Statistically Reviewing Construction Accidents within South Australia during 2002-2013

M. Reza Hosseini[a], Mojtaba Maghrebi[b*], Raufdeen Rameezdeen[c], S. Travis Waller[b]

[a]School of Architecture and Built Environment, Deakin University, Melbourne, Australia
[b] School of Civil and Environmental Engineering, University of New South Wales (UNSW), Sydney, Australia
[c] School of Natural and Built Environments ,University of South Australia, Adelaide, Australia
E-mail: maghrebi@unsw.edu.au

ABSTRACT

One of the main concerns of construction site managers, as well as insurance companies in the construction industry is the large number of construction accidents. In this study all the accidents occurred on construction sites within the period of 2002-2013 in South Australia (SA) have been considered to investigate the main factors affecting the occurrence of construction accidents. To this end, the available database was analysed from different prospective such as the year of accident, month of accident, time of accident, new worker (Yes/No), age of worker and size of the company. The findings revealed that newly-introduced regulation in SA has had a positive effect in reducing the number of accidents on construction sites. Nevertheless, the findings regarding the impacts of the level of experience of workers and the month in which accidents had happened showed contradictory results against the findings of previous studies. The study concludes with proposing future areas of research on the topic.

Keywords – Construction Accidents, Construction Projects, South Australia

1 Introduction

The safety record of the construction industry is very poor compared to other industries [1]. Occupational injury rates in construction are among the highest of all major industries [2] due to the unique nature of construction projects [3]. Construction is risky because of outdoor operations, poor working conditions, the use of many different resources, working in tough environments such as; noise, vibration, dust, manual handling of materials, working at height and the continual change of conditions from project to project [4,5]. In addition, the coordination of different contractors, sub-contractors and operations during construction projects can result in increased risk of injuries [5].

Koehn, et al. [6] and Zakaria, et al. [7] showed that construction accidents occur as a result of negligence of safety precautions by the workers or unavailability of the same. Researchers emphasize safety culture as an important element in accident prevention [8]. Some of the important steps in preventing a hazard are pre-planning for safety, safety orientation, safety training and a written safety policy. To prevent accidents from recurring, there is also the need to establish post investigation of the causes [9]. In that sense, a detailed evaluation and a critical analysis of accidents in the construction industry is of immense importance. Against this backdrop, previous studies on construction accidents have looked into the causes, types of injuries and their magnitude, place of injury and the type of trades that are vulnerable [10-12]. By analysing past accidents in detail, the underlying causes could be unearthed in order to learn lessons from them and to devise suitable mitigation measures. According to Gibb, et al. [13], "Workplace safety improvements are shaped by knowledge and assumptions about how accidents happen".

However, most of these past studies have used very complicated statistical techniques which are like a black box that does not lend an easy understanding of the interrelations between these factors. Data visualization is a very simple yet powerful technique that provides a safety analyst with a wealth of transparent information [14] through the interrelationships in order to provide meaningful mitigation measures. In that context, analyses of a relatively less explored South Australian construction industry's accident record for the last 13 years to visualize the interrelationships between various factors that precede an accident might be of great value

to the body of knowledge. The present study comprised analysing a total of 25,941construction accidents. Thus, the findings were deemed valuable for research purposes in view of the practical origin of the data and its large sample size. In practical terms, findings achieved through visualisations of data in the present study would be readily translated to empirical guidelines in order to manage construction projects in a safer environment.

2 Literature Review

Accident on a construction site is an uncontrollable occurrence, which results in injuries or damages [15] and has been regarded as one of the main problems adversely affecting construction projects [16]. As a result, identifying the main causes of accidents has been an active field of research in the construction context. Davies and Tomasin [17] have identified falls, struck by or struck against objects, lifting and carrying, over-extension, machinery, electricity, fire and explosion and transport as the major causes of construction accidents. In Japan, South Korea, Taiwan and Singapore, the most common type of construction accidents was due to falling from a height [18]. Other researchers also stressed the role of falling from a height as the primary source of accidents [19]. Similarly, Wang, et al. [16] estimated that half of the construction accidents involved falling from heights and being struck by objects. Likewise, it was revealed that the highest rates for compensation cases involving medical costs were for falls from height, being struck by an object and lifting/movement. Struck-by accidents primarily involve workers struck by equipment, private vehicles, falling materials, vertically hoisted materials, horizontally transported materials, and trench cave [20]. Contact with electricity or electric discharge also found to be a major cause of construction accidents [19].

Apart from determining the causes of accidents, a number of investigators have focused on ascertaining the major factors affecting the occurrence of accidents and mapping out the relationship between accidents and certain characteristics as described next.

Holland and Hinze [21] examined the effects of time on accidents in a construction setting and found no significant relationship. However, Kines [22] identified that unlike non-fatal falls, a disproportionate number of fatal falls have occurred in the afternoon hours, particularly between 1:00 p.m. and 3:59 p.m. [23] also provides evidence that work hours are linked to injury frequency of young male workers. As another factor affecting accidents, Wang, et al. [16] identified that the workers on construction sites are mostly in the age group of 20-50 years and there is no significant relationship between accidents and age. Likewise, according to Al-Tabatabai [24] the age group of 25-35 are highly exposed to construction accidents. On the contrary, Li [25] revealed that majority of serious injuries come from the age group of 47-56.

Chi, et al. [26] identified that inexperienced workers and those working for smaller companies were found to be at greatest risk of fatal falls. According to Wang, et al. [16], accidents happened at a lower rate for workers with shorter than 1 year and longer than 11 years of experience and most accidents involved persons with 1 to 10 years of work experience. From another vantage point, Ai Lin Teo, et al. [27] identified two main reasons for unsafe work behaviours as lack of awareness about safety (do not know) and poor attitude towards safety (do not care). According to Bielby and Read [28], half of all people who die on a construction site have only been working there for less than two weeks.

In the same vein, according to Kamardeen [29], most of the accidents in the construction industry occur due to negligence in the implementation of safety measures recommended by the authorities. That is, many accidents in the construction sites can be avoided through proper safety and health management [30]. Traditionally, legislation and regulation are the main drivers to the development of health and safety risk management [31]. However, evidence shows that when selecting an appropriate risk control, targeting hazards at their source to act on the work environment is more effective than controls that change worker behaviour [1]. Moreover it is has been established that the elimination of potential accidents requires identification of unsafe practices on site, as approximately 90% of all workplace injuries can be traced back to unsafe practices and behaviours [32]. Further illustrating the importance of risk identification, [33] suggested that risk management failings are often the cause of construction accidents suggesting that most accidents are foreseeable and preventable.

As discussed above, investigating the factors affecting occurrence of accidents on construction sites and unearthing the relationships between accidents and certain characteristics becomes very relevant as the driving force behind conducting the present study.

3 Methods

Data for the present study was provided by the state government's occupational health, safety and welfare agency *i.e. SafeWork South Australia*. The agency is the entity in charge of the prevention of occupational accidents and diseases in South Australia and associated compensations. Data was an assemblage of South Australian construction workers' claims for compensation collated by *WorkCover SA* (a state agency responsible for accident compensation under the Workers Rehabilitation and Compensation Act of 1986) for the purpose of policy analysis based on the reports

recorded by WorkCover SA, The database was made available to researchers only after agreeing to sign a confidentiality agreement according to which any use of data should not reveal the identity of victims. The data covered the recorded details of 25,941 accidents. Each accident was associated with a wide range of values including the time, date of occurrence, incurred cost, age of injured/deceased worker, gender, nationality, number of lost working days, status of disability, type of work and level and type of injury. The available database covered all the reported construction accidents occurred within the state of South Australia (SA) in Australia within the period of 2002-2013. In this paper the construction accidents are analysed based on a number of attributes as mentioned above.

At the outset, the database was cleaned in order to deal with the detrimental effects of missed values. This took a considerable amount of time and effort due to the fact that the dataset was recorded and entered manually and in light of the rather large size of the database. For analysing the information and extraction of results out of available data, *data visualization* approach was implemented. This method was regarded as justifiable considering its approved abilities in data exploration through portraying available data in easily-comprehensible visual forms. That is, such visualizations facilitates directly interacting with data, getting insight into the meaning of data, and reaching conclusions as asserted by Keim [14]. As suggested by Keim [14] data visualization could be deployed as a 'hypothesis generation process' when available data is noisy or nonhomogeneous.

Besides implementing data visualization yields fast and trustworthy results compared to similar methods. As no a priori hypothesis was available about the data in the present study, an exploratory data visualization procedure was pursued. This involved searching, visualizing and interpretation of the data to uncover underlying, useful and implicit facts as termed by Keim, et al. [34]. For the purpose of visualizing data, histograms and bar-plots were used as the most widely-accepted and understandable visual representations of data as pointed out by Elmqvist, et al. [35].

4 Results and Discussions

4.1 Effects of regulations

The association between the year of accidents and the number of accidents was considered as illustrated in Figure 1. As inferred, the number of accidents in the period of 2002-2011 are more or less. Yet, this value was shows a noticeable drop from 2012 onward. This is in consistency with observations made by Cooke and Lingard [36] according to which accidents in 2008-09 in the Australian construction industry accounted for 11% of all compensation claims.

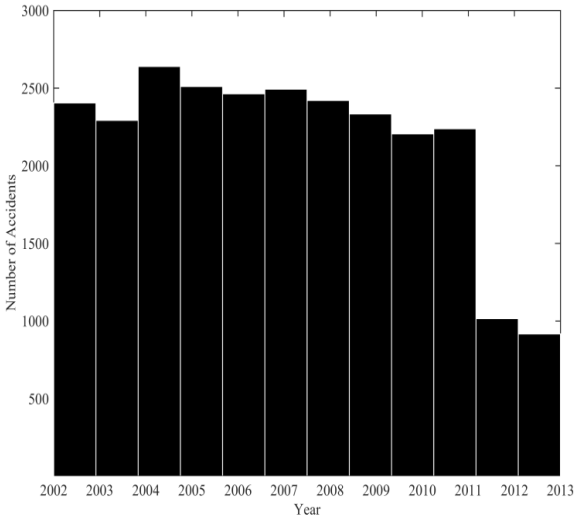

Figure 1 Number of construction accidents for each year (2002-2013)

The drop in the number of accidents could be attributed to the impacts of regulations introduced in SA. That is, the federal government of Australia harmonized the Work Health and Safety (WHS) legislation from a wide range of jurisdictions and introduced a new national model of Work Health and Safety Legislation of 2011. With South Australia on board as part of the Intergovernmental Agreement, the state government enforced the new WHS legislation with effect from the first January 2013. The package included the:

- Work Health and Safety Act 2012 (SA); and
- Work Health and Safety Regulations 2012 (SA).

The driving force behind necessity of harmonizing the legislation was the unreasonable burden of rising in business costs because of repetitive and overlapping regulations in different jurisdictions. Harmonized WHS regulations are based on the premise that it is vital to distribute and share the safety-related responsibilities between construction professionals as well as designers. Even though it might be too early to conclude, the noticeable reduction in number of accidents from 2012 onwards may be party related to the introduction of this new regulation package in which designers are being held accountable for health and safety accidents. This is described by many researchers as a good move towards providing a safer work environments for construction workers [37] as acknowledged by the findings of the present study. The findings also reaffirm the findings of previous studies regarding the substantial effects of legislation and regulation as the main drivers to comply with health and safety principles as denoted by Aneziris, et al. [31].

4.2 Effects of time

As illustrated in Figure 2, in January and December a relatively fewer number of accidents occurred. This issue could be justified in view of the New Year holidays inasmuch as commonly construction sites are not 100% active during these two months with fewer workers working on-site. Nevertheless, the findings of a study in the US [38] revealed that the largest number of accidents on construction sites occurred in June whereas in March the lowest number of accidents were observed. Such a glaring difference between the results calls for conducting further research alongside considering the factors affecting weather or temperature conditions among the potential factors for devising preventive plans.

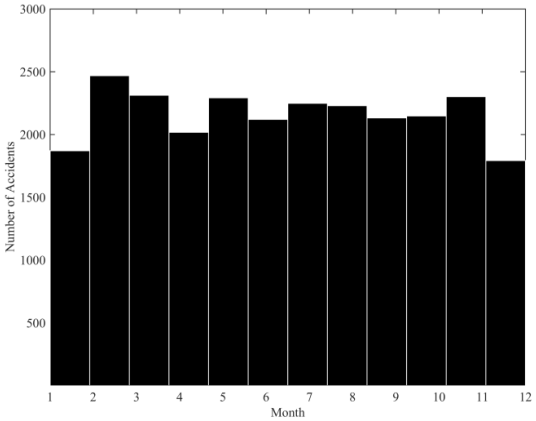

Figure 2 Number of construction accidents for each month

Figure 3, illustrates the number of construction accidents during 24 time slots that each one covers an hour of a day. Among the late working hours, the period of 2-3 am contains relatively more accidents. However, during the normal working hours an interesting pattern is surfaced. Assuming 6-7 am as the starting time for first shift in a day, the number of accidents increases by 10 am and will remain constant till 12 pm. A dramatic drop is observed in the number of accidents prior to 2 pm. The number increases between 2-3 pm, however after this time, the number of accidents gradually decreases, and following a significant drop after 4 pm. Figure 3 is indirectly reflective of the working loads during an ordinary working day on construction sites and could be attributed to the detrimental effects of fatigue of workers in occurrence of accidents after working for 2-3 hours as stated by [33].

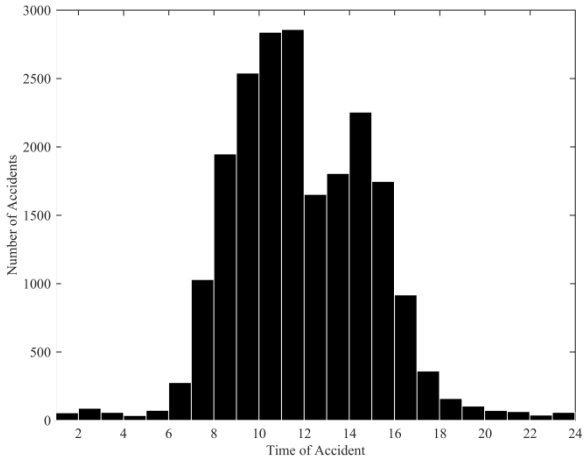

Figure 3 – Number of construction accidents for each time slot

4.3 Effects of company size

Another interesting achievement is related to the relation between the size of company (number of employees) and number of accidents as illustrated in Figure 4. It can be perceived that most of accidents occur in projects delivered by companies with fewer than 25 employees. Likewise, by increasing the size of company the number of accidents is decrease meaningfully.

It could be proffered that in South Australia, accidents usually occur in companies with fewer than 25 employees, which are titled as small enterprises within the Australian context [39]. This observation reaffirms the stances of Chi, et al. [26] arguing that workers in small companies are more prone to accidents compared their counterparts working for large-sized enterprises.

4.4 Effects of workers' age

As inferred from Figure 6 that while the number of accidents for workers within 20-40 years old are more or less the same, by increasing the age of workers the number of accidents reduces significantly. This is particularly meaningful for workers in their 50s and 60s. Drawing any conclusion based on observing this trend requires more investigation as according to Wang, et al. [16], most of site-based construction workers are in their 20s and 30s as the reason behind high number of accidents occurring for these age groups.

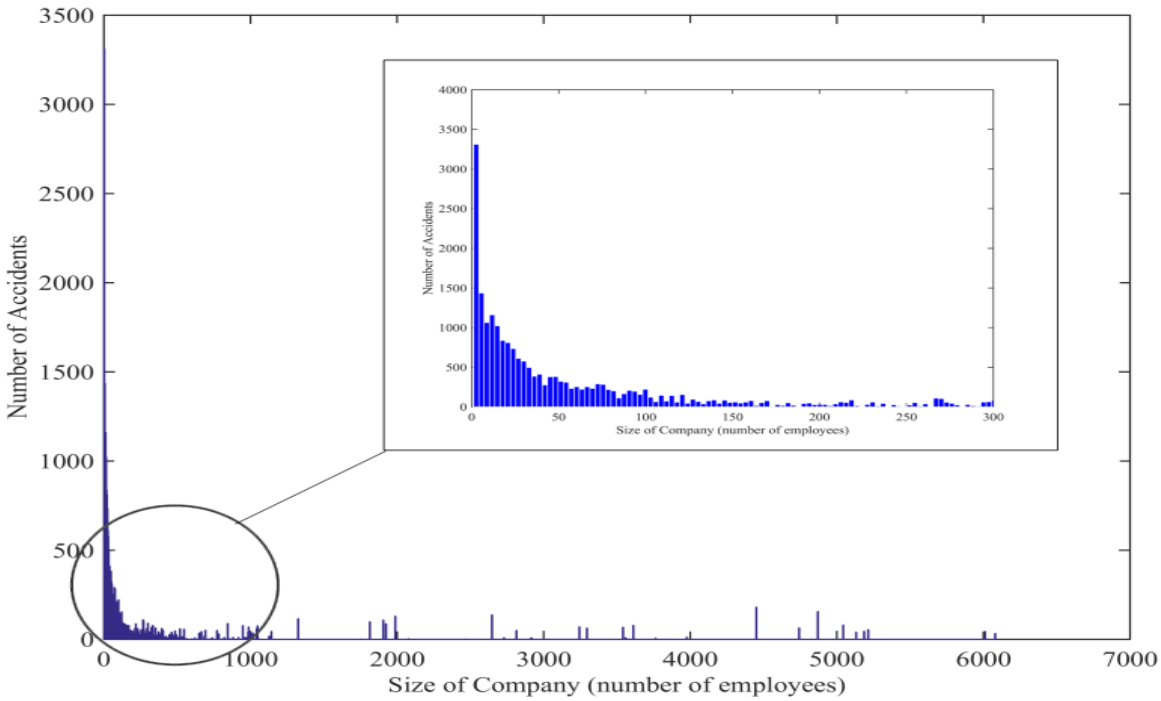

Figure 4 – Relation between the number of construction accidents and size of company

Figure 5 also acknowledges the arguments by Al-Tabatabai [24] asserting that workers in the age group of 25-35 are highly exposed to accidents on construction sites. This warrants focusing on implementing specific preventive measures for the mentioned age group. On the other hand, decreasing the number of accidents for older workers might be a manifestation of the effects of experience of workers as described next.

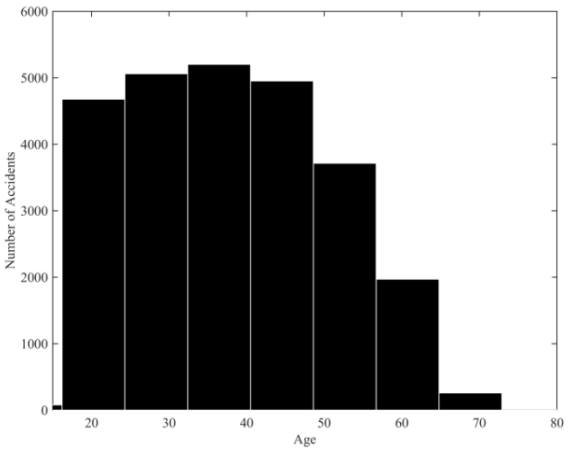

Figure 5 – Relation between age of injured/died workers and the number of construction accidents

4.5 Effects of experience

The dichotomy as illustrated in Figure 6 does not support the view idea that new workers are more prone to danger than experienced workers. That is according to the results of the present study experienced workers were involved in around 80% of accidents.

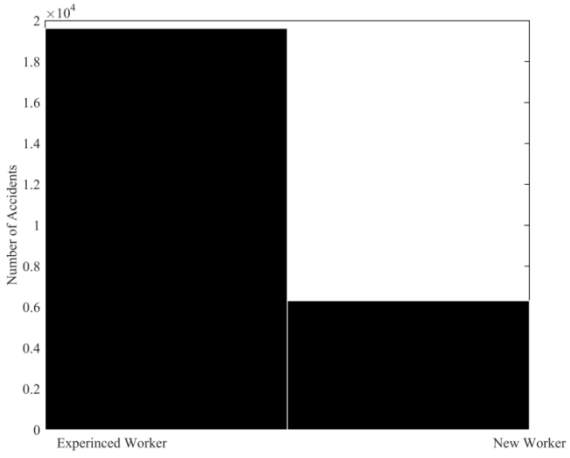

Figure 6 – Number of experienced/new worker involved in construction accidents

The results in South Australia are not in line with the findings of the study by Im, et al. [40] according to

which nearly around half of fatal accidents occurred within newly-employed construction workers within a month after employment pointing to the effects of lack of experience and knowledge of workers of the working conditions on sites. Likewise, many studies have reported the same findings supporting the view that an increase in age of the worker is positively correlated with the degree of accident severity suffered [10,11]. However, the findings of this study acknowledge the observations in South Australia i.e. [12] indicating that unexperienced workers were involved in merely 5% of serious accidents. Another justification for this observation is offered in light of the dominance of the aging workforce in the South Australian construction industry as asserted by Hosseini, et al. [41].

4.6 Fatal accidents

One of the critical aspects of the database is the number of fatal accidents. Figure 7 illustrates the records of fatal accidents in South Australia among a total of 25,941 accidents. This shows that among all accidents only 36 accidents claimed life. Thus, less than 2% of accidents were fatal in nature in the South Australian construction industry. However this number is still unacceptable and is deemed a warning. On the other hand, evidence shows that different circumstances and causes are the sources of these two types of accidents. This warrants devising different mitigation plans as argued in great length by Gibb, et al. [13].

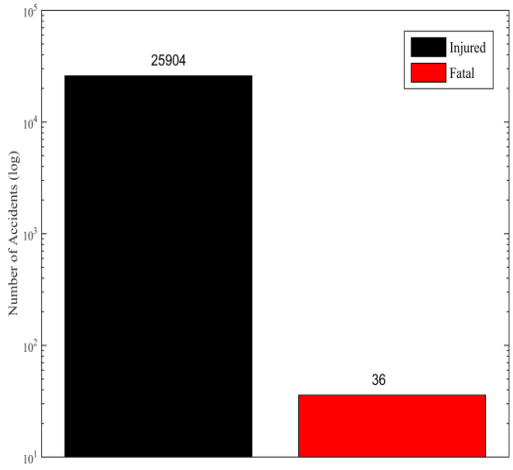

Figure 7 – Number of injured/fatality accidents

Conclusion

The findings of the study calls for conducting further research and investigation in view of the noticeable discrepancies differences between the results of this study and findings of prior investigations. The findings partially acknowledge the positive effects of newly-introduced WHS regime in South Australia in providing a safer environment on construction sites. Furthermore, the findings highlights the outmost importance of taking measures to ensure the safety of construction workers working for SMEs in light of the results of the present study confirming the association between the size of the company and accidents occurrence.

On top of that, the findings of the present study bring to light fertile grounds for future research inasmuch as the opposing results pertinent to the impacts of age of workers, level of experience of workers and time of fatal accidents. Additionally, specific investigations to map out the conditions and factors as the causes of fatal accidents should be considered as a very relevant area for future studies on the topic.

References

[1] M. Charles, J. Pillay, R. Ryan, Guide to Best Practice for Safer Construction: Literature Review from Concept to Completion, Australia: Cooperative Research Centre for Construction Innovation (2007).

[2] M.M. Lehtola, H.F. van der Molen, J. Lappalainen, P.L. Hoonakker, H. Hsiao, R.A. Haslam, A.R. Hale, J.H. Verbeek, The effectiveness of interventions for preventing injuries in the construction industry: a systematic review, American journal of preventive medicine 35 (1) (2008) 77-85.

[3] C. Tam, S. Zeng, Z. Deng, Identifying elements of poor construction safety management in China, Safety Science 42 (7) (2004) 569-586.

[4] R.M. Choudhry, D. Fang, S. Mohamed, The nature of safety culture: A survey of the state-of-the-art, Safety Science 45 (10) (2007) 993-1012.

[5] A. Pinto, I.L. Nunes, R.A. Ribeiro, Occupational risk assessment in construction industry–Overview and reflection, Safety Science 49 (5) (2011) 616-624.

[6] E.E. Koehn, R.K. Kothari, C.-S. Pan, Safety in developing countries: professional and bureaucratic problems, Journal of Construction Engineering and Management 121 (3) (1995) 261-265.

[7] Z. Zakaria, Z.H. Hussin, N. Noordin, Z. Zakaria, Accidents at the Construction site in Northern Area: Malaysian Experienced, Management Science and Engineering 4 (3) (2010) 106-116.

[8] T.M. Toole, Construction site safety roles, Journal of Construction Engineering and Management 128 (3) (2002) 203-210.

[9] J. Hinze, G. Wilson, Moving toward a zero injury objective, Journal of Construction Engineering and Management 126 (5) (2000) 399-403.

[10] M.A.C. López, D.O. Ritzel, I. Fontaneda, O.J.G. Alcantara, Construction industry accidents in Spain, Journal of safety research 39 (5) (2008) 497-507.

[11] A.L. Arquillos, J.C.R. Romero, A. Gibb, Analysis of construction accidents in Spain, 2003-2008, Journal of safety research 43 (5) (2012) 381-388.

[12] J. Dumrak, S. Mostafa, I. Kamardeen, R. Rameezdeen, Factors associated with the severity of construction accidents: The case of South Australia, Australasian Journal of Construction Economics and Building 13 (4) (2013) 32-49.
[13] A. Gibb, H. Lingard, M. Behm, T. Cooke, Construction accident causality: learning from different countries and differing consequences, Construction Management and Economics 32 (5) (2014) 446-459.
[14] D.A. Keim, Information visualization and visual data mining, Visualization and Computer Graphics, IEEE Transactions on 8 (1) (2002) 1-8.
[15] J.C. Laney, Site safety, Longman Inc., New York, NY, 1982.
[16] Y. Wang, Y. Zhang, S.W. Poon, H. Huang, A study of construction site accident statistics, Proceedings of Triennial Conference CIB W099: Implementation of Safety and Health on Construction Sites, 2002, pp. 223-227.
[17] V.J. Davies, K. Tomasin, Construction safety handbook, Thomas Telford Ltd., London, 1996.
[18] R. Navon, O. Kolton, Algorithms for automated monitoring and control of fall hazards, Journal of computing in civil engineering 21 (1) (2007) 21-28.
[19] F.K. Wong, A.P. Chan, M.C. Yam, E.Y. Wong, K.T. Tse, K.K. Yip, E. Cheung, Findings from a research study of construction safety in Hong Kong: Accidents related to fall of person from height, Journal of Engineering, Design and Technology 7 (2) (2009) 130-142.
[20] J. Hinze, X. Huang, L. Terry, The nature of struck-by accidents, Journal of Construction Engineering and Management 131 (2) (2005) 262-268.
[21] N. Holland, J. Hinze, Daylight Savings Time Changes and Construction Accidents, Journal of Construction Engineering and Management 126 (5) (2000) 404-406.
[22] P. Kines, Construction workers' falls through roofs:: Fatal versus serious injuries, Journal of Safety Research 33 (2) (2002) 195-208.
[23] R. Jane Loudoun, Injuries sustained by young males in construction during day and night work, Construction Management and Economics 28 (12) (2010) 1313-1320.
[24] H.M. Al-Tabatabai, Analyzing construction site accidents in Kuwait, Kuwait J. Sci. Eng 29 (2) (2002) 213-238.
[25] R.Y.M. Li, Workers' Compensation for Non-fatal Accidents on Non-fatal Accidents: Review of Hong Kong Court Cases, Asian Social Science 5 (11) (2009) p15.
[26] C.-F. Chi, T.-C. Chang, H.-I. Ting, Accident patterns and prevention measures for fatal occupational falls in the construction industry, Applied ergonomics 36 (4) (2005) 391-400.
[27] E. Ai Lin Teo, F. Yean Yng Ling, D. Sern Yau Ong, Fostering safe work behaviour in workers at construction sites, Engineering, Construction and Architectural Management 12 (4) (2005) 410-422.
[28] S. Bielby, J. Read, Site safety handbook, Construction Industry Research and Information Association, London, 2001.
[29] I. Kamardeen, Strategic safety management information system for building projects in Singapore, Engineering, Construction and Architectural Management 16 (1) (2009) 8-25.
[30] S.-H. Lin, W.-J. Tang, J.-Y. Miao, Z.-M. Wang, P.-X. Wang, Safety climate measurement at workplace in China: A validity and reliability assessment, Safety Science 46 (7) (2008) 1037-1046.
[31] O.N. Aneziris, E. Topali, I.A. Papazoglou, Occupational risk of building construction, Reliability Engineering & System Safety 105 (2012) 36-46.
[32] E.A.L. Teo, F.Y.Y. Ling, A.F.W. Chong, Framework for project managers to manage construction safety, International Journal of project management 23 (4) (2005) 329-341.
[33] R. Haslam, S. Hide, A.G. Gibb, D.E. Gyi, T. Pavitt, S. Atkinson, A. Duff, Contributing factors in construction accidents, Applied ergonomics 36 (4) (2005) 401-415.
[34] D.A. Keim, F. Mansmann, J. Schneidewind, H. Ziegler, Challenges in Visual Data Analysis, Tenth International Conference on Information Visualization, 2006, pp. 9-16.
[35] N. Elmqvist, P. Dragicevic, J. Fekete, Rolling the Dice: Multidimensional Visual Exploration using Scatterplot Matrix Navigation, IEEE Transactions on Visualization and Computer Graphics 14 (6) (2008) 1539-1148.
[36] T. Cooke, H. Lingard, A retrospective analysis of work-related deaths in the Australian construction industry, ARCOM Twenty-seventh Annual Conference, Association of Researchers in Construction Management (ARCOM), 2011, pp. 279-288.
[37] R. Johnstone, Harmonising occupational health and safety regulation in Australia: The first report of the national OHS review, (2008).
[38] I.B. Horwitz, B.P. McCall, Disabling and Fatal Occupational Claim Rates, Risks, and Costs in the Oregon Construction Industry 1990–1997, Journal of Occupational and Environmental Hygiene 1 (10) (2004) 688-698.
[39] M. Hardie, G. Newell, Factors influencing technical innovation in construction SMEs: an Australian perspective, Engineering, Construction and Architectural Management 18 (6) (2011) 618-636.
[40] H.-J. Im, Y.-J. Kwon, S.-G. Kim, Y.-K. Kim, Y.-S. Ju, H.-P. Lee, The characteristics of fatal occupational injuries in Korea's construction industry, 1997–2004, Safety Science 47 (8) (2009) 1159-1162.
[41] M.R. Hosseini, N. Chileshe, G. Zillante, Investigating the factors associated with job satisfaction of construction workers in South Australia, Australasian Journal of Construction Economics and Building 14 (3) (2014) 1-17.