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BENCHMARKING CONSTRUCTION SAFETY PERFORMANCE AT A GLOBAL LEVEL: A CASE STUDY OF US, CANADA, AND NEW ZEALAND

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Abstract: Construction safety plateau has become a global issue. To sustain the continuous improvement of the global construction safety performance, research studies on construction safety performance at a global scale, i.e. comparing safety performance across countries, are needed. To fill in this gap, this paper starts with a preliminary study by comparing the safety performance of the Canada, US, and New Zealand construction sites and by investigating the impact of three demographic factors on construction safety performance of workers, including age, work experience, and union membership. Safety surveys were collected from 2015 to 2017. In total, 837 surveys were collected from Canadian construction sites, 420 surveys were from US construction sites, and 40 were from New Zealand. The major findings are as follows. First, the top five physical injures that were reported most frequently are the same across the 3 countries, including cut, puncture, or open wound, headache or dizziness, strain or sprain, persistent fatigue, and skin rash or burn. Second, the top five unsafe events that were reported most frequently are the same across the 3 countries, including overexerted, slipped, tripped, or fell on the same level, pinch, exposed to chemicals, and struck against something fixed. Third, the most frequently reported unsafe event for all the 3 countries is overexerted. Finally, union membership has an extensive impact on the occurrence of safety incidents for both Canada and US sample. In future, more data are needed from New Zealand construction sites to enable further exploration.

1 INTRODUCTION

Construction safety plateau has become a global issue, which has been observed in Canada, US, and New Zealand (Chen et al. 2017). To sustain the continuous improvement of construction safety performance, works on both safety climate and technology application have been conducted. For example, Chen et al. (2018) explored the differences of safety climate and safety performance between residential and heavy civil sectors. For technology application, visualization techniques (e.g. building information modelling (BIM)), robotics (e.g. drones), and virtual / augmented reality (VR/AR) have become the current focus (Behzadan and Kamat 2013, Cheng and Teizer 2013, Guo et al. 2012, Le et al. 2015, Lin et al. 2011, Zhang et al. 2013). Going back to the safety climate research, one important question is the research scale. The works by Chen et al. (2017, 2018) were focused on a province scale, while some other works were focused on a company scale (Choudhry et al. 2009), or a site level (Lingard et al. 2017). However, there are no research studies that have compared the construction safety climate or performance at a global level or a

country level. Given that safety plateau has become a global issue, it is necessary to identify the reasons why some countries are doing better in safety performance than others.

A global benchmark of construction safety practices enables positive learning between countries, which will benefit all the participating countries. Considering this, this paper starts with a preliminary study by comparing the safety performance of the Canada, US, and New Zealand construction sites and by investigating the impact of three demographic factors on construction safety performance, including age, work experience, and union membership.

2 METHOD

The data were collected via a self-administered survey (Chen et al. 2017) via a strict protocol (Chen et al. 2015). The survey has information including demographics and incident reporting. In total, 837 surveys were collected from Canadian construction sites, 420 surveys were from US construction sites, and 40 were from New Zealand from 2015 to 2017. The Canadian data were collected from the province of Ontario, Canada, and the US data were collected from 20 states in US, e.g. Texas and Wisconsin.

In the survey, incident reporting responses were discrete choices of 'never', 'once', 'two to three times', 'four to five times', and 'more than 5 times' in the previous 3 months. For each of the incident questions, these were transcribed as 0, 1, 2, 4, and 5 respectively. As such, incident counts reported herein are conservative. Then, for each of the three incident categories, namely, physical injuries, unsafe events, and job stress symptoms, the incident counts were summed for each respondent.

Regarding the data analysis in this paper, demographics of the survey participants from the 3 countries were first compared. Then, safety incident data of the participants were shown, including the frequency of physical injuries, unsafe events, and job stress. In the end, the safety performance data were correlated with age groups (i.e. <25, 25-54, 55+), work experience groups (0-5 yrs, 6-14 yrs, 15-22 yrs, and > 22 yrs), and union membership (yes or no). In the meantime, non-parametric techniques that do not require normality of the data were used, including Spearman's rank-order correlation, Kruskal-Wallis Test (i.e. comparing K groups), and Mann-Whitney Test (i.e. comparing two groups).

3 RESULTS

3.1 Demographics

Table 1 shows the demographics of the participants from the three countries. Male workers still dominate the samples. A mature workforce of the three countries were found, i.e. the average age was approximately 36+ and the average work time in the construction industry was longer than 12 years. The 40 participants from New Zealand had a relative shorter working time with their current employers compared to US and Canada participants. In terms of the mobility, all the participants from the three countries had around 2 employers in the previous 3 years before the survey time, while US participants reported a more frequent mobility between the projects. In addition, reasonably consistent weekly working hours were reported by the participants from the three countries, i.e. ranging from 42 to 45 hours per week. For safety training percentage, more than 95% of all the participants had experienced safety training. There were 28% of the US participants having the experience of being a safety committee member, which was lower than Canada and New Zealand percentage. In addition, New Zealand participants were non-unionized (95% of the participants did not belong to a union), and Canada and US participants had approximately 57% to 61% union members. Moreover, Canada participants had the largest supervisor percentage (i.e. 31%). US participants were more from large companies (i.e. 500+ employees), while Canada and New Zealand had 56% and 73% were from small companies (i.e. 5-99 employees).

Table 1: Demographics of the participants

Demographics	Canada	US	New Zealand
Gender (Male %)	98.1	96.2	92.5
Average age	37.1	38.5	35.8
Yrs in construction	14.4	15.2	12.0
Yrs with current employer	6.4	5.6	3.7
No.of employers in the previous 3 Yrs	2.3	2.0	2.1
No. of projects in the previous 3 Yrs	9.9	17.2	9.6
Average weekly hours	44.3	45.2	41.8
Safety training (%)	97.8	96.3	95.0
Safety committee (%)	38.3	28.0	38.5
Union membership (%)	60.6	56.6	5.0
Job position (%)			
Supervisor	31.4	20.6	10.0
Journeyman	50.6	60.8	77.5
Apprentice	17.9	18.6	12.5
Size of employer (%)			
Micro 1-4	5.0	1.7	7.7
Small 5-99	55.9	17.6	73.1
Medium 100-499	25.6	13.4	19.2
Large 500+	13.5	67.3	0.0

3.2 Frequency of Individual Safety Incidents

Table 2 shows the frequency of the 11 individual physical injuries. Although the frequency varies across the countries. The top five physical injures that were reported most frequently are the same across the three countries, including cut, puncture, or open wound, headache or dizziness, strain or sprain, e.g. back pain, persistent fatigue, and skin rash or burn. For example, approximately 25%, 19%, and 23% of the participants from Canada, US, and New Zealand sites reported at least one occurrence of skin rash or burn in the previous 3 months before the survey time.

Table 2: Frequency of physical injuries comparison

Physical injuries	% reporting at least one incident in the previous 3 months before the survey time		
	Canada	US	New Zealand
Cut, puncture, or open wound	53.5	26.4	45.0
Headache or dizziness	52.8	49.2	45.0
Strain or sprain, e.g. back pain	50.8	34.2	52.5
Persistent fatigue	47.7	38.9	52.5
Skin rash or burn	24.7	18.9	22.5
Eye injury	11.8	4.1	15.0
Respiratory injuries	10.7	7.3	10.0
Temporary loss of hearing	8.9	8.3	7.5
Electric shock	6.8	6.7	15.0
Dislocated or fractured bone	4.3	3.9	2.5
Hernia	3.9	3.9	0.0

Table 3 shows the frequency of the10 individual unsafe events. Again, the frequency of the individual unsafe events varies across the countries. The top five unsafe events that were reported most frequently are the same across the three countries, including over exerted, slipped, tripped, or fell on the same level, pinch, exposed to chemicals, and struck against something fixed. The most frequently reported unsafe event is

overexerted, where 42%, 35%, and 33% of the participants from Canada, US, and New Zealand sites reported at least one occurrence in the previous 3 months before the survey time.

Table 3: Frequency of unsafe events comparison

Unsafe events	% reporting at least one incident in the previous 3 months before the survey time		
	Canada	US	New Zealand
Over exerted	41.9	34.7	32.5
Slipped, tripped, or fell on the same level	34.5	22.3	25.0
Pinch	34.3	24.3	20.5
Exposed to chemicals	33.6	24.4	25.0
Struck against something fixed	8.8	8.3	17.9
Struck by falling objects	8.3	8.0	10.0
Fell from height	5.5	4.7	10.0
Contacted with moving machine	3.1	4.7	15.0
Struck by moving vehicles	2.9	0.8	5.0
Trapped by something	2.3	1.8	10.0

Table 4 shows the frequency of the 6 individual job stress symptoms. Canada and US participants reported a relatively consistent pattern, while the 40 New Zealand reported relative more frequent job stress symptoms. Of course, this may be biased by the small sample size of the New Zealand. In addition, the most frequently reported job stress symptom is lost too much sleep due to work related worries, where 37%, 34%, and 58% of the Canada, US, and New Zealand participants reported at least one occurrence of this in the previous 3 months before the survey time.

Table 4: Frequency of job stress symptoms comparison

Job stress symptoms	% reporting at least one incident in the previous 3 months before the survey time		
	Canada	US	New Zealand
Lost too much sleep due to work related worries	36.8	34.2	57.5
Constantly under strain	30.1	30.1	43.6
Unable to concentrate	28.8	27.5	50.0
Unable to enjoy normal activities	28.6	30.6	55.0
Incapable of making decisions	16.0	20.5	40.0
Losing confidence in themselves	15.0	15.5	33.3

3.3 Correlations between Age, Work Experience, and Union Membership

As mentioned in the method part, an aggregated score of physical injuries, unsafe events, and job stress was obtained by summing the frequency of all the individual safety incidents in each category. For example, in Table 5, the frequency of physical injuries is the sum of the 11 individual physical injuries.

Overall, US participants reported the least number of safety incidents, for example, the average frequency of physical injuries from Canada sites is 6.0, US is 3.7, and New Zealand is 5.4. To identify the safety performance of young, middle-aged, and old workers, age was divided into 3 groups: <25, 25-54, and 55+. Non-parametric tests, i.e. Kruskal-Wallis Test and Mann-Whitney Test, were conducted for Canada and US samples to identify whether there are significant differences of the safety incidents between the 3 age groups. The two tests were not done for New Zealand sample due to the limited sample size. It was found that:

- For US sample, there were no significant differences of the three types of safety incidents between the 3 age groups;
- For Canada sample, job stress level of the younger workers was significantly higher than that of the middle-aged group;

- For Canada sample, physical in injuries, unsafe events, and job stress of the younger workers were significantly more frequent than those of the older workers;
- For Canada sample, physical injuries and unsafe events of the middle-aged workers were significantly more frequent than those of the older workers.

Table 5: Age and safety performance

	Canada	US	New Zealand
Physical injuries	6.0	3.7	5.4
<25	7.1	3.1	7.8
25-54	6.0	3.9	5.3
55+	4.1	2.9	0.0
Unsafe events	3.6	2.1	3.0
<25	4.4	2.4	5.3
25-54	3.6	2.2	2.8
55+	2.2	1.6	0.0
Job stress	3.6	3.4	5.8
<25	4.4	2.3	9.5
25-54	3.5	3.6	5.4
55+	3.2	2.9	6.0

Canada: <25 (N=120); 25-54 (N=601); 55+ (N=73)

US: <25 (N=49); 25-54 (N=300); 55+ (N=37)

New Zealand: <25 (N=4); 25-54 (N=35); 55+ (N=1)

McCabe et al. (2017) reported that workers with 6-14 years' experience reported the most frequent occurrences of safety incidents, although no statistical tests were conducted. Given this, in this paper, a similar analysis was conducted for the Canada, US, and New Zealand samples.

The workers' experience was divided into 4 groups: 0-5 years, 6-14 years, 15-22 years, and more than 22 years. Consistent with the findings by McCabe et al. (2017), workers with 6-14 years of experience from the Canada sample reported the highest number of physical injuries, unsafe events, and job stress; workers with 6-14 years of experience from the US sample reported the highest number of physical injuries and job stress. Although the small size of the New Zealand sample makes it difficult for this analysis, workers with less than or equal to 5 years of experience (N=17) reported a much higher number of physical injuries, unsafe events, and job stress compared with workers with 6-14 years of experience (N=11).

Table 6: worker experience and safety performance

	Canada	US	New Zealand
Physical injuries	6.0	3.7	5.4
0-5	6.1	3.9	7.2
6-14	6.6	4.1	3.5
15-22	5.8	3.6	5.5
>22	5.2	3.3	4.1
Unsafe events	3.6	2.1	3.0
0-5	4.0	2.6	3.6
6-14	4.1	2.4	3.0
15-22	3.3	1.8	4.3
>22	2.9	1.8	1.0
Job stress	3.6	3.4	5.8
0-5	3.6	3.3	7.3
6-14	3.9	4.0	3.0
15-22	3.2	3.5	6.0
>22	3.5	2.7	6.4

Canada: 0-5 (N=211); 6-14 (N=245); 15-22 (N=146); 22> (N=192)
US: 0-5 (N=92); 6-14 (N=96); 15-22 (N=110); 22> (N=88)
New Zealand: 0-5 (N=17); 6-14 (N=11); 15-22 (N=4); 22> (N=8)

Table 7 shows the correlations between union membership and individual safety incidents for Canada and US samples. This analysis was not conducted for the New Zealand because 95% of the New Zealand participants were non-unionized. As shown in Table 7, it was found that:

- For Canada sample, union workers reported a significantly higher frequency of 6 individual physical injuries, 4 individual unsafe events, and a significant lower frequency of 2 individual job stress symptoms;
- For US sample, union workers reported a significantly higher frequency of 5 individual physical injuries and 2 individual unsafe events (i.e. over exerted and slipped, tripped, or fell on the same level), and a significant lower frequency of 2 individual unsafe events (i.e. struck against something fixed and contacted with moving machine).
- For both Canada and US sample, union workers reported a significantly higher frequency of 3 individual physical injuries (i.e. skin rash or burn, strain or sprain e.g. back pain, and cut or puncture open wound), and a significantly higher frequency of 2 individual unsafe events (i.e. over exerted and slipped, tripped, or fell on the same level).

Table 7: Correlations between union membership and individual safety incidents

	Canada	US
Physical injuries		
Headache or dizziness		.14
Persistent fatigue		.13
Skin rash or burn	.07	.17
Strain or sprain e.g. back pain [h]	.15	.17
Cut or puncture open wound	.17	.14
Eye injury	.10	
Dislocated or fractured bone [h]	.07	
Hernia	.10	
Unsafe events		
Exposed to chemicals	.12	
Over exerted [h]	.12	.15
Slipped, tripped, or fell on the same level [h]	.11	.19
Struck by moving vehicles [h]	.08	
Struck against something fixed [h]		-.14
Contacted with moving machine		-.13
Pinch	.11	
Job stress		
Lost too much sleep due to work related worries	-.09	
Incapable of making decisions	-.08	

Note: Spearman's rank-order correlation, $p<0.05$;

[h]: high cost claim injuries or unsafe events

In addition, in Table 7, 6 high cost claim injuries or unsafe events are indicated (Chen et al. 2016). It is interesting to find that union workers from the Canada sample experienced significantly more frequent incidents compared to non-union workers in 5 of the 6 incidents. For US sample, union workers experienced significantly more frequent incidents compared to non-union workers in 3 of the 6 incidents, and significantly less frequent incidents in 1 of the 6 incidents.

4 CONCLUSIONS

Aiming to build a global benchmark of the construction safety performance, this paper shows some preliminary results based on survey data collected from Canada, US, and New Zealand construction sites. On the whole, US participants reported less incidents compared to Canada and New Zealand, while some consistent results were found:

- The top five physical injures that were reported most frequently are the same across the three countries, including cut, puncture, or open wound, headache or dizziness, strain or sprain, persistent fatigue, and skin rash or burn.
- The top five unsafe events that were reported most frequently are the same across the three countries, including overexerted, slipped, tripped, or fell on the same level, pinch, exposed to chemicals, and struck against something fixed.
- The most frequently reported unsafe event for all the three countries is overexerted.
- The most frequently reported job stress symptom for all the three countries is lost too much sleep due to work related worries.

In addition, the correlations between age, work experience, union membership and safety incidents were also explored. Age impact on the Canada participants is more significant, i.e. younger workers reported more incidents. Workers with 6-14 years of experience from the US sample also reported the most frequent of physical injuries and job stress compared to the other 3 experience groups (i.e. 0-5 years, 15-22 years, 22+ years), although no statistical tests were conducted. On the contrary, for New Zealand sample, workers (N=17) with least experience (i.e. 0-5 years) reported the most frequent safety incidents of all the three types. In the end, union membership has an extensive impact on the occurrence of safety incidents for both Canada and US sample.

One limitation of the paper is the small sample size of the New Zealand, which has prevented us from making any valid conclusions of the New Zealand data. In future, more data are needed from New Zealand construction sites. To interpret the data, the survey data also need to be linked to the official government statistical data. Other factors, including safety climate, and safety programs need to be explored and compared.

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