Occupational Health and Safety at Surrey Engineering Operations:

An Examination of Frequency, Severity, and Temporal Aspects

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Executive Summary

Engineering Operations is responsible for the maintenance of the City of Surrey's municipal infrastructure, and employs a range of staff from administrators and clerks to tradespersons and labourers. These employees are essential to the efficient operation of Engineering Operations, and their exposure to risk of injury is largely based on their job roles and responsibilities. Public works employees are engaged in varied and complex tasks some of which may potentially increase their exposure to injury. Working at a job site with heavy equipment and power tools has certain inherent risks and while every reasonable measure can be taken to avoid injuries, it is impossible to guarantee zero risk. However, it remains a key objective.

Every occupation and work setting is susceptible to risk. Engineering Operations is no exception. At the vehicle maintenance shop, on the way to or from a job site, or even while training, public works employees face the possibility of suffering an injury. Work-related accidents impose a considerable burden on the employee, family, and colleagues and have implications for Engineering Operations and the City of Surrey from the need to adjust staffing levels to accommodate injuries and short-term disability. Occupational health and safety initiatives, ongoing training and crew safety talks, as well as protective gear are several areas where time, energy, and resources are well-spent. Efforts in these areas continue and contribute to ensuring the overall safety of public works employees. Despite these ongoing efforts and accomplishments, injuries occur. A better understanding of how, when, and where employee injuries arise can help to identify effective injury prevention strategies. **It is predicted that Labourer 2 workers between the ages of 45 to 59 face the greatest risk of injury at Engineering Operations. These injuries will take place on Mondays and cluster over the summer months, and will occur in the field. Injuries will also impact Tradesperson 2 and Trades Improver 2 workers at or near maintenance yards, and will lead to more severe outcomes such as medical attention and/or short-term disability. A strong focus on preventing and/or reducing injuries for these three employee groups will greatly serve to reduce the safety incidence number in line with Engineering Operation's four year safety goals and objectives.**

Since 2005, workplace injuries at Engineering Operations have been in steady decline. The reduction in job-related accidents supports a growing culture of awareness by managers and staff around the importance of employee safety and injury prevention in the workplace. It is a crucial message, and one that needs steady reinforcement with occupational groups at different times and places to ensure that workplace injuries continue to decline. It is a message that needs to be continuously monitored for its effectiveness in reducing workplace injuries with a view to acting upon the data to support evidence-based decision-making.

Study Findings

- Temporally, 23% of work-related injuries occurred on Mondays with a steady decline toward Friday. Monday and Tuesday comprise nearly half of all outdoor worker injuries. Employees returning to work after the weekend seemingly pay less attention to job-site risks and could benefit from a refresher on the merits of workplace safety.

- Workplace injuries tend to cluster in the summer months. Thirty-one percent of worker injuries took place in June, July, and August. January shows a higher than average increase of worker injuries. Employees returning to work from holidays may be less attuned to injury prevention. An opportunity exists to reiterate injury prevention messaging at this time.

- Labourer 2 workers experience the most injuries relative to all other occupational groups. The position requires twisting, extended reaching, and stooping under heavy and/or shifting loads. Labourer 2 workers are typically middle-aged employees and face a different set of health issues than younger labourers. This study makes an important distinction between "indoor workers" and "outdoor workers." It is maintained that outdoor workers face a greater risk of injury given the nature of their roles and responsibilities.

- One-half of job-related injuries affect outdoor workers between the ages of 45 to 59 years, reflecting higher injury rates for older employees. The contributing factor in almost one-quarter of Labourer 2 injuries was overexertion when lifting, wielding, and pulling or pushing objects.

- The majority of employee injuries occurred in the field while carrying out regular maintenance work on roads, drainage, waste, sewers or water utilities. One-half of employees injured at fleet and garage locations are Tradesperson 2 workers. These individuals are skilled trades' professionals in their late 40s with injuries to their fingers, hands and/or eyes.

- Sprains, strains, and tears as well as bruises and contusions, including cuts and lacerations comprise nearly 65% of all outside worker injuries in the period under review. Overexertion is a factor in nearly 40% of such accidents. Forty-eight percent of such overexertion accidents involved the lower back region, as well as the shoulder and neck.

- Between 2005 and 2010, Labourer 2 overexertion injuries remained at the 6-year average rate of 5.1 incidents per 100 person-years worked. However, from 2012 to 2015, Labourer 2 workers experienced a 21.7 increase in the frequency rate of overexertion injuries. While the rate of public works injuries is steadily declining, injuries to Labourer 2 employees merit closer attention.

- Bayesian analysis of odds ratios and relative risk indicate that Tradesperson 2 and Trades Improver 2 employees face much greater odds of overexertion, sprains, strains, and tears leading to negative health impacts and lost work time. Health outcomes such as short-term disability and medical intervention due to injury are higher for these two occupational groups relative to others examined in the study.

Workplace injuries and the effectiveness of injury prevention at Engineering Operations should be closely monitored. This study calls for the development and application of business intelligence (BI) tools, metrics, and rubrics for this purpose. Performance measurement would greatly enhance the ability of managers and supervisors to identify and quickly act on the drivers of workplace injury.

Introduction

RATIONALE

Occupational health and safety research and surveillance are essential for the prevention and control of injuries, illnesses, and hazards that occur in the workplace. An in-depth analysis of workplace injuries can help to provide insights about where risks exist, and what strategies are needed to prevent job-related accidents. This study examines employee injury data from 2005 to 2015 with a view to understanding the scope, nature, and impact of the problem and identifying specific injury prevention programs to reduce or prevent workplace hazards and to ensure the safety of all employees.

Engineering Operations has made impressive strides toward the vision of an injury-free workplace. The major goal for 2016 is to improve employee safety (year 2 of 5). The 2014 goal was to reduce short-duration employee absenteeism due to preventable accidents by 50% in the next 5 years. Engineering Operations realized a significant achievement in 2015 with the reduction in worker injuries by 50% from the previous year. The new goal is to reduce the safety incidence number by 90% over the next 4 years (2014 being the base year). This study is intended to support Engineering Operations in meeting their employee safety goals by examining the underlying nature and characteristics of workplace injuries. The ongoing goal of Surrey Engineering Operations and continuous improvement speak to the benefits of sharing knowledge, resources, and expertise in protecting the City's most valuable asset – municipal employees.

INTENT OF STUDY

The aim of this study is to examine the frequency, severity, locational, and temporal aspects of employee injuries at Surrey's Engineering Operation Division and to predict where and when injuries are most likely to occur. It makes recommendations to enhance the occupational health and safety of municipal employees, and to reduce employee absenteeism due to preventable accidents. Four specific questions are posed and frame this study:

1. Has there been an increase in the frequency of employee injuries at Surrey's Engineering Operations? What is likely to happen in the future?
2. At which location are employee injuries most prevalent? What are the leading types of existing and future injuries and how can they be prevented?
3. Which age cohort and occupational group are most susceptible to injury in the near and long -term? How can these employee injuries be prevented or mitigated?
4. Does the intersection of hot temperature, aged workers, and overexertion contribute to worker injuries in the field?

In order to answer the above four questions, the scope of this research involved:

- Undertaking an analysis of Surrey Engineering Operations employee injury data and yearly staff counts from 2005 to 2015, daily temperature data for Surrey, as well as a literature review of relevant academic publications, technical reports, and statistical methods.

Literature Review

There is a wealth of literature related to occupational health and safety and the prevention of workplace injuries. The available material is divided into three main categories: (1) governmental; (2) occupational health and safety; and (3) academic. In addition, relevant sports injury literature was consulted. Literature relating to Bayesian inference, tools, and techniques was also examined.

Fan, McLeod, and Koehoorn (2012) examined the rates and distribution of serious work-related injuries by demographic, work and injury characteristics in British Columbia (BC) from 2002 to 2008, using population-based data. Claims for workers with a serious injury were extracted from worker's compensation data. Serious injuries were defined by long-duration, high costs, serious medical diagnosis, or fatality. Persons between the ages of 35-44 had the highest overall injury rate compared to the youngest age group. The rate for strains and sprains was high for the 35-44 age cohorts, which is consistent with the findings of this injury study. Given projected demographic shifts and increasing workplace participation of older workers, intervention programs should be carefully implemented with consideration of demographic groups at-risk of serious injuries in the workplace.

Garrido, Bittner, Harth, and Preisser (2015) found that public works employees are exposed to several occupational stressors which may affect their quality of life. Their study determined that the most common complaint was musculoskeletal issues, specifically back pain. They recommended interventions to enhance ergonomic work in order to reduce back complaints and enhance safety. Researchers Jeong, Lee, and Lee (2016) investigated patterns of workplace injuries and work-related illnesses of household waste collectors and labourers. There were significant differences in the effect of worker's length of employment, injured part of body, type of accident, agency of accident, and collection process. Results show that most injuries occur in workers in their 50s and older. It is inevitable that worker's physical abilities decline with age, but in addition to these physical changes, there is also concern related to aged vision, auditory, and mobility capabilities. Work-related injuries among public works employees are mostly musculoskeletal conditions due to damaging postures. These and other areas of concern along with the needs of an aging workforce should be the primary focus of any injury prevention program in Surrey.

Kuijer, Sluiter, and Frings-Dresen (2010) assessed work demands, acute physiologic responses, illnesses, and injuries as a starting point for worker health surveillance. They proposed a regime of surveillance for the periodic examination of putatively exposed or injured workers, with the aim of tracking and acting upon the potential of re-injury. Surveillance may be performed for three purposes: (1) to prevent the onset, recurrence, or worsening of work-related injury or disease in individuals; (2) to watch and promote individual's health; and (3) to watch and promote individual's ability to perform satisfactorily a job without endangering the health and safety of self and/or others.

Myers *et. al.* (1999) identified factors associated with acute low back injury among municipal employees of a large city. For each of 200 injured patients, 2 co-worker controls were randomly selected, the first matched on gender, job, and department and the second matched on gender and job classification. In-person interviews were conducted to collect data on demographics, work history, work characteristics, work injuries, back pain, psychosocial and work organization, health behaviors, and anthropometric and ergonomic factors related to the job. Psychosocial work organization variables were examined with factor analysis techniques; an aggregate value for job strain was entered into the final model. Risk factors were examined utilizing multivariate logistic regression techniques.

High job strain was the most important factor affecting back injury (odds ratio [OR] = 2.12, 95% confidence interval [CI] = 1.28, 3.52), and it showed a significant dose-response effect. Body mass index (OR = 1.54, 95% CI = 1.08, 2.18) and a work movement index (twisting, extended reaching, and stooping) (OR = 1.42, 95% CI = 0.97, 2.08) were also significant factors. Results suggest that increasing workers' control over their jobs reduces levels of job strain. Ergonomic strategies and worksite health promotion may help reduce other risk factors. The literature review helped to inform and guide the development of this study, and to develop recommendations to prevent and reduce workplace injuries at Engineering Operations.

Engineering Operations Division

Surrey's Engineering Operations Division is responsible for the day-to-day operations and maintenance of the municipal road networks, storm drainage, drinking water, sanitary sewer, and waste collection utilities. It provides services in the following four areas:

ROADS AND DRAINAGE MAINTENANCE

The Roads and Drainage section maintains municipal roads and sidewalks and provides snow and ice control operations. The section is also responsible for storm water management, flood control, and the maintenance of dykes and bridge structures.

WATER UTILITY

The Water section is responsible for the maintenance of a drinking water distribution system that delivers high quality water to residents and businesses and water supply for fire suppression. Operations crews respond to emergency calls for broken water mains and services, undertake regular maintenance of the valves, pump stations, and fire hydrants. They are also responsible for installing service connections, water quality monitoring, water metering, backflow prevention, or water mains construction and maintenance, including flushing.

SANITARY SEWER UTILITY

The Sanitary Sewer section is responsible for maintenance and construction of the City's sanitary sewer infrastructure, installing service connections, inspection and maintenance of sanitary sewer mains, maintenance and operation of pump stations and valves, and flow monitoring.

WASTE COLLECTION SERVICES

The Solid Waste section is responsible for collection of garbage, recycling, and organics from over 117,444 one-and two family dwellings and approximately 35,226 multi-family residential customers (21,625 licensed businesses). In order to provide services in all of the four sections, Engineering Operations employs a wide variety of individuals in several occupational groups. Each individual faces unique risks of injury relative to their job classification, roles, and duties. External drivers may also be a determinant of workplace injuries in the near and long-term, and are considered in the following section.

THE ROAD AHEAD

The City of Surrey is expanding at an exponential rate and municipal infrastructure must keep pace with continuing population growth as well as the demand for housing and amenities. Surrey's population had increased significantly between 2004 and 2014 and continued growth is expected. During these 10 years, the City's population increased by approximately 100,000 residents (Estimates are based on a combination of Surrey's Building Permit data and BC Assessment information). According to July 2016 City population estimates and projections, Surrey can anticipate 577,456 residents by the year 2021. The City can also expect 209,477 residential units by 2021, a percentage increase of 11% from 2016 (N=188,648). While many residents will obtain housing in Surrey’s urban core, others will chose to locate where future land development is expected. This has budget and resource implications for the City in terms of servicing existing municipal infrastructure and accommodating the planned growth and expansion of Surrey communities.

From an Engineering Operations perspective, such an expansion translates into more servicing of road networks, storm drainage infrastructure, water treatment facilities, sanitary sewer lines, and waste collection utilities. With these factors in mind, the study identifies when, where, and why employee injuries occur in order to prevent and/or reduce existing injuries and to enhance workplace safety in the future. Taking immediate action based on all the available evidence will help to further drive down the rate of employee injuries at Surrey public works.

Thirty-six occupational groups at Engineering Operations experienced a variety of job-related injuries from 2005 to 2015. During this 11-year period, injuries had affected a broad range of employees from office staff to workers employed in the trades and labourers. Every staff member faces the risk of injury at some time during their tenure of employment. No employee is immune from job-related injury at the workplace. Employee injuries can, and often do happen anywhere in the workplace. Injury prevention programs must be focused and consistently applied throughout the organization. Measuring the results of these prevention efforts is essential to meeting the organization’s injury prevention goals and objectives. The study proposes recommendations on how this may be best achieved.

Methodology, Statistical Tools, and Techniques

The first part of this study is exploratory and considers employee injury data at a high level, and had identified injury patterns, trends, and frequencies for advanced analyses (N=1094). Time-series analysis was carried out using autoregressive integrated moving average (ARIMA) models as a procedure to either confirm or refute hypotheses. This technique is employed to better understand the data or to predict future points in the series. In this study, ARIMA models were used to test the hypothesized relationship between employee overexertion, aged workers, and hot temperature.

Variables and coding structure conformed to recording and classification standards as set out in *Coding of Work Injury or Disease Information* (Z795-03), a publication by the Canadian Standards

Association (CSA). The CSA is a non-profit organization that develops standards for industry, government, and consumer groups. Injury standards are endorsed by the Canadian Centre for Occupational Health and Safety (CCOHS), a federal agency dedicated to the elimination of work-related illnesses and injuries.

In terms of data pre-processing, ten occupational groups each having a total of ≥25 work-related injuries from 2005 to 2015 were selected for analysis (n=972). Data was cleaned and coded to allow for in-depth investigation. Table 1 reveals the top three occupational groups that had suffered work-related injuries from 2005 to 2015 were Labourer 2, Trades Improver 1, and Tradesperson 2 employees. (The Truck Driver 2 category was subsequently dropped from analysis as the value of the weight variable was zero. Such cases are invisible to statistical procedures and graphs which need positively weighted cases). It is important to note that several employees perform more than one of the jobs in the occupational groups as specified below:

Table 1: Employee Injuries by Top Occupational Groups of Injury at Engineering Operations*

Data from January 1, 2005 to December 30, 2015

Occupational Code	Occupation Description	Frequency of Injury
14230	Labourer 2	314
15284	Trades Improver 1	198
15316	Tradesperson 2	120
14225	Labourer 1	102
15291	Trades Improver 2	64
13420	Chargehand	48
13930	Equipment Operator 4	41
14007	Foreman	31
15329	Tradesperson 3	29
15389	Truck Driver 2	25

*Note: Occupational groups with the greatest frequency of workplace injuries in descending order of magnitude. Sample size cut-off is ≤ 25 cases due to low sample size and reduced statistical power.

(n=972)

In total, 31 records listed as “No Injury” were removed from the dataset. Non-classifiable injuries were retained. Employee injuries occurring on weekends, while infrequent, were similarly retained. For the purposes of this study, staff employed under any one of the ten occupational groups is considered an ‘outdoor worker.’ To reiterate, these employees typically do not work in an office setting but work outside at or near a job site. They are exposed to a greater risk of workplace injury than office workers and, as such, constitute the focus of this study.

INJURY-INCIDENCE AND RISK FACTOR STATISTICS

The following ratios were employed:

- Risk ratio (RR) is a measure of the risk of a certain event happening in one group compared to the risk of the same event happening in another group. In injury studies, relative risk is the probability of the occurrence of an injury in a group that has been exposed to some hazard, environmental or toxic influence, relative to its probability in a randomly selected population.

- Odds ratio (OR) represent the probability of a certain event. They provide a comparison estimate between two variables and show a proportionate value between them. For example, an odds ratio may state that Tradesperson 2 employees have a 3 in 5 chance of being seriously injured with negative health outcomes. This ratio shows the proportion of how many tradespersons are injured compared to the total number of tradespersons employed at the organization. Odds ratios are used to compare the relative odds of the occurrence of the outcome of interest (e.g., time loss from work), given exposure to the variable of interest (e.g., injury).

- A confidence interval (CI) is a range around a measurement that conveys how precise the actual measurement is. For most injury programs, the measurement in question is a proportion or a rate (e.g., injury incidence rate). Confidence intervals are used to quantify the uncertainty by providing a lower limit and upper limit that represent a range of values that will represent the true population parameter with a specified level of confidence.

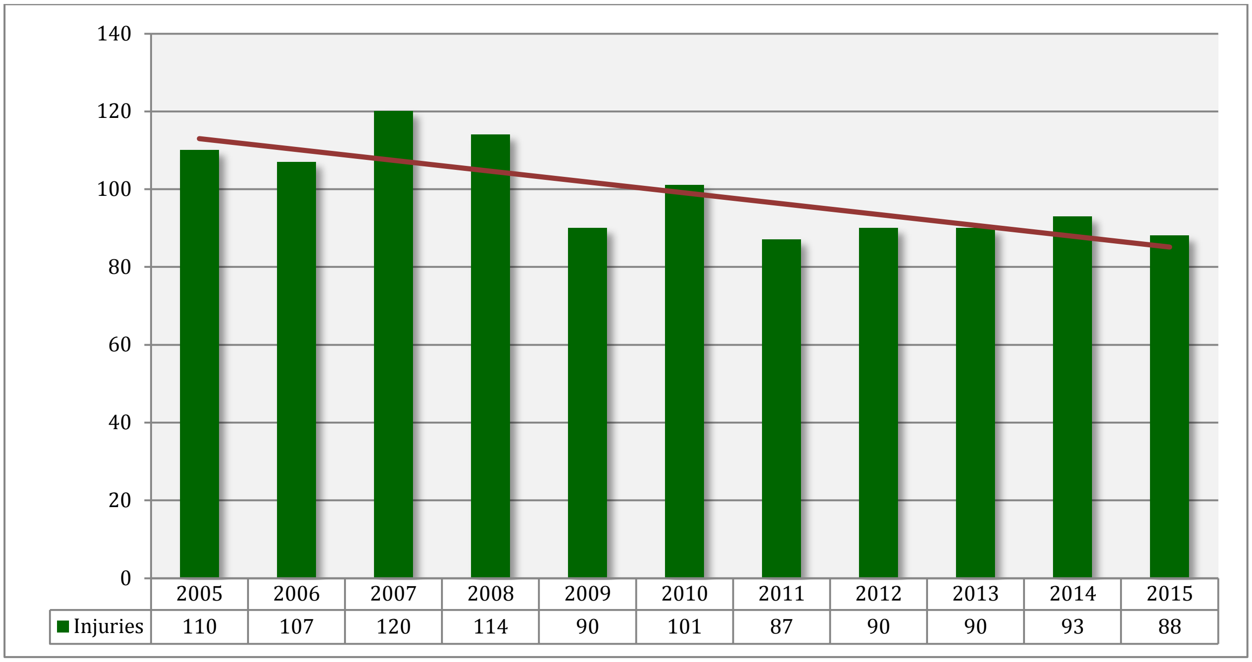
Data Analysis

DESCRIPTIVE STATISTICS

Chart 1 indicates a steady decline in workplace injuries at Surrey's Engineering Operations from 2005 to 2015. Since 2011, the frequency of employee injuries had consistently remained below the 11-year average of 99 accidents. The reduction in workplace injuries over the past five years speaks to a culture of growing employee safety awareness and continuing vigilance by managers and staff around the importance of injury prevention in the workplace. It is a crucial message, and one that needs constant reinforcement with certain occupational groups at different times and places to ensure that workplace injuries continue to decline.

Chart 1: Frequency of Employee Injuries at Engineering Operations

Data from January 1, 2005 to December 30, 2015



(N=1090)

When examining the temporal factors of workplace injury, 23% of incidents occurred on Mondays with a steady decline toward the end of the week. Chart 2 indicates that injuries occurring on Mondays and Tuesdays account for nearly 46% of all outdoor worker injuries in the study period (n=972). One possible explanation is that employees returning to work on Mondays pay less attention to job site risks and safety after weekends. It is also possible that new projects are assigned on Mondays and Tuesdays or remaining unfulfilled tasks left over from past weeks become due and are acted upon. It could be that more physically demanding or complex projects are assigned on Mondays rather than later in the week, exposing workers to a greater risk of injury. Whatever the reason, or combination of reasons, it makes sense to hold safety crew talks at the start of the week for those outdoor workers who face a greater risk of injury.

Chart 2: Employee Injuries by Day of Week at Engineering Operations

Data from January 1, 2005 to December 30, 2015

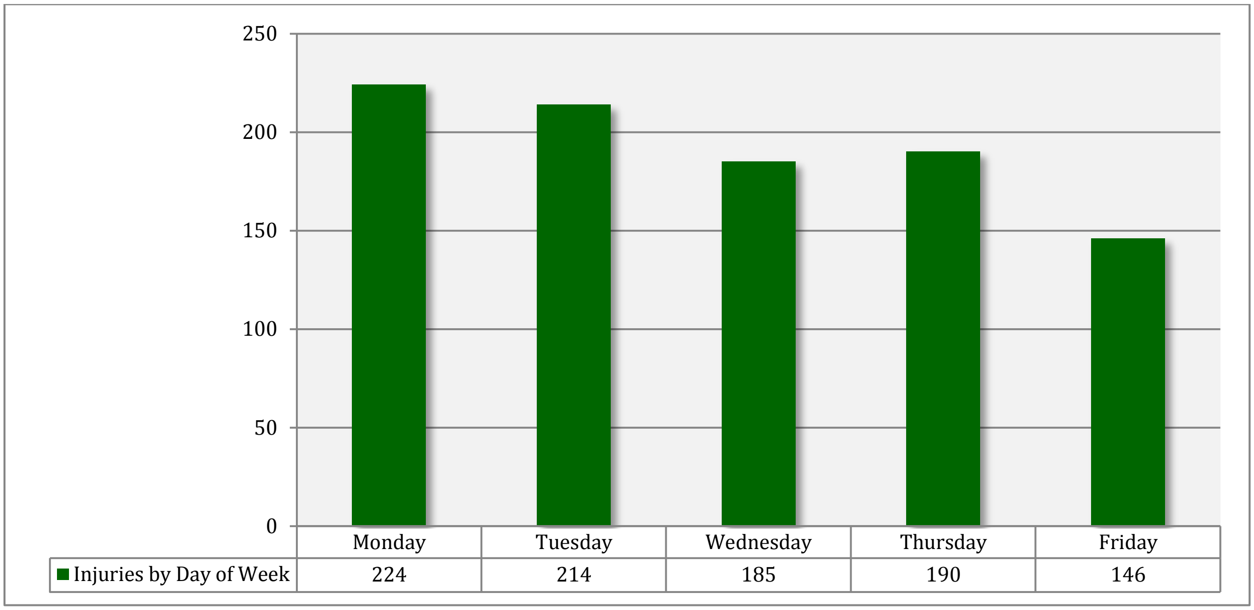
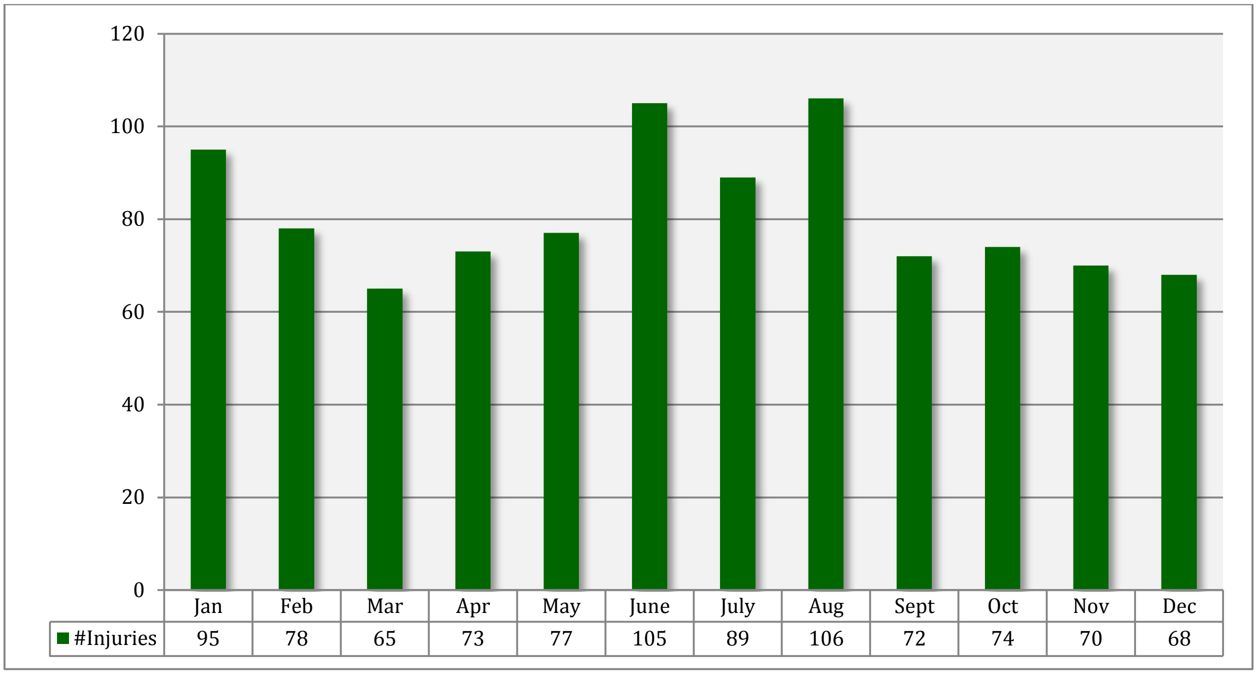


Chart 3 reveals that workplace injuries tend to peak in the summer months. Thirty-one per cent of accidents involving outdoor workers from 2005 to 2015 occurred in June, July, and August. Several plausible explanations exist. It is possible that summer months are set aside for large outdoor projects given favourable weather conditions and less traffic congestion on City streets, thereby resulting in more employees working outside and exposed to greater risk of injury. It has been asserted that employee overexertion, aging workers, and hot temperature may contribute to a heightened risk of workplace accidents. This assertion is explored in a later section of the study. It is possible that owing to summer vacations, fewer remaining outdoor workers are performing more work at greater intensity levels as they cover for co-workers on leave.

January shows a higher than average increase in the number of workplace injuries, and may be partly explained by slipping accidents due to poor weather or icy conditions. Aside from seasonal hazards, there are behavioural aspects at play. Employees returning from holidays may be less vigilant about job site risks and safety considerations after taking a few weeks off work. A refresher on workplace safety is required. It would be timely to hold crew safety talks and/or injury prevention workshops in early January when the majority of outdoor workers return to duty.

Chart 3: Employee Injuries by Month at Engineering Operations

Data from January 1, 2005 to December 30, 2015



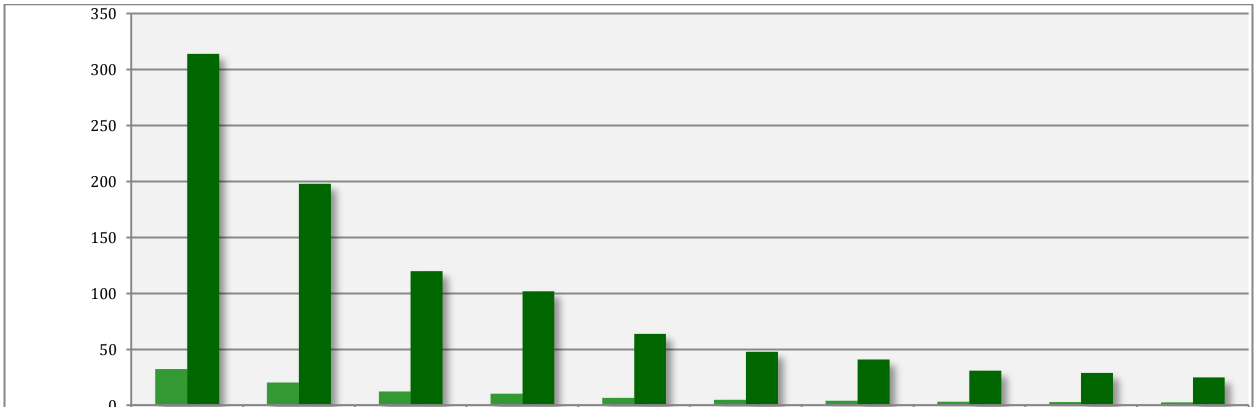
Average: 81 injuries.

(n=972)

Labourer 2 workers experience the most injuries compared to all other occupational groups at Engineering Operations, making up nearly 29% of injuries (N=1090). When looking at outdoor workers as a whole, Labourer 2 staff account for nearly one-third of injuries (n=972). This is not surprising given the physically demanding roles and duties of labourers in the field. Labourers are responsible for manual and semi-skilled tasks involving considerable physical effort in the performance of a variety of construction and maintenance duties while operating small equipment and power hand tools. The position involves heavy manual outdoor work in all types of weather conditions. It requires twisting, extended reaching, and stooping under heavy and/or shifting loads. Labourer 2 employees are workers at a mean age of 40 years and, as such, face a different set of health challenges than younger Labourer 1 workers (mean age 27 years).

Chart 4: Employee Injuries by Occupational Group at Engineering Operations

Data from January 1, 2005 to December 30, 2015



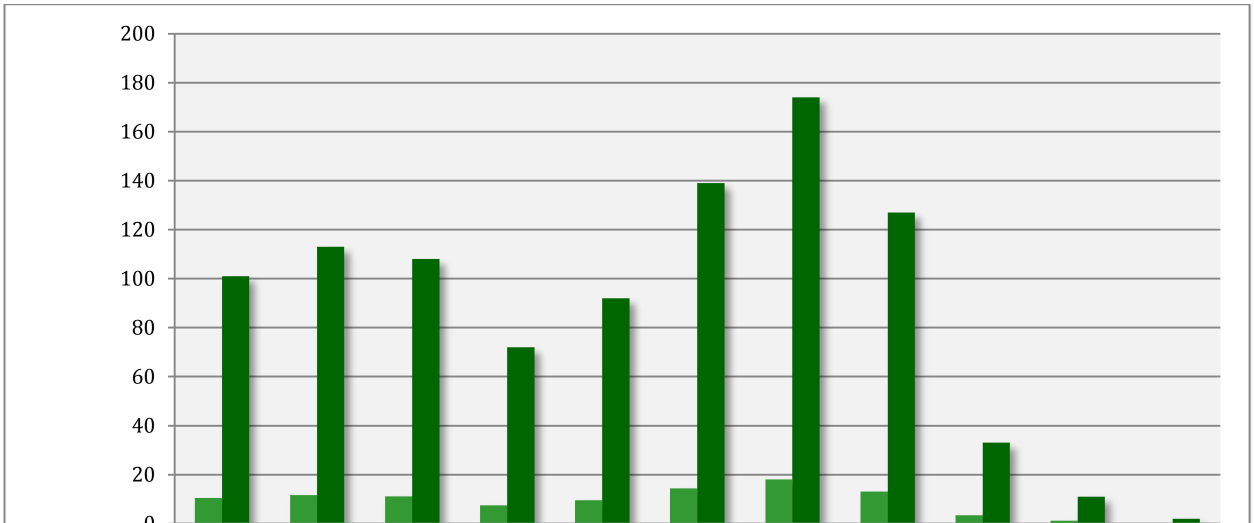
	Labourer 2	Trades Improver 1	Tradesperson 2	Labourer 1	Trades Improver 2	Chargehand	Equipment Operator 4	Foreman	Tradesperson 3	Truck Driver 2
% injuries	32.3	20.3	12.3	10.5	6.6	4.9	4.2	3.2	3	2.6
# injuries	314	198	120	102	64	48	41	31	29	25

(n=972)

Demographically-speaking, about one-half of injuries at Engineering Operations from 2005 to 2015 impact workers between the ages of 45 to 59 years (n=440), indicating a higher risk of injury for older employees (in particular outdoor workers engaged in physically demanding work). As Chart 5 indicates the 50-54 age group accounts for 18% of all reported injuries in the study. A closer examination of this age cohort reveals that Labourer 2 employees make up 23% of injuries (n=213). The contributing factor in almost one-quarter of Labourer 2 injuries within this age cohort was overexertion when lifting, wielding, pulling or pushing objects (n=50). Overexertion continues to be a factor in many public works injuries in Canada, and is found in comparable areas of activity such as firefighting and construction where physical demands are made on employees (Tyakoff, Garis and Thomas, 2015). These demands can involve sudden, intensive bouts of physical activity and/or more prolonged activity with possible negative implications for worker health and safety.

Chart 5: Employee Injuries by Age at Engineering Operations

Data from January 1, 2005 to December 30, 2015



	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74
% Injuries	10.4	11.6	11.1	7.4	9.5	14.3	18	13	3.4	1.1	0.2
# Injuries	101	113	108	72	92	139	174	127	33	11	2

(n=972)

Kendall's Tau and Spearman's Rank Correlation Coefficient was used as a procedure to assess statistical associations based on ranks of the data. Ranking data is carried out on the variables that are separately put in order and numbered. In terms of outdoor workers, there is a significant correlation between date of injury and number of years employed for specific age cohorts. Correlation is significant at the 0.01 level (2-tailed). The age of an injured worker is strongly correlated with length of service. Twelve percent of injuries to outdoor workers under age 35 occurred among those within their first five years of employment. Fifteen percent of injuries to outdoor workers between 50 to 54 years occurred among those with 10 or more years of service (n=972). It can be said that younger workers or those relatively new to the organization are at a heightened risk of injury and older workers are also at risk.

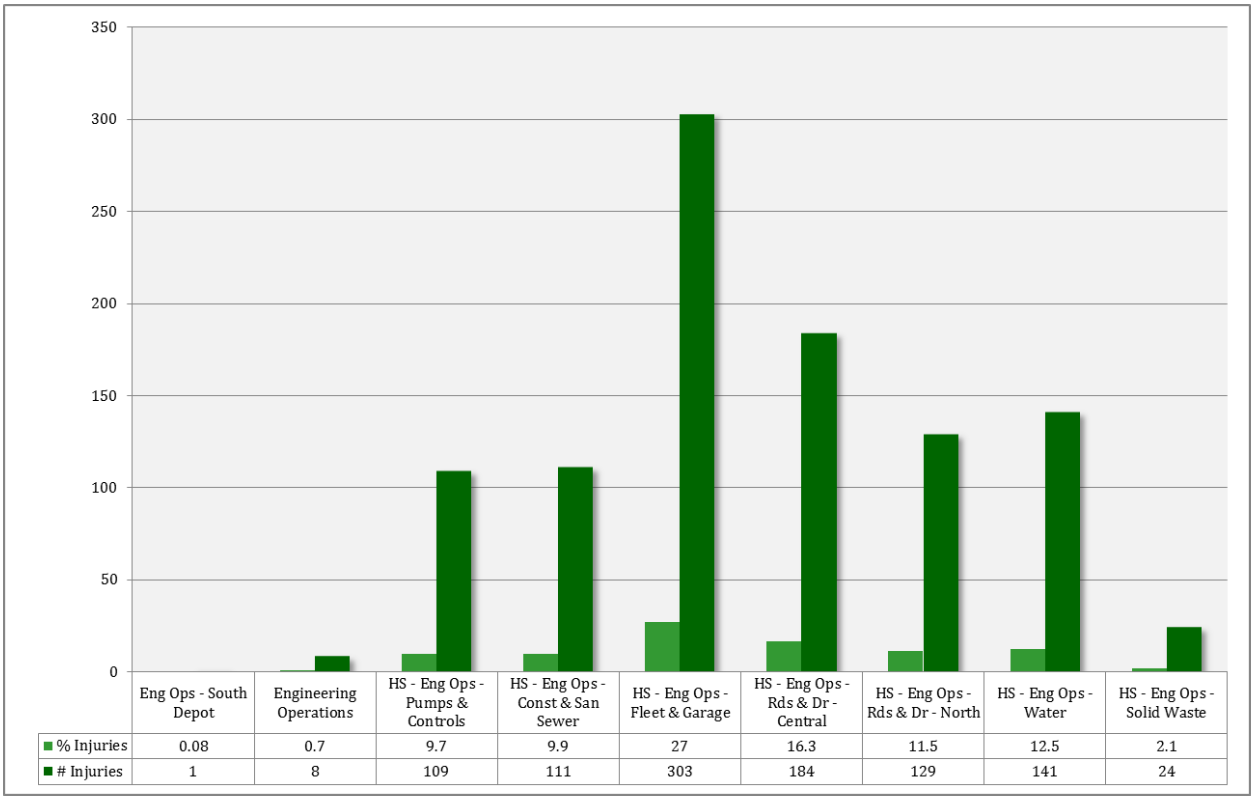
Older workers tend to have fewer accidents, but when an older worker does get injured, their injuries are often more severe. They also may take longer to recuperate. In addition, the types of injuries can be different. Younger workers tend to get more eye or hand injuries, while older workers who have been working for many years report more back injuries. Many workplace injuries are the result of doing the same tasks again and again. Repetitive motion injuries, for example, develop over time. An older worker may report more musculoskeletal injuries since they have had longer for the condition to develop. Since older workers tend to have more severe injuries when they do occur, it is important to make adjustments to work settings or work patterns to keep them as safe as possible. It is also important to make sure a worker is suited for a particular task and is safely able to do it. Injury prevention programs and scheduling can be designed to address risk of injury at key points along the employee's trajectory of employment.

Figure 1: Kendall’s Tau and Spearman’s Rank Correlation Coefficient			Incident Date	Years from Last Hire Date
Kendall's Tau B	Incident Date	Correlation Coefficient	1.000	-.383**
		Sig. (2-tailed)	.	.000
		N	199	199
	Years from Last HireDate	Correlation Coefficient	-.383**	1.000
		Sig. (2-tailed)	.000	.
		N	199	199
Spearman's Rho	Incident Date	Correlation Coefficient	1.000	-.528**
		Sig. (2-tailed)	.	.000
		N	199	199
	Years from Last Hire Date	Correlation Coefficient	-.528**	1.000
		Sig. (2-tailed)	.000	.
		N	199	199

Chart 6 indicates that 20% of employee injuries occurred at fleet and garage locations. The majority of other remaining injuries took place in the field and involved maintenance work on City roads, drainage, waste/sewers or water works. Approximately half of workers injured at or near fleet and garage locations were Tradesperson 2 employees. These workers are skilled trades’ professionals usually in their late 40s having sustained accidents to their fingers, hands or eyes. This is an obvious finding given the level of eye-hand coordination required when operating power tools. Thirty per cent of such injuries had resulted in short-term disability with the majority of files created for reporting purposes only. Tradespersons and injury will be examined in greater detail in a later section of this study. The personal health records of injured employees were not accessed for this study, therefore, no assessment can be made about post-injury and severity.

Chart 6: Location of Employee Injuries at Engineering Operations

Data from January 1, 2005 to December 30, 2015



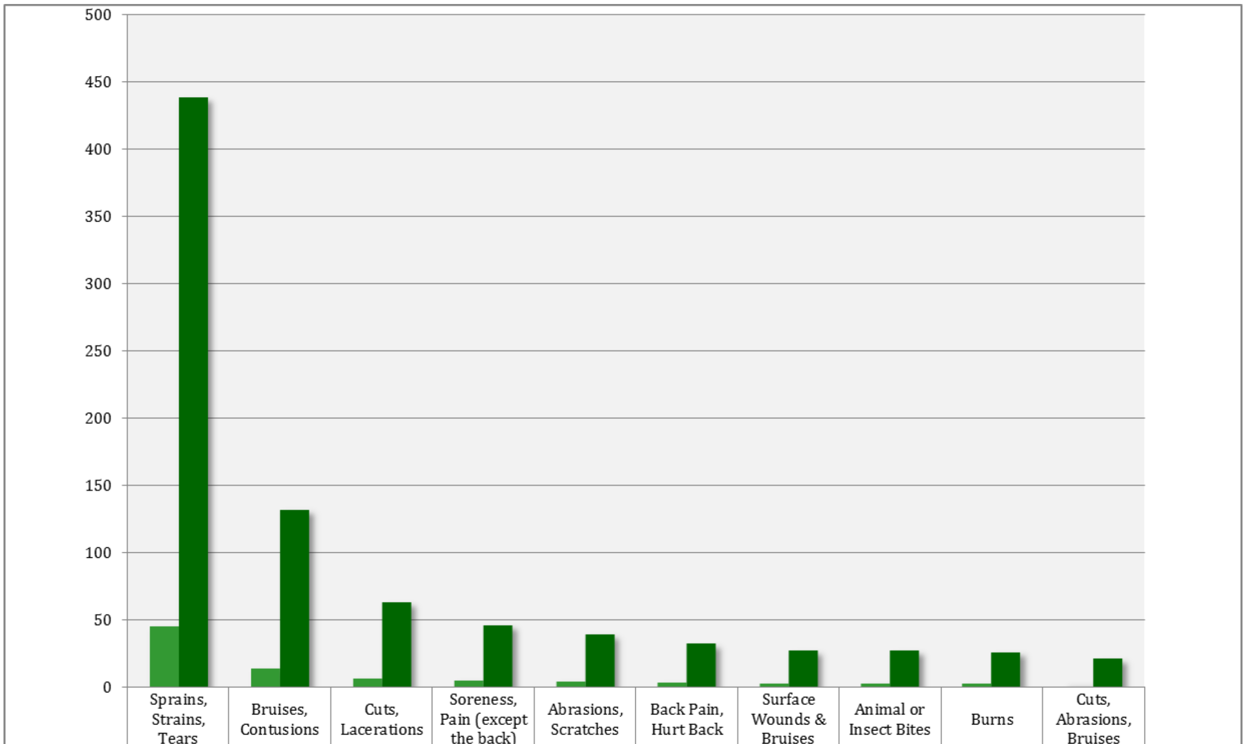
(n=972)

Chart 7 indicates that sprains, strains, and tears as well as bruises and contusions, including cuts and lacerations comprise nearly 65% of all outside worker injuries from 2005 to 2015 (n=972). Overexertion is a key contributing factor in 39% of such sprain, strain, and tear injuries involving outside workers (n=972). Forty-eight per cent of overexertion accidents had engaged the lower back region, as well as the shoulder and neck.

It is fair to say that every worker who lifts or does other manual handling tasks is at some risk for musculoskeletal injury. In such cases, low back pain (LBP) is the most prevalent type of injury. The complete elimination of this risk is not realistic. However, Engineering Operations has worked hard over the years to prevent the most serious employee injuries from taking place while continuing to focus on less severe injuries that may have a cumulative or aggravating effect over time.

Chart 7: Nature of Employee Injury at Engineering Operations

Data from January 1, 2005 to December 30, 2015



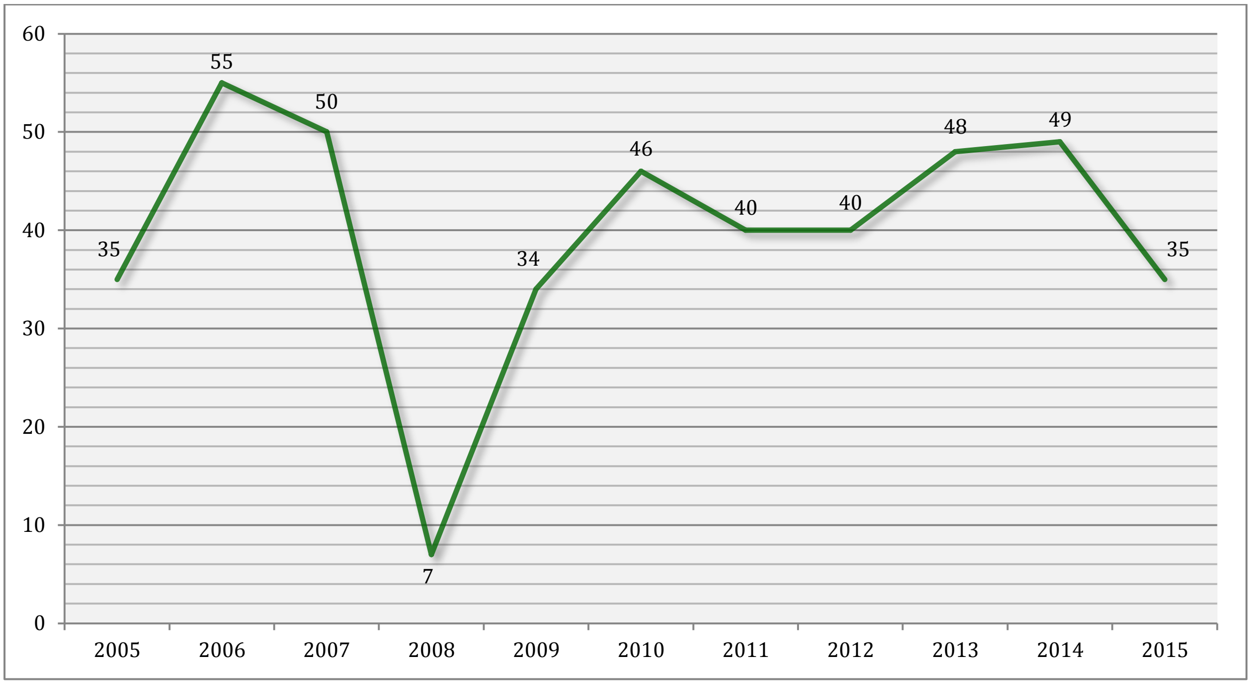
	Sprains, Strains, Tears	Bruises, Contusions	Cuts, Lacerations	Soreness, Pain (except the back)	Abrasions, Scratches	Back Pain, Hurt Back	Surface Wounds & Bruises	Animal or Insect Bites	Burns	Cuts, Abrasions, Bruises
% Injuries	45.1	13.5	6.4	4.7	4	3.3	2.8	2.8	2.6	2.1
# Injuries	439	132	63	46	39	32	27	27	26	21

(n=972)

When examining incidences of sprains, strains, and tears by year, Chart 8 indicates a remarkable 86% drop in this type of injury from 2007 to 2008. It would be helpful to determine if there was a particular event, data reporting anomaly or the existence of a specific injury prevention program that led to such a steep decline. If a successful injury prevention program, its lessons learned may be replicated. More recently, in 2015, this type of employee injury had decreased by 25.8% from the previous year, and stayed below the average of 40 injuries per year.

Chart 8: Sprains, Strains, and Tears at Engineering Operations

Data from January 1, 2005 to December 30, 2015

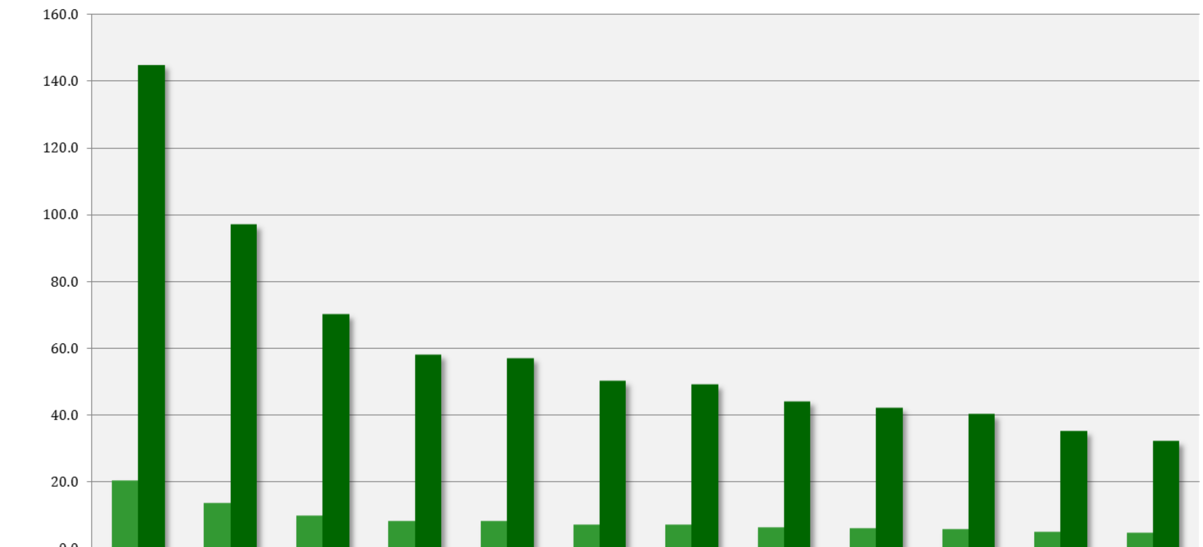


(n=972)

Labourer 2 workers experienced the highest frequency of sprains, strains, and tears in the outdoor worker sample (n=972). Overexertion was a leading factor in 41% of such cases, a health issue facing the 40 year old labourer (n=151). Thirty-six per cent of Labourer 2 sprains, strains, and tears had involved the employee's back region. It is important, therefore, to consider the role of overexertion on middle- aged labourers with a view to preventing or mitigating lower back injuries. This is an important injury metric that can be monitored.

Chart 9: Body Part Injured at Engineering Operations

Data from January 1, 2005 to December 30, 2015



	Lower Back, Unspecified	Finger(s), Fingernail(s)	Knee(s)	Eye(s)	Shoulder, Clavicle, Scapula	Elbow(s)	Ankle(s)	Back, Spine, Spinal Cord	Arm(s)	Thumb, Other Finger(s)	Hand(s), Except Finger(s)	Wrist(s)
% Injuries	20.2	13.5	9.7	8.0	7.9	6.9	6.8	6.0	5.8	5.6	4.8	4.4
# Injuries	145	97	70	58	57	50	49	44	42	40	35	32

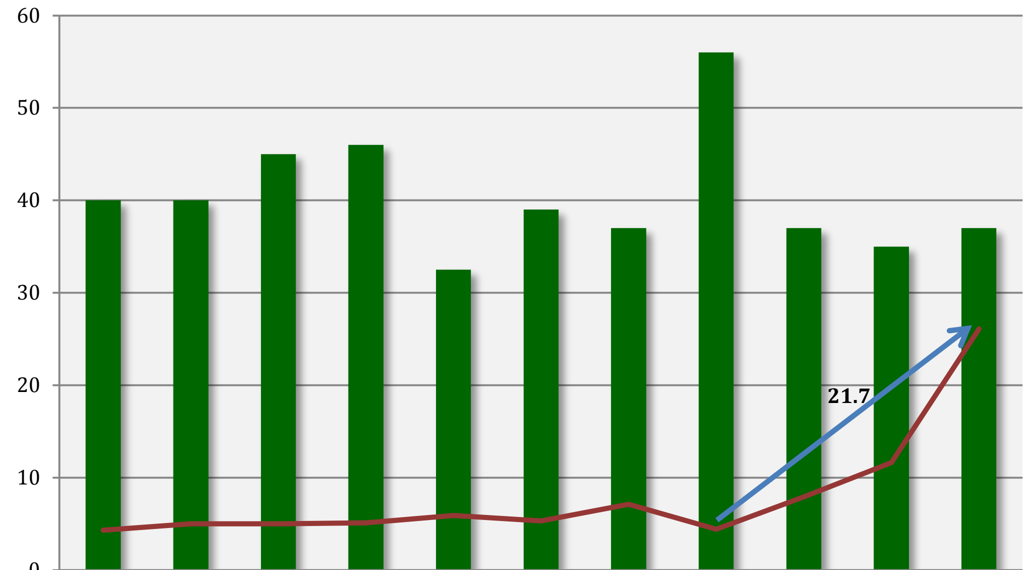
(n=719)

Of the 972 documented cases of outside worker injuries from 2005 to 2015, there were no claims for long-term disability (LTD), a remarkable testament to safe workplace practices existing at Surrey's Engineering Operations. Approximately 58% of worker injury files in this period were created for reporting purposes only (RPO). In such cases, injuries were of a relatively minor nature and did not require medical attention or lost work time. Twenty-six per cent of injuries had resulted in claims of short-term disability (STD), which effectively means time loss from work. The number of days off work due to injury (disability days) was unavailable, therefore, severity rates could not be derived. Fifteen per cent of injuries were defined as health care only (HCO), meaning that an injury did not lead to time loss but required some form of medical attention, usually at a clinic.

When examining the short-term disability category (n=261), a marker of time loss and moderate injury, Labourer 2 workers had comprised nearly one-third of such claims. Over 60% of short-term disability claims made by Labourer 2 workers related to sprains, strains, and tears with overexertion as the driver (43%). Fifty-nine per cent of such injuries had aggravated the employee's lower back region.

Chart 10: Age and Frequency Rate of Labourer 2 Overexertion Type Injuries per 100 Person-Years Worked

Data from January 1, 2005 to December 30, 2015



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Average age	40	40	45	46	32.5	39	37	56	37	35	37
Frequency rate	4.3	5.0	5.0	5.1	5.9	5.3	7.1	4.4	7.9	11.6	26.1

Note: Comparable data for Labourer 1 injuries were too few for meaningful analysis.

(n=71)

Frequency rate is the frequency of injury per unit of exposure, where exposure refers to the total amount of time that workers were exposed to workplace conditions. This unit of exposure is typically measured by person-hours or person-years worked in a project, company, industry or geographical area. Common units for reporting frequency rates are rate per 1,000,000 hours worked and rate per 100 person-years. Rate per 100 person-years was used as the denominator in this study. Between 2005 and 2010, the frequency of overexertion injuries involving Labourer 2 employees remained at or near the 6-year average rate of 5 incidents per 100 person-years worked. However, from 2012 to 2015, Labourer 2 workers experienced a 21.7 increase in the frequency rate of overexertion injuries. Data reveals that injuries had mostly affected labourers between the ages of 35 to 37 years, which is consistent with the literature relating to age and injury. It can be said that overexertion injuries afflict certain occupational groups, mostly outdoor workers, in particular labourers in their mid-to-late thirties. Given their physically demanding roles, labourers are vulnerable to unique health challenges which should be monitored as they age in the workforce with a view to addressing the potential for overexertion in the field.

Labourer 1 workers in their early thirties being considered for promotion into the Labourer 2 pool could be offered tailored programs with a message on how to prevent overexertion type injuries in their new role. Such intervention could involve monitoring and rigorous follow-up by managers and supervisors using pre and posttests to measure the success of injury prevention programs. By undertaking such a pre-emptive strategy, younger labourers can be appropriately educated about the inherent job risks before they age in the workforce.

Time-Series Analysis

It has been asserted that there exists a relationship between employee overexertion, aged workers, and hot temperature in particular for workers undertaking manual work outdoors. Workers become overheated from two primary sources: (1) the environmental conditions in which they work; and (2) the internal heat generated by physical labour. Heat-related illnesses and injuries occur when the body is not able to lose enough heat to balance the heat generated by physical work and external heat sources. Weather conditions are the primary external heat sources for outdoor workers. In order to test this hypothesis, employee injury data were transformed into a time-series format and merged with daily meteorological data. The study did not consider employee health or fitness levels (e.g., Body Mass Index) at time of injury; such personal health information is inaccessible. As well, exact time of injury data is unavailable.

Eleven-year daily historical temperature data for Surrey was obtained from the Meteorological Services of Canada. It contained daily maximum temperature, daily minimum temperature, and daily mean temperature among other variables (daily humidity data was unavailable for all years under study). To minimize the impact of seasonality, the study period was restricted to the warm season for Surrey. Daily maximum temperature or T_{max} was used as a variable in this study. Higher temperature is often associated with mid-morning to afternoon hours, and corresponds to a 9am to 5pm standard work day. Higher temperature is often concentrated within this time period, especially in June, July, and August when temperatures can peak.

While seasonal variations exist and day temperatures fluctuate, daily maximum temperature is a logical choice when considering municipal employee work schedules. Other temperature measures have practical shortcomings. For example, daily mean temperature is a 24-hour average that includes cooler early morning and cooler nighttime temperatures and would skew results as most City employees are typically off-duty during these periods.

Hot temperature is subjective but efforts to quantify acceptable ranges for outdoor workers exist. The United States (US) Department of Labor, Occupational Safety and Health Administration (OSHA) has developed a widely-referenced heat index with accompanying risk levels and recommended protective measures. The OSHA heat index is referred to by WorkSafeBC as a useful tool for employers to use in limiting their workers exposure to heat stress, illness, and injury.

Table 4: Heat Index (US Department of Labor, OSHA)

Temperature Ranges	Risk Level	Protective Measures
Less than 32.7 °C	Lower (Caution)	Basic heat safety and planning
32.7 to 39.4 °C	Moderate	Implement precautions and heighten awareness
39.4 to 46.1 °C	High	Additional precautions to protect workers
Greater than 46.1 °C	Very High to Extreme	Triggers even more aggressive protective measures

Source: Adapted from the United States Department of Labor, Occupational Safety and Health Administration, 2016

The ARIMA statistical procedure was conducted using SPSS v.24 to test the hypothesized relationship between employee overexertion, aged workers, and hot temperature. It found that overexertion injuries did not increase with T_{max}, and age was not a factor. A Bivariate Pearson Correlation statistical procedure was conducted which bears out this finding (see Appendix A).

Daily maximum temperature in Surrey rarely exceeds the lower risk level of 32.7 °C; however, heat waves in the OSHA-defined moderate range of 32.7 to 39.4 °C have occurred. While intense they are, for the most part, short lived. Most people can work safely when the heat index is $\leq$32.7 °C, with only basic measures for worker safety and health. For temperatures in the lower risk level, protective measures include a "water, rest, and shade" protocol with adequate medical services located nearby if required.

Bayesian Analysis

Table 5 displays risk ratios, odds ratios, and confidence intervals for nine occupational groups at Surrey public works experiencing the most strains, sprains, and tears where overexertion is a contributing factor. Organization of the information in a contingency table below facilitates analysis and interpretation. Workers who reported health care only (HCO) or short-term disability (STD) were grouped in a *higher-risk* category given that injuries occurred. The nature and severity of these injuries were unspecified but they required some form of medical intervention. Incidents listed as reporting purposes only (RPO) were placed in a *lower-risk* category since no health care or no work time-loss was required.

Table 5: Risk Estimate Statistics for Nine Occupational Groups: Overexertion and Sprains, Strains, and Tears*

Data from January 1, 2005 to December 30, 2015

Occupational Group	Risk Ratio *Reporting Purposes Only*	Risk Ratio *Health Care Only & Short-Term Disability*	Odds Ratio *For Risk*	95% Confidence Interval	
				Lower	*Upper*
Labourer 2	1.032	.963	.933	.484	1.800
Trades Improver 1	1.185	.875	.736	.340	1.590
Tradesperson 2	.729	1.406	1.929	.387	9.601
Labourer 1	2.824	.635	.225	.021	2.356
Trades Improver 2	.960	1.040	1.083	.273	4.293
Chargehand	1.344	.587	.436	.084	2.269
Equipment Operator 4	1.436	.738	.514	.085	3.109
Foreman	4.714	.257	.055	.004	.663
Tradesperson 3	1.313	.375	.286	.019	4.237
Truck Driver 2*	N/A	-	-	-	-

Note: On at least one case, the value of the Truck Driver 2 weight variable was zero. Such cases are invisible to statistical procedures and graphs which need positively weighted cases. Several employees perform more than one of the jobs in the above specified occupational groups.

(n=426)

Odds ratios are used to determine whether a particular exposure (e.g., overexertion) is a risk factor for a particular outcome (e.g., negative health), and to compare the magnitude of various risk factors for that outcome. An OR=1 means the exposure does not affect odds of outcome, OR$\geq$ 1 means the exposure is associated with higher odds of outcome, and OR$\leq$ 1 means the exposure is associated with lower odds of outcome. Table 5 reveals that Tradesperson 2 (OR = 1.929, 95% CI = .387, 9.601) and Trades Improver 2 (OR = 1.083, 95% CI = .273, 4.293) employees face greater odds of negative health outcomes from overexertion leading to sprains, strains and tears than other workers considered. The odds ratios are above the mean (0.688) and standard deviation (0.573), and are statistically-significant. A 95% confidence interval or CI is used to estimate the precision of the OR. A large CI indicates a low level of precision of the OR, whereas a small CI indicates a higher precision of the OR. When examining the contingency table, tradespersons reveal low CIs (in particular Trades Improver 2), and injury ratios indicate greater confidence levels.

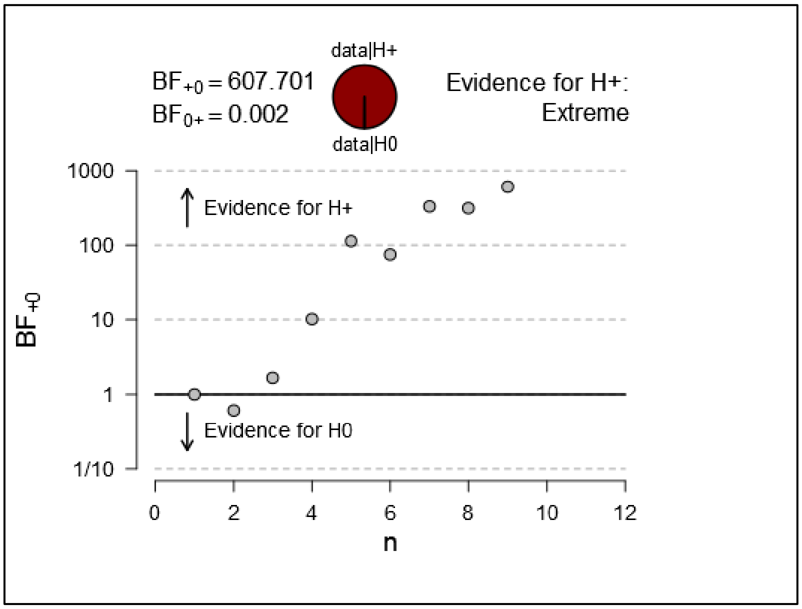
The average age of Tradesperson 2 and Trades Improver 2 workers is 48 and 46 years, respectively, which is higher than the average age of other outdoor workers (43.7 years). Given their advancing age and the role overexertion plays in triggering sprain, strains, it is helpful to design specialized injury prevention programs for these at-risk cohorts. Risk ratios indicate that Tradesperson 2 and Trades Improver 2 employees are not only susceptible to musculoskeletal injuries where overexertion is a factor but are also more likely to require a medical response and/or work time loss when they occur.

Risk ratios for Tradesperson 2 and Trades Improver 2 workers is 1.406 and 1.040 respectively, which is substantially higher than the average (0.764) and standard deviation (0.353) for all other cases. Injury research shows that sprains, strains, and tears can become cumulative if exposure to overexertion continues unabated, and may lead to more serious injuries as these workers age into their jobs and physical endurance and acuity declines over time. It should be stated that Labourer 2 employees are also susceptible to these types of injuries; however, their risk factor statistics demonstrate lower odds of a negative health outcome. It is useful, therefore, to fashion a surveillance response around these cohorts to prevent or mitigate injuries.

In conducting Bayesian Correlation Pairs, the probability of negative health outcomes for Tradesperson 2, Trades Improver 2, and Labourer 2 workers is correlated positively. That is, there is statistical evidence that shows the odds of injury resulting in negative health outcomes are extremely high. Figure 3 displays Bayesian Correlation Pairs which is weighed according to Lee and Wagenmakers' (2014) standard of evidence (see Appendix B). The last three trending points in the graph below are the three above-mentioned occupational groups at greatest risk of injury; all three exceed 100 points in the Bayesian scoring system. These findings are statistically-significant and verify earlier findings relating to the risks facing these cohorts which support the need for a customized injury suppression or mitigation strategy.

FIGURE 3: Bayesian Analysis of Odds Ratios and Relative Risk across Nine Occupational Groups

Data from January 1, 2005 to December 30, 2015



(n=426)

It is important, therefore, to design specialized injury prevention programs for Tradesperson 2 and Trades Improver 2 workers to reduce the associated harms. While these workers from these two occupational groups experience fewer injuries than Labourer 2 workers, they face greater odds of negative health outcomes due to injury. The following conclusion summarizes the key findings of this study.

Conclusion

In conclusion, with respect to the four main research questions, the following can be summarized:

1. There has been a steady decline in the overall frequency of employee injuries at Surrey's Engineering Operations. Since 2011, the number of employee injuries had consistently remained below the 11-year average of 99 injuries.

2. Approximately 80% of all worker injuries take place in the field while servicing municipal infrastructure, facilities, and utilities. One-half of workers injuries occuring at fleet and garage locations involved Tradesperson 2 employees. Outdoor workers encounter more injuries than all other occupational groups combined.

3. Labourer 2 employees are susceptible to sprain, strain, and tear injuries affecting the lower back region. These workers are in their mid-to-late thirties. While the frequency rate per unit of exposure increased since 2012, the negative health outcomes are minimal. Tradespersons 2 and Trades Improver 2 workers face greater odds of suffering a negative health outcome when injured relative to all other occupational groups studied.

4. Contrary to popular belief, overexertion, aged workers, and hot temperature are not positively correlated. While overexertion is a health concern and should be monitored, it is not necessarily caused by warmer temperatures. A sensible water, rest, and shade protocol during warm days is sufficient.

Recommendations

This study proposes the following four recommendations to address workplace injuries:

1. Conduct injury prevention sessions each Monday morning prior to the start of work. Sessions should be tailored to meet the specific needs of at-risk occupational groups, in particular Tradesperson 2, Trades Improver 2, and Labourer 2 employees. This can be enhanced with crew safety talks.

2. Prepare information posters and related material identifying specific risks and the necessary precautions for the most adversely impacted employees. Posters can be developed seasonally and quarterly, and displayed where worker injuries cluster in time and space.

3. Develop a business intelligence application to monitor worker injuries and track the effectiveness of injury prevention programs at Engineering Operations. For daily monitoring purposes, injury metrics can be accessed and evaluated through the use and application of business intelligence tools (e.g., QlikView).

4. Deliver a fitness and injury prevention regime to meet the age-specific needs of employees who may be prone to recurring injuries and/or musculoskeletal disorders. A fitness program consisting of core strength and flexibility will help to reduce the frequency and severity of worker injuries. Such a program can be offered in the gym facility at Engineering Operations.

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Appendix A

PEARSON CORRELATION

The Bivariate Pearson Correlation produces a sample correlation coefficient, *r*, which measures the strength and direction of linear relationships between pairs of continuous variables. By extension, the Pearson Correlation evaluates whether there is statistical evidence for a linear relationship among the same pairs of variables in the population. When Pearson's *r* is close to 1 this means that there is a strong relationship between two variables. This means that changes in one variable are strongly correlated with changes in the second variable. When Pearson's r is close to 0 this means that there is a weak relationship between two variables. This means that changes in one variable are not correlated with changes in the second variable.

FIGURE 2: Pearson Correlation of T_{max} and Age when Injured

		T_{max}	Age when Injured
T_{max}	Pearson Correlation	1	-.122
	Sig. (2-tailed)		.085
	N	199	199
Age when Injured	Pearson Correlation	-.122	1
	Sig. (2-tailed)	.085	
	N	199	199

A Pearson Correlation 2-tailed test indicates there is no evidence to suggest a positive correlation between employee overexertion, aged workers, and hot temperature for workers engaged in manual work outdoors. It was used as a statistical procedure to validate earlier findings with respect to the "hot temperature" hypothesis.

Appendix B

BAYESIAN ANALYSIS

Bayesian analysis is increasingly used in a number of areas ranging from academic research to operational deployment. Surrey Fire Service successfully uses Bayesian algorithms in its Deccan LiveMUM software, a real-time operational module that provides dispatchers with instant move-up recommendations. By listening to the CAD live, LiveMUM identifies gaps in coverage based on geographic area and call demand to instantaneously recommend optimal move-ups for apparatus.

Bayesian inference is a method of statistical inference in which Bayes' theorem is used to update the probability for a hypothesis as more evidence or information becomes available. A probability is a number between 0 and 1 (including both) that represents a degree of belief in a fact or prediction. The value 1 represents certainty that a fact is true, or that a prediction will come true. The value 0 represents certainty that the fact is false. Intermediate values represent degrees of certainty. For example, the value 0.5 means that a predicted outcome is as likely to happen as it is not. A conditional probability is a probability based on a number of factors that make up a condition. The usual notation for conditional probability is p(A I B), which is the probability of A given that B is true. Conjoint probability is the probability that two things are true. Therefore, p($A$and$B$) means the probability that A and B are both true (Downey 2014, 41-47). In Bayesian inference, uncertainty or degree of belief is quantified by probability. Prior beliefs are updated by means of the data to yield posterior beliefs. Bayes' probability through Naïve Bayes or a related procedure in JASP™ is ideal for handling smaller data sizes, and is employed in this study.

Bayesian output generated by JASP™ was interpreted and weighed using Lee and Wagenmakers' (2014) grades of evidence standard. Likelihood ratios (LR) with corresponding strength of evidence are listed below.

Figure 3: Bayesian Grades of Evidence

Bayes Factor	Evidence
1-3	Anecdotal
3-10	Moderate
10-30	Strong
30-100	Very Strong
≥100	Extreme

Source: Lee and Wagenmakers, 2014

Bayesian analysis has considerable potential for use as a tool to assess the validity of research evidence. The key strength of such an application lies in the provision of a statistically coherent method for combining probabilities across a complex framework based on both belief and evidence. The research of John Kruschke (2015) and Allen Downey (2013) were consulted, as well as the works of Michael Lee and Eric-Jan Wagenmakers (2014).

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