AUTHENTICATION STUDY ON CHARACTERISTICS OF SAFETY MANAGEMENT CUSTOMS IN CONSTRUCTION ENGINEERING

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Abstract *- Comprehensive safety management system is an integral part of prevailing safety culture of any organisation. However, the Safety Management System (SMS) and good safety practices may vary at every national, regional and organisational level for various reasons. A well poised and consummate safety management system will certainly reduce the frequency and occurrence of untoward incidents at work place. The aim of the research is to investigate the prevailing factor structure for SMS and to test the efficacy of factor structure for appropriateness of the construction safety management systems and best practices. This cross-sectional study used questionnaire survey consisting 14 variables which were used in previous studies to measure the strategic and operational constructs of SMS. The modified SMS questionnaire was administered to 130 respondents working at various construction sites in Chennai, India. The respondents were engineers and supervisors having good degree of exposure with construction engineering background. Both exploratory and confirmatory factor analyses were performed and analysed the results statistically. Five out of fourteen variables were dropped to achieve good factor structure after performing Exploratory Factor Analysis (EFA) using Statistical Package for the Social Sciences (SPSS). Confirmatory Factor Analysis (CFA) was carried out using Analysis of Moment Structures (AMOS). The results revealed acceptable model fit indices for the SMS factor structure under examination.*

Keywords - *Safety Management, Construction Engineering, Factor Analysis, Safety, Training*

I. INTRODUCTION

Construction engineering industry has its inherent and distinctive features that influence the safety culture in strategic and operational aspects. Construction industry is the most affected sector by the Volatility, Uncertainty, Complexity and Ambiguity (VUCA) phenomenon prevailing across the globe. As this VUCA phenomenon predominantly influences the leadership qualities, it is imperative to look intensely into the strategic and operational leadership aspects which cultivates and sustains the safety culture at organisation level. According to [1] the construction industry is highly susceptible and risk prone in view of its following six inherent characteristics in the context of developing countries like India.

- Uncertainty and interdependence amongst the various activities
- Weak entry and exit barriers due to its dynamic nature
- Aggressive Competition and meagre profit margins
- Economic pressures due to confrontation to fragmentation
- Highly labour intensive with high dependency on unskilled workforce
- Gender imbalance due to its laborious nature of work and dominance of masculinity attitude associated with taking safety risks for questions on paper guidelines; please contact the conference publications committee as indicated on the conference website. Information about final paper submission is available from the conference website.

In view of aforesaid complexities every organisations attempt to modify its SMS and practices in accordance with its dominant national cultural orientations and its core organisational culture. A scale is developed and deployed in any country or any region of the country having specific cultural settings may not reflect the same outcomes

when it is tested in a differentiated cultural context. Needless to reiterate that it is very much essential to test any established or newly developed SMS questionnaire construct for its validity and stability in several regions of the country having diversified range of cultural backgrounds. In this order, this study attempt to test SMS questionnaire construct used in previous studies [2-4].

II. RESEARCH METHODOLOGY

For this study, the SMS questionnaire had appropriately been re-examined and restructured to reflect the prevalent safety management practices and cultures [5, 6]. The questionnaires having fourteen variables were administered to 130 civil engineering professionals at various civil engineering constructions sites in the city of Chennai. The sample size 130 is well above the prescribed sampling guidelines five cases per variable [7]. The respondents were briefed before the survey and assured the anonymity and confidentiality of the responses to facilitate the free flow of responses which were on top of the mind without any hesitation or any room for second thought. The respondent needs to provide his quantum of agreeableness to the each statement in the questionnaire in 5 point Likert scale. Prior to exploratory analysis, T-test and ANOVA had been performed and the results showed that, there were no statistically vital difference of opinions among two independent groups form supervisors and engineers and also among the three levels of management cadre employees of supervisors, engineers and managers. The EFA is expected to be exploratory in its own way. Although, it is not required to prescribe hard and fast formula, the following steps shall be taken into consideration to perform EFA [8].

- Data cleaning/screening
- Extraction technique/method
- Number of factors/dimensions
- Rotation technique/method
- Interpretation of factor solutions
- Evaluation of factor solutions for its robustness

The safety management system survey has 14 items pertaining to safety plan, observations, communication, competency, accountabilities and cooperation. Principal Component analysis (PCA) with Varimax rotation and Kaiser Normalisation was adopted for this factor analysis. SPSS is used for this EFA. Previous studies were the basis for retaining number and labelling of factors.

A. Confirmatory Factor Analysis (CFA)

It facilitates the researchers to how better the measured items characterise the constructs under study. The researcher can examine analytically a theory which is established on the fundamental concepts in psychological studies. In order to arrive a reasonably clear understanding of the merit of measures under examination, the CFA results must be dovetailed with its construct validity. No valid decisions can be made sans valid measurements [9]. AMOS is used for this CFA. The inevitability and advantages of CFA over EFA should not be overlooked in research. EFA may be adequate during the initial phases of research on a construct however the practice of CFA would be more beneficial at subsequent phases [10, 11].

B. Assessment of Measurement Model

According to [12], three important properties of measurement were examined in order to confirm that the model under study possesses acceptable range of reliability and validity. The measured three properties are individual item reliability, convergent and discriminant validities. The measured values are presented in Table 3 and Table 4.

III. RESULTS AND DISCUSSIONS

A. Exploratory Factor Analysis

All requisite preliminary analysis like data screening, suitability checks had been done before performing factor analysis and the observed test results are given in Table 1 and Table 2.

TABLE 1: SUMMARY OF EFA

S. No	Description of items	Values
1	Number of Variables for EFA	14
2	Sample size	130
3	Ratio (Cases to Variable)	9.29*
4	KMO (Keiser Meyer- Olkin) Statistic	0.859
5	Bartlett's test of Sphericity Chi-Square	700.289
6	Degree of Freedom (d_f)	36
7	P value	<0.001
8	Factors extracted for factor solution	2
9	Variables retained after EFA	9
10	Total percentage variance explained	72.71%

*Rule of thumb: Minimum 5 cases required per variable under examination

B. Assessment of Model Validity

As discussed earlier the three important measurement properties are calculated and tabulated as below in Table 3 and Table 4. The convergent validity denotes the high proportion of common variance and which can be measured in several ways. The factor loading for the individual items are well above 0.70 the cut off value [13] which demonstrates the acceptable level of individual item wise reliability. The Average Variance Extracted (AVE) is also another form of convergent validity and should be equal to 0.50 or above. The cronbach's alpha for the individual construct are also

well above the threshold value of 0.70 mark [14]. Construct Reliability is an alternative measure of convergent validity [15] which demonstrates the internal consistency among the constructs when the measures are greater than or equal to 0.70. The discriminant validity is supported, if there is a significant difference exists between the, theoretically, two different constructs [16]. The estimates of variance extracted must be greater than the estimate of squared correlation which are placed in diagonal of the matrix and higher than the values in corresponding row or column Table 4 reveals good degree of discriminant validity which is adequate to carry on for further analysis. Further, each construct in this congeneric model has more than three indicators and hence the model is identified.

TABLE 2: SMS PRACTICES-FACTOR LOADINGS OF EFA

Factors	Variable Number	Description of variables	Loading
Strategic (SMS F1) Variance = 38.70% Eigen value = 3.483 Cronbach's Alpha = 0.894	Q12SMS	Safety performance norms for employing workmen	0.892
	Q11SMS	Safety performance norms for recruiting supervisors/engineers	0.880
	Q13SMS	Site safety plan	0.779
	Q10SMS	Safety norms for contractors/sub-contractors selection	0.773
	Q5SMS	Safety Communication	0.747
Operational (SMS F2) Variance = 34.01% Eigen value = 3.061 Cronbach's Alpha = 0.879	Q7SMS	Monitoring and maintaining safety performance records	0.887
	Q9SMS	Hazard identification and reporting	0.868
	Q8SMS	Incident/Near miss reporting	0.842
	Q1SMS	Contractors owns safety responsibilities	0.748

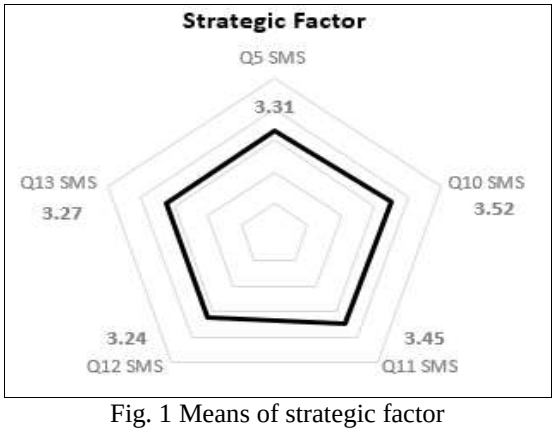

Fig. 1 Means of strategic factor

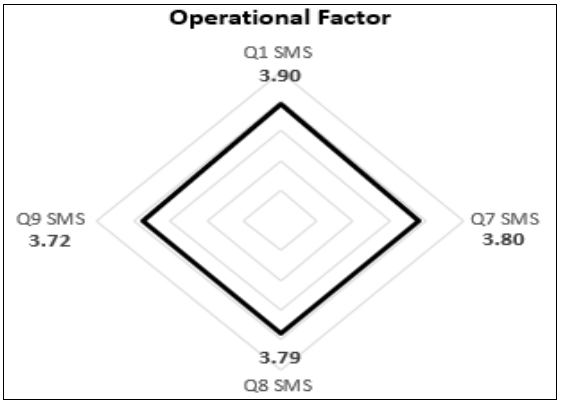

Fig. 2 Means of operational factor

TABLE 3: CONSTRUCTS RELIABILITY AND VALIDITY

Factors	Cronbach's Alpha	Construct Reliability	Average Variance Extracted
SMS F1 (Strategic)	0.894	0.895	0.631
SMS F2 (Operational)	0.879	0.883	0.654

TABLE 4: DISCRIMINANT VALIDITY

Factors	SMS F1 (Strategic)	SMS F2 (Operational)
SMS F1 (Strategic)	**0.794**	
SMS F2 (Operational)	0.193	**0.809**

C. Assessment of model structure

The two factor model for CFA is presented in Figure 3 along with loading assesses and the integrity of fit indices is given in Table 5.

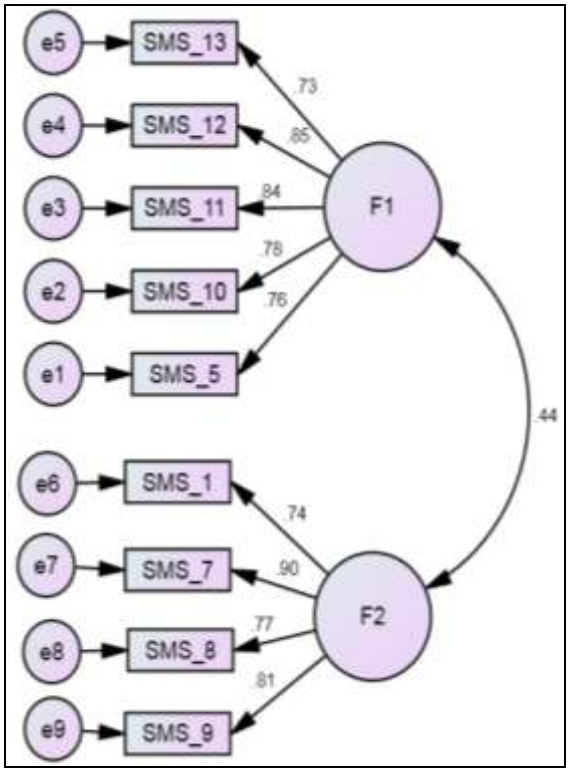

Fig. 3 CFA results for the SMS

TABLE 5: GOODNESS OF FIT STATISTICS FOR SMS

S. No	Goodness of Fit Statistics	Values	Remarks & Acceptable values
1	**Chi-Square (x^2)**		
	Chi-Square	63.018	In AMOS, it is called CMIN
	Degrees of Freedom (d_f)	25	Over-identified, Positive & Most preferred type
	Probability level	0.000	Statistically significant
2	**Absolute Fit Measures**		
	Goodness of Fit Index (GFI)	0.905	> 0.90 is okay
	Root Mean Square of Error Approximation	0.105	< 0.100 is okay
	Root Mean Square Residual	0.040	< 0.08 is okay and RMR < 0.05 signifies very good fit
	Normed Chi-Square (CMIN/d_f)	2.521	Between 2 and 5 is okay
3	**Incremental Fit Indices**		
	Normed Fit Index (NFI)	0.913	> 0.90 is okay
	Tucker - Lewis Fit Index (TLI)	0.925	> 0.90 is okay
	Comparative Fit Index (CFI)	0.946	> 0.90 is okay and (CFI>NFI)
	Relative Fit Index (RFI)	0.879	> 0.90 is okay
	Incremental Fit Index (IFI)	0.947	> 0.90 is okay
4	**Parsimony Fit Indices**		
	Adjusted Good Fit Index (AGFI)	0.836	> 0.90 is acceptable
	Parsimony adjusted GFI (PGFI)	0.523	Between 0.5 and 0.8 is acceptable

According to the rule of thumb [17], apart from the traditional chi-square results for evaluating overall model fit, we depend on minimum one valid index from absolute fit and one index from incremental fit for the assessment of model fit. The p- value is closer to zero and also significant at 0.05 levels for type 1 error. However, rigorous adherence to suggested threshold values could lead to occurrences of type 1 error [18]. Hence, it is very much indispensable to examine carefully the other useful fit indices also to rule out the incorrect rejection of reasonably a satisfactory model.

From the Table 5, it can clearly be seen that three out of four absolute indices are in acceptable range although we need at least one index for acceptable model. Further, four out of five incremental fit indices are also in acceptable range. Parsimony adjusted Goodness of Fit Index (PGFI) is in between 0.5 and 0.8 range is acceptable [19, 20]. Hence, the results suggest that the model fit under study is reasonably acceptable.

IV. CONCLUSION

No absolute value for the several indices of fit, suggests a good fit. These are only guidelines available to help researchers for the purpose of testing. The values pertaining to the most satisfactory models might vary from time to time and rely substantially on the size of sample, communalities of the dimensions extracted and number of measured variables/items. However, this study being cross sectional and sample size is fewer than 200, it is suggested to go for additional and multiple sampling for confirmatory factor analysis in future. It is also observed that the variable related to safety training is not appearing in this two factor structure. Safety training is of paramount importance for cultivating and sustaining safety performance and safety culture at civil engineering construction sites employing unskilled and migrant workers. In view of fragmented and dynamic nature of construction industry, it is also recommended to include additional variables pertaining to tactical factor in the construct which focus predominantly on safety training to the line management personnel in civil engineering construction. Further research is also fortified to examine the validity and stability of the factor structure with the inclusion of tactical factor which focus predominantly on safety training to the line management personnel in civil engineering construction.

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