this line of research.

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REFERENCES

Avecilla-Benitez, M. A., Sospedra, I., Cano-Climent, A., Richart-Martinez, M. and Oliver-Roig, A. (2019). "Development and Validation of a New Questionnaire Assessing Feeding Styles in Toddlers: Toddler Feeding Style Questionnaire (TFSQ)." Journal of pediatric nursing, 47, e65-e74.

Granger, C. W. J. (1969). "Investigating causal relations by econometric models and cross-spectral methods." Econometrica, 37(3), 424-438.

Hair, J.F., Anderson, R.E., Tatham, R.L., and Black, W.C. (1998). *Multivariate data analysis*. Macmillan, New York.

Hinze, J., Hallowell, M., & Baud, K. (2013). "Construction-Safety Best Practices and Relationships to Safety Performance." Journal of Construction Engineering and Management, 139(10).

Hollnagel, E. (2008). "Risk plus barriers = safety?" Safety Science, 46(2), 221-229.

Huang, X. Y., & Hinze, J. (2006). "Owner's role in construction safety." Journal of Construction Engineering and Management-ASCE, 132(2), 164-173.

Jin, R., Zou, P. X. W., Piroozfar, P., Wood, H., Yang, Y., Yan, L., & Han, Y. (2019). "A science mapping approach based review of construction safety research." Safety Science, 113, 285-297.

Kumar, P., Gupta, S., Agarwal, M., & Singh, U. (2016). "Categorization and standardization of accidental risk-criticality levels of human error to develop risk and safety management policy." Safety Science, 85, 88-98.

Mearns, K., Whitaker, S. M., & Flin, R. (2003). "Safety climate, safety management practice and safety performance in offshore environments." Safety Science, 41(8), 641-680.

Rajendran, S., & Gambatese, J. A. (2009). "Development and Initial Validation of Sustainable Construction Safety and Health Rating System." Journal of Construction Engineering and Management, 135(10), 1067-1075.

Stiles, S., Ryan, B., & Golightly, D. (2018). "Evaluating attitudes to safety leadership within rail construction projects." Safety Science, S0925753517313103.

Vinodkumar, M. N., & Bhasi, M. . (2011). "A study on the impact of management system certification on safety management." Safety Science, 49(3), 498-507.

Wang, C. X. (2012). "Safety responsibilities for owner and example in public works." Procedia Engineering, 43, 523-527.

Wu, C. L., Fang, D. P., & Li, N. (2015). "Roles of owners' leadership in construction safety: The case of high-speed railway construction projects in China." International Journal of Project Management, 33(8), 1665-1679.

Wu, C. L., Wang, F., Zou, P. X. W., & Fang, D. P. (2016). "How safety leadership works among owners, contractors and subcontractors in construction projects." International Journal of Project Management, 34(5), 789-805.

Zhang, P. Y., Li, N., Fang, D. P., & Wu, H. J. (2017). "Supervisor-Focused Behavior-Based Safety Method for the Construction Industry: Case Study in Hong Kong." Journal of Construction Engineering and Management, 143(7).

Identifying the Factors Influencing Hazard Recognition Capability of Construction Workers

Mu'awiya Abubakar[1]; Yahaya Makarfi Ibrahim[2]; Kabir Bala[3]; Ahmed Doko Ibrahim[4]; and Muhammad Abdullahi[5]

[1]Dept. of Building, Ahmadu Bello Univ., Zaria-Nigeria. E-mail: muawiyaabubakar1@gmail.com
[2]Dept. of Quantity Surveying, Ahmadu Bello Univ., Zaria-Nigeria. E-mail: makarfi@gmail.com
[3]Dept. of Building, Ahmadu Bello Univ., Zaria-Nigeria. E-mail: balakabir@gmail.com
[4]Dept. of Quantity Surveying, Ahmadu Bello Univ., Zaria-Nigeria. E-mail: adibrahim2@yahoo.com
[5]Dept. of Quantity Surveying, Ahmadu Bello Univ., Zaria-Nigeria. E-mail: bnabdallah02@gmail.com

ABSTRACT

Literature on construction safety have reported the importance of hazard recognition to any safety management initiative. The persistence of poor safety records of the construction industry has been linked to the inability of workers to recognise and manage work hazards. This is certainly among the major reasons for the growing research interests on the improvement of hazard recognition performance of construction workers. To avert the negative consequences of poor hazard recognition of construction workers, it is important to understand the factors that influence their hazard recognition capabilities. This will enable the development of appropriate strategies to improve the level of hazards recognized and managed by the workers, thereby achieving the desired improvement on the general safety performance of the construction industry. This paper reports on efforts to provide empirical evidences of factors influencing hazard recognition capability of construction workers. A total of 53 factors were identified from literature and validated with 14 construction experts. The factors were grouped as personal, organisational, social, and project factors. The paper is the first step in a larger study aimed at developing a model for evaluating hazard recognition capability of construction workers.

KEYWORDS: Construction workers, hazard recognition, safety management,

INTRODUCTION

Studies on construction safety have established the importance of hazard recognition to safety management. The persistence of poor safety records of the construction industry has been linked to the inability of workers to recognise and manage hazards in dynamic construction environments (Albert & Hallowel, 2014). Any efforts towards to improve hazard recognition of construction workers will benefit from understanding the factors that influence their hazard recognition capabilities. Different authors have proposed different measures for improving hazard recognition capability of construction workers (Namian, Zuluaga, and Albert 2016). Unfortunately, these solutions have not taken into consideration all the factors that hinder or aid the ability of workers to recognise work hazards in relation to their work environments. So far, there has not been any effort towards determining the hazard recognition competence of construction workers based on the different attributes of hazard recognition related to the workers and their environment, and the hazard recognition techniques used do not take into account the factors that influence workers' hazard recognition capabilities based on the nature of jobs and trades they engage in, and on which the hazards are being managed. This is important

because different construction trades, present different safety risks, and thus different hazards (Patel, et al 2008). It is instructive to note that no effective hazard management strategy can be developed without improving the hazard recognition capability of construction workers.

Previous studies have documented the contributing factors to the inability of workers in construction and allied sectors to recognize hazards at work places (Namian, Zuluaga, and Albert, 2016). However, the works have not been exhaustive, as there are other important factors that have not been covered, which have significant potentials for impacting hazard recognition of workers. Some of these factors may be related to different cultural and geographical backgrounds of the workers. Establishing these additional factors will be useful to the attempts being made to understand the different dimensions of the factors affecting workers hazard recognition performance. It will also help in the development of effective strategies for improving the number of hazards recognized in workplace, towards ensuring better health and safety performance of the construction industry.

In the same vein, there has not been any clear and systematic criteria used in categorizing the different factors into the clusters/groups. Thus no effort has been reported to empirically establish the different categorisations of the factors in relation to the specific areas/players in the construction processes such as workers, projects, site characteristics, and so on. For this reason, it will be important to have a scientific basis for the categorisations based on identified features of the factors. This is important as it will guide future research to be focused in aligning different hazard recognition improvement strategies to the specific areas of hazard recognition. This paper has made an attempt to address these loopholes by systematically identifying and categorizing the critical factors influencing construction workers' hazard recognition capabilities.

LITERATURE REVIEW

Among the first major attempts to document the contributing factors to the inability of workers in construction and allied sectors to recognize hazards at work places is the work of Namian, et al. (2016) in which they established 36 factors that influence hazard recognition performance of construction workers. The factors were identified through literature review and interview of construction managers and safety professionals. They assembled the factors into five categories as personal, organisational, social, and situational, industry related and miscellaneous factors. This and other studies on the factors impacting hazard recognition performance of construction workers have tried to explore how human characteristics play a role in the way a worker recognise job hazards, assess their risks and manage them. In addition to the factors identified by Namian et al. (2016), others have established some factors, and went further to examine their influence on hazard recognition performance of workers.

For example, Tam, Fung, Yeung, and Tung (2003) established the relationship between the personal characteristics of construction workers (such as smoking and drinking habits, job positions, age, risk perception level, and their cultural and linguistic backgrounds) and their recognition of safety signs and symbols on site. Teo and Ling (2009) established that personnel characteristics have significant impact on the construction site safety performance. This impact have been linked to, among other things, the way the workers detect work hazards on site.

Moreover, Tixier, Hallowell, Albert, and Boven (2014) measured the impact of emotions on risk perception in a work place context and found that workers' emotional states influence their risk-taking behaviour and by implication, the extent of hazard recognition. Bhandari, Hallowell, Boven, Gruber, and Welker (2016) established the influence of emotions on hazard identification skills of workers. These two studies have revealed interesting results that hazard recognition

skills can be greatly influenced by psychological factors. Furthermore, studies on personal cognitive factors that influence the behaviour of construction workers include the works of Goh and Sa'adon (2015); Mohammadpour, Asadi, and Karan (2016); Hasanzadeh, Esmaeili, and Dodd (2017). All these studies have wholly or partly focused on different cognitive factors that influence the behavior and ability of workers to recognize and manage work hazards on construction sites.

Another important category of factors influencing hazard recognition of workers, is the social factors. Construction activities are carried out in groups, teams and work crews. These collection of different workers tend to develop some culture, norms and values as a result of the interactions between members. These values and norms have been reported to significantly affect the way workers recognize and deal with a number of work hazards. Studies on these include the work of Albert and Hallowel (2014) and Jiang, Fang, and Zhang (2015). Similarly, Choi and Lee (2016) examined the social norms and social identification in safety behavior of construction workers. In all these, the interaction between different personalities in a construction environment context have been reported to significantly influence hazard recognition and management capabilities of construction workers.

Arguing for context and environment, construction works are undertaken in organizational settings, the structure, policy and culture of which may influence the workers hazard recognition competencies. In this regard, Slates (2008) argued that only leadership and organizational commitment are important in ensuring employee involvement, training, hazard identification and management. Working conditions in an organization and the behaviour of workers were also seen to impact hazard recognition and the extent of accident and injury causation(Chi, Han, & Kim, 2013). Moreover, the safety management system of a company and the level employee and supervisors involvement have been reported to impact workers hazard recognition capability (Namian et al., 2016; Patel & Jha, 2015; Slates, 2008 ; Tam et al., 2003).

In another perspective, studies have established the influence of construction projects related factors on the capability of workers to recognize hazards. Based on the premise that different construction works involve different trades, which in turn, present different sets of hazards, Patel and Jha (2017), Namian et al. (2016), Choe and Leite (2017), argued that the nature and attributes of the job or tasks performed by workers have significant influence on the hazard recognition levels of the workers. It was on this note that Patel and Jha (2017) developed a framework to evaluate a construction project hazard index, which represents the hazard level of a construction project.

Other factors include the project level safety and hazard recognition training, which greatly enhances hazard recognition(Namian et al., 2016). Similarly, Sawacha, Naoum, and Fong (1999), Shang and Shen (2016) and Namian et al. (2016) identified Site layout configuration and level of traffic on the site to have significant influence on the ability of workers to recognize hazards. Delivery and productivity pressure on the workers and workers' distractions can also greatly influence hazard recognition (Feng, Teo, & Peng, 2012; Namian et al., 2016; Patel, Kikani, & Jha, 2016). Others include operational unfamiliarity of construction tools Jeelani, Albert, and Gambatese (2017), project scope and schedule changes (Namian et al., 2016), and so on. To further substantiate some of these factors, Jeelani, Albert, Azevedo, and Jaselskis (2017) undertook a study to identify specific reasons why construction hazards remain unrecognized at work interfaces. The study revealed among other reasons, the multiplicity of hazards in a particular place, low prevalence of certain hazards, the time taken between hazard exposure and manifestation of effects, task unfamiliarity and so on. All these project related characteristics

play significant role in determining the extent to which construction workers recognise and manage work hazards.

To put all these different categories into context, Jiang et al. (2015) posit that construction safety management is a system that has so many components. Therefore, they used the concept of system dynamics to explore the causation of construction accidents and poor hazard recognition. Hence, all the different segments of the system such as the organization, the workers and managers, and the project environments interact with one another to influence the level of hazard recognition and general safety management in every setting.

METHODOLOGY

The objective of the paper was addressed using literature review to identify the factors affecting hazard recognition capability and their validation with construction experts. The validation was aimed at providing an empirical evidence on their extent of influence and the categorization into the different groups established from literature.

A semi-structured questionnaire was used for the purpose of expert validation of the factors. The factors were presented in four sections, based on the findings of the literature review in sections as personal factors, social factors, organisational factors, and project factors. The respondents were asked to indicate the extent of influence of the factors on hazard recognition capability of construction workers on a scale of 1 to 5, where 1= Not influential, 2= slightly influential, 3= moderately influential, 4= influential and 5= very influential. Options were also left for the experts to make suggestions if they felt some factors were left out.

A panel of five researchers with experience ranging between 10 to 25 years were selected for a pilot evaluation of the questionnaire to ensure validity. Their suggestions were used to improve the questionnaire. The questionnaire was then distributed to 14 experienced construction managers and safety managers purposively selected for the survey. The exercise involved filling the questionnaires, and a follow up interview, meant to probe their responses. The interviews lasted between 45 minutes to 1 hour. The responses were analysed using the Statistical Package for Social Sciences (SPSS) version 23. The interview data were analysed through qualitative content analysis. The results obtained were presented in tables.

RESULTS AND DISCUSSIONS

Respondents' profile

The demographics of the respondents are all presented in table 1.

Table 1 shows the backgrounds of the experts that participated in the validation exercise. All the experts have acquired professional experience from 10 years and above. Overall, the experts have an average of over 17 years and a cumulative of 244 years of professional experience. This signifies the extent of quality and dependability of information obtained from the questionnaire and interview and therefore adds to the validity of the results. Professionally, 43% of them are safety managers, while 57% are construction managers.

Responses on the Factors Influencing Hazard Recognition of Construction Workers

The responses of the experts on the level of influence of the factors were analysed using SPSS. Means and standard deviations were computed for each factor as presented in the following tables.

A total of 20 personal factors that influence workers' hazard recognition levels identified from literature are presented. Table 2 shows the results of the evaluation. An overall group mean of 4.09 and group standard deviation of 1.05 were recorded for the entire personal factors category. This indicates that the experts rated all the sub factors closely around the scale of 4, which signifies that most of them agreed that factors influence hazard recognition level of workers. It can be seen that, 12 recorded mean values greater than 4.0, while about 9 of the factors recorded relatively very low standard deviations less than 1. This signifies that there is some consensus among the experts in rating the personal factors affecting hazard recognition capabilities of workers.

Table 1. Characteristics of the Experts

Characteristics of the Experts				
Years of Experience of the Experts				
Year Range	Frequency	Percent	Average	Cumulative
6-10	2	14.3	**17.4**	**244**
11-15	4	28.6		
16-20	3	21.4		
21-25	3	21.4		
26-30	2	14.3		
Total	**14**	**100**		
Discipline of the Experts				
Disciplines	Frequency	Percent		
Safety Manager	6	42.9		
Construction Manager	8	57.1		
Total	**14**	**100.0**		

The factor with the highest mean value score is the knowledge and experience with a mean score of 4.93 (SD 0.27), very close to the highest scale of influence, which is 5. This signifies the level of importance knowledge and experience have in hazard recognition according to the experts. Aside this, all other factors that followed it with mean values ranging from 4.79 to 4.21 are all sub factors that are either related to the level of knowledge gained through safety training, or related to the inherent worker characteristics that influence behaviour in different circumstances such as safety training.

The two factors with very low rating of less than 3, are the impact of luck on hazard recognition of workers (mean 2.71) and the effect of workers' race and ethnicity (2.57) on their ability to recognise work hazards. Although these factors were found in literature, the experts felt they have least influence on hazard recognition of workers. In probing the responses, 9 out of the 14 respondents opined that neither luck, nor race and ethnicity of the workers has any scientific link to hazard recognition of workers.

Table 3 presents the result of evaluating the relevance of the social factors in the evaluation of the hazard recognition levels of workers in a construction context. Unlike the personal factors, it can be seen that the sub factors under this category recorded an overall group mean of 3.66 and a standard deviation of 2.28. All other sub factors in this category recorded mean values between 3.00 to 3.93. This indicates the level of consensus between the experts on the influence of all the sub factors under this category.

Table 2. Influence of the Personal Factors

Codes	Sub factors	Mean	S.D
A	Overall group rating of the personal factors	4.09	1.05
A1	Knowledge and Experience (competence)	4.93	0.27
A2	Auditory ability	4.79	0.43
A3	Safety training to recognize hazards	4.71	0.61
A4	Attitude towards safety in general	4.71	0.47
A5	Response to recognized hazards	4.71	0.61
A6	Visual ability	4.71	0.47
A7	Safety complacency	4.57	0.65
A8	Substances (drugs, alcohol etc) abuse	4.57	1.08
A9	Experience in using hazard recognition techniques	4.50	0.76
A10	Emotional disposition	4.43	0.85
A11	Appreciation of the risks associated with job	4.29	1.14
A12	Risk-taking ability	4.21	1.05
A13	Fatigue/depletion	3.93	1.27
A14	Involvement in/witnessing a previous construction accident	3.86	1.61
A15	Belief system (luck, superstition, etc)	3.71	1.64
A16	Location of hazards	3.50	1.56
A17	Large number of construction tasks on site	3.29	1.54
A18	Cause - Effect Clarity	3.29	1.6
A19	Physical Worker Characteristics	2.71	1.64
A20	Race and ethnicity	2.57	1.79

Source: Validation exercise (2019)

Table 3. Influence of the Social Factors

Codes	Sub factors under the social factors	Mean	S.D
B	Overall group rating of the social factors	3.66	1.28
B1	coworkers and superiors' support for hazard recognition	3.93	1.07
B2	work group/team members norms	3.86	1.03
B3	Social conformance	3.86	1.41
B4	hazard recognition ability and motivation level of peers	3.64	1.28
B5	size and composition of work crew	3.00	1.62

Source: Validation exercise (2019)

Results of the organisational factors are presented in Table 4. All the 11 factors were rated as 'influential, with an overall group mean score of 4.51 and a standard deviation of 0.72. Almost all the factors recorded a mean value very closed to the overall group mean. This shows the extent of agreement among the experts on the influence of all the organizational factors to hazard recognition capability of workers.

The factor with the highest mean value of 4.86 is the one on organizational safety policy that supports hazard recognition and management. This result is emphasizing the important role played by the organizational safety policy in the achievement of high level of hazard recognition by workers. Another sub factor that came close to the policy issue is the issue of training

programs in the organisation. The mean score of 4.6 and standard deviation of 0.5 (the lowest in the list) shows that the experts rated this factor with very high level of agreement to show the importance of training in ensuring good hazard recognition level of workers.

Table 4. Influence of the Organisational Factors

Codes	Sub factors under the Organisational factors	Mean	S.D
C	Overall group rating	4.51	0.72
C1	Organizational safety policy	4.86	0.54
C2	Safety Training Programs	4.64	0.50
C3	Organizational structure with responsibilities for hazard recognition and management	4.57	0.65
C4	Use of incentive to motivate and empower employees for hazard recognition and management	4.57	0.51
C5	Hazardous tendencies of all equipment used in the organisation	4.50	1.09
C6	Communication system for managing hazard information	4.50	0.52
C7	Supervisory environment	4.50	0.52
C8	Employee involvement in hazard recognition and safety planning	4.50	0.86
C9	Organizational campaigns to promote hazard recognition	4.43	0.65
C10	Use of hazard identification (both manual and automated) tools	4.29	0.73
C11	Organisational policy on the use of psychoactive substances	4.21	1.42

Source: Validation exercise (2019)

Some of the experts suggested additional factors that were not considered under the organizational factors. However, only 2 of them were found to be relevant and got included in the list. These are the top management commitment to hazard recognition and management, and the use of 'lessons learned' programs which records and share knowledge on new hazard types encountered by workers on site.

The overall group mean recorded here is 4.27 with a standard deviation of 0.89. It can be seen here also that 12 out of the total of 15 sub factors have recorded mean values greater than 3, which means they are mostly 'relevant'. However, a close look at the spread of the individual means and standard deviations recorded by the sub factors shows some level of dispersion in agreement among the experts in rating the influence of these sub factors. Factors D1 and D2 both recorded similar mean value and standard deviation of 4.79 and 0.43 respectively. These were followed by sub factors D3 to D6, all of which recorded the same mean value of 4.64 each and standard deviation of 0.50, expect D6, which has a standard deviation of 0.63, away from the rest. This signifies some level of agreement among the experts in rating the influence of the sub factors.

It can be seen that D8 to D12 have recorded different mean values, all within the range of 4.0. Notably, their standard deviations are relatively farther away at 1.0 and above. This confirms the extent of dispersion in the experts' rating on the relevance of these sub factors.

Overall, all the factors in this category have been rated by the experts to be influential to construction workers' hazard recognition capabilities based on the characteristics of the construction project. One of the interviewees asserted that the project is the center of all the

hazards, therefore, the nature of project determines the extent of hazard recognition of a worker irrespective of his training and the organization that performs the work.

Table 5. Influence of the Project Factors

Codes	Sub factors under the Project factors	Mean	S.D
D	Overall group rating	4.27	0.89
D1	Project owner and community support hazard recognition and management	4.79	0.43
D2	The use of mechanical plants and equipment	4.79	0.43
D3	Hazard recognition practices employed in the project	4.64	0.50
D4	Job specific safety training	4.64	0.50
D5	House-keeping practices	4.64	0.50
D6	Project safety climate	4.64	0.63
D7	Traffic on the project site	4.29	0.83
D8	Construction site layout plan	4.21	1.12
D9	The productivity and delivery pressure of the project	4.14	1.23
D10	Project characteristics (e.g. size, scope, materials, height etc)	4.14	1.10
D11	Site configuration (e.g. topography, soil condition, access, space, etc)	4.07	1.14
D12	Site condition (e.g. elements of weather)	4.07	1.07
D13	Project scope and schedule changes	3.86	1.23
D14	Noise on the project site	3.86	0.95
D15	Equipment/tools characteristics	3.86	1.17

Source: Validation exercise (2019)

On the suitability of the grouping of factors, majority (85%) of the experts agreed, while 7.1% strongly agreed that the grouping of the factors is suitable for any further assessment of their effect on hazard recognition capability of construction workers.

Table 6. Overall Group Means Comparison between the Questionnaire and the Interview

Categories of Factors	Interview Assessment		Questionnaire Assessment	
	Overall Group Means	Ranks	Overall Group Means	Ranks
Personal factors	4.00	2	3.09	3
Social factors	2.57	4	2.66	4
Organisational factors	4.29	1	3.51	1
Project factors	3.40	3	3.27	2

Source: Validation exercise (2019)

Ranking of the Groups of factors

To further confirm the validity and consistency of the experts' evaluation, the interviewees were asked to rank the four groups of factors based on their level of overall influence and relevance. Table 6 presents a comparison between the group means of the groups of factors in the initial questionnaire survey and the follow up interview.