Trends in Work-related Injury Frequency Rate in Canada*

Maritime operations have experienced a notable decline, contributing to an overall downward trend

Missy Zhang

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This paper aims to examine whether and how work-related injury rate has declined in Canada from 2008 to 2020. Using Statistics Canada data, it was found that there was an overall downward trend in the frequency of injuries over time, with the decline most pronounced in maritime operations. Particularly, it is closely related to the proportion of outdoor workers in the industry. In addition, this paper shares insights into injury prevention strategies for Canadian workplaces, and highlights the industries and worker populations that may be most vulnerable to workplace injuries.

1 Introduction

In recent years, work-related injuries have emerged as a critical issue in Canada, affecting workers across various industries. These injuries can have devastating physical and psychological impacts on workers and can also result in a significant economic burden on society. Despite a decrease in the number of injuries in recent years, there were still 37,024 work-related injuries reported in 2020 alone (Canada Employment and Social Development 2022). To address this issue and improve workplace safety, it is crucial to understand injury trends over time and across different sectors. This report aims to analyze work-related injury data and explore factors that contribute to work-related injuries. By identifying areas that require improvement and highlighting successful initiatives, this report aims to contribute to the ongoing efforts to create safer workplaces and reduce the incidence of work-related injuries.

This report utilizes data of injury statistics in Canada by industry sector from 2008 to 2020 obtained from the Open Government Data of Statistics Canada (Statistics Canada 2023) and

*Code and data are available at: https://github.com/MissyZhang/occupational_injury.

used programming language `R` (R Core Team 2020) to build models and analyze trends. The estimand of this report is work-related injury frequency rate, which is measured by injuries (disabling, fatal and minor) per one million hours worked. This paper delves into the overall trend of injury frequency rate in Canada by industry using multiple linear regression model. It was found that there was an overall downward trend in the frequency of injuries over time, with the decline most pronounced in maritime operations. Particularly, it is closely related to the proportion of outdoor workers in the industry.

The remainder of the paper is split into four sections. Section 2 explores the cleaned dataset and identifies key variables. Visualizations are presented to show correlations. Section 3 observes injury frequency rate has decreased over time before constructing the regression model. Section 4 presents model findings on injury frequency rate evolution. Section 5 discusses implications, solutions, and study limitations.

2 Data

2.1 Data source and methodology

The dataset provides a summary of occupational injury statistics and rates in the Canadian Federal Jurisdiction between 2008 and 2020, and it was sourced from the Open Government Portal of Statistics Canada. The data was collected from the Employer's Annual Hazardous Occurrence Report (EAHOR), which is submitted by federally regulated employers to the Labour Program. Under the Canada Labour Code, federal jurisdiction encompasses work and/or undertakings that fall under the legislative authority of the Parliament of Canada, including work deemed to be for the common good of at least two provinces and outside the exclusive authority of provincial legislatures Employment and Canada (2020). Industries under Federal Jurisdiction include interprovincial and international transportation, telecommunications and broadcasting, banks, postal services, feed, flour, seed and grain, miscellaneous industries, and first nation band councils and indigenous self-governments Employment and Canada (2021). One limitation of the survey methodology is that the it only captures incidents in industries under federal jurisdiction, which excludes provincially regulated workplaces and industries not classified as falling under federal jurisdiction. As a result, the dataset may not be representative of the entire Canadian workforce and could lead to an underestimation of the true incidence and severity of occupational injuries in Canada.

The original dataset contains 317 observations and 16 variables with all kinds of information about injury statistics and rates. This report wants to focus on exploring the trend of injury rate and investigating the possible factors that may affect injury rate. Thus, I will be interested in the variables "Year", "Industry", and "Injury frequency rate". `R` (R Core Team 2020), and R packages `tidyverse` (Wickham et al. 2019), `dplyr`(Wickham et al. 2021), and `kableExtra` (Zhu 2021) are utilized to create an extract of the cleaned dataset (Table 1).

Table 1: Extracting the first ten rows from the Injury data

Industry	Year	Injury Frequency Rate
Air Transportation	2020	39.7
Air Transportation	2019	36.5
Air Transportation	2018	39.8
Air Transportation	2017	45.4
Air Transportation	2016	65.3
Air Transportation	2015	54.0
Air Transportation	2014	55.1
Air Transportation	2013	49.2
Air Transportation	2012	72.2
Air Transportation	2011	80.2

Table 1 shows the first ten rows of the cleaned dataset. It contains 231 observations and 3 variables in total. The injury frequency rate is measured by all occupational injuries (disabling, fatal and minor) per one million hours worked in a given industry and year.

2.2 Data Visualization

In order to get further familiarized with the dataset and estimate the possible associations between the nation's injury rate and other factors, exploratory analysis is carried out by conducting data visualizations to observe whether the patterns between certain factors matches the generally expectations of the trend of injury rate in Canada. First, we will have a look through the overall trend of injury rate in Canada.

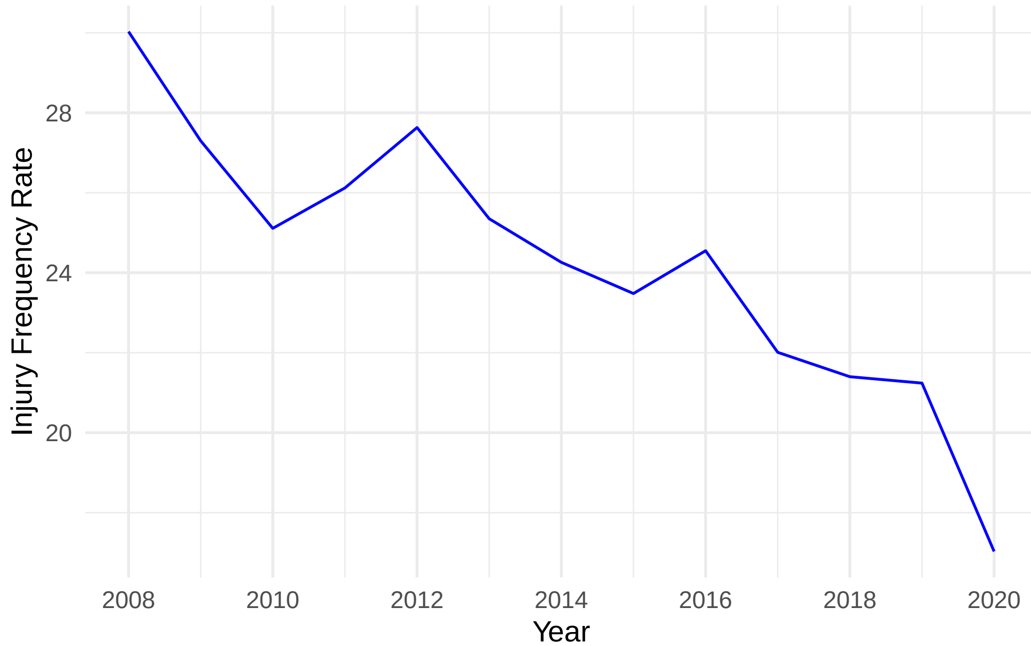

Figure 1: Work-related injury frequency rate by year in Canada from 2008 to 2020

As Figure 1 has demonstrated, Canada's overall injury frequency rate has fluctuated downward since 2008, indicating an improvement in the safety performance of federally regulated workplaces. However, there were two notable periods of increase in the injury frequency rate in 2010-2012 and 2015-2016. Despite these increases, the average injury frequency rate in Canada decreased from 30 in 2008 to 17 in 2020, indicating an overall positive trend in occupational safety.

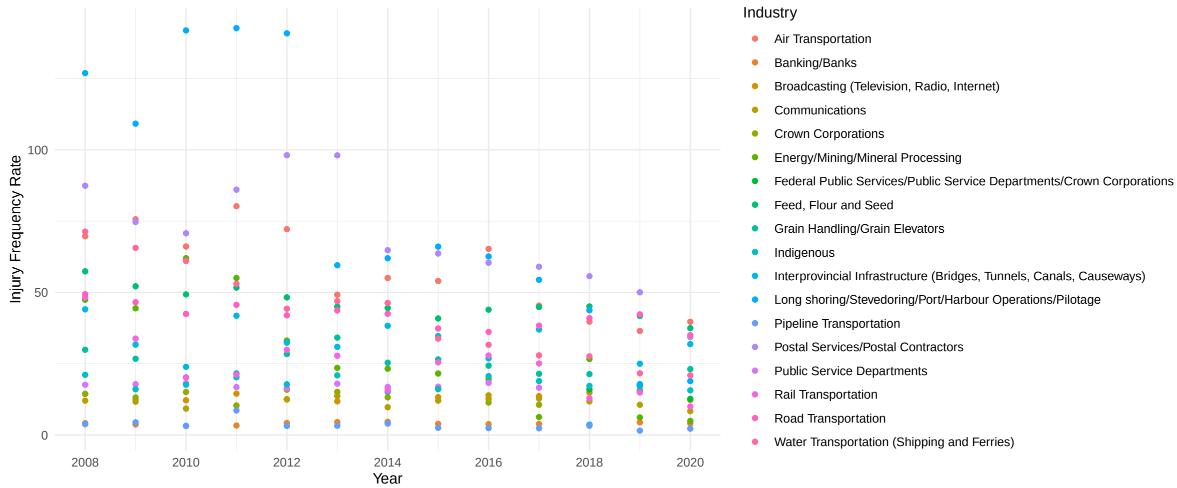

Figure 2: Work-related injury frequency rate by year and industry in Canada from 2008 to 2020

Figure 2 provides a breakdown of the data by different industries, revealing varying degrees of improvement in injury frequency rates over time. Notably, the Long shoring/Stevedoring/Port/Harbour Operations/Pilotage industry has shown the greatest decrease in injury frequency rate among all industries, as indicated by the blue dots on the figure. In contrast, Banking/Banks displays the smallest decrease in injury frequency rate, with a flatter slope in the figure. The differences in injury frequency rates among these industries can likely be attributed to variations in their work environments and tasks. For example, industries such as Long shoring/Stevedoring/Port/Harbour Operations/Pilotage may have implemented more rigorous safety protocols and procedures due to the inherently high-risk nature of their work, while Banking/Banks may not face the same physical hazards and thus may not have undergone the same level of safety improvements.

3 Model

By the exploratory analysis of the data, it was found that year and industry have some correlation with the injury frequency rate in Canada. The relationship seems to be linear as the figures generally demonstrate decreasing trends. Therefore, to further proceed the analysis and predict the future situation regarding injury rate, a multiple linear regression model will be constructed.

Prior to constructing the model, the dataset is split into the training set and the testing set with a proportion of 8:2. The training set is used to build the multiple linear regression models, and the testing set is used to test the accuracy and unbiasedness of the model. R package `tidymodels` (Kuhn and Wickham 2020b) is used to split the dataset.

Two models are initially constructed based on the different possible factors that might have an effect on injury frequency rate in Canada. The first model has continuous variable year, categorical variable industry as its predictor variables, and the injury frequency rate as its response variable. I would also like to check whether the variables year and industry are implicitly related. Therefore, the second model has continuous variable year, categorical variable industry, and the interaction between them as its predictor variables, and the injury frequency rate as its response variable. To compare these two models to find out which is more accurate and is better at prediction, AIC and BIC tests are carried out, and R^2 is examined. Furthermore, the testing dataset is used to test how the two models perform when extra data is involved. RMSE is measured by the testing data to compare the prediction power of the two models. In Appendix Section A, these tests are performed and the test statistics of the two models are compared to select the model with better performance.

As a result, model 2 has a better performance than model 1, and is selected as the final model to model the behavior of Income inequality in Canada as time passed. The assumption check for the model is done in Appendix Section B.

The final model is displayed below:

$$Y_{ij} = \beta_0 + \beta_1 Year_i + \beta_2 Industry_j + \beta_3 Year_i Industry_j \tag{1}$$

In Model Equation 1:

- Y_{ij} is the injury frequency rate in i^{th} year and industry j.
- β_0 is the coefficient for intercept.
- β_1 is the coefficient for the continuous year variable.
- β_2 is the coefficient corresponding to industry j.
- β_3 is the coefficient for the interaction term between i^{th} year and industry j.
- The baseline of this model is year 0 and Air Transportation industry.

4 Results

Model Equation 1 is eventually selected that better demonstrates the correlation between year, industry, and the injury frequency rate in Canada. Figure 3 presents a visualization of this multiple linear regression model, where each line represents the trend of injury frequency rate over time for a specific industry. The figure shows that injury frequency rate generally decreases as the year increases, indicating an improvement in workplace safety over time. Additionally, we can see that different industries have varying injury frequency rates, suggesting that industry type is also a significant factor in workplace safety.

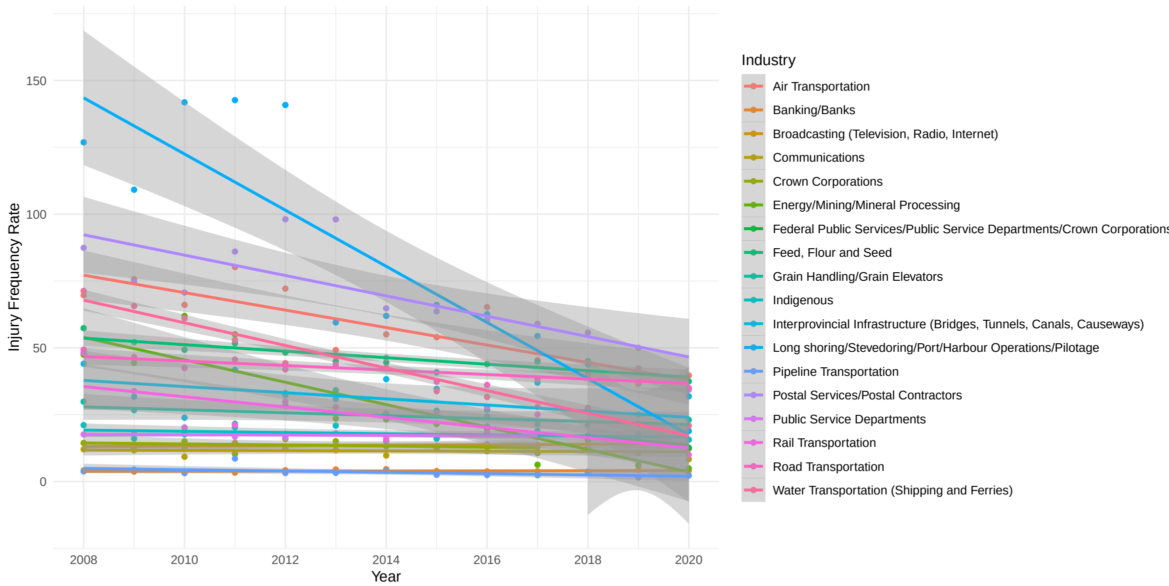

Figure 3: Work-related injury frequency rate by year and industry in Canada from 2008 to 2020

Table 2 displays the coefficients of the predictor variables in Model Equation 1. The model uses year 0 and the Air Transportation industry as the reference point and includes an interaction term between year and Air Transportation. The model sets a strict minimum value of 2008 for the "Year" variable. To estimate the injury frequency rate in industries other than Air Transportation, we need to consider the coefficients β_2 and β_3 which indicate the industry and the interaction between year and the specified industry, respectively. The coefficient values for these variables can be found in Table 2 under the "Coefficients" column.

Table 2: Model Coefficients and 95 percent Confidence Interval

	Coefficients	Confidence Interval Lower Bound	Confidence Interval Upper Bound
Intercept	6858.4	4365.0	9351.8
Banking/Banks	-6899.6	-10592.4	-3206.7
Broadcasting (Television, Radio, Internet)	-6868.3	-10464.3	-3272.2
Communications	-6545.3	-10288.0	-2802.6
Crown Corporations	-6444.2	-10560.6	-2327.7
Energy/Mining/Mineral Processing	1498.1	-1956.8	4953.0
Federal Public Services/Public Service Departments/Crown Corporations	-3481.4	-24732.5	17769.7
Feed, Flour and Seed	-4299.8	-7708.2	-891.3
Grain Handling/Grain Elevators	-5831.6	-9165.8	-2497.4
Indigenous	-6384.7	-9793.8	-2975.6
Interprovincial Infrastructure (Bridges, Tunnels, Canals, Causeways)	-6479.7	-10127.4	-2831.9
Long shoring/Stevedoring/Port/Harbour Operations/Pilotage	12705.9	9084.2	16327.5
Pipeline Transportation	-6303.4	-9723.9	-2882.9
Postal Services/Postal Contractors	-512.9	-4054.7	3028.9
Public Service Departments	-6583.9	-12730.4	-437.4
Rail Transportation	-3174.3	-6579.9	231.3
Road Transportation	-4923.1	-8358.9	-1487.3
Water Transportation (Shipping and Ferries)	1559.5	-2044.5	5163.6
Year	-3.4	-4.6	-2.1
Year: Banking/Banks	3.4	1.6	5.2
Year: Broadcasting (Television, Radio, Internet)	3.4	1.6	5.2
Year: Communications	3.2	1.4	5.1
Year: Crown Corporations	3.2	1.1	5.2
Year: Energy/Mining/Mineral Processing	-0.8	-2.5	1.0
Year: Federal Public Services/Public Service Departments/Crown Corporations	1.7	-8.8	12.2
Year: Feed, Flour and Seed	2.1	0.4	3.8
Year: Grain Handling/Grain Elevators	2.9	1.2	4.5
Year: Indigenous	3.1	1.5	4.8
Year: Interprovincial Infrastructure (Bridges, Tunnels, Canals, Causeways)	3.2	1.4	5.0
Year: Long shoring/Stevedoring/Port/Harbour Operations/Pilotage	-6.3	-8.1	-4.5
Year: Pipeline Transportation	3.1	1.4	4.8
Year: Postal Services/Postal Contractors	0.3	-1.5	2.0
Year: Public Service Departments	3.2	0.2	6.3
Year: Rail Transportation	1.6	-0.1	3.3
Year: Road Transportation	2.4	0.7	4.1
Year: Water Transportation (Shipping and Ferries)	-0.8	-2.6	1.0

As Table 2 shows, with the exception of Banking/Banks and Broadcasting (Television, Radio, Internet), all other industries experienced a decrease in injury frequency rates. The industry with the largest decline in injury frequency rates is Long shoring/Stevedoring/Port/Harbour Operations/Pilotage, with a reduction of 9.7 for every one unit increase in the "year" variable. After Long shoring/Stevedoring/Port/Harbour Operations/Pilotage, the industries with the second fastest decline in injury frequency rates are Water Transportation (Shipping and Ferries) and Energy/Mining/Mineral Processing. For every one unit increase in the "year" variable, their estimated injury frequency rates decreased by 4.2. On the other hand, Banking/Banks and Broadcasting (Television, Radio, Internet) have demonstrated the lowest decline in injury frequency rates over time. Specifically, as the "Year" variable increases by 1, the estimated injury frequency rates remain relatively stable in these sectors. While Long shoring/Stevedoring/Port/Harbour Operations/Pilotage had the highest estimated injury frequency rate earlier in 2008, the situation has changed over time. As of the end of 2020, the Postal Services/Postal Contractors industry has surpassed them, becoming the industry with the highest estimated injury frequency rate.

5 Discussion

5.1 Trends in injury frequency rate by year

In Section 4, we have talked about the outcome of the model, which is that time is the main factor decreasing the work-related injury frequency rate in Canada. Between 2008 and 2020, the injury frequency rate has decreased from 30.03 to 17.03 for 13. This could be due to the implementation of stricter safety regulations and guidelines in the workplace. In Canada, the Occupational Health and Safety (OHS) regulations have been in place since the 1970s and are updated annually since 2006 to keep up with new technologies and hazards (Kuhn and Wickham 2020a). These regulations aim to ensure that employers provide a safe working environment for their workers, and that employees are trained to recognize and mitigate potential hazards and risks. Over the years, the regulations have evolved to address emerging issues and promote safe work practices.

Another contributing factor to the decline in work-related injuries in Canada is the increase in technology and automation in the workplace. With advancements in technology, many of the physically demanding jobs that were once commonplace have been automated, leading to a reduction in physical injuries in the workplace (Kropp and McRae 2022). This shift towards automation has also led to an increase in the demand for workers with technological skills, leading to a decline in physical and manual labour jobs (Susan Lund and Robinson 2021).

However, despite the decline in work-related injuries, there are potential problems that may arise as a result. For example, the decrease in work-related injuries may lead to complacency in the workplace, where employees may become less vigilant about safety protocols. Additionally, the decrease in work-related injuries may also lead to a lack of attention and resources towards workplace safety, as some employers may view it as less of a priority.

Even with the advancements in technology and automation, there are still potential hazards and risks that need to be addressed. Regular safety audits and risk assessments can help identify potential hazards and mitigate them before they become a problem. Employers should also provide regular training and education to their employees to ensure they are aware of potential hazards and know how to properly use equipment and machinery. Finally, it's important to create a culture of safety in the workplace, where all employees are encouraged to prioritize safety and report any potential hazards or incidents. By doing so, employers can ensure that their employees are working in a safe and healthy environment, while also reducing the risk of work-related injuries and accidents.

5.2 The role of industry

After analyzing the decrease in injury frequency rates across various industries, our findings show that Long shoring/Stevedoring/Port/Harbour Operations/Pilotage has experienced the highest rate of decrease in injury frequency rate, followed by Water Transportation (Shipping and Ferries) and Energy/Mining/Mineral Processing. However, Banking/Banks and Broadcasting (Television, Radio, Internet) have relatively stable injury frequency rates. This disparity suggests that certain industries prioritize mitigating work-related hazards more than others.

For example, despite ranking first in injury frequency rate in 2008, Long shoring/Stevedoring/Port/Harbour Operations/Pilotage has shown a significant decrease in injury frequency rate over the years. This improvement can be attributed to the implementation of strict safety regulations and protocols and the adoption of new technologies to reduce manual labor. In contrast, the relatively stable injury frequency rates in Banking/Banks and Broadcasting (Television, Radio, Internet) could indicate a lack of prioritization in implementing measures to mitigate work-related injuries. While these industries are generally safe, they can still lead to injuries such as musculoskeletal disorders caused by prolonged sitting and computer use.

5.3 Weaknesses and next steps

The paper delves into injury frequency rates in industries under federal jurisdiction in Canada. However, it acknowledges that the data may not accurately reflect the true incidence and severity of occupational injuries in Canada, as it only considers a subset of the workforce. Therefore, the findings must be interpreted with caution when extrapolated to the broader population. To address the limitation of the survey methodology, future research could include data from provincially regulated workplaces and industries not classified as falling under federal jurisdiction to provide a more comprehensive analysis of work-related injuries in Canada.

This paper analyzed how injury frequency rate in Canada is affected by time and different industries. However, injury frequency rate is only an aspect of work-related injury. Other aspects of work-related injury include the severity of injuries, the types of injuries, and the long-term impacts on the affected workers. Future research could explore these variations and provide a more comprehensive understanding of work-related injuries in Canada.

Appendix

A Model Testing

The `modelsummary` R package (Arel-Bundock 2022) is a useful tool for displaying the coefficients of two models, as well as conducting various tests to compare their performance.

The coefficient of determination (R^2) is a statistical measure that indicates how well a model explains the variation in its response variable. A low R^2 value suggests that the model does not fit the data well. As per Table 3, Model 1 explains 81.7% of the variability, while Model 2 explains 93.2% of the variability. Both models exhibit a relatively high R^2 value, indicating their good explanatory power.

AIC (Akaike's Information Criteria) and BIC (Bayesian Information Criteria) are measures of the prediction ability of a multiple linear regression model. AIC focuses on the model's ability to fit unknown data, while BIC considers the true model and favors simpler models (Kellen 2010). Lower AIC and BIC values suggest better prediction power of the model. According to Table 3, Model 2 has slightly lower AIC and BIC values compared to Model 1, suggesting that Model 2 has stronger prediction capabilities.

Table 3: Comparing Model 1 and Model 2's Statistics

	Model 1	Model 2
(Intercept)	3771.03	6858.39
	(487.75)	(1261.02)
IndustryBanking/Banks	-54.07	-6899.55
	(5.34)	(1867.60)
IndustryBroadcasting (Television, Radio, Internet)	-44.29	-6868.27
	(5.20)	(1818.67)
IndustryCommunications	-49.59	-6545.29
	(5.72)	(1892.81)
IndustryCrown Corporations	-48.75	-6444.17
	(5.19)	(2081.85)
IndustryEnergy/Mining/Mineral Processing	-29.67	1498.10
	(4.97)	(1747.28)
IndustryFederal Public Services/Public Service Departments/Crown Corporations	-34.97	-3481.40
	(7.75)	(10747.51)
IndustryFeed, Flour and Seed	-12.49	-4299.77
	(5.07)	(1723.77)
IndustryGrain Handling/Grain Elevators	-35.55	-5831.56
	(4.97)	(1686.24)

	Model 1	Model 2
IndustryIndigenous	-41.71	-6384.71
	(5.19)	(1724.11)
IndustryInterprovincial Infrastructure (Bridges, Tunnels, Canals, Causeways)	-26.92	-6479.69
	(5.19)	(1844.81)
IndustryLong shoring/Stevedoring/Port/Harbour Operations/Pilotage	23.57	12705.87
	(5.19)	(1831.60)
IndustryPipeline Transportation	-56.38	-6303.43
	(5.07)	(1729.89)
IndustryPostal Services/Postal Contractors	10.57	-512.93
	(5.33)	(1791.22)
IndustryPublic Service Departments	-47.68	-6583.88
	(5.75)	(3108.52)
IndustryRail Transportation	-35.16	-3174.31
	(4.97)	(1722.35)
IndustryRoad Transportation	-16.92	-4923.10
	(5.08)	(1737.60)
IndustryWater Transportation (Shipping and Ferries)	-17.59	1559.53
	(5.19)	(1822.71)
Year	-1.84	-3.38
	(0.24)	(0.63)
IndustryBanking/Banks × Year		3.40
		(0.93)
IndustryBroadcasting (Television, Radio, Internet) × Year		3.39
		(0.90)
IndustryCommunications × Year		3.23
		(0.94)
IndustryCrown Corporations × Year		3.18
		(1.03)
IndustryEnergy/Mining/Mineral Processing × Year		-0.76
		(0.87)
IndustryFederal Public Services/Public Service Departments/Crown Corporations × Year		1.71
		(5.32)
IndustryFeed, Flour and Seed × Year		2.13
		(0.86)
IndustryGrain Handling/Grain Elevators × Year		2.88
		(0.84)
IndustryIndigenous × Year		3.15
		(0.86)

	Model 1	Model 2
IndustryInterprovincial Infrastructure (Bridges, Tunnels, Canals, Causeways) × Year		3.21
		(0.92)
IndustryLong shoring/Stevedoring/Port/Harbour Operations/Pilotage × Year		-6.30
		(0.91)
IndustryPipeline Transportation × Year		3.10
		(0.86)
IndustryPostal Services/Postal Contractors × Year		0.26
		(0.89)
IndustryPublic Service Departments × Year		3.25
		(1.55)
IndustryRail Transportation × Year		1.56
		(0.86)
IndustryRoad Transportation × Year		2.44
		(0.86)
IndustryWater Transportation (Shipping and Ferries) × Year		-0.78
		(0.91)
Num.Obs.	174	174
R2	0.817	0.932
R2 Adj.	0.795	0.915
AIC	1366.6	1227.5
BIC	1429.8	1344.4
Log.Lik.	-663.324	-576.767
RMSE	10.95	6.66

Table 4: Comparing RMSE between two models

Dataset	Model 1	Model 2
train	10.9	6.7
test	15.9	9.3

The RMSE (Root Mean Square Error) is a statistical measure that quantifies the average deviation between the predicted values of a multiple linear regression model and their corresponding actual values. A lower RMSE indicates better predictive performance of the model. Upon analysis of Table 4, it can be observed that the RMSE values for both models are comparable in both the training and testing datasets, suggesting that the dataset is unbiased and the models are performing as expected. Furthermore, Model 2 demonstrates lower RMSE values compared to Model 1 in both the training and testing datasets, suggesting that Model 2 exhibits more accurate predictions of the data.

B Model Assumption Check

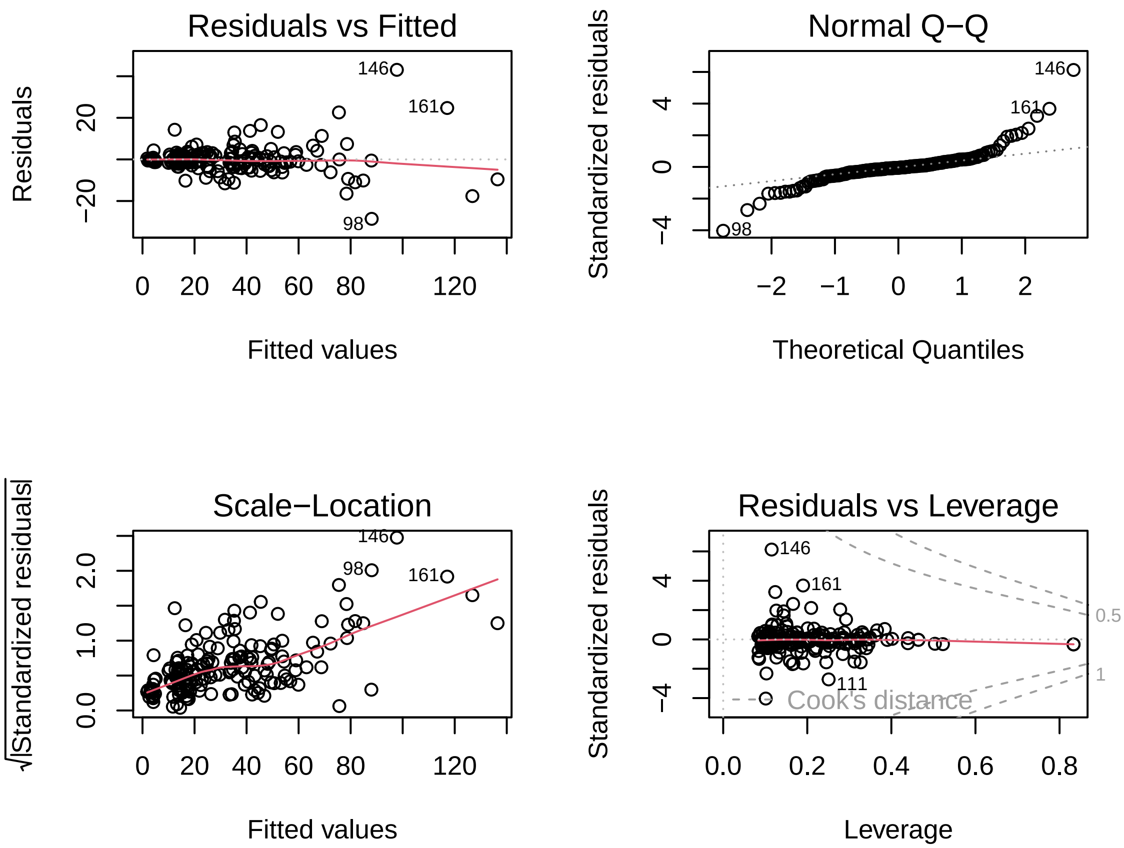

Figure 4: Checking the assumptions of linear model

The multiple linear regression model's assumptions were thoroughly examined to ensure its validity for the dataset, as shown in Figure 4.

The Residuals vs. Fitted plot (top-left) displays a mostly horizontal line with no noticeable patterns, indicating a linear relationship between the dependent and independent variables.

The Normal Q-Q plot (top-right) reveals that most points fall along the dashed line, although there is a notable number of points deviating from the line on the right tail end, suggesting that the residuals may not be perfectly normally distributed.

The Scale-Location plot (bottom-left) exhibits a non-horizontal red line, indicating that the variance of the residuals changes as the fitted values vary. This suggests a potential violation of the homoscedasticity assumption, which assumes that the residuals' variance is consistent across all X values. An alternative model was attempted with a square-root transformation of the dependent variable, but the issue of heteroscedasticity persisted.

The Residuals vs. Leverage plot (bottom-right) identified two outliers with Cook's distances exceeding the threshold at points 146 and 161, as well as one influential point at point 111.

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