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Using workers' compensation claims data to characterize occupational injuries in the biofuels industry

Sai K. Ramaswamy
Wenatchee Valley College

Gretchen A. Mosher
Iowa State University, gamosher@iastate.edu

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Abstract

Biofuels production is a fast growing and emerging industry. Occupational injuries are a serious problem due to their human, financial and social costs, yet little research has been published on injuries in the biofuels industry. Learning from past injuries are essential for preventing future occurrences, but the lack of injury information hinders this effort in the biofuels industry. The present study addresses this knowledge gap by utilizing data from over 900 workers' compensation claims reported from 2008 to 2016 by ethanol and biodiesel facilities in the U.S. to characterize injury costs and severity. The total amount paid for each claim was used as a measure of injury severity, and the effects of age, tenure, type of claim, body part injured, nature and, cause of injury on the cost of work-related injuries were investigated. Contingency tables were used to classify the variable pairs, chi-square test and chi-square residuals were employed to evaluate the relation between the variable pairs and identify the at-risk groups. Results showed age, tenure of employee, type of claim, body part injured, nature of injury and, cause of injury have a significant influence in determining the claim amount. Age group 46–50, tenure group 1–2 years, strain and fractures injuries, slips, falls, or trips and, injuries to lower extremities were some of the at-risk groups identified. The findings from the study will assist biofuel producers to develop precisely targeted safety interventions that are effective in preventing worker injuries and also mitigating the financial and social losses from occupational injuries.

Keywords

Occupational injury, Workers compensation, Injury severity, Contingency table

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ABSTRACT

Biofuels production is a fast growing and emerging industry. Occupational injuries are a serious problem due to their human, financial and social costs, yet little research has been published on injuries in the biofuels industry. Learning from past injuries are essential for preventing future occurrences, but the lack of injury information hinders this effort in the biofuels industry. The present study addresses this knowledge gap by utilizing data from over 900 workers' compensation claims reported from 2008 to 2016 by ethanol and biodiesel facilities in the U.S. to characterize injury costs and severity. The total amount paid for each claim was used as a measure of injury severity, and the effects of age, tenure, type of claim, body part injured, nature and, cause of injury on the cost of work-related injuries were investigated. Contingency tables were used to classify the variable pairs, chi-square test and chi-square residuals were employed to evaluate the relation between the variable pairs and identify the at-risk groups. Results showed age, tenure of employee, type of claim, body part injured, nature of injury and, cause of injury have a significant influence in determining the claim amount. Age group 46-50, tenure group 1-2 years, strain and fractures injuries, slips, falls, or trips and, injuries to lower extremities were some of the at-risk groups identified. The findings from the study will assist biofuel producers to develop precisely targeted safety interventions that are effective in preventing worker injuries and also mitigating the financial and social losses from occupational injuries.

Keywords: *Occupational injury; Workers Compensation; Injury severity; Contingency Table*

1. Introduction

The production of biofuels such as ethanol and biodiesel is a fast-growing business witnessing constant changes and improvements to its production processes (Dias et al., 2012; Gubicza et al., 2016; Moreno & Cozzani, 2015; Priambodo et al., 2015; Scovronick & Wilkinson, 2014). The manufacturing of biofuels involves processing, handling, and storing of grains such as corn, sorghum, wheat, and oilseeds as well as hazardous chemicals such as ammonia and sulfuric acid. The combination of grain handling and chemical hazards present a dangerous work environment (OSHA, 2016a, 2016b). Handling and storing flammable liquids, working with heavy equipment, dealing with combustible dust and confined spaces, grain engulfment, working at heights, slips, falls, and trips are just some of the occupational safety hazards in biofuels production (OSHA, 2016b).

The presence of occupational safety hazards is a precursor for incidents and injuries in the workplace (Bevilacqua et al., 2012; Khanzode et al., 2012; Vredenburgh, 2002). Data gathered from trade journals, Occupational Safety and Health Administration (OSHA) records, Environmental Protection Agency (EPA) reports, academic, and newspaper articles suggest an increase in frequency of safety incidents, which in turn has resulted in higher levels of injuries and fatalities in biofuels producing facilities (Calvo Olivares et al., 2014, 2015; Rivera et al., 2015). Despite the increased risk of worker injuries, very little scientific work has explored health and safety in the biofuels industry (Harper et al., 2008; Rivera et al., 2015; Riviere & Marlair, 2010).

Work-related injuries not only affect the injured worker and their family adversely but also impact the company in the form of increased medical, liability and insurance premium costs (Hajakbari & Minaei-Bidgoli, 2014). In addition to direct costs such as medical and indemnity payments, there are several indirect costs associated with workplace injuries. These indirect costs include equipment damage, equipment repair, incident investigation time, the cost of hiring and training an injured worker’s replacement, loss of reputation, loss of employee morale, loss of confidence and negative media attention (Gavious et al., 2009; Griend, 2011; Manuele, 2013). According to Bird et al. (1996), for every dollar in direct costs, there are $5 to $50 in property damage costs and $1 to $3 in other indirect costs associated with work-related injuries. Furthermore, Manuele (2013) suggested that the ratio of direct to indirect costs used by safety practitioners to estimate total injury costs is 1: 4.

The average direct cost estimate for a work-related injury in the biofuels industry is $7,150 (Griend, 2011). Using the 1:4 ratio, the estimate for indirect costs per injury equals approximately $28,600. Since biofuels production is a highly cost-sensitive business (Festel, 2008; Haarlemmer et al., 2014), such high injury costs represent a threat to the profitability of a biofuels operation. Hence, an improved understanding of injuries and fatalities in the biofuels industry is necessary to prevent work-related injury risks before they occur.

Learning from past safety events is a critical component of improving worker safety and preventing work-related injuries (Kletz, 2008; Pasman, 2009). Examining injuries and identifying associated causes provides valuable information that can help prevent recurrence of similar injuries (Ferjencik & Jalovy, 2010). Analysis of incident and injury data can also help identify at-risk groups (Anderson, 2009; Pirdavani et al., 2010), so targeted injury prevention strategies can be developed, thus improving the return on safety investments (Abdolhamidzadeh et al., 2011; Khanzode et al., 2011; B. K. Kim et al., 2012). In one example, Chettouh et al. (2016) examined incidents in an oil refinery and uncovered evidence that employees lacked safety awareness. One result of the research was suggested improvements to the hiring process and increased investments in safety education and professional competency. Likewise, Marhavilas et al. (2011) analyzed occupational injury data for an electric power provider and found that workers under the age of 45 years had the greatest risk of fractures, bruises and sprains injuries, caused due to slips, falls, and impacts with stationary objects.

Obtaining detailed historical records of safety events for data analysis is a challenge in the process industry (Meel et al., 2007; Pasman, 2009). In the U.S., organizations such as Occupational Safety and Health Administration, U.S Environmental Protection Agency, National Fire Protection Association, and the National Response Center track and collect data on industrial incidents (Keren, 2010). However, these organizations differ in their interests, procedures, and scope of data collection, and it is difficult to use their data for studying past incidents in a specific industry (Morrison et al., 2011; Tauseef et al., 2011). While some investigation has resulted in the development of an incident database for the biofuels industry (Calvo Olivares et al., 2014, 2015), this database does not contain detailed historical records of work-related injuries.

The majority of employers in the U.S, including those in the biofuels industry, purchase workers' compensation insurance to provide medical and indemnity benefits to an employee who suffers a work-related injury (Sengupta, Reno, Burton Jr, & Baldwin, 2012). For an employer, workers' compensation insurance covers direct costs of a work-related injury, including medical expenses and wage replacement incurred by the injured employee (Bird et al., 1996; Griend, 2011; Manuele, 2013). Workers' compensation data contains information that can contribute to injury prevention activities (Utterback et al., 2012). Several researchers have used workers' compensation claims data to study occupational injuries in various industries (Coleman & Kerkering, 2007; Frank Neuhauser et al., 2013; Sears et al., 2013; Smith, Hogg-Johnson, Mustard et al., 2012). To date, little research has explored the application of workers' compensation claims data to characterize occupational injuries in the biofuels industry.

This study examined occupational injuries in biofuel production facilities using workers' compensation claims data provided by a leading Midwest-based insurance company. The purpose of this study was to characterize the direct cost of occupational injury using the information obtained from the workers' compensation claims including variables such as age, tenure of employee, and nature, cause and type of injury. A secondary purpose of the study was to identify and classify at-risk groups within the biofuels production industry.

2. Background

For the last ten years, the biofuels industry in the United States has been one of the fastest growing areas of the agribusinesses sector (Olivares et al., 2014; OSHA, 2016a). Between 2006 and 2012, biofuel production in the U.S. increased more than three-fold, making the U.S. the number one producer of biofuel products in the world (EIA, 2016). The rapid growth in biofuels production has been accompanied by an increasing number of occupational injuries in the industry (Moreno & Cozzani, 2015; Olivares et al., 2014; Rivera et al., 2015).

A typical large-scale commercial biofuels facility utilizes approximately 50 tons of raw biological material daily (Vimmerstedt et al., 2013). Most commercial biofuels facilities store large quantities of grain along with chemical additives necessary for biofuel production including sulfuric acid, sodium hydroxide, methanol, and glycerol within their facility (Hardy et al., 2006; Marchetti et al., 2008; Vlysidis et al., 2011). From an occupational safety perspective, biofuel production combines the hazards of both grain handling and chemical processing facilities, which increases the importance of safety interventions for the industry (OSHA, 2016a).

The production of ethanol and biodiesel involves a substantial amount of routine processes (Nigam & Singh, 2011). The routine nature of the process encourages a tendency to ignore safety aspects (Rivera et al., 2015), despite the known documented hazards of grain handling and chemical facilities (Freeman et al., 1998; Niskanen, 2012; Reniers, 2009; Riedel & Field, 2011; Roberts & Field, 2010). As the biofuels industry continues to evolve with new and improved production technologies, workers in this industry will likely be exposed to unknown and known risks including explosions, fire, electrical, confined spaces, contact with chemicals, and slips, trips and falls (Spellman, 2013).

The existence of occupational safety hazards amplifies the risk of worker injuries (Bevilacqua et al., 2012; Khanzode et al., 2012). Workplace safety incidents are classified as major or simple (Jorgensen, 2011, 2015, 2016). Major safety events result in a high number of injuries and/or fatalities and cause widespread damage to property and the environment (Jorgensen, 2016). Major safety events such as an explosion, fire, or containment of chemicals are rare events involving complex event sequences, and they make up a small percentage of the total number of workplace incidents (Jorgensen, 2015, 2016). Smaller safety events impact the immediate occupational area and result in the injury or fatality to a single employee (Jorgensen, 2016). Smaller safety events such as slips, falls, trips, contusions, and lacerations, occur more frequently and result in a higher rate of worker injuries and fatalities than do major safety incidents (Jorgensen, 2011, 2015, 2016). According to the International Association of Oil and Gas Producers, more than half of all oil and gas incidents are small incidents such as slips, trips and falls (Attwood et al., 2006). These small workplace safety incidents are seldom investigated (Jorgensen, 2011) because they are perceived to be workers’ fault rather than engineering or environment issues (Vredenburgh, 2002).

The lack of a unified source of safety incident data in the biofuels industry has been a major challenge to identifying probable contributing factors of incidents that can help develop appropriate intervention strategies (Calvo Olivares et al., 2014, 2015; Mulloy et al., 2013; Sumner & Layde, 2009). Furthermore, the report of incidents and worker injuries occurring in the biofuels industry are difficult to obtain as they are spread across multiple sources including OSHA investigation summaries, media reports, and trade association publications (Calvo Olivares et al., 2014, 2015; OSHA, 2016a). Obtaining information on simple safety incidents is still a major challenge in the agribusiness industries including biofuels, as there is no single source or entity collecting data on these incidents (Douphrate et al., 2006; Issa et al., 2016; Riedel & Field, 2011).

Workers' compensation insurance claims records can partially address the informational gap about occupational injuries in the biofuels industry, enhancing the ability to develop effective safety intervention (Utterback et al., 2014). Workers' compensation insurance provides an injured worker medical benefits, a portion of the employee's wage, and a lump sum payment when the employee suffers a permanent impairment (Sengupta et al., 2012). Most employers in the U.S. except in Texas are required to provide their employees with workers' compensation insurance. U.S. employers in all industries spend approximately $85 billion each year on workers' compensation insurance costs for their employees (Sengupta et al., 2012; Utterback & Schnorr, 2010). In addition to providing benefits to the injured worker, workers' compensation insurance also protects employers from lawsuits and monetary losses resulting from occupational injuries.

Workers' compensation data contains valuable information commonly used in injury characterization (Utterback et al., 2012). In addition to information on the direct costs of the injury such as medical, indemnity, and disability payments, data on the industry, occupation, nature of injury, cause of injury and demographic information of the injured worker are also captured in workers' compensation claims data (Nestoriak & Pierce, 2009; Utterback et al., 2012). The size and volume of workers' compensation datasets provide a comprehensive understanding of injury patterns, which can then be used to analyze causal factors leading to an injury (Oleinick & Zaidman, 2004).

Previous research has shown that workers' compensation claims data can be used to characterize the risk, scope, and nature of workplace injuries across multiple industries. Frank Neuhauser et al. (2013) utilized workers' compensation data to compare injury incidence by gender and age while controlling for the occupation and type of industry of the injured worker. Sears et al. (2013) used workers' compensation data from the Washington State Department of Labor and Industries to predict occupational disability and medical cost outcomes. Smith, Hogg-Johnson et al. (2012) compared risk factors associated with severe versus less severe occupational injuries using workers' compensation data in industries such as agriculture, mining, and manufacturing. Coleman and Kerkering (2007) studied occupational injuries in coal mines and used workers' compensation data to distinguish between lower and higher risk operations and time periods. Schwatka et al. (2013) studied the relationship between age and injury type on claim amount in the construction industry using workers' compensation claims from 1998 to 2008. Finally, Bookman (2012), Douphrate et al. (2006) studied workplaces injuries in production agriculture with a focus on injury prevention.

Despite the benefits of using workers' compensation claims data to characterize and predict injuries, very little research has effectively utilized the information source to characterize work-related injuries in the biofuels industry. Accordingly, the purpose of this study was to examine workers' compensation claims data to investigate how variables such as employee age, tenure, nature and cause of injury and type of claim influence the claim amount. Understanding these relationships helps in the development of focused mitigation strategies to prevent worker injuries. Also, the findings of this study may be used to model the direct costs associated with occupational injuries so biofuels producers and workers' compensation insurance providers can better understand the risks and losses from occupational injuries.

3. Methods and Data

Nearly all workers in the U.S. are covered by workers' compensation insurance provided by their employer (Utterback et al., 2014). Employers provide this benefit to their employees by either purchasing insurance from an insurance carrier or through self-insurance (Reville et al., 2001a). When an employee is injured on the job, the insurance carrier or the self-insured employer pays the medical and indemnity costs. To provide information and to facilitate the payment, employers must create a report of the worker's injury to inform their insurance provider (Utterback et al., 2012). Data collected during the claims process are provided by employees, employers, insurance companies and other involved parties (Utterback et al., 2014). The collection of information from multiple stakeholders makes claims records an excellent data source for work-related injuries (Dement et al., 2004; Janicak, 2010; Kim et al., 2012; Reville et al., 2001b).

The dataset used in this study were obtained from a private insurance company headquartered in a Midwest state. The company specializes in insurance products for agribusinesses including biofuels facilities. The dataset consisted of 921 claims reported from 2008 to 2016. Of the 921 claims, 145 claims were from biodiesel producing facilities, while the remaining 776 were from ethanol producing facilities. The oldest claim in the dataset had an injury date of January 2nd 2008, and the newest claim injury date was February 24th 2016.

The list of variables obtained from the dataset used in this research is shown in Table 1. All information recorded in the dataset were vetted and verified by insurance company personnel. Using the demographic information provided in the dataset, age of the employee was calculated as the difference between the date of birth and the injury date. Similarly, the tenure of the employee was calculated as the difference between the date of hire and injury date.The claim amount variable used as a proxy for injury severity was categorized as "<$3,000", " $3,000-$9,999", and "10,000+".

Since the variables analyzed in this study were all categorical, the statistical analysis began with the construction of frequency counts, percentages, and contingency tables. To characterize the claim amount using the employee and injury variables, contingency tables were used to classify the variable pairs and chi-square tests were used to validate the relationship. For the posthoc tests to identify the at-risk groups, residual analysis was used to determine the nature of relationship between the row variable and the column variable of the contingency tables (Agresti & Finlay, 2008). The residual is the difference between the observed value of a specific variable pair and its expected value (Agresti & Finlay, 2008). A positive residual implies that the observed value was greater than the expected value, while a negative residual implies the observed value was less than expected value. Descriptive analysis was performed using Microsoft Excel and the inferential analyses were performed with statistical software SAS version 9.4.

Table 1: *List of variables*

#	Column Name	Description
1	Claim	Unique identifier for each claim record
2	Effective Year	Filing year of the claim
3	Account	Unique identifier to differentiate claims for each customer
4	Market	Type of business (biodiesel or ethanol)
5	Gender	Gender of injured worker
6	State	Name of state where injury occurred
7	Date of Birth	Date of birth of injured worker
8	Date of Hire	Date on which the present company hired the injured worker
9	Injury Date	Date on which the injury occurred
10	Claim Description	One-line narration of incident resulting in injury; Example: "Employee was cleaning equipment and employee opened up a line and acid sprayed in his face and mouth."
11	Claim Status	If the claim is still open or closed
12	Type of claim	Indicates if the claim was "medical only", "permanent disability", "death".
13	Body Part	Body part(s) injured
14	Cause of Injury	Main cause of injury. For example: " Dust, gasses or fumes inhalation", "Foreign matter in eyes", "Chemical exposure" etc.
15	Nature of Injury	Describes the type of injury such as Fracture, Strain, Contusion etc.
16	Claim amount	Total amount paid out in medical, indemnity and other miscellaneous payments. Used as a proxy for injury severity in this study.

In SAS, residuals are standardised and calculated as:

$$\textit{S}\text{tandardized residual} = \frac{n_{ij}\text{-}e_{ij}}{\sqrt{e_{ij}\left(1\text{-}p_{i.}\right)\ (\left(1\text{-}p_{.j}\right)}}$$

Where n_{ij} is the observed value, e_{ij} is the expected value for the i^{th} row j^{th} column cell. $p_{i.}$ is row total for i^{th} row and $p_{.j}$ is the column total for the j^{th} column. According to Agresti and Finlay (2008), an adjusted residual of +/- 2 is evidence of dependence between the row and column variables while an adjusted residual of +/- 3 is evidence of strong dependence.

Comparing the adjusted residuals of each cell in a contingency table identified the cells where the degree of dependence between the two variables was the strongest (Sharpe, 2015).

The purpose of this study was to characterize the direct cost of occupational injury using demographic (age and tenure) and injury characteristics (nature, type, and cause of injury, body part injured). The claim amount was used as a proxy for direct injury cost, and the broad research question that guided this study asked if the claim amount in selected biofuels operations was dependent on the employee demographics and injury characteristics. Specifically, the following sub research questions listed below were analyzed:

Is the claim amount independent of:

i. Age of employee
ii. Tenure of employee
iii. Type of claim
iv. Nature and Cause of injury
v. Body part injured

4. Results and Discussion

4.1. Characterizing claim amount based on employee age

The first research question investigated if the claim amount and the age of the injured employee were independent. The claim amount is the sum of all payments made by the workers' compensation insurance provider to the injured employee. This amount includes medical, indemnity, and other miscellaneous payments made to the injured employee as compensation for his or her occupational injury. For this reason, severe injuries, such as those resulting in long-term or permanent disability or death are assumed to have a higher claim amount than less severe injuries requiring less medical treatment (Sears et al., 2014; Sears et al., 2013).

To explore the relationship between employee age and the claim amount, a contingency table with age as the row variable and claim amount as the column variable was tabulated as shown in Table 2. Each cell in the contingency table is a count of claims corresponding to the respective age group and claim amount category. The last row in Table 2 shows the total number of claims in each claim amount category, while the last column indicates the number of claims corresponding to each age group.

The distribution of data indicates that nearly 90% of the claims were less than \$10,000, suggesting most injuries were minor. A chi-square test was conducted to evaluate if the claim amount was independent of the age of the employee. The test results showed a p-value of less than 0.05 providing evidence that the claim amount and the age of the employee were not independent.

This finding suggests that the age of the employee is a significant predictive factor for the claim amount. Specifically, younger employees (those under 30) show a higher than expected rate of lower cost injuries and a lower than expected rate of high cost injuries. Patterns with older employees were not as clear. Employees aged 46 to 50 had a higher than expected rate of claims above \$10,000 and a lower than expected rate of claims below \$3,000. However, the same patterns were not seen in employees older than 50. One hypothesis is that as employees age, they work more carefully and mitigate injuries through more purposeful safety work practices. As employees reach their mid-40s, it is possible that they can still physically perform at the same level as younger employees - until they are injured. The findings suggest that employees aged 46 to 50 have a slower recovery, which increases the cost of their workers' compensation claim as compared to a younger employee.

Table 2: Age of employee and claim amount

	Claim amount			
Age (years)	<$3000	$3000-$9999	$10,000 & above	Total
<25	71 (2.7*)	3 (-1.1)	2 (-2.4*)	76
26-30	94 (2.6*)	4 (-1.3)	5 (-2.1*)	103
31-35	99 (1.8)	4 (-1.5)	9 (-1.0)	112
36-40	89 (-1.2)	11 (1.2)	14 (0.5)	114
41-45	107 (0.1)	11 (0.7)	12 (-0.6)	130
46-50	92 (-3.2**)	12 (1.1)	24 (3.1**)	128
51-55	100 (-0.6)	8 (-0.3)	17 (1.1)	125
56-60	68 (-1.9)	11 (2.0*)	12 (0.7)	91
60+	36 (0.6)	1 (-1.2)	5 (0.2)	42
Total	756	65	100	921

χ^2 35.09; df= 16; p-value= 0.0039 and α = 0.05; N=921
Residuals in brackets; * evidence of relationship; ** evidence of strong relationship

The findings of this study are consistent with previous research that suggested the link between the age of the employee and severity of work-related injuries (Laflamme, 1996; Rogers & Wiatrowski, 2005; Salminen, 2004; Takahashi & Miura, 2016). According to Rogers and Wiatrowski (2005), and Salminen (2004), young workers below the age of 25 years have a higher risk of injuries than older workers, but the injuries they receive take less recovery time. This is different than older workers, who may have fewer injuries, but the injuries they receive are more severe, and therefore, more expensive from a workers' compensation claims perspective. This finding supports the results from previous studies (Laflamme, 1996; Rogers & Wiatrowski, 2005; Salminen, 2004; Takahashi & Miura, 2016) who concluded that older workers are likely to have more severe injuries than younger workers. What is not clear from the data is whether the injuries themselves are more severe, or whether they appear to be more severe because older workers take a longer time to recover. In other words, the same injury that would result in little to no time off work for a younger employee could mean several days of recovery for an older employee. These days off work would increase the claim amount paid, making the injury appear more severe. The work environment of biofuels facilities requires physically-intensive work that may have a higher influence on workers over the age of 45 than those in their 20s.

4.2. Characterizing claim amount based on employee tenure

The second research question investigated if the tenure of the injured employee and the claim amount were independent of each other. The contingency table used to investigate this research question is shown in Table 3. 916 of the 921 available records were analyzed because the remaining records did not contain the tenure information. The distribution of claims indicates that nearly half of all injury-causing safety incidents involved an employee with two or fewer years of work experience. Similarly, nearly three-quarters of all injury-causing safety incidents involved an employee with five or fewer years of experience.

This finding is different from the results of Cheng et al. (2013) who studied employees in the petrochemical production industry. Cheng et al. (2013) analyzed occupational injuries recorded in the Council of Labor Affairs in Taiwan, and found that the majority of workers injured had more than three years of work experience. According to Vinodhkumar and Bhasi

(2009), the length of service of an employee in a company positively influences their skills and attitudes towards safety. Therefore, this difference could be attributed to employees in biofuels production taking less time to learn about occupational hazards as compared to the employees in the petrochemicals industry. Furthermore, the production of biofuels involves a routine process (Nigam & Singh, 2011), therefore employees in this industry are likely to have a shorter learning cycle when compared to employees in other petrochemical industries. It is worth noting that the study of Cheng et al. (2013) analyzed only those safety incidents that resulted in injuries to three or more employees while this study analyzed safety incidents that resulted in injuries to one or more employees.

Table 3: Tenure of employee and claim amount

	Claim amount			
Tenure (years)	<$3,000	$3000-$9999	$10,000+	Total
<1	104 (0.0)	11 (0.7)	12 (-0.6)	127
1-2	267 (2.8*)	14 (-2.1*)	26 (-1.7)	307
3-5	185 (-0.1)	16 (0.0)	25 (0.1)	226
6-10	116 (-1.8)	17 (2.2*)	18 (0.4)	151
11-20	51 (0.1)	3 (-0.7)	8 (0.5)	62
20+	28 (-2.9*)	4 (0.6)	11 (3.2**)	43
Total	751	65	100	916

$\chi^2 = 21.34$; df= 10; p-value= 0.0189 and $\alpha = 0.05$; N=916
Residuals in brackets; * evidence of dependence; ** evidence of strong dependence

The chi-square test of independence between the tenure of the injured employee and the claim amount resulted in a p-value of less than the 0.05 significance level. This result implies, the tenure of the injured employee is also a significant predictive factor for the claim amount.

Residual analysis showed that employees who have the least and greatest tenure in the organization have higher than expected injury rates. Employees in the 1-2 years and 20 years and above tenure category show evidence of a significant relationship with the claim amount. This result implies that both newer employees and highly experienced employees in the biofuel facilities investigated in this study are the most at-risk groups for occupational injury. This finding aligns with the findings of Khanzode et al. (2012). According to Khanzode et al. (2012), the risk of injury is high during the initial years on the job, decreases when an employee acquires sufficient work experience, and then increases again for the highly experienced employee

Previous studies in the petrochemical industries (Cheng et al., 2013; Nouri et al., 2008) as well as non-petrochemical industries have also suggested a relationship between employee tenure and injury severity, but the specifics of the relationship differs. Construction industry research (Lopez Arquillos et al., 2012; Suarez-Cebador et al., 2014) have suggested a relationship between tenure and injury severity, where workers with three years or less have a higher rate of occupational injuries. Other researchers (Nouri et al., 2008) suggest that more experienced employees tend to have higher number incidents.

Residual analysis indicates several other important relationships. Newer workers have a higher than expected rate of low severity injuries (those with claim amounts less than $3,000), but a lower than expected rate of more severe injuries (those with claim amounts greater than $3,000). More tenured employees show an opposite pattern. Employees with more than 20 years on the job have a lower than expected rate of non-severe injuries, but a higher than expected rate of more severe injuries. The finding is not new, as Vinodkumar and Bhasi (2009) have also concluded that workers with a longer tenure have a higher likelihood of more severe injuries.

The reason for this may follow the same line of reasoning as the relationship between employee age and amount of claim. The injury rates for newer and more experienced employees are similar but the key difference is the severity. The same non-severe injury to a newer (likely younger) employee could turn into a much higher severity injury to a more experience (and likely older) employee. This is especially true in the biofuels industry, where common hazards include items such strains, slips, trips, and falls, and fractures may have a greater impact on more experienced workers. The days needed to recover off the job add to the amount of claim paid out, making the injury appears more severe in the workers' compensation claims data.

4.3. Characterizing claim amount based on the type of claim

The third research question investigated the relationship between the claim amount and the type of claim. The variable type of claim, had three categories, "medical only", "temporary disability", and "death or permanent disability". "Medical-only" relates to occupational safety incidents where the employee's injury required medical treatment only and did not result in any temporary or permanent incapacitation. This implies the claims in the medical-only category had a low injury severity and required minimal medical attention. The next claim category – temporary disability – is defined as injuries where employees are not able to work fully or to their expected capacity for a specific amount of time. In these cases, injured employees are paid two-thirds of their monthly salary in addition to the medical payments (Manning, 2012). The final claim category – death or permanent disability – has the highest injury severity. A claim is classified in the death or permanent disability category when the injured employee is expected to have either long-term physical challenges or permanent loss of functionality with some part of the body (Corso et al., 2006). The contingency table used to classify the claim amount using the type of claim is shown in Table 4.

Table 4: Type of claim and claim amount

	Claim amount			
Type of claim	<$3,000	$3,000-$9,999	$10,000+	Total
Medical only	747 (23.6**)	38 (-6.8**)	10 (-23.5**)	795
Temporary disability	3 (-8.5**)	11 (8.0**)	8 (3.9**)	22
Death or Permanent disability	6 (-21.5**)	16 (3.5**)	82 (23.7**)	103
Total	756	65	100	921

$\chi^2 = 696.97$; df = 4; p-value= <0.001 and $\alpha = 0.05$; N=921
Residuals in brackets; * evidence of dependence; ** evidence of strong dependence

The distribution of claims based on the type of claim showed that 86% of the claims were medical only, 2% of the claims involved temporary disability, and 11% of the claims involved the death or disability of an employee. Out of the 103 claims in the death and permanent disability category, only one claim involved the death of the employee. This suggests that most injuries in the biofuels facilities investigated in this research were minor injuries requiring only medical attention and no lost workdays. The chi-square test to investigate the relationship between the type of claim and claim amount had a p-value of less than 0.05 significance level, indicating that type of claim is a significant predictive factor for claim amount. The test results for this research question shows a large chi-square statistics value; this implies a strong relationship between the type of claim and the claim amount.

This evidence of a strong relationship between the two variables explains why both claim amount and type of claim can be used as a proxy for injury severity as suggested by previous research (Beery et al., 2014). Medical-only claims are the least severe and have the lowest claim amount when compared with the other two types of claim: death or permanent disability and temporary disability. The residuals from the chi-square test shown in brackets in Table 4 further corroborate the findings of Beery et al.(2014), finding strong significant relationships between type of injury and claim amount. The high value of the residuals is particularly noteworthy. In each cell of Table 4, the value of residual is greater than 3, providing solid evidence of a strong statistical relationship between the type of injury and claim amount.

Much of the attention to safety management in biofuels facilities is focused on large hazards, yet it is the lower claim amounts that make up the bulk of the pay out for this insurance provider. Although claims involving permanent disability and death are high profile and generate a lot of attention, targeting hazards to mitigate less severe injuries would seem to make good financial sense to the insurance provider. Targeting the hazards that result in minor injuries has the potential to help biofuel facilities lower workers' compensation costs and keep their employees working more safely, both positive outcomes.

4.4. Characterizing claim amount based on the nature and cause of injury

The fourth research question investigated if the claim amount was independent of the nature and cause of injury. The contingency tables used to classify the claim amount by nature of injury are shown in Table 5.

The distribution of claims in Table 5 revealed that strain and sprain injuries were the most common type of injuries followed by "others" and lacerations. Fractures and foreign body were the least common types of injuries. Nearly 37% of claims were for strain and sprain injuries while only 4% of the claims were for fractures or foreign body. The Chi-square test suggested that the claim amount was not independent of the nature of the injury. This finding means the nature of the injury is a significant predictive factor for the claim amount.

Table 5: Nature of injury and claim amount

	Claim amount			
Nature of injury	<$3,000	$3,000-$9,999	$10,000+	Total
Strain & sprain	262 (-2.9*)	28 (1.1)	49 (2.7*)	339
Others	110 (-1.0)	11 (0.4)	18 (0.9)	139
Laceration	115 (3.1*)	6 (-1.1)	4 (1.5)	125
Burn	101 (1.3)	6 (1.7)	12 (-3.0**)	119
Contusion	105 (1.9)	7 (-1.0)	7 (-1.7)	119
Foreign body	39 (2.6*)	1 (-1.2)	0 (-2.3*)	40
Fracture	24 (-3.7**)	6 (2.0)	10 (2.9*)	40
Total	756	65	100	921

χ^2 = 40.04; df = 12; p-value= <0.001 and α = 0.05; N=921
Residuals in brackets; * evidence of dependence; ** evidence of strong dependence

Residual analysis gives a more complete picture injury severity. Injuries such as strain and sprain, laceration, foreign body, and fracture show a significant relationship with claims of less than $3,000. Residual patterns indicate that, in the case of strain and sprain and fractures injuries, the number of claims in the $3,000 or below category was less than the expected value, but the number of claims in the $10,000 and above category was more than the expected value. This finding suggests that strain and sprain and fracture injuries are likely to be more expensive when compared to all other types of injuries. The opposite pattern is noted for lacerations and foreign body injuries. These injuries tend to have lower costs than all other types of injuries and are likely to be less expensive.

A review of the literature indicates that strain and sprain injuries are the most common type of injury across many industries (Nur et al., 2014; Schwatka et al., 2013; van Tulder et al., 2007). In the U.S., strain injuries alone cost $6.5 billion in workers' compensation costs with the average claim ranging from $5000 to $8000 (Baldwin & Butler, 2006; van Tulder et al., 2007). However, studies by Attwood et al. (2006) and Cheng et al. (2013) investigating occupational injuries in the oil and gas and petrochemical industries did not list strain injuries in their list of injury types.

The fact that strain and sprain injuries were the most common type of injuries in biofuel facilities suggests that there may be work tasks unique to the biofuels industry that may be contributing to higher levels of strain injuries when compared to other process-based industries like petrochemical. Fracture, burn, foreign body, laceration and contusion injuries have all been listed as the primary types of injuries in petrochemical industries by prior studies, yet these types of injuries do not seem as prevalent in biofuels production (Bertolini et al., 2009; Owens & Hazeldean, 1995; Wu, 2004).

Consistent with the nature of injury, the classification of claim amount based on the cause of injury, as shown in Table 6 indicated that "strain or injured by" is the most common cause of injury followed by slips, trips, and falls. Nearly 47% of claims involved a strain injury or a slip, trip, or fall injury. The chi-square test showed the claim amount was not independent of the cause of the injury, indicating the cause of injury is also significant predictive factor for claim amount.

Table 6: Cause of injury and claim amount

	Claim amount			
Cause of injury	<$3,000	$3,000-$9,999	$10,000+	Total
Strain or injured by	197 (-1.9)	19 (0.4)	36 (2.1*)	252
Slip, fall or trip	131 (-3.6**)	15 (0.7)	34 (3.9**)	180
Others	130 (2.8*)	7 (-1.1)	7 (-2.5)	144
Heat or cold Exposures	115 (1.6)	5 (-1.6)	12 (-0.7)	132
Struck or injured by	89 (0.8)	11 (1.4)	5 (-2.1*)	105
Cut, puncture, scrape	77 (2.1*)	4 (-0.9)	4 (-1.9)	85
Caught in, or under, or between	17 (-1.0)	4 (1.9)	2 (-0.3)	23
Total	756	65	100	921

$\chi^2 = 39.6$; df = 12; p-value= <0.001 and $\alpha = 0.05$; N=921
Residuals in brackets; * evidence of dependence; ** evidence of strong dependence

Residual analysis from the chi-square test indicate slips, trips, and falls have the strongest relationship with claim amount. Residual patterns suggest that for categories strain or injured by and slips, trips, and falls, the number of claims in the $10,000 and above category was greater than the expected value while the number of claims in the $3,000 or below category was less than the expected value. This finding suggests that injuries due to slips, trips, and falls or injuries involving a strain or injured by are likely to be more expensive than the other injuries. For the remaining categories including others, struck or injured by and cut puncture scrape, the residual values indicate a lower claim amount. Based on these analyses, targeting slips, trips, and falls and strain related injuries through safety interventions could potentially reduce the claim amount significantly. Lowering the claims paid out on lower cost and less severe injuries has the potential to lower the amount spent on insurance services, granting more capital for other business activites. Lowering claim amounts on low severity injuries represents a clear opportunity to increase revenue in the low-margin and competitive biofuels business environment.

4.5. Characterizing claim amount based on injured body part

The final research question investigated if the claim amount was independent of the injured body part. A contingency table constructed to address this research question is shown in Table 7.

Table 7: Body part injured and claim amount

	Claim amount			
Body part	<$3,000	$3,000-$9,999	$10,000+	Total
Upper extremities	273 (1.0)	19 (-1.1)	34 (-0.3)	326
Trunk	183 (0.1)	21 (1.6)	18 (-1.5)	222
Lower extremities	127 (-3.3**)	14 (0.6)	32 (3.6**)	173
Head & neck	149 (3.6**)	8 (-1.2)	5 (-3.5**)	162
Multiple	24 (-3.1**)	3 (0.2)	11 (3.7**)	38
Total	756	65	100	921

$\chi^2 = 40.5$; df = 8; p-value= <0.001 and $\alpha = 0.05$; N=921
Residuals in brackets; * evidence of dependence; ** evidence of strong dependence

The distribution of data suggests that upper extremities were the most frequently injured body part, followed by the trunk and lower extremities such as toes and feet. Although these represented the highest two categories of injuries, neither category showed a significant relationship with claim amount. In both cases, the distributions fell within expectations. This finding is consistent with the results from Marhavilas et al. (2011), who also reported that the most injured body parts were upper extremities and the head and neck of the employee . The chi-square test results indicated the claim amount was not independent of the body part injured. This finding suggests the body part injured is a significant predictive factor for claim amount.

Examining the residuals indicates that lower extremities, head and neck, and multiple body part injuries show evidence of strongest relationship with the claim amount. For both lower extremities and multiple body part injuries, the number of claims in the below $3,000 category was less than the expected value while the number of claims in the greater than $10,000 category was more than the expected value. This finding suggests injuries to lower extremities and multiple body parts are more expensive as compared to the rest of the categories. However, for the head and neck injuries, the opposite pattern is noted, with head and neck injuries more likely to have lower severity and lower cost.

Further investigation of the claim records provided additional information on the cause of the body part injury. Lower extremity injuries tended to result from slips, trips, and falls. Heat or cold exposures were found to correspond to multiple and head and neck injuries. Grain dust and hot and cold liquid entering the eye were other factors influencing head and neck and multiple body part injuries. These findings suggest that implementing safety interventions to prevent slips, trips, and falls and providing improved personal protective equipment to prevent hot and cold exposure to employees' eyes and face has potential to significantly reduce the claim amounts in these areas.

Although tasks such as housekeeping, buying and maintaining personal protective equipment, and shoveling snow and ice are not fun to complete, they provide a significant mitigation potential for lower extremity, head and neck, and multiple body part injuries resulting from slips, trips, and falls. Taking a careful account of safety hazards in the biofuel facility and mitigating the hazard to prevent injury saves the organization both monetarily and through the time and energy it takes to hire and train replacements for injured employees.

5. Conclusion

Occupational injuries in the biofuels industry have received little attention in the research literature. The lack of a centralized source of data to investigate these incidents continues to be a challenge. This study used workers' compensation claims data to investigate and characterize workplace injuries in the biofuels industry. The objective of this study was to characterize the relationship of the claim amount with employee age and tenure, nature and cause of injury, type of claim and the body part injured.

These data are collected as part of the workers' compensation claim process. This study found that the employee age, tenure, type of claim, injured body part, nature and cause of injury have a significant influence on the claim amount. Since the claim amount is a proxy for injury severity this study shows that employee age, tenure, type of claim, injured body part, nature and cause of injury have a significant influence on the severity of occupational injuries.

Of all the variables analyzed, the type of claim was found to have the most significant influence on the claim amount as compared to all other variables. Furthermore, employees who are in their mid to late 40s or who have less than 2 years tenure on the job have been identified as the most at-risk groups. Strain and sprain, laceration, foreign body, and fractures have a significant influence on the claim amount, while strain or injured by, slips, fall, or trips were found to be the most significant causes. Injuries due to slips, trips and falls or strain related injuries tend to be more expensive than injuries due to other causes. Finally, injuries to lower extremities, head and neck, and injuries to multiple body parts have an influence on claim amount and injuries to lower extremities and multiple body parts likely to be more expensive than injurie to other body parts.

While workers' compensation data are extremely useful in injury characterization studies, the recording of information during the workers' compensation claims process may be influenced by human error in the collection and recording of data. Also, the scope of analysis is narrowed by the information available in the dataset. However, analysis of a large number of claims, recorded over an extended period of time, characterizes the strength and rigorousness of this study.

The findings of this study will enhance the understanding of the risks of injury in biofuel facilities, as it highlights areas where safety efforts can be focused. Future work should investigate the role employee age and tenure in the severity of the injury using injury data rather than claim amount. Other research should involve analyzing the relationships between the non-cost related variables and also investigating interaction effects between variables. A multivariate model of the claim amount can be constructed so biofuels facility managers, as well as worker's compensation insurance providers, can better analyze the risks from occupational accidents in the biofuel industry, with a dual goal of enhancing worker safety and lowering costs linked to employee injuries.

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