Harnessing AI to Increase Workplace Safety

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Canadian Home Builders' Association - Newfoundland and Labrador

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TRAINING WORKS
KNOWLEDGE BY DESIGN

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Abbreviations

AWCBC: Association of Workers' Compensation Boards of Canada

CCOHS: Canadian Centre for Occupational Health and Safety

CHBA: Canadian Home Builders Association

NWISP: National Work Injuries Statistics Program

OHS: Occupational Health and Safety

WPNL: WorkplaceNL

Definitions

For this document, the following terms and definitions apply:

Incident: In the context of occupational health and safety, an incident is defined as an occurrence, condition, or situation arising in the course of work that resulted in or could have resulted in injuries, illnesses, damage to health, or fatalities (CCOHS, 2019). Incident is also sometimes used interchangeably with 'accident' in some literature and data. However, 'incident' is more often chosen over 'accident,' as 'accident' implies the event was related to fate or chance and may inflict blame on the worker (CCOHS, 2019).

Lagging indicator: a measure that reflects past incidents or accidents that have already occurred. These indicators often include metrics like injury rates, lost workdays due to injury, or property damage.

Leading indicator: early signals or measures that help predict potential hazards or risks before they occur. These indicators proactively identify trends or patterns that may indicate an increased risk of accidents or injuries in a workplace or environment.

Workplace Compensation Board Terms

Fatality: A death resulting from a work-related incident (including disease) that has been accepted for compensation by a Board/Commission (NWISP).

Industry: The AWCBC definition of industry is "a group of enterprises (for example, companies or establishments) that are engaged in the same or similar kind of economic activity. Boards/Commissions classify businesses according to their industrial activity for administrative purposes."

Injury or disease: Any injury or disease resulting from a work-related event or exposure to a noxious substance. Disease, as distinct from a physical injury, results from conditions in the work environment (NWISP).

Lost time claim: An injury where a worker is compensated by a Board/Commission for a loss of wages following a work-related injury (or exposure to a noxious substance) or receives compensation for a permanent disability with or without any time lost in employment (NOTE: Ontario and Newfoundland and Labrador do not include claims that receive compensation for a permanent disability without any time lost) (NWISP).

Occupation: The AWCBC definition of occupation is "the principal activity a person is engaged in at his or her place of work. The occupation of an injured or ill employee is coded according to the National Occupational Classification (NOC)."

Serious injury: WPNL's definition of a serious injury is a claim that meets the following criteria: The claimant had an injury in one of the injury codes, and the claimant received at least four weeks of wage loss; **or** the claimant's health care costs were greater than $2000; or the claim resulted in a fatality (Workplace, 2023).

1.0 Executive Summary

Introduction

The residential construction sector in Newfoundland and Labrador is a significant contributor to the region's economy, comprising 31% of construction employment, with 8% focused on new housing and 23% on residential renovation (Build Force Canada, 2024). However, as the demand for residential construction increases, a forecasted shortage of qualified workers poses additional safety risks in an industry where workplace incidents and injuries are already prevalent. This research project was designed to explore the linkages between worker and organizational safety behaviors (through qualitative and quantitative data) and incident patterns within this sector, with the goal of developing an algorithm that could predict workplace incidents and accidents. By leveraging data analytics, the project aimed to provide new insights to support occupational health and safety (OHS) in the province.

Research Objectives

The project sought to address two primary research questions:

1. Behavioral Linkages: What specific behaviors or patterns of behaviors (organizational and individual) can be linked to workplace incidents, accidents, and injuries within the residential construction sector, and how can these insights be used to enhance an OHS program?

2. Algorithm Development: Can an algorithm developed in this study accurately identify behaviors in safety data that lead to incidents and accidents?

Project Rationale

Sectors and organizations worldwide are collecting and analyzing increasing amounts of data, the potential to use these insights to improve safety outcomes in industries such as residential construction is immense. Companies are already using big data in various domains such as customer behavior, healthcare, and supply chain management to reveal patterns and trends that were previously undetectable (Marr, 2018; Bradlow et al., 2017; Wang et al., 2018; Waller and Fawcett, 2013). In the context of occupational health and safety (OHS), big data and analytics hold promise for predicting and preventing workplace injuries. For instance, Goldcorp, a gold mining company, used data analytics to examine safety incidents and operational data, uncovering relationships between various factors and injury rates (Stewart, 2013). Despite the widespread data collection, a significant portion of collected data remains unanalyzed, often referred to as "dark data" (Gualtieri, 2016; Schembera and Durán, 2020). This research project aimed to address similar challenges within the residential construction sector by exploring the feasibility of predictive analytics for incident prediction and prevention.

Project Limitations

While the research was ambitious in its scope, several limitations impacted the ability to fully achieve the project's objectives:

1. Participant Access: Securing participants for interviews and surveys from the residential construction industry proved challenging. Many organizations in this sector are micro (1-9 employees) or small enterprises (10-50 employees) with

limited capacity to engage in research activities, which constrained the collection of qualitative data. The limited engagement from industry stakeholders, though understandable, affected the breadth of data that could be gathered.

2. Data Accessibility: The availability of both leading and lagging indicator data for the incident prediction model was limited. Comprehensive workplace incident statistics are not systematically collected by federal and provincial governments, and provincially, workplace audits and associated data are not digitized. This lack of digitization and systematic data collection posed significant challenges in gathering the necessary data for the algorithm. Additionally, data provided by WorkplaceNL excluded unreported or unaccepted claims, and was limited to incidents that resulted in a monetary payout. These limitations further hindered the development of a predictive model.

3. Data Protection: The protection of personal health information under the Personal Health Information Act (PHIA) required de-identification before public release, which limited the number of claims and variables available for analysis, such as age, date of incident claim, nature of injury, and the event leading to injury. This necessary step, while crucial for privacy, reduced the richness of the dataset, further complicating efforts to develop a predictive algorithm.

4. Competency Model: Although the project faced limitations in data collection that prevented the full development of a predictive algorithm, the information gathered throughout this project was utilized to tailor a competency model for the residential construction sector. This model incorporates key competencies specific to behavioral-based safety, drawing on both new insights from the project and previous work by TW, including a comprehensive training assessment completed for CHBA-NL in 2017. While not a predictive tool, the competency model provides a foundation for identifying critical safety behaviors and can be further refined over time to enhance the understanding and prediction of behaviors that contribute to incidents and accidents.

Despite these limitations, the research project provided information on the current state of health and safety data within Newfoundland and Labrador's residential construction sector. The primary goal of developing a predictive algorithm for workplace incidents was not fully achieved, largely due to the limited availability and format of the necessary data. However, the project has laid a foundation for future research by identifying gaps that must be addressed to realize the potential of predictive analytics in this field.

Moreover, the creation of the competency model offers a practical tool that regardless of its predictive capability, can be used to enhance safety programs in the sector.

To advance the development of predictive models in the residential construction sector, future efforts must focus on improving data collection practices. This includes ensuring the data is collected in a comprehensive, detailed, and digitized format, which is essential for effective data analysis. Additionally, greater coordination between industry stakeholders will be crucial to gather the necessary data and insights to support the development of robust predictive algorithms.

2.0 Background

Occupational health and safety (OHS) programs are fundamental to ensuring the well-being of workers across all sectors, particularly in industries where the risks are inherently high, such as construction. In Canada, the legal framework underscores the responsibility of both employers and employees to maintain a safe working environment, recognizing that health and safety are collective responsibilities. Despite these protections, workplace incidents remain a significant issue, particularly within the construction sector, which recorded the highest number of workplace fatalities in Canada in 2022. This statistic highlights the need for improved methods of predicting and preventing incidents to ensure that workers are equipped with the necessary skills to maintain safety on site.

The residential construction sector, which represents a substantial portion of the construction industry in Newfoundland and Labrador, is facing significant challenges. With approximately 31% of construction employment in the province tied to residential construction, the demand for skilled workers is high, yet the availability of workers who meet job requirements is limited. This gap highlights the need for ongoing and enhanced training, particularly in health and safety, to ensure that workers can perform their tasks safely.

In this context, the current research project was undertaken to address two critical questions:

1. What specific behaviors and/or patterns of behavior can be linked to workplace incidents, accidents, and injuries within the residential construction sector, and how can these insights be used to enhance OHS programs?
2. Can an algorithm be developed to identify, from safety reports, the behaviors that lead to incidents and accidents?

The impetus for this research lies in the potential to leverage both leading and lagging safety indicators to develop a predictive algorithm. This algorithm would analyze data from these indicators to identify behaviors that precede incidents (at the organizational and individual level). These behaviours would then be structured within a competency model that the industry can use as a preventative measure, targeting specific behaviors for development and reducing the likelihood of incidents.

Leading and lagging indicators are crucial tools for evaluating and improving OHS programs. Lagging indicators, such as injury severity rates and workers' compensation claims, provide insights into past incidents but are limited in their ability to predict future risks. In contrast, leading indicators, such as safety training hours and near-miss reporting, offer a proactive approach by identifying potential safety issues before they result in incidents. This project attempted to harness the predictive power of these indicators, using them to train an algorithm that can predict workplace incidents by identifying and addressing data trends specific to organizational and individual behaviors.

Behavior-Based Safety (BBS) is central to this research, highlighting the critical role of understanding and influencing both worker and organizational behaviors to improve workplace safety. BBS recognizes that incidents are typically the result of a combination of factors, such as organizational culture and environmental conditions, rather than individual worker errors alone. The research hoped to develop a predictive algorithm to identify key behaviors that contribute to incidents. If successful, these behaviors would be incorporated into a competency model designed to guide training and skills development within the sector. This approach, rooted in BBS principles, promotes a blame-free environment and collective responsibility for safety, encouraging workers and organizations to actively identify and address hazards, ultimately fostering a safer and more effective workplace.

3.0 Project Methodology

The research methodology for this study was designed to provide a comprehensive understanding of the occupational health and safety (OHS) challenges within the residential construction sector and was to be applied to both the creation of the predictive algorithm and the behavioural based competency model. To achieve this, the study employed a mixed-methods approach, combining qualitative and quantitative analyses. The qualitative component aimed to capture the lived experiences and perceptions of workers and leaders in the sector, while the quantitative component sought to identify patterns and correlations in workplace incident data that could inform predictive models. Together, these methods were used to explore both the individual and organizational behaviors that contribute to safety outcomes and to develop a competency model that targets key behaviors for improvement.

Qualitative Research

This study employed a range of qualitative methods including: a jurisdictional scan, interviews, roundtables, surveys, and site visits to explore safety culture and practices within the residential construction sector in Newfoundland and Labrador. Each method provided insights into the operational realities and safety challenges in the industry.

Environmental Scan

An environmental scan was undertaken to further the understanding of injury and incident prediction in the residential construction landscape. The environmental scan focused on finding data and literature surrounding safety leading and lagging indicators and how they are used to predict workplace injuries and incidents. Additionally, research surrounding unsafe behaviours was explored, as human factors account for approximately 80% of workplace incidents in complex, high-risk industries such as construction, oil and gas, mining, transportation, nuclear, and healthcare (Garrett & Teizer, 2009). Where research on residential construction in Canada was limited, this scan turned to industrial sectors, where OHS programs involving workplace safety were most advanced.

Roundtables and Interviews

A series of interviews and roundtables were completed to gain insights into the operational reality of the residential construction sector in Newfoundland and Labrador. Individual interviews were conducted with four participants (n=4) in leadership positions. Additionally, two roundtable discussions were held: one for front-line workers (n=7) and one for leadership (n=7). All participants were from companies in the St. John's region, with operating experience ranging from 10 to 45 years. All participating organizations have less than 15 employees and use six to 15+ sub-trades, employing two to six people. All interviews were recorded, later transcribed, and coded by a team of analysts using MAXQDA 2022 (VERBI Software). Grounded theory methods were employed to analyze the interviews. Through open-ended questioning and a semi-structured approach, participants were encouraged to share their insights without predetermined categories or biases (Bryman, 2011). All interviews and surveys followed the guidelines set forth by ethics in human research, including voluntary participation, informed consent, and confidentiality (Research Ethics Board, 2023). Questions were designed to collect rich qualitative data on their perspectives, experiences, and practices related to safety in the residential construction industry. The interview question guide can be found in Appendix 1.

Following the interviews, an open coding process was undertaken to identify patterns, themes, and relationships within the data. Line-by-line coding was performed to assign descriptive labels to segments of the interviews. Next, codes were organized into broader categories based on similarities and connections, allowing for the emergence of key safety-related themes and safety-related competencies. For example, the vigilance and decision-making competencies were coded when discussing the lack of documentation or wearing PPE. If workers are not wearing the required PPE for the job, there is a decision made not to wear it, and vigilance is required to ensure you complete documentation and wear the required PPE. A complete list of codes can be found in Appendix 2.

Surveys

Surveys were deployed to capture data on leading and lagging safety indicators within the residential construction sector. Two survey categories were developed: one for workers and another for leadership. Categories for questions included demographics, self-reported incidents and injuries, workplace stress, safety behaviour, training, safety culture and awareness, and management commitment to safety. Questions were developed and informed by previous safety culture research and are listed in Appendix 3 (Givehchi et al., 2017; Newaz et al., 2018).

Initially, the target audience for the survey was residential construction workers in Newfoundland and Labrador. Surveys were distributed through site visits, emails, the CHBA Newsletter, and the CHBA Home Show. However, low response rates led to strategies such as shortening the survey, adding engaging graphics, reassuring confidentiality, and expanding the audience to include all Canadian construction workers. Despite these efforts, the response rate remained inadequate, prompting the introduction of an incentive. This, however, led to a significant challenge: the emergence of fraudulent “bot” responses, which necessitated the development of a bot detection system to filter out non-human responses by assigning ‘bot’ points and categorizing them as “certain” or “uncertain.”

Five hundred ninety-two (592) responses for the worker survey and 165 responses for the leadership survey were received. Analysts sorted the survey responses using the ‘bot’ point column and human discretion to assess the responses. Surveys were sorted into two categories: certain and uncertain. Certain responses were submitted prior to the release of the incentive or had other signs they were indeed not a ‘bot’ (e.g., responses submitted using a construction company email domain, submitted a unique response in “other”). Uncertain responses had zero ‘bot’ points and no ‘bot’ activity discerned by analysts but could not be accurately considered human responses. For the worker surveys, there were six certain responses (n = 6) and 18 uncertain responses (n = 18), and for the leadership surveys, there were three certain responses (n = 3) and five uncertain responses (n = 5).

Survey Challenges and Opportunities

The surveys involved a topic and questions of a sensitive nature surrounding personal experiences with OHS relating to their company. The odds of survey responses were found to be reduced when questions were of a sensitive nature, as observed by Edwards et al., 2023. The challenges faced by online surveys in terms of data quality include declining survey response rates, fraudulent responses, data integrity issues, inattention or carelessness of participants, non-representative samples, inconsistencies in data, low response rates, inattentive or careless responses, lack of participant engagement, limited control over participant characteristics, lack of data validation, limited control over survey distribution, privacy concerns, and lack of transparency (Goodrich et al., 2023).

Site Visits

Two (2) separate site visits were conducted in St. John's to observe safety practices on residential construction sites. Both organizations had been in business 10+ years and had less than 15 employees. While direct interviews with frontline workers were not possible, a visual assessment of the sites provided valuable insights into safety practices and norms.

One notable observation was workers' inconsistent use of personal protective equipment (PPE) on both sites. While some workers were observed wearing goggles, ear protection, boots, and gloves, there was a noticeable lack of essential safety gear such as hard hats and hi-viz vests. Poor indoor and outdoor housekeeping created potential hazards and risks on the sites (e.g. wood cluttering the floor posed tripping hazards). Additionally, the presence of non-English-speaking workers highlighted potential communication barriers that could impede effective safety practices and procedures.

While there were efforts to comply with basic safety measures, such as wearing some forms of PPE, there was a lack of consistent enforcement and approach to safety issues. The absence of comprehensive safety protocols and the presence of communication barriers further suggest that safety may not be fully integrated into every aspect of the organization's operations

Key Themes from Interviews, Site Visits, Surveys, and Roundtables

Site Visits:

- Inconsistent Use of PPE: Observations revealed inconsistent use of personal protective equipment (PPE) across sites. While some workers adhered to PPE requirements, others neglected essential safety gear such as hard hats and hi-viz vests, indicating a gap in safety awareness and enforcement.

- Poor Housekeeping Practices: Both indoor and outdoor areas exhibited poor housekeeping, with clutter such as wood scraps posing tripping hazards.

- Communication Barriers: The presence of non-English-speaking workers on some sites highlighted potential communication challenges, which could impede effective safety practices and adherence to protocols.

Surveys:

- Low Incident Reporting: The surveys indicated that minor incidents, such as cuts and bruises, were often unreported as they were considered part of the job. This low level of reporting reflects a broader issue of underreporting safety incidents within the industry.

- Safety Culture Variability: There was variability in safety culture across organizations, with larger companies more likely to have formalized safety programs and smaller ones relying on informal practices.

Roundtables and Interviews:

The roundtable and interview insights highlight several key themes related to safety in the residential construction sector:

- Impact of Organization Size on Safety: Smaller companies, often with fewer than ten employees, struggle to implement formal safety policies due to limited resources. In contrast, larger companies have the capacity to regularly enforce safety protocols, provide training, and track incidents.

- Informal Safety Management: In small teams, safety is typically managed informally through daily discussions rather than formal meetings, with minimal documentation due to the high demands of job tasks.

- Labour Shortages and High Turnover: The current labour shortage and high turnover in subcontracting firms make it difficult to ensure that safety policies are consistently enforced. Training is mostly done on the job,

with new employees learning about hazards as they encounter them.

- COVID-19 Impact: The pandemic has reduced pre-COVID safety practices like toolbox talks, as new safety protocols for the virus were implemented.

- Need for Tailored Safety Training: Participants emphasized the need for safety training that is specifically tailored to the residential construction industry. Training in hazard identification, risk assessment, and situational awareness was highlighted as crucial.

- Lack of Formal Safety Culture: While safety is recognized as a priority, there is a lack of formal safety culture, with non-compliance often due to the perceived inconvenience of formal procedures and documentation. This is especially true for smaller organizations with limited resources.

- Underreporting of Incidents: Many minor incidents go unreported, as they are seen as part of the job. Only incidents requiring medical attention are typically recorded.

- Need for Collaboration: There is a strong consensus on the need for collaboration between small residential construction companies and organizations like Occupational Health and Safety, WorkplaceNL, and the Newfoundland and Labrador Construction Safety Association. Such collaboration could help improve safety awareness, compliance with legislation, and the development of tools for easier safety management.

4.0 Injury and Incident Prediction - Quantitative Methodology

Data Selection Methods

Leading indicators were investigated for injury and incident prediction in the residential construction sector in Newfoundland and Labrador. To narrow in on the leading indicators, researchers referenced a list of safety performance indicators in the construction industry compiled from top publications between 2000 and 2019 (Shaikh et al., 2021). The following leading indicators from the list were identified as being likely to obtain data from incident reports, industry datasets, or workplace claims datasets for the residential construction sector:

- Employee training and engagement

- Near miss reporting

- Project hazard and risk assessments

- Safety inspection records

- Housekeeping schedule (site hazard assessments)

- Use of PPE

- Breaks taken or provided
- Exposure to hazards

Safety leading indicator data and information were requested from residential construction sector research partners and participants. Indicators requested were hazard and risk assessments, housekeeping and break schedules, records of training, and near-miss reporting. However, leading indicators are not widely recorded in the residential construction sector.

Safety inspection record data was requested from The Department of Digital Government and Service NL, Occupational Health & Safety Division. Pass or fail safety inspection data from the construction industry has the potential for predictive modelling of incidents. The Department could not share the investigation reports due to the *Personal Health Information Act* (PHIA) (Government of Newfoundland, 2023). They provided a de-identified overview of safety inspection activity data summaries. However, this data did not provide specific violation information or data points on the violations to use in an algorithm.

Occupation-based exposure data was obtained from the O*NET® 28.2 Database. The O*NET database contains variables that describe occupation and worker characteristics, including work context (exposure). The exposure information in this database uses incumbent responses from surveys to rate on a scale of 0-100 the frequency they are exposed to a given occupational risk or context. It is important to note that the information in this database is based on United States occupational information and participants. They implement a Standard Occupational Classification system similar to the Canadian National Occupational Codes; therefore, occupations can be correlated.

Unable to obtain leading indicator data besides exposure, we turned to lagging indicators for incident prediction. The following lagging indicators were identified as data of interest:

- Incident and accident reports, including information on the causes, including human or environmental factors
- Recorded injuries and fatalities
- Penalties given for unsafe behaviour or corrective action data
- Lost time and fatality claims

While the residential construction sector and federal and provincial governments do not systematically collect detailed workplace incident statistics—including non-injury incidents, injuries, fatalities, and near-misses—valuable estimates are available through provincial Workers' Compensation Boards (WCBs) based on workplace incident claims. It is important to note that although valuable data is available here, one of the most significant limitations is the data does not account for unaccepted claims, injuries, or incidents that have occurred but were not reported to WCB for compensation. This observation is supported by Bittle et al. (2018).

Workplace injury claims data was obtained via request from WorkplaceNL (WPNL), the WCB for the province of Newfoundland and Labrador. The provided dataset contained

1399 rows of data, each representing an individual claim accepted between 2015 and 2020. Due to the nature of occupational incidents and injuries, this data was limited by access and shortage. Workplace incident claims data is personal health information protected by Section 5 of the *Personal Health Information Act* (PHIA) (Government of Newfoundland, 2023). Before public release, data protected under PHIA must undergo appropriate de-identification to mask the identity of individuals in the dataset. The WPNL claims data de-identification process involved:

- Removing employer names.
- Removing fatalities.
- Removing gender.
- Removing the date of claim.
- Removing one entry that had exceptional circumstances.
- Classifying any sub-industry with fewer than ten (10) entries as “other”.

Following the de-identification process, the data did not have timestamps nor a data field stating whether the claim was open or closed. Therefore, the dataset could not be trended. In addition, the proportions of injuries to workforce demographics could not be accounted for.

When a claim is filed under a given subindustry, it may not correlate to the task performed at the time the injury or claim occurred. Therefore, the subindustries were not used to group the residential construction sector claims from the non-residential construction claims. For example, a claim could be filed under the subindustry consultant, but the task could correlate with home renovations. While the occupation does not correlate to the task completed at the time of injury, the occupation NOCs can correlate to the O*NET occupational exposure data. The claims were instead grouped by occupation to assess the total claims (Figure 1). Construction trades helpers and labourers have the most claims (259 claims), followed by carpenters (254 claims). The proportion of serious injuries in Construction trades helpers and labourers is 10.0%, and in Carpenters is 15.0% (Figure 2).

Figure 1: Injury Claims by Occupation: Top Ten Occupations with the Highest Claims

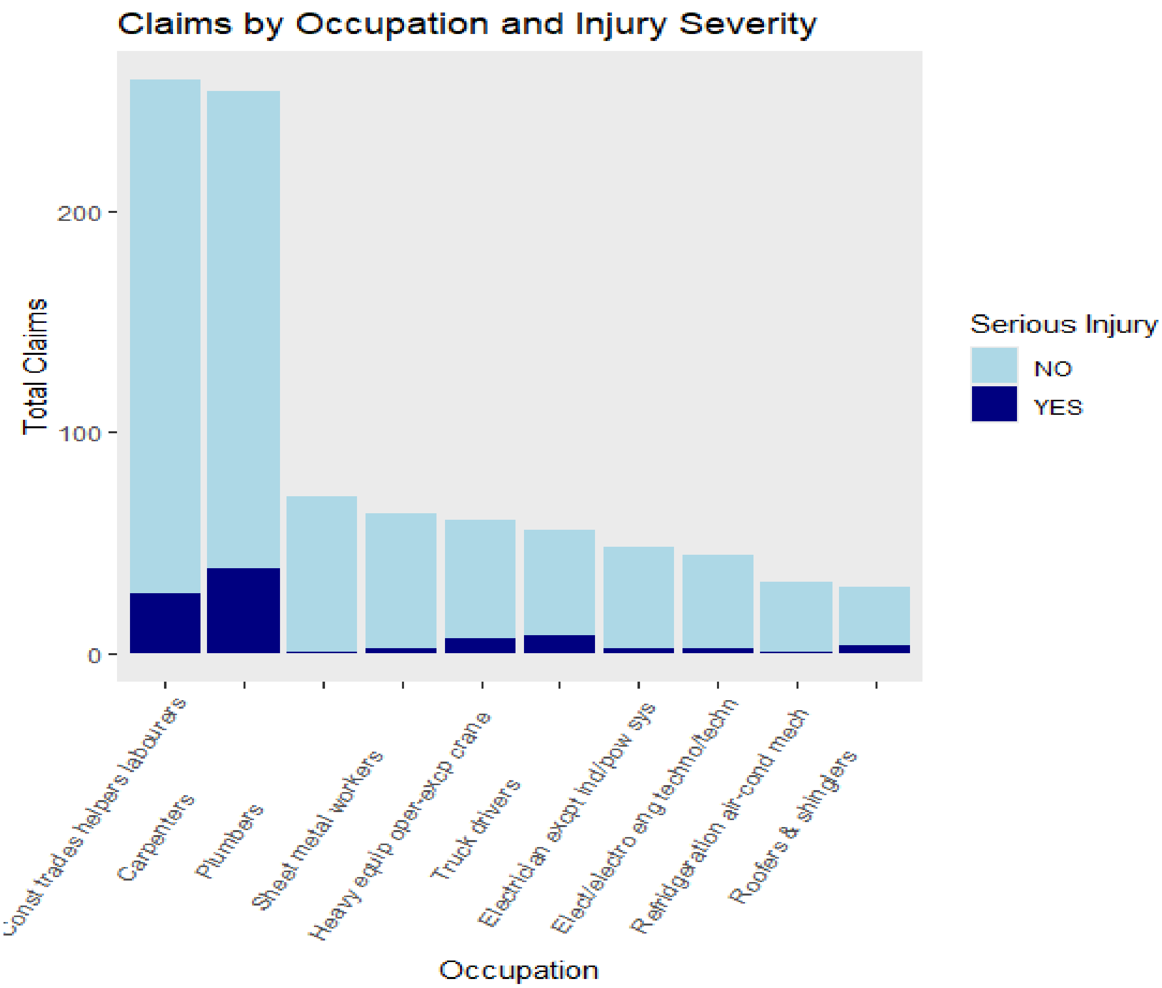
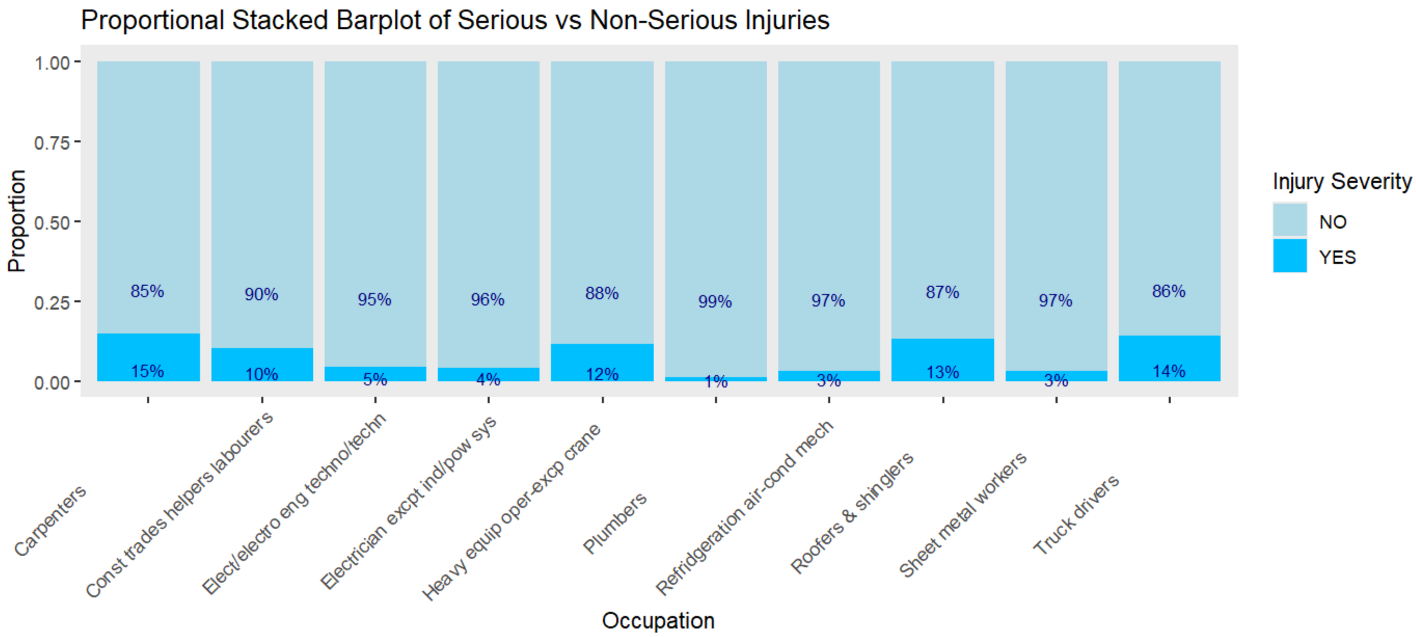


Figure 2: Proportion of Serious vs. Non-Serious Claims Within Each Occupation



Based on the highest claim amounts associated with Construction Trades Helpers and Labourers (NOC 7271) and Carpenters (NOC 7611) and considering their significance in the residential construction industry, this model will primarily concentrate on these specific occupations. The data variables were narrowed as the number of unique entries for occupations was 112, which would increase complexity and difficulty in analysis. However, data for modelling injury and incidents require more rows of data to obtain stronger predictions.

AWCBC provides publicly available datasets as part of the National Work Injury, Disease and Fatality Statistics Program (NWISP). Provincial WCBs report data to the AWCBC. The AWCBC data was selected for the predictive analysis due to the following considerations:

- WPNL data's value is in the lost time dollars, medical aid, and lost time weeks. We cannot use these fields for analysis without knowing if the claim is open or closed and without the date the claim was made.
- AWCBC provides data from other jurisdictions, providing a more robust dataset.
- AWCBC provides fatalities, while WPNL fatalities are restricted due to deidentification.
- Fewer deidentification limitations. For claim counts, AWCBC uses a threshold of 3, and WPNL uses a threshold of 9.

Like WPNL, AWCBC includes only accepted claims and does not fully represent the injuries and incidents in the construction industry. In addition, the AWCBC data is in a matrix table format, with four data files containing claim counts grouped by occupation (National Occupational Classification (NOC)). It is important to note that there are limitations on variables included in each dataset – there can only be four variables in each file, including the occupation as one. The variables included for the occupations in the construction industry, Construction Trades Helpers and Labourers (NOC 7271) and Carpenters (NOC 7611):

- Year
- Jurisdiction (province)
- Event (accident type; injury event)
- Nature of injury
- Body part injured

Injury and Incident Predictive Model

Data Analysis Methodology

Using the AWCBC lost time claims data, the following research question was explored:

1. Will an algorithm that is developed for this study identify in safety reports the behaviours that lead to incidents and accidents?

To address the research question, two specific occupations (Carpenters – coded as 7271 and Construction trade helpers and labourers – coded as 7611) from the data source were selected for analysis. Furthermore, as this project was an initial step in identifying and developing predictive leading indicators, two events (falls and overexertion) were selected from the larger dataset. These occupations were selected as they represent a considerable number of lost time claims within the construction industry (n = 11255).

Where possible, risk exposure was used to contextualize the lost time claims. In the O*Net Work Context dataset, "risk exposure" refers to how often people in certain jobs face potential dangers or complete specific tasks, and it is shown as the percentage of workers in those jobs who answered a survey about it.

In the O*Net Work Context (risk exposure) dataset, risk exposure is represented by the percentage of the workforce in a specific occupation who responded to a survey of how often they are exposed to or complete particular tasks. The O*Net survey questions were on a 5-Likert scale: every day, once a week, once a month, once a year, and never. Based on a focused literature review related to the most prevalent injuries for carpenters and construction trade helpers, the primary focus was placed on falls and overexertion injuries. For example, WPNL's Construction Industry Fact Sheet (2022) identified that these two events account for a combined total of 22% of the lost time claims, and construction workers make up 44% of the occupations associated with these types of claims.

A 5-year block of time (2018 to 2022) was selected from the AWCBC data to explore the research question. The data represented information collected from all ten provinces and three territories in Canada. Given the limited data for some of the provinces and territories, a decision was made to use the aggregated data totals for the entire country. Once selected, the data were consolidated into a smaller dataset containing the two occupations (Carpenters – coded as 7271 and Construction trade helpers and labourers – coded as 7611) and two event types (falls and overexertion). For analyses, the event variable was further divided into five specific types as follows:

- Falls, uns.
- Fall to lower level
- Jump to a lower level
- Fall on the same level
- Fall, n.e.c. (not elsewhere coded)
- Overexertion

These types follow the AWCBC coding framework. Similarly, the nature of injury was divided into 16 distinct types as follows:

- Traumatic injuries and disorders, uns.
- Traumatic injuries to bones, nerves, spinal cord
- Traumatic injuries to muscles, tendons, ligaments, joints, etc.
- Open wounds
- Surface wounds and bruises
- Intracranial injuries
- Multiple traumatic injuries and disorders
- Other traumatic injuries and disorders
- Nervous system and sense organs diseases
- Digestive system diseases and disorders
- Musculoskeletal system and connective tissue diseases and disorders
- Symptoms
- Other symptoms, signs, and ill-defined conditions, n.e.c.
- Mental disorders or syndromes
- Multiple diseases, conditions, and disorders
- Unknown

Finally, the body part data was divided per the AWCBC code framework. The 26 distinct types are as follows:

- Head, uns.
- Cranial region, including skull
- Ear(s)
- Face
- Neck, except for the internal location of diseases or disorders
- Trunk, uns.
- Shoulder, including clavicle, scapula and trapezius muscle if the shoulder is mentioned
- Chest, including ribs, internal organs
- Back, including spine, spinal cord
- Abdomen
- Pelvic region
- Multiple trunk locations
- Arm(s)
- Wrist(s)
- Hand(s), except finger(s)
- Finger(s), fingernail(s)
- Multiple upper extremities locations
- Lower extremities, uns.
- Leg(s)
- Ankle(s)
- Foot(feet), except toe(s)
- Toe(s), toenail(s)
- Multiple lower extremities locations
- Lower extremities, n.e.c.
- Multiple body parts
- Unknown

As these data are qualitative, they needed to be converted to quantitative values for analyses. A "dummy code" is a simplified way of representing categories or groups in statistics, typically using numerical values to stand for different groups without any inherent order or meaning. Therefore, numerical dummy codes are created for each occupation, event, nature of injury, and body part. Once assigned dummy codes, the data were analyzed to explore correlational relationships. To ensure that a comparison between the two occupations could be made, only lost time claims were used, where a total claim number was provided for both the carpenter and the construction trade helpers and labourers. This reduction in data resulted in a dataset with 262 lost-time claims (131 lost-time claims for each occupation).

After further review of the "context" data relating to risk exposure, it was not possible to directly connect the values for the two occupations across the event, nature of injury, or body part. For example, the O*Net dataset indicates that a value of 63 (carpenters) and 30 (construction helpers and labourers) be used for the "exposure to high places." As there are only two values, they would not change across the different types of lost time claims and provided little insight related to the dataset. For example, a lost time claim for a carpenter who had fallen on the same level and sustained a traumatic injury to their wrist would have a context value of 63, and this same value would be used for someone who sustained a traumatic injury to an ankle after falling to a lower level. Therefore, these values were not included in the analyses.

Pearson Correlation Analysis

Before performing a predictive analysis, a Pearson's correlation analysis was carried out to examine the relationship between the incident claims variables and the total number of claims identified over the 5-year period. This analysis helps to understand whether there is a strong or weak relationship between each incident claim variable and the overall number of claims. A correlation coefficient close to +1 or -1 indicates a strong relationship, while a coefficient closer to 0 suggests a weaker relationship. The analysis will also reveal the direction (positive or negative) of these relationships. If the correlation coefficient is positive, it means that as one variable increases, the other variable also tends to increase. Conversely, a negative correlation means that as one variable increases, the other tends to decrease. Correlation analysis assists in building regression models by identifying potential predictor variables that are most strongly related to the outcome variable, helping to select the most relevant variables for model accuracy. In addition, regression analysis often assumes certain conditions, such as linearity and independence between variables. Correlation analysis helps check these assumptions.

Table 3 displays the correlation matrix containing the correlation coefficients, showing the relationship between the variables and the total claim amount within each variable. An R^2 value of 0.03 was observed. The correlation between the total number of events and nature of injury was statistically significant (at an alpha level of .05) and positive (p = .01) with an R^2 value of 0.03. The correlation results also indicated a significant negative relationship (p = .05) between the event and nature of injury (R^2 = .01).

Figure 3: Correlation matrix for AWCBC lost time claims data (falls and overexertion). The variable 'Total' represents each variable's overall number of claims. A variable always has a perfect correlation to itself (i.e., an R-value of 1. Bolded values were found to be statistically significant.

	Event	Occupation	Nature of injury	Body part	Total
Event	1				
Occupation	-1.21074E-15	1			
Nature of injury	0.119205047	-5.48508E-16	1		
Body part	-0.011564278	8.32572E-18	-0.072952766	1	
Total	-0.074846718	0.004423574	-0.157101209	0.074603521	1

To better explain these findings, the results suggest that as the total number of lost-time claims increases, the value used to code (dummy codes) the nature of the injury decreases. Therefore, higher total values are significantly associated with codes closest to a dummy code value of 1 (e.g., Traumatic injuries and disorders, uns., Traumatic injuries to bones, nerves, spinal cord, Traumatic injuries to muscles, tendons, ligaments, joints, etc., Open wounds, Surface wounds and bruises). As an example from the data, there was a combined total (both occupations) of 2268 lost time claims categorized in the traumatic injuries to bones, nerves, and/or spinal cord associated with falls to a lower level across the 5-year block. In contrast, there were only 297 lost time claims, which were coded as intracranial lost-time cases.

Predictive Analysis

A multiple linear regression analysis was carried out using the total events and nature of injury correlation results as a basis for further analyses. The regression analysis incorporated the occupation, event, nature of the injury, and body part to predict the number of lost time claims that would potentially occur. Based on the dataset for the 5-year period, the multiple regression produced the following equation:

*Predicted total number of lost time claims = 349.57 - (Event * 20.81) + (Occupation *4.35) - (Nature of injury * 331.67) + (Body part * 48.94)*

Therefore, the equation would predict 48.03 lost time claims using the number of lost time claims for falls to a lower level for carpenters who sustained traumatic injuries to muscles, tendons, ligaments, joints, etc., specifically wrist injuries within the 5-year block.

*Predicted total number of lost time claims = 349.57 - (1.1 * 20.81) + (1 *4.35) - (1.02 * 331.67) + (1.13 * 48.94)*

= 349.57 – 22.89 + 4.35 – 338.3 + 55.3

= 48.03

The value from the original dataset was noted as 32 lost-time claims for these same variable totals. The difference in the two values ~16 is likely due to the data's variability. To compare the two occupations, the regression equation for the construction trade helpers and labourers resulted in 48.47 total lost time claims. In contrast, the dataset value was noted as 20 lost time claims. The R^2 values for the regression equation were found to be 0.03, with an adjusted R^2 value of 0.02 and a standard error of 48.86. Therefore, only ~3% of the variability in the data is accounted for by the regression equation. A more detailed and extensive dataset should be used to develop more robust predictions.

Predictive Model Challenges and Opportunities

Based on the research question and the available dataset, an algorithm to predict safety behaviours leading to incidents was not feasible. However, it is possible to use both correlational and regression analyses to better understand the relationship and likelihood of a lost-time claim, given that the dataset is not limited in size and detail. In addition, any contextualization of the data regarding risk exposure will require a greater level of detail, which can be connected directly to the specific events, nature of the injury, and body part.

5.0 Behaviour-Based Safety Competency Model

Despite the inability to create a predictive algorithm to identify key behaviors that lead to incidents, Training Works utilized the data gathered during this project to develop a behavior-based competency model. Although these behaviors could not be pinpointed by the algorithm, they were carefully selected based on Training Works' extensive experience within the homebuilding industry, including a comprehensive training needs assessment conducted in 2017 and the current project. Furthermore, these key behaviors are foundational BBS safety behaviours that have been adapted specifically to suit the homebuilding industry, as they are relevant across various sectors.

Comprised of 11 key competencies and over 120 behaviours, categorized into the six levels of Bloom's taxonomy, the model will help employers within the residential construction industry collect relevant data during health and safety reviews, provide a benchmark for training development, and raise awareness about the safe behaviours required to prevent incidents and accidents.

Figure 4: *Behaviour-Based Safety Competency Model.*

The Behaviour-Based Safety (BBS) competency model outlines the skills, knowledge, and behaviours necessary for individuals to effectively implement safety on the job and develop safe behaviours to prevent incidents and injuries (Figure 3). The interviews, roundtables, on-site visits, and research were used to tailor the BBS competency model for the residential construction industry. The eleven identified competencies in the model include:

1. Mindfulness

Mindfulness is being present in the moment and taking time to think before you act.

2. Vigilance

Vigilance means keeping your focus and staying alert while doing work tasks. To be safe, you must continuously monitor the people, the machines, and the work site.

3. Active Listening

Listening to understand the speaker's message. When you listen with this goal in mind, it decreases the number of mistakes at work.

4. Effective Inquiry

Effective inquiry means asking questions with a purpose. You can use effective inquiry to get more details, solve problems, make decisions, or show the topic from another point of view.

5. Closed-loop Communication

Closed-loop communication is a tool to make sure the message is understood. This process helps avoid mistakes in communication. It gives the speaker the chance to say the message. It also allows the listener to accept the message or ask for more details.

6. Assertiveness

Assertive communication is about making sure your message is understood.

7. Strategic Decision Making

Following a step-by-step process to decide. Split-second decision-making is critical to keeping a workplace safe and keeping the operation running smoothly.

8. Team Building

A team is a group of people that work together. You are a part of a large team; all workers in the company are on this team, and you are all working to reach the same goal. You are also a part of a smaller team, people you work with daily. No matter the size of your team, you all work together to reach a goal.

9. Workload Management

A good manager or supervisor assigns tasks to individuals based on their role in the company and skill level. You must also understand how to manage your tasks with the team and goal in mind.

10. Coaching

Coaching is a big part of day-to-day tasks within construction. Behaviour-based safety programs are rooted in coaching. All team members must help each other to become safe in the workplace. By coaching others, you are sharing your know-how and skills.

11. Situational awareness

Situational awareness refers to an individual's or a team's ability to perceive, comprehend, and anticipate risks in their work environment. Situational awareness enables individuals to make informed decisions, take appropriate actions, and effectively respond to changing circumstances to prevent accidents, injuries, and other safety incidents.

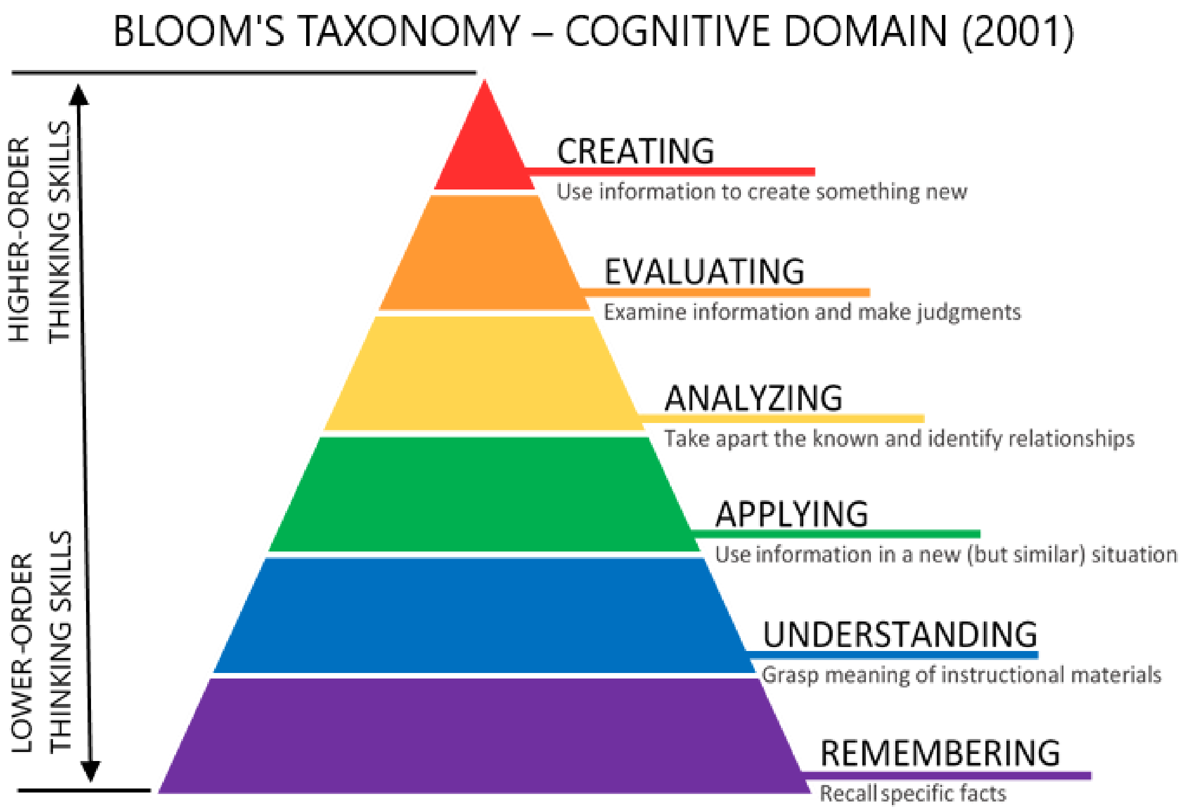
Bloom's Taxonomy

The BBS model was aligned with Bloom's Taxonomy, a hierarchical framework used to classify educational objectives into levels of complexity and specificity (Bloom, 1956; Krathwohl, 2002). The taxonomy organizes cognitive skills into a pyramid with six levels, arranged from the simplest to the most complex (Figure 5).

Educators use Bloom's Taxonomy to design learning objectives, assessments, and instructional strategies catering to different cognitive complexity levels. Educators can create more effective learning experiences that promote deeper understanding and critical thinking skills by understanding where each learning objective falls within the taxonomy. By aligning the BBS competency model with Bloom's Taxonomy, the model can be used to test a learner's understanding of a given competency.

A full proprietary competency model, including behaviours and Bloom's Taxonomy alignment, has been provided to the CHBA and WPNL.

Figure 5: Bloom's Taxonomy



6.0 Discussion: Challenges in Data Collection for Predictive Algorithm Development

The development of a predictive algorithm to identify key behaviors leading to incidents in the residential construction sector faced significant challenges, particularly in collecting the necessary data. While the intention was to harness comprehensive datasets of both leading and lagging indicators, the reality of data collection presented several obstacles that need to be acknowledged and addressed through collaborative efforts among all stakeholders.

One of the primary challenges was the lack of comprehensive data collection practices within the industry. Although various stakeholders, including provincial and federal government departments responsible for safety, have made strides in improving workplace safety, the focus has often been more on compliance rather than on the preventative measures needed to capture the data required for predictive analytics. Without clear guidelines for data collection and standardized reporting across regions, it becomes difficult to gather the consistent and detailed data necessary for building predictive models.

Additionally, the industry itself faces hurdles in integrating data collection into safety management systems. Many companies, particularly smaller ones, lack the resources or infrastructure to capture and analyze leading indicators such as near-miss reports, safety observations, and training completion rates.

Workers' Compensation Boards (WCBs) also play a crucial role in this process. However, while WCBs collect data through workplace incident claims, the data is often limited by factors such as non-reporting of incidents and the protection of personal health information under laws like the Personal Health Information Act (PHIA). These limitations restrict the availability of comprehensive datasets, which are crucial for predictive modeling. Additionally, the process of de-identifying data to protect individual privacy further reduces the number of available claims and relevant variables, hindering the depth of analysis possible.

Despite these challenges, there is a strong case for continuing efforts to improve data collection practices. Governments can support these efforts by shifting policies towards a more preventative approach. By introducing funding programs, incentives, and resources for training and implementing preventative safety measures, the industry can better participate in these initiatives. In addition, establishing clear guidelines and demonstrating the value of leading and lagging indicators to employers will be essential in encouraging widespread adoption.

Addressing these challenges requires a collaborative approach among all stakeholders: government bodies, industry players, WCBs, and workers. By working together, it is possible to address the barriers to effective data collection and begin moving towards the development of robust predictive models that can significantly enhance occupational health and safety in the residential construction sector. These data-driven approaches will enable a proactive stance on safety, leading to a safer working environment and a potential reduction in incident rates across the industry.

Appendix 1 – Interview Question Guides

Industry Leadership: One-on-One Interview

**Important note: a semi-structured approach was used for the interviews. The following questions may not have been asked in complete, and additional questions may have been probed dependent on each interview.*

1. How many employees do you have?

   Information received: size of company. Can relate to workplace safety practices.

2. How many years have you been in business?

   Information received: years of experience; age of company. Can relate to workplace safety practices.

3. What is your most primary line of business?

   Information received: what tasks they perform most often. Can relate to the safety risks and hazards associated with their work.

4. How many contractors/subtrades do you typically have in the run of a month?

   Information received: if they work with other contactors/subtrades and how many.

   - Probing questions:
     - When your contractors/subtrades are on site, are you responsible for their safety?

5. Do you track and/or record the number of incidents (near misses)?

   Information received: if a company keeps record of their near misses. Near-miss records are a leading indicator as they can give insight into potential risks and how to mitigate them. Can give insight into if the company tracks and addressing hazards and risks.

6. How does your team identify hazards in the workplace?

   Information received: if a company performs hazard and risk assessments before they begin work. Can give insight into if team members identify risks and hazards.

   - Probing questions:
     - If a hazard is identified, what steps do you normally take or what steps are recommended to your employees to take?
     - Provide an example if you can recall.

7. What types of safety training or certificates does your team have – either formal or informal?

Information received: if employees receive formal and/or informal safety training. Can provide insights into safety culture and experience.

- Probing questions:
    - Is safety training you implement meet the minimum safety requirements? Or does it go beyond the minimum requirements?
    - Are you and/or your team members core certified?

8. What is the PPE gear you have on site?

   Information received: to gain insight into what PPE is required versus what is actually worn on site.

9. Looking at the industry, if you could make any kind of safety improvements, what would you look to improving?

   Information received: insight into what industry leaders believe to be important in safety culture, and areas they see that could use improvement.

Industry Leadership: Roundtable

**Important note: a semi-structure approach was used for the interviews. The following questions may not have been asked in complete, and additional questions may have been probed dependent on each interview.*

1. How long does it take to build a home? Average time per square foot.

   Information received: Can reveal the average time it takes to build a home, where the estimated value can be used in injury and severity rate calculations. Can also reveal organizations differences in the pace they work. Do all organizations normally work at the same pace? Some faster? Some slower? Does this eventually correlate to their safety culture and practices?

2. Are regular safety audits performed at your job sites?

3. How often is employee safety training conducted or updated?

   - Probing questions:
       - Is training formal, semi-formal, non-formal?
       - As leaders, can you identify any training or knowledge gaps on your team?
       - Do you have a budget for training?

4. What safety discussions take place with your team? In other words, at what point(s) in the project do you review safe procedures, issues, hazards, and training?

5. Do you feel all accidents can be prevented?

6. What is your ‘why’ to safety?

7. How is health and safety linked to your business?
   - Is health and safety a core value in the company?
   - Improved performance?

8. Does your break procedure change when site or environmental conditions change?

9. Do your employee’s have health benefits? What are these benefits?

10. How do you encourage employees to participate in decisions which affect their safety?
    - An employee right to participate, right to refuse, right to know (training).
    - Opportunity for health and safety committees.
    - Opportunity to operate as health and safety officer.

11. When an accident or injury occurs, what is your process for identifying what happened?
    - Management looks for causes, not guilty persons, when an accident occurs.
    - Answer to this question can provide insight on organization’s perception on cause of accidents – do they blame the people, or do they find the root cause?

12. What kinds of accidents do you see the most? (Examples: slips, trips, falls, fall from heights, hand tool injury, overexertion (strains, tears, etc.).

    Information received:

13. Are you tracking near misses?

    Information received:

    - Probing questions:
      - Follow up to those who answer Yes, ask them how are they tracking them? How are they using them to improve employee safety?

14. Following our discussion today and hearing what other industry experts have to say, do you feel you could do more to improve your workplace health and safety culture?

Information received: perception of industry leaders on what could be improved in OHS.

- Probing questions:
  - If they answer no, they could be confident in what they're doing is enough.
  - Follow up with those who answered YES: In which ways do you think you could improve?
  - Safety can always improve.

Appendix 2 – Interview Codes

Roundtable Code Book

Code System with Frequency of Appearance

1 contradiction	3
2 Behaviours	0
2.1 unsafe behaviour	2
2.1.1 complacent	13
2.2 safe behaviour	1
3 Emotions and Perceptions	0
3.1 perception on safety	2
3.1.1 negative safety perception	4
3.1.2 positive safety perception	5
3.2 frustration	8
4 Safety Culture	4
4.1 lack of enforcing safety	7
4.2 responsibility for safety	11
4.3 industry safety culture	11
4.4 implementing safety	2
4.5 lack of implementing safety	11
4.6 PPE	5
4.7 slack on safety	6
4.8 safety as an inconvenience	10
4.9 toolbox talks	3
5 Policy	0
5.1 insurance	2
5.2 lack of reporting	4
5.3 OHS	3
5.4 safety association	4
5.5 WPNL	0
5.6 enforcement	0
5.7 regulatory gap	18
5.8 workers compensation	2
5.9 policy	11
5.10 compliance	18
5.11 noncompliance	13
5.12 liability	10

5.13 NIC code	1
5.14 formal policy	11
5.15 workplace rates	0
6 Organizational	0
6.1 equipment	2
6.2 renovations	0
6.3 site complexity	2
6.4 labour shortage	2
6.5 digital tools	9
6.6 Under the table	8
6.7 workday tasks	0
6.8 informal documentation	0
6.9 safety documentation	5
6.10 scaffolders	2
6.11 roofers	4
6.12 hierarchy	0
6.13 workplace improvement	2
6.14 employee safety rep	0
6.15 staff turnover	3
6.16 experienced	1
6.17 company growth	0
6.18 tasks	0
6.19 company records	1
6.20 project size	5
6.21 informal policy	6
6.22 employee records	0
6.23 subcontractors	12
6.24 number of subtrades	2
6.25 number of employees	2
6.26 years in business	0
6.27 new employees	0
6.28 inexperience	2
6.29 COVID	2
6.30 commercial work	1
6.31 residential	2
6.32 staffing	0

6.33 small crew	1
7 Training	0
7.1 Retention	1
7.2 formal training	0
7.3 training gap	3
7.4 training	3
7.4.1 WHIMIS	0
7.4.2 Fall arrest	6
7.4.3 first aid	1
7.5 core certified	7
7.6 exceeding training requirements	0
7.7 informal training	0
8 Hazards	0
8.1 hazard mitigation	5
8.1.1 housekeeping	0
8.2 hazard elimination	0
8.3 hazard identification	6
8.3.1 trip hazards	1
8.3.2 icy conditions	1
8.4 risk exposure	2
8.5 risk elimination	1
9 Competencies	0
9.1 accountability	7
9.2 awareness	13
9.3 communication gap	5
9.4 coaching	3
9.5 workload management	7
9.6 decision making	17
9.7 vigilance	28
9.8 mindfulness	8
9.9 communication	11
9.9.1 effective inquiry	0
9.9.2 active listening	0
9.9.3 assertiveness	7
9.10 teamwork	0
9.11 common sense	0

10 Incidents	1
10.1 severity	1
10.2 body part	0
10.3 drugs	0
10.4 near misses	11
10.5 accident	2
10.6 injury type	0
10.7 reoccurring injury	0
10.8 incident	1
10.9 lost time incident	0
10.10 number of incidents	0
10.11 occupational disease	0
11 Competencies	0

Key Informant Code Book
Code System with Frequency of Appearance

1 Behaviours	1
1.1 unsafe behaviour	2
1.2 complacent	4
2 Emotions and Perceptions	2
2.1 industry mentality	1
2.2 perception on safety	1
2.2.1 negative safety perception	6
2.2.2 positive safety perception	12
2.3 frustration	2
3 Safety Culture	8
3.1 responsibility for safety	4
3.2 industry safety culture	11
3.3 implementing safety	5
3.4 new program	6
3.5 lack of implementing safety	5
3.6 weak safety regulations	2
3.7 PPE	3
3.8 slack on safety	3
3.9 safety as an inconvenience	9
3.10 toolbox talks	6
4 Policy	0

4.1 lack of enforcing safety	2
4.2 safety documentation	2
4.3 informal documentation	1
4.4 safety association	1
4.5 WPNL	1
4.6 enforcement	1
4.7 compliance	2
4.8 regulatory gap	4
4.9 workers compensation	1
4.10 policy	9
4.11 liability	11
4.12 NIC code	1
4.13 formal policy	9
4.14 workplace rates	1
5 Organizational	0
5.1 labour shortage	4
5.2 workday tasks	1
5.3 occupational disease	2
5.4 renovations	2
5.5 equipment	1
5.6 site complexity	2
5.7 hierarchy	3
5.8 workplace improvement	1
5.9 employee safety rep	1
5.10 staff turnover	4
5.11 experienced	2
5.12 company growth	3
5.13 tasks	1
5.14 company records	10
5.15 project size	2
5.16 informal policy	16
5.17 employee records	3
5.18 subcontractors	5
5.19 number of subtrades	5
5.20 number of employees	5
5.21 years in business	4

5.22 new employees	7
5.23 inexperience	3
5.24 COVID	4
5.25 commercial work	3
5.26 residential	1
5.27 staffing	4
5.28 small crew	11
6 Training	0
6.1 formal training	1
6.2 WHIMIS	1
6.3 training gap	6
6.4 lack of training	2
6.5 fall arrest	5
6.6 training	14
6.7 first aid	2
6.8 core certified	15
6.9 exceeding training requirements	2
6.10 mandatory training	7
6.11 informal training	3
7 Hazards	1
7.1 risk elimination	2
7.2 icy conditions	1
7.3 hazard mitigation	5
7.4 hazard elimination	8
7.5 trip hazards	2
7.6 hazard identification	14
7.7 housekeeping	13
8 Incidents	0
8.1 severity	3
8.2 body part	1
8.3 drugs	1
8.4 near misses	13
8.5 accident	2
8.6 injury type	1
8.7 reoccurring injury	1
8.8 incident	5

8.9 lost time incident	2
8.10 number of incidents	2
9 Competencies	0
9.1 awareness	5
9.1.1 accountability	17
9.1.2 communication gap	3
9.1.3 coaching	10
9.1.4 workload management	9
9.1.5 decision making	27
9.1.6 vigilance	47
9.1.7 mindfulness	20
9.1.8 communication	28
9.1.8.1 active listening	0
9.1.8.2 effective inquiry	3
9.1.8.3 assertiveness	1
9.1.9 teamwork	6
9.1.10 common sense	7

Appendix 3 – Survey Questionnaires

Leadership Questionnaire
Demographics

1. What is your gender?
2. What is your age?
3. Work experience in the construction industry (in years)?
4. What is your leadership position?
5. What is your primary occupation?
6. What is your secondary occupation (if applicable)?
7. What is the size of the company in which you are employed?
8. What is the province or territory in which you are employed?

Self-reported incidents and near-miss involvement

9. Personally, have you experienced an injury or accident at any time in your career?
10. Has an injury or accident occurred within your team in the past 12 months?
11. Has a near-miss occurred within your team in the past 12 months?
12. Personally, have you experienced a near-miss in the past 12 months?
13. Personally, have you experienced a near-miss at any time in your career?
14. In the past 12 months, has a team member exercised their right to refuse unsafe work on your worksite?
15. In the past 12 months, has a stop work order been issued on your team's project?
16. In the next 12-month period, how likely do you think it is that one of your team members (6-point Likert scale):
    a. Become injured or fall ill on the job.
    b. Exercise the right to refuse unsafe work on the job.
    c. Experience a near-miss.
    d. A stop work order could be issued.

Workplace stress and safety behaviour

17. On average, how stressed do you feel at work (5-point scale)?
18. I feel (Likert):
    a. Safety is considered when setting project timelines and schedules.
    b. A zero tolerance for safety violations is always enforced.
    c. I voluntarily carry out activities that help improve workplace safety.
    d. Formal safety requirements have gone further than needed and are an administrative burden.

Training

19. Select the following training and certifications you hold:
    a. Fall protection.
    b. High angle rope rescue.
    c. HazMat Awareness.
    d. Fall protection basic rescue (FPBR).
    e. First Aid.
    f. WHIMIS (workplace hazardous materials information system).
    g. Hazard communication.
    h. Electrical safety.
    i. Confined spaces.
    j. Respiratory protection.
    k. Personal protective equipment (PPE).
    l. On-the-job training (formal or semi-formal).
    m. Other.
20. Did the above training provide you with the tools and knowledge you needed to complete your job safely and effectively (Likert)?
21. Please respond to the following statements (Likert):
    a. Everyone receives the necessary workplace health and safety training when starting a job, changing jobs, using new techniques, or starting a new task.
    b. You would allow an employee to carry out a task or enter a worksite if you believed they were competent but did not have formal training.

Safety culture and awareness

22. Please respond to each statement (Likert):
    a. Everyone has the tools and/or equipment they need to complete their work safety.
    b. Systems are in place to identify, prevent, and deal with hazards on the worksite.
    c. I quickly correct any safety hazard – even if it is costly.
    d. Safety audits are regularly conducted.
    e. You wear personal protective equipment (PPE) on site always.
23. I believe my team follows safety policies, procedures, and practices (5-point scale, rarely to all the time)
24. Do you hold discussions surrounding site safety (formal or informal)?

Worker Questionnaire

Demographics

1. What is your gender?
2. What is your age?
3. Work experience in the construction industry (in years)?
4. What is your position?
5. What is your primary occupation?
6. What is your secondary occupation (if applicable)?
7. What is the size of the company in which you are employed?
8. What is the province or territory in which you are employed?

Self-reported incidents and near-miss involvement

9. Have you experienced an injury or accident at any time in your career?
10. Have you experienced an injury or accident in the past 12 months?
11. Have you experienced a near-miss in the past 12 months?
12. Have you experienced a near-miss at any time in your career?
13. In the past 12 months, have you or a team member exercised your right to refuse unsafe work on the job?
14. In the next 12-month period, how likely do you think it is that one of your team members:
    a. Become injured or fall ill on the job.
    b. Exercise the right to refuse unsafe work on the job.
    c. Experience a near-miss.

Workplace stress

15. On average, how stressed do you feel at work (5-point scale)?
16. I feel my employer provides (Likert):
    a. Adequate time to complete all tasks that are asked of me.
    b. Adequate resources and other supports for workplace mental wellbeing.

Training

17. Select the following training and certifications you hold:
    a. Fall protection.
    b. High angle rope rescue.
    c. HazMat Awareness.
    d. Fall protection basic rescue (FPBR).
    e. First Aid.

f. WHIMIS (workplace hazardous materials information system).
g. Hazard communication.
h. Electrical safety.
i. Confined spaces.
j. Respiratory protection.
k. Personal protective equipment (PPE).
l. On-the-job training (formal or semi-formal).
m. Other.

18. Does the above training provide you with the tools and knowledge you needed to complete your job safely and effectively (Likert)?
19. You receive the necessary workplace health and safety training when starting a job, changing jobs, using new techniques, or starting a new task. (Likert):

Management commitment to safety

20. Please respond to each statement (Likert):

    a. Everyone has the tools and/or equipment they need to complete their work safety.
    b. Systems are in place to identify, prevent, and deal with hazards on the worksite.
    c. Management quickly correct any safety hazard – even if it is costly.
    d. You feel comfortable enough in your workplace to bring safety issues up to the supervisor, manager, or owner.
    e. You wear personal protective equipment (PPE) on site always.

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