A Conceptual Model for Predicting Construction Worker Injury

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***Abstract*—**Construction is a dangerous industry globally, with high rates of fatal and non-fatal injuries. However, there is paucity of analytical research that considers the predicators of injuries among construction workers in South Africa construction industry and in the developing countries. The objective of this study was to review existing research literature to identify the variables that are predictors of occupational injuries among construction workers. It also aimed to identify the gaps that exist in the current literature. The review spanned two decades between the periods January 1995 to 2015 and was based on a systematic keyword combination search in two databases that is- emerald and science direct and in google. Twenty one quantitative and mixed method research studies were justified to be relevant for analysis in this current study. They were analysed using thematic content analysis, by identifying themes. All the studies reviewed had different predictors of construction workers injury. Furthermore, no study identified the leadership characteristics of the different construction workers especially the tradesmen, hence these are major gaps identified in the current literature. Despite the gaps identified, five broad themes that are perceived to be predictors of construction workers injuries were identified, these are: work related variables, demographic variables, unsafe health and safety (H&S) behaviour, poor safety climate, and psychosocial factors. This paper finally proposed a conceptual model for construction worker injury occurrence.

***Index Terms*—**conceptual, injury, predictor, worker.

I. Introduction

The construction industry is one of the critical pillars of social and economic development in the underdeveloped, developed and developing countries.

The construction industry contributed about 2.7% year on year of the total Gross Domestic Product (GDP) to the South Africa economy in third quarter of 2014 [1]. Hence, the construction industry importance and roles in the development of the economy of any nation can never be underestimated.

However, despite its importance to the social economic development of different countries its construction health and safety (H&S) performance has for many years been a major problem and concern to industry stakeholders [2] [3] largely because construction projects are generally complex and hazardous. They are complex [3] because of the extensive use of sophisticated plant, equipment, modern methods of construction, and its multidisciplinary workforce and multi-tasked aspects of its project team and workforce [4]. The construction industry is hazardous because of the high incidence of accidents and fatalities [5]. It is further opined that when compared with other labour intensive industries, construction industry has historically experienced a disproportionately high rate of disability injuries and fatalities for its size [6]. Further, construction workers were two to three times more likely to die on the job than workers in other industries, while the risk of serious injury was almost three times higher [7]. The International Labour Organization (ILO) [8] further indicated that 25 to 40 per cent of fatalities in the industrialised world workplace occur in construction.

The incident rate for fatal accidents in most countries in the construction industry is high [9][10]. In the United Kingdom, the Health and Safety Executive (HSE) reported that in 2010/2011, 50 fatal injuries occurred in construction compared to an average of 61 in the previous five years [11]. However, despite this decrease the number of fatalities is still unacceptable. In the United States of America (U.S.A.), the number of work-related fatalities declined by 10% in 2010. However, the construction industry still accounted for far more fatal work injuries than any other industry sector with 774 fatal work injuries at an average rate of 9.8 per 100, 000 workers in 2010 [12].

In South Africa though, there is no reliable data on accident cases in construction, because contractors do not report accidents at the appropriate ministry nor keep proper records on accidents.

It has been implied that the construction in South Africa sector paid out more than R287 million (about USD34[1] million) on claims for injuries and illnesses, that were work-related in the period ending March 2012. In that time the construction injury rate was significantly higher. There were 171 fatalities and 755 injuries during the period 2007-2010 [13]. Furthermore, in a recent accident on June 4th 2015 in Pretoria South Africa, five construction workers were injured when the scaffold collapsed at approximately 10-15 meters high [14]. Such injuries could lead to permanent disability or death.

Fatalities can result in direct and indirect cost. Direct costs are: medical bills, premiums for compensation benefits, liability and property loss while the indirect costs are: time lost in attending burial ceremonies, time lost in fatality investigation, down time of damaged equipment and losses arising from site closure [15].

The construction industry in South Africa continues to pose an inherent risk to the H&S of its employees and subcontractors. This can negatively impact on the employee morale, resulting in a loss in productivity and reputational risk. Hence, the industry needs to inculcate the desired H&S culture to its workforce [16], in order to stifle injury occurrence of its construction workers.

II. Problem Statement

Despite the benefits of the construction industry highlighted in this paper. The construction industry is viewed as a dangerous working environment, which would lead to

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[1] 1USD = ZAR8.441 this rate was in the year 2012

families losing their loved once or living them permanently or temporarily injured. This could eventually lead to the loose of financial support of the family especially when one was a bread winner. In relation to this problem this current study is a literature discourse to unearth information from previous studies related to the determinants of injuries on construction site based on the construction worker. The research question to be answered is:

What are the predicators of construction workers injuries on site?

Research objectives:

- To identify predictors of construction workers injury; and
- Propose a conceptual model for health and safety predictor

III. Methodology

The literature search spanning two decades in the period January 1995 to December 2015 was undertaken. This was based on systematic keyword combination search in a number of databases namely; emerald and science direct. The researcher also utilized google search. Advance search was used for the data base engines and basic search for google. The keywords used for the data base search of articles were; "injury predictors" AND "construction workers". The basic search the author used "injury predictors for construction workers". The search in the data bases retrieved 4888 articles. However, after filtering the articles only 16 were relevant. Google search retrieved 390 000 articles and reports. Five relevant articles and report which were not duplicates with those obtained from emerald and science direct search were used. The criteria for including the article or report were: the article/report should be peer-reviewed, be written in English, it should state the aim of the study, method used, present the results and a conclusion; and finally, report or contain results relating to the aim of this literature review. This approach is similar to the study of Gildberg et al., [17]. To describe the predictors of construction worker injury, 20 articles and a report met the requirements. The non-experiential data was analyzed using thematic content analysis. The articles were read several times to obtain a sense of the content and the emerging themes noted. The themes were further categorized into sub-themes. According to Baxter [18] themes are threads of meaning that are recurring in domain after domain.

IV. Literature Review On Construction Workers Injury Predictors

In a study conducted in the United States of America (USA), using 143 injury reports suggested that age predicted the type of injury of construction workers. The study indicated that older workers and younger workers sustained different types of injuries. Older workers sustained increased sprains/strains. Furthermore, the type of occupation/trade was established to be prone to high injury rate. The highest rates of injuries were reported by labourers, carpenters, iron workers, and operators. In a study by Holte et al., [20] conducted in Norway, they established that the prevalence of injuries was high among apprentices in companies that employed 10-19 employees. This size of company was also a predictor of risk to employees getting injury. The study deduced that employees in electrical trade in companies in the employ of between 10-19 employees and employees in building trade in the companies employing 20-49 employees were at risk of getting injured. This may infer that these companies are small, hence lack proper H&S management system to assist in managing their H&S portfolio. Furthermore, the study implied that apprentices were in a bold position to report an injury when they had worked in the company between 19–24 months. However, the study suggested that as an apprentice working in the company for three months and less stifles the employee from reporting injury incurred. It can therefore be suggested that as an employee in order to report injuries you need to have worked longer in the organization.

In study conducted in the Hong Kong by Carol et al., [21] they implied that positive workforce safety attitude and acceptance of safety rules and procedures were significant predictors of injury occurrence. The prediction deduced is an increase in the positive workforce safety attitude and acceptance of safety rules and procedures would decrease injury occurrence. In relation to supervisors the study established that reasonable production schedule was a predictor of injury occurrence. Regarding managers results management commitment and effective safety management were good predicators of injury occurrence. It can therefore be suggested from this findings that negative safety climate among construction workers has a likelihood of increasing injury occurrence. In a study conducted by Moore et al., [22] in the USA, they drew inference of the 112 incidents they analysed, there was lack of fall protection or they were used incorrectly. There was minimal planning, lack of training to the roofers and little or no adherence to the Occupational Safety and Health Administration legislation.

According to Adane et al., [23], in a study conducted in Ethiopia, they came to the conclusion that occupational injuries were common among building construction workers in the study area; the prevalence of the injuries were associated with preventable and modifiable factors such as lack of personal protect equipment (PPE), working overtime, lack of vocational training, workers dissatisfaction with their job. Gender and age were also a contributing factor to workers injuries. Furthermore, most of the building construction workers in this study were unaware of the presence of occupational health hazards associated with their work and they denied access to personal protective equipment's and health and safety training. This research also found that majority of the employees 90% did not undertake periodic medical check-up. Schofield et al., [24] found that drug testing programs were predictors of lower injury for the pre-employment/post-accident employees. Unionized and non-unionized employees did not predict lower injuries. Abbas et al., [25] in a study undertaken in Egypt, indicated that extended working hours, poor safety climate, short duration of work, job dissatisfaction, young age, and job stress were significant risk factors and good predictors of occupational injuries. However, it is interesting to note that sleeping disturbance, and poor machinery maintenance and design did not predict occupational injuries among the construction workers [19]. Yoon et al., [26] found from a quantitative non-experimental study that when occupational health and safety management system (OHSMS) is implemented there was reduction of work related accidents and fatal accidents rates. It can therefore be suggested that when OHSMS is poorly implemented or not implemented accidents will occur among construction workers.

In a quantitative non-experimental study in the USA by Dong et al., [27] established that the type of occupation predicts accident occurrence. It was established that

construction labourers, construction helpers, ironworkers and roofers are the most dangerous occupations with the highest death rates for falls from roofs. Other types of occupation that were to some extend predictors of accidents were: carpenters, sheet metal and welders. Furthermore, when working on residential roofs would also predict accidents. In addition age predicted accidents when working on roofs. Workers who were younger than 20 years or older than 44 years were venerable to accidents. Race and the citizenship of the worker predicted accidents when working on roofs. Hispanics and immigrants had a high death rate of falls from roofs. Lingard et al., [28] found that immediate factors, that is- site layout, unsafe actions, and communication failure were predictors of plant related fatalities. Furthermore, shaping factors like site constraints, inadequate supervision, plant design and skill of operator were deemed good predictors. Finally they inferred that originating influences that is- safety culture and construction process design were good predictors of plant related fatalities in Australia.

In Taiwan, Cheng et al., [29] undertook a non-experimental quantitative study on factors contributing to occupational injuries in the construction industry. They implied that the causes of accidents leading to injury were: source of injury, unsafe condition, accident location, unsafe acts, project type, gender, safety and health management, worker age and enterprise size. In study conducted in Hong Kong by Leung et al., [30] they found that construction workers injuries were predicted directly by lack of goal setting and the safety behaviour of construction workers. However, the study further indicated that safety behaviour is directly influenced by emotional stress, physical stress and inappropriate safety equipment. It is therefore important to note that workers behaviour is caused by other factors hence leading to workers injuries. In a study by Zhang [31] in China the predictors of injury occurrence among immigrant workers were; training, gender, contract of employment and the age of the workers.

In a study conducted in Norway, young workers are at a higher risk to be involved in workplace injuries compared to older workers, hence age can be deemed to be a predictor of workers injuries. Physical demands (vibration and heavy lifting) and control over work pace are associated with increased risk for injuries. This may indicate that the distribution of work tasks between different age groups has an impact on injury occurrence. Safety climate is not associated with injuries [32]. Abbe et al., [33] conducted a study in the USA. The authors found that injuries were influenced by job control, responsibility for safety of others, safety climate, training, job certainty and personal safety compliance. The study also posited that physical symptom (headache) and psychological symptom (feeling sad on the job) were associated with injury occurrence. Im et al., [34] in a study in Korea established that gender, age, duration of employment, company size and cause of injury e.g. fall from height, structure collapse, and electric shock were injury predictors of construction workers. The type of occupation was also a predictor of injury. This was influenced by falling from heights. The trades dearly affected were to painters, plasterers and scaffolders.

Wong et al., [35] conducted a study in Hong Kong. They found that factors leading to fall accidents were, lack of experience, fatigue, the equipment used that is- the ladder, and the negative attitude of workers, which can be indicated as a "don't care attitude". Dong et al., [36] found that age, job tenure, occupation, size of organization and types of construction project had an influence in workers falling, therefore leading to injuries. Hinze et al., [37] opined that injury related to the eyes was influenced by not wearing eye protection. Furthermore, injury on the right or the left eye was influenced by the type of work equipment used. They implied that when grinding metal, 66% of injuries affected the right eye, whereas the use of hammers was associated with the left eye injury. Age was also a determinant of eye injury. Workers in the age group between 25 and 35 were prone to eye injury. The role of the worker also led to eye injury. Close to 65% of operators were injured compared to 35% of bystanders. Hence, the work environment was inferred to be a contributor of eye injury. This is supported by the number of bystanders who incurred eye injury. It can also be stated that different objects caused eye injury. The construction workers were frequently injured by metal fragments.

In a study by Nissen [38] 11% of immigrant workers had experienced a workplace injury which resulted in loss of work of a day or more. Thirty-nine percent had witnessed a worksite accident within the past year serious enough to cause a fellow worker to be taken to the hospital. In their entire construction work career (average length: approximately seven and a half years), eighteen percent had witnessed a death at a worksite where they worked. In Gillen et al., [39] study implied that the union workers, safety climate, and psychological job demands were the factors considered influencing severity of injury.

V. Results And Discussion

The literature review revealed five broad central emergent themes, that is- demographic variables, work related variables, unsafe health and safety behaviour, poor safety climate and psychosocial factors. The subsequent themes are discussed hereto.

A. Demographic variables

This variable has been indicated to be a good predictor of injury. The demographic variables constitute, gender, age, educational level, job tenure of employee, ethnicity, size and type of company. Study by Zhang [31] posits gender has an influence in injury occurrence of construction workers. Male migrant workers are 10% likely to be injured than their female counterparts. Adane et al., [23] concurs with this result. Lingard et al., [28] found that most decedents occurred on male workers. It can be opined that construction work is inherently a masculine profession hence majority of male workers get injured or die. Therefore, attention by policy makers needs to focus on male workers by offering them H&S training.

Age of the worker also influenced construction related injury [23][27][31][36][37]. However, the age groups were categorized differently in all the studies. Adane et al., [23] posited that workers older (>45 years) were likely to be injured than those in the age group 14 to 29 years. Hinze et al., [37] implied that workers in the age group 25 to 35 were prone to eye injuries. Kjestveit et al., [32] indicated that young workers less than 25 years were at a higher risk of workplace injuries compared to older workers. Hence, age is a predictor of workers injuries. According to Lingard et al., [28] most fatal incidents occurred to workers aged between 46 and 55. Dong et al., [27] attest that the high rate of roof fatalities

was high among young (<20 years) and older (>44 years) construction workers. In relation to this finding, all age groups should be reminded or trained on H&S at workplace, as the results vary from one author to another. Adane et al., [23] implied that lack of vocational training is a good predictor of worker injury.

In relation to tenure of employment, those workers who had worked for 1 year or less were susceptible to fatal incident. Further, ethnicity was also a good determinant of fatal accidents [36]. Furthermore, the type of company according to Dong et al., [27] and Dong et al., [36] would be susceptible with high fatality rate. They found that roofing contractors working in residential construction sites were venerable to fatal incidents. Furthermore Dong et al., [27] and Dong, et al., [36] posited that companies employing 10 or fewer workers are likely to incur more fatal accidents. Hence, the following hypothesis H_1 is stated:

H_1: Demographic variable will influence injury occurrence among construction workers

B. Work related variables

The subthemes of work related variables unearthed in this study are; type of occupation, hours of work, degree of physical effort required in doing the work, type of plant/machinery or equipment used. These sub-themes are good determinants of construction worker injury. Holte et al., [20] and Choi [19] asserted that the type of occupation is a catalyst of worker injury. According to Choi [19] the occupation most affected are labourers, carpenters, iron workers and operators. Dong et al., [27] indicates that ironworkers and roofers incurred fatal accidents. Holte et al., [20] on the other hand posits that electrical trade and building trade were most affected. According to Kjestveit et al., [32] injury in young workers is catalysed by the physical demand of work activities when using vibrating tools, lifting heavy objects, repetitive movement, and working with arms above shoulders. The work task between different age groups has an impact on the type of injury occurrence. This sentiment is supported by Choi [19]. Lingard et al., [28] found that drivers/operators were susceptible to fatal incidents. They further attest that different types of plant used led to incidents on site. The most frequent plants causing the incidents were cranes, excavators, and trucks. Abbas et al., [25] indicated that poor machinery design and maintenance influenced occupational injury of workers. Adane et al., [23] found that the likely hood of injury occurring is catalyzed when the workers work for more than 8 hours a day. Therefore, the following hypothesis H_2 is stated:

H_2: Work related variable will influence injury occurrence among construction workers

C. Unsafe health and safety behaviour

The unsafe workers behaviour in H&S has a likelihood of predicting injury occurrence. This is supported in the study of Moore et al., [22], Abbas et al., [25] and Hinze, et al., [37]. According to Hinze et al., [37] Workers defiance of not using PPEs led to different types of injuries. Hinze et al., [37] found that the lack of wearing safety googles led to construction workers injuring their eyes. Furthermore, when workers use damaged or unmaintained equipment and machinery there is possibility of injury occurrence. However Abbas et al., [25] findings are not in support of Hinzes' findings. In relation to job satisfaction Adane et al., [23] and Abbas et al., [25] posited that job dissatisfaction influenced injury occurrence among construction workers.

It is suggested the need to undertake a further study using this predictors. Moore et al., [22] attests that poor behaviour, for example not adhering to H&S standards would predict injury or fatal accident. The health aspect was also deemed to be a predictor of injury occurrence among the construction workers. The health behavior considered were:. drug abuse which includes smoking, and alcohol abuse. According to Schofield et al., [24] drug testing programs are associated with lower injury rates. It can therefore be stated that when drug testing is not undertaken injuries might occur. Hence, this study postulates the following hypothesis H_3.

H_3: Unsafe health and safety behaviour will influence injury occurrence among construction workers

D. Poor safety climate

It has been posited in the studies of Lingard et al., [28], Abbas et al., [25] and Carol, et al., [21] when upstream measures are lacking, the possibility of fatalities occurring on construction site increases. Carol et al., [21] found that the safety climate rating was quite low in their study. This implied that upper management personnel prioritize production more than the workers safety. However, Kjestveit et al., [32] found that safety climate was not a good predicator of workers injuries. This finding is interesting which needs to be explored in future studies. The following hypothesis H_4 is proposed:

H_4: Poor safety climate will influence injury occurrence among construction workers

E. Psychosocial factors

According to Leung et al., [30] when workers incur emotional and physical stress at work it influences their safety behaviour. In Leung et al., study injury is indirectly caused by emotional and physical stress. Abbe et al., [33] found that physical stress as a result of the worker suffering from headache predicted injuries. However, Abbas et al., [25] implied that job stress predicts workers occupational injuries. In their study they did not test two separate variables. Social support is defined as a sub-theme of psychosocial factor. In the study of Kjestveit, et al., [32] and Gillen et al., [39] it did not predict workers injury. However, according to Abbe et al., [33] it predicted self-reporting when an injury occurred. Therefore hypothesis H_5 is postulated:

H_5: Psychosocial factors will influence injury occurrence among construction workers

Based on this discussion, a conceptual model in Figure 1 is proposed.

F. Proposed conceptual model for construction worker injury occurrence

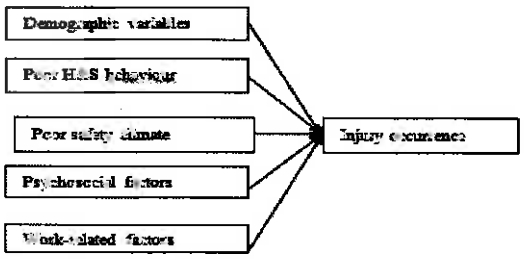

Fig.1 Proposed Conceptual Injury Predictor Model

VI. Conclusion And Recommendations

The studies reviewed had different combination of predictors of construction workers injury. Furthermore, no study has considered the leadership characteristic of the construction worker. Despite these gaps in the literature, this review identified five broad predictors that might determine construction workers injury occurrence on construction sites in South Africa. These predictors are; work related variables, demographic variables, unsafe health and safety behaviour, poor safety climate, and psychosocial factors.

The authors propose a conceptual model that will predict construction worker injury occurrence in the South African construction industry, using logistic regression analysis.

The model to be developed is an upstream management tool that will assist the construction companies H&S department in ensuring their workers are prevented from work related injury. It is further envisaged that the model will determine the predictors of workers injury. This will assist the top management in different organizations in South Africa and even in other developing countries to channel their H&S resources in a resourceful area.

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