broader organizational safety information system. The findings provide empirical insight into the variability of observation behavior across production units and highlight the importance of contextualizing observation data when evaluating safety performance and drawing conclusions about safety culture.

2. Safety observations in research literature

Understanding the relationship between safety observations and accident outcomes requires a clear conceptualization of what safety observations represent, how they function within organizational safety systems, and how they relate to broader constructs such as safety culture, safety climate, and reporting behavior. This section reviews the theoretical foundations that inform the present study.

2.1. Safety observations as organizational information practices

Safety observations refer to documented reports of hazards, unsafe conditions, unsafe behaviors, near misses, or positive safety practices. They represent a structured mechanism through which employees and supervisors communicate safety-relevant information to the organization. Prior research emphasizes that safety observations are not simply acts of noticing risks but acts of reporting, which transform individual perceptions into organizational knowledge (Pulkkinen et al., 2025; Kines et al., 2011).

Observation systems therefore function as organizational information practices that enable the collection, interpretation, and dissemination of safety-relevant signals across different organizational levels. Through these practices, individual experiences of risk are translated into data that can support decision-making, learning, and preventive action.

Previous research has identified several theoretical functions of safety observations. First, they support hazard identification and weak-signal detection by enabling early recognition of deteriorating conditions before accidents occur (Kines et al., 2011). Second, observation systems can reinforce safe behaviors through feedback, monitoring, and recognition mechanisms that shape everyday work practices (Cooper, 2000).

Third, they contribute to organizational learning by allowing organizations to identify recurring patterns, systemic weaknesses, and latent risks (Robson et al., 2001). Finally, observation activity may function as a cultural signal reflecting employee engagement, trust in reporting systems, and leadership commitment to safety (Guldenmund, 2000; Zohar, 2000).

These functions position safety observations as potential leading indicators of safety performance. However, their effectiveness depends strongly on reporting quality, follow-up actions, and the broader organizational context in which observation systems operate.

2.2. Safety culture, safety climate, and reporting behavior

Safety observations are frequently interpreted as indicators of safety culture and safety climate, although these constructs are conceptually distinct. Safety climate refers to employees' shared perceptions of the priority of safety within an organization at a given point in time (Zohar, 2000), whereas safety culture refers to deeper and more enduring organizational values, norms, and assumptions related to safety (Guldenmund, 2000).

Safety climate influences reporting behavior through several organizational mechanisms. These include perceived management support for safety initiatives (Neal & Griffin, 2006), the consistency of supervisory actions and expectations (Zohar & Luria, 2005), and the visibility of follow-up and corrective actions after safety issues are reported (Clarke, 2006). When employees perceive that management responds constructively to reported issues, the likelihood of reporting hazards, near misses, and unsafe practices increases.

Psychological safety also plays a critical role in shaping reporting behavior. Employees' belief that reporting safety concerns will not lead to punishment, blame, or embarrassment is a key antecedent of open reporting (Edmondson, 1999; Hofmann & Morgeson, 1999). When psychological safety is low, employees are more likely to report only low-risk or socially acceptable issues, which reduces the informational value of safety observation data.

Consequently, variation in observation activity may reflect broader organizational factors such as trust in management, openness of communication, perceived fairness, workgroup norms, and leadership engagement. Observation frequency should therefore not be interpreted solely as a technical performance metric but also as a behavioral expression of safety climate and reporting culture.

2.3. Safety observations as leading indicators: Opportunities and limitations

Safety observations are frequently promoted as leading indicators of safety performance, yet the mechanisms linking observation activity to accident outcomes are indirect and complex. Reporting hazards, unsafe conditions, and near misses can support hazard identification and organizational learning, which in turn may contribute to improved risk control. Empirical research suggests that organizations characterized by strong workforce involvement, delegated safety responsibilities, and active management engagement tend to experience lower injury rates (Shannon et al., 1997).

Research on safety climate provides additional theoretical support for these relationships. Neal and Griffin (2006) show that a positive safety climate increases safety motivation and, through this mechanism, safety behavior, which subsequently predicts lower accident rates. Although their model does not examine safety observations directly, observation activity can be understood as a form of safety participation, representing a behavioral pathway through which employees contribute to risk identification and prevention. Similarly, Kines et al. (2011) emphasize that open communication, reporting practices, and learning processes are central components of a strong safety climate and proactive risk management.

However, the empirical and theoretical foundations linking observation frequency to accident reduction remain contested. Increased reporting may enhance hazard identification and control, thereby contributing indirectly to improved safety outcomes (Shannon et al., 1997), but the relationship is far from deterministic. Neal and Griffin (2006) argue that higher levels of observation activity may reflect stronger safety climate and more proactive safety behaviors rather than serving as a causal mechanism in themselves. Likewise, Kines et al. (2011) highlight that near-miss reporting can support organizational learning and strengthen safety systems, but only when supported by a mature reporting culture.

At the same time, several scholars caution against overinterpreting observation counts. Clarke (2006) notes that the low base rate of accidents makes statistical associations difficult to detect. Guldenmund (2000) emphasizes that reporting bias may distort observation data, while Robson et al. (2001) warn of the possibility of reverse causality, whereby accident events themselves trigger increased observation activity and reporting.

Taken together, these limitations suggest that safety observation frequency should not be interpreted as a standalone predictor of accident outcomes. Instead, observation activity is better understood as a context-dependent indicator of organizational engagement, reporting culture, and the maturity of safety management practices.

2.4. Organizational variation in safety observation practices

Even within a single organization, production units may differ substantially in terms of workload and production intensity, leadership practices, workforce stability, reporting norms, local safety initiatives, and the usability of reporting systems (Pulkkinen et al., 2025). Such differences can generate distinct safety observation profiles that do not necessarily correspond directly to accident outcomes. As a result, variation in observation activity may reflect differences in reporting behavior, organizational engagement, or operational conditions rather than differences in underlying risk alone.

Understanding these differences requires examining not only the volume of safety observations but also their distribution across observation types, their temporal patterns, and their stability over time. Variation across these dimensions may reveal differences in how safety practices are enacted at the unit level and how reporting behavior evolves within local organizational contexts.

In this study, safety observations are therefore conceptualized as organizational signals emerging from the interaction of reporting culture, safety climate, leadership behavior, operational conditions, organizational target setting, and system usability. This perspective enables the analysis of observation practices as part of a broader organizational information system. It also provides a theoretical basis for examining how observation patterns vary across production units and how such variation relates to accident occurrence when exposure is controlled.

2.5. Summary and implications for the present study

The literature reviewed above highlights the complex and context-dependent nature of safety observation practices. Several key insights emerge from prior research.

First, safety observations are multidimensional practices embedded within broader organizational processes such as safety culture, safety climate, and reporting behavior. Second, observation frequency reflects not only hazard exposure but also factors such as psychological safety, leadership engagement, organizational target setting, and the usability of reporting systems.

Third, the relationship between observation activity and accident outcomes is unlikely to be linear or deterministic and may be influenced by contextual factors, reporting biases, and potential reverse causality. Finally, variation in observation activity between organizational units may reveal differences in safety climate, reporting culture, operational conditions, or local safety practices.

Building on this framework, the present study adopts an exploratory empirical approach to examine how safety observation practices vary across production units operating within the same organizational context. Using three years of monthly observation and accident data normalized by working hours, the study investigates differences in observation volume, observation types, and temporal reporting patterns across units, and examines how these patterns relate to total recordable injuries (TRIs).

Rather than treating observation frequency as a direct predictor of accident occurrence, the study conceptualizes safety observations as organizational information signals that reflect broader patterns of engagement, reporting behavior, and safety management practices. By analyzing these patterns across units operating under comparable organizational conditions, the study provides empirical insight into how observation metrics function in practice and how they should be interpreted when assessing safety performance.

3. Data and methods

3.1. Research design

This study adopts a quantitative, multi-unit longitudinal research design to examine variation in safety observation practices and accident outcomes across seven production units (A–G) within the same industrial organization. The organization operates globally with approximately 20,000 employees across around 30 countries. The units included in the study operate under comparable production processes, safety management systems, and reporting procedures, enabling the examination of unit-level differences under relatively controlled organizational conditions.

The empirical analysis is based on three years of monthly safety observation and accident data collected between 2023 and 2025. The unit of analysis is the production unit–month, which allows the study to examine both cross-unit variation and temporal patterns in observation activity and accident occurrence.

The research design follows recommendations from prior safety research emphasizing the value of analyzing leading and lagging indicators together to better understand safety performance dynamics (Kines et al., 2011; Shannon et al., 1997). By examining safety observations and accident outcomes within the same organizational context and over time, the design enables the identification of patterns and associations that may not be visible in single-unit or cross-sectional studies.

Because the aim of the study is exploratory rather than predictive, the analysis focuses on identifying patterns, associations, and unit-level differences rather than establishing causal relationships between observation activity and accident outcomes.

3.2. Data source and sampling frame

The empirical data were obtained from a global forest-industry company operating multiple paper and board production units. To ensure meaningful comparability, only production units with similar production processes, risk profiles, and safety management systems were included in the analysis. This sampling approach follows methodological guidance emphasizing that cross-unit comparisons require sufficiently comparable operational contexts in order to avoid structural confounding (Guldenmund, 2000; Robson et al., 2001).

The dataset covers 36 consecutive months (January 2023–December

2025) and includes monthly working hours for own employees, monthly counts of safety observations by category, and monthly counts of lost-time injuries (LTI) and medical-treatment injuries (MTI) among own employees. In total, the dataset contains 252 unit–month observations (7 units × 36 months).

From 2023 onwards, the organization introduced a safety observation incentive scheme as part of its short-term incentive program for both leaders and employees. During the study period (2023–2025), the organization set an annual reporting target requiring employees to submit ten safety observations per person per year. The incentive structure was linked to the proportion of employees reaching this target. In 2023, the target was achieved when 75% of employees reported 10 safety observations. The required proportion increased to 80% in 2024 and further to 85% in 2025.

This incentive mechanism may influence reporting behavior and therefore represents an important contextual factor when interpreting variation in observation activity across units. Consequently, differences in observation frequency between units should not be interpreted solely as differences in underlying risk exposure but also as potential reflections of organizational incentives, reporting culture, and engagement with safety management practices.

In addition, while the organization operates globally, the analyzed production units are examined within a shared corporate framework and follow comparable production processes, safety management systems, and reporting procedures. The study focuses on organizational-level variation within a shared corporate context rather than explicitly analyzing country-level differences. Potential influences related to regulatory frameworks and societal culture are therefore acknowledged as a limitation and are not explicitly controlled for in the analysis.

3.3. Operationalization of variables

Safety observations were defined as documented reports submitted through the company's digital safety reporting system. The observation categories included unsafe conditions, unsafe behaviors, positive behaviors, positive working conditions, near misses, chemical safety issues, and fire hazards or smoldering events.

This definition follows prior research emphasizing that safety observations represent formally reported safety-relevant information rather than the mere act of noticing hazards in the work environment (Pulkkinen et al., 2025; Törner & Pousette, 2009). In organizational safety systems, observations function as structured inputs to safety management processes, enabling the documentation, communication, and analysis of safety-related events and conditions.

To account for differences in production unit size and workload, observation activity was normalized by working hours. The observation rate was calculated by dividing the total number of observations by the total number of working hours and multiplying the result by 100. This normalization allows observation activity to be compared across production units with different workforce sizes and working hour volumes.

Accident outcomes were measured using three indicators: lost-time injuries (LTI), medical-treatment injuries (MTI), and total recordable injuries (TRI). The TRI indicator was calculated as the sum of LTI and MTI cases.

To ensure comparability across production units with different exposure levels, accident occurrence was standardized using the TRI rate. The TRI rate was calculated by dividing the total number of TRI cases by the total number of working hours and multiplying the result by 1,000,000. The multiplier of 1,000,000 was used to align the analysis with common industrial reporting practices applied within the studied organizational context and to improve comparability across units with differing working hour volumes.

3.4. Analytical strategy

The analytical strategy was designed to address the exploratory research questions while acknowledging the limitations associated with relatively small unit-level samples and the low base rate of accident events.

First, descriptive statistics were used to examine the total number of safety observations, the distribution across observation categories, and differences in observation structures between production units. Descriptive analysis was also used to examine accident counts and distributions across units and over time. In addition, monthly trends in accident occurrence and observation activity were visualized to examine temporal variation in reporting behavior and accident patterns across the study period. This approach follows prior safety research emphasizing the value of descriptive profiling in multi-unit safety analyses (Kines et al., 2011; Shannon et al., 1997).

Second, correlation analysis was conducted to examine the association between observation activity and accident occurrence. Pearson correlation coefficients were calculated between unit-level observation rates and TRI rates using aggregated averages for the period 2023–2025. In addition, a complementary comparison was conducted in which the three-year average observation activity was compared with TRI levels recorded in 2025 in order to explore whether longer-term observation patterns were associated with subsequent accident occurrence. Because the analysis is based on only seven aggregated production units, the results are interpreted cautiously and are not used to infer causal or predictive relationships. This approach aligns with methodological guidance warning against overinterpreting correlations derived from small samples (Robson et al., 2001).

Finally, the analysis focuses on identifying descriptive safety performance profiles across production units. These profiles are derived from the combined patterns of observation activity, observation composition, accident occurrence, and the temporal stability of reporting. Rather than testing causal hypotheses, the analysis seeks to identify empirical patterns that may reflect differences in reporting behavior, safety engagement, or organizational practices. This approach is consistent with exploratory safety culture research that uses empirical patterns to generate hypotheses about organizational differences (Guldenmund, 2000; Neal & Griffin, 2006).

All data were provided in aggregated form by the participating organization. The dataset contained no personal or individually identifiable information, and the analysis focuses exclusively on unit-level safety indicators. The study therefore complies with standard ethical principles for organizational safety research, including confidentiality and responsible handling of operational safety data (Hofmann & Morgeson, 1999).

4. Results

Seven production units were analyzed with respect to the distribution of safety observation categories during the study period 2023–2025. In total, the dataset includes 141,634 safety observations. The results reveal substantial variation both in the overall volume of observations and in their distribution across observation types.

Unit G displayed clearly the highest reporting activity across all observation categories, accounting for a large share of the total observations and substantially exceeding the other production units. Units E and D formed a second group with relatively high observation levels, whereas units A, B, C and F reported markedly lower observation volumes overall.

Constructive observations related to working conditions constituted the largest observation category across all units. Positive behavioral observations formed the second largest category, although their distribution varied considerably between units. Constructive behavioral observations and positive working condition observations also showed notable variation across production units, indicating differences in reporting practices and observation focus.

Near-miss reporting occurred in all units but with moderate variation in frequency. Chemical safety observations were relatively infrequent compared with other categories but still exhibited meaningful differences between units. Fire-related observations were rare across all production units.

Overall, the results demonstrate pronounced unit-level differences in both the intensity and structural composition of safety observations. Units characterized by higher reporting activity tended to report more observations across all categories, whereas units with lower reporting levels showed consistently lower frequencies across observation types. These patterns suggest that variation in observation activity may reflect differences in reporting practices, safety engagement, and local safety management processes rather than differences in underlying risk exposure alone (Table 1).

Examination of the accident data revealed clear differences between production units in both the number and distribution of injuries. Lost-time injuries (LTI) constituted the majority of recorded cases during the study period.

The highest LTI counts were observed in units B, G, E and D, whereas units C and A reported substantially fewer cases. Unit F recorded no LTI cases during the study period.

Medical treatment injuries (MTI) were less frequent overall but also showed variation between units. Unit D reported the highest number of MTI cases, followed by unit E, while only isolated cases were recorded in units G, B and C.

When assessed using total recordable injuries (TRI), the highest accident levels were observed in units D, E and B. Units G and C formed an intermediate group, whereas units A and F clearly represented the lowest accident occurrence levels in the dataset.

Overall, the results demonstrate pronounced unit-level differences in accident occurrence, indicating variation in operational conditions, reporting practices, or safety performance across the production units (Table 2).

To further examine differences in safety observation practices, the relative distribution of observation categories was analyzed across production units (Table 3). This analysis focuses on the proportional balance between behavioral observations, work condition observations, and near-miss reporting.

The results indicate that observation composition varies across production units. Behavioral observations account for a relatively higher share in unit A, whereas work condition observations are more dominant in units B and E. In the remaining units, the distribution of observation types is more balanced, although moderate variation is still observed.

Near-miss reporting constitutes a small share of total observations in all units and shows only limited variation. No consistent relationship was observed between the relative shares of constructive or positive observations and TRI levels. For example, units with relatively higher shares of behavioral observations did not consistently display lower TRI levels than units characterized by a stronger emphasis on work condition observations.

Overall, the results demonstrate that while observation activity differs between units in both volume and structure, the relative composition of observation categories exhibits a narrower range of variation than total observation counts.

Table 2
LTI, MTI and TRI cases among company employees by production unit.

Unit	LTI	MTI	TRI
A	3	0	3
B	27	1	28
C	11	1	12
D	21	9	30
E	23	6	29
F	0	0	0
G	24	2	26

Table 3
Observation composition (%) and total recordable injury (TRI) by production unit.

Unit	Behavior %	Near miss %	Work conditions %	TRI
A	43.6%	1.5%	54.2%	3
B	20.6%	1.4%	77.6%	28
C	29.5%	1.6%	68.4%	12
D	29.4%	1.5%	68.4%	30
E	25.6%	1.1%	72.2%	29
F	29.7%	1.1%	67.9%	0
G	29.2%	0.6%	69.4%	26

Examination of the monthly total recordable injury (TRI) figures over the 2023–2025 study period reveals clear differences between production units in both overall accident levels and temporal variation (Fig. 1).

Unit F maintained a constant zero TRI level throughout the observation period, while unit A also displayed very low accident levels with only occasional isolated cases. In contrast, units B, D, E and G exhibited substantially higher variability, with noticeable month-to-month fluctuations and several individual peaks in the monthly data. These fluctuations are also visible in the LOESS-smoothed trends, indicating that accident occurrence in these units varied considerably over time.

Units C and D displayed more structured temporal patterns, with moderate fluctuations that suggest possible seasonal or operational influences. Overall, the trend analysis indicates three broad patterns: highly stable low-accident units (A and F), units with moderate variation (C and E), and units characterized by higher accident levels and stronger short-term fluctuations (B, D and G).

Examination of monthly safety observation rates per 100 working hours during the 2023–2025 study period reveals a clear intra-annual pattern across the production units (Fig. 2). Observation activity generally declines during the early and mid-summer months and increases toward the end of the year, indicating a broadly shared temporal structure in reporting behavior.

Unit G shows the highest overall observation rates and the most pronounced seasonal variation. Units E and C display a similar but less pronounced pattern, while units A and F exhibit relatively stable reporting levels throughout the year. Units B and D represent intermediate profiles with moderate temporal fluctuations.

Overall, safety observation activity is not evenly distributed across the year but follows a recurring seasonal pattern across production units.

Table 1
Number of safety observation per type (2023–2025).

Unit	Near miss	Work Conditions – Constructive	Work Conditions – Positive	Behavior – Constructive	Behavior – Positive	Small smoldering fire / Fire	Chemical Safety	Fire hazard situation	Total
A	196	5420	1883	911	4977	15	42	42	13,486
B	188	7779	2618	749	2007	11	39	13	13,404
C	271	6311	5396	1356	3687	6	65	18	17,110
D	230	8728	1691	2740	1739	1	49	54	15,232
E	249	14,288	2188	2770	3090	19	171	54	22,829
F	113	5546	1264	960	2016	21	92	22	10,034
G	318	27,941	6452	4113	10,372	68	178	97	49,539
Total	1565	76,013	21,492	13,599	27,888	141	636	300	141,634

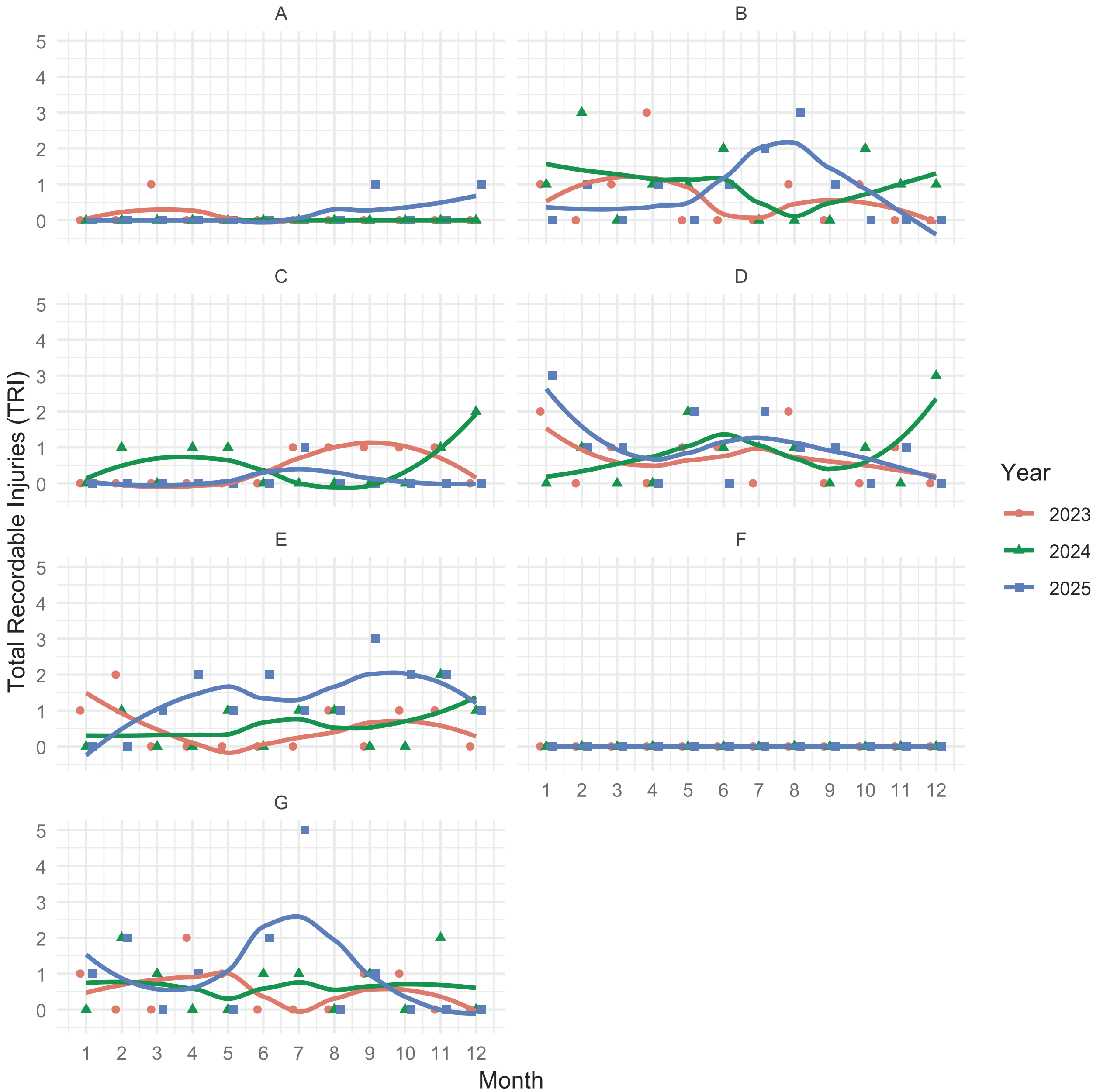

Fig. 1. Monthly TRI counts per production unit (2023–2025). Points represent monthly observations and curves show LOESS-smoothed trends.

While the magnitude of variation differs between units, most units show reduced observation activity during mid-year and increased reporting toward the end of the year. This late-year increase may partly reflect the annual observation targets embedded in the organization's incentive scheme, which may encourage additional reporting toward the end of the reporting period.

Finally, the association between safety observation activity and accident occurrence was examined by aggregating both variables at the production-unit level and normalizing them by total working hours for the study period 2023–2025. Safety observations were expressed as the number of observations per 100 working hours, while accident occurrence was measured using the total recordable injury (TRI) rate.

The scatter plot indicates substantial variation in observation activity across production units, whereas TRI levels follow a different distributional pattern (Fig. 3). The correlation coefficient between observation rates and TRI levels is $r = -0.042$, indicating that there is essentially no linear association between the two variables at the unit level.

Although no clear linear relationship is observed, the scatter plot highlights notable differences between units. For example, unit F represents a clear reference case with a TRI level of zero combined with relatively high observation activity, while units D and E exhibit higher TRI levels despite moderate to high observation rates. Overall, the results suggest that safety observation activity does not function as a direct indicator of accident frequency but rather reflects broader organizational practices related to reporting behavior, operational conditions, and safety management processes.

To further examine the relationship between safety observation activity and accident occurrence, safety observation rates aggregated over the three-year period (2023–2025) were compared with TRI levels recorded in 2025. This comparison was conducted to explore whether longer-term observation activity is associated with subsequent accident occurrence at the unit level. Observation activity was expressed as the number of safety observations per 100 working hours.

The scatter plot indicates a weak positive association between observation activity and TRI levels across production units (Fig. 4). The

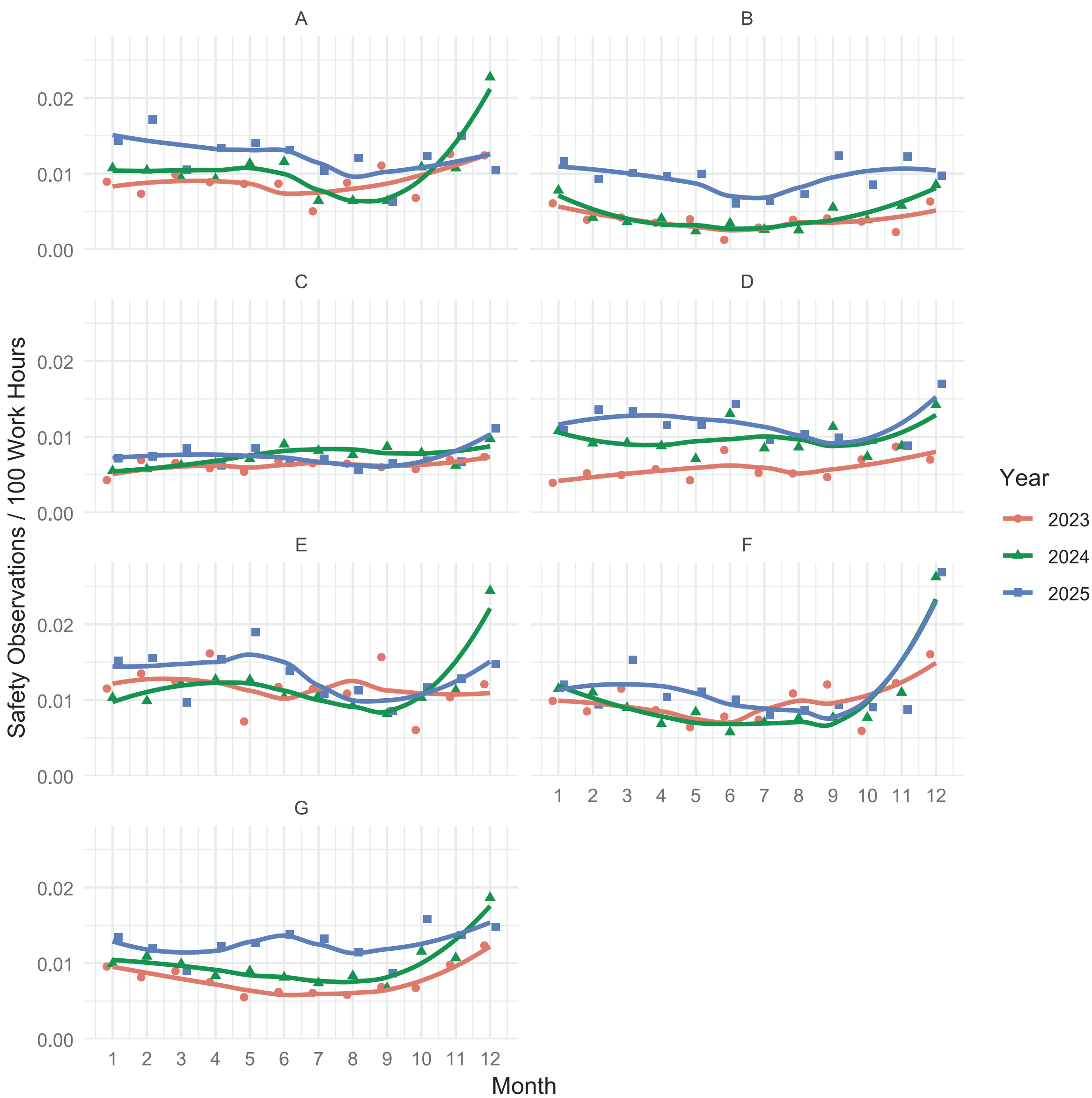

Fig. 2. Monthly safety observations per 100 working hours by production unit (2023–2025). Points represent monthly values and curves show LOESS-smoothed trends.

correlation coefficient between the variables is r = 0.23, suggesting that units with higher observation rates also tend to report higher TRI levels.

The figure also highlights considerable variation between production units. Units D and E display both relatively high observation activity and higher TRI levels, whereas units B and C show lower observation rates with intermediate accident levels. Unit F forms a distinct case with a relatively high observation rate but no recorded TRI cases in 2025.

Overall, the results indicate that higher observation activity does not necessarily correspond to lower accident occurrence at the unit level. Instead, the observed pattern suggests that both observation activity and accident reporting may be influenced by broader organizational factors such as reporting practices, operational exposure, and safety management engagement.

Overall, the results reveal substantial variation between production units in both safety observation activity and accident occurrence during the study period 2023–2025. The dataset includes a total of 141,634 safety observations, with marked differences between units in both the volume of observations and the distribution of observation types. In particular, unit G consistently reported the highest observation activity across several categories, whereas several other units exhibited considerably lower reporting levels. Similar variation was observed in accident occurrence, with clear differences in both the total number of injuries and the distribution of injury types across production units.

The temporal analyses further indicate that both accident occurrence and observation activity exhibit notable fluctuations over time. Monthly TRI levels varied considerably between units, with some units displaying relatively stable accident patterns while others showed pronounced month-to-month variation. Safety observation activity also followed a recurring intra-annual pattern characterized by reduced reporting during mid-year and increased activity toward the end of the year. This pattern may partly reflect the incentive structure linked to annual observation targets, which can encourage increased reporting toward the end of the reporting period.

When observation activity and accident occurrence were compared at the unit level, no consistent relationship between the variables was observed. The three-year aggregated comparison indicated essentially no linear association between observation rates and TRI levels, whereas the comparison between aggregated observation activity and TRI levels in 2025 suggested a weak positive relationship. Taken together, these findings indicate that safety observation activity alone cannot be

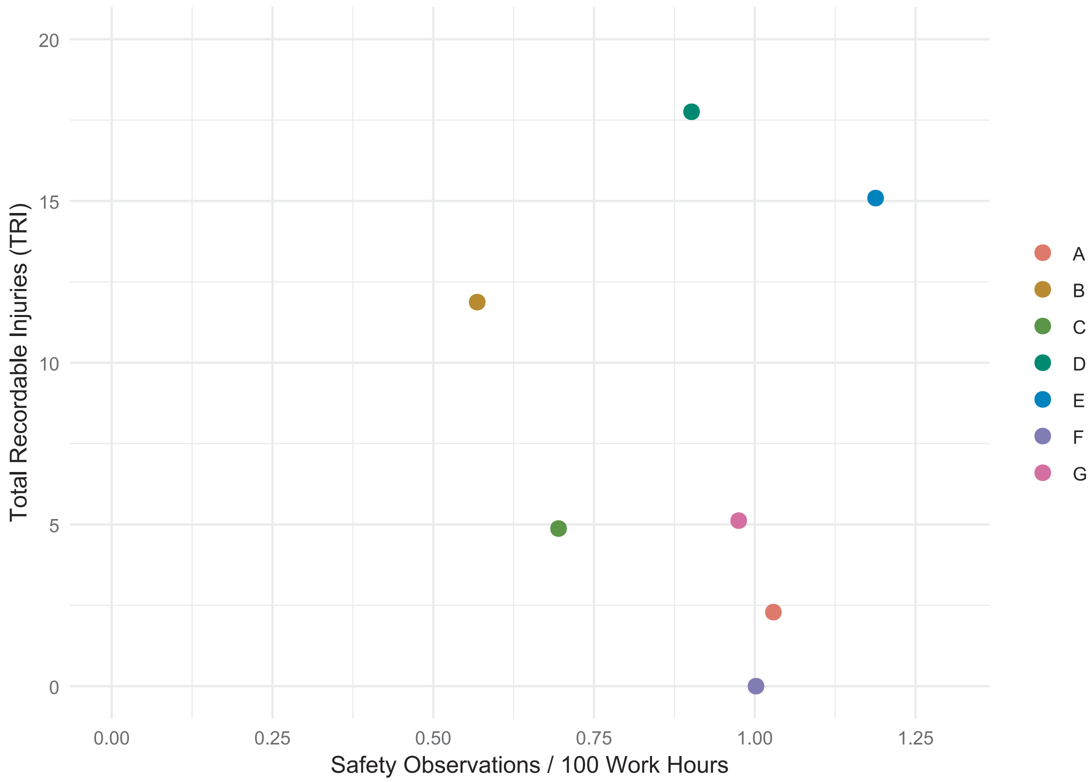

Fig. 3. Safety observations per 100 working hours and total recordable injuries (TRI) across production units (2023–2025).

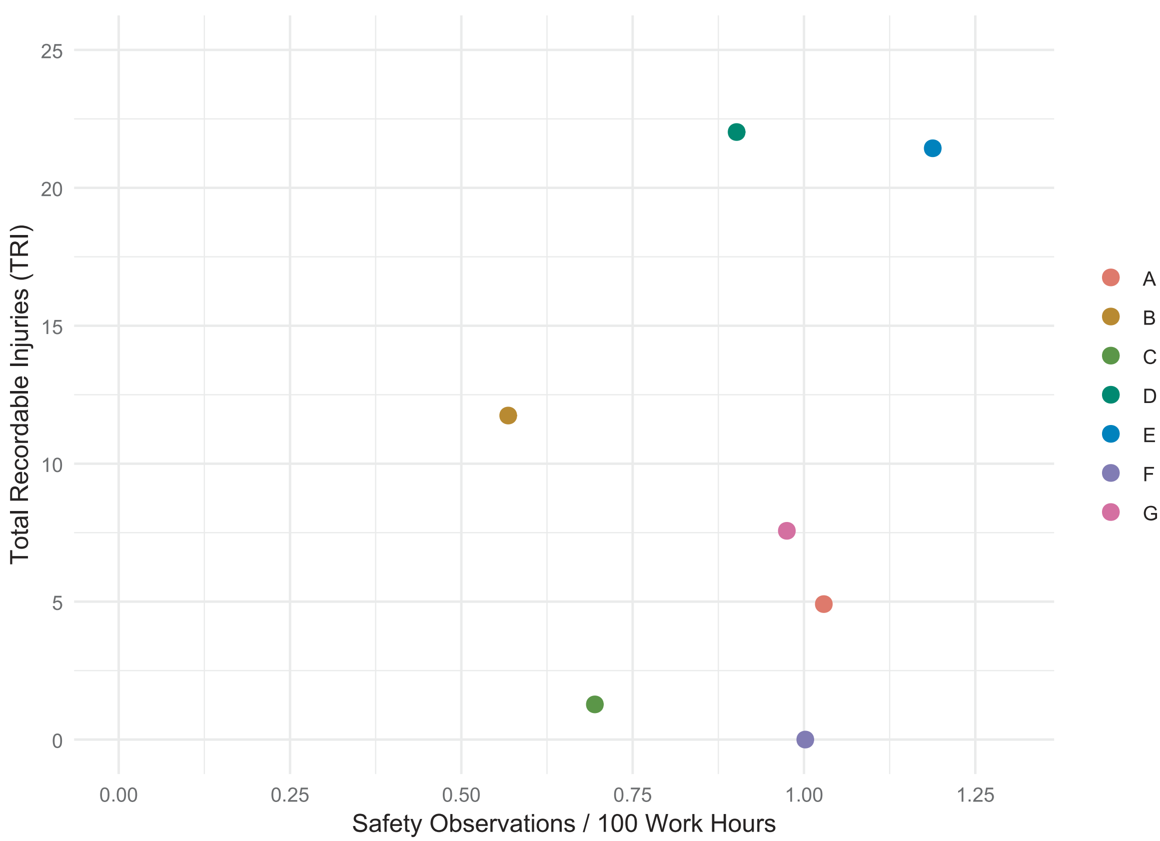

Fig. 4. Relationship between safety observation rates (three-year average per 100 working hours) and total recordable injuries (TRI) in 2025 across production units.

interpreted as a direct predictor of accident occurrence. Instead, the variation between production units suggests that both observation reporting and accident outcomes are influenced by contextual factors such as operational conditions, reporting practices, and local safety management processes.

5. Conclusions

This study examined the structure, temporal distribution, and relationship between safety observations and accident occurrence across seven production units during the period 2023–2025. The results reveal substantial variation between production units in both the volume and composition of safety observations as well as in accident occurrence. The dataset includes over 141,000 safety observations, providing a robust empirical basis for analyzing observation practices within a single organizational context. Differences were identified not only in the total number of observations but also in the distribution of observation types, indicating variation in reporting practices, safety management, and potential differences in safety culture across units. This finding aligns with earlier research suggesting that safety indicators often reflect organizational safety climate and management practices as much as underlying risk levels (Guldenmund, 2000; Clarke, 2006).

The findings further demonstrate that the number of safety observations alone does not function as a reliable indicator of accident frequency. At the production-unit level, no consistent linear relationship was observed between observation activity and TRI levels. Similarly, the analysis of observation composition showed no consistent relationship between specific observation categories and TRI levels. These findings suggest that neither observation counts nor observation structure can be interpreted as direct predictors of accident occurrence. Rather, safety indicators appear to operate within a broader organizational system in which management practices, organizational conditions, reporting practices, and potential differences in safety culture shape safety outcomes indirectly (Shannon et al., 1997; Neal & Griffin, 2006). In this context, safety observations form part of a broader safety information framework that provides insight into organizational safety performance.

The temporal analysis identified a recurring reporting pattern, with observation activity increasing toward the end of the year. This pattern suggests that reporting behavior is influenced, at least in part, by organizational practices such as annual safety targets and performance metrics. In addition, the inclusion of positive behavioral and working condition observations means that a substantial proportion of reported observations does not directly reflect hazardous conditions. As a result, observation activity may represent a combination of risk-related reporting and organizational behavior aimed at meeting reporting targets. This further indicates that safety observation counts alone may be insufficient as standalone leading indicators of safety performance. Previous research has demonstrated that reporting systems and managerial mechanisms can significantly shape both the production and interpretation of safety indicators (Clarke, 2006; Kines et al., 2011). Consequently, safety observation data should be interpreted in relation to organizational reporting structures and incentive systems rather than as neutral representations of underlying risk.

The findings also underline the importance of systematically classifying safety observations. The distribution of observations across categories such as working conditions, behavioral factors, and risk-related issues provides valuable insight into the organization's risk structure and safety practices. Structured categorization enhances the analytical value of observation data and supports organizational learning processes in safety management (Guldenmund, 2000; Kines et al., 2011).

In addition, safety observations may reveal underlying structural and managerial challenges. As noted by Paasonen and Lindfors (2021), occupational safety offence cases often expose organizational weaknesses, including unclear responsibilities, managerial passivity, and discrepancies between formal safety procedures and actual work practices. The present findings suggest that differences in observation profiles and reporting practices may similarly reflect broader variations in safety management and organizational culture.

Overall, the study indicates that safety observations represent an important source of information for organizational safety management, but their interpretation requires consideration of the broader organizational context alongside quantitative analysis. The findings support the growing research perspective in which safety observations are viewed as part of a wider safety information ecosystem, where multiple safety indicators are analyzed in combination (Shannon et al., 1997; Guldenmund, 2000; Fruhen et al., 2013). Integrating observation data with accident statistics and operational risk indicators may strengthen organizational learning and support the development of more proactive safety management approaches.

The present study focuses on the volume and structure of safety observations, but does not include direct measures of observation quality, severity, or follow-up actions. As a result, it is not possible to assess whether observations were risk-based, led to corrective actions, or contributed to the identification of high-risk conditions. This represents an important limitation, as observation counts alone do not necessarily reflect the practical effectiveness or relevance of safety reporting.

At the same time, the relatively small number of production units limits the potential for strong statistical inference, and the findings should therefore be interpreted primarily as descriptive rather than causal. The correlation results may also be sensitive to variation at the level of individual units. Nevertheless, the large observation dataset provides valuable empirical insight into the dynamics of safety observation reporting and its relationship to accident occurrence in industrial settings.

Building on these findings, future research should examine more closely the mechanisms through which safety observations contribute to organizational learning and risk management. In particular, further work is needed to analyze how different categories of observations, such as behavioral, condition-related, and risk-focused reports, differ in their informational value and how they relate to safety outcomes over time. The longitudinal structure of the dataset also provides opportunities for more advanced analyses of temporal dynamics, including the examination of lagged relationships between observation activity and accident occurrence. A more fine-grained analysis of observation content, including the application of AI-assisted qualitative methods, may help to clarify the pathways through which observation systems support proactive safety management.

In addition, the role of employee participation and engagement in shaping reporting practices warrants further investigation, as these factors are likely to influence both the volume and quality of safety observations. These questions will be addressed in subsequent studies, which aim to deepen the analysis of observation types and explore the organizational and participatory mechanisms underlying effective safety reporting systems.

CRediT authorship contribution statement

Jani Jumppanen: . **Jyri Paasonen:** Writing – original draft. **Mikko Aaltonen:** .

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Clarke, S. (2006). *The relationship between safety climate and safety performance: A meta-analytic review. Journal of Occupational Health Psychology, 11*(4), 315–327.
Cooper, M. D. (2000). *Towards a model of safety culture. Safety Science, 36*(2), 111–136.
Edmondson, A. (1999). *Psychological safety and learning behavior in work teams. Administrative Science Quarterly, 44*, 350–383.
Frazier, M. L., Fainshmidt, S., Klinger, R. L., Pezeshkan, A., & Vracheva, V. (2017). *Psychological safety: A meta-analytic review and extension. Personnel Psychology, 70*(1), 113–165.

Fruhen, L., Mearns, K., Flin, R., & Kirwan, B. (2013). *From the surface to the underlying meaning – an analysis of senior managers' safety culture perceptions. Safety Science, 68*, 44–52.
Guldenmund, F. W. (2000). *The nature of safety culture: A review of theory and research. Safety Science, 34*, 215–257.
Hale, A. (2009). *Why safety performance indicators? Safety science, 47*(4), 479–480.
Hofmann, D. A., & Morgeson, F. P. (1999). *Safety-related behavior as a social exchange: The role of perceived organizational support and leader–member exchange. Journal of Applied Psychology, 84*(2), 286–296.
Hollnagel, E. (2018). *Safety-II in Practice: Developing the Resilience Potentials*.
Kines, P., Lappalainen, J., Mikkelsen, K. L., Olsen, E., Pousette, A., Tharaldsen, J., Tomasson, K., & Törner, M. (2011). *Nordic Safety climate Questionnaire (NOSACQ-50): A new tool for diagnosing occupational safety climate. International Journal of Industrial Ergonomics, 41*(6), 634–646.
Le Coze, J.-C. (2019). *Safety science research: Evolution, challenges and new directions. Safety Science*.
Neal, A., & Griffin, M. A. (2006). *A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. Journal of Applied Psychology, 91*(4), 946–953.
Newman, A., Donohue, R., & Eva, N. (2017). *Psychological safety: A systematic review of the literature. Human Resource Management Review., 27*(3), 521–535.
Paasonen, J., & Lindfors, H. (2021). *Työturvallisuuslainsäädännön rikkomusten rangaistuskäytännöstä. Defensor Legis, 2*(2021), 390–410.
Pulkkinen, J., Nenonen, N., & Lindholm, M. (2025). *Identifying Practices in the Safety Observation Process in finnish Organizations. Human Systems Engineering and Design, IHSED2025), 198*, 429–436.
Rae, A. J., Provan, D. J., Weber, D. E., & Dekker, W. A. (2018). *Safety clutter: The accumulation and persistence of 'safety' work that does not contribute to operational safety. Policy and Practice in Health and Safety, 16*(2), 194–211.
Rae, A. J., & Provan, D. J. (2019). *Safety work versus the safety of work. Safety Science, 111*, 119–127.
Reiman, T., & Pietikäinen, E. (2012). *Leading indicators of system safety – monitoring and driving the organizational safety potential. Safety Science, 50*(10), 1993–2000.
Robson, L. S., Shannon, H. S., Goldenhar, L. M., & Hale, A. R. (2001). *Guide to evaluating the effectiveness of strategies for preventing work injuries*. Institute for Work & Health.
Shannon, H. S., Mayr, J., & Haines, T. (1997). *Overview of the relationship between organizational and workplace factors and injury rates. Safety Science, 26*(3), 201–217.
Törner, M., & Pousette, A. (2009). *Safety in construction – a comprehensive description of the characteristics of high safety standards in construction work, from the combined perspective of supervisors and experienced workers. Journal of Safety Research, 40*(6), 399–409.
van der Beek, D., & Schraagen, J. M. (2015). *ADAPTER: Analysing and developing adaptability and performance in teams to enhance resilience. Reliability engineering & system safety, 141*, 33–44.
Zohar, D. (2000). *A group-level model of safety climate: Testing the effect of group climate on microaccidents in manufacturing jobs. Journal of Applied Psychology, 85*(4), 587–596.
Zohar, D., & Luria, G. (2005). *A multilevel model of safety climate: Cross-level relationships between organization and group-level climates. Journal of Applied Psychology, 90*(4), 616–628.
Zohar, D., & Polachek, T. (2014). *Discourse-based intervention for modifying supervisory communication as leverage for safety climate and performance improvement: A randomized field study. Journal of Applied Psychology, 99*(1), 113–124.

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