British Columbia Forest Safety Council (BCFSC)
Overview Report

Project Name
Bow Tie Analysis of Working at Heights in Wood Products Manufacturing

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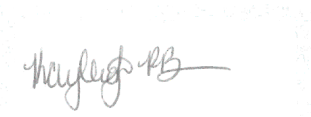

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

This report provides an overview of a bow tie analysis of working at heights (WAH) in wood products manufacturing. This work was undertaken to understand how WAH incidents can happen, examine challenges with WAH risk reduction, and identify potential approaches to improve WAH safety.

The bow tie analysis was developed in a workshop involving numerous personnel from wood products manufacturing in May 2023 in Prince George. The information provided by the workshop participants formed the basis of the analysis. During the bow tie workshop, there were a number of challenges identifying with WAH risk management. Many of the current controls are procedural (administrative), which are easily influenced by human action and inaction. Areas for improvement that were identified include safety culture and hazard awareness, the application of the hierarchy of controls to identify opportunities to eliminate WAH, and training for supervisors and workers.

Numerous controls have been characterized as critical based on the significant role they play in risk reduction. These controls include:

- Eliminating WAH by performing work on the ground, installing platforms or catwalks, or using alternate equipment (e.g., scaffolding, mobile ladders, rolling platforms) instead of ladders.
- Equipment (including guardrails, self-retracting lanyards, fall protection system, self-rescue devices)
- Training
- Pre-planning, pre-use inspections, and field-level risk assessment (FLRA)
- Rescue plan and pre-planning

A literature review was also undertaken to validate the workshop outcomes, and to identify lessons learned, best-practices and challenges. Much of the literature investigated WAH in the construction industry and many consistencies in the challenges related to procedural controls were found.

Recommendations include developing resources to close management system gaps, creating tools to help implement safeguards higher in the hierarchy of controls, as well as exploring the use of the BCFSC approach to critical control management to help ensure the reliability of administrative controls. This includes the creation of a Field Level Inherently Safer Design (FLISD) pre-work review to help identify and implement more preferred and effective risk reduction measures with respect to the hierarchy of controls.

LIST OF ABBREVIATIONS USED

BCFSC	British Columbia Forest Safety Council
CCM	Critical Control Management
CCPS/EI	Center for Chemical Process Safety/Energy Institute
CSA	Canadian Standards Association
ERP	Emergency Response Plan
FFH	Fall from Heights
FLRA or FLHA	Field-Level Risk Assessment or Field-Level Hazard Assessment
ISD	Inherently Safer Design
MAG	Manufacturing Advisory Group
ME	Mobile Equipment
MOC	Management of Change
WAH	Working at Heights
PHA	Process Hazard Analysis
PPE	Personal Protective Equipment
SRL/SRD	Self Rescue Lanyard/Self Rescue Device
SOP	Standard Operating Procedure
SWP	Safe Work Procedure
WSBC	WorkSafeBC (Workers' Compensation Board of British Columbia)

ACKNOWLEDGEMENTS

Obex Risk Ltd. would like to thank each of the bow tie workshop participants, including representatives from the Manufacturing Advisory Group (MAG) companies and wood pellet industry, for their active participation and contribution to the analysis. Obex Risk Ltd. also wishes to thank Bill Laturnus of the British Columbia Forest Safety Council (BCFSC) for arranging the project, coordinating the onsite logistics of the bow tie workshop in Prince George, and providing workshop assistance.

Obex Risk Ltd. acknowledges funding from BCFSC to conduct this work.

1 INTRODUCTION

This report summarizes a bow tie analysis that was conducted to evaluate the working at heights (WAH) hazard in wood products manufacturing (sawmills and wood pellet plants). This bow tie analysis was conducted with BC Forest Safety Council (BCFSC) and representatives from wood products manufacturing companies, including the Manufacturing Advisory Group (MAG) companies.

1.1 Wood products manufacturing and working at heights hazards

Wood products manufacturing requires WAH in plant areas while performing activities, such as routine and non-routine maintenance tasks, rail car loading in pellet plants and sawmills, and entering and exiting large mobile equipment (ME). WAH presents the risk of a fall from heights (FFH), which can lead to injuries, fatalities, and business interruption. WAH was identified by the MAG as a key area of focus for the improvement of risk management.

1.2 Motivation for conducting bow tie analysis

Work was undertaken to conduct a bow tie analysis workshop, a type of process hazard analysis (PHA), for hazardous scenarios involving WAH in wood products manufacturing. Bow tie analysis improves the understanding of how incidents can arise, the barriers in place to prevent incidents from occurring, weaknesses in these barriers, and controls that are in place to help ensure barriers are more effective. The work also involved identifying areas for further investigation with the potential to enhance safety and address current issues. This workshop was a BCFSC initiative to support MAG and wood products manufacturing. The results will be used to identify gaps and support the development of WAH safety resources for the industry.

1.3 Objectives of bow tie analysis and subsequent evaluation

The objective of the bow tie workshop was to evaluate WAH hazards in wood products manufacturing. Following the development of the bow tie, it was examined to support resource development by considering:

- Trends, recurring themes, and issues found throughout the bow tie to help identify priorities.

- How barriers/controls deemed critical for preventing or mitigating a WAH incident may fail. This will help identify approaches to improve their reliability.

Literature review was also completed to validate the results of the analysis in order to confirm results or identify differences, as well as explore the current state of WAH research and development in other industries and fields, and to identify lessons learned, best-practices and challenges.

1.4 Scope

The scope of the bow tie workshop was the hazard posed by WAH in wood products manufacturing to employees and contractors. The physical scope of the bow tie analysis was the primary areas in a sawmill and wood pellet production.

The analytical scope was the hazard of WAH in wood a sawmill or wood pellet plant with the undesired event being a fall from heights. No height limit was set, and the high-priority scenarios that were focussed on were high frequency and high potential for negative outcomes.

2 BOW TIE ANALYSIS OVERVIEW AND WORKSHOP SUMMARY

Bow tie analysis (also known as a bow tie diagram) is a PHA tool. Bow tie analysis demonstrates and communicates how different scenarios and conditions can lead to the loss of control of a hazard and lead to consequences. Figure 1 is a generic bow tie analysis to illustrate the structure. The elements of a bow tie analysis are shown in Figure 1 and are as follows: hazard, top event, threat, prevention barrier, consequence, mitigation barrier, degradation factor and degradation control. The definitions of the bow tie analysis elements are outlined in Table 1.

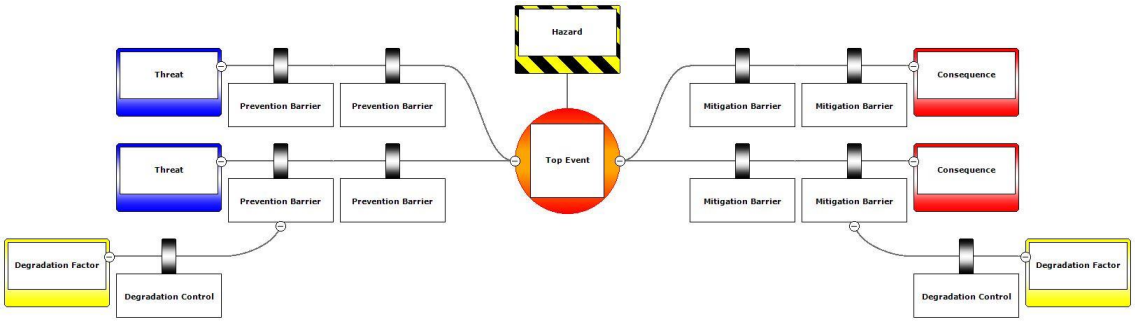

Figure 1. Generic bow tie analysis

Table 1. Definitions of bow tie analysis elements (CCPS/EI, 2018)

Hazard	An operation, activity, or material with the potential to cause harm to people, property, the environment, or business; a source of harm
Top Event	Within the bow tie diagram, a central event between a threat and a consequence corresponding to the loss of containment or loss of control of the hazard
Threats	A possible initiating event that can result in a loss of control or containment of a hazard (the top event)
Consequences	The undesirable result of loss of containment or control (top event); usually measured are health and safety effects, environmental impacts, loss of property and business interruption
Barriers	A control measure that on its own can prevent a threat developing into a top event (prevention barrier) or can mitigate the consequence of a top event after it has occurred (mitigation barrier). A barrier must be effective, independent and auditable.

Table 1. Definitions of bow tie analysis elements continued (CCPS/EI, 2018)

Degradation Factors	A situation, condition, defect, or error that compromises the function of a main pathway barrier by defeating it or degrading its effectiveness.
Degradation Controls	Measures that help prevent the degradation factor from impairing the barrier. They lie on the pathway connecting the degradation threat to the main pathway barrier.

The WAH bow tie was completed during a workshop in May 2023 over two eight-hour sessions. The workshop was held in-person in Prince George, BC. It involved a group of eight diverse subject matter experts, including health and safety resources, supervisors, and managers. The workshop was led by K. Rayner Brown (Obex Risk Ltd.), who was facilitator and scribe. Workshop assistance was provided by B. Laturnus (BCFSC Senior Safety Advisor, Manufacturing).

3 BOW TIE ANALYSIS RESULTS AND DISCUSSION

This section is an overview of the results of the bow tie analysis. The hazard that was identified was “working from heights”; as outlined previously, no height limit was set. The top event was “fall from heights.” Excerpts of the bow tie analysis are given in Attachment A.

3.1 Summary of threats, highest risk activities and challenges

The bow tie analysis helped to identify the highest risk activities and challenges associated with controlling hazards when undertaking the WAH, as well as maintaining the effectiveness of the existing safeguards. Table 2 summarizes the scenarios (threats) that could lead to a fall from heights. The threats have been categorized by respective work areas and activities. It was identified that environmental factors will play a role at all heights, and hence is an ongoing issue that needs to be consistently addressed across a range of conditions.

Table 2. Threats that could lead to a fall from heights (FFH)

Predictable / Planned WAH
Working from a ladder
Working at unguarded edges
Unpredictable WAH
Unpredictable/non-routine maintenance activities/upset conditions. Assumption: there is no guard rail available - have to use fall protection system)
Equipment, Surfaces, Mobile Equipment
Performing work on top of equipment/any surface (e.g., top of rail car, packages). Can be affected by environmental factors.
Mechanics and maintenance personnel working on LeTourneaus/ Wagners, cranes, and production equipment
Slips trips and falls while entering or exiting mobile equipment (uneven ground, slippery, icy, muddy, oily, performing task while entering/exiting, environmental factors)
Being thrown out of basket while using manlifts/aerial work platform
Equipment failure on elevated work platforms (for example, hydraulics, which then requires personnel to rappel down)
Environmental and Worksite Conditions
Seasonality effects (adjustments required due to winter gear and parkas, dexterity issues caused by cold, wind, bulky gloves, and heavy boots, and slippery surfaces caused by ice build up)
Environmental factors that can impact visibility and personnel performance, including wind, fog, and hot weather

Table 2. Threats that could lead to a fall from heights (FFH) continued

Worksite conditions with poor lighting or visibility due to facility configuration, dirt, debris, or dust
Human Factors
Fatigue or not fit for duty (age of worker, less agile, complacency, fitness level/weight/strength, balance and condition, focus or lack thereof, fear of heights). Lack of experience / hands-on skills; human factors
Personnel rushing. Examples: not considering the process, rushing to collect equipment, not having systems in place. Leads to issues such as decreased awareness, not having correct tools, not performing or having an incomplete risk assessment. This could happen at times such as routine maintenance activities due to complacency.
Job Factors
Overreaching
Moving / handling equipment or heavy loads; welding, tools, using hand crane
Work area: effects of lateral and vertical movement to perform work

During the workshop, it was identified that management system challenges are the primary driver of WAH risks. Many of the WAH controls that are used are administrative, which are susceptible to the influences of human behaviours and actions.

The needs of operations that were identified include:

- Enhancing safety culture to support systematic changes and awareness for WAH risk reduction.
- Making improvements in supervisor training (e.g., course) and identify ways to provide additional support for supervisors, including for inspections of equipment and documentation.
- Developing methods to improve crew resource management.
- Reducing the heavy reliance on administrative controls.
- Standardizing the content in training programs and providing more information.
- Developing practical solutions for in the field for workers and supervisors.
- Identifying ways to educate workers on hazard awareness (e.g., why someone needs to complete the WFH FLRA[1] card and instilling this as a core value) and help workers understand what the FLRA is for. Additionally, ways to "reduce the friction" and "keep them simple" need to be developed.
- Exploring ways to explicitly consider human factors.
- Developing processes to assess job design and ways to reduce WAH risk.

[1] Field-level risk assessment

- Enhancing the understanding and application of the hierarchy of controls. Providing workers with a process to eliminate hazards in the job design or work area through inherently safer design (ISD) (minimization, substitution, moderation, and simplification)

3.2 Critical controls, degradation factors and degradation factor controls

The barriers in the bow tie analysis were reviewed to evaluate if there any controls that play a significant role in risk reduction and could be deemed "critical controls" and prioritized for further analysis. A critical control can be defined as a safeguard that plays a significant role in risk reduction of a given hazard. A critical control can be identified by considering questions such as the following:

- Is the control crucial to preventing or minimizing an unwanted event?
- Is the control the only one available?
- If the control was missing or were to fail, would the severity or likelihood of the unwanted event significantly increase?
- Does the control appear frequently in the bow tie analysis?

Using the questions given above, critical controls for WAH include:

- Eliminating WAH by performing work on the ground, installing platforms or catwalks, or using alternate equipment (e.g., scaffolding, mobile ladders, rolling platforms) instead of ladders.
- Equipment (including self-retracting lanyards, fall protection system, self-rescue device
- Training
- Pre-planning, pre-use inspections, and FLRA
- Rescue plan and pre-planning

The rescue plan and pre-planning was identified as an important aspect of WAH risk management; it is a critical and complex control that could be the focus of a dedicated bow tie analysis. Considerations for the rescue plan and pre-planning in the use of equipment that is outlined in rescue plan and that personnel are trained on. A challenge associated with rescue planning is that some technical rope used for rope rescue can be prohibitively expensive; however, devices such as Rollgliss rescue devices[2] are more feasible. It was recommended to undertake sharing across industry of the makes and models of Self-Rescuer systems (SRL/SRD - self rescue lanyard/device) that have been

[2] 3M DBI-SALA Rollgliss device example and details: https://www.3m.com/3M/en_US/p/d/v100324139/

found by some company representatives to be well-suited. Additionally, the Petzl brand[3] was recommended, with a focus on prioritizing this equipment for maintenance personnel.

The degradation factors and degradation factor controls for each of the critical controls outlined above are described in Table 3.

Table 3. Critical controls with corresponding degradation factors and degradation factor controls

Control: Eliminating WAH by performing work on the ground, installing platforms or catwalks, or using alternate equipment (e.g., scaffolding, mobile ladders, rolling platforms) instead of ladders.	
Degradation Factor	**Degradation Factor Control**
Cost and resources	Develop business case including the ROI (return on investment) for budget.
Lack of awareness/critical thinking about this approach (eliminating WAH) as an option	Provide education, communication and awareness of the hierarchy of controls. Engage third parties/contractors to perform assessments and identify opportunities to eliminate WAH.
Not physically possible	
Aerial platform malfunctions	Keep rescue bag with aerial platform.
Equipment is not available or cannot physically be accommodated	Conduct pre-planning. Ensure procurement process considers potential challenges with equipment.
Time and cost associated with scaffold	
Scaffolding is not inspected regularly. Lack of supervisor training and awareness; knowledge for the supervisors is needed.	Implement tagging system. If scaffolding is being used for extended periods of time, make business case to install a permanent solution.
Scaffolding not installed properly or used properly	Conduct pre-use inspection and provide training for personnel who use scaffolding. Ensure personnel installing scaffolding is certified as competent, and establish formalized procedure for scaffolding installation and inspection.

[3] Information on Petzl devices: (https://www.petzl.com/INT/en/Professional

Table 3 continued. Critical controls with corresponding degradation factors and degradation factor controls

Control: Eliminating WAH by performing work on the ground, installing platforms or catwalks, or using alternate equipment (e.g., scaffolding, mobile ladders, rolling platforms) instead of ladders.	
Degradation Factor	**Degradation Factor Control**
Poor condition or construction of scaffolding	Ensure personnel installing scaffolding is certified as competent. Formalized procedure for scaffolding installation and inspection.
Control: Self-retracting lanyard	
Degradation Factor	**Degradation Factor Control**
Can fail (can get cut if working over sharp edge)	Complete annual inspections. Complete pre-use inspections.
Brake can fail if working horizontally (outside of 22 degrees)	Provide training and education on keeping the anchor above you: consider addition of trolly (movable anchor).
Lifeline rating compromised/inadequate	Add a secondary/redundant lifeline.
Lanyard material not appropriate for trade (e.g., metal for electrician, or webbing for welders)	Provide training and education. Ensure procurement process includes considerations of the correct tools/equipment for specific job types. Standardize the allocation/use of lanyard type.
Control: Fall protection system	
Degradation Factor	**Degradation Factor Control**
Incorrect system is used for job	Completion of observational competency-based training and assessment and follow-up observations by supervisor. Add this step (describe system used) to the FLHA (comparable to mini-fall protection plan).
Fall distance not properly calculated (incorrectly calculated or not calculated)	Add this step to the FLHA (comparable to mini-fall protection plan)
Anchors not rated for work, inspected, or available	

Table 3 continued. Critical controls with corresponding degradation factors and degradation factor controls

Control: Fall protection system	
Degradation Factor	**Degradation Factor Control**
Supervisors do not have time to complete safety tasks (e.g., training)	Evaluate ways that managers can provide more resources. Consider cross-shift / cross-over coordination (some overtime required)
Control: Personal Protective Equipment (PPE), including helmet with chin straps, Self-Rescuer system (e.g., SRL - self rescue lanyard or SRD - self rescue device)	
Degradation Factor	**Degradation Factor Control**
PPE not being used properly	Complete observations. Complete Buddy checks. Provide training. Conduct drills.
PPE not available	Complete routine inspections
Incorrect size (too large or too small)	Use trial sizes to determine correct size (fit test). Ensure procurement process is adequate and knowledgeable of equipment to be ordered.
Uncomfortable (e.g., wearing coveralls); claustrophobia	
Degraded or poor condition	Complete routine inspections.
Expired	Complete routine inspections.
Fear of heights	
Control: Training	
Degradation Factor	**Degradation Factor Control**
Training not received	Review training program and process.
Training not recalled by personnel	Consider refresher training. Review training courses to ensure optimal delivery.
Poor quality of training	Review training program and process.
Control: Pre-planning, pre-use inspections, and FLRA	
Degradation Factor	**Degradation Factor Control**
FLRA, inspections, or pre-planning not performed	Complete audits and observations (along with competency assessments). Provide annual or bi-annual refresher training for workers.

Table 3 continued. Critical controls with corresponding degradation factors and degradation factor controls

Control: Pre-planning, pre-use inspections, and FLRA	
Degradation Factor	**Degradation Factor Control**
Rushing, not completed (not noticing items that need to be fixed, or recurring issues not fixed)	Conduct supervisor audits. Develop inspection approaches that are feasible to be completed. Ensure that inspection results go to individuals that will perform corrective actions. Conduct inspections that drive action (e.g., acceptable or deficient).
Not trained on how to perform inspection, and personnel performing audits and observations lack skills to audit properly.	Provide supervisor training on hazards and controls of fall protection / working from heights (e.g., identify hazard and go to resource for help). Needs to be recurring training. Training program needs to identify key individual to perform this (such as supervisor, subject matter expert, competent individual).
Control: Rescue plan and pre-planning (including Emergency Response Plan, Incident Command, Rescue Drills and Training and Procedures)	
Degradation Factor	**Degradation Factor Control**
Trained personnel are not present or are involved in the incident so they cannot respond	Perform scheduling as part of pre-planning. Try to have staff supervisor on site; define roles and responsibilities in ERP, including management. Need to define training for personnel who would respond.
Rescue plan not in place	Establish project management and planning process; develop work orders before project.
Rescue equipment is not available	Gather and locate equipment as part of pre-planning.
Roles and responsibilities are unclear	Review training program and process.
Plan out of date (not updated following changes in equipment or processes)	Review training program and process.

Table 3 continued. Critical controls with corresponding degradation factors and degradation factor controls

Control: Rescue plan and pre-planning (including Emergency Response Plan, Incident Command, Rescue Drills and Training and Procedures)	
Degradation Factor	**Degradation Factor Control**
Events happen very rarely so complacency can occur (human factors); there is also minimal opportunities to gain experience responding	Consider additional refreshing training and drills.
Personnel do not know drills and training	Develop engaging drills. Include diverse personnel in training; need to identify appropriate personnel. Include rescue as part of ERP.

BCFSC previously supported an industry-wide initiative with wood pellet plants on implementing a critical control management (CCM) process for combustible dust hazards. This approach provides a systematic method for identifying and assigning responsibilities and tasks for ensuring the reliability of critical controls. The CCM approach may be of value to apply to critical controls for WAH identified by operations. More information about the CCM process can be found at https://www.bcforestsafe.org/critical-control-implementation/ (BCFSC, 2023).

3.3 Identified opportunities for improvement

When examining each of the threats the bow tie analysis, opportunities for improvements were identified by the workshop team. The barriers were evaluated to identify degradation factors; by understanding how barriers fail, these degradation factor controls could be targeted for additional efforts to ensure reliability and effectiveness. The opportunities for improvement related to each of the threats are given in Table 4. These options are summarized and could be further explored to address issues with WAH hazards.

Table 4. Opportunities for improvement to address hazardous WAH scenarios

Threat	Opportunity for improvement
Working from a ladder	Create tools that can be used for a business case to communicate the return on investment (ROI) to implement changes such as a catwalk or platform with guardrails. Create tools and resources that can be used to communicate and enhance the understanding and awareness of the hierarchy of controls, and how to eliminate WAH by changing the job design. Need to improve awareness and critical thinking about using different approaches to job design. Consider using a scissor lift, scaffolding, mobile ladders, rolling platforms, instead of ladders. - Routine inspection is necessary. Develop resources to support supervisor training and awareness to improve their knowledge to support effective inspections. - Consider implementing a tagging system that indicates the load rating (best-practice used in the oil and gas, and construction industries) To help ensure the effectiveness of a company ladder usage policy: - Create educational and training resources targeted to new and young workers. - Ensure expertise from experienced and knowledgeable personnel is transferred and exchanged as part of retirement and attrition planning. Develop resources and activities to promote a culture-shift and enhance stakeholder buy-in to ensure administrative controls, such as pre-use inspections, are completed.

Table 4 continued. Opportunities for improvement to address hazardous WAH scenarios

Threat	Opportunity for improvement
Working from a ladder	Audits and observations need to be improved, as personnel performing them could lack the skills to conduct these activities properly. Recurring training needs to be developed, and key individuals that can perform these need to be identified (e.g., supervisor, subject matter expert, competent individual). Develop tools to provide supervisor training on hazards and controls of WAH. For example, a hazard is identified and individuals can go to the resource for help.
Performing unpredictable/non-routine maintenance activities (e.g., during upset conditions.) Assumption: there is no guard rail available - have to use fall protection system)	When using fall protection systems, the incorrect system could be used for a given job. - Consider adding an additional section in the FLHA that entails describing the system used (comparable to a mini-fall protection plan) - Implement observational competency-based training and assessment, and follow-up observations (completed by supervisor); this has been identified as a key activity. When using fall protection systems, the fall distance may not be calculated or could be incorrectly calculated. - Consider adding an additional section in the FLHA that entails describing the system used (comparable to a mini-fall protection plan)
Entering or exiting mobile equipment leading to slips trips and falls due to uneven, slippery, icy, muddy or oily, surfaces while performing tasks	Add-on pouches with salt and sand on the side of mobile equipment so personnel can apply before exiting; this action could be added to the pre-trip inspection. The pouches would need to be regularly refilled following use.

Table 4 continued. Opportunities for improvement to address hazardous WAH scenarios

Threat	Opportunity for improvement
Performing work on top of equipment/any surface (e.g., top of rail car, packages). Can be affected by environmental factors. Could slip while accessing fixed equipment/surfaces.	Self-rescue devices require routine inspections. - Develop resources to support supervisor training and awareness to improve their knowledge to support effective inspections. - Develop resources and activities to promote a culture-shift and enhance stakeholder buy-in to ensure inspections are completed. The same improvements regarding fall protection systems previously listed are also relevant to this scenario.
Performing maintenance work (by mechanics and maintenance personnel) on LeTourneaus/ Wagners, cranes	Create tools that can be used for a business case to communicate the return on investment (ROI) to implement changes such as a catwalk or platform with guardrails. Create tools and resources that can be used to communicate and enhance the understanding and awareness of the hierarchy of controls, and how to eliminate WAH by changing the job design. Need to improve awareness and critical thinking about using different approaches to job design
Working at unguarded edges	As part of Management of Change (MOC) and capital projects: incorporate design features that supports fall restraint or reduces WAH hazards (e.g., Are there working from heights hazards?) To ensure safer use of fall restraint or travel restraint systems: - Develop resources to support supervisor training and awareness to improve their knowledge to support effective inspections. - Develop resources and activities to promote a culture-shift and enhance stakeholder buy-in to ensure inspections are completed.

Table 4 continued. Opportunities for improvement to address hazardous WAH scenarios

Threat	Opportunity for improvement
Working at unguarded edges	To ensure safer use of fall restraint or travel restraint systems: - Implement observational competency-based training and assessment, and follow-up observations (completed by supervisor); this has been identified as a key activity. - Consider adding an additional section in the FLHA that entails describing the system used (comparable to a mini-fall protection plan)
Changing tools, conditions or methods while performing routine tasks	BCFSC and Obex Risk will support the development of a Field Level Inherently Safer Design (FLISD) pre-work process to help personnel explore improved risk reduction measures.
Working on scissor lifts/aerial work platform: worker could be thrown out of basket, or equipment could fail(e.g., hydraulics fail and now workers need to rappel down.)	A documented fall protection plan is required, but the documentation could be inaccessible or not readily available. Develop a centralized, easily accessible resource for users.
Personnel rushing. Examples: not considering the process, rushing to collect equipment, not having systems in place. Leads to issues such as decreased awareness, not having correct tools, not performing or having an incomplete risk assessment. This could happen at times such as routine maintenance activities due to complacency.	Explore options to address these scenarios and make processes more robust against human factors.
Poor worksite conditions due to lighting, visibility, facility, dirt, debris, or dust.	Consider lighting upgrades. Assess operational conditions that could be causing excess dirt and debris, and potential actions that could mitigate this.

Table 4 continued. Opportunities for improvement to address hazardous WAH scenarios

Threat	Opportunity for improvement
Working in limited space due to work area and presence of other workers (e.g., different trades, conflicting work scope.) Could cause weight of loads and personnel to exceed load rating.	The same improvements regarding job redesign and improving the understanding of the hierarchy of controls previously listed are also relevant to this scenario.
Work area presents potential for overreaching; effects of lateral and vertical movement to perform work.	The same improvements regarding job redesign and improving the understanding of the hierarchy of controls previously listed are also relevant to this scenario.
Moving or handling equipment or heavy loads. Examples: welding equipment, tools, hand crane.	When using toe boards, tool lanyards (where feasible) and creating control zones below work to prevent tools from falling onto personnel below, issues can be encountered. These issues include missing toe boards, personnel entering the control zones, tools not being on a lanyard, or control zones not being established. Consider the use of a light projector (e.g., Laserglow[4]) to help establish control zones. Magnetic retracting barriers[5] can also be used to establish control zones. The same improvements regarding job redesign and improving the understanding of the hierarchy of controls previously listed are also relevant to this scenario.

[4] Laserglow Safety Projection & Collision Avoidance Systems: https://safety.laserglow.com/

[5] Magnetic retracting barrier example: https://www.mcmaster.com/products/safety-barricade-tape/magnetic-mount-retractable-belt-barriers/

4 LITERATURE REVIEW OF WORKING AT HEIGHTS

A literature review on working at heights in industrial settings was completed to learn about how other industries are addressing and managing the WAH risk and identify any potential approaches for risk reduction in wood products manufacturing. Using the Google Scholar search engine, “working at heights safety” was searched and publications from 2000 to present were included.

Literature was reviewed to further explore the hazardous scenarios and conditions, including those in other industries, that lead to FFH. In a recent publication by Zermane et al. (2021), it was outlined that failure to wear PPE, lack of supervision and leadership, and deficiencies in work standards or following them correctly, are significant causes of FFH. It was identified that supervisors or safety personnel (site safety superiors, SSS) play a critical role on advising and helping to supervise high-risk tasks. Management commitment is also included within leadership and cultivating a strong safety culture.

- Safety training performed before any WAH activity routinely to educate personnel on the hazards and how to properly use PPE (e.g., fall protection systems)
- Worksite conditions, environmental factors, physical and mental stressors were also identified as influences on WAH incidents (which is also consistent with the bow tie workshop)

Wong et al. (2016) offers that due to improvements in safety technology and education, FFH are less likely to be caused by inadequate technology or hazard unawareness, and rather faults in the organizational system need to be identified to implement preventative controls. This research investigated human factors involved in FFH, and found that gaps in technical environment, organizational process, and inadequate supervision were present in most FFH accident case studies. Four classes of elements related to human factors were identified:

1. Inadequate planning or planning error
    - Organizational process (formal system for managing safety at management level); operations, procedures (documentation), oversight (monitoring and inspecting of resources, processes, culture)
    - Inadequate supervision (lack of supervision that results in workers failing to identify hazards, recognize, and control the risk).
    - Planned inappropriate operations (job design is poor and presents excessive risk to workers)

2. Routine inadequate adherence to policies at the workplace and supervision to correct issues (e.g., taking off safety harness during WAH); the researchers referred to these as “violations.”
3. Hidden hazards caused by other parties (for example, hazards presented by contractors or different companies being involved onsite). This class highlights the need for effective communication and coordination between different organizations and workers onsite.
4. “Incapable staffing” was the term used by the researchers to refer to this class that involved a distinct grouping of crew resource management (crew composition, crew members with necessary expertise) and decision errors (decision is insufficient or faulty to achieve target result/outcome). This class attributes FFH due to issues with crew resource management and lack of supervision that causes incorrect decisions.

In summary, key areas of focus for improvement include job planning, reducing violations, communication across project and activity stakeholders, crew resource management and supervision. This is consistent with the findings of the bow tie workshop and outcomes of MAG audits.

Preventative measures were recommended:

- Development of training programs targeted towards managers and supervisors to enhance their skills for safety management and supervision. This may include creating a focus for managers and supervisors on identifying and working to correct gaps in safety management.
- Establishment of formalized, routine safety awareness exercises prior to the undertaking work daily.
- Industry-wide promotion of correct and regular use of fall protection equipment, particularly on small projects.
- Development of standard technical and managerial procedures by industry for particularly high-risk work, and promotion of these practices among smaller companies and contractors that may not have strong technical and managerial skills.

In a recent review article by Firdaus and Erwandi (2023), six factors were identified as causes of FFH:

- Risky behaviour (e.g., not using PPE properly, rushing the work, mistakes in making decisions)
- Unsafe conditions (open edges of building, holes in floor, inappropriate scaffolding, poor lighting, poor housekeeping)

- Management and organization (training, management commitment to the work program, inadequate work procedures, inadequate supervision, fall protection equipment not provided, poor communication)
- Human factors (age, inexperienced, knowledge gaps, fatigue)
- Work / job factors (material preparation, structural, scaffolding, completion work)
- External factors (weather)

To address the issues given above, Firdaus and Erwandi (2023) highlighted the following to enhance safety:

- Safety outreach programs to raise awareness
- Training programs to improve knowledge and skills
- Supervision needed at each work location
- Management needs to prepare safety management programs, rewards for workers that follow the program and discipline for workers who do not.

Pham et al. (2018) examines the improvement of WAH on transmission towers, and outlines means to address issues with positioning stationary marked and certified anchor points, including:

- Coloured indicators in designated locations on the support structure that can help workers identify when there is an anchor available to use, and states the working and destructive loads as per standards and PPE.
- Installing certified anchor points following the worker's movement path and working area.
- On ladder-type open structures, install a rigid anchor line that provides continuous support for worker along the work path
- Use a designated, distinct symbol for an anchor point or line that enhances the convenience and efficiency of planning for WAH.

Bussier and Chong (2022) investigate the connection between safeguards and human error, specifically the role of psychological distress. The objectives of this work was to identify influences on the psychological condition of workers, understand the relationship between psychological factors, human error and safeguards, and identify potential ways to improve safety culture for WAH. Psychological distress may be defined as "an unconstructive feeling or emotion that influences someone's performance." The research offered an approach to identify and reduce psychological distress to enhance safety. Organizations should implement individual and organizational tools for reducing psychological distress risks, including training for developing active coping tools for different factors that lead to stress at work, such as assertiveness, communication, time

management, problem solving and effective management. Psychological training provides workers the ability to learn about and identify the signs of psychological distress and behaviours, and remedial tools (e.g., positive mindset, relaxation, breathing). Establishing counselling and routine psychological assessments will enhance the long-term sustainability and maintenance of this training program.

Literature review also identified recent publications describing new research and development being performed in field on new tools and technology to improve WAH risk reduction. While this technology is not yet commercially available, these approaches may be of use for considering or identifying new devices or equipment that could be integrated into operations to improve safety.

Shanti et al. (2022) describe the use of drones / unmanned aerial vehicles (UAV) to perform real-time monitoring of WAH safety hazards in construction sites. The drone was used to take videos and photos and detect personal fall arrest system (PFAS) components (safety harness, lifeline, helmet) and was able to detect non-conformities. (e.g., unavailability of safety harness, lifeline not attached to anchor point, not wearing safety helmet). This research demonstrated that a drone can be a valuable tool to help safety officers monitor worker safety during WAH.

Tariq et al. (2023) describe the use of building information modelling (BIM) to visualize safety standards, which enhances the ability of safety managers to ensure necessary protection measures are implemented. This system resulted in a safety clause library that helped safety managers provide necessary equipment, enhanced awareness of safety requirements in workers, and a database of standards that could be easily maintained and updated.

Yuan et al. (2019) discuss Prevention through Design (PtD), with the recognition of the hierarchy of controls, including the elimination of hazards being most preferred and at the top of the hierarchy. This research focussed on the construction industry and involved the development of a platform that integrated BIM and a PtD knowledge base through reference to current safety regulations, documents, best-practices, hazards, and control measures. This research is also consistent with the findings of the workshop with the need to focus on eliminating unnecessary hazards through design of worksite or job.

Lastly, Loreto et al. (2018) outline a virtual reality WAH simulator to help as a way to verify their workers' ability to WAH, or to provide immersive training without exposure to the real hazard.

5 RECOMMENDATIONS AND CLOSING REMARKS

Based on the evaluation completed within the scope of this overview report, additional areas for further work in WAH risk reduction include the following:

- Examine opportunities to eliminate WAH through evaluating if the task can be performed at ground level instead of at heights, installing catwalks or platform with guardrails, or using a scissor lift, scaffolding, mobile ladders, rolling platforms, instead of ladders.
- WAH is a significant hazard of focus in the construction industry, so it is recommended that best-practices and lessons learned from this industry be further examined.
- Develop and provide tools to enhance the understanding of the hierarchy of controls, job design and work area design to identify ways that WAH heights hazards could be eliminated through ISD.
- Consider integrating other engineering controls that can add an additional layer of protection.
- Explore alternate technologies, programs and systems that could enhance training, education, and hazard awareness for workers in the field, as well as improve supervisor capacity and abilities.
- Scaffolding has also been identified as a high-risk area, so a renewed focus risk reduction associated with scaffolding is recommended.
- Review the BCFSC process for critical control management (CCM) and consider applying it to critical controls for WAH.
- Explore systems and programs that can address gaps in safety management systems, such as adopting CSA Z1009:22 Management of work at heights standard.

In closing, this report summarized the key outcomes of the bow tie analysis workshop conducted for working at heights (WAH) in wood products manufacturing. This multidisciplinary workshop successfully identify key opportunities and next steps to enhancing WAH safety, including strengthening safety culture and hazard identification, providing additional training and resources, as well as implementing more preferred and effective controls to reduce a heavy reliance on procedural measures. Controls, including the elimination of WAH, engineering equipment, as well as task planning, have been identified as critical for preventing FFH and should be examined through the CCM process to help ensure reliability and effectiveness.

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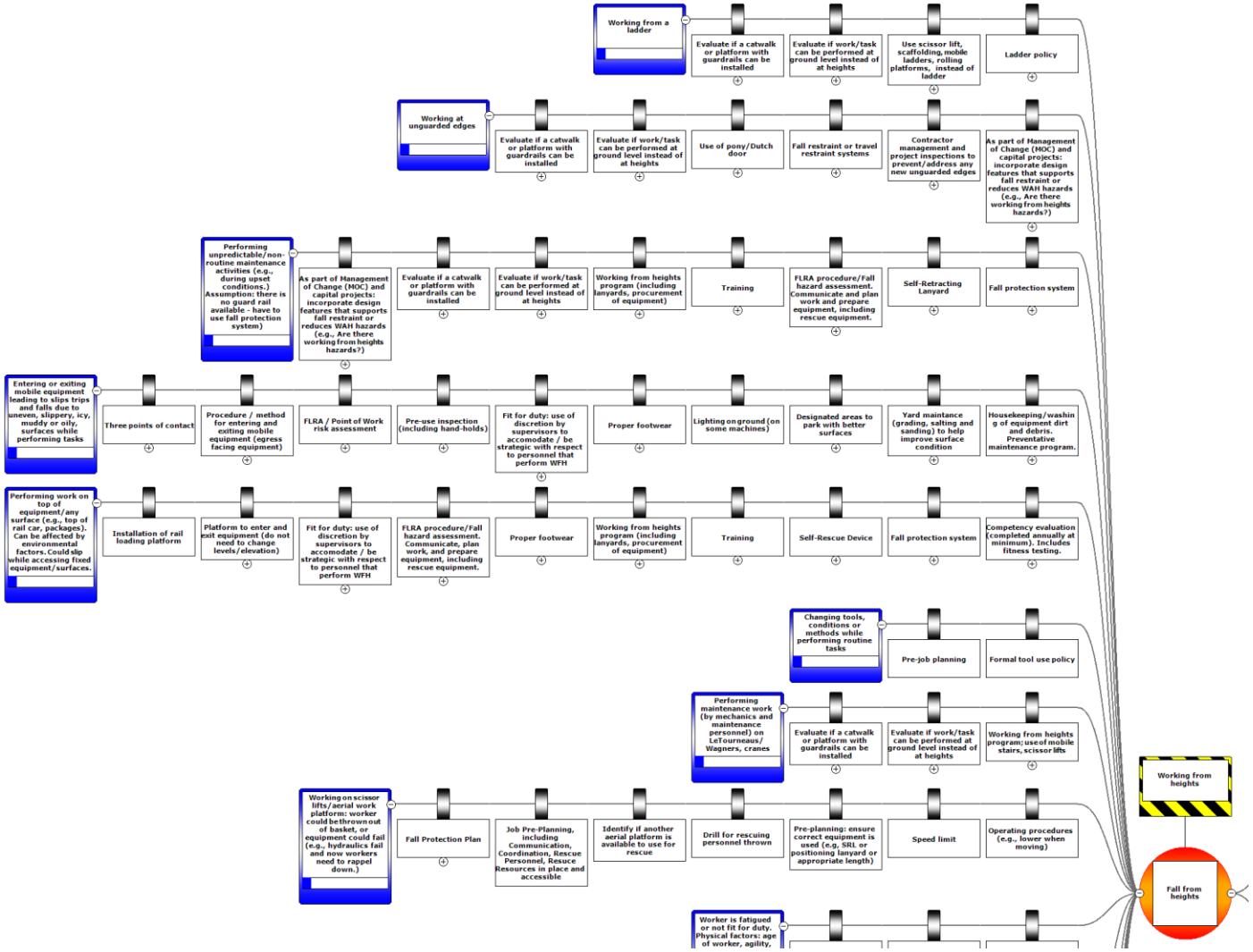
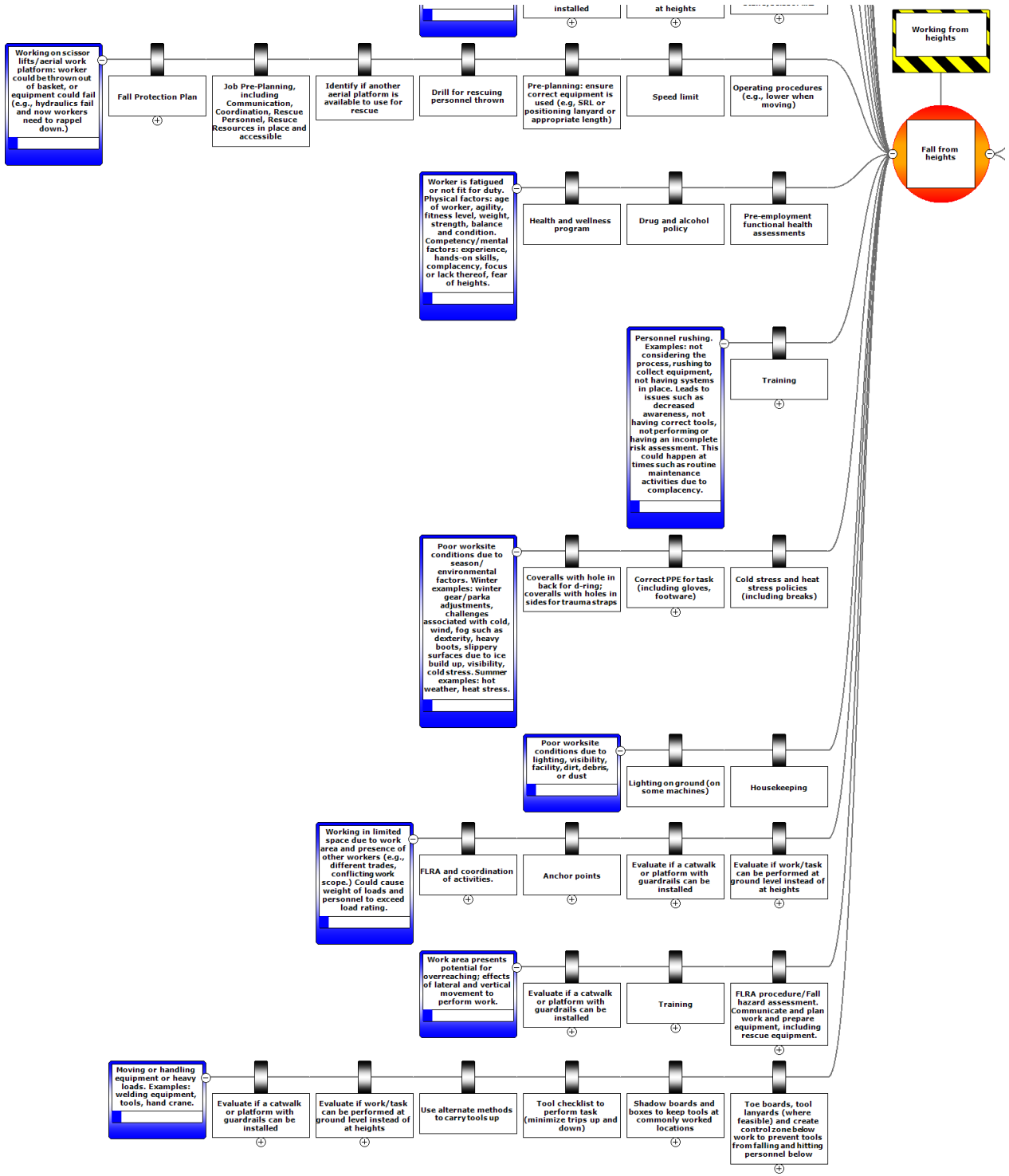
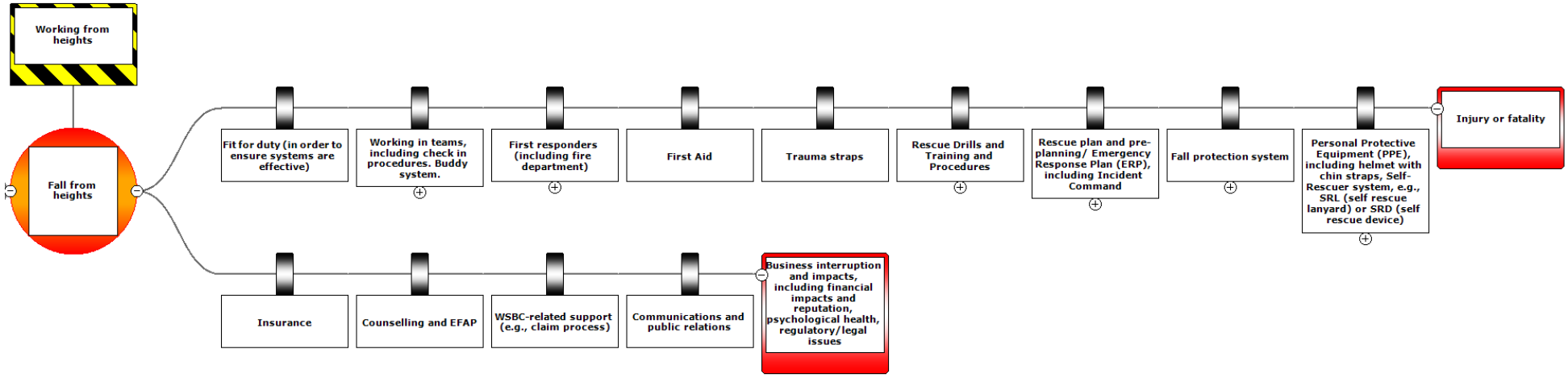
ATTACHMENT A: Working from heights bow tie analysis excerpts







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