Fatal Construction Accidents in Hong Kong

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ABSTRACT

The construction industry is infamous for its dismal safety records. In Hong Kong, the ratio of fatal accidents per thousand workers increases with the gross value of work performed per worker for a 21-year period between 1995 and 2015. There were more deaths when workers worked more. There has not been any significant drop in construction fatalities. This paper offers a comprehensive analysis of the fatal accidents, including when and how they occurred. Contextual data of fatal incidents in the construction industry of Hong Kong from 2006 to 2015 were collected from local news compiled by WiseNews. The majority of victims were workers aged 45 and above, reflecting acute problems of labor aging and skilled labor shortages, which are issues not only in Hong Kong but throughout the world. Not unexpectedly, most workers died in the hot humid days in summer after working for 2 hours in the morning or 1 hour after a lunch break. Principal component analysis (PCA) and cluster analysis suggest that more fatal accidents occurred in repair, maintenance, alteration and addition (RMAA) works from the private sector. Hence safety governance should be more focused on this particular sector. This is the first study to explore the overall fatalities in Hong Kong construction trades with a focus on the analysis of the relationships between the

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recorded variables. The findings for Hong Kong provide insight for future research on solutions to reduce accidents in the construction industry around the world.

INTRODUCTION

Construction is one of the most dangerous industries around the world. Sunindijo and Zou (2012) found that in many countries, “the fatality and incidence rates of the construction industry are considerably higher than the all-industry average”. Quoting International Labour Organization (ILO), Murie (2007) stated that construction “accounts for around 7% of the world’s employment but 30–40% of the world’s fatal occupational injuries. 100,000 workers are killed on construction sites every year—one person killed every five minutes because of bad, and illegal, working conditions”. Wong et al. (2016) found that in the United States (US) in 2012 alone, 775 construction workers (representing 19.6% of worker fatalities) lost their lives, and in the United Kingdom (UK) in 2013, construction accounted for 27% of fatal injuries and 10% of major injuries though it employed only about 5% of the workforce. The case of Hong Kong would provide an insight into the problem and inform further research to enhance construction safety.

LITERATURE REVIEW

Construction Accidents

Table 1 gives a snapshot of the grim situations in a number of countries, as reported by their respective statistics agencies. In the US in 2015, construction had the largest number of fatal accidents (one fifth of all fatalities) though its fatality rate ranked the fourth (after “agriculture, forestry, fishing and hunting”, “transportation and warehousing”, and “mining, quarrying, and oil and gas extraction”) (Occupational Safety and Health Administration 2017). In the UK in 2015/2016, construction had the second largest number of fatal accidents, accounting for 43 fatalities, after "Services Industry" (45 cases) (HSE 2016). The fatality rate of construction activities was the top one in 2014 among all economic activities of the total of 28 countries in European Union (EU-28) (Statistics Explained 2017). In Japan, construction also had the most fatal accidents from 2014 to 2016, followed by "tertiary industry" and "manufacturing" (JISHA 2017). Back in Hong Kong in 2015 alone, of the total of 25 industrial fatalities, 19 happened in the construction industry (The Labour Department 2016). With the highest fatality rate, Hong Kong appears to be the worst performer among the advanced economies listed in the table. In general, Table 1 shows that in all the listed countries except Australia and Great Britain, more people have died working in the construction industry than in any other industries.

No one should die for constructing or maintaining a building or a bridge, not in the contemporary civilized world. Nothing should be more important than the protection of workers' lives if the construction industry is to be sustainable. In Hong Kong, perceived dangerous and unpleasant working conditions are considered to be a major barrier in attracting young people to replenish the ageing workforce of the construction industry (Tao et al. 2017). Measures and policies have been introduced to attract younger workers to join the construction industry, including increased wages and improved site safety. More stringent laws and regulations for onsite safety measures have been legislated and enforced by the Labour Department and the Buildings Department since an accident occurred during the demolition of the Wing On Building (early 2000s). In addition, since 1997, workers must receive mandatory occupational safety and health training before they can work on sites. However, progress in construction safety has been slow.

While the number of accidents continued to drop throughout the 21 years between 1995 and 2015, the number of fatalities did not show a similar decreasing trend since 2000. Table 2 shows the occurrences of accidents and fatalities, as well as the gross value of construction at constant (2000) market prices in Hong Kong for these 21 years. Both accident and fatality rates were very high during 1995-1999, when the Airport Core Program was near its completion and the construction industry reached its peak. Both rates have since decreased as the industry went into recession. It is suggested that there may not have been a real improvement in site safety. Accident rates declined simply when there was less work and workers were not required to work long hours. On the other hand, when there was more work, the increased demand on workers could not be readily met because the labor supply was inelastic. Hong Kong is not well known for innovation in technology or management to drive up total factor productivity. Hence, it is believed that the available workforces had to work extra-long hours to meet demand and were thus more accident-prone. For example, during the peak (1995), each worker produced $1.528 million of gross work per annum. This was the highest level of labor productivity in the 21-year period, and the accident and fatality rates both peaked during this time. Strong correlations were found between the accident/ fatality rates and the gross value of work per worker, defined as the gross value of construction work at constant (2000) prices divided by the number of site workers (Figure 1 and Figure 2). The correlation coefficient between the accident rate and gross value of work per worker and the correlation coefficient between the fatality rate and gross value of work per worker are 82% and 81% respectively, both significant at the 0.01-level (2-tailed). The results indicate that the higher the labor productivity (gross value of work per worker) is, the higher the accident and fatality rates are.

Previous research has studied different perspectives of construction safety in Hong Kong (Chan and Hon 2016; Chan et al. 2008; Wong et al. 2005; Yi and Chan 2014). Indeed, Zhou, et. al. (2015) in their extensive review of literature on construction safety identified 439 relevant papers published between 1978 and 2013. Of these papers, almost 20% were conducted in the United States, and Hong Kong was one of the other "notable countries or regions with significant number of studies". They found that Hong Kong had 28 papers published. However, there is no research on fatal accidents covering the entire industry over a long period. It is vital to understand where, when and how fatalities occur. This study covered fatalities only because all individual cases were reported by the local press. The data are thus in the public domain, and there is no problem of "under-reporting", where contractors do not report accident cases to avoid fines and penalties. Individual accident cases are tracked by the Labour Department, but these are not accessible to us due to confidentiality, despite our repeated calls. Nevertheless, this study covered the population of the worst cases of construction accidents, i.e., fatalities, so that further informed research can be conducted.

Working Hours

The issue of working hours is explored here, since we have identified statistically significant strong correlations between the fatality/accident rates and gross value of work per worker.

Weekly working hours around the world

There were two primary standards for weekly working hours across nations by the mid-twentieth century. At the end of World War I, the work week was generally limited to 48 hours (Lee, McCann, & Messenger 2007). By 1962, more countries adopted the 40-hour limit instead, according to a review on laws governing working time by the International Labour Organisation (Lee et. al 2007). Out of 93 countries, 35 had 48-hour limit while the others adopted the lower 40-hour limit for weekly work. Asia generally used to adopt the 48-hour limit, but then trended to the lower statutory hours during the 20th century, e.g. China adopted the 40-hour limit in 1995. To date, the 40-hour limit is the most prevalent standard (Lee et. al, 2007, Tucker & Folkard 2012). Working over 8 to 9 hours a day, and more than a total of 40 hours a week can be regarded as extended working hours (Tucker & Folkard 2012). However, there are a large number of workforces working more than 40 hours per week. With reference from the data of the Third EU Survey on Working Conditions in 15 European countries, Costa et al. (2004) reported that there were 84% of the employed and 44% of the self-employed working more than 40 hours weekly. In addition, Tucker & Folkard (2012) looked at 2005 labor statistics, and concluded that nearly one third of the workforces in the United States had regularly worked over 40 hours per week.

Hong Kong has not had laws governing the working hours in the construction industry. According to a survey conducted by UBS (2015), a banking group in Switzerland, Hong Kong had the longest working week of 71 cities. The average weekly working hours was 50.1, followed by the distant second, Mumbai, where the average was 43.8. The global average being 36 hours and 23 minutes, a Hong Kong employee typically worked 38 percent more hours. Construction was one of the 15 occupations covered by the survey. In their survey, a typical construction worker is "unskilled or semi-skilled laborer without technical training, approximate age and status: 25, single". The gross annual income was US$29,930 in 2015. The UBS (2015) made a sarcastic remark that "(a)ll workaholics should move to Hong Kong, where working hours average over 50 per week, with only 17 days of holiday annually. Those who like time off should consider finding a job in Paris, where people work only around 35 hours per week (in line with new government regulations) and have 29 days of paid vacation".

To address the community concerns over employees' long working hours in Hong Kong, the Government set up the Standard Working Hours Committee (SWHC) in April 2013. The SWHC would advise the Government "on the working hours situation in Hong Kong including whether a statutory SWH regime or any other alternatives should be considered" (Standard Working Hours Committee 2017). Understandably, this is a very controversial issue. There has been great divide between employers and employees. All the six employees' representatives have walked away from the negotiations ever since November of 2015 (Siu 2015). Finally, the Executive Council on 13th June, 2017 passed a proposal that employers will be required to enter into contract with their employees earning monthly salary of no more than HK$11,000 the number of working hours and the rate of overtime payment, which shall not be less than the regular rate (Li 2017). Unionists and workers have generally expressed anger at the proposal. Instead of having to comply with standard working hours, employers can negotiate with their workers the number of working hours and the overtime rate. Further, skilled construction workers these days are typically paid more than HK$11,000 a month. They are not even covered by this proposal. It is not anticipated that there would be any reduction or major change in working hours in construction in the foreseeable future.

Long working hours

Construction work in Hong Kong is often performed over long hours. According to a questionnaire survey of 92,933 on-the-job students from the Green Card Courses organized by the Hong Kong Occupational Safety and Health Council and the Construction Industry Training Authority between June 1997 and October 1999 (Occupational Safety and Health Council et. al 2003), 70 percent of the participants experienced overtime work. The results revealed that overtime working is common in the construction trades of Hong Kong. Long work hours in the construction industry have been attributed to unrealistic tendering and programming. Contractors are often required to complete construction projects within a tight schedule. Without bargaining power over their clients, contractors are often “bullied” into accepting whatever time is left after a prolonged design and pre-construction process. Consequently, a six- or even seven-day work week is not uncommon for contractors to complete projects on time, provided that they comply with the relevant laws and regulations, such as the Noise Control Ordinance by obtaining a Construction Noise Permit.

Long work hours not only have an adverse impact on health (Dembe et al. 2008; Burchell et al. 2007; Boisard et al. 2003; and Sparks et al. 1997) but have been identified as the cause of two major problems: site safety and recruitment. Sites have to be perceived to be safe enough to attract young people. However, there are more construction site fatalities in Hong Kong than in many other countries. Compared to other countries, Hong Kong was much worse than Australia in 2003-2013 and the US in 2014 (Safe Work Australia 2015; U.S. Bureau of Labor Statistics 2016a). Overtime working adversely affects site safety. Dembe et al. (2005) analyzed 110,236 job records in the United States and found that overtime work (over 40 working hours per week) increased the occurrence of occupational injury, with a 61% higher injury rate compared with non-overtime work. In addition, overtime work was identified as one of the factors that "clearly affect occupational accident rate" (Occupational Safety and Health Council et al. 2003). The odds ratios of getting injured for those who described themselves doing overtime work as "seldom", "sometimes" and "frequent" are 1.0, 1.19 and 1.23 respectively. These results are statistically significant (P-values<0.001).

Furthermore, long work hours often lead to fatigue. Fatigue was regarded by respondents of a questionnaire survey as the most critical factor resulting in accidents in oil and gas construction (Chan 2011). Fatigue is also suggested to be associated with physical and cognitive function among construction workers and therefore poses safety hazards to individuals (Zhang et al. 2015). Therefore, the ILO recommended that individuals should not work more than 48 hours per week (Tucker and Folkard 2012). In addition to injuries and loss of life, overtime work can also lead to economic loss. The cost for working time lost and days-off due to industrial injuries can severely impact productivity. In the survey of more than nine thousand participants from the Green Card Courses mentioned previously, the average annual time lost per person was 1.8 days, i.e., 165,730 working-days lost in a year (Occupational Safety and Health Council et al. 2003). This number is derived from only the sampled subjects only; the real number for the whole industry would be much larger.

The research gap

There are previous studies on construction safety in Hong Kong (Chan and Hon 2016; Chan et al. 2008; Wong et al. 2005; and Yi and Chan 2014) that have addressed different aspects of construction safety, e.g., fall from height, thermal environment and safety in the RMAA works. However, there is a lack of comprehensive analysis of the timing of accidents and how they occurred, covering both new works and RMAA sectors. Tucker and Folkard (2012) conducted a comprehensive review of previous research on the links between working time arrangement and health, wellbeing and safety. They concluded that many researches on working time arrangement relied on self-reported data and with relatively small samples. To address the problems above, this research investigated the potential impacts of the working time on construction site safety in Hong Kong by making reference to reported fatality cases. Additionally, this study covered all sectors of the construction industry, bridging the research gap of RMAA and the entire industry. A background study like this will inform further research on working hours and the related issues of fatigue, site safety and work-life balance.

METHODOLOGY

Data collection

The records held in the Labour Department, the statutory body to which all accident and fatal cases must be reported, were not made available to us. The Department claimed that it was due to data privacy reasons. We therefore had to resort to the public domain to identify fatal cases one by one to obtain the data. After comparing the search results from WiseNews and Factiva, two major search engines for local and regional newspapers, we found that WiseNews would return more reports than Factiva under the same key words. Thus, WiseNews was employed to collect contextual data of fatal incidents. The collection of data consisted of three stages. With reference to research of Hon and Chan (2013) on RMAA works, several possible key words (in Cantonese Chinese) were identified. After discussion with academic and industrial experts, more key words were identified to supplement the search. After a trial search of the year 2015, the final list of key words was finalized accordingly. The cases were reported in the press for a ten-year period between 1 January 2006 and 31 December 2015. Consequently, we found more cases from WiseNews than reported by the Labour Department. Previous literature indicates that trade, age, and day of incident are major factors associated with construction fatalities (Chan et al. 2008; Chi et al. 2005; Huang and Hinze 2003). Therefore, these factors were employed for data categorization and coding. A total of 256 cases were reported, and case details from different local newspapers were coded.

Data analysis

Data were analyzed to explore the patterns in fatal cases. In addition to descriptive statistics, Pearson correlation coefficients were utilized to analyze the relationships in the data. Principal Component Analysis (PCA) was performed to combine the number of variables into a smaller set of linear combinations, which are called "principal components", for easy interpretation of what is otherwise a larger set of variables. PCA is used here to identify the hidden factors as "collective terms" (Backhaus, Erichson & Weiber 2013) or "virtual variables" to highlight the most distinguish characteristics/variables that can describe these fatal cases. Technically speaking, it is a method for deriving sets of variables that collectively have the largest variance. The first set will have the largest variance, which will become less and less in the subsequent sets. As Wendler & Gröttrup (2016) explained, PCA "is a method for determining factors that can be used to explain common variance among several variables. It tries to reproduce the variance of the original variables (principal components) after determining subsets of them". PCA looks for "collective terms" (principal components) that can be described as "the general description" for the common variance (Backhaus 2011 and Wendler & Gröttrup 2016). Thus, principal component analysis (PCA) was performed to identify the combinations of variables that could best distinguish fatal cases.

Data collected from the press include the date and hour of the day when the fatal accident occurred, gender and age of victim, type of accident, and type and sector (public/private) of the construction project. Listwise deletion was adopted to exclude cases with missing data. Consequently, 225 cases were analyzed via PCA, with focus on the 8 variables from the dataset obtained through WiseNews.

While the purpose of PCA is "to find subsets of variables", the aim of cluster analysis is "to cluster objects" themselves (Wendler & Gröttrup 2016). Thus, in an attempt to distinguish the fatal cases into different groups and to explore the common features of them, cluster analysis was performed to identify the most distinguishable groups as in Chan and Hon (2016). Two-step cluster analysis was adopted to analyze both categorical and continuous variables, as found from data collected through WiseNews.

RESULTS

Descriptive statistics

Overall fatal incidents on construction sites in Hong Kong

Table 3 shows that there are more fatal accidents reported in WiseNews (Set 2) than from the Labour Department (Set 1). This may be due to the different definitions adopted by different sources. With reference to Table 3, one distinguishing figure from these two sets of data is the number of fatalities caused by "others". A total of 42 fatalities are included in Set 2, while there is none in Set 1. This research includes all types of fatalities on site, e.g., sudden death from uncertain causes, such as heart attack and heat stroke, are included in our set but not necessarily in that of the Labour Department. These sudden deaths may have occurred due to fatigue after long hours of hard work. All these cases are grouped under our "others" category. However, these types of deaths are not listed under any type of incidents by the Labour Department. Another notable difference is the fatalities resulting from "Struck by moving vehicle", in which Set 2 has 9 more cases than Set 1. The fatalities in Set 2 include death caused by vehicles not exactly on site but nearby, which may be the reason why there is a difference. "Fall of person from height" is the top killer of construction workers based on the data obtained from both WiseNews and the Labour Department. Wong et al. (2005) investigated all fall injuries in the Architectural Services Department's projects from 1994 to 2003 and provided recommendations for safety improvement. However, there has not been a discernible reduction in falls. In general, the differences in the numbers can be explained by the complexity of accidents. Site fatalities may occur from a chain of events and are thus categorized into different types by different sources. However, the local press has reported 34% more fatal cases than the Labour Department.

Hours of the day of the incidents

Construction workers in Hong Kong usually start work at 8:00 am and finish at 6:00 pm, with a one-hour lunch break at noon and a 30-minute tea break at 3:15 pm (Yi and Chan 2014). As shown in Figure 3 most fatal incidents occurred in late morning and early afternoon, that is, between 10:01 and 11:00, and 14:01 and 15:00, with 33 and 34 cases, respectively. These periods are two hours before and one hour after lunch, i.e., two hours after working in the morning and one hour after the lunch break. This is similar to the finding of Huang and Hinze (2003). They analyzed data provided by the US Occupational Safety and Health Administration (OSHA) between 1990 and 2001, and found that most accidents occurred “between 10:00 and 11:00 in the morning and between 13:00 and 14:00 in the afternoon”. An explanation for this timing is fatigue, which can affect the physical and cognitive functions of construction workers (Zhang et al. 2015). Fang et al. (2015) found a linear relationship between error rates and fatigue when the level of fatigue exceeded 20. The fatigue level of a subject in their study was measured by the Chinese version of the ‘Fatigue Assessment Scale for Construction Workers’ (FASCW), which was developed by Zhang (2014). It consisted of a three-dimension scale, which included “physical inactiveness”, “mental fatigue”, and “discomfort”. The participants indicated their perception in accordance with each dimension. The results were then put into reliability and validity test. Fatigue is also considered a leading risk in the construction industry. Wong et al. (2005) found that exhaustion or fatigue in construction workers is a main causal factor for fall incidents. The effects of fatigue may result from the effects of overtime work. Dembe et al. (2005) concluded that working more than 40 hours per week increases the risk of occupational injuries. Construction workers from Hong Kong normally work more than 48 hours weekly. The long work week can lead to cumulative fatigue, resulting in greater risk of occupational injury.

Days of the week of the incidents

Figure 4 shows the total fatal accidents by day of the week and by age distribution. Most fatal accidents between 2006 and 2015 occurred on Mondays and Tuesdays (43 cases on each), the beginning of the 6-day workweek, and most victims were aged 45 and above.

Wong et al. (2005) reported that, in general, Mondays were more prone to fatal accidents of all kinds, and they recommended that pre-work safety talks at the beginning of the week could be introduced to enhance safety on Mondays. Wednesdays, with 40 cases, have the second largest number of incidents. Apart from 7 cases without available data, the age distribution of the fatalities is also displayed in Figure 4. The age groups were categorized with reference to the Construction Workers Registration Authority and Hon (2012). As shown in Figure 4, the age groups of "45-54" and "over 55" have the most fatalities. This is consistent with the findings from The Current Population Survey in the US. The greatest number of fatal work injuries were in age groups "45 to 54" and "55 to 64", while the age group over 65 held the highest fatal injury rate in all industries (U.S. Bureau of Labor Statistics 2016b). In Hong Kong, victims who were older than 55 accounted for most of the fatal incidents that occurred on Saturdays (21 cases). Their physical conditions may not be as good as that of younger workers, and they may get tired sooner. They are thus more vulnerable to accidents after working for five days on site and are in need of more and/or longer breaks during a day's work, if not more training in preventive measures.

Fall of persons from height

Figure 5 shows the days fatal accidents occurred due to "fall of person from height", the leading cause of death. Among the 117 cases, most occurred on Mondays (24 cases), followed by Thursdays (20 cases) and Saturdays (17 cases). This type of fatality occurs at the beginning, the middle and the end of week, and there does not seem to be a specific pattern. However, Chan et al. (2008) found that Fridays had the largest number of fatal falls, followed by Tuesdays and Thursdays. This difference may be attributed to the different time series of their studies. This study has a longer and more recent time series compared to the previous two, thus providing updated results.

Months of the year of the incidents

As shown in Figure 6, July to October had the higher number of site fatalities. Similarly in Japan, August had the greatest number of fatal construction accident in 2015, 40 fatalities, followed by October, 35 cases (JISHA 2017). The month July in Hong Kong has the longest sunshine and the highest daily global solar radiation in the year. It has the hottest, most humid and longest sunshine (Hong Kong Observatory 2015), giving rise to a very unpleasant environment for work and making workers prone to site accidents. This hostile climate continues right into the autumn month of October and beyond. Heat stress is found to be a major occupational hazard to construction workers in Hong Kong (Chan et al 2012). In addition, for outdoor activities, rainfall can lead to wet and slippery floor surfaces, thus leading to more accidents (Kim et al. 2013). All these factors make July the most dangerous month for outdoor work in Hong Kong. The Labour Department (2005) reports that July and August are the most accident-prone. Wong et al. (2005) also found more fall injuries in the summer. To date, a number of controls have been put in place to address safety issues of working in hot and humid environments, e.g., anti-heat stress clothing and additional breaks.

However, the effectiveness of these controls needs to be monitored as they have been implemented for only a couple of years. In addition, the effect of long work hours remains unclear when working in hot and humid conditions. Further research should focus on the effect of fatigue on site safety, especially with respect to working in a hostile environment.

Age of victims

As indicated in Figure 7, apart from the 7 cases marked as 'Unknown', there are more deaths among the older groups, except for the group aged 60 or above. In addition, the correlation coefficient between age group and number of total fatal incidents is 0.829 and is significant at the 0.01 level. More aged workers get killed, likely due to the decline in physical and psychosocial conditions as manual workers are getting older. The number of deaths expectedly drops at the retirement age group of 60 and above. Those who continue to work may work fewer hours because it may take longer time for aged workers to recover from the strain of site work.

More aged workers died not only in absolute but also in relative terms. Figure 8 presents, for the 10-year period between 2006 and 2015, the proportions of the total fatalities to the total number of registered workers for each age group. The age groups of "45-49", "50-54", and "55-59" have higher percentages of fatalities, indicating that the aged workforce is more prone to site fatalities, especially the age group "45 to 59". This is also consistent with the findings from the United States Bureau. It is found that most victims were aged "45 to 54" and "55 to 64" (U.S. Bureau of Labor Statistics 2016b). Statistics from Japan's Industrial

Safety and Health Association indicated that in 2015, most fatal construction injuries occurred in the age group of "60 or above". There were 125 victims died at the age of "60 or above", followed by the age of "50-59" and "40-49", 73 and 58 cases respectively (JISHA 2017). However, our findings suggested that the age group of "45 to 59" had greater fatal injury rate instead of "45 to 64". In Hong Kong, workers older than 60 might still hold on to their registration but might not work as much as others, if they have not retired altogether. Otherwise, the majority of deaths were from the older workforce (aged 45-60), who may be more skilled and experienced, suggesting a dire consequence of aging laborers in the construction industry. In addition, the survey from the US covered all industries while our findings focus specifically on construction. It appears that being more skillful and experienced does not make up for the demands of a strenuous work site. There is, however, a relatively low ratio in the age group of "40-44". This is probably the "golden age", when a worker may still be physically strong enough to sustain the hardship of site work, yet experienced enough to avoid site accidents. However, in the younger group (aged 20-39), the younger the workers were, the less accidents they experienced, suggesting that for construction, the physical condition of the workers is more important than their years of experience in preventing accidents.

Principal component analysis

PCA analyzes and determines the principal components (PC) that account for the most variance and have the highest correlation with the original variables. The variance is represented by eigenvalues. The loading values represent the eigenvector in the extracted components and variables. Eigenvalues greater than 1.0 are usually adopted to extract the PCs (Field 2009). Four PCs were extracted. These four PCs together explain 61.976% of the variance (Table 4).

The four PCs were then rotated using the varimax method, as shown in Table 5, to assign components with associated variables that have high loading values and consequently high correlations. The PCs categorize and group the fatal cases into 4 groups described by a set of variables reduced from 8 to 4.

The first PC is strongly related to the sector and type of project, the second is related to gender and hour of the day of the incident, the third is related to month and age, and the fourth is related to day of the week. Hence, PCA suggests that the most distinguishing factor is the nature of the project. Indeed, the two variables “type of works” and “sector of site” have correlation coefficients greater than 0.5 with the first component. PC1 can be considered a “project component” as the two variables describe the nature of the construction project. Explaining almost one-fifth of the total variance, PC1 suggests that the nature of the project alone differentiates the analyzed fatal cases the most. Fatal incidents that occurred in RMAA works in the private sector form the most distinguishable group of fatal accidents. In Japan in 2015, small workplace that had 9 workers or below had the greatest number of industrial fatality in the construction sector. 183 industrial fatalities happened in this kind of small workplace, accounting for more than a half of the total fatal work injuries in construction (JISHA 2017). Likewise, a study on the fatal construction accident pattern of Taiwan found that small companies were under higher risk in fatal falls (Chi, Chang, and Ting 2005). Zhou, et. al. (2015) in their extensive review of literature on construction safety identified 439 relevant papers published between 1978 and 2013 also found that “accident rate is higher in small construction businesses than in larger ones”. They attributed this to the few resources that small construction businesses have, and the consequent difficulty in effectively performing construction safety management. RMAA works in Hong Kong usually were carried out in median and small workplaces with relatively small group of workers. In addition, RMAA works are often carried out by subcontractors which are median and small size of private companies. These characteristics are consistent with the findings from Japan and Taiwan. This type of construction project might have limited safety governance. RMAA works are dispersed, and it is difficult to legislate, impose and monitor safety standards and requirements. For example, contractors are required by law to employ safety officers on site. However, there is no such law stipulated for RMAA projects. The resources allocated to safety management, if any, could be minimal. Therefore, some safety measures commensurate with the nature of RMAA projects should be formulated and implemented to safeguard workers.

Hour of the day, month, and day of the week of the incident have the strongest correlations with PC2, PC3 and PC4 respectively, reflecting the most accident-prone timing of the incidents, as shown in Figures 3, 6 and 4.

Cluster analysis

Two-step cluster analysis was employed to analyze both categorical and continuous variables. After excluding 5 cases with large amounts of missing data, 251 cases were used for two-step cluster analysis.

The variables “month”, “day of the week”, “hour of the day”, “type of the incident”, “victim’s age” and “victim’s trade of work” were analyzed first. “Type of incident” and “victim’s trade of work” dominated all clusters, and the other variables had little effect on cluster formation. Therefore, these two variables were excluded in the two-step cluster analysis so that clusters could be formed. The variables “month”, “day”, “hour”, and “victims’ age” were then analyzed via cluster analysis, and 25% was employed for the noise handling. The data were found to be clustered into four groups. The average silhouette was 0.3, indicating that the cluster quality is fair. The predictor importance of the four variables was: Month (1.00) > age (0.96) > time (0.63) > day of the week (0.21).

Cluster 1: Accident occurred in the middle of the year (around July)
Median age of victims was 30-34
Accident occurred around 2:01-3:00 pm
Accident occurred in the beginning of the week

Cluster 2: Accident occurred around August
Median age of victims was 50-54
Accident occurred around 10:01-11:00 am

Accident occurred in the middle of the week

Cluster 3: Accident occurred around October

Median age of victims was 45-49, early 50s

Accident occurred around 4:01-5:00 pm

Accident occurred Thursday and Friday

Cluster 4: Accident occurred around March

Median age of victims was 50-54, and 55 above

Accident occurred around 2:01-3:00 pm

Accident occurred in the beginning of the week

The results of the cluster analysis suggest that:

1. The variable “month of the incident” has the strongest predictor importance, followed by “age of victim”, “time of the incident”, and “day of the week of the incident”. This is consistent with the PCA results. Male workers dominate the manual workforce in construction and hence the number of fatalities. Accordingly, “gender” was excluded from this cluster analysis.

2. Cluster 1 includes cases where the victim’s median age was 30 to 34 years old, accidents that occurred at the beginning of the workweek at approximately 2:01-3:00 pm and in the middle of the year. Chan and Hon (2016) found that young workers were prone to accidents in RMAA projects after, somewhat paradoxically, a long rest from the weekend. Both findings suggest that a safety briefing session should be held on Mondays to remind workers, especially younger workers, of the safety measures, and a

more comprehensive safety check should be performed at the start of the week. Clusters 2, 3 and 4 include victims whose ages are between 45 and 54. Table 6 shows that these workers are generally prone to accidents after the age of 45. More training should be provided for aged workers so that they can look after their physical well-being as they are aging.

3. In terms of the hour of the day of the incident, Clusters 1, 3 and 4 have accidents that occur in the afternoon. Workers might become fatigued after long hours of work. Measures such as longer and more frequent breaks should be introduced to help workers recover to enhance site safety. Day of the week of the accident is another dimension of the dataset. However, both PCA and cluster analysis suggest that its weighting is less than that of the other variables. Finally, as expected, more fatal accidents occurred in summer.

4. There are more fatal accidents in the private sector (151) than in the public sector (79). All clusters involve private sector projects. In addition, the results of another two-step cluster analysis on “sector” and “type of work” confirm the findings of our PCA, that is, RMAA projects in the private sector are prone to fatal incidents.

LIMITATION AND FUTRUE RESEARCH

This is the first study to explore the overall fatalities in Hong Kong with a focus on the relationships between the recorded variables. As WiseNews covers press reports, the data may not be consistent with those provided by the government. However, the findings were derived from the most comprehensive set of publicly available fatality reports. This study provides insight for future research on, for example, the contextual situations and the chain of events that lead to the occurrence of not only construction fatalities but non-fatal accidents, finally providing solutions to reduce construction fatalities and accidents in Hong Kong and beyond. However, there are limitations in the study. WiseNews were relied on press reports. Firstly, there might be missing cases when the press did not follow up non-fatal cases, where the victims died later. Secondly, the cause of death for some cases could not be ascertained. For example, the fall of persons to death might be primarily due to sudden stroke or heat stress, rather than carelessness. Thirdly, the data were limited to manual construction workers of Hong Kong in a ten-year period. Further research into boarder geographical regions and longer periods would help put this study into a wider context.

CONCLUSION

This study explored all the reported fatalities in the construction industry of Hong Kong from 2006 to 2015. Two hours before and one hour after lunch, or two hours after working in the morning and one hour after the lunch break, were found to be more fatality-prone on construction sites. The age groups of "45-49", "50-54", and "55-59" dominated the fatalities, in both absolute and relative numbers. The results highlight the acute problems arising from labor aging and labor shortages. July was the most fatality-prone month. As shown by the statistical analyses, an exhausted and fatigued worker would be particularly exposed to dangers, especially during the hot and humid season. PCA and cluster analysis suggested that safety governance should be focused on RMAA projects from the private sector. Training or retraining programs should be provided to manual works aged 45 and beyond. Improved safety briefing sessions should be introduced on Monday mornings for young workers. More rests and breaks, and avoidance of high risk work in the afternoons, especially in the hottest months (July and August) should be planned at the beginning of the project to help enhance site safety. Our findings on the timing of the accidents, age of the victims and identification of RMAA sector as the most accident-prone are similar to what have been found elsewhere. This is not unexpected because the construction industry has something in common among countries around the globe. Two of them are: (1) the labor aging and shortage problems, especially in advanced economies, and (2) building contractors, especially maintenance contractors, are usually small indigenous local firms. This in turn raises more questions on what we should do to rectify the problems. The provision of further training and of more breaks during the hot season should be done immediately. However, for the long-term, we have to address the structural problems of labor shortage and labor-intensiveness of the building and maintenance sector through capital-labor substitution. Further mechanization, automation and prefabrication have to be explored to reduce the need of labor and working hours. This labor supply crisis has indeed given us the opportunity to seriously reflect on what has to be done. Is there an optimal mix of labor and technology that will sustain the construction industry? What would be the changes in the required skill sets and the consequences for training? Based on the findings presented here, the next stage of our research will involve different stakeholders to explore the short and long term, and the more specific, solutions. The talk of reforming the industry cannot remain just talk forever. With the highest fatality and the longest working hours, and hence the possible connection between the two, Hong Kong probably provides the extreme case for further comparative study. This study nevertheless suggests that the construction industry around the globe probably shares more commonalities of accidents than differences. Surely one can learn from each other to address the acute problem of safety in construction.

DATA AVAILABILITY STATEMENT

Some of data generated or analyzed during the study are included in the published paper. Other data generated or analyzed during the study are available from the corresponding author by request.

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