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Safety Impacts of a Mobile Labour Force

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Abstract: The nature of employment in the construction industry is characterized by short job tenure and high project mobility. These are important characteristics of the construction labour sector. Workers must move to where the work is, and they often move from employer to employer as work is completed and new projects are identified. We do not always consider, however, their impact on worker safety. The aim of the research described in this paper was to determine the impacts of age, tenure and project mobility on safety in the Ontario non-residential construction sector.

Key findings from this study show that increased job tenure positively impacts worker safety and workers with the shortest job tenure were further negatively impacted if they had high project mobility. In most jurisdictions, each time workers change employers and projects, they must adjust to a new safety culture. It would be very difficult to change the nature of employment in the construction industry; however, it may be possible to create an environment that mimics longer job tenure through the establishment of industry wide safety and prevention programs. Consistent safety cultures across firms may provide the same benefits as long term employment with one firm.

1 Introduction

Experts in the construction industry are interested in improving the safety of workers not only for humanitarian reasons but also because of the increasing costs of medical services and the corresponding rise in costs of worker compensation. In Ontario, the costs related to accidents in construction industry can be conservatively estimated by the premiums charged by the Workplace Safety and Insurance Board (WSIB). Their 2013 rates for construction, which are reflected in the 700 series rate groups, range from 3.69% (electrical and incidental construction services) to 18.31% (form work and demolition) of payroll with an unweighted average of 8.69% (WSIB 2013). The unweighted average premium across all industries in the province is $3.52, just 40% of the construction average. These costs do not include incidental and intangible costs that are borne by the employer when an accident occurs, such as internal accident investigations, productivity losses, and work flow impacts. This unproductive cost could be reduced by improving safety performance throughout the industry.

A number of studies have explored the empirical regularity that younger workers are more likely to experience workplace injuries than older workers. A meta analysis of 108 studies concluded that younger workers (specifically those under 25 years of age) had higher overall injury rates than older workers. However, younger workers generally have lower rates of fatal injury than their older counterparts (Salminen, 2004). It is frequently asserted that the poorer accident record of younger workers is due to their lack of experience, but the notion of experience may be more nuanced. For example, Breslin et al. (2007) found that younger workers (16 to 18 year olds) have less power, or are less willing, to raise safety concerns with mangers and older co-workers and that their safety concerns were discounted or

disregarded. In general, studies of the relationship between age and occupational injuries have not focussed on the construction industry and its specific nature of employment.

Employment in the construction industry is characterized by short job tenure and high project mobility, which are not always accounted for when considering the influences that unique characteristics of the construction industry can have on the safety of workers (Hinze and Gambatese 2003). A major data collection effort to address this shortcoming was undertaken in 2004-2006.

2 The Data

The data collection instrument was a questionnaire focused on three types of data: demographic, attitudinal, and safety incidents. The demographic data included age, trade, number of years in construction (experience), number of years with the present employer (job tenure), number of construction employers worked for in the last 3 years, number of projects worked on in the last 3 years (project mobility), average number of hours worked per week in high season, average number of hours worked per week in low season, whether the respondent was ever a member in a safety committee, whether the respondent was a member in a union, and their job position.

The attitudinal data was based on thirteen validated factor scales from other studies. For each factor, a series of statements were made, and the respondent provided the degree to which s/he agreed with the statement using a 5-point Likert-scale. Because this part of the questionnaire was reported elsewhere (McCabe et al. 2008), it will not be discussed further.

The safety incident reporting section had two categories: accidents, and injuries, which was further broken down into physical injuries and psychological injuries (Table 1). Respondents indicated the number of incidents they experienced in the previous 3 months. No attempt was made to connect accidents to injuries.

Table 1: Injury and Accident Definitions

Physical injuries	
Headache or dizziness	Eye injury
Persistent fatigue	Electrical shock
Respiratory injuries (e.g. difficulty breathing)	Dislocated / fractured bone
Strain or sprain (e.g. back pain)	Skin rash / burn
Cut or puncture (open wound)	Hernia
Temporary loss of hearing	
Psychological injuries	
Lost much sleep due to work related worries	Felt constantly under strain
Been unable to concentrate on work related tasks	Been losing confidence in myself
Been unable to enjoy my normal day-to-day activities	Felt incapable of making decisions
Accidents	
Was exposed to chemicals such as gases & fumes	Slipped, tripped or fell on the same level
Over exerted myself while handling, lifting or carrying	Was struck by a moving vehicle
Trapped by something collapsing, caving in or overturning	Was struck by flying/falling object(s)
Struck against something fixed or stationary	Fell from height
	Contacted moving machinery

The questionnaire had 105 questions and took 15 to 20 minutes to complete. Contractors were contacted directly for permission to access their project sites. The questionnaires were distributed during safety meetings and breaks. As each participant completed the questionnaire, it was put it into a slotted locked box. The data were entered into a database upon return to the office. In all, 911 valid questionnaires were collected from 84 non-residential Ontario construction sites.

The data were analysed using parametric and non-parametric techniques: correlation (Spearman's Rho) to identify relationships that may exist; and, inferential tests to identify differences between group means. Spearman's Rho was used as the data were generally not normally distributed and therefore violated Pearson's r assumptions. Inferential statistical tests checked for differences between groups of the same variable in relation to other variables by comparing the group means. Since the normality assumptions of the t-test and one-way ANOVA were not met, non-parametric equivalents, Mann-Whitney and Kruskal-Wallis respectively, were also used. The significance level for the tests was 0.05 and missing cases were excluded on an analysis-by-analysis basis. Post-hoc tests (Tukey's Honestly Significant Differences (HSD), Dunnet's C) were performed to determine which groups differ from each other.

3 Discussion of the results

Nine hundred and eleven valid responses gave a sampling error of +/-2.7% and +/-4.3% at 90% and 99% confidence respectively. Continuous demographics variables were transferred into discrete variables using quartiles to assist with the analysis.

3.1 Demographics

As shown in Table 2, the mean age of the workers was 38.3 years, which compared well with the average USA age in 2005 of 37.5 years (CPWR 2008). Years of experience were slightly skewed to the right, with a mean of 15.4 years. Job tenure in the sample was highly skewed, with a mean of 5.34 years, but a median of just 2.5 years. There appears little loyalty in either direction between worker and employer, although some workers had been with their current employer for decades (14.6% greater than 10 years, 4.6% greater than 20 years, and 1.2% greater than 30 years). Workers were also asked how many employers they had worked for in the previous 3 years, reporting a mean of 2.91 employers and median of 2.0. Project mobility was also highly skewed, as clear evidence of a unique characteristic of the construction industry.

Table 2: Demographic data

			Quartile Definition			
Demographic	Mean	Median	1	2	3	4
Age (yrs)	38.3	38	18-29	30-38	39-45	46-69
Experience (yrs)	15.1	14	0-5	6-14	15-22	≥23
Job Tenure (yrs)	5.34	2.5	0-0.99	1-2.5	2.6-7	>7
Project Mobility (no. projects)	10.8	5	1-3	4-5	6-10	≥11

Correlation between the four demographic factors is shown in Table 3. While age and experience are highly correlated (R=0.80), age is moderately correlated to job tenure (R=0.36). Project mobility is unrelated to the other factors (R<0.10), supporting the claim that project mobility is common throughout this sector of the construction industry.

Table 3: Demographic Data Correlation

	Age	Experience	Tenure	Mobility
Age	1			
Experience	0.80	1		
Tenure	0.36	0.41	1	
Mobility	-0.04	-0.02	0.09	1

3.2 Injuries and Accidents

The number of each injury or accident that respondents experienced in the previous 3 months are shown in Table 4 along with the percent of respondents who reported no occurrence.

Table 4: Safety Incidents in Previous 3 Months

	Mean	Median	None (%)
Physical injuries	5.83	4	18.7%
Psychological injuries	3.57	1	45.2%
Accidents	3.38	2	34.1%

3.3 Age

Significant differences in injury rates between young and older workers exist (CSAO 2004b), as supported by these data. Age is inversely correlated with all the incident categories with the mean number of incidents in the 4th age quartile approximately half of those experienced by respondents in the first quartile (Table 5). Statistically significant decreases in incident rates occurred between each age quartile for physical injuries (sig 0.05), between the 3rd and 4th quartile for psychological injuries (sig 0.01), and between the 2nd and 3rd age quartiles for accidents (sig 0.01).

Table 5: Safety Incidents by Age

Age	Physical Injuries	Psychological Injuries	Accidents
18-29	7.7	4.4	4.4
30-38	6.1	3.6	3.5
39-45	4.9	3.4	2.5
46-69	3.5	2.2	2.3

Deteriorating safety behaviour is often exhibited by mid-career workers [EHS 2007]. This is supported by the data (Table 6), where workers aged 39-45 reported increased physical injuries and accidents with increased experience in the industry. These increases may be evidence of the start of physical wear and tear injuries or a level of complacency that occurs with intense repetitive work. Others may start to believe that the job hazards have been exaggerated because they have continued their unsafe habits without adverse consequences [EHS 2007]. These workers may require refresher training to correct unsafe behaviours [Dickety et al. 2002, as cited in Gadd & Collins 2002].

Table 6: Safety Incidents by Experience in Age Quartile 3 (39-45 yrs)

Experience	Physical Injuries	Psychological Injuries	Accidents
0-5	3.4	1.7	1.8
6-14	3.6	3.7	2.0
15-22	5.3	3.8	2.5
≥23	6.4	4.0	3.6

Because it is not practical for employers to wait for their workers to age in order to reduce injury rates, other factors associated with lower injury and accident rates were examined.

3.4 Project Mobility

High project mobility (the movement of workers between projects) is an inherent characteristic of the construction industry. With each project and work site, workers face new challenges for the type of work to be performed and the hazards particular to that site. Mobility on its own does not impact safety incidents, except for an increase in psychological injuries (sig 0.1) as workers move into the highest mobility quartile (Table 7).

Table 7: Safety Incidents by Project Mobility

Project Mobility	Age (yrs)	Experience (yrs)	Tenure (yrs)	Physical Injuries	Psychological Injuries	Accidents
1-3	38.3	15.5	5.5	5.4	3.4	3.0
4-5	37.8	15.0	4.8	5.8	3.3	3.2
6-10	37.1	14.7	4.4	5.6	**3.2**	3.2
11+	35.5	14.1	5.4	6.1	**4.1**	3.7

Combining youth with high project mobility significantly increases psychological injuries (sig 0.1) as these workers move from the 3rd to the 4th mobility quartiles (Table 8). This may be due to the stress of having to learn trade skills while continuously changing project-specific expectations and practices. Note that within this age group, physical injuries and accidents also increase with project mobility, although it is not statistically significant.

Mobility also impacts older workers. Extreme mobility in the third and fourth age quartiles increases accidents. Psychological symptoms demonstrate different reactions to mobility depending on the age.

Table 8: Safety Incidents by Mobility and Age

Project Mobility	Age			
	18-29	30-38	39-45	46-69
Physical Injuries				
1-3	7.5	6.4	5.2	3.5
4-5	8.1	7.5	4.7	4.1
6-10	8.1	7.0	4.8	3.5
11+	8.3	6.0	6.1	4.4
Psychological Injuries				
1-3	3.7	4.6	3	3.1
4-5	3.9	3.9	3.5	2.4
6-10	**4.6**	3.0	3.8	1.5
11+	**5.7**	4.0	4.5	2.8
Accidents				
1-3	4.4	3.8	2.7	1.9
4-5	3.8	4.0	2.5	2.8
6-10	5.0	3.9	**2.2**	**2.3**
11+	4.8	3.3	**3.6**	**3.3**

3.5 Employment Tenure

Age and experience are reasonably constant with changes in tenure, particularly in quartiles 1 to 3 (Table 9). Mobility increases with tenure, indicating a tendency for employers to move their long term employees from site to site. Although psychological injuries are only slightly affected by tenure, physical injuries and accidents significantly decrease as tenure increases. In fact, reductions in accidents are observed after 2.5 years (sig 0.05) and again after 7 years with the same employer (sig 0.1); physical injuries also see a major drop in occurrence after 7 years (sig 0.01).

Table 9: Incidents by Tenure

Tenure (yrs)	Age (yrs)	Experience (yrs)	Mobility (projects)	Physical Injuries	Psychological Injuries	Accidents
0-0.9	36.2	14.0	7.3	5.9	3.7	3.6
1-2.5	33.7	11.1	8.8	6.2	3.6	**3.9**
2.6-7	36.7	13.2	10.6	**6.0**	3.3	**3.0**
>7	43.8	22.3	12.1	**4.0**	3.1	**2.3**

Table 10 shows that reduced incidents are not just a phenomenon of age. From age quartile 2 to 3, the positive impact of increased job tenure on accidents is evident. Even the workers aged 46-69 saw a major reduction in accidents with increased tenure although it is not statically significant. Although the number of accidents reduces with age, improvement in accident rates can be accelerated by increasing job tenure after the age of 30. However, the oldest workers had the fewest incidents, without regard to their tenure.

A remarkable finding is that reduced accidents are associated with increased tenure particularly in the second and third age quartiles. In the second age quartile there is a drop from 4.5 accidents to 3.4 accidents between tenure quartiles 2 and 3 (sig 0.01). The stability of having one employer for an extended time appears to be especially important to workers in this age bracket. Those working for their current employer for more than 2.5 years experienced 1.5 fewer physical injuries and 0.9 fewer accidents than those with less tenure. Psychological injuries were unaffected.

Table 10: Incidents by Tenure and Age

Tenure Quartiles	Age Quartiles			
	18-29	30-38	39-45	46-69
Number of Physical Injuries				
0-0.9	8.0	5.7	5.7	4.2
1-2.5	8.0	6.7	6.4	2.8
2.6-7	7.9	7.5	4.7	4.1
>7	-	6.1	4.2	3.4
Number of Psychological Injuries				
0-0.9	5.0	4.2	3.4	2.2
1-2.5	4.7	3.3	3.8	2.5
2.6-7	3.8	4.0	3.3	2.7
>7	-	4.4	3.8	2.4
Number of Accidents				
0-0.9	4.3	4.6	3.0	3.0
1-2.5	4.6	4.5	3.4	2.5
2.6-7	4.5	3.4	1.7	2.3
>7	-	2.4	2.5	2.1

For workers with 14 or fewer years of experience (Table 11), short tenure can result in increased psychological symptoms, whereas experienced workers seem psychologically unaffected by tenure. Physical symptoms significantly decline in the 4th tenure and experience quartiles, whereas accidents decrease during the 2nd experience quartile and 3rd tenure quartile (6 years for experience and 2.6 year for job tenure). In general, when physical symptoms and accidents are considered, those with the most experience appear to benefit most from increased tenure.

Among the shortest tenure workers, those with less experience have more physical injuries but fewer accidents. Also note that across each tenure quartile, all incidents decrease between experience quartiles 3 and 4.

Table 11: Incidents by Tenure and Experience

Tenure Quartiles	Experience Quartiles			
	0-5	6-14	15-22	≥23
Number of physical Injuries				
0-0.9	7.1	5.9	6.0	5.2
1-2.5	7.0	6.2	6.9	5.5
2.6-7	7.3	7.0	5.7	4.5
>7	-	5.2	5.2	2.9
Number of Psychological Injuries				
0-0.9	3.7	4.9	3.9	3.0
1-2.5	3.5	4.4	3.8	3.4
2.6-7	3.2	3.6	3.8	3.4
>7	-	4.2	3.5	2.8
Number of Accidents				
0-0.9	3.4	4.1	4.6	3.4
1-2.5	3.8	5.2	3.8	3.4
2.6-7	4.1	3.3	2.8	2.0
>7	-	2.8	2.8	2.1

The data suggest that workers with short job tenure are further impacted by working on many projects. Among workers who joined a company in the past year (Table 12), those who had worked on more projects reported more physical injuries, psychological injuries, and accidents. A smaller increase in each of these incidents is seen in tenure quartile 2; workers in tenure quartiles 3 and 4 seem largely unaffected by the number of projects they work on.

Table 12: Incidents by Tenure and Mobility

Mobility Quartiles	Mean Tenure	Job Tenure (years)			
		Quartile 1 0-0.9	Quartile 2 1-2.5	Quartile 3 2.6-7	Quartile 4 >7
Number of Physical Injuries					
1-3	5.6	5.2	6.3	6.5	4.3
4-5	4.9	5.2	7.7	6.3	4.6
6-10	4.5	6.5	6.9	6.2	4.0
≥11	5.5	8.7	6.7	6.3	4.4
Number of Psychological Injuries					
1-3	5.6	2.0	3.7	3.8	4.2
4-5	4.9	3.2	3.9	3.4	3.2
6-10	4.5	3.8	3.3	3.4	3.0
≥11	5.5	6.7	4.8	3.8	3.1
Number of Accidents					
1-3	5.6	2.9	3.8	3.3	2.4
4-5	4.9	3.2	4.0	3.3	2.6
6-10	4.5	4.2	4.5	2.6	1.8
≥11	5.5	5.0	4.4	3.1	3.2

4 Regression Analysis

To further verify the one-to-one relationships that appear to be emerging from the data, multivariate regression models are estimated for each of three outcomes – the number of physical injuries, the

number of psychological injuries and the total number of accidents. Age (continuous, as opposed to categorical), experience in years, tenure in years and project mobility (the number of projects worked on in the last 3 years) are the dependent variables.

The three dependent variables are "count" measures – that is, they measure the number of separate physical, psychological and total accidents reported by each survey respondent. Since each incident is a discrete event, the dependent variables are not strictly continuous (there are no partial injuries) and many workers report no accidents of any kind, resulting in clustering around zero. Consequently, it is appropriate to use Poisson regression techniques.

The Poisson regression model is:

$$\text{prob}(\text{Y} = \text{y}_\text{i}) = \frac{\exp(-\lambda_i)\lambda_i^{y_i}}{y_i!}$$

$$\lambda_i = x_i'\beta$$

where y_i is the number of physical injuries, psychological injuries, or accidents experienced by the i^{th} worker and $\mathbf{x}_{it}$ is a vector of explanatory variables. B is a vector of coefficients to be estimated. The regressions are estimated using maximum-likelihood techniques.

The regression results are presented in Table 13. The coefficients on age are negative and statistically significant across all three of the incident measures. A one year increase in age is associated with a 2.7 percent decrease in the number of physical injuries, a 3.2 percent reduction in the number of psychological injuries, and a 2.7 percent reduction in the number of accidents.

Years of experience in the construction industry is positive and statistically significant in all of the Poisson regressions. A one year increase in experience is associated with a 0.6 percent, 1.8 percent and 1.1 percent increase in the number of physical injuries, psychological injuries, and accidents that a construction worker reported having experienced. Although this result is counterintuitive and opposes the results previously discussed, it reflects that with experience comes long term physical wear and tear injuries.

Tenure is negative and statistically significant in the physical injuries and accidents equations, but is not statistically significant in the psychological injuries model. A one year increase in tenure with the current employer is associated with a 1.7 percent reduction in the number of physical injuries and a 2.7 percent reduction in accidents. Mobility (the number of projects worked on in the last 3 years) is not statistically significant in any of the three regressions.

Table 13: Poisson Estimates of the Number of Accidents

	Dependent Variables*					
Independent Variables	Physical Injuries		Psychological Injuries		Accidents	
Age (in years)	-0.027	(10.87)	-0.032	(9.89)	-0.027	(8.15)
Experience	0.006	(2.48)	0.018	(5.46)	0.011	(3.30)
Tenure	-0.017	(5.58)	0.002	(0.48)	-0.027	(6.34)
Mobility	0.002	(1.86)	-0.000	(0.02)	0.001	(0.97)
Constant	2.290		2.223		2.161	

*Note: absolute value of t-statistic is shown in parentheses. This value is greyed if the coefficient is not statistically significant.

5 Conclusions

The key findings from this study show that two of the inherent characteristics of the construction industry, short employment tenure and high project mobility, have a significant impact on the safety performance of a site. The effect is amplified when deleterious factors combine. In summary:

- Young workers (aged 18-29) are well known to experience more injuries and accidents than other age groups. This is reflected in the negative regression coefficients.
- As young workers experience increased project mobility, their safety incident rates of all types also increase.
- Workers aged 39 years and older (age quartiles 3 and 4) experience more accidents if they have high project mobility.
- Workers aged 39-45 (age quartile 3) reported more physical injuries with increased experience. Increased physical injuries may be a result of the physical wear and tear that accumulates after many years of physical work. Those in the same age bracket that started their construction career later reported fewer physical injuries.
- Workers aged 39-45 (age quartile 3) reported more accidents with increased experience. This may result from slower reflexes due to physical wear and tear as in the previous point. Or, it may reflect the development of a cavalier attitude toward safety.
- In all incident types, safety incidents decreased with longer employment tenure. This is supported with negative regression coefficients for physical injuries and accidents. The coefficient for psychological injuries was not statistically significant.
- The positive effect of increased employment tenure on accidents is amplified in those aged 30-45 (age groups 2 and 3).
- The positive effect of increased employment tenure on psychological injuries is amplified in those with 6-22 years of experience (groups 2 and 3).
- As the number of projects that a new employee (less than one year tenure) worked on increased, so did the number of safety incidents of all types. The effect of high mobility lessened after one year with the same employer. New employees could benefit from more worksite stability and guidance.
- Regression analysis supported the inverse relationship between age and employment tenure with safety incidents.

It could be very difficult for some sectors of the industry to increase employment tenure or decrease project mobility due to the nature of the work and employment conditions. It is possible to mimic these conditions through safety groups, an initiative that has been successfully implemented in several provinces including Ontario. Future work may include a follow up study to determine how the industry has improved and the impacts of targeted safety programs.

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