A principal components analysis of safety performance measures: A study among construction workers in Gauteng, South Africa

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Abstract

The health and safety (H&S) of construction workers has been a subject of much deliberation for decades. However, there is scant literature focusing on aspects of workers' safety performance (SP) relating to their unhealthy and unsafe eating behavior. The paper presents findings on a principal components analysis (PCA) of H&S performance measures. A 10-item questionnaire which was developed after an extensive literature review was used to collect empirical data on SP of construction workers in the Gauteng Province of South Africa. Results showed that SP could be reasonably measured by two constructs. The two constructs were clearly defined by the PCA as trailing and prevailing. The emerged trailing measures were named lagging indicators while the prevailing ones were designated as leading indicators. The results lend support to extant literature which advocates the use of both leading and lagging safety performance indicators for effectively assessing construction workers' safety performance. The study provides evidence which could be beneficial in psychometric evaluation of construction workers' safety performance and behaviours on construction sites.

Keywords: construction workers, exploratory factor analysis, Gauteng, safety performance

1. Introduction

The construction industry is fraught with accidents and deaths on an unacceptable level. This is in spite of its recognized contribution to socio-economic development with regard to contribution to Gross Domestic Product (GDP) and improvement in the quality of lives of an economy's citizens through job provision (Khan, 2008; Ofori, 2012). Although a decline in the number of fatal injuries in recent years has been indicated, statistics still report unacceptably high rates of accidents, injuries and fatalities (Musonda, 2012; Health and Safety Executive (HSE), 2014). The number and cost of injuries and deaths in the construction industry are deplorable and many of them are preventable (Janackovic et al., 2013). It is necessary to improve the H&S system continually in order to reduce the costs and increase companies' competitiveness and efficiency (Janackovic et al., ibid.).

Furthermore, attention to construction workers' H&S is crucial since they are at the centre of construction activities and as such are indispensable. Individual workers and their supervisors must make daily decisions about safety at work because it influences or competes with other performance facets of the job. These can be related to the task itself (e.g., safety vs. on-time delivery or productivity), or to the worker performing the task (e.g., safety vs. personal discomfort or extra effort) (Huang et al., 2013). Poor safety at work could result from workers' unhealthy eating behaviours, among other things (Melia & Becerril, 2009; Lingard & Turner, 2015). Continuous attention to and integrated management of safety and health increases operational excellence and profitability in the sense that the occurrence of injuries and deaths is reduced, avoidable expenditure on on-site exigencies is reduced, productivity is increased, and in fact, morale and motivation among employees as well as implications of H&S are realised (Janackovic et al., 2013).

Much research has been conducted on H&S measurement and management (Lin et al., 2009) and in the construction industry specifically (Hinze et al., 2013; Lingard et al., 2013). However, most literature focused on the work environment, managerial and organizational aspects of H&S. Few studies have been devoted to safety performance measures related to the lifestyle behaviours of the workers which have been suggested to be unhealthy (Melia & Becerril, 2009). The present study identifies safety performance measures which could be related to workers' unhealthy eating behaviours and explores underlying structures of the measures. The objective of the current paper is to analyse the structure of the safety performance measures used in the study. The study could be useful to researchers and employers in the construction industry in assessing safety behaviours and performance of the workers.

2. Measuring Health and Safety Performance

According to Atkins (2011), the use of a set of safety performance indicators provides a greater indication of safety performance than concentrating on one measure in isolation (or indeed a small number of random measures). Good safety performance indicators should be quantifiable and permit statistical inferential procedures and should be valid and representative of what is to be measured (Roelen & Klompstra, 2012). The interpretations should relate to the system and its operational context (Herrera, 2012). The following measures were identified from extant literature as being indicative of safety performance:

- *Record of accidents, injury and ill-health statistics* (Hinze et al., 2013). This traditional metric was traditionally used to measure H&S performance. However, some researchers argue that measuring H&S performance by the frequency of accidents and injuries is sometimes inappropriate, unreliable and deceptive as gross under-reporting could occur (Musonda, 2012). Therefore, injury rates often do not reflect the potential severity of an event, merely the consequence; they reflect outcomes, not causes.
- *Use of correct personal protective equipment* (PPE) (Biggs et al., 2009; Construction Industry Institute (CII), 2014).
- *Risk assessment*: Identification of the tasks, hazards and the risks of a job prior to work enables implementation of protective measures to ensure that work is done safely (Campbell Institute, 2014).
- Number of reported incidents/reporting of incidents or close-calls (Hinze et al., 2013; Campbell Institute, 2014).
- *Medical treatment beyond first aid* (Biggs et al., 2009; International Council on Mining and Metals (ICMM), 2014). First aid involves a particular level of treatment (such as cleaning and covering of wounds, use of non-prescription medication, etc; whereas medical treatment occurs when an injury or disease requires a higher degree of care and management to ensure a full recovery, for instance, treatment of fractures, suturing of wounds and prescribing and providing drugs to manage symptoms (ICMM, 2014).
- *Restricted activity days*: Loss of working capacity or inability to perform normal or routine work functions on the next calendar day after an injury reflects poor worker safety performance (ILO, 2003).

- *Lost work days*: Absence from work due to an injury, for more than three consecutive working days is considered serious and compensable (ILO, 2003; Cameron & Duff, 2007).
- *Non-injury incidents or near-misses* (Biggs et al., 2009; Hinze et al., 2013; CII, 2014).

The above-mentioned indicators relate to construction workers, prior to or after an incident, and were therefore adopted as the indicators of worker safety performance, in the current study. This implies that some indicators may be trailing (also called lagging indicators), providing data about incidents after the fact (Hinze et al., 2013), whereas others may be prevailing (called leading indicators), potentially leading to an injury or incident (Biggs et al., 2009). Both leading and lagging indicators reflect safety performance (Hinze et al., 2013; Lingard et al., 2013).

3. Methods

To achieve the objective of the study, a literature review of literature related to safety performance of workers in general and construction workers in particular. Various sources including academic and professional journals, books, government reports, newspapers, magazines, theses and dissertations were consulted. A 5-point likert-scale questionnaire was thereafter developed to elicit information workers' safety performance on construction sites. The identified items related specifically to those measures which could be associated with unhealthy eating, since this was the purpose of the main study. The questionnaire, which consisted of 10 items, was pilot-tested, reviewed and revised by experts (consisting of the researcher's supervisors and a statistician). The final questionnaire had response categories were assigned 1, 2, 3, 4 and 5, for "on every project", "more than two times", "two times", "once before" and "never", respectively. Therefore, higher scores were meant to represent higher safety performance.

The questionnaire was self-administered to construction workers on building and civil engineering construction sites in Midrand, Samrand, Johannesburg and Centurion. The participants, selected through heterogeneity and convenience sampling, included workers who were actively engaged in the physical construction activities as opposed to the site managers and supervisors. This group was chosen as they were the most susceptible to poor safety performance on construction sites. A cover letter accompanied the questionnaire to explain the purpose of the study and obtain informed consent. The respondents participated voluntarily and anonymously. Out of a total of 220 questionnaires, 183 were completed and used for the empirical analysis.

The raw data were analysed using Statistical Package for Social Sciences (SPSS) version 22. The Cronbach's alpha and mean inter-item correlations were used to assess the internal consistency reliability of the scale. Principal components analysis (PCA) using principal axis factoring and oblimin rotation was then conducted to examine underlying structures of the theorized variables. However, prior to the factor analysis, preliminary considerations for PCA were assessed. The sample size requirement of 150+ was met (Pallant, 2013). Suitability of data for factor analysis was assessed using the Kaiser-Meyer-Olkin (KMO) and Bartlett's sphericity tests. Missing data were excluded using listwise deletion. The data were however skewed, concentrating on the "never" category. Outliers were identified and removed before analysis The Kaiser's criterion (retaining eigenvalues above 1), scree test (retaining factors above the "breaking point") were used to determine the emerging components or empirical constructs.

4. Results and Discussion

Prior to performing the PCA, suitability of the data for PCA was tested. The KMO value was 0.832, exceeding the recommended value of 0.6 and the Bartlett's test of sphericity reached statistical significance at p = .000 (< .05), supporting the factorability of the data. The correlation matrix which showed the presence of many coefficients of 0.3 and above also supported the suitability of data for PCA.

PCA of the ten items revealed that only two components had eigenvalues above 1 (4.511 and 1.885) as shown in Table 1, and the results of the scree test (Figure 1) also supported that only the first two components accounted for approximately 64% of the variance. The two components were thereafter rotated to reveal their item-loadings (Table 2). Seven of the factors strongly loaded on the first component, while the remaining three loaded on the second. The two components were then adopted as the empirical constructs.

Table 1: Percentage variance explained by the safety performance measures

Factor		Initial Eigenvalues			Extraction Sums of Squared Loadings		
		Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	been away from work for more than three days due to an injury	4.511	45.106	45.106	4.114	41.143	41.143
2	been treated medically for injuries (more than simple first aid) on site	1.885	18.851	63.958	1.459	14.594	55.738
3	been asked to do limited work after an injury	.815	8.148	72.106			
4	been involved in incidents or near-misses	.710	7.097	79.202			
5	been injured at work	.594	5.938	85.141			
6	been sick at work	.451	4.506	89.647			
7	failed to report an accident or incident	.330	3.297	92.944			
8	failed to consider the possible risks in a particular task	.296	2.959	95.903			
9	accepted any kind of work, not minding the danger/risk involved	.235	2.353	98.256			
10	failed to wear personal protective equipment (PPE)	.174	1.744	100.000			

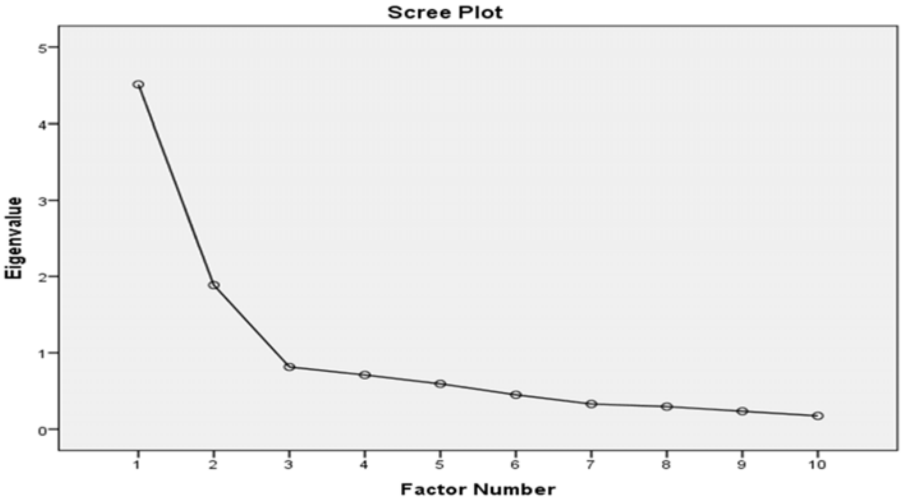

Figure 1: Scree plot showing constructs above the breaking point

Table 2: Loading matrix of the safety performance measures

	Measures	Component	
		1	2
1	been away from work for more than three days due to an injury	.946	-.119
2	been treated medically for injuries (more than simple first aid) on site	.872	-.009
3	been asked to do limited work after an injury	.813	-.177
4	been involved in incidents or near-misses	.670	.011
5	been injured at work	.651	.289
6	been sick at work	.613	.049
7	failed to report an accident or incident	.465	.258
8	failed to consider the possible risks in a particular task	-.073	.850
9	accepted any kind of work, not minding the danger/risk involved	-.036	.704
10	failed to wear personal protective equipment (PPE)	.124	.564

The interpretation of the two components showed that positive measures clumped together and negative measures did the same, consistent with positive and negative schedule scales used in extant literature (Pallant, 2013). Hence, the first component with negative items was named *lagging indicators*, while the second component with positive items was named *leading indicators* (ICMM, 2014).

In relation to construction safety performance, prevailing performance measures are leading indicators which provide information that prompt actions to achieve desired outcomes and/or avoid unwanted outcomes whereas trailing performance measures are lagging indicators that provide safety results, for instance, the extent of worker injuries (Hinze et al., 2013). Differentiating and using both indicators provide a more reliable and/or accurate measurement of safety performance (Lingard et al., 2013; Hinze et al, 2013). Leading metrics can be useful in predicting future levels of safety performance, thereby providing information which could guide implementation of interventions to improve and impact positively on the safety process, before any negative (trailing) incidences occur (Hinze et al., ibid.). The study provides support to extant literature which advocates the use of both leading and lagging indicators to measure safety performance in the construction industry. They should also be used to assess worker safety performance. Many a time, workplace safety programmes focus attention on lagging indicators that report on the outcomes of safety initiatives, but fail to give equal consideration to leading indicators which measure the behaviours and activities of the workers before accidents occur. A combination of both classifications to support behavioural changes can lead to sustainable worker safety levels in the long run. The use and adoption of both should be encouraged to drive H&S continuous improvement (Construction Owners Association of Alberta (COAA), 2011).

Validity and reliability of the theoretical and empirical constructs

Through an extensive and thorough literature review and synthesis, expert reviews and validation as well as pilot-testing, construct validity of the questionnaire was enhanced (Olson, 2010). The Cronbach's alpha internal consistency reliability test indicated good internal consistency of the constructs both before and after PCA. Before PCA, the scale was considered to be reliable and representative of what is to be measured (Roelen & Klompstra, 2012), with a good alpha index of 0.83 (Pallant, 2013). After PCA, the internal consistency reliability of the constructs, tested using both the Cronbach's alpha and mean inter-item indices, was equally good as evinced in table 3. Cronbach's alpha values of above 0.7 indicate acceptable internal consistency reliability and mean inter-item coefficients ranging from 0.2 to 0.4 indicate good internal consistency (Pallant, 2013).

Table 3: Internal consistency reliability of empirical constructs

	Cronbach's alpha	Mean inter-item correlations	Number of items
Lagging measures	0.885	0.530	7
Leading measures	0.763	0.521	3

5. Conclusion

The study sought to explore the underlying structure of safety performance measures. Safety performance was found to be measured by two components. The components had positive and negative safety performance measures, respectively. They were therefore named leading and lagging measures, accordingly. Lagging and leading measures should therefore be used to evaluate and effectively manage safety performance of construction workers.

The study provides evidence which could be useful in psychometric evaluation of construction workers' safety performance and behaviours on construction sites. By highlighting safety performance/behaviours of the workers, construction stakeholders could be enabled to make informed decisions regarding improving H&S performance of the workers, and thus improve the productivity, profits and competitiveness in their establishments. The limitations of the current study warrant mention. Firstly, the study was conducted in only one province in South Africa and may not be generalized to workers in the entire country or other countries. Secondly, the method of data collection was quantitative. More in-depth information could have been elicited with a follow up qualitative technique such as interviews, especially to shed more light on the “never” category responses. Future studies could therefore attempt the study using a different approach to extract more information or determine if dissimilar results would be obtained.

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