Interrelation between human factor-related accidents and work patterns in the construction industry

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Abstract

The shortage of labor in the construction industry is quickly becoming a global phenomenon. To encourage more people to begin careers in construction, both work patterns that promote more leisure and accident rate reduction need to be put in place. This study used logistic regression to analyze 7,497 accident cases that have occurred in the Hong Kong construction industry. Principally, it was found that human factor-related accidents and work patterns are interrelated for both millennials and non-millennials. Therefore, adjusting work patterns may reduce accident rates, which could encourage more people, both young and old, to choose a career in the construction industry.

Introduction

Globally, the construction industry is facing a labor shortage. Turner and Townsend (2017) stipulated that

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24 out of the 43 (56%) global markets analyzed in a survey suffer from skills shortage in the construction industry. This is up from 20 reported a year earlier, which indicates the persistence of the problem. Essentially, the Hong Kong Construction Association (2017) reported the labor shortage over a five year period from 2013 to 2017, with a current shortage rate of 5.47%. The estimated increase in total labor supply in Hong Kong is also expected to be lower than the expected increase in demand for construction workers. According to The Government of Hong Kong SAR (2015), total manpower requirements in the construction industry should rise at an average annual rate of 1.4%, while total manpower supply in Hong Kong is expected to increase by only 0.4% on average annually from 2012 to 2022. Concurrently, the Hong Kong construction industry also faces an aging population problem. According to the Construction Workers Registration Board (2017), as of April 2017, 66.11% of registered construction workers were over 40 years of age. This phenomenon also seems to be global, as countries such as the United Kingdom (McNair & Flynn, 2006), and the United States of America (The Centre for Construction Research and Training, 2014) face a similar dilemma. This aging problem highlights the labor shortage problem because it reveals the unwillingness of the younger generation to join the construction industry.

Older people are more prone to accidents (Dong et al., 2012) and higher injury costs (Schwatka et al., 2012). They also have a declined physical fitness, which affects their overall performance and productivity (Jebens et al., 2015). Likewise, skills shortages may lead to decline in productivity and lack of industrial growth (Lobo & Wilkinson, 2008). This suggests that both an aging workforce and a

skills/labor shortage have negative effects on the construction industry. Stunted growth and productivity in the construction industry can have a devastating effect on the economy (Dang & Low, 2011), hence the need to address the issue of the labor shortage and the aging workforce in the construction industry.

Though various strategies such as increased training, increased wages and labor migration have been proposed and implemented to decrease the shortage rate and the participation rate of the younger workforce (Ho, 2016; MacKenzie et al., 2000), more still needs to be done due to the persistence of the problems. Ho (2016) suggested that improved working conditions, including health, safety, and welfare, could improve the attractiveness of Hong Kong construction industry to potential employees.

Therefore, the objective of this study is to examine if work patterns and human factor-related accidents are interrelated in order to suggest policies that would reduce accident rates and thereby encourage the younger generation to choose a career in the construction industry thus reducing the construction industry workforce shortage. The next section of this paper presents the literature review. This is followed by the research method adopted in this study and the results and discussion section. The final section presents the conclusions of the paper.

Literature Review

Human Factor-related Accidents

In accident causation models, multiple causation theory suggests that for every accident, there may be many contributing factors, causes, and sub-causes (Raouf, 2011). These contributing factors can be categorized into behavioral factors and environmental factors. The behavioral factors are human factors specific to the individual workers themselves, such as poor physical and mental state, lack of knowledge, inappropriate attitude and lack of skills. Environmental factors, on the other hand, are related to the physical working conditions under which the workers do their jobs, such as a dangerous working environment and degradation of equipment, (Raouf, 2011). In Hong Kong, Choudhry and Fang (2008) found that workers were involved in unsafe acts due to lack of safety awareness and psychological factors, among others. Human error accounts for 80% of incidents in complex high-risk systems in the construction industry (Garrett & Teizer, 2009). Hence, there is the need to investigate if accidents in Hong Kong are also more related to human factors than to environmental factors.

Work Patterns

Work pattern is the manner in which a job is performed, such as shift work, hours worked, and days of the week (Farlex, 2018). Studies have shown that certain work patterns have effects on accidents, generally. They are major contributing factors in human-related accidents. For instance, Wagstaff and Lie (2011) and Dembe et al. (2005) found that working long hours and shift work could increase the risk of accidents.

69 Costa (1996) also demonstrated that night work can cause interferences with work performance and
70 efficiency, resulting in errors and accidents, among other issues. Dembe et al. (2005) reported that
71 working overtime could result in a 61% increase in injury hazard rate. Working at least 12 hours per day
72 has a 37% increased hazard rate, and working at least 60 hours per week increased hazard rates by 23%.
73 Wagstaff and Lie (2011) determined that both shift work and long working hours have a negative effect
74 on safety at work. The authors reported that work periods longer than eight hours have cumulatively
75 increased accident risk. The risk of accidents for those working 12 hours a day would be twice as high as
76 those working 8 hours a day. Hence, there is also the need to include the effects of night work in the
77 examination of human factor-related accidents.
78
79 Additionally, previous studies have shown that accidents are more likely to occur in the early part of the
80 week (Rozenfeld et al., 2010), and accident severity increases as the week progresses (Camino López et
81 al., 2008). In Hong Kong, Tao et al. (2017) discovered that the younger generation places more
82 importance on taking Saturdays off than on money. In Australia, Lingard et al. (2008) found that a
83 compressed work week was positively received, although waged workers expressed concerns about the
84 impact on their take-home pay. Therefore, this study includes the examination of the relationship between
85 certain days of the week; Monday, Saturday, Sunday and human factor-related accidents.
86
87 To maximize productive time and to enhance health and safety, Yi and Chan (2013) proposed an optimal

work-rest schedule of 15 minute breaks after two hours of work in the morning, and 20 minute breaks after 1 hour and 55 minutes of work in the afternoon for construction rebar workers during hot weather in Hong Kong. Accordingly, this study also includes an investigation of the relationship between human factor-related accidents and work patterns that involve working more than two hours without adequate rest.

Other Factors affecting Human Factor-Related Accidents

Soltanzadeh et al. (2016) found that unsafe acts cause accidents that are by definition more human factor-related than environmental and is understandably associated with accident severity. Yau (2004) also found that some specific human factors have significant effects on accident severity for private vehicle owners in Hong Kong. Hence, there is a need to consider controls for accident severity in this study. In addition, several studies have shown the relationship between accidents and location (Dumrak et al., 2013; Huang & Hinze, 2003; López Arquillos et al., 2012); hence, there is also a need to consider the location of the accident, as well. Dong et al. (2004) found that safety and health training were associated with reduced work injury related compensation claims, especially for young workers. Additionally, training has been identified as one of the critical factors needed to predict accident risk (Lee & Halpin, 2003). Hence, there is the need to consider training. Lastly, there is a need to manage environmental factors, as previous studies have identified it as an accident causation factor (see for instance Mitropoulos et al., 2005; Sawacha et al., 1999).

107

108 ***Research Gap***

109 Many previous studies have concentrated only on investigating work patterns and accidents generally

110 ((see Dembe et al., 2005; Wagstaff & Lie, 2011)). Cottini and Lucifora (2013) investigated workplace

111 mental health conditions across 15 European countries. They concluded that adverse job demands, such

112 as shift work and intensive tasks, are strongly associated with reported mental problems, e.g., stress. In

113 construction research, Chan (2011) identified fatigue as a leading risk factor of construction accidents.

114 Therefore, work patterns would most likely influence accidents through their effects on the physical and

115 emotional well-being of the workers, hence, there is a need to investigate the relationship between human

116 factor-related accidents and work patterns in the construction industry. However, a study into the

117 relationship between work patterns and human factor-related accidents would provide insight into the

118 association between work patterns and the physical and emotional well-being of workers. Additionally,

119 human factors have been identified as the greatest contributor to danger, and they are more difficult to

120 control compared with environmental or technical factors (Reason, 1995). Thus, research on their

121 determinants would make it easier to develop effective control measures. Additionally, very little has been

122 done to investigate the generational differences among workers in relation to work patterns and human

123 factor-related accidents in the construction industry in an attempt to solve the aging population problem in

124 the industry.

125

Research Method

This study draws inferences from both reviewed literature and data analyses. The data used for this study were collected from Mass Transit Railway Corporation Limited (MTRC). MTRC is a company that operates and manages Hong Kong's Mass Transit Railway making an average of 5.6 million passenger trips per weekday (MTR Corporation, 2016). It also engages in property development, making it one of the major players in the Hong Kong construction industry. As of 31st December 2015, railway construction and property development in progress for MTRC was around HK$37billion (MTR Corporation, 2015). This represents 17% of the gross value of construction projects in Hong Kong in 2015 (HK$224billion) (Census and Statistics Department, 2017). In addition, MTRC has built, operated and maintained mass transit railway systems and provided related services in China Mainland, the UK, Sweden and Australia (MTR Corporation, 2016). Considering all the aforementioned efforts, it is safe to suggest that the use of data collected from MTRC is suitable to achieve the purpose of this study.

The data consist of a total of 7,497 recorded accidents between May 2009 and October 2015. These accidents occurred during the construction of five new railway projects i.e., the Shatin-Central Link, West Island Line, Express Rail Link, South Island Line and Kwun Tong Line. These projects involved both the construction of railway lines (civil work) and the construction of railway stations (building work) as part of the Hong Kong Government's Railway Development Strategy. The railway stations are multi-level buildings with multiple shopping complexes. Additionally, the various trades of the construction industry

145 are well represented in the data (please see Table 1). Therefore, the construction industry is well
146 exemplified in the data.

147

148 Logistic regression was adopted in estimating the relationship between human factor-related accidents
149 and work patterns. Logistic regression was used because the dependent variable (human factor-related
150 accidents) considered in this study is a binary variable. Logistic regression is especially formulated to
151 predict the probability that an event will occur using a binary dependent variable given or a combination
152 of explanatory variables which can either be categorical or continuous (Hair et al., 2006). This approach
153 has been used in previous accident studies in the construction industry (see, for instance, Chau et al., 2004;
154 Chau et al., 2002). The data were subdivided into two categories: millennials and non-millennials.
155 Subsequently, each dataset, including the dataset for all victims, were analyzed. In line with Ng et al.
156 (2010); Real et al. (2010), 1980 was used as the cut off benchmark for millennials. Out of the 7,497
157 records of this study, 1,941 have missing values. Hence, two methods, listwise deletion (LD) and multiple
158 imputation (MI), were used to address the issue and the results were subsequently compared. In listwise
159 deletion, all incomplete cases are dropped entirely from the analysis. Graham (2009) indicated that this
160 method of handling missing data might lead to biased parameter estimates and the loss of power when the
161 number of missing cases is greater than 5%. Though, when the sample size is large, the loss of power and
162 the biased parameter estimate is reduced (Acock, 2005). Multiple Imputation is used to generate possible
163 values for missing cases through the pooling of multiple simulated values. It entails three stages:

imputation, analysis, and pooling (Peng & Zhu, 2008). During the imputation stage, each missing value is replaced by simulated values multiple times, thereby creating multiple datasets. The analysis stage fits the model using the various datasets while the pooling stage combines the model from the various datasets. The main limitation of MI is that each application of MI produces slightly different imputed values and related statistics, so the results cannot always be replicated (Peng & Zhu, 2008). The MI method was found to have superior performance to other techniques of handling missing data in logistic regression (Peng & Zhu, 2008). Therefore, the method was adopted. Prior construction research using logistic regression has used MI methods (see, for instance, Alexander et al., 2012; Spee et al., 2016).

As discussed in the literature review, human factor-related accidents refer to accidents with contributing factors specific to the individual workers themselves, such as poor physical and mental state, lack of knowledge, inappropriate attitude and lack of skills. Environmental factor-related accidents are due to the physical working condition such as dangerous working environment and degradation of equipment. In this research, the victims and their supervisors identified various contributory factors to the accidents according to their opinions and they were subsequently grouped into human and environmental factors. Human factor is the dependent variable. To model it, a value of 1 was assigned to any accident record where a human-related factor was mentioned to have been partly/jointly responsible for the accident, while a value of 0 was assigned if no such factor was indicated. The independent variables are those discussed in the literature review above, under the “Work Pattern” and “Other Factors Affecting Human

183 Factor-Related Accidents" sections. They are "night", "2 hours after rest", "Monday", "Saturday" and
184 "Sunday". All the variables are presented in binary form (see Table 3). "Night" starts from 7pm to 7am, a
185 value of 1 was assigned if the accident occurred during the period and 0 otherwise. "2 hours after rest"
186 include the periods 10.01am to 12noon, 3.01pm to 3.15pm and 5.46pm to 6pm (Yi & Chan, 2014). A
187 value of 1 was assigned if the accident occurred during the period and 0 otherwise. Additionally, a value
188 of 1 was assigned if the accident occurred either on Sunday, Monday or Saturday, and 0 otherwise.

189

190 Other variables were included as control variables to control the effect of non-human factors on accidents.
191 They are "accident category", "treatment given", "environmental factor", "place of the accident" and
192 "apprentice". "Accident category" and "treatment given" are measures of "accident severity" while
193 "apprentice" was used to model training received.

194

195 Accidents that resulted in three or more sick leave days were categorized as reportable accidents and were
196 assigned a value of 1 and 0 otherwise. Regarding the place of accident, civil worksite was assigned the
197 value of 1 and 0 otherwise. If an environmental factor was reported, the value of 1 was assigned and 0
198 otherwise. A victim who was an apprentice at the time of the accident was assigned a value of 1 and 0
199 otherwise. The definitions and measurements of the categorical and binary variables as highlighted above
200 are summarized in Table 3.

Results

The proportion of accidents that occurred at each of the five project sites is presented in Figure 1. Most of the accidents occurred during the period of January 2013 to October 2015 with 79.1% of the accidents taking place at that time (see Table 2). Of the victims, 95.1% (6007) were male workers, while only 4.1% (307) were female workers. The gender of 1,183 victims was not stated. Figure 2 shows the age distribution of the victims; 44% of the victims were between 31 to 55 years old. Additionally, 40% of the accidents occurred between June and September (see Figure 3). 84% of the accidents occurred between Monday and Friday (See Figure 4) and 80% of the accidents occurred between 9 am and 6 pm (see Figure 5). Additionally, 60% of the victims had 3 months or less experience onsite (Figure 6).

The correlation analysis of both the dependent and independent variables are presented in Table 4. It reveals that environmental factors and human factors have the highest correlation of 0.78. None of the other variables had correlations above 0.5. The multicollinearity test conducted also confirms this (see Table 5) as all the Variance Inflation Factors (VIF) are less than 2. The logistic regression results are presented in Tables 6, 7, 8 and 9. For the LD dataset for all victims, the Cox & Snell R-Squared is 0.48 and the Nagelkerke R Square is 0.64. The Cox & Snell R-Square ranges between 0 and less than 1, while Nagelkerke R-Square, on the other hand, has values that range between 0 and 1 (Hair et al., 2006). The closer the values are to one, the greater the model fit (Hair et al., 2006). Thus, the dependent variables

220 explain 64% of the variation in human factor-related accidents. The MI dataset for all victims yielded
221 better model fit with a Cox & Snell R-Squared of 0.48 and Nagelkerke R Square of 0.67. Since the MI
222 datasets yielded a better model fit, it was used for the millennials versus non-millennials analysis. The
223 Cox & Snell R-Squared and the Nagelkerke R Square were 0.50 and 0.69, respectively, for millennials
224 and 0.48 and 0.67, respectively, for non-millennials.
225
226 For the work-pattern related factors, “night”, “2 hours after work” and “Monday” were found to be
227 significant in both the MI and LD datasets for all victims. The odds that the accident was caused by
228 human factors increased at night. Workers work at night due to either night shift work or overtime work.
229 Therefore, this indicates that shift work, as well as overtime work, may increase stress and fatigue level,
230 which may cause human errors and eventually lead to accidents (Cottini & Lucifora, 2013; Dembe et al.,
231 2005). Furthermore, the odds that the accident is caused by a human factor increased two hours after rest.
232 This substantiates that long working hours without adequate rest may increase stress and fatigue levels,
233 causing human errors and, consequently, more accidents (Yi & Chan, 2013). Additionally, this study
234 established that the odds that the accident was caused by a human factor increased on Mondays when all
235 victims are considered. This is consistent with the Monday-effect proponents (Campolieti & Hyatt, 2006;
236 Card & McCall, 1996). For the millennials, among the work pattern variables, only “Monday” is
237 significant, while for non-millennials, “2 hours after rest” and “night” are the significant variables. This
238 indicates that non-millennials are prone to human factor-related accidents when working at night and

239 when adequate rest periods are not provided. This is likely because they are older and are more prone to
240 accidents (Dong et al., 2012). Millennials, on the other hand, are more prone to human factor-related
241 accidents on Mondays as depicted by the logistic regression results. This may be attributed to the fact that
242 the safety measures that need to be put in place before starting work after the weekend break might not
243 have been adhered to. To prevent accidents among the younger generation, policies should be put in place
244 to ensure that safety measures are observed. Constant reminders of safety measures especially after the
245 weekend and vacation breaks should be provided. Other policies to prevent accidents, especially for
246 non-millennials may include reorganization of rest periods so there are multiple rest periods rather than
247 single long ones. Additionally, training on health and sleep management may be provided regularly to
248 workers who work at night to help them stay alert at night.
249
250 All the control variables were statistically significant for both the LD and MI datasets for all victims.
251 They are accident category, place of the accident, environmental factors, apprentice, and treatment given.
252 They were all significant at above 97% confidence levels. The likelihood that the accident was caused by
253 human factors increased when the accident was reportable (requires more than three days' sick leave).
254 This confirms that there exists a relationship between accident severity and human factor-related
255 accidents. On the other hand, there seems to exist a negative relationship between treatment given and
256 human factor-related accidents. This may be due to the increased safety initiatives being implemented by
257 MTRC which has led to fewer cases of lost time accidents (MTR Corporation, 2016). In this study, only

22% of the accidents required hospital treatment. It was also established from this study that the likelihood that the accident is caused by human factors increased when working on a civil engineering worksite compared to other work sites such as a building worksite. The plausible reason for this is unknown at the moment. A reasonable suggestion would be that a typical civil engineering worksite seems to be technologically more complex and requires more attention to details than other worksites. A detailed look at the data suggests that 50% of the human factor-related accidents were due to “lack of concentration”. In addition, the results show that the possibility that an accident is caused by human factors increased when an environmental factor is also responsible for the accident. Since workers are responsible for taking care of their personal equipment, those who are more prone to behavioral issues (a human factor-related accident) may also be more likely to be negligent with their equipment, thereby triggering an accident that is also environmental factor-related. The result similarly signifies that the probability that the accident is caused by a human factor decreased when the victim is an apprentice. This suggests that apprentices tend to be a lot more focused and less stressed on the job. Additionally, apprentices tend to take on less responsibility and less risky assignments. Hence, they are less likely to be involved in accidents. For the millennials, environmental factors, apprentice status and place of accidents were significant, while environmental factors and apprentice status were the only significant factors for non-millennials.

Limitation

The major limitation of this study is that the data do not include variables such as number of work hours per week, overtime work done per week and work shift practice of each victim that can be used to measure work patterns directly. This necessitates the need to explore more time factors as work pattern variables. Such variables should be taken into consideration when collecting accident data in the future. Additionally, further research can be done to ascertain the direct effect of accidents on the career choices of millennials.

Conclusion

The Hong Kong construction industry faces labor shortages and aging population problems. The aging labor force and labor shortage problems can be addressed only by attracting more people to join the construction industry. To encourage more people, both young and old, to begin a career in construction, work patterns that promote site safety need to be implemented. The dismal records of site safety have discouraged not only the younger generation from joining the construction industry but also their parents from allowing them to do so (Tao et al., 2017). This study, therefore, has aimed to investigate the relationship between work-pattern and human factor-related accidents to offer suggestions that might help minimize accident rates. A total of 7,497 recorded accidents between May 2009 and October 2015 were collected from MTRC. Logistic regression was performed, and it was found that eight variables, “accident category”, “place of accident”, “Monday”, “night”, “2 hours after rest”, “environmental factor”, “apprentice”, and “treatment given”, were found to be significantly associated with human factor-related

accidents when all victims were considered. For millennials, “Monday”, environmental factor”, “apprentice” and “place of accident” were found to be significant, while “night”, “2 hours after rest”, “environmental factor” and “apprentice” were found to be significant for non-millennials. Most importantly, human factor-related accidents and work patterns were found to be significantly interrelated among all age groups. To reduce accident rates among millennials, it is proposed that constant training and safety reminders be provided, especially after weekend breaks or other vacation breaks. For non-millennials, it is proposed that rest periods should be restructured and training on health and sleep management should be provided regularly to reduce human factor-related accidents. In all, the devastating effects of accidents may actually discourage people from working in the construction industry. Therefore, reduced accident rates in both millennials and non-millennials should encourage both the younger and the older generation to join the construction industry.

Data Availability Statement

The data used for this study were provided by a third party. Requests for data should be directed to MTRC as indicated in the acknowledgements.

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