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Health & Safety Knowledge at Construction Sites: Modalities and Characteristics

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Abstract Background/Purpose: The article has investigated the characteristic and modalities of imparting H & S knowledge to workers at construction sites and examining how the outcome can be applied in enhancement of Health and Safety performance in construction sites. Methods: A questionnaire survey was administered to 61 building contracting firms that had projects in the commercial capital city of Tanzania, Dar es Salaam. The study investigated approaches used by building contractors class I and II in imparting Health and Safety knowledge to workers at construction sites, the nature of knowledge as whether tacit/explicit or formal/informal and respective challenges pertaining to the process. Results and conclusion: The results have shown explicit form of knowledge as the most dominant type of knowledge used in imparting Health and Safety Knowledge for both classes of building contractors studied. Variation in the priority of approaches used by the two classes of building contractors has been established, not of statistical significance. A reactive as against preventive mode of imparting Health and Safety knowledge is noted for both classes of contractors. The nature of challenges observed is dominantly endogenous.

Keywords Health and Safety Knowledge, Construction sites, Modalities

1. Introduction

The construction industry being among the most hazardous industry, employing high numbers of workers, risks pertaining to injury or damage is high [1]. The sector has been estimated to account for one in every six fatal accidents recorded at work annually and at least 60,000 fatal accidents in construction sites around the world each year, representing one fatal accident every 10 minutes [2].

Construction activities are associated with Health & Safety (H & S) risk factors; hence a high spate of accidents has been identified in construction projects [3,4]. As performance of the construction industry in H & S continues to be less than satisfactory [3,5], this implicates shortfalls in the construction industry processes, routines, practices and norms that overall, affect the industry.

Worldwide studies have reiterated safety concerns in the construction industry [6,7,3,5,8]. Previous works have explored how technology could enhance safety in buildings [7], the significance of H & S communication [9], workers cohesion in safety performance [6], and H & S implementation motivators [10]. While Cecchini et al. [11] had touched on safety knowledge in agricultural sector, other than Okoye et al. [12], not much has been researched on the nature and type of H & S knowledge imparted to workers in construction sites.

In Tanzania the construction industry is among the fastest growing and expanding economic sectors in the country. Though the industry employs 9-11% of the national workforce it still accounts for 25-45% of fatalities and ranks top in fatality rate followed by transport and mining sectors [13]. The sector however has a significant contribution to the Tanzania economy as between year 2012 and 2017 its share of Gross Domestic Product (GDP) in the category of industry and construction increased from 9.8 to 12.2%; with its contribution in this category ranging from 38.5 to 48.6% [14]. See table 1.

The industry also dominantly employs an age profile that is crucial for a country's development [14]. The prevalence of a vast informal sector and its significance to a developing economy [15-17] hence justifies the need to have H & S concerns.

Liyanage [18] had cautioned on the misconception of mere provision of safety information to workers at construction sites and making a presumption that it guarantees its conversion to knowledge that can be applied, or embedded to workers' beliefs and values. Investigating and documenting the characteristic of H & S knowledge in construction sites, how it is imparted to workers is viewed

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by the author as a starting point towards its performance enhancement in construction sites. Challenges faced by contractors in imparting H & S knowledge to workers at construction sites have also been explored in this article aiming at identifying their characteristics and potential mitigation.

Table 1. Shares to GDP by economic activity Tanzania mainland at current prices base year 2015 - %

Economic activity	2012	2013	2014	2015	2016	2017
Agriculture, Forestry, Fishing	26.6	26.8	25.8	26.7	27.4	28.7
Industry & Construction	25.4	25.5	25.1	24.5	24.9	25.1
Construction	9.8	10.9	10.8	11.1	11.3	12.2
Services	40.6	40.3	41.3	40.4	39.5	37.9
All economic activities	92.6	92.5	92.2	91.7	91.8	91.8
Taxes	7.4	7.5	7.8	8.3	8.3	8.2
GDP at market prices	100	100	100	100	100	100

Source: Revised National accounts statistics for Tanzania [14]

The article has anchored its theoretical aspect on the knowledge conversion model [19], adopting the authors' ideas that for creation of knowledge a conversion process of tacit to explicit knowledge has to occur. Knowledge has been defined as '*the whole body of cognition and skills that individuals use to solve problems, it includes both theories and practical everyday rules and instruction for action*' [20]. Adopting this definition, H & S knowledge is thus expected, to be embedded in organization routines, processes, practices and norms; explained as *practical everyday rules* [20,21]. An interesting feature of knowledge is that it is always based on data and information, bound by individuality and perception, beliefs and relationships. This view has been recapped by various researchers [12,22-25,19].

According to Nonaka and Takeuchi [19], there are two types of knowledge, tacit and explicit; the latter as one that can be expressed in formal, systematic language that can be shared in the form of data, scientific formulae, specification or manuals; characterized by ease of transmission, storage and retrieval. Tacit knowledge is personalized, hard to exemplify, or explain; typically extracted through actions, procedures, routines, commitment, ideals, values as well as emotions [19].

Construction sites are typified by informal, hard to pin down know how, crafts and skills; aspects which reflect tacit knowledge. Since cognitive elements of tacit knowledge are based on mental models such as schemata, paradigms, perspectives, beliefs and viewpoints that help in setting up analogies, understanding the modality of imparting H & S knowledge to workers would bring to light an individual's perception of H & S knowledge and how it can be transmitted effectively. This is crucial as it dictates the way a person makes judgments, evaluates information and makes decision [26]; a factor that is viewed by the author to potentially contribute in enhancement of H & S at construction sites.

The study henceforth had set to explore: the nature of H & S knowledge imparted to workers at construction sites and whether of dominantly tacit or explicit; examined the modality of imparting H & S knowledge to workers considering: whether by training; response by the management/ contractor on reported H & S concerns; setting H & S priorities by the contractor or firm; inspections at construction sites; by addressing emergencies; leading by examples; management/ contractor collecting ideas for hazard control from workers; implementing hazard control; or by making improvements on feedback of H & S concerns. Also the study examined the nature of challenges faced by contractors in imparting H & S knowledge to workers; exploring the endogeneity and exogenous characteristics of such challenges.

2. Materials and Methods

The Tanzania Contractors Registration Board (TCRB) is a Government Regulatory Board established by Act of Parliament No. 17 of 1997 with the objective to register and regulate all types of Contractors and to promote the development of their capacities for the purpose of protecting consumers of construction services in Tanzania. The TCRB has five categories of contractor registration, Civil, Building, Electrical, Mechanical and Specialist contractors. Furthermore the contractors are classified into seven classes based on the maximum value of a single contract that one is allowed to execute. For contractors under building category the class limits of Class I to VII are shown in Table 2.

Table 2. Contract vale Class limits for Building contractors in Tanzania [27]

Class	Class Limit (Mill. TZS)	Class Limit (USD); 1 USD= TZS. 2,277*
One	Unlimited	Unlimited
Two	5,000	2,195,871.76
Three	3,000	1,317,23.05
Four	1,800	790,513.83
Five	900	395,256.91
Six	450	197,628.45
Seven	200	87,834

**Bank of Tanzania Exchange rate as of 22nd February 2019.

According to section 10 of the Tanzania Contractors Registration Act No. 17 determination of class registration is guided by six key criteria that assess the capability of a contractor. A contractor on applying for a class category has to score a minimum of 60 points based on weighted parameters that assess capability; these parameters prioritized by weight include: financial status, staff qualification, plant and equipment, office and services facilities, experience of the firm/individual experience and

safety gear [28]. For this study these criteria were assigned weights as shown in Table 3 where it is noted the "safety criterion" is the lowest.

Table 3. Criteria for categorizing building contractors' class 1 to III [28]

Criteria	Weight	Rank
Financial Status	30	1
Staff qualification	25	2
Plant & Equipment	20	3
Office & services Facilities	10	4
Experience of firm/individual experience	10	4
Safety Gear	5	5

Data for this study was collected from Dar es Salaam which is the commercial capital city of Tanzania, and is the most active region in Tanzania for construction activities. The population was then narrowed to building contractors class I and II only because the author perceives due to the high capital investment (see Table 2) and complex nature of buildings that they undertake, the level of H & S risk is relatively high hence are expected to have relatively more information on H & S.

According to the TCRB (2017), the number of building contractors with ongoing building projects in Dar es Salaam during the year 2018 in class I and II were 131 and 31respectively and from this population the sample size was established using Slovin's (1960) formula.

$$\text{Given by:} \quad n = N / (1+N*e^2) \tag{1}$$

Where n=sample size; N= Total population size; e= margin of error. Thus N = 162; Margin of error (e) = 0.1, Hence sample size

$$(n) = 162/ (1+162*0.01) = 61.43 \tag{2}$$

From the computed sample size of 61 contracting firms from Class I and II, selection was done from each stratum adopting the proportioning approach:

For class I building contractors = 131/162 x sample size

$$= 131/162 \text{ x } 61 = 49 \tag{3}$$

For class II building contractors

$$= 31/162 \text{ x sample size} = 31/162 \text{ x } 61 = 12 \tag{4}$$

Therefore the sample size drawn from each strata for class I and II were 49 and 12 representing 37.4% and 38.7% respectively; a size considered as an adequate representation [29]. Purposive sampling was opted for targeting respective firms that were undertaking relatively complex or challenging building projects during the research period. Information rich [30,31] building contractors were considered, that had on-going construction of multi- storey buildings and those working in congested sites. Construction experience and reputation were also essential factors considered in the selection of a contracting firm. A total of 61 questionnaires were distributed to Class I and II building contractors and 54 were returned, reflecting a response rate of 88.5%.

3. Results and Discussion

The questionnaire collected respondents' profiles and H & Safety information such as, existence of H & Safety policy, programmes, and the nature of workers employment. Out of the 54 firms, 50 firms (92.6%) reported to have H & S policy in place. Nature of employment of workers was examined amongst the respondents and it was noted that 55.56% of the contracting firms used a combination of casual and contract employments, followed by 25.93% employed on contract arrangement and casual employment being 18.52%. A total of 88.89% reported to have a H & S programme and only 11.11% reported not to have any programme in place.

The study in investigating the nature of H & S knowledge in construction sites, collected approaches used by building contractors in imparting knowledge of H & S to workers. An assessment was made as whether the nature of knowledge was dominantly tacit or explicit. The study examined whether approaches used to impart knowledge were through training in H & S, response by the management/ contractor on reported H & S concerns, setting H & S priorities, H & S inspections at construction sites, addressing emergencies, leading by examples, collection of hazard control ideas by the management/ contractors, implementing hazard control or making improvements on feedback of H & S concerns. A Likert scale was used to rank respondents' opinion where: 1= not applied; 2= minimal application 3= moderate application; 4= high application. The interpretation made by the study is that: mean scores of 3.5 to 4 to indicate "high application"; while mean scores of 2.5 – 3.4 to indicate "moderate application"; and mean scores below 2.5, "minimal application". The results are shown in Table 4.

Table 4. Approaches for imparting H & S knowledge to workers: Contractors Class I

Contractors approaches on H & S					a)	b)	c)	d)	e)	
Scores	1	2	3	4						
Provide training	2	5	14	21	138	3.286	5	M	FM	XP
Respond to workers	0	4	19	19	141	3.357	4	M	IF	TC/XP
H & S priorities	0	4	16	22	144	3.429	3	H	FM	TC/XP
Inspect	0	2	16	24	148	3.524	2	H	FM	XP
Address emergencies	0	2	14	26	150	3.571	1	H	FM	XP
Lead by examples	0	3	14	25	148	3.524	2	H	IF	TC
Collect hazard control ideas	6	14	12	10	110	2.619	7	M	FM	XP

Contractors approaches on H & S					a)	b)	c)	d)	e)	
Implement hazard control	3	8	12	19	131	3.119	6	M	FM	TC/XP
Improve on feedback	0	8	14	20	138	3.286	5	M	FM	TC/XP

Key: (Table 4 & 5)

M	Moderate application		a)	Total weight
H	High application		b)	Mean scores
FM	Formal mode of imparting knowledge		c)	Rank
IF	Informal mode of imparting knowledge		d)	Application
TC	Tacit form of knowledge		e)	Knowledge type
XP	Explicit form of knowledge			

From Table 4 it is noted that out of the nine affirmative actions, the top most ranked are “address emergencies” followed by “inspect construction sites“ and “lead by examples” that are both second in rank, and the third “set H & S priorities”. The least approaches by Class I contractors were “implement hazard control” followed by “collect hazard control ideas”. Of the three top ranked approaches of imparting H & Safety knowledge, two are of explicit nature and only one “lead by examples” is tacit. While the latter is characterized by informality the former is more formal in nature. The data also shows for class I category of building contractors, the application of the identified approaches for the top four in rank are highly applied. These are “address of emergence”, “lead by examples”, “set H & S priorities” and “respond to workers’ H & S concerns”.

Table 5 reflects responses of building contractors Class II showing the three top ranked approaches are “conducting inspection at construction sites”, “setting H & S priorities” and “response to workers reporting on H & S concerns”. The lowest in rank under this category had mean scores of 2.750. These were “collect hazard control ideas” and “lead by examples” that are both lowest; followed by “implement hazard control” and “improve on feedback” both being second lowest. Of the three top ranked approaches under this class, two thirds are characterized by a combination of tacit /explicit type of knowledge while one out of the three is explicit knowledge. Noted for class II contractors, the identified approaches are all moderately applied.

Further, the study observed for Class II building contractor the top ranked approaches for imparting H & S knowledge are of reactive mode and include “inspection at construction sites”, “address of emergencies” and “response to workers report on H & S concerns”. Only “setting of H & S priorities” amongst the top ranked is a preventive approach. For Class I building contractor category, likewise of the top three, two approaches are of reactive mode as for the Class II building contractors. These are, “address of emergencies” and “inspect construction sites”. At least for this category “lead by examples” is noted in the second order, and not “one reacting to a H & S” incident. Overall for both classes, dominancy of a reactive mode of imparting H & S knowledge is noted.

Training which has adamantly been echoed as a means of imparting knowledge in various research studies [4,11,13,26,32-34] is seen to be lowly ranked by the Class I building contractors and ranked third, by Class II contractors. Based on the outcome of the results, the author’s plausible explanation is the potential for Class I contractors preferring to opt for “lead by examples” which is high up in rank (2^{nd} in rank) in lieu of training. The opposite is observed to be true for Class II where “lead by examples” is low (5^{th} in rank) but “training” is amongst the top ranked.

Table 5. Approaches for imparting H & Safety knowledge by Contractors Class II

Contractors approaches on H & S					a)	b)	c)	d)	e)	
Scores	1	2	3	4						
Provide training	1	2	6	3	35	2.917	3	M	FM	XP
Respond to workers	0	2	5	5	39	3.250	1	M	IF	TC/XP
H & S priorities	0	1	7	4	39	3.250	1	M	FM	TC/XP
Inspect	0	3	3	6	39	3.250	1	M	FM	TC/XP
Address emergencies	1	2	4	5	37	3.083	2	M	FM	XP
Lead by examples	1	3	6	2	33	2.750	5	M	IF	TC
Collect hazard control ideas	1	3	6	2	33	2.750	5	M	FM	XP
Implement hazard control	1	2	7	2	34	2.833	4	M	FM	TC/XP
Improve on feedback	1	3	5	3	34	2.833	4	M	FM	TC/XP

Overall results indicate deployment of affirmative action by both categories of contractors ranging from moderate to high. Nevertheless as the results have shown a variation in prioritization of approaches in imparting and communicating H & S knowledge amongst the two classes of building contractors, this prompted the author to assess whether the variance is of statistical significance or was just of chance or from sampling error.

A null hypothesis was posited as such:

Ho: Approaches used by Class I and II contractors in imparting H & S knowledge to workers are the same

$$Ho: \mu^1=\mu^2 \quad (1)$$

Ha: Approaches used by Class I and II contractors in imparting H & S knowledge to workers are not the same"

$$Ha: \mu^1\neq\mu^2 \quad (2)$$

A t- test was done using the mean scores of the two categories of contractors (see Table 6)

Table 6. t- Test results testing statistical significance of approaches used by Class I and II contractors

Ms Class I	Ms Class II	t-Test: Two-Sample Assuming Unequal Variances		
3.286	2.917			
3.357	3.250		*Class I*	*Class II*
3.429	3.250	Mean	3.3015873	2.990741
3.524	3.250	Variance	0.08630952	0.047647
3.571	3.083	Observations	9	9
3.524	2.750	Hypothesized Mean Difference	0	
2.619	2.750	df	15	
3.119	2.833	t Stat	2.54792141	
3.286	2.833	P(T<=t) one-tail	0.01114481	
		t Critical one-tail	1.75305036	
		P(T<=t) two-tail	0.02228962	
		t Critical two-tail	2.13144955	

Results show t- statistics greater than t- critical hence the null hypotheses Ho is rejected; that the approaches used by contractors in imparting knowledge to site workers is not the same. However, the observed difference between the sample means (i.e. 3.3045 and 3.0246) is not convincing for one to state the approaches used by the classes of contractors differ significantly. The variance for the two classes of contractors is also minimal indicating a commonality in the approaches used. Of further interest is the observation that the type of knowledge dominantly used by both is explicit knowledge; a type of knowledge that is relatively easy to communicate, store and retrieve. A scenario that may be argued as conducive for enhancement of H &S performance in construction sites. See table 6.

The study had also explored challenges faced by contractors in imparting H & S knowledge to workers and examined the nature of challenges. Mean scores were established for both classes of contractors and the results ranked as shown in Table 7.

The top most challenge reported by respondents is noted to be of external origin, "insufficient inspection by regulatory authorities". The second and third are of endogenous nature, and are, "inadequate workers' participation" and "a poor H & S culture". The least challenge as reported by respondents was "insufficient budget for H & S". Of the twelve challenges, only one is of exogenous nature while the rest are endogenous. The implication of such scenario is that the reported challenges are within the control of an organization.

Table 7. Nature of contractors challenges in imparting H & S knowledge to workers

Challenges/ Scores	1	2	3	4	a)	b)	c)	d)	e)
Insufficient safety inspection by regulatory authorities	0	0	5	22	3.81	H	1	Ex.	Exg.
Inadequate workers' participation on H & S	0	0	8	19	3.7	H	2	In.	End.
Poor H & S culture	0	0	10	17	3.63	H	3	In.	End.
Unfavourable work environment	0	0	14	13	3.48	M	4	In.	End.
Inadequate safety knowledge of workers	0	1	16	10	3.33	M	5	In.	End.
Low awareness of H & S by workers	0	6	10	11	3.19	M	6	In.	End.
Negligence of workers on H & S matters	3	3	10	11	3.07	M	7	In.	End.
Poor management commitment of H & S	3	5	10	9	2.93	M	8	In.	End.
Poor communication between employers and workers	1	8	12	6	2.85	M	9	In.	End.
Poor education and training of H & S to workers	2	7	12	6	2.81	M	10	In.	End
Absence of essential signs and posters of H & S at construction site	2	8	12	5	2.74	M	11	In.	End.
	5	6	9	7	2.67	M	12	In.	End.

Key: (Table 7)

a)	Mean scores		b)	Magnitude of challenge
c)	Rank		d)	Source of challenge
e)	Characteristic challenge			
H	High magnitude		M	Moderate magnitude
Ex.	External source		In.	Internal source
Exg.	Exogenous nature		End.	Endogenous nature

4. Conclusions

Theoretical and practical implication

The article has established that mechanisms for creating H & S knowledge at construction sites exist. This view is based on Nonaka and Takeuchi's [19] knowledge creation concept that for creation of knowledge, a conversion process of tacit to explicit knowledge has to occur. The study has shown the co-existence of the two types of knowledge in the approaches used by contractors to impart knowledge, which creates grounds for the creation of H & S knowledge. However, the dominance of the explicit knowledge that was observed in both classes of contractors may not be a very good indication as this alone is not suffice to create knowledge [19]. Firms are considered to gain in H & S performance if they could work towards enhancement of tacit knowledge both at organizational and individual level whereby through a conversion process H & S knowledge is created [19]. Efforts towards such goals require initiatives such as having brainstorming sessions on H & S by workers at construction sites, tool box meetings, apprenticeship, job rotations, adaptive changes, informal networks and nurturing a culture of valuing H & S at construction sites. H & S information exists in various forms and is communicated variably, however for it to make an impact in H & S performance, a conversion process of the information to knowledge is essential; as in itself it remains as data or information [18].

The dominancy of a reactive approach to imparting H & S knowledge to workers at construction sites is also viewed by the author as not a healthy precedent for enhancing H & S performance at construction sites. The limitations of inspections such as ownership of the task shifting from worker to the inspector, missing out and inspection cost [35], all potentially jeopardize the overall goal. Adopting the P-A-F model philosophy applied in the quality cost field [36], could be a solution where prevention and appraisal are given the most weight. The prevention culture has also been advocated for not only improvising protection, but also health promotion [37].

Furthermore, through a statistical analysis it has been established that the differences in approaches used by contractors in imparting H & S knowledge to workers is not of statistical significance. Though among the two classes of contractors, Class I contractors illustrated a higher application of the identified parameters of imparting H & S knowledge while Class II were less robust.

Challenges faced by contractors in the course of imparting H & S knowledge to workers were noted to be dominantly of endogenous nature. A fact that implicates the respondents to have leverage on addressing the challenges. It is thus recommended by the author, for excelling in H & S performance it is imperative for firms to put conceited efforts toward capturing and fostering tacit knowledge both at individual and organizational level. By doing this, firms would be acknowledging the dynamism of knowledge creation through a conversion process of tacit-explicit knowledge [19], which eventually would enhance H & S knowledge in construction sites.

Last, the author adopts Okoye et.al's [12] reiteration that safety learning should not only be considered as an acquisition of knowledge through instructions and training in classrooms or other formal settings ; rather safety knowledge should be considered as the final outcome of a dynamic and collective construction process. In this case, a safe workplace is the result of constant engineering of diverse elements, such as knowledge and skills, equipment, and social interactions.

The study is limited to building contractors who were practising in the commercial city of Tanzania, Dar es Salaam during the period of research; hence conditions pertaining to the Tanzania construction industry could be an influencing factor to the results limiting a wider application. Nevertheless the results are presumed to have a wide application for construction industries with similar economies such as those in developing countries.

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