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EFFECTIVENESS OF APPLYING A BEHAVIOR-BASED SAFETY PROGRAM IN INDUSTRIAL MODULAR CONSTRUCTION

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Abstract: Behavior-based safety (BBS) management programs aim to reduce the occurrence of accidents by preventing unsafe behaviors through observation and intervention. Although the application of BBS program is encouraged throughout safety management literature, the quantitative impact of implementing BBS programs on industrial modular construction worksites remains relatively unexplored. This research proposes a data-driven framework to determine whether the (i) implementation of a BBS program improves company safety performance, (ii) adoption rate of a safety program correlates with safety performance, and (iii) information collected by a safety program can identify proactive indicators of accident prevention. The proposed framework was used at an industrial-construction company in Alberta, Canada. Its BBS program, requires the workers to complete daily, anonymous risk reviews of their peers. Data, collected from BBS cards and incident reports, were extracted, analyzed, and visualized based on the company's safety management systems. The results show that the implementation of the BBS management program can potentially reduce incident rates, the filling rate of BBS cards can be inversely correlated with total incident rates, and certain safety categories in the BBS cards can be identified as proactive indicators of safety performance. Altogether, these results suggest that—to maintain low accident rates—the company can emphasize the completion of BBS cards and the assessment of identified proactive safety indicators.

1 INTRODUCTION

The construction industry has long been criticized for its poor safety performance. Construction safety is an important concern when delivering construction operations, as incidents can delay project schedules and increase project costs (Wanberg et al. 2013). Consequently, exploration and identification of the causes of workplace accidents are pertinent, since they may result in the adoption of safety strategies capable of proactively controlling onsite safety risks.

Companies' safety strategies for controlling risk level on construction sites are often dictated by company-developed Safety Management Systems (SMS). An SMS is formally conceptualized as "consisting of [safety] programs, processes, policies, and procedures for which there is a formal function overseeing their development, implementation, and ongoing administration" (Wachter and Yorio 2014). Kyriakidis et al. (2012) and Jiang et al. (2015) found that the occurrence of unsafe worker behavior was inversely correlated to SMS implementation. Indeed, it has been estimated that 80% of construction incidents are related to unsafe worker behaviors (Lingard and Rowlinson 2005).

A suggested SMS program method for controlling worker behavior, named as Behavior-Based Safety (BBS) observation program, is aimed to improve project safety performance. This program focuses on observing, preventing, and modifying workers' unsafe behaviors by the use of intervention- and observation-based methods, such as goal setting and instant feedback. As such, a BBS program may be deployed to facilitate the recording of safety observations by company employees, and most importantly, to reduce the incident rates of unsafe construction operations.

Several companies across various sectors have reported significant improvements to safety performance following the implementation of BBS programs [e.g., pipeline (McSween 2003), petroleum (Ismail et al. 2012), and construction industry (Zhang and Fang 2013)]. However, whether or not similar patterns can be observed across all industrial companies and sectors, which are characterized by varying work environments, safety culture, and employee compliance, remains unknown. Indeed, without the development of an appropriate assessment method, it remains difficult for construction companies to quantify the impact of BBS program implementation on safety performance, to determine the impact of worker compliance on program efficacy, and to improve upon existing practices and procedures.

Thus, the objective of this research study is to propose a data-driven framework that can assess the effectiveness of a BBS program to improve safety performance. The developed framework is used to determine whether (i) the implementation of a BBS program improved safety performance, (ii) the adoption rate of a safety program was related to safety performance, and (iii) the information collected from the safety program could identify proactive indicators for accident prevention at an industrial-construction company in Alberta, Canada.

2 BEHAVIOR-BASED SAFETY PROGRAM

The Behavior-Based Safety (BBS) program is an integrated management process that focuses on human behavior (Cox et al. 2004). Since its development in 1980, the method has been widely implemented across numerous industrial sectors throughout North America and Europe (Li et al. 2015).

Compared to other industries, implementation of the BBS program in the construction sector is challenging due to the dynamic and transitory nature of construction sites and workforces (Ringen et al. 1995). Worker behavior is more easily controlled in a stationary work environment compared to the dynamic work environment associated with construction processes. For instance, in a static work setting, worker behavior is more easily controlled than in a dynamic environment, where workers tasks, movements, and environment are variable and can jeopardize workers' safety intentions and risk perceptions (Cooper 2000).

Although previous researchers, such as Hallowell et al. (2013), have suggested that adoption rates of a BBS program can be used as a leading indicator of safety performance, the use of adoption rates as a proactive accident warning sign lacks empirical support. Furthermore, there is no definitive list of safety factors that should be assessed in the BBS program. As worker behavior can be affected by a spectrum of factors, such as work pressures, psychological factors, individual and environmental conditions, coworkers, and economic factors (Choudhry and Fang 2008; Jiang et al. 2015), factors affecting safety vary from company-to-company. While many companies adopt safety measures relevant to their specific work environment and purposes, the effectiveness of these measurements is not often evaluated. Furthermore, the deployment and continued application of the BBS program is a time-intensive process, requiring persistent management intervention and active worker participation. Management is often required to expend time ensuring workers are adhering to BBS practices and workers to expend a substantial amount of time evaluating their peers.

The development of a framework capable of quantifying the impact of BBS program on safety performance could address both of these practical challenges. First, quantification and empirical evidence demonstrating the ability of BBS programs to improve safety performance has the potential to incite and encourage increased employee participation in BBS programs, reducing time spent by management for enforcement. Furthermore, examination of the factors collected during the observation and recording process of the BBS program could assist the company in eliminating factors found on BBS cards that have little or no effect on safety performance, thereby lessening the overall time-intensiveness of the BBS program.

3 METHODOLOGY

A data-driven approach is proposed to extract, analyze, and visualize safety data. The proposed framework is summarized in Figure 1. First, safety databases are located. Then, data are extracted and generated by querying relevant databases. The *Pearson correlation test* and a *paired-sample t-test* are used to analyze the data and to determine if implementation of the BBS program improves safety performance. Calculations of the TIR value, the TRIR value, the Pearson correlation test, and the paired-sample t-test are discussed in the following subsections.

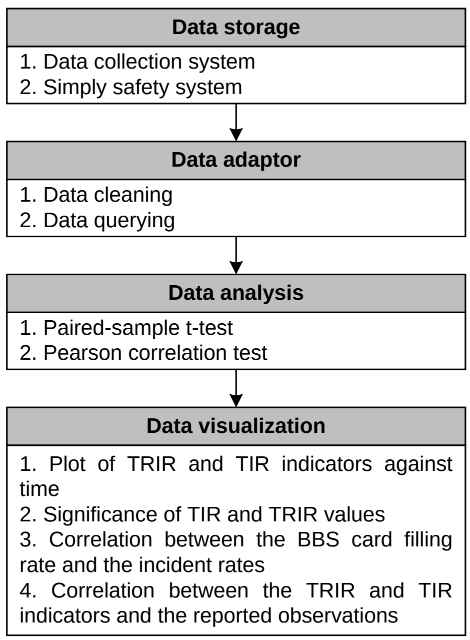


Figure 1: Methodology framework

3.1 Total recordable incident rate (TRIR) and the total incident rate (TIR)

In practice, output of the BBS analysis is based on the total recordable incident rate (TRIR) and the total incident rate (TIR). TRIR and TIR are safety indicators that are commonly used across multiple industries. These rates represent past performance (i.e., lagging indicators) rather than predicting future performance (i.e., leading indicators). The incident rates are standardized to allow occupational safety and health administrations or other regulatory agencies to statistically compare data and to identify industries that may require additional program assistance.

TRIR measures a company's total *recordable* injury rate by factoring in the number of working hours of a facility. It is a ratio of the number of recordable injuries to the number of working hours based on 200 000 labour hours (Equation 1). This number (200 000) equates to 100 employees working 40 hours per week for 50 weeks per year. According to CII (2014), the average TRIR value for the construction industry is 0.36.

$$[1]\quad \mathrm{TRIR} = \frac{\text{Number of recordable injuries} \times 200{,}000}{\text{Number of working hours}}$$

Mathematically, the TIR value is calculated as per Equation 2, yet it determines the *total* (recordable and non-recordable) injury rate. Currently, there is no benchmark average TIR value for the construction industry. However, since non-recordable accidents occur more frequently than recordable accidents, their control and investigation can result in improved TRIR values (Bird and Germain 1996).

$$[2]\quad \mathrm{TIR} = \frac{\text{Number of injuries} \times 200{,}000}{\text{Number of working hours}}$$

3.2 Paired-sample t-test and Pearson correlation test

The *paired-sample t-test* is a statistical procedure used to determine the probability that the mean difference between two sets of observations is 0 (Moore and McCabe 1993). In a paired sample t-test, each subject or entity is measured twice (e.g. the TRIR and TIR before and after an intervention), resulting in pairs of observations. The t-value is calculated based on Equation (3). Based on the t-value, the p-value is inferred. Throughout scientific literature, an intervention is considered to produce a significant effect if it results in a p-value of less than 0.05.

$$[3]\quad t = \frac{\left(\sum_{i=1}^{n}(y_i - x_i)\right)/n}{\sqrt{\dfrac{\sum_{i=1}^{n}(y_i - x_i)^2 - \left(\sum_{i=1}^{n}(y_i - x_i)^2\right)/n}{n(n-1)}}}$$

The *Pearson correlation test* is used to statistically calculate the correlation of two sets of variables (e.g., $\{x_1,\ldots,x_n\}$ and $\{y_1,\ldots,y_n\}$). Equation 4 calculates the *Pearson correlation coefficient*, r. The value of r ranges from +1 to -1. A value of zero indicates that there is no relationship between the two variables. A value greater than 0 indicates a positive association: that is, as the value of one variable increases, so does the other. A value less than zero indicates a negative association: that is, as the value of one variable increases, the value of the other decreases (Laerd 2017). In social sciences (De Vaus 2002), a correlation value between 0.50-0.69 and between 0.30-0.49 is indicative of a strong or moderate correlation, respectively.

$$[4]\quad r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)}\sqrt{\sum_{i=1}^{n}\left(y_i - \bar{y}\right)}}$$

4 CASE STUDY

This section demonstrates the method application of the proposed data-driven approach at an industrial-construction company in Alberta, Canada. Here, a BBS program requiring workers to perform anonymous, daily risk reviews of their peers was implemented in September 2014. Data was collected from the BBS cards completed by workers at the module yard and fabrication shop of the company. Total working hours prior to and following the implementation of the BBS program were 2 922 895.75 and 3 938 170.00, respectively.

4.1 Data extraction

Safety data was scattered across two different databases, namely a *data collection system* and *simple safety system*. The records of the BBS cards were stored in the *data collection system,* as depicted in Figure 2. This system is capable of producing safety report information, such as the quantity of BBS cards filled, quantity of at-risk observations, and quantity of near-miss observations, and allows users to group safety reports by project or data type.

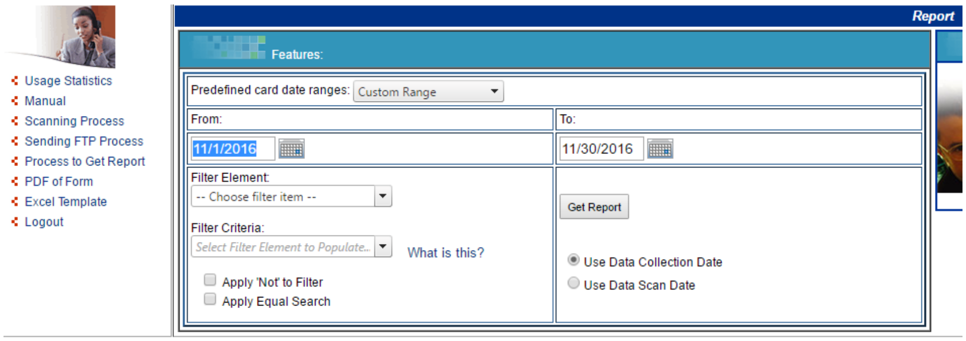
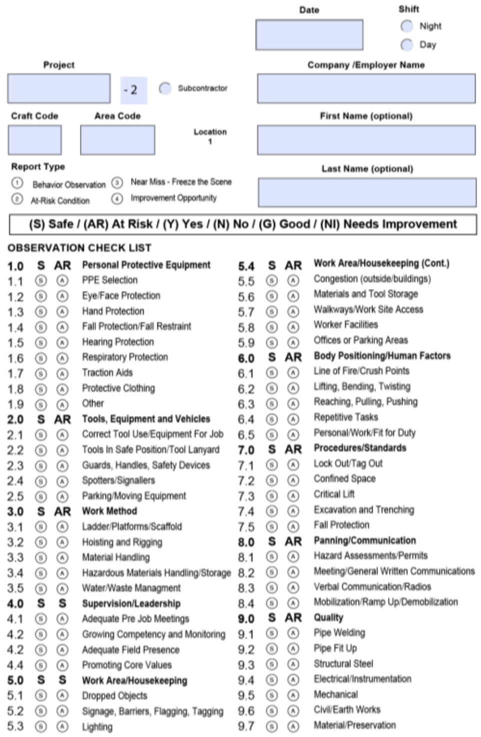


Figure 2: Data collection system

The BBS card is a field-level tool used by supervisors and workers to monitor adherence to and understanding of SMS system requirements. The card is useful for tracking undesirable situations and initiating corrective actions. For example, three observations of “failing to wear safety glasses” provide an opportunity to reinforce the requirement for mandatory eye protection through supervisory intervention. The BBS card can be used to identify risky situations before they become recordable incidents.

The BBS cards, as shown in Figure 3, were filled, on a daily basis, prior to performing tasks. A total of 163 385 BBS cards were submitted and collected between September 2014 to October 2016. The BBS cards were classified into four *report types*: (i) behavior observation, (ii) at-risk, (iii) near-miss, and (iv) improvement opportunities. In the *behavior observation* report, an observer evaluates the behavior of a co-worker. In an *at-risk* situation, an observer evaluates the behavior of coworkers performing high-risk tasks. A *near-miss* is defined as an unplanned event that did not result in injury, illness, or damage due to a fortunate break in the chain of events. In a *near-miss* report, an observer reports the conditions in which the near-miss condition occurred. In the *improvement opportunities* report, an observer may suggest the requirement for SMS improvement based on the factors included in the BBS card.

The implementation of BBS program required each worker to fill and submit an observation report consisting of 53 safety requirements. Examples of these requirements include: check if the eye and face protection is enough; check if tools are in a safe position; check if there are hazardous materials nearby; check if the lighting is enough; and check if the work area is congested. By filling such reports prior to performing the construction tasks, potential hazards are eliminated and as a result, incident rates may be reduced.


Date
Shift
Night
Day
Project
- 2
Subcontractor
Company /Employer Name
Craft Code
Area Code
Location
1
First Name (optional)
Report Type
① Behavior Observation
③ Near Miss - Freeze the Scene
② At-Risk Condition
④ Improvement Opportunity
Last Name (optional)
(S) Safe / (AR) At Risk / (Y) Yes / (N) No / (G) Good / (NI) Needs Improvement

OBSERVATION CHECK LIST

1.0 S AR Personal Protective Equipment
1.1 Ⓢ Ⓐ PPE Selection
1.2 Ⓢ Ⓐ Eye/Face Protection
1.3 Ⓢ Ⓐ Hand Protection
1.4 Ⓢ Ⓐ Fall Protection/Fall Restraint
1.5 Ⓢ Ⓐ Hearing Protection
1.6 Ⓢ Ⓐ Respiratory Protection
1.7 Ⓢ Ⓐ Traction Aids
1.8 Ⓢ Ⓐ Protective Clothing
1.9 Ⓢ Ⓐ Other
2.0 S AR Tools, Equipment and Vehicles
2.1 Ⓢ Ⓐ Correct Tool Use/Equipment For Job
2.2 Ⓢ Ⓐ Tools In Safe Position/Tool Lanyard
2.3 Ⓢ Ⓐ Guards, Handles, Safety Devices
2.4 Ⓢ Ⓐ Spotters/Signallers
2.5 Ⓢ Ⓐ Parking/Moving Equipment
3.0 S AR Work Method
3.1 Ⓢ Ⓐ Ladder/Platforms/Scaffold
3.2 Ⓢ Ⓐ Hoisting and Rigging
3.3 Ⓢ Ⓐ Material Handling
3.4 Ⓢ Ⓐ Hazardous Materials Handling/Storage
3.5 Ⓢ Ⓐ Water/Waste Managment
4.0 S S Supervision/Leadership
4.1 Ⓢ Ⓐ Adequate Pre Job Meetings
4.2 Ⓢ Ⓐ Growing Competency and Monitoring
4.2 Ⓢ Ⓐ Adequate Field Presence
4.4 Ⓢ Ⓐ Promoting Core Values
5.0 S S Work Area/Housekeeping
5.1 Ⓢ Ⓐ Dropped Objects
5.2 Ⓢ Ⓐ Signage, Barriers, Flagging, Tagging
5.3 Ⓢ Ⓐ Lighting
5.4 S AR Work Area/Housekeeping (Cont.)
5.5 Ⓢ Ⓐ Congestion (outside/buildings)
5.6 Ⓢ Ⓐ Materials and Tool Storage
5.7 Ⓢ Ⓐ Walkways/Work Site Access
5.8 Ⓢ Ⓐ Worker Facilities
5.9 Ⓢ Ⓐ Offices or Parking Areas
6.0 S AR Body Positioning/Human Factors
6.1 Ⓢ Ⓐ Line of Fire/Crush Points
6.2 Ⓢ Ⓐ Lifting, Bending, Twisting
6.3 Ⓢ Ⓐ Reaching, Pulling, Pushing
6.4 Ⓢ Ⓐ Repetitive Tasks
6.5 Ⓢ Ⓐ Personal/Work/Fit for Duty
7.0 S AR Procedures/Standards
7.1 Ⓢ Ⓐ Lock Out/Tag Out
7.2 Ⓢ Ⓐ Confined Space
7.3 Ⓢ Ⓐ Critical Lift
7.4 Ⓢ Ⓐ Excavation and Trenching
7.5 Ⓢ Ⓐ Fall Protection
8.0 S AR Panning/Communication
8.1 Ⓢ Ⓐ Hazard Assessments/Permits
8.2 Ⓢ Ⓐ Meeting/General Written Communications
8.3 Ⓢ Ⓐ Verbal Communication/Radios
8.4 Ⓢ Ⓐ Mobilization/Ramp Up/Demobilization
9.0 S AR Quality
9.1 Ⓢ Ⓐ Pipe Welding
9.2 Ⓢ Ⓐ Pipe Fit Up
9.3 Ⓢ Ⓐ Structural Steel
9.4 Ⓢ Ⓐ Electrical/Instrumentation
9.5 Ⓢ Ⓐ Mechanical
9.6 Ⓢ Ⓐ Civil/Earth Works
9.7 Ⓢ Ⓐ Material/Preservation

Figure 3: BBS card

In the *simple safety system*, data related to accidents and working hours, such as information regarding project safety performance, incident investigation, worker involvement in the accident, and accident information such as time, direct causes, root causes, location, injuries (if any), and incident type, are stored. A sample report was generated, as shown in Figure 4. With respect to industrial projects, the total number of incidents associated with the categories of environmental, fire and explosion, equipment and property damage, first aid, medical aid (M/A) recordable, fatality, and near-miss were included in the report. The values of TRIR and the TIR were automatically calculated. Notably, while this information is crucial for understanding post-accident facts, specific, proactive indicators have yet to be defined.

Project Name	Hours	Total Incidents	Environmental	Fires / Explosion	Property Damage	Equipment Damage	First Aid	M/A Recordable	Fatality	Near Miss Reported	TRIR	Total Incident Rate
A	24,999.50	1	0	0	1	0	0	0	0	0	0.0	0.0
B	31,041.50	0	0	0	0	0	0	0	0	0	0.0	0.0
C	10,545.50	0	0	0	0	0	0	0	0	0	0.0	0.0
D	59,149.75	0	0	0	0	0	0	0	0	0	0.0	0.0
E	353,401.50	29	1	0	3	4	17	0	0	4	0.0	9.6
F	14,650.25	0	0	0	0	0	0	0	0	0	0.0	0.0
G	0.00	0	0	0	0	0	0	0	0	0	0.0	0.0
H	0.00	0	0	0	0	0	0	0	0	0	0.0	0.0
Total	493,788.00	30	1	0	4	4	17	0	0	4	0.0	6.9

Figure 4: Report generated by simple safety system

4.2 Data adaptor

Since the databases of *data collection system* and *simply safety system* were not fully integrated, a number of Microsoft Access-based queries were developed to extract information for each available item in the BBS cards. The queries were used to determine the quantities of behavior-based observations, at-risk conditions, near-miss observations, and improvement opportunities for each month with respect to particular specialty trades. An example is shown in Figure 5.

Incidents were recorded from January 2012 to October 2016. Note that the incident rates from October 2013 to May 2015 were removed from the dataset due to the limited number of projects executed during this period. The reduced workload observed during this period was uncharacteristic for this company. In an attempt to analyze sample data that are reflective of “normal” conditions, these data points were removed.

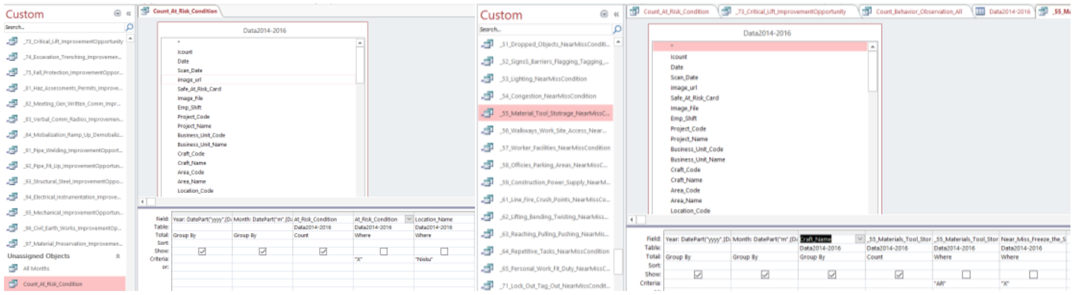


Figure 5: Queries used to extract information from the databases

4.3 Data analysis and visualization

The impact of BBS program implementation was visualized by plotting TRIR and TIR indicators against time, as illustrated in Figure 6. Results show that TIR rates were reduced following implementation of the BBS program. Prior to adopting the BBS program, TIR values were around 5, with TIR exceeding a value of 6 for six months. In contrast, TIR values were below 4 for all months except March 2015. Notably, TRIR values were greater than 0 for two months, and many of the reported incidents during this period were non-recordable incidents, such as first aids, near misses, and equipment/property damage.

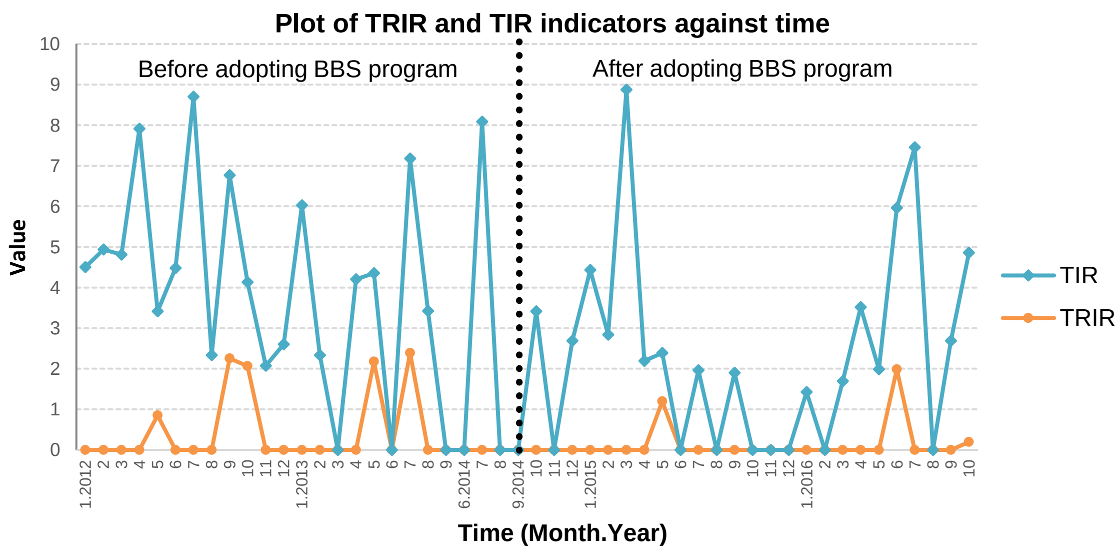


Figure 6: Plot of TRIR and TIR indicators against time

To determine if BBS program implementation could improve safety performance, safety records were analyzed using a paired-sample t-test to determine if the monthly TRIR (μ=0.44; 22 months) and TIR (μ=3.75; n=22 months) values before and after (TRIR, μ=0.14; TIR, μ=1.91; n=26 months) BBS implementation were statistically different (Table 1). The p-value for $TRIR_{Before}$ and $TRIR_{After}$ is 0.152, suggesting that implementation of the BBS program did not have a significant effect on TRIR. It is important to note, however, that the statistical insignificance may be due to the small number of recordable incidents. While the effect was statistically insignificant, that BBS implementation was found to reduce first-aid accidents and that first-aid incidents correlate with the occurrence of severe injuries and fatalities (Bird and Garmain 1996), it is likely that a significant effect of this program on TRIR values may emerge over time and with a larger sample size. In contrast, the p-value between TIR_{Before} and TIR_{After} was 0.002, indicating that implementation of the BBS program impacted the TIR.

Table 1: Significance (p-value) of TIR and TRIR before and after BBS program implementation

Indicators	Mean	Std. Error Mean	p-value
TIR_{Before}-TIR_{After}	1.8375	0.2005	0.002
$TRIR_{Before}$-$TRIR_{After}$	0.2982	0.5311	0.152

Correlations between the monthly filling rate of BBS cards and TRIR and TIR values were determined for each report category (behavior observation, at-risk condition, near-miss, and improvement opportunity) using the *Pearson correlation test* (Table 2). While none of the report types were found to correlate with TRIR values, these findings may be a consequence of the small number of recordable incidents. However, results did demonstrate that the completion rate of the BBS cards was significantly correlated with TIR values for three report categories, namely behavior observation, at-risk condition, and improvement opportunity. Although the near-miss observation was not correlated with accident rates, this may be a consequence of the near-miss procedure, which requires completion of BBS card only for near-miss incidents of high impact and severity. The negative (significant) correlation values indicate that higher filling rates of BBS cards were associated with reduced accident rates, suggesting that filling rates of BBS cards can be used as a proactive indicator of safety performance. Indeed, observation of unsafe behaviors could mitigate potential risks before performing construction operations, thus lowering incident rates.

Correlations between report types and TIR values were moderate, suggesting that other, unexamined safety assessment factors, such as site conditions and environment, may also affect TIR values. Furthermore, the results suggest that the companies could improve safety performance by implementing additional safety measures, such as site inspections and hazard identification, which would address these unexamined factors.

Table 2: Correlations (r) between filling rates of BBS cards and TRIR and TIR values

Report types	r-value (TRIR)	r-value (TIR)
Behavior observation	0.14	-0.39*
At-risk condition	0.09	-0.40*
Near-miss	-0.06	-0.07
Improvement opportunity	0.10	-0.40*

**Correlation is significant at 0.05 level*

Since there are nine categories included in the BBS card (Table 3), the *Pearson correlation test* was conducted to examine the association between category-associated reported incidences and TRIR and TIR values. Note that only BBS cards with at-risk observations reported by workers were included (i.e., a check of “AR” and not “S” in the BBS card). Certain categories, such as (1) personal protective equipment, (4) supervision and leadership, (5) work area housekeeping, (7) procedures and standards, and (8) planning and communication, were correlated with TIR values. The negative values indicate that the increased observation rates of particular risk factors were associated with reduced TIR values. Notably, certain categories, namely (9) quality, (6) body positioning and human factors, (3) work method, and (2) tools, equipment, and vehicles, were not correlated with TRIR or TIR values of any report type, demonstrating that incident occurrence is not related to an “AR” assessment of these factors.

These findings also suggest that certain safety factors, which are currently assessed by “yes” or “no” scales or by undefined assessment procedures, may not be conducive to accurate quantification. For instance, a defined metric for assessing factors such as “6.4 Repetitive tasks” and “5.5 Congestion (outside/buildings)” is not available. Therefore, workers subjectively decide and classify the observation as either “AR” or “S.” The record of such observation is, consequently, ambiguous and may be contributing to the weak nature of the observed correlation. In contrast, safety factors included in the category of “1.0 Personal protective equipment” are, comparatively, much less ambiguous, as personal protective equipment requirements are clearly defined by company policies.

Table 3: Correlation between TRIR and TIR indicators and reported observations

Categories	Behavior observation	At-risk condition	Near-miss	Improvement opportunity

		TRIR	TIR	TRIR	TIR	TRIR	TIR	TRIR	TIR
1.	Personal protective equipment	0.14	-0.45*	0.1	-0.41*	-0.18	-0.25	-0.06	-0.51*
2.	Tools, equipment, and vehicles	0.11	-0.28	0.13	-0.4	0.21	-0.27	0.13	-0.24
3.	Work method	0.21	-0.35	0.1	-0.25	-0.01	-0.32	0.27	-0.34
4.	Supervision and leadership	-0.1	0	-0.13	-0.56**	0.23	0.17	-0.13	-0.3
5.	Work area housekeeping	0.12	-0.35	-0.01	-0.43*	0.07	-0.39	0.14	-0.44*
6.	Body positioning and human factors	0.36	-0.25	0.3	-0.28	0.08	-0.13	0.06	-0.32
7.	Procedures and standards	0.2	-0.39	0.08	-0.27	-0.14	-0.41*	-0.06	-0.32
8.	Planning and communication	0.07	-0.52**	-0.05	-0.45*	-0.09	0.11	0.17	-0.19
9.	Quality	0.11	-0.2	0.01	-0.29	-0.09	-0.19	0.17	-0.35

**Correlation is significant at 0.05 level*

***Correlation is significant at 0.01 level*

5 CONCLUSION

This paper has (1) proposed a data-driven approach to extract, analyze, and visualize safety performance data from safety management systems to determine the impact of BBS programs on safety performance and (2) applied the proposed approach to quantify the impact of implementing BBS program. In the proposed framework, data is extracted and adapted from safety management systems. Results are visualized by plotting TRIR and TIR indicators against time. Then, a paired-sample t-test and a Pearson correlation test are used to determine the effectiveness of BBS implementation and the impact of program adoption rates on TRIR and TIR values, respectively.

The proposed framework was applied at a case company in Alberta, Canada. Given the data collected at the case company, the primary findings of this research are summarized as follows: (1) Implementation of a BBS program was shown reduce total incident rates at a company in Alberta, Canada. (2) Program adoption rates (assessed as BBS card filling rates) were found to inversely correlate with incident rates, indicating that BBS card filling rates can be used as leading safety indicators at the case study company. (3) The absence of a correlation between certain factors and incident rates at the case study company was likely a consequence of ambiguous assessment procedures. Specifically, these results indicate that BBS program procedures at the case company should be refined to ensure that assessment metrics are defined clearly and that irrelevant factors are removed.

A primary limitation of this study is the dynamic and variable environment of the construction industry. Although the proposed framework is expected to function as intended at many industrial construction companies, it is important to note that it may not apply to all worksites, as the contents of BBS cards varies between companies. Accordingly, due to inter-company variability, extrapolation of the case study conclusions to other companies should be done with caution.

However, findings of the present study suggest that: (1) BBS programs may be an effective means of modifying worker behavior, which may, in turn, lead to improved safety performance. (2) BBS program effectiveness may be associated with program compliance. (3) Management should both routinely refine—and continuously ensure worker compliance of—their BBS program procedures, as these factors may affect BBS program effectiveness.

Further research is required to benchmark the association between adoption rates and TRIR/TIR indicators across other companies and industries. Future research aimed at (i) identifying the minimum filling rate of BBS cards for achieving satisfactory safety performance, (ii) defining safety assessment factors that should be considered in BBS cards based on incident investigations, work quality, worker ergonomics, and human factors, (iii) evaluating standardized measurement procedures for objectively assessing the safety factors, and (iv) integrating safety and scheduling databases for streamlining the data flow will be crucial to improving BBS program assessment, effectiveness, and compliance.

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