TECHNICAL APPENDICES

TSSA PUBLIC SAFETY REPORT 2021

TECHNICAL STANDARDS & SAFETY AUTHORITY

TSSA

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Appendix I – Enhancements

In keeping with its commitment to continuous improvement and based on feedback from stakeholders (e.g., feedback obtained from board and advisory council presentations), TSSA continues to enhance the structure and style of its reporting. Based on new information and data, TSSA also enhances its processes and methodologies in analysis and reporting. Changes to this year's *Public Safety Report* affecting the results of analysis are discussed below. Structural changes are not identified, as they are considered as enhancements to the readability of the report and do not impact the analysis.

Updates:

1. The risk of injury or fatality (RIF) calculation continues to migrate to the new calculation. This fiscal year, TSSA shows both the old and new method while using the new method exclusively for decision-making.
2. The areas of concern figure (i.e., inverted triangle) is being retired in favour of risk profiles that illustrate sources of risk by location for both the fuels and elevator program areas. From these risk profiles, TSSA chose the top three risks as "top risks" for further analysis.
3. TSSA has put further consideration into the audience of the report. As recommended by the Safety Risk Officer, TSSA has defined its audience as its industry stakeholders and the Ministry of Government and Consumer Services (MGCS). This fiscal year's report is therefore more focused in the presentation to that audience.
4. For the amusement devices, elevators, escalators and ski lift programs, the qualitative analyses were performed for all causes and not just external factors.
5. In order to streamline the report and to focus on relevant information, several appendices were deleted since the previous fiscal year: In-Depth Root Cause Analysis (IDRCA); Collaborator Safety; Risk-Informed Inspection Order Management; References (footnotes were used instead); and Risk Model Peer Group.
6. Significant data cleansing work has resulted in the updating of some records. For example, occurrences from previous years have had their investigations completed and some orders have been revoked/rescinded. TSSA presents a new extract of available data every year and so comparisons against previous versions can lead to small differences.

New Information:

1. TSSA has put considerable effort into automating the calculations and analyses. This fiscal year, Power BI was used to connect incidents and near miss occurrences to the observed injury burden, combined RIF, and program RIF calculations. Power BI is a Microsoft business analytics service that provides interactive visualizations and business intelligence capabilities that can create reports and dashboards. Natural language processing and GIS APIs[1] were used to perform qualitative and location analyses.

[1] GIS APIs (Geographic Information System Application Programming Interfaces) are a collection of library modules that resemble various functionalities of GIS software through programming.

Appendix J – List of Acronyms

CAD	Code Adoption Document
CO	Carbon Monoxide
DALY	Disability-Adjusted Life Year
FE/mpy	Fatality Equivalent(s)/million people/year
IDRCA	In-Depth Root Cause Analysis
PSRM	Public Safety Risk Management
RBS	Risk-Based Scheduling
RCA	Root Cause Analysis
RIDM	Risk-Informed Decision Making
RIF	Risk of Injury or Fatality
RSMP	Risk and Safety Management Plan
TTC	Time to Compliance

Appendix K – Glossary of Terms

Area of High Risk	This is a risk source that requires mitigating actions because it exceeds the risk acceptability criteria for either the general population (1.00 FE/mpy) or for sensitive sub-populations (0.30 FE/mpy). TSSA identifies these risk sources as safety issues that require risk management strategies. These strategies can include regulatory actions (such as Director's Orders), as well as advisories and bulletins, collaborative partnerships with stakeholders and public education.
Area of Low Risk	Risk sources that are well below the risk acceptability criteria are within broadly acceptable levels due to TSSA's preventive/predictive inspection programs. While TSSA considers these risk sources as not being of immediate concern, it continues to monitor and oversee these sources using the various regulatory tools available, such as engineering reviews and periodic inspections.
Area of Medium Risk	When a risk source approaches the risk acceptability criteria, TSSA utilizes enhanced monitoring. TSSA considers these risk sources to be potentially emerging areas of risk and monitors (including investigating specific incidents in the affected program area) and/or addresses them through mitigation strategies.
Code Adoption Document (CAD)	The Code Adoption Document (CAD) is a default regulatory instrument for mandatory requirements of general application, such as the adoption of codes and standards. This instrument is used to identify and communicate changes to TSSA-specific requirements.
Compliance Rate	The Compliance Rate is the percentage of periodic inspections compliant with the *Technical Standards and Safety Act, 2000* (the Act) and its associated regulations.
Director's Order	A regulatory decision made by a Statutory Director under the powers given to him/her as per the Act. **Director's Order, Limited Use (s. 27)** Places limits on the operation of a thing that is found to be defective or to not comply with the conditions of its authorization after the thing is fabricated or installed. 27. *A director may,* *(a) establish the limits of operation and use of things that are found to be defective or do not conform with its authorization after fabrication or installation;* *(b) permit the operation and use of such thing within such limits as are prescribed, or if there are no such limits, as the director considers safe.* **Director's Order, Public Safety (s. 31)** Used only where there is or may be a demonstrable threat to public safety and the subject matter has not otherwise been provided for in the Act or its associated regulations. It can require regulation, use or disuse of specified things. 31. *In cases where there is or may be a demonstrable threat to public safety, a director may make an order with respect to the following matters if they have not otherwise been provided for in this Act, the regulations or a Minister's order:* *1. Requiring and establishing the form and location of notices, markings or other forms of identification to be used in conjunction with equipment or other things that are prescribed.* *2. Regulating, governing and providing for the authorization of the design, fabrication, processing, handling, installation, operation, access, use, repair, maintenance, inspection, location, construction, removing, alteration, service, testing, filling, replacement, blocking, dismantling, destruction, removal from service and transportation of any thing, whether new or used, or a part of a thing and any equipment or attachment used in connection with it.*

Disability-Adjusted Life Year (DALY)	A DALY of 1.0 is the loss of one year of healthy life of a single person due to an injury. Please see Appendix M for a full description. **Injury Burden** Quantified health impact determined by integrating injuries and fatalities observed across the population exposed to TSSA-regulated devices/technologies over a period of time. The DALY metric is used to combine injuries and fatalities into a single metric. The injury burden is expressed in the units of fatality-equivalents per exposed population (in millions) per year. Refer to Appendix M for additional details.
External Factors	External Factors are the safety impact related to failures associated with factors outside the direct control of TSSA's safety system (e.g., behaviour of users/consumers of technologies and devices in lieu of their intended use, environmental/weather conditions, utility failures, etc.). Refer to Appendix O for additional details.
Fatality-Equivalent (FE)	Fatality-equivalent/million people/year (FE/mpy) is a unit of measure obtained by integrating quantified health impacts into a single count of equivalent fatalities for benchmarking and decision-making purposes. Refer to Appendix M for additional details.
Fiscal Year	TSSA's fiscal year runs annually from May 1 April 30 (e.g., 2021 represents fiscal year 2021, which runs from May 1, 2020, to April 30, 2021)
Health Impact	Health Impact refers qualitatively to injuries or fatalities sustained by the public as a result of exposure to TSSA-regulated devices/technologies. A health impact could be one of fatal, permanent or non-permanent injuries. **Permanent Injury** An injury sustained by an individual that partially or totally impairs the normal abilities of that individual for the rest of his/her expected remaining life. **Non-Permanent Injury** The consequence of an incident occurrence wherein there was an observed health impact that was estimated to be non-permanent based on the nature of the injury and its associated severity using a methodology developed by the World Health Organization (WHO). A non-permanent injury has no significant impact on the individual's life expectancy at the time of injury.
In-Depth Root Cause Analysis (IDRCA)	This formal approach, *In-Depth Root Cause Analysis (IDRCA),* uses Root Cause Analysis (RCA) principles to determine and document underlying causes related to occurrences under the TSSA regulatory mandate but with additional focus and effort. **Root Cause Analysis (RCA)** A method of problem solving using a specified range of approaches, tools and techniques to uncover the most basic reason (underlying cause) for an occurrence that can be reasonably identified.
Incident Management System	A structured framework that translates the legislated regulatory responsibilities of TSSA, specifically as it pertains to incident investigations into a management system. This management system contains policies, procedures, roles and responsibilities and associated processes that enable the receipt, investigation and analysis of reported incidents and near miss occurrences.

Incident Management Information System	An Incident Management Information System is a public safety decision-support information tool that enables TSSA to document the receipt, dispatch, investigation and analysis of reported incidents and near miss occurrences and forms a component of the Incident Management System.
Inspection	An Inspection is an official examination of a device, system or procedure conducted by an inspector under the Act in accordance with Section 17 of the Act.
Inspection Order	The authority to issue an order comes from Section 21 of the Act and is served by an inspector to one who contravenes and/or who corrects a contravention to the Act or its associated regulations. Under this section, an inspector may also seal anything with respect to amusement devices, boilers and pressure vessels, elevating devices, fuels and operating engineers, as referred to in the regulations. Where there is or may be a demonstrable threat to public safety, whether or not the thing is subject to an authorization, an inspection order includes the specific nature of identified contravention, the conditions and actions to be taken to correct the contravention and the allowable time to comply for each identified contravention. Orders can be classified into high-, medium-, and low-risk categories, which statutory directors can define to suit the needs of their program area. With the exception of Operating Engineers, the classifications are defined below. **High-Risk Inspection Order** Issued where non-compliance is identified and warrants an inspection order for immediate action within 0 to 10 days, for time to comply with regulatory requirements. **Medium-Risk Inspection Order** Issued where non-compliance is identified and warrants an inspection order for action within 11 to 60 days, for time to comply with regulatory requirements. **Low-Risk Inspection Order** Issued where a non-compliance is identified and warrants an inspection order for action within 90 days, for time to comply with regulatory requirements.
Non-compliance with the Regulatory System	Non-compliance with the Regulatory System refers to the safety impact associated with the violation of established regulatory controls (e.g., TSSA-enforced regulations). Refer to Appendix O for additional details.
Occurrence	An Occurrence is the realization of a hazard which results in, or has the potential to result in, a consequence to people or property. **Incident** An occurrence involving a system/device/component/tradesperson under TSSA's jurisdiction, whereby a hazard is exposed resulting in a consequence to people or property. **Near Miss** An occurrence involving a system/device/component/tradesperson under TSSA's jurisdiction, whereby a hazard is exposed demonstrating an instance of elevated exposure to risk, while in this particular instance resulting in no consequence to people or property.

Occurrence Involving...	**Door Closing** - A consequence that could result when elevator doors close and impact a user who is entering or exiting an elevator or attempting to prevent the doors from closing. **Entanglement** - A consequence that could result when a user's ski equipment becomes crossed, causing them to lose balance. Applies only to ski lifts. **Entrapment** – This depends on context. A consequence that could result when a user's clothing, footwear or accessories becomes caught in the moving parts of a device. Applies to amusement devices, elevators, escalators and moving walks and ski lifts. Can also refer to being stranded in an elevator. **Levelling** - A consequence that could result when an elevator does not level at the floor landing thereby creating a tripping hazard. **Physical Impact** - A consequence that could result when a user of a device comes into contact with the device (e.g., falling roof tiles on an elevator car). Applies to amusement devices, elevators, escalators and moving walks and ski lifts. **Trips or Falls** - A consequence that could result when a user of a device stumbles or falls upon entry into or exit from a device. Applies to amusement devices, elevators, escalators and moving walks and ski lifts.
Operational Risk	Operational Risk is the potential risk of injury or fatality associated with the operation and maintenance of things or class of things regulated under the Act and does not account for sources of risks manifested during the design and installation stages. Operational Risk considers only those risks that can be observed during an inspection and can be addressed through the issuance of inspection orders. **High, Medium, Low Operational Risk** High-, medium-, and low-risk devices/facilities are those with inspection intervals of 6 months, 6 to 24 months and greater than or equal to 24 months respectively.
Periodic Inspection	A Periodic Inspection is an inspection conducted at such intervals as may be determined by the statutory director, risk-based scheduling (where applicable), or required by code or regulation for the purpose of ensuring the safe operation of a device/facility.
Potential Gaps in Regulatory System	Potential Gaps in Regulatory System refer to the safety impact associated with gaps in the regulatory system or where no regulatory control exists. Refer to Appendix O for additional details.
Risk	Risk is the combination of the probability of occurrence of harm from a thing or a class of things under Section 2 of the Act and the severity of that harm.
Risk-Informed Decision Making (RIDM)	Risk-Informed Decision Making (RIDM) is an approach to regulatory decision making, in which insights from probabilistic risk assessments are considered with other engineering insights. The risk-informed approach has been a key element in TSSA's regulatory success, allowing TSSA to: • Understand the nature of public safety risks; • Quickly develop preventative strategies to address safety hazards; • Target activity where it will have the greatest impact on risk; and • Improve safety outcomes generally. Refer to Appendix L for more information.

Risk of Injury or Fatality (RIF)	Risk of Injury or Fatality (RIF) is the injury burden predicted using a simulation model to combine the probability of occurrence of harm (estimated as occurrence rates) to someone interacting with or exposed to TSSA-regulated devices/technologies and severity of that harm. The Risk of Injury or Fatality (RIF) metric is expressed in fatality-equivalents per exposed population (expressed in millions) per year (FE/mpy). This measure of risk accounts for historical occurrences while taking into consideration the uncertainties and variability inherent in the involved parameters such as the occurrence rate, number of victims, age of each victim and types of injuries sustained. Refer to Appendix M for additional details. **Composite Risk of Injury or Fatality** A single quantified measure of risk of injury or fatality across TSSA-regulated sectors in Ontario. The estimate is only for reporting purposes and may be used for benchmarking.
Sensitive Sub-populations	Sensitive Sub-populations are populations with persons more at risk than the general population because they are less able to respond to an occurrence (e.g., in schools, retirement and long-term care homes, etc.).
Time to Compliance (TTC)	Time to Compliance (TTC) refers to the time required for a client to have the work completed as specified in a TSSA inspector's order due to a deficiency found during an inspection. Also known as time to comply.
Trend	A Trend is a statistically representative measure for the noticeable tendency or movement toward, or in, a particular direction over a measured period of time (e.g., positive trend, negative trend and no significant quarterly trend). Refer to Appendix M for additional details.

Appendix L – Risk-Informed Decision Making at TSSA

Introduction

TSSA statutory directors have general supervisory and administrative responsibility of the Act and its associated regulations to ensure the safety of Ontarians.

The *Public Safety Report* is a key component of TSSA's Risk-Informed Decision Making (RIDM) framework and provides information on the state of safety of Ontarians interacting with TSSA-regulated devices/technologies. The *Public Safety Report* is also a public document that describes the safety strategies established by the statutory directors and those responsible for preventative and educational tools to enhance safety and reduce the risk of injury or fatality to Ontarians.

Initiated in 2007, TSSA's RIDM framework is an evidence-based, scientific approach to identifying, analyzing, measuring and managing the Risk of Injury or Fatality (RIF) to Ontarians caused through interaction with TSSA-regulated technologies, devices and products. It is a framework to assist in the effective use of available regulatory tools under the Act, through efficient allocation of TSSA's resources, and leveraging partnerships with stakeholders. As a framework, it continues to evolve to align with and lead best practices around the world.

Reducing Risks – Understanding and Managing Causes and Behaviours

The RIF to Ontarians across the different TSSA-regulated sectors is estimated primarily using information gathered through reported and investigated occurrences (incidents and near misses) and complemented with information collected through TSSA's inspections and other regulatory oversight tools. The information collected allows TSSA to analyze the primary causes associated with occurrences, and helps statutory directors establish and implement strategies aimed at reducing risks.

The process to address risks to Ontarians is a three-stage process comprised of:

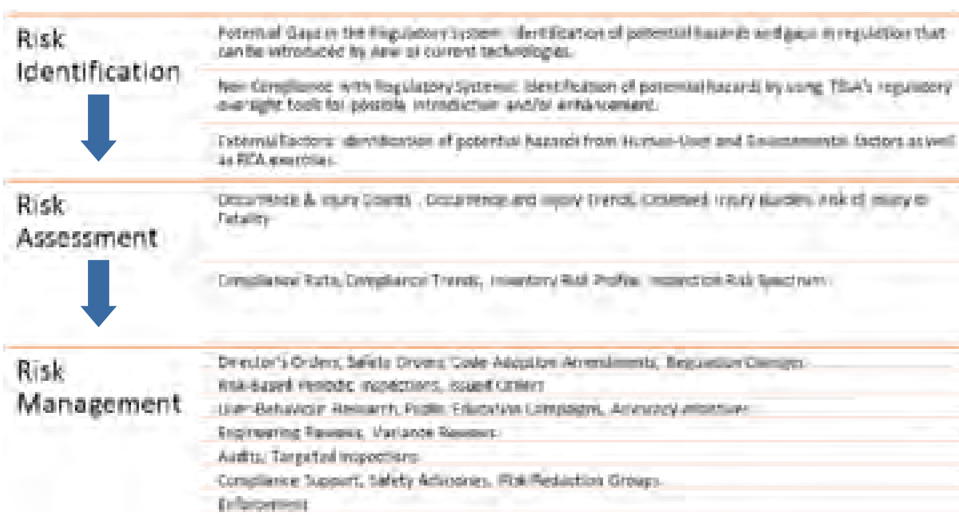
1. Risk identification (through cause categorization);

2. Risk assessment; and

3. Risk management.

This process represents the public safety risk management framework and is illustrated in Figure L1.

Figure L1: Public Safety Risk Management Framework[2]



[2] Depending upon the nature of the risk, TSSA considers a variety of tools, such as regulation changes, technological solutions, enforcement activities, and public education to help best manage public safety risks.

1. Risk Identification

Risk is identified and then segmented into one of three primary causal categories to aid downstream strategy development and implementation. These causal categories, identified in Figure L1 and as defined in Appendix O, include the following:

Potential Gaps in Regulatory System

Advancements in regulated sectors, including emerging technologies lacking adequate regulatory oversight (including codes and standards), form one aspect of this category. Risks in such cases are typically unknown or may not be estimated due to limited data availability. However, the potential hazards with such technologies may be known or ascertained.

A subset of this category involves safety gaps that are inadequately addressed by the current regulatory system. Examples include technologies designed to older codes and standards that may be prone to fail over time.

In both cases, TSSA may be able to address the gaps through interim tools such as Director's Orders. In certain instances, TSSA may recommend the need to affect changes to regulations.

Non-compliance with Regulatory System

This category of occurrences results from actions not compliant with the regulatory requirements by those statutorily responsible for the design, manufacture, installation, operation, user interaction and/or maintenance of TSSA-regulated devices/technologies. The level of understanding, education, required skills and training of these regulated stakeholders or responsible parties, such as owners of technologies, installation and maintenance technicians, along with their intent to comply, affects this category of risks.

The level of regulatory oversight varies from program to program. In most instances, the regulatory expectations of TSSA are specified in the Act and its associated regulations. A key oversight function involves TSSA conducting initial and periodic inspections of devices before and during their operation.

Risks falling in this category are identified and reduced through the introduction and/or enhancement of TSSA's existing regulatory oversight tools. Increasing levels of risk in this category may require the introduction, expansion or modification of existing TSSA regulatory oversight powers such as inspections and audits. Another important regulatory tool to manage significant risks involves the use of Director's Orders and, in certain instances, regulatory changes may also be recommended. TSSA may also use advocacy tools and form collaborative partnerships with relevant stakeholders such as other government agencies, like-minded (or focused) safety organizations/associations, regulated sectors and affected parties, to raise awareness and influence behavioral change and compliance.

External Factors

Occurrences can take place despite the presence of an adequate regulatory management system. Risks in this category are typically caused by users' (such as the public) interactions with TSSA-regulated technologies. A comprehensive understanding of human factors helps TSSA set up appropriate public education/safety advocacy tools through collaborative partnerships with stakeholders including consumer advocacy groups, regulated sectors, safety organizations, etc., to reduce risk in this category.

Other reasons include environmental factors, such as weather, deliberate intent or sabotage, occurrences involving TSSA-regulated technologies but due to factors outside of TSSA's jurisdiction, etc. Typically, in such cases, other regulatory agencies may take on primary investigation and management of the risks with TSSA's technical support and expertise. In rare circumstances, changes may be made to regulatory tools to address risk.

In certain circumstances, a formal approach entitled *In-Depth Root Cause Analysis (IDRCA)* is used, which relies on Root Cause Analysis (RCA) principles to determine and document underlying causes related to occurrences under TSSA's regulatory mandate but with additional focus and effort.

2. Risk Assessment

The RIF across TSSA's regulated sectors is the primary method of estimating risk to Ontarians. The RIF method uses information gathered through reported and investigated occurrences (i.e., both incidents and near misses) and associated injuries. This information is analyzed quantitatively using an approach that integrates predictive analytics with simulations to estimate the potential risk that would be sustained by Ontarians from exposure to regulated devices/technologies.

TSSA's risk assessment involves the collection of information through inspections conducted on regulated devices/technologies, and other regulatory oversight tools. Non-compliance information from inspections is used to generate compliance metrics, such as the compliance rate, inspection risk spectrum and the inventory risk profile.

The intent of the risk assessment component is to assess the risk of a given source. The quantitative aspect of risk is delivered through measurement using the RIF and supplemented with the observed injury burden and activity counts. Where clean data is available (i.e., validated population counts, statistically-significant data size), specific drilldowns of risk are generated. Greater specificity in identifying risks allows TSSA to target resources specifically to address the largest source of risk and potentially reduce the risk that is intended to be managed.

3. Risk Management

After completing the risk identification and assessment processes, the identified risks in their causal categories undergo a risk management process using TSSA's existing regulatory oversight tools, which aid the statutory directors in establishing and implementing strategies aimed at reducing risks.

To aid decision-makers in selecting controls to manage and mitigate risks, Table L1 captures the hierarchy of controls.

Table L1: Control Solutions[3] to Manage and/or Mitigate Risks

CONTROL NAME	PURPOSE OF CONTROL
Elimination	Remove or eliminate hazards altogether
Substitution	Replace hazards (with less hazardous options)
Engineering	Implementation of safeguarding technologies to prevent and/or mitigate hazards and therefore minimize exposure
Administrative	Codes and regulatory changes (new and/or improvements), education, training, procedures, etc.

As indicated in Table L1, elimination is the strongest and most effective control as it physically removes the hazard, and therefore, results in the greatest reduction in risk. However, the ability to resort to an elimination control may be restricted due to regulatory purview.

In such cases, the decision-maker would have to move down the hierarchy and evaluate the efficacy of substitution and subsequent controls. Cost-benefit analysis and stakeholder consultation are recommended in evaluating the applicability and efficacy of applying a control, or a set of controls, to a particular risk.

Conclusion

TSSA's RIDM framework is recognized and used for addressing broader public policy issues. It aligns with the recently published guideline UL2984: *Management of Public Risks – Principles and Guidelines,* a vision that was put forward by TSSA and successfully accepted by national and international bodies.

This report acts as a primary source of information for risk-informed decision making. TSSA's RIDM framework continues to assist statutory directors across all safety programs in making regular day-to-day decisions while helping tackle larger and more complex strategic regulatory decisions. An important element of the framework is continuous improvement and confirmation of decisions as new findings become available. TSSA continues to aggregate data from inspections year over year and there are times that decisions need to be revisited with up-to-date data.

[3] Adapted from Hierarchy of Controls from US Centers for Disease Control (CDC), The National Institute for Occupational Safety and Health (NIOSH), Hierarchy of Controls. Retrieved on April 12, 2017 from https://www.cdc.gov/niosh/topics/hierarchy/default.html.

Appendix M – Metrics

Disability-Adjusted Life Year (DALY)

The Risk of Injury or Fatality (RIF) metric is determined using the Disability-Adjusted Life Year (DALY) metric. The DALY is a universal health impact metric, introduced by the World Health Organization (WHO) as a single measure to quantify the burden of diseases and injuries. The DALY can be thought of as equivalent years of "healthy" life lost by virtue of being in states of poor health or disability and/or due to premature fatality.

A DALY of 1.0 is the loss of one year of healthy life of a single person due to an injury. For example, a DALY of 28.1 means that 28.1 years of "healthy" life were lost due to injuries arising from all the sectors that TSSA regulates.

The expected health impact for a fatality is calculated based on the standard life expectancy at age of death in years and is based on age and sex (e.g., fatality of a male child aged five would translate to 70 DALY assuming an average life expectancy of 75 years). The expected health impact for an injury is calculated by multiplying the average duration of the injury by a weight factor that reflects the severity of the injury on a scale from 0 (being in perfect health) to 1 (being fatal).

Health loss is characterized by three dominant aspects of public health:

- Quality of life;
- Quantity of life; and
- Social magnitude.

The quality of life is measured by duration of injury and life expectancy of a victim. The quantity of life lost is expressed through disability weights, and the social magnitude is characterized by the number of people affected.

The expected health impact in units of DALY can be calculated by the following equation:

(Short-term Weight * Short-term Duration) +
(Fraction Long-term) * (Long-term Weight * Long-term Duration)

There are four injury types categorized in the TSSA database:

i) Fatality;
ii) Permanent injury;
iii) Non-permanent injury; and
iv) No injury.

The permanent and non-permanent injuries are further characterized by 28 specific types of injury descriptions. In the above equation, disability weights, fraction long-term and short-term durations, associated with the various injury descriptions, have been adopted and/or modified from the Australian Burden of Disease and Injury Study[4]. The long-term duration is the expected life expectancy at the time of injury and is applicable in the case of a permanent injury.

Consider the following hypothetical example to better understand the evaluation of expected health impact. Assume a male victim sustains a spinal injury at the age of 30 years due to the malfunctioning of a regulated technology. Using the cohort life expectancy of 48.1 years for males aged 25 to 34, the equivalent healthy years lost due to the spinal injury can be calculated as 21.31 DALYs by using the above equation. In this calculation, the short-term weight of 0 and duration of 0 years were used respectively, and the fraction long-term and long-term duration parameters were taken to be 1 and 0.443 respectively.

[4] Begg S, Vos T, Barker B, Stevenson C, Stanley L and Lopez A. "The burden of disease and injury in Australia." (2003). Cat. No. PHE 82. Canberra: AIHW 2007.

Injury Burden

The observed health impact is quantified based on each victim's age and injury type in denominations of DALY and is then scaled by the time period under study, the median life expectancy and the exposed population to determine the injury burden in units of fatality-equivalents per exposed population per year. Note that the scaling factors are dynamic and subject to change year-over-year or once every five years during a nation-wide census update.

This edition of the *Public Safety Report* includes the observed injury burden expressed using actual DALYs, as well as the risk of injury or fatality. The former reflects the health impact experienced in a given year, while the latter is a prediction of the injury burden expected in the future based on historical data.

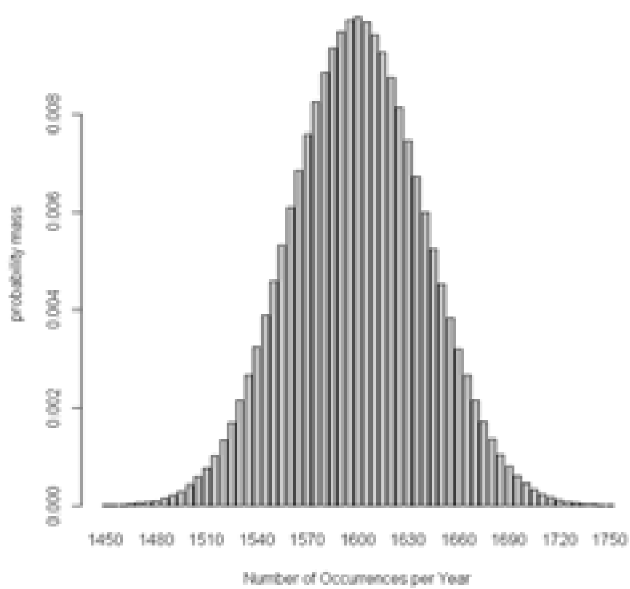
Risk of Injury or Fatality

The Risk of Injury or Fatality (RIF) approach determines predicted injury burden by accounting for historical occurrences while taking into consideration the uncertainties and variability inherent in the involved parameters and predicts the future state of safety in terms of fatality-equivalents per exposed population per year. The rationale behind this approach is that there is a potential for some of the occurrences without health impacts to manifest themselves as incidents with injuries and fatalities in the future. A simulation approach is used to conduct the predictions based on actual observations. Parametric uncertainties are taken as probability distributions which are then input into the prediction model:

(a) One major uncertainty is in the actual number of occurrences. This attribute is subject to reporting bias which means that an unknown fraction of incidents goes unreported to TSSA. The randomness is assumed to follow a Poisson distribution[5] with the observed occurrence rate as the input parameter.

Figure M1 illustrates the breadth of uncertainty in the occurrence rate when, for example, 1,600 occurrences a year are observed on average.

Figure M1: Probability Mass Distribution of the Occurrence Rate (Example)

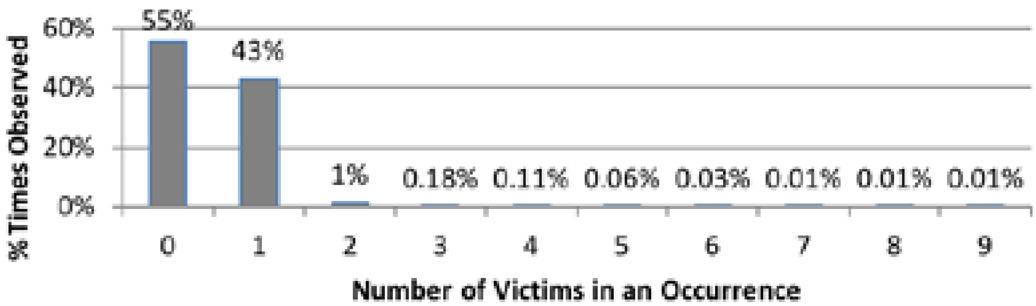


[5] https://en.wikipedia.org/wiki/Poisson_distribution

(b) The number of victims involved in an occurrence is assumed to be a discrete empirical probability distribution constructed from historical observations. This scheme ensures that extreme tail events are assigned a minimal probability, instead of assuming that they are equally likely compared to the most representative estimate.

Figure M2 illustrates the victim count distribution for a typical composite TSSA state of safety prediction. The example shows that there are no victims involved in 55 per cent of the cases, one victim involved in 43 per cent of the occurrences and as high as nine victims in less than 0.01 per cent of the occurrences.

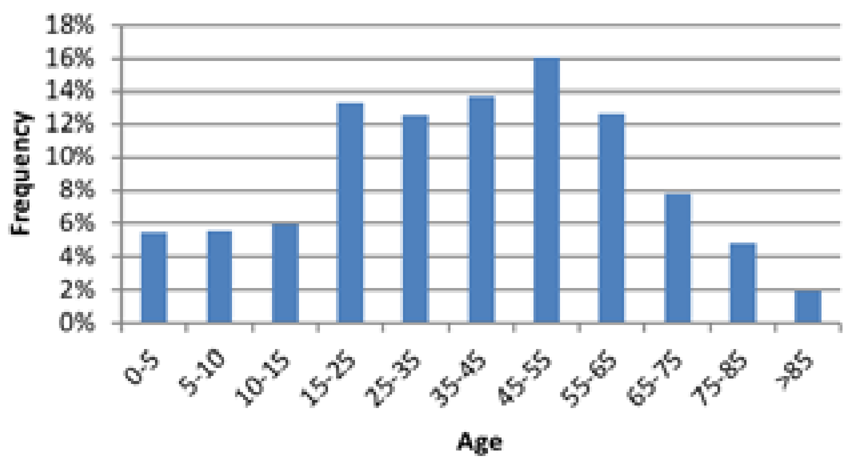
Figure M2: Frequency of the Number of Victims in an Occurrence (Example)



(c) The age of a victim is also uncertain, and the range is between that of being an infant and an elderly person. It is sampled from an age-based population census estimate from Statistics Canada.

Ontarians aged 15 – 65 constitute about 70 per cent of the population, as seen in Figure M3, and are more likely to be victims of an occurrence.

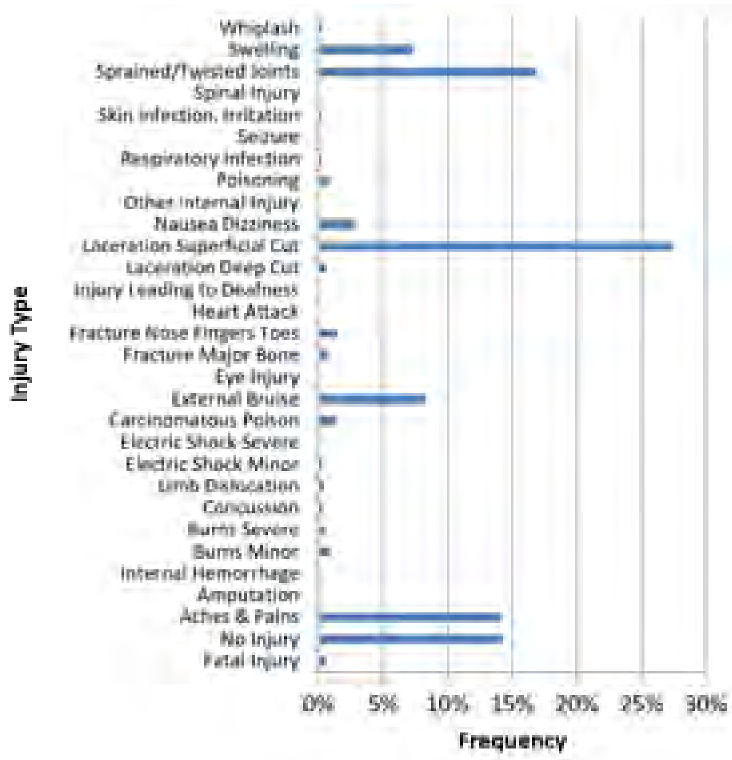
Figure M3: Age Distribution for Predicted Risk Simulation (Example)



(d) The number and type of injuries is sampled from a distribution constructed out of observations. This distribution is dependent on the program and the specific occurrence type under consideration.

An injured victim is likely to sustain superficial cuts, sprains, aches and pains or no injury at all more often than a fatal injury, as seen in Figure M4. The distribution is for illustrative purposes only and varies depending on the regulated sector under study.

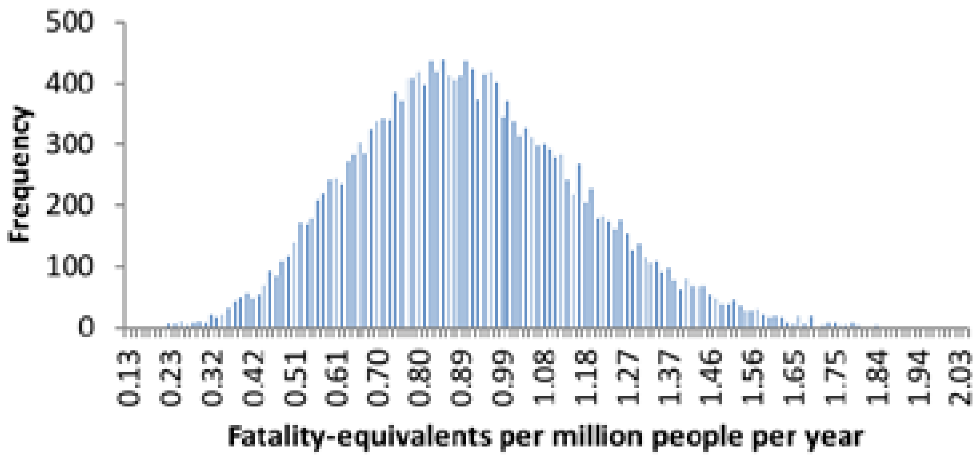
Figure M4: Injury Distribution for the Composite Risk of Injury or Fatality (Example)



In fiscal year 2019, the calculation was updated to improve accuracy and reduce numerical instabilities. In particular, the victim and number of injury distributions now rely on empirical distributions rather than uniform distributions.

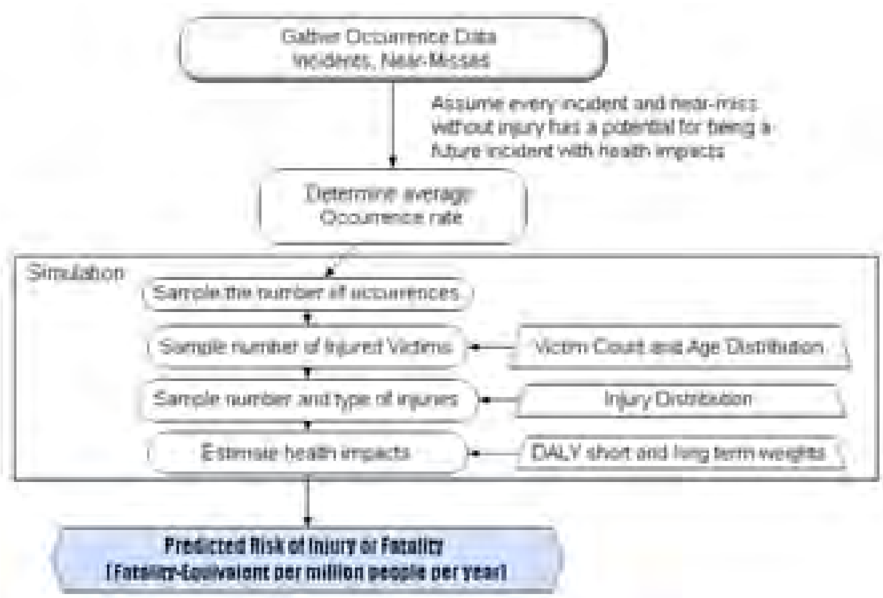
The end result of a risk simulation is a frequency distribution of predicted health impacts, as exemplified in Figure M5. The mean value is used for reporting purposes in the report. In Figure M5, the respective estimate is 0.91 fatality-equivalents/million/year. Note that the risk of injury or fatality is expected to be somewhat larger than the corresponding observed risk. This is a result of the model design to consider near misses as potential incidents and to ensure that a larger set of uncertainties are incorporated into the model that are not exhaustively captured in the actual observations.

Figure M5: Risk of Injury or Fatality Distribution (Example)



The procedure followed to determine the anticipated health impacts is shown in Figure M6.

Figure M6: Flowchart to Predict Future Health Impacts



Statistical Methods

The statistical analysis of the time-series data in this report includes data analysis and trend tests.

When presenting data, it is often desirable to know whether the measured indicator is increasing or decreasing over time. While time-series plots tempt the reader to make visual assumptions on the behaviour of variables over time, trend tests allow for rigorous statistical hypotheses testing. This has three additional advantages over graphical data analysis:

- It ensures a systematic, consistent method of data analysis;
- It yields a measure of the increase or decrease over time; and
- It presents a measure of the strength of the evidence (the p-value).

The current format of the *Public Safety Report* does not include the p-value explicitly, but it is used as a step in the trend analysis.

The Mann-Kendall test[6] is a non-parametric trend test and does not require any assumption of normality or canonical distributions in the data. This test is robust and allows missing data to be present in the analysis.

The trend analysis presented in this report considers the predominantly seasonal nature of the operation of devices (i.e., amusement devices and ski lifts). The trend analysis confirms and takes into account seasonality while establishing historical patterns of safety and compliance performance.

There are many instances where seasonality is the source of variation in the response variable. As such, this report uses Kruskal-Wallis[7] statistics for testing seasonality in the time series, which was done using Python's pymannkendall 1.4.2 package[8]. The assertions of any of these tests are made with 95 per cent confidence, and if evidence is found for seasonality, then the Seasonal Mann-Kendall trend test is used instead of the Mann-Kendall test.

[6] https://en.wikipedia.org/wiki/Trend_analysis
[7] https://en.wikipedia.org/wiki/Kruskal%E2%80%93Wallis_one-way_analysis_of_variance
[8] pyMannKendall: a python package for non parametric Mann Kendall family of trend tests. https://pypi.org/project/pymannkendall/

Assumptions and Sources of Uncertainty

The analysis of compliance trends is provided over a rolling five-year period, which aligns with TSSA's strategic planning process. This approach allows for appropriate measurement and reporting on the effectiveness of these strategies. Trend analysis on incidents and near miss occurrences is based on an indefinite period, limited by the nature and quality of information available in TSSA's database. This will help in better understanding the changing risk profile over extended periods of time.

In producing this report, TSSA's Public Safety Risk Management (PSRM) team of the Strategic Analytics department has made every effort to ensure a high level of quality control over its calculations and methodologies. To this effect, TSSA takes every precaution to ensure the accuracy and quality of data presented in the *Public Safety Report.* Intrinsically, PSRM developed a Quality Management System in 2012 to ensure accurate presentation of public safety information. Occasionally, it is necessary to make restatements to results reported in previous years, typically a result of timeframe factors, such as information received subsequently to the issuance of the report, localized reporting lags for periodic data, investigations completed, and other issues.

Analysis involving reported and inspected incidents and near miss occurrences may be impacted by reporting biases. Due to the varied nature of reporting across the different regulated sectors, TSSA is currently unable to quantify the level of reporting bias and is, therefore, not currently in a position to account for this uncertainty.

Some figures were created using numbers that have been rounded off for ease of display and, as such, some totals may not add up fully or may exceed the 100th percentile.

The average rate of injury and the observed injury burden figures are assumed on a fixed Ontario population size of 14,755,211[9] in the calculation, resulting in some degree of uncertainty. However, it is not considered to be significant.

Occasionally, data records can be misclassified. For example, an amusement device occurrence might be mistakenly entered into the database as an elevating device occurrence. This would not affect the overall RIF calculation, but would be filtered out for the program RIF calculation. Misclassified data such as this would be followed up with the relevant program so the data can be corrected for future editions of the *Public Safety Report.* In addition, data records may have missing or inaccurate information, such as a victim's age being unknown in an occurrence report. When a victim's age is unknown, the risk software assumes an average age. If age information is later found to be inaccurate, then this would again be followed up with the relevant program to modify the database, so it could be corrected for future editions of the *Public Safety Report.* Assumptions can also be made while entering data. For example, a decision will need to be made on whether an injury should be described as a "minor" or a "severe" burn, which requires some degree of interpretation. TSSA makes every effort to minimize these sources of uncertainty and makes corrections, if applicable, when they are discovered.

This report contains occurrences that were reported and had their investigations completed, and had their data entered into TSSA's information system. It does not include ongoing inspections or investigations. Accordingly, this may result in a slight underreporting in some numbers. Since TSSA aims for a prompt turn-around time, it is expected that the impact is largely isolated to the results for the most recent year (in this case, fiscal year 2021).

[9] The population of Ontario in Q1 2021 was 14,755,211 per Statistics Canada (ref: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000901).

Appendix N – Risk-Based Inspection Scheduling

Introduction

TSSA conducts periodic inspections of devices and facilities administered under the Act, based on prescribed intervals set in regulations or at the discretion of the statutory director responsible for the specific regulations using the director's powers laid out in the Act and/or the regulations. As part of TSSA's RIDM framework, TSSA has adopted a risk-informed approach to schedule the frequency of inspections when not prescribed. This scientific and evidence-based approach helps TSSA to focus its resource allocation efforts on the basis of safety risk to Ontarians while ensuring objectivity, consistency, fairness and transparency.

TSSA's patented approach for risk-based scheduling (RBS) of devices and facilities is based on the non-compliance observed (hereafter "orders issued") during inspections, as well as occurrences caused by non-compliance with regulations. Devices or facilities that have had no occurrences caused by non-compliance with regulatory requirements, and/or relatively small number of low-risk non-compliances found during inspections, are likely to be inspected at longer intervals. Short inspection intervals would be recommended for devices or facilities that have many high-risk orders issued against them and/or have occurrences caused by non-compliance with regulations.

Not only can the RBS method inform inspection scheduling, it gives an indication as to the estimated risk profile in a particular area of concern. In cases where the regulations specify intervals, RBS profiles can be generated exclusively for reporting purposes (e.g., amusement devices, liquid fuels). Since not all programs use RBS for scheduling, it is reported instead as the Inventory Risk Profile.

The RBS 2.5 Model

TSSA initially developed and obtained a patent for the model (RBS 2.0) in 2013. However, since that time, TSSA has been making enhancements to the model based on implementation in the field and new information and this appendix describes the most up-to-date version (v. 2.5).

The conceptual basis for the model involves a mathematical aggregation of orders issued during inspections and enforcement actions. Risk scores are determined for all orders, drawing primarily on the standard orders risk assessment; the key difference being when determining the recommended time to compliance (TTC), the risk is defined as *frequency x consequence* while for the RBS the risk is defined as *probability x consequence.* In the case of the determination of the TTC, the objective is to determine the time by when the aggregated consequences of potential occurrences due to an observed non-compliance (if left unaddressed) could reach a threshold. However, the objective of RBS is to determine the time by when the probable accumulation of non-compliance would result in a cumulative consequence. For orders where no risk score is currently available or not determined (e.g., non-standard orders), the issued TTC is used as a surrogate to derive a risk score based on the median risk score of all standard orders with a similar TTC.

The RBS calculation considers all orders issued over the past three periodic inspections and any other applicable inspection activities in that time interval. For instance, if Device A has periodic inspections conducted in 2012, 2014, and 2016, then any additional inspections, such as enforcement actions and ad-hoc inspections, since 2012 will be included. These order scores are then summed to arrive at an inspection risk score. Devices with occurrences caused by non-compliance with regulations are additionally penalized by assigning each occurrence a DALY value based on the most likely significant consequence (or the 99.5th percentile of all injury-carrying occurrences) and added this value to the inspection risk score. A time-weighted average of the inspection risk scores and the time duration between inspections is calculated to arrive at a device or facility risk score.

It is assumed that the risk of a facility/device is close to zero immediately after a periodic inspection. It is also assumed that, in the absence of inspections, the perceived risk gradually accumulates over time due to unobserved non-compliance at a rate specific to a facility/device based on historical observations. The rate is determined based on the following factors:

1. Probable Occurrence Rate for Facility/Device - This is determined by dividing the Facility/Device Risk Score with the average health impacts (measured in fatality-equivalents) per occurrence based on incident history across all facilities/devices and all occurrences with known health impacts.
2. Shape Factor (p) – This provides the shape of the curve that helps determine the rate of accumulation of the perceived risk over time. It is determined by fitting an appropriate statistical distribution to observed time to occurrence since the last inspection. The shape factor is applied to all facilities/devices.

A cumulative risk curve is constructed for each facility/device based on the facility/device specific occurrence rate (described above) and the shape factor. The recommended periodic inspection interval is obtained from the curve as the time to chance of a fraction of one fatality-equivalent as determined by the statutory director. A tolerability interval is obtained from the curve as the time to chance of one fatality-equivalent.

For operational reasons and to address uncertainty in the risk estimates, the statutory director sets the maximum and minimum inspection intervals (for example, the statutory director for the Elevating Devices Safety Program has set the minimum and maximum intervals at six months and five years respectively).

For most applications, the risk acceptability threshold is kept constant, but as per the Auditor General's recommendation, there is a variable risk threshold for propane facilities such that the acceptable level of risk is dependant on surrounding land use. For example, a facility with sensitive receptors in its hazard radius has a risk threshold 3 per cent of that which is used in a remote/industrial area. Similarly, a facility in a high-density residential area has a risk threshold 10 per cent of that which is used in a remote/industrial area.

Appendix O – Causal Analysis Categories

TSSA designates occurrences with a root cause into three categories. The description of each category and the associated mapping of root cause information are listed below. Occurrences that do not have an established root cause after inspection are contained in a fourth category: root cause not established.

Potential Gaps in Regulatory System

Occurrences in this causal category indicate potential areas in need of regulatory change or improvement. They are consistent with the regulatory gap and impact analysis currently used by the Ministry of Government and Consumer Services to effectively improve the regulatory system without imposing unnecessary additional regulatory burden.

Table O1: Causes Contained in the Potential Gaps in Regulatory System Category

CATEGORY	DEFINITION	SUB-CATEGORIES
Design	Factors related to the engineering outline and physical make-up of a device for its intended purpose.	• Defective or inadequate design. • Defective/inadequate safety features, or devices.
Management	Factors related to the levels of responsibility that are accountable for specific activities, programs and systems of operation.	• Gaps in the regulatory management system.

Non-compliance with Regulatory System

Occurrences in this causal category most appropriately reflect TSSA's effectiveness in administering the safety system and obtaining compliance. They allow TSSA to allocate enforcement resources to areas of greatest risk.

Table 02: Causes Contained in the Non-compliance with Regulatory System Category

CATEGORY	DEFINITION	SUB-CATEGORIES
Design	Factors related to the engineering outline and physical make-up of a device for its intended purpose.	• Inappropriate equipment or material selection. • Inappropriate drawing, specification or data.
Equipment/ Material/ Component	Factors related to a device (machinery), the physical constituents of a device (material used or make-up) or a specific unit of an overall device of machinery.	• Defective, failed, or malfunctioning equipment. • Defective or failed component, including safety devices. • Defective or failed material. • Defective assembly. • Electrical or instrument noise or malfunction. • Contamination of material, component or equipment.
Human Factors	Factors related to actions or inactions of humans in the execution of activities in the operation of equipment or in the general work environment.	• Inadequate or unsafe operating environment. • Failure to follow maintenance procedures. • Failure to follow operating procedures. • Failure to follow installation procedures. • Inappropriate plant operator attendance. • Incomplete or inadequate internal communication. • Incomplete or inadequate external communication.
Maintenance Procedures	Factors related to repair and upkeep activities required for the preservation of a device during its useful lifecycle.	• Defective or inadequate maintenance procedures. • Lack of maintenance procedures.
Management	Factors related to the levels of responsibility that are accountable for specific activities, programs and systems of operation.	• Inadequate or defective management systems. • Lack of management systems. • Improper or negligent work practices.
Procedures	Factors related to guidelines that outline how specific activities should be executed.	• Defective or inadequate operating procedures. • Lack of operating procedures. • Lack of or inadequate safety procedures. • Defective or inadequate installation procedures. • Lack of installation procedures.
Training	Factors related to documented programs that prepare employees for the proper execution of specific work activities as required.	• Lack of training programs. • Defective or inadequate training programs.

External Factors

Occurrences in this causal category indicate those outside the control or influence of TSSA. This category prevents misrepresentation of TSSA's performance with respect to compliance or the effectiveness of provincial regulations and allows for the identification of other mitigation measures.

Table 03: Causes Contained in the External Factors Category

CATEGORY	DEFINITION	SUB-CATEGORIES
External Events	Events representing occurrences beyond human control or TSSA regulatory control.	• Weather or other environmental conditions. • Utilities disruption or failure. • External incidents. • Sabotage, terrorism, vandalism or theft. • Non-compliance with non-TSSA regulations.
Human Factors	Refers to the use of regulated technology by a user in a manner that TSSA cannot reasonably know or anticipate and may result in an occurrence.	• Special conditions. • Failure to follow user instructions. • Deliberate intent or sabotage.