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Analytical Hierarchy Process (AHP) based Safety Climate Maturity Model for building construction projects in Tanzania

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Abstract

Tanzania's construction boom, while promising, casts a long shadow with its persistent safety challenges. Addressing these concerns requires not just reactive measures, but a proactive approach to cultivating a safety-mature construction environment. This research delves into this crucial aspect, proposing an Analytical Hierarchy Process (AHP)-based safety maturity model specifically tailored to Tanzanian building projects. MS Excel was used to create an Analytical Hierarchy Process by eight Safety and Health experts who tested the approach after the Smart PLS was used to identify important variables using factor reduction. Out of the 143 variables in the questionnaire, 19 factors were identified as essential factors to be used in this study using the Exploratory Factor Analysis (EFA). The general safety climate index (SCI) of 2.60 of the construction projects was determined. It indicated that the safety climate maturity of construction projects is in a compliant level because the range of SCI is within 2-3 (Level 3) indicating the safety climate processes and procedures are formal and defined. This research aspires to be a roadmap and guiding stakeholders towards safer construction sites, a thriving industry, and a brighter future where human well-being and project success go hand in hand.

Keywords: Analytical Hierarchy Process; construction safety; maturity model; safety climate; safety performance.

Introduction

Tanzania's construction industry is experiencing a period of rapid growth, yet concerns about safety remain a persistent shadow (Kikwasi and Escalante, 2020; Mwemezi, Kikwasi and Phoya, 2023). Beyond statistics and reactive measures, fostering a culture of safety maturity is crucial for sustainable progress. This research embarks on this critical journey, proposing an innovative Analytical Hierarchy Process (AHP)-based safety maturity model specifically tailored to Tanzanian building projects (Gunduz and Almuajebh, 2020).

Imagine a comprehensive framework that dissects the intricate web of factors influencing safety in construction. AHP framework is a well-known technique for organizing and analysing group complex decisions (Jankovic and Popovic, 2019). The AHP model goes beyond simple checklists which leveraging the power of the AHP (Goepel, 2013). Through expert judgment and stakeholder perspectives, the AHP assigns weighted priorities to various safety elements, creating a nuanced understanding of their relative importance (Lee et al. 2021).

Critical leverage points/areas where focused actions can result in the greatest increases in safety maturity are found by analysing the model's output. This study is a future where safety maturity becomes a cornerstone of the Tanzanian construction industry. It aspires to be a roadmap, guiding stakeholders towards safer sites, a thriving industry, and a brighter future where human well-being and project success go hand in hand. This research paper consists of several sections include the introduction which highlights the Tanzania construction industry and the safety climate categories, materials and methods section which has established the research sample size and the analytical Hierarch Process (AHP) methodology, results and discussion section and conclusion section of the research.

Construction industry

The construction industry in Tanzania faces challenges in ensuring worker safety, with a high rate of accidents and fatalities. Research suggests that the safety climate and the perception of safety within a project, play a crucial role. Analytical Hierarchy Process (AHP) offers a structured approach to evaluating this climate. Various studies have explored the use of AHP to assess safety climate factors in construction projects. For instance, a study by Shen et al. (1998) aimed to develop a maintenance plan which is based on a rational assessment of priorities and up-to-date knowledge of the condition of the property stock which will help to ensure the best use of available resource using AHP (Shen et al. (1998)).

Another study by Wakchaure and Jha (2012) applied AHP to determine the bridge health index and for the allocation of resources. Their framework, based on the AHP be applied easily by different stakeholders for ranking a number of bridges in a bridge stock for maintenance actions, thereby optimizing resources (Wakchaure and Jha 2012). These studies showcase the potential of AHP in understanding and improving safety climate in construction industry. By identifying the most critical factors influencing safety perceptions, stakeholders can develop targeted interventions to create a safer work environment for construction workers in Tanzania.

The analytic hierarchy process (AHP) was used in different research to determine the weights of the most important factors to develop a model to assess safety performance (Başaran et al. 2023) or a multi-criteria decision-making (Das et al. 2010) or others (Vaidya and Kumar 2006, Başaran et al. 2023).

Safety climate categories

There are three categories of factors used in determining the safety climate at the construction sites in Tanzania. These factors are safety leading factors, safety management process factors and safety lagging factors (safety performance). Safety leading factors are the factors that influence the safety climate of a construction site. These factors can be grouped into four categories.

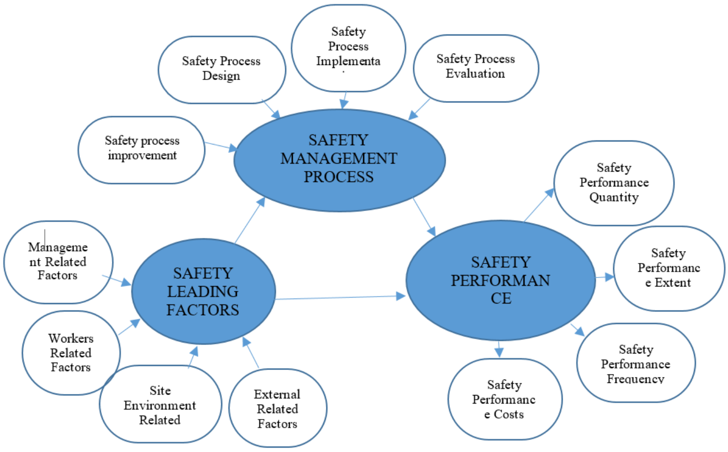

Figure 1: Conceptual framework

Project management factors are established as crucial factors influencing construction safety. Effective project management involves planning, organizing, staffing, leading, and controlling safety aspects. This implies that meticulously planning safety procedures, assigning roles accordingly, and supervising adherence to these plans are essential for a safe work environment (Gunduz and Almuajebh 2020).However, research has shown how attitudes, abilities, practices, and personalities that every worker brings to the workplace might have an impact on safety results (Dennerlein et al. 2022).Site-related factors have demonstrated that have the potential to either favourably or unfavourably affect worker safety and productivity. For example, a safe work environment is enhanced by appropriate scaffolding, well-maintained equipment, and clear walkways; on the other hand, unsafe conditions are created by disorganized workspaces and faulty machinery (AparnaShruthi and Venkatasubramanian, 2017).Conversely, external factors have also had an impact on overall safety performance. The project's subcontractors' safety cultures, governing body standards, and weather conditions are a few examples of exterior factors (Rivera et al. 2021).

Nevertheless, the safety management process factors are the safety processes that organizations undertake to create a safe work environment. As far as this research paper is concerned, the Plan-Do-Check-Act (PDCA) will be used to measure the whole safety climate management process of the model. Plan-Do-Check-Act (PDCA) is a four-step process for continuous improvement. It is a cyclical process that can be used to improve any process or system. The ‘Plan’ phase (safety process design) identifies the project’s safety goals and establishes a plan to achieve them. The ‘Do’ phase (safety process implementation) focuses on how effective communication, resource allocation, and adherence to safety protocols during construction influence overall safety outcomes (Carvalho et al. 2015).In the case of the ‘Check’ phase (safety process evaluation), it involves evaluating the implemented plan using data collection through learning from experience and adapting safety plans for future projects (Bridges et al., 2017).While the ‘Act’ phase (safety process improvement) uses evaluation results to refine the project’s safety plan, potentially involving adjustments to procedures or protocols, the ‘Check’ phase can inform best practices for future construction endeavors (Johnson et al. 2010).The PDCA cycle is repeated until the goal is achieved or until it is determined that the goal is not achievable.

Safety lagging factors (safety performance) are the factors that measure how well an organization is managing its safety risks in a project. It is typically not only measured by many measures, such as the number of incidents, accidents, and injuries that occur, but also by other factors, such as the number of near misses, fatalities, damages to property, financial loss, compensation due to accidents, overtime associated with slow operation, production time lost, slowdown in operation, decrease in morale, loss of client, and equipment breakdown due to unsafe practice (Chan et al. 2023).

Materials and methods

Sample size

In this study, a series of methods are used in the research design. The first step was to collect and analyse literature studies to gather factors that affect safety on construction sites. After that, a questionnaire survey was conducted to determine the most important factors among the collected factors from the literature that affect the safety climate at construction sites in Tanzania. Interviews, mail, and email messages were used to conduct the questionnaire survey. The population samples collected from the Contractors Registration Board (CRB) registry show a total of 757 registered building projects within classes 1-4.The sample size formula for the small and finite population is provided by (Kothari, 2004) and is given as;

$$n = \frac{Z^2 \times N \times pq}{<N-1> e^2 + Z^2 \times pq} \quad ..(1) \qquad = \frac{1.96^2 \times 757 \times 0.5^2}{< 757 - 1 > 0.05^2 + 1.96^2 \times 0.5^2}$$

$$n = \frac{727.0228}{2.854} = 255$$

Where; Z is z value from a table of confidence interval (CI=95%=1.96) N=Population size=757 respondents; p is sample proportion=0.5, q=1-p = 0.5; e^2=Margin error (5%=0.05)

The sample size of this research was 255 respondents whereby clients were 26 were Class 1, 50 were Class II, 74 were Class III and 105 were Class IV. Construction workplace safety is complex, with numerous factors influencing it. To identify the factors that affect the safety climate at construction sites, an in-depth literature review was carried out. As such, 143 factors that affect the safety climate at construction sites were compiled and reviewed. Then, these factors were examined by preparing a survey questionnaire in which various construction safety professionals (including owners, managers, engineers, supervisors, etc.) participated. The purpose of this questionnaire is to identify the most important factors that affect the safety climate of construction projects in Tanzania. Using SPSS, EFA was performed with all the 143 factors for the several iterations, and nineteen factors were identified which are; ERF1, ERF2, MRF6, SMP1.3, SMP1.4, SMP2.2, SMP2.3, SMP3.2, SMP3.3, SMP4.1, SMP4.2, SPC10, SPC9, SPE14, SPF3, SPF4, SRF16, WRF7 and WRF8. The final factors are shown in Tables 2, 3 & 4 due to the best factor loadings.

Table 1: Safety leading factors variables

Factors	Denotes	Variables	Factor loadings
Project Management Related Factors (MRF)	MRF6	Management takes corrective actions promptly about safety	1
Worker's Related Factors (WRF)	WRF7	Workers feel comfortable reporting safety concerns and unsafe conditions	
	WRF8	Workers participate in safety activities, such as safety meetings, training, and inspections	
Site environment Related	SRF16	The safety practices are adequate to	1

factors (SRF)		prevent slips, trips, and falls	
External Related Factors ERF	ERF1	The project safety practices are in compliance with all applicable industry safety regulations	0.888
	ERF2	The project has been inspected by government safety agencies	0.837

Table 2: Safety management process variables

Factors	Denotes	Variables	Factor loadings
Safety process design -SMP1	SMP1.3	The project has a process for risks assessment	0.998
	SMP1.4	There is a Risk management plan for handling safety issues	0.998
Safety Process implementation -SMP2	SMP2.2	Safety inspections are conducted regularly	0.779
	SMP2.3	Workers feel comfortable reporting safety concerns	0.914
Safety process evaluation -SMP3	SMP3.2	The project conducts regular safety audits to assess the effectiveness of its safety processes and systems	0.892
	SMP3.3	Workers feel comfortable providing feedback on safety processes and systems	0.897
Safety process improvement SMP4	SMP4.1	The project makes changes to its safety processes and systems based on the results of its safety process reviews	0.87
	SMP4.2	The project communicates changes to its safety processes and systems to workers in a timely and effective manner	0.849

Table 3: Safety performance variables

Factors	Denotes	Variables	Factor loadings
Safety performance Extent (SPE)	SPE14	Extent of equipment breakdown due to unsafe practice	1
Safety performance Frequency (SPF)	SPF3	Frequent of accidents	0.977
	SPF4	Frequent of near misses	0.985
Safety performance Costs (SPC)	SPC9	Costs of Overtime associated with slow in operation	0.721
	SPC10	Costs of Production time loss	0.785

Procedures for developing AHP

First, the target, main criteria, sub criteria, and alternatives were established. Eight experts examined the sub-criteria, and the major criteria was determined using the AHP scale for combinations. The alternatives were the different criteria that solutions must be evaluated against. Once the hierarchy was built, a numerical scale was assigned to each pair of alternatives. The selection of experts was conducted through recommendations from the research participants from the construction industry.

Table 4: Nine AHP numerical scale (Saaty, 2008)

Scale	***Definition***
1	Equally important
3	Variable A is slightly more important than variable B
5	Variable A is important than variable B
7	Variable A is more important than variable B
9	Variable A is absolutely more important than variable B
2,4,6 and 8	Value between the two closest numbers

The next step was to model the problem. According to the AHP methodology, a problem is a related set of sub-problems. The AHP method therefore relies on breaking the problem into a hierarchy of smaller problems. In the process of breaking down the sub-problem, criteria to evaluate the solutions emerge. Using MS Excel, the process of assigning priority among criteria using pairwise comparison was conducted. The AHP method uses pairwise comparison to create a matrix. In this case, the experts were asked to weigh the relative importance of different criteria established by SEM in their safety categories.

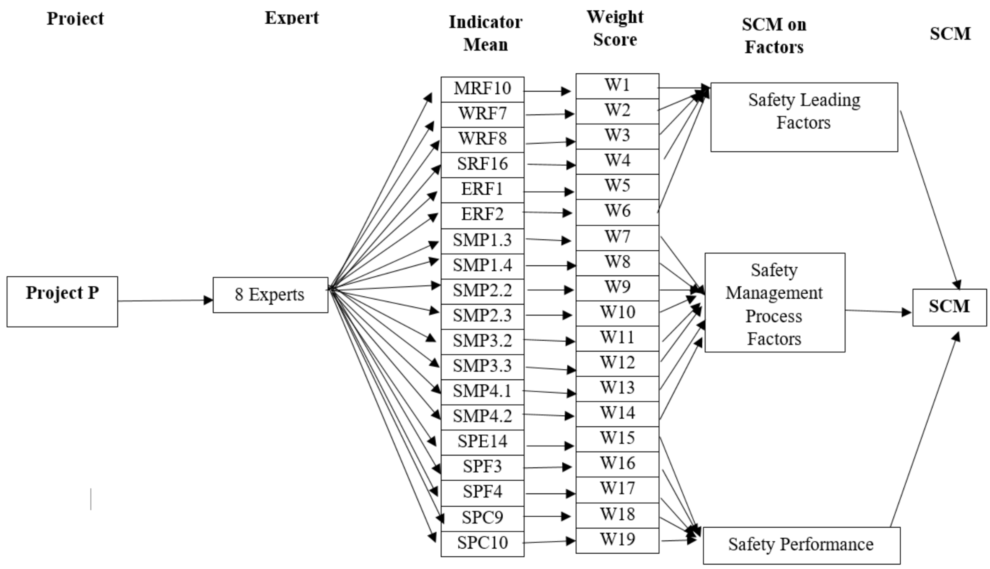

Figure 2: Research process

Then the consistency ratio and index were determined in order to understand if each size of matrix measures the degree of departure from pure inconsistency (Saaty, 1990). Their formula are determined below;

$$CR = \frac{CI}{RI} \ldots\ldots.. (2)$$

Where; CR=Consistency ratio
CI=Consistency Index
RI=Random index

$$CI = \frac{\lambda_{max} - 1}{n-1} \ldots\ldots\ldots.(3)$$

Where; CI= Consistency Index
λ=Product of weight
n=number of criteria

The relative importance scale between two alternatives as suggested by Saaty (Saaty, 2005) was used, whereby they scaled the attributing values that vary from 1 to 9. The scale determines the relative importance of an alternative when compared. The Random index between *n* alternatives is shown in Table 6 (Franek and Kresta, 2014).The best consistency ratio (CR) for *n* alternatives should be less than 0.1.

Table 5: Scale Random Index (RI)

n	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49	1.51	1.54	1.56	1.57	1.58

To determine the relative weights, the mathematical calculation was then created in MS Excel based on the data and relative weights were assigned to the criteria. Experts prepared the pairwise comparison matrix from several alternatives of the safety leading factors, safety process factors and safety lagging factors (Safety performance) of the construction sites obtained from EFA. The best alternative was used to determine the safety climate maturity in this study. Finally, the mean value of each indicator was multiplied by the weight value to determine the SCM value of each safety factor. The project's SCM is determined by determining the average of each safety climate factor.

Results and Discussion

The Analytical Hierarchy Process (AHP) was utilized to find the weights of the 19 factors affecting the safety climate. Developing the hierarchy of the problem at hand was the initial step in applying the AHP (Cheung et al., 2001). Each expert is asked to rank each component on a scale of importance in relation to others (pairwise comparisons) in light of the objective after each factor was given weight by comparing it to another factor (Fong and Choi, 2000). In this study, the opinions of 8 safety experts whose experience ranges from 5 to 20 years, were solicited. A scale of one to nine was used for these pairwise comparisons, one means that both factors are equally preferred, while nine indicates that one factor is greatly preferred over the other. The Table 6 presents both pairwise comparison matrix, normalised pair-wise comparison matrix and criteria weight percentage matrix for the SLF's six components calibrated using MS excel.

Table 6: Matrix for safety leading factors

			Pair-wise Comparison Matrix			
	MRF6	**WRF7**	**WRF8**	**SRF16**	**ERF1**	**ERF2**
MRF6	1	2	5	3	3	3
WRF7	0.5	1	1	2	1	3
WRF8	0.2	1	1	2	2	2
SRF16	0.333333	0.5	1	1	3	2
ERF1	0.333333	1	0.5	0.333333	1	2
ERF2	0.333333	0.333333	0.5	0.5	0.5	1
SUM	2.7	5.833333	8.5	8.833333	10.5	13
			Normalised pair-wise comparison matrix			
MRF6	0.37037	0.342857	0.588235	0.339623	0.285714	0.230769
WRF7	0.185185	0.171429	0.117647	0.226415	0.095238	0.230769
WRF8	0.074074	0.171429	0.117647	0.226415	0.190476	0.153846
SRF16	0.123457	0.085714	0.058824	0.113208	0.285714	0.153846
ERF1	0.123457	0.171429	0.058824	0.037736	0.095238	0.153846

ERF2	0.123457	0.057143	0.058824	0.056604	0.047619	0.076923
Criteria weight percentage matrix						
C W	0.359595	0.171114	0.155648	0.136794	0.106755	0.070095
CW (%)	35.95948	17.11139	15.56479	13.67938	10.67548	7.009485
SUM	2.7	5.833333	8.5	8.833333	10.5	13
CA	0.970906	0.998164	1.323007	1.208345	1.120926	0.911233

The consistency index (CI) is then calculated using the value of λmax shown below for each category. The consistency ratio (CR) is then calculated, where the RI changes depending on the number of evaluation criteria used and is 1.25 for six criteria. The consistency of the judgments is satisfactory as the CR is 0.085 (Table 9), i.e. less than 0.1. However, the weights of all six factors in this construct were calculated as presented in Table 6. The MRF6 factor was ranked as the most important factor affecting safety performance with the highest weight of 0.35 (35%).

Safety climate management process factors which were retrieved SPSS were also provided to experts to develop the pairwise comparison matrix, normalised pair-wise comparison matrix and criteria weight percentage matrix. The results are presented in Table 7.

Table 7: Matrix for safety climate management process

Pair-wise Comparison Matrix								
	SMP1.3	***SMP1.4***	***SMP2.2***	***SMP2.3***	***SMP3.2***	***SMP3.3***	***SMP4.1***	***SMP4.2***
SMP1.3	1	1	2	2	3	2	3	3
SMP1.4	1	1	1	3	2	1	4	1
SMP2.2	0.5	1	1	2	3	3	2	5
SMP2.3	0.5	0.3333	1	1	1	2	2	3
SMP3.2	0.3333	0.5	0.3333	1	1	1	5	2
SMP3.3	0.5	1	0.3333	0.5	1	1	3	1
SMP4.1	0.3333	0.25	0.5	0.5	0.2	0.33333	1	2
SMP4.2	0.3333	1	0.2	0.3333	0.5	1	0.5	1
SUM	**4.5**	**6.0833**	**5.8666**	**10.333**	**11.7**	**11.3333**	**20.5**	**88**
Normalized pair-wise comparison matrix								
SMP1.3	0.222	0.1643	0.340	0.193	0.256	0.176	0.146	0.1667
SMP1.4	0.2222	0.1644	0.1705	0.290323	0.17094	0.088235	0.1951	0.055556
SMP2.2	0.1111	0.1644	0.1705	0.193548	0.25641	0.264706	0.0976	0.277778
SMP2.3	0.1111	0.0548	0.0852	0.096774	0.08547	0.176471	0.0976	0.166667
SMP3.2	0.0740	0.0822	0.0568	0.096774	0.08547	0.088235	0.2439	0.111111
SMP3.3	0.1111	0.1644	0.0567	0.048387	0.08547	0.088235	0.1463	0.055556
SMP4.1	0.0740	0.0411	0.0852	0.048387	0.01709	0.029412	0.0488	0.111111
SMP4.2	0.0740	0.1644	0.0340	0.032258	0.04273	0.088235	0.0244	0.055556
Criteria weight percentage matrix								
C W	0.2084	0.1697	0.192	0.10926	0.10482	0.09454	0.0567	0.064465
CW (%)	20.834	16.965	19.199	10.92594	10.4822	9.453779	5.68977	6.446534
SUM	66.695	53.595	35.724	-12.5925	-16.142	-24.3698	-48.427	-54.4818
CA	4.5	6.0833	5.8667	10.33333	11.7	11.33333	20.5	18
C W	0.9376	1.0320	1.1263	1.129014	1.2264	1.071428	1.1664	1.160376

Furthermore, the weights of all eight factors in this construct were calculated as presented in Table 7. The SMP1.3 factor was ranked as the most important factor affecting safety performance with the highest weight of 0.21(21%). Finally, the weights of all five factors for safety performance factor were calculated as presented in Table 8. The SPE14 factor was ranked as the most important factor affecting safety performance with the highest weight of 0.36 (36%).

Table 8: Matrix for Safety Performance Factors

		Pair-wise Comparison Matrix			
	SPE14	**SPF3**	**SPF4**	**SPC9**	**SPC10**
SPE14 z	1	2	2	5	2
SPF3	0.5	1	3	2	3
SPF4	0.5	0	1	3	2
SPC9	0.2	0.5	0.333333	1	1
SPC10	0.5	0.33333	0.5	1	1
SUM	2.7	4.16667	6.833333	12	9
		Normalized pair-wise comparison matrix			
SPE14	0.3704	0.48	0.2927	0.4166	0.2222
SPF3	0.1852	0.24	0.4391	0.16667	0.33333
SPF4	0.1852	0.08	0.1463	0.25	0.22222
SPC9	0.0741	0.12	0.0489	0.083333	0.11111
SPC10	0.1852	0.08	0.0732	0.083333	0.11111
		Criteria weight percentage matrix			
Criteria Weights	0.356388	0.272842	0.17675	0.08746	0.10656
Criteria weight (%)	35.63884	27.28419	17.67498	8.74598	10.6560
SUM	2.7	4.166667	6.833333	12	9
CA	0.962249	1.136841	1.20779	1.049518	0.95904

The consistency ratio (CR) is calculated by Eq. (2), where the RI changes depending on how many evaluation criteria are used and equals 1.4 for eight criteria. The consistency of judgments is satisfactory because the CR is 0.07 (Table 9), which is less than 0.1.

Table 9: Consistency ratio

	SLF	**SMPF**	**SPF**
Lambda Max	6.532581	8.8497	5.315438482
Consistency Index (CI)	0.106516	0.1213	0.078859621
Random Index (RI)	1.25	1.4	1.11
Consistency ratio (CR)	0.085213	0.0867	0.0710

To clearly demonstrate the proposed methodology, Table 10 presents the SCM Safety Climate Maturity Level for this study. The table establishes the index in which the safety climate maturity will be assessed. Score value will be determined by calculating the total safety climate maturity of the project using the equation 4.

Table 10: Safety Climate Maturity Level

M	*Name*	*Descriptions*	*Safety Climate outputs*	*Score value*

1	Inattentive	No need for attention on given processes and procedures in place.	Performance on improving SCM is consistently poor. Near miss, accident and injury are very high	$0 < y \leq 1$
2	Reactive	Project processes and procedures may exist but unstructured and not defined.	Performance on improving SC Maturity is fair.	$1 < y \leq 2$
3	Compliant	Project processes and procedures are formal and defined.	Performance on improving SC Maturity is mostly good.	$2<y \leq 3$
4	Proactive	Procedures and processes are planned, well-defined and conform to best practices.	Performance on improving SC Maturity is very good and consistently repeated	$3 < y \leq 4$
5	Exemplary	Processes and procedures are standardized, fully integrated	Performance is best in the industry. Near miss, accident and injury are very low	$4< y \leq 5$

To clearly demonstrate the methodology proposed, Table 11 presents the SCM score calculation in different maturity levels. In order to determine the Safety Climate Maturity Index, the score value will be determined by the equation 4 below;

$$SCI = \frac{\mu 1 * W1 + \mu 2 * W2 + \mu 3 * W3}{3} \quad \text{........ (4)}$$

Where; μ =Average mean value of a factor
W =Total weight of the factor
SCI=Safety climate index

According to this, all safety climate measures must be transformed to be more harmonized and simpler. Note that the equation can calculate the total safety climate scores that is the average of the individual safety climate score of each SCM factor.

Table 11: Safety climate maturity score

			L1	L 2	L3	L4	L 5	
SLF	Mean	μ1	1	2	3	4	5	2.55192
	Weight	W1	1	1	1	1	1	1
	T1	μ1*W1	1	2	3	4	5	2.55192
SMPF	Mean	μ2	1	2	3	4	5	2.46862
	Weight	W2	1	1	1	1	1	1
	T2	μ2*W2	1	2	3	4	5	2.46862
SP	Mean	μ3	1	2	3	4	5	2.79966
	Weight	W3	1	1	1	1	1	1
	T3	μ3*W3	1	2	3	4	5	2.79966
SCI	Average	(T1+T2+T3)/3	1	2	3	4	5	2.60673
	Range		0-1	1-2	2-3	3-4	4-5	
	SCI	Level 2		2.60				

The SCIM score of safety climate indicators was found to be 2.55192 that of safety climate management process to be 2.46862 and that of safety performance factors to be 2.60673 as shown in details in Table 12.

Table 12: General safety climate maturity (SCM) score

Factor	*Mean score*		*Weight*	*ISCMI*	*SCI*
MRF6	2.0776		0.3595948		
WRF7	2.14424		0.1711139		
WRF8	2.41864		0.1556479		
SRF16	2.21872		0.1367938		
ERF1	3.40256		0.1067548		
ERF2	3.04976		0.0700948		
μ1	2.55192	**W1**	1	2.55192	
SMP1.3	2.22264		0.208369		
SMP1.4	2.21872		0.1696545		
SMP2.2	2.14032		0.1919941		
SMP2.3	2.4108		0.1092594		2.60673
SMP3.2	2.08152		0.1048221		
SMP3.3	2.22264		0.0945378		
SMP4.1	3.40256		0.0568977		
SMP4.2	3.04976		0.0644653		
μ2	2.46862	**W2**	1	2.46862	
SPE14	3.59464		0.3563884		
SPF3	2.05408		0.2728419		
SPF4	2.1168		0.1767498		
SPC9	3.21048		0.0874598		
SPC10	3.02232		0.1065601		
μ3	2.799664	**W3**	1	2.79966	

From Table 12, it is argued that since the obtained SCI from calculation is 2.60 and is within the range of level 3 then it is argued that the safety climate maturity of the construction projects is in an Compliant level because the range is within 2-3 scores (Level 3) which indicates that the whole of the building construction project safety climate processes and procedures are formal and defined and performance on improving SC maturity is mostly good. The Figure 3 present a SCMM of the research using AHP which consists of all stages of assessing the building construction projects and their Safety Climate Indices (SCI).

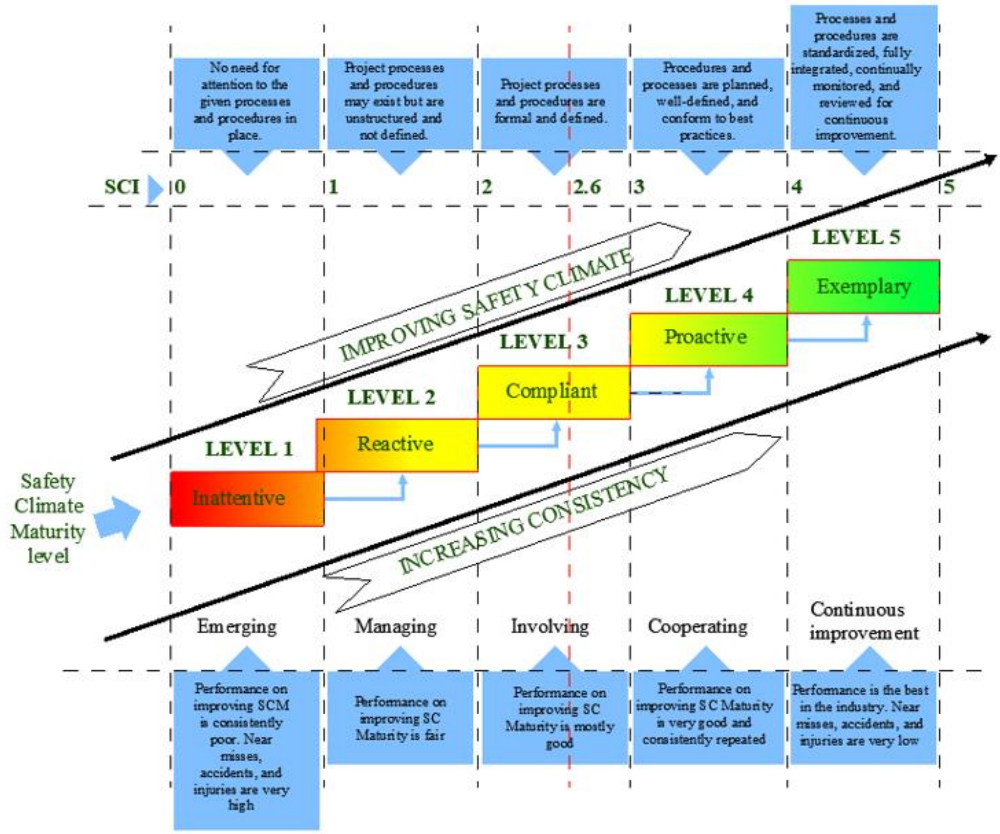

Figure 2: Safety climate maturity model (SCMM)

On the other hand, four projects, namely Alterations and vertical extension to office block, Cables (Factory) and office, erection of pastoral complex on plot No 1&2 Uzunguni area and proposed construction of lecture theatre A and B were randomly selected to measure their safety climate maturity. It has been observed that the projects in Classes I had a higher safety climate maturity than the projects in the lower classes. Because of the management influence on the workers to participate in safety activities, most of the workers prioritized safety in their workplaces which enabled their projects to have a higher safety climate maturity. The maturity levels of the safety climate in the projects are indicated in Table 13.

Table 13: Project Safety Climate Maturity

Class	Factor	Mean score		Weight		ISCMI	SCI
C- I	**Alterations and Vertical Extension to Office Block Laxson Construction Co Ltd Dar es Salaam**						**2.74**
	SLF	$\mu1$	2.827	W1	1	2.827	
	SMP	$\mu2$	2.615	W2	1	2.615	
	SP	$\mu3$	2.785	W3	1	2.785	
C- II	**Cables (Factory) & Office Simba Developers Limited Golani, Kimbiji, Kigamboni Dar es Salaam**						**2.65**
	SLF	$\mu1$	2.663	W1	1	2.663	

	SMP	μ_2	2.52	W_2	1	2.52	
	SP	μ_3	2.752	W_3	1	2.752	
C-III	**Erection of Pastoral Complex on Plot No 1&2 Uzunguni Area PEK Brother's (T) Limited Mwanza**						**2.62**
	SLF	μ_1	2.642	W_1	1	2.642	
	SMP	μ_2	2.471	W_2	1	2.471	
	SP	μ_3	2.741	W_3	1	2.741	
C-IV	**Proposed Construction of Lecture Theater A And B Tender No:Ae/085/2021/2022/Hq/W/01 Li Jun Development Construction Company Limited Lita Tengeru Campus-Arusha**						**2.59**
	SLF	μ_1	2.5032	W_1	1	2.5032	
	SMP	μ_2	2.408	W_2	1	2.408	
	SP	μ_3	2.870	W_3	1	2.870	

Therefore, in order to validate the model, the analysis of the responses obtained from construction projects participants was conducted so as to understand the suitability and usefulness of the proposed SCMM and its assessment matrix using twelve (12) validation criteria indicated in Table 14. The model documentation variable has a higher mean value than the other variables, indicating the validity of the survey instrument for recording participants responses. The overall summary is presented in Table 14, and it shows that all criteria for validating the model have means ranging between 3 and 4.

Table 14: Criteria for validating the adequacy and suitability of the SCMM and its assessment matrix

Variables	*Denotes*	*Mean*	*SD*	*Variance*
Attributes Relevance	SCMMA1	4.29	0.629	0.396
Attributes Coverage	SCMMA2	4.07	0.660	0.436
Attributes Correctness	SCMMA3	3.48	0.869	0.754
Attributes Clarity	SCMMA4	4.21	0.577	0.333
Levels Sufficiency	SCML1	3.93	0.706	0.499
Non-overlapping of Levels	SCML2	4.34	0.637	0.405
Model Understanding	EOUND1	4.07	0.626	0.392
Model Documentation	EOUND2	4.39	0.629	0.396
Score appropriateness	EOU1	4.22	0.601	0.361
Use Convenience	EOU2	4.35	0.525	0.275
Usefulness of Model	UAP1	4.10	0.635	0.404
Model Practicality	UAP2	4.07	0.560	0.313

The practical implications of the AHP-based safety climate maturity model for building construction projects in Tanzania are significant. By providing a structured approach to assess safety performance, the model enables organizations to identify strengths and weaknesses in their safety management systems. This information can be used to develop targeted improvement plans, allocate resources effectively, and prioritize safety initiatives. Additionally, the model can help organizations benchmark their safety performance against industry standards and best practices, fostering continuous improvement. Ultimately, the adoption of this model can contribute to a safer and more sustainable construction industry in Tanzania, reducing accidents, injuries, and fatalities.

The AHP model proposed in this research presents several limitations. Firstly, the model's accuracy and reliability depend heavily on the consistency and objectivity of expert judgments. Inconsistent or biased expert assessments can significantly impact the final results. Secondly, the AHP methodology assumes a hierarchical structure of decision criteria, which may not always be applicable to complex real-world scenarios. Additionally, the model's generalizability may be limited to the specific context of building construction projects in Tanzania, as cultural, social, and economic factors can influence safety climate perceptions and behaviors. Finally, the AHP model does not explicitly account for the dynamic nature of safety climate, which can be influenced by various factors such as organizational changes, technological advancements, and regulatory updates.

Conclusion

To assess the building construction project's safety climate maturity, a safety climate index was created. The AHP determined the relative weights of the indicators established under EFA based on a questionnaire survey of Tanzanian experts in safety and health. "Management provides opportunities for feedback and reporting on safety issues to workers" or MRF6 received the maximum importance (35%) in first group, "The project has a process for risks assessment" or SMP1.3 received (21%) for the second group, while "Extent of equipment break-down due to unsafe practice" or SPE14 received (36%) of the safety climate priority in the third group.

The weights from variables obtained were used for the determination of SCI index, as well as for deciding the safety climate priority.19 safety climate indicators were selected for the preparation of comprehensive definitions: excellent, good, fair, poor and critical. A range of values has also been assigned to indicators by using personal judgment and discussions with the experts. The developed safety climate index equation takes into consideration the weights of the indicators established by the experts and the mean values obtained from the survey.

The calculated Safety Climate Index (SCI) of 2.60 falls within the range of Level 3, indicating a compliant level of safety climate maturity. This suggests that the building construction project has formalized safety processes and procedures, and is actively working to improve its safety climate.

The proposed model would contribute by bringing objectivity and transparency to the determination of safety climate maturity for different building construction projects in Tanzania.

Based on the findings and limitations of the AHP model, several recommendations can be proposed to enhance its application in assessing safety climate maturity in building construction projects in Tanzania. First, it is crucial to carefully select and train experts to ensure the consistency and reliability of judgments. Second, sensitivity analysis can be conducted to assess the impact of variations in expert judgments on the final results. Third, further research should focus on developing models to evaluate SCM in areas such as road construction, industrial construction, etc. Fourth, the digitization of the already developed model for evaluating SCM should be conducted to facilitate the development of a computer-based system that is easy to work with.

The AHP-based safety climate maturity model offers a robust framework for assessing and improving safety performance in building construction projects in Tanzania. By systematically evaluating critical safety factors and prioritizing areas for improvement, stakeholders can enhance climate, reduce accidents, and ultimately create safer work environments. Adopting this model empowers organizations to take proactive steps towards a more mature safety climate, aligning with industry best practices and regulatory requirements.

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