Critical Factors for Proper Implementation of Safety Management System in Construction Projects of Nepal: SEM Approach

Basant Bhatta, Dinesh Sukamani*, Kreeti Bajracharya and Subash Kumar Bhattarai

***Abstract*— The purpose of this study is to identify the major critical factors for the proper implementation of a safety management system (SMS) in construction projects in Nepal. Additionally, an evaluation matrix was utilized to assess the current state of SMS implementation across various types of construction projects. A conceptual SEM-PLS path model was developed, and data from 400 respondents, comprising professional technical labor in building projects in Nepal, were collected through a questionnaire survey. The findings of the study indicated that "safety commitment factors" emerged as the most significant critical factors, with a path coefficient of 0.219 and a t-value of 5.127, surpassing other factors. The Maximum Degree of Membership (MDM) principle was employed to identify the level of impact of critical factors on SMS. The final evaluation results for public and private building construction were determined to be 0.495 and 0.489, respectively, placing them in the fourth (IV) level, indicating poor implementation. Therefore, it is imperative for construction professionals to prioritize the mentioned constructs and indicators for the proper implementation of SMS. The findings of this study can serve as a valuable resource to enhance SMS practices in similar construction projects.**

***Keywords*: SEM-PLS Model, Critical factors, MDM principle, Safety Management System, Construction Projects**

I. INTRODUCTION

The construction industry stands out as one of the riskiest sectors worldwide, fraught with numerous hazards and uncertainties throughout its processes, often resulting in accidents. These accidents stem from various factors, including the industry's distinct nature, human behavior, demanding working conditions, and inadequate safety management practices. Collectively, these factors contribute to the adoption of unsafe work methods, equipment, and procedures [1].

Data from several industrialized countries indicate that construction workers are three to four times more likely to die from workplace accidents compared to workers in other industries [2].

Similarly, the Nepalese construction industry has long experienced a high rate of occupational incidents resulting in serious injuries and death. It is estimated that approximately 20,000 workers suffer from workplace accidents each year, resulting in about 200 fatalities in Nepal [3].

Despite the existence of various laws, policies, and guidelines for safety management in Nepal, Nepalese construction companies struggle to integrate Occupational Health and Safety (OHS) into their daily operations. This challenge leads to a loss of competitive advantage to foreign companies that prioritize OHS [4]. The implementation of safety management programs in Nepal remains limited or at a primitive stage [5], partly due to inadequate or ineffective government policies and regulations on safety management [6], which contribute to poor safety performance in the Nepalese construction industry.

A safety management system (SMS) is a systematic approach to managing safety, encompassing organizational structures, accountabilities, policies, and procedures [7]. The concept of SMS overlaps with that of an OHS management system [8]. The successful implementation of an SMS in the workplace depends on having a well-designed system. Many countries have developed national SMSs for construction sites based on accepted practices, with the number of factors used varying depending on the unique needs of the local construction industry [9].

Nepal's National Occupational Safety and Health (OSH) framework is improving, but further growth is required. The Ministry of Labour, Employment, and Social Security (MoLESS) remains committed to this cause, as seen by the addition of an occupational safety and health chapter to the Labour Act of 2017. This milestone was followed by the adoption of the National OSH Policy in 2019 and the subsequent development of the National OSH Profile. These measures demonstrate the Nepalese government's desire and intend to ratify the International Labour Organization's Convention 155 on Occupational Safety and Health 1981, and improve its national OSH system in line with international standards [10].

The primary objective of this research is to identify the main critical factors for the proper implementation of SMS in construction projects in Nepal, using the SEM-PLS model. Additionally, the research aims to assess the current impact level of these identified critical factors on SMS implementation across various construction projects using an evaluation matrix based on the Maximum Degree of Membership (MDM) principle.

The SEM-PLS model is preferable to multiple linear regression and other multivariate techniques for this study because it can simultaneously assess complex relationships, handle latent variables, and evaluate measurement errors while using methods like bootstrapping for more accurate estimates. Additionally, it provides a comprehensive model

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Basant Bhatta is a Master's Graduate from Construction Management at Nepal Engineering College-CPS, Lalitpur, Nepal. (e-mail: basantbhatta57@gmail.com)

Dinesh Sukamani is Assistant Professor at Nepal Engineering College-CPS, Lalitpur, Nepal. (Corresponding author, phone: +9779841110140; e-mail:dineshs@nec.edu.np)

Kreeti Bajracharya is a Master's Graduate from Construction Management at Nepal Engineering College-CPS, Lalitpur, Nepal. (e-mail: bajracharyakreeti@gmail.com)

Subash Kumar Bhattarai is Lead in Heath Infrastructure and Policy, HERD International, Kathmandu, Nepal. (e-mail: subash.bhattarai@herdint.com)

fit and is ideal for assessing the impact of multiple factors, making it the best approach for identifying and evaluating critical factors in Safety Management System implementation.

II. LITERATURE REVIEW

A. Key Crucial Elements for Successful Implementation of SMS in Construction Projects:

Numerous studies have been performed to investigate the factors for proper implementation of SMS in the construction industry. For example, a study in Malaysia explored various factors influencing the SMS implementation at construction sites, identifying several influential factors, namely resource factor, management factor, personal factor, HRM/incentive factor, and relationship factor. The findings revealed that personal awareness was the most important influencing factor was, closely followed by communication [9]. Similarly, the factors influencing Health and Safety (H&S) performance for SMS framework development in United Kingdom were observed. These factors were classified into six categories as 'organizational', 'managerial', 'legislative', 'social', 'environmental' and 'personnel'[11]. An analysis of Critical Success Factors (CSFs) for safety program implementation in Thailand's medium- to large-scale construction projects identified four key categories: worker participation, safety control and prevention systems, safety protocols, and organizational leadership commitment [12].

The implementation of SMS was found to involve variety of success elements, which were categorized into five classes: senior-level commitment to safety, project-staff competency profiles, safety climate, project management, and safety requirements and incentives [13, 14]. An important element for the effective implementation of SMS is the presence of well-defined safety objectives and strong commitment from senior management, including the allocation of appropriate manpower, financial resources, and time allocation [8, 12, 14-16]. A competency profile outlines the knowledge, skills, abilities, demonstration, and behavior required for project personnel to ensure and execute work safely and effectively within an organization [8, 9, 14, 17].

Successful SMS implementation can be encouraged and improved through an effective project management. Safety organization showing the responsibilities and accountabilities of key personnel, Strategic subcontractor selection, Teamwork, Frequent staff group meetings (tool box talks), Well-functioned communication system, Proactive risk management, Continuous improvement of PDCA (Plan-Do-Check-Act) cycle were recognized as an important factors for the effective implementation of SMS in the construction industry [18-20].

Employee involvement in safety concerns, hazard identification, and reporting, along with management commitment, has diverse effects on work-group procedures and the safety management system, which, in turn affect workers' safety knowledge and behavior [21].

Factors impacting the maintenance and improvement of OHSAS 18001 in Iran include management commitment, safety communication, employee's involvement, integration, training, safety culture, internal incentives and external incentives [22]. External Factors, such as legal requirements, contractual requirements and accreditation requirements should not be avoided, despite receiving sufficient attention in past studies [23].

Ensuring the provision of personal protective equipment, implementing safety labels/signage in the workplace, and establishing proper safety rules were identified as key factors for scaling safety performance in the proper implementation of SMS [24]. The elements listed above were determined to be crucial for effective SMS implementation and have the potential to significantly impact construction safety.

TABLE I
CONSTRUCT ALONG WITH ITS CORRESPONDING INDICATORS FACTORS

Construct	Code	Description of factor	Supportive sources
Safety Commitment (SC)	SC1	Clear commitment from senior management	[8, 14, 15]
	SC2	Clear and reasonable safety goals	[12]
	SC3	Spent enough money to buy the necessary tools and plant to complete the work safely	[8, 14, 15]
	SC4	Allocation of enough labor to finish tasks safely	[14-16]
	SC5	Given sufficient time to carry out the assigned tasks safely	[14-16]
Competency profile (CP)	CP1	Demonstrated safety leadership by the senior management	[9, 14]
	CP2	Appointing a knowledgeable and capable safety manager	[8, 14, 17]
	CP3	Safety training and education for project managers	[17]
	CP4	Safety behaviors of project manager	[9, 17]
	CP5	Personal quality of safety manager	[8, 17]
Employees Participation (EP)	EP1	Participation of employees in safety issues	[21]
	EP2	Employees actively identify and report worksite hazards	[21]
	EP3	Safety awareness of the employees	[21]
	EP4	Personal attitude and behavior of employees towards safety	[21]
Project Management (PM)	PM1	Safety structure outlining the roles and responsibilities of essential personnel	[18]
	PM2	Strategic subcontractor selection	[20]
	PM3	Teamwork	[20]

Construct	Code	Description of factor	Supportive sources
	PM4	Frequent staff group meetings	[18]
	PM5	Well-functioned communication system	[19]
	PM6	Proactive risk management	[19]
	PM7	Continuous improvement of PDCA (Plan-Do-Check-Act) cycle	[20]
Safety requirement and incentives (SR)	SR1	Incentives from clients for safety promotion	[22]
	SR2	Incentives from the company itself	[22]
	SR3	Fulfilled safety-related legislation	[22, 23]
	SR4	Fulfilled Contractual/client requirements	[23]
	SR5	Requirement to certify the safety management system	[23]
Safety Management System (SMS)	SMS1	My company provides employees with personal safety gear	[24]
	SMS2	My company installs safety signs and labels in the workplace	[24]
	SMS3	My organization establishes proper safety rules	[24]

B. *Conceptual framework*

This study seeks to identify the critical factors influencing the effective implementation of Safety Management Systems (SMS) in Nepal's construction sector. The research framework is presented in Figure 1 (Appendix).

III. METHODOLOGY

Structural equation modeling (SEM) is a statistical method that examines a structural theory pertinent to an occurrence using a confirmatory method. It demonstrates how causal mechanisms are built up for observations on diverse constructs. SEM is increasingly used construction management studies. In this study, we used partial least square structural equation modeling (PLS-SEM), a method recommended in prior literature [25].the aim of the study is to forecast and define a target construct ,as well as to recognize its predecessors. Excel and Smart PLS (v.3.2.8) software were used for the analysis. Additionally, the SEM-PLS model's quantitative relationship between latent and observed variable serves as the foundation for comparative studies of private and public construction projects, determining the latent factor's level of impact on SMS implementation. A similar methodology was used in the past studies [26].

A. *Questionnaire design*

The study aimed to identify 26 indicators across five components that contribute to the proper implementation of SMS, based on previous literature along with three additional SMS indicators. A pretest survey was conducted with five academic experts to ensure the clarity of the questions. Based on their feedback, the questions were revised to enhance content validity. All indicator items were assessed using a Likert scale, ranging from 1 (totally agree) to 5 (totally disagree). Table 1 presents each indicator item utilized in the model.

B. *Questionnaire response profile*

The research focuses on Nepali construction companies. Out of 450 distributed questionnaires, 400 responses were received. Data collection tools included Google Forms, personal emails, direct face-to-face interviews, and telephonic interviews. Additionally, several construction projects were invited to participate, and upon their agreement, visits to their locations were planned to gather data. Among the 400 respondents, 242 were from public construction projects and 158 were from private construction projects. The respondents included project managers and front-line workers (e.g., project/contract managers, contractors, safety officers, project engineers, site engineers, overseers, supervisors), all of whom had a thorough understanding of construction site safety.

C. *Hypothesis*

Based on previous literature and theoretical examination, five critical hypotheses have been generated, which are essential for modeling in SEM. Our hypotheses focus on factors crucial for the proper implementation of SMS: safety commitment, competency profile, employee participation, project management, and safety requirements and incentives. These factors are expected to significantly impact SMS implementation on construction sites, forming the foundation of our theoretical research model.

Hypothesis H1:
Competency profile factors positively and significantly affects SMS implementation.
Hypothesis H2:
Employees participation factors positively and significantly affects SMS implementation.

Hypothesis H3:
Project management factors positively and significantly affects SMS implementation.
Hypothesis H4:
Safety commitment factors positively and significantly affects SMS implementation.
Hypothesis H5:
Safety requirement and incentive factors positively and significantly affects SMS implementation.

IV. PLS-SEM MODEL TESTING AND RESULTS:

PLS-SEM is preferred because of its adaptability to normally distributed data and minimal sample size. Additionally, PLS-SEM has stronger statistical power, making it the optimal method for exploratory research [27, 28]. The PLS path model consist of two components: the structural model and the measurement model of. The validity of both models was tested using PLS-SEM, along with hypotheses also testing. Here, the structural model establishes the relationship between the constructs and unobserved variables, while the measurement model defines the relationship between the constructs and the attributes [29, 30]. The measurement model was examined for consistency reliability, indicator reliability, discriminant validity, and convergent validity because this study used reflectively specified constructs. Additionally, the coefficient of determination (R^2) of the endogenous construct, predictive relevance (Q^2), and hypothesis testing were examined using a structural model to assess the multi-collinearity issue. Finally, an evaluation matrix was used to determine the actual state of all construction categories in terms of SMS implementation.

A. Preliminary analysis

Since the 400 responses exceeded the 200 edge level, the sample size was deemed sufficient for SEM analysis. [31]. Additionally, G-power analysis (Fig 2 of Appendix) demonstrated that more than 265 respondents are needed for SEM modeling, which further demonstrated that our sample size is adequate for study. Pioneer researcher have indicated that in exploratory factor analysis, the Kaiser-Meyer-Olkin (KMO)value should be greater than 0.7 to indicate that each model component has enough items. Moreover the Bartlett value should be significant for p-values less than 0.005 to indicate that the correlation matrix differs significantly from the specified matrix [32] as shown in Table 1, of the Appendix.

B. The Measurement Model's Validity and Dependability

The PLS analysis process begins by assessing the measurement model's validity and reliability. Table II reports the indicator loadings, average variance extracted (AVE), composite reliability (CR), and Cronbach's alpha (CA) to evaluate the construct's measurement quality. An indicator loading above 0.5 confirms its reliability [33], while CR and Cronbach's alpha values exceeding 0.7 demonstrate internal consistency [29]. Additionally, convergent validity is supported if the AVE surpasses 0.5 [34, 35]. Items CP4, CP5, PM1, PM6 and PM7 were removed due to their loading being below 0.5 [6]. The measurement model with AVE and indicator loadings is shown in Figure 4 of Appendix.

TABLE II
RESULT OF CONVERGENT VALIDITY AND INDICATORS

Construct	Indicator Items	Indicator Loading	Average variance extracted (AVE)	Composite Reliability (CR)	Cronbach's Alpha (CA)
CP	CP1	0.831	0.737	0.894	0.821
	CP2	0.871			
	CP3	0.873			
EP	EP1	0.786	0.606	0.860	0.784
	EP2	0.787			
	EP3	0.783			
	EP4	0.758			
PM	PM2	0.619	0.606	0.858	0.778
	PM3	0.811			
	PM4	0.869			
	PM5	0.792			
SC	SC1	0.894	0.675	0.911	0.875
	SC2	0.894			
	SC3	0.873			
	SC4	0.786			
	SC5	0.630			
SMS	SMS1	0.891	0.693	0.869	0.774
	SMS2	0.914			
	SMS3	0.671			
SR	SR1	0.611	0.584	0.874	0.823
	SR2	0.799			
	SR3	0.840			
	SR4	0.843			
	SR5	0.701			

Moreover, Table III displays the correlation between each construct and square root of its AVE values. The square root AVE values, highlighted in bold, exceed their correlation coefficient with other variables. This indicates that they meet the criteria for discriminant validity.

Cross-loadings, the Fornell-Larker criterion, and the heterotrait monotrait ratio (HTMT) were employed to test the discriminant validity [6].

TABLE III
DISCRIMINANT VALIDITY (FORNELL AND LARKER CRITERIA)

	CP	EP	PM	SC	SMS	SR
CP	**0.859**					
EP	0.435	**0.778**				
PM	0.605	0.552	**0.778**			
SC	0.299	0.158	0.222	**0.822**		
SMS	0.449	0.399	0.495	0.347	**0.832**	
SR	0.464	0.442	0.556	0.153	0.416	**0.764**

Table III presents the square roots of Average Variance Extracted (AVE) values for latent variables, displayed as bolded diagonal elements. These diagonal values exceed all off-diagonal correlation coefficients in their respective rows and columns, demonstrating discriminant validity. The non-diagonal elements represent inter-construct correlations [36].

Table IV reports the HTMT ratio of correlations between the model constructs. (HTMT) value is below the cutoff of 0.9 [37].

TABLE IV
DISCRIMINANT VALIDITY: HETROTRAIT-MONOTRAIT RATIO (HTMT)

	CP	EP	PM	SC	SMS	SR
CP						
EP	0.546					
PM	0.755	0.703				
SC	0.360	0.181	0.257			
SMS	0.557	0.503	0.620	0.410		
SR	0.543	0.522	0.668	0.184	0.478	

Similarly, the bold diagonal elements in Table V denotes item cross loading on its construct. It is demonstrated that, when tying with another cross-loading, all consistent apparent variables have a higher cross-loading value than their latent variable. [38, 39].

TABLE V
RESULT OF DISCRIMINANT VALIDITY; INDICATOR ITEMS CROSS LOADING

FACTORS	CP	EP	PM	SC	SMS	SR
CP1	**0.831**	0.291	0.395	0.192	0.389	0.441
CP2	**0.871**	0.413	0.591	0.294	0.383	0.386
CP3	**0.873**	0.418	0.575	0.284	0.384	0.366
EP1	0.299	**0.786**	0.403	0.202	0.339	0.293
EP2	0.388	**0.787**	0.462	0.065	0.277	0.324
EP3	0.316	**0.783**	0.355	0.093	0.307	0.283
EP4	0.361	**0.758**	0.500	0.118	0.312	0.477
PM2	0.401	0.313	**0.619**	0.065	0.308	0.446
PM3	0.569	0.445	**0.811**	0.180	0.408	0.471
PM4	0.521	0.503	**0.869**	0.246	0.441	0.449
PM5	0.378	0.435	**0.792**	0.173	0.371	0.373
SC1	0.248	0.192	0.236	**0.894**	0.355	0.179
SC2	0.202	0.085	0.189	**0.894**	0.290	0.093
SC3	0.288	0.153	0.216	**0.873**	0.282	0.206
SC4	0.241	0.113	0.086	**0.786**	0.256	0.123
SC5	0.265	0.088	0.167	**0.630**	0.219	-0.011
SMS1	0.324	0.354	0.368	0.337	**0.891**	0.348
SMS2	0.462	0.370	0.524	0.312	**0.914**	0.459
SMS3	0.320	0.259	0.312	0.202	**0.671**	0.178
SR1	0.200	0.126	0.203	0.017	0.145	**0.611**
SR2	0.414	0.468	0.524	0.178	0.407	**0.799**
SR3	0.368	0.291	0.441	0.179	0.357	**0.840**
SR4	0.338	0.320	0.401	0.090	0.309	**0.843**
SR5	0.392	0.381	0.451	0.042	0.277	**0.701**

C. *Evaluation of Structural Model*

In the analysis and validation of the structural model, the major five steps to measure the structural model includes model fit, collinearity test, structural model path coefficient, evaluating the level of R^2 and predictive relevance Q^2,. The indices of model fit showed that the final model had an acceptable fit, with SRMR=0.078 and NFI=0.903. Both values lies within the acceptable range of the threshold value. i.e SRMR < 0.08 and NFI > 0.9 [40, 41]. This indicates that the links between the observed variables and the latent variables are well-defined when the model fits.

TABLE VI
RESULT OF COLLINARITY ASSESSMENT

Exogenous variables	Endogenous variable	Variance Inflation Factors (VIF)	Q^2
CP	SMS	1.737	0.456
EP	SMS	1.517	0.342
PM	SMS	2.083	0.356
SC	SMS	1.102	0.520
SR	SMS	1.548	0.389

Table VI displays the results of the collinearity evaluation, indicating that the data were free of multi-collinearity issues as the Variance Inflation Factor (VIF) was below the threshold value of 5 [37]. The Stone-Geisser's factor, which was derived through the procedure of blind calculation, is used to determine Q2, which is the predictive relevance of the structural model [42]. The Q^2 value must be higher than zero for the relevance of the corresponding construct. Table VI shows that all predictive relevance Q^2 values were falls within the cut-off range. The coefficient of determination (R^2) of dependent construct is shown in Fig 4 of the appendix.

Additionally, coefficient of determination (R^2) for the endogenous latent variable must be greater than 0.26 [43, 44]. During calculation, the R^2 value was found to be 0.352, with an adjusted R^2 to 0.344, that was higher than the threshold value. This indicates that the model was in the possible degree to describe the variance of SMS implementation through the constraining factors. The value 0.344 indicates that 34.4% of total variance in the dependent variable can be explained by the independent variables.

A unit change in the predictor construct is shown by the path coefficient along with the conventional change of the endogenous construct. An examination of all latent variables is represented by the beta value; the higher the beta value, the stronger or bigger the influence of the exogenous (predictor) variable on the endogenous (dependent) variable [45]. The t-test value is used to compute the beta value. For non-parametric bootstrapping, the t-value is calculated by generating a predetermined number of samples. In order to calculate t-values, bootstrapping was performed to create 5000 samples [37, 46]. Pioneers recommended that for a two-tailed test, t-value > = 1.96 at p = 0.05 level, t-value > = 2.58 at p = 0.01 level, t-value >= 3.29 at p = 0.001 level [47]. We adhered to these cutoff points. All pathways in this model had t-values that were higher than the cutoff of 1.96 at the 5% significance level, as shown in Table VII. This shows that the Safety Management System was significantly impacted by each path in the model.

Furthermore, both the inner structural model and the outer measurement model exhibit considerable reliability and validity. The outcomes of all five hypotheses (H1–H5) are presented in Table VII, highlighting the significance of the SEM model. Among the five hypotheses, two (H1, H2) were supported at a 5% significance level, one (H5) was supported at a 1% significance level, and two (H3 and H4) were supported at less than a 1% significance level, as shown in Table VII. The path coefficients analysis in the inner structural model indicated that the relationship between the safety commitment factor and the implementation of the safety management system in construction projects was the most significant among all constructs, with the highest t-value of 5.127 and a beta value of 0.219. The structural model with t-values is shown in Figure 6 of the appendix

TABLE VII
TESTING THE HYPOTHESIS IN THE STRUCTURAL MODEL

Hypothesis	**Relation**	**Beta (O)**	**T Statistics**	**P value**	**Decision**
H1	CP ->SMS	0.131	2.136	0.017*	Supported
H2	EP -> SMS	0.122	2.125	0.017*	Supported
H3	PM -> SMS	0.218	3.600	0.000***	Supported
H4	SC -> SMS	0.219	5.127	0.000***	Supported
H5	SR -> SMS	0.147	2.556	0.005**	Supported

Note: t-value >= 1.96 at p = 0.05 level*, t-value >= 2.58 at p = 0.01 level**, t-value >= 3.29 at p = 0.001 level***

D. *Evaluation Process*

Many researchers have employed various evaluation techniques, but in this study, we opted for a systematic approach based on SEM to evaluate SMS. By categorizing respondents into two groups—private and public construction projects—we reused previous data for SEM-PLS modeling. Of the total respondents, 158 were from private construction projects, and 242 were from public construction projects. This classification facilitated a comparative study between the two types of construction projects, enabling us to measure the impact level of critical factors in SMS implementation.

Evaluation Matrix

The study implemented the same number of judgments as per the questionnaire of each indicator of each latent construct factor, which is denoted by:

$$A_{ij}^{ln} = (i= 1, 2, 3, 4, 5: j= 1, 2, 3: n= 1, 2, 3, 4, 5) \quad (1)$$

In this case, i stands for the quantity of predictor constructs, and j for the various construct indicators. Each construct required a minimum of three indicators; therefore, the researcher selected three indicators with the highest path coefficients, in comparison to constructs containing more than three indicators. [48]. Additionally, 'n' denotes the base of judgment, ranging from 1 (completely agree) to 5 (completely disagree). The lower the judgment, the better will be the SMS implementation on the site. Evaluation of SMS implementation was divided into five segments "**I (excellent), II (good), III (fair), IV (poor) and V (very poor)**". The fraction share of each indicator was denoted by A_{ij}^{ln}, calculated by eq^n (2). Furthermore, l specifies the types of construction projects i.e., public and private construction projects. The evaluation matrix for the ith fraction share of the lth construction project type was represented by the vector A^l_j, as shown in eq^n (3), where "a" refers to the respondent's judgement of each sub factors.

$$A_{ij}^{ln} = \frac{a_{ij}^{ln}}{\sum_{n=1}^{5} a_{ij}^{ln}} \text{ i= 1, 2, 3, 4, 5: j= 1, 2, 3: l= 1, 2: n= 1, 2, 3, 4, 5} \quad (2)$$

$$A_i^l = \begin{bmatrix} A_{i1}^{l1} & A_{i2}^{l2} & A_{i3}^{l3} & A_{i4}^{l4} & A_{i5}^{l5} \\ A_{i2}^{l1} & A_{i2}^{l1} & A_{i2}^{l1} & A_{i2}^{l1} & A_{i2}^{l1} \\ A_{i3}^{l1} & A_{i3}^{l2} & A_{i3}^{l3} & A_{i3}^{l4} & A_{i3}^{l5} \end{bmatrix} \quad (3)$$

Weight Determination

Following the confirmation of valid convergent and discriminant validity, the researchers utilized the path coefficient values from the partial least squares (PLS) model presented in Table V. The statistical significance of the path coefficients was determined by calculating the ratio of each standardized regression coefficient to its corresponding standard error. Let λ_{ij}= (i=1, 2, 3, 4, 5; j=1, 2, 3) shows the value of path coefficient of the jth indicator in the ith form. The jth indicator weight in the ith indicator was denoted by β_{ij}, obtained by eq^n (4). All indicator weights in the ith form were given by eq^n (5). Also, let x_i (i=1, 2, 3, 4, 5) symbolize the value of path coefficient in the ith form, the ith form weight signified by W_i can be acquired by eq^n (6). Weight can be obtained in all its aspects by eq^n (7).

$$\beta_{ij} = \frac{\lambda_{ij}}{\sum_{j=1}^{5} \lambda_{ij}}, \text{ i=1,2,3,4,5: j=1, 2, 3} \quad (4)$$

$$\beta_i = [\beta_{i1} \quad \beta_{i2} \quad \beta_{i3}] \quad (5)$$

$$W_i = \frac{x_i}{\sum_{i=1}^{5} x_i}, \text{i=1,2,3,4,5} \quad (6)$$

$$W = [w1 \quad w2 \quad w3 \quad w4 \quad w5] \quad (7)$$

Calculation and Results

The effective measurement of SMS implementation helps in making decisions to promote the use of SMS on construction projects Basis on the evaluation matrix, A and the weight matrix W, the evaluation vector of the ith indicator concerning the lth construction group, denoted by P_i^l, was calculated by eq^n (8). Likewise, the extensive evaluation vector of the lth construction project, denoted as P^1, was calculated by eq^n (9). The Maximum Degree of Membership (MDM) principle was used, where the level of SMS implementation evaluation was determined by selecting the maximum value from the five levels. For example, P^1 with the distribution (0.03, 0.14, 0.16, 0.64, 0.03) was rated as IV (poor), which was in the fourth level it had the maximum value among all five levels [48].

$$P_i^l = \beta_i * A_i^l = [P_i^{l1} \quad P_i^{l2} \quad P_i^{l3} \quad P_i^{l4} \quad P_i^{l5}], \text{ i= 1, 2, 3, 4, 5: } l\text{= 1, 2} \quad (8)$$

$$P^l = W * \begin{bmatrix} P_i^{l1} \\ P_i^{l2} \\ P_i^{l3} \\ P_i^{l4} \\ P_i^{l5} \end{bmatrix} \quad (9)$$

Analysis of Results

The information gathered for the first indicator (EP:Employee Participation) of a public construction project was used as an example to explain the precise calculation procedure. A total of 242 respondents and their judgments are shown in Table VIII. Eq^n (3) was used to evaluate matrix A_i^l for Employees participation in public construction projects. Weights of indicators in the first aspect were determined as βi [0.33, 0.33, and 0.33], whereas weights of all five constructions were calculated as W [0.146, 0.176, 0.262, 0.260, and 0.157] using equations (5) and (7). Similarly, using equations (7) and (8), the final assessment result for SMS deployment in public construction was calculated as P1 = [0.039, 0.146, 0.269, 0.495, and 0.051]. Maximum Degree of Membership (MDM) principle [48] was applied where the impact level of critical factors on SMS were acknowledged in this manner that maximum value within five level (i.e. excellent, good, fair, poor, very poor) was taken as the final result which was 0.495 at the fourth (IV) level indicating that was in the poor range. Similarly, final evaluation result for SMS implementation in private building construction was calculated as P2= [0.064, 0.141, 0.231, 0.489, 0.076] with a maximum value of 0.489, which is at the fourth (IV) level, indicating a poor range.

TABLE VIII
RESPONDENT JUDGEMENTS ON EMPLOYEES' PARTICIPATION OF PUBLIC CONSTRUCTION PROJECTS

S.N.	Judgement				
	Completely Agree (I)	**Agree (II)**	**Fair (III)**	**Disagree (IV)**	**Completely disagree (V)**
EP1	10	35	48	145	3
EP2	3	35	45	155	3
EP3	10	32	23	165	13

$$A_1^1 = \begin{bmatrix} 0.041 & 0.145 & 0.198 & 0.599 & 0.012 \\ 0.012 & 0.145 & 0.186 & 0.640 & 0.012 \\ 0.041 & 0.132 & 0.095 & 0.681 & 0.053 \end{bmatrix}$$

The above matrix is the evaluation matrix of judgements of employee's participation.

TABLE IX
FINAL OUTPUT OF SMS IMPLEMENTATION WITH RESPECT TO VARIOUS CONSTRUCTION INDUSTRY TYPES

Category	Evaluation Distribution				
	I (Excellent)	II (Good)	III (Fair)	IV (Poor)	V (Very poor)
Public	0.039	0.146	0.269	**0.495**	0.051
Private	0.064	0.141	0.231	**0.489**	0.076

Evaluation results of the five latent factors for SMS implementation in public and private construction projects are shown in Fig 6 and Fig 7 of appendix, correspondingly. Figure 7 shows that all five latent factors i.e. EP, PM, SR, SC, CP are inclined towards poor range in the selected public construction projects. This indicates the need for greater focus on these constructs and their items to improve SMS implementation. Similarly, Figure 8 shows that the latent factors i.e. EP, PM, SR, CP are completely inclined towards the poor range in selected private construction projects. Additionally, the SC factors are inclined towards fair range which indicates the selected private construction projects need to focus more on EP, PM, SR and CP and their items, as SC is already in fair range for proper implementation of SMS

V. DISCUSSION

The results from all five hypothetical paths (H1–H5) underscore the importance of the SEM model. Of the five hypotheses, two (H1, H2) were supported at a 5% significance level, one (H5) at a 1% significance level, and two (H3, H4) at less than a 1% significance level. The R^2 value for the SMS construct was 0.352, with an adjusted R^2 of 0.344, indicating that the model reasonably describes the variation in SMS implementation based on the factors. This adjusted R^2 value of 0.344 suggests that 34.4% of the variance in the dependent variable can be explained by the independent variables [44]. Furthermore, an increase of one standard deviation in the constructs CP, EP, PM, SC, and SR results in increases in the standard deviations of SMS by 13.1%, 12.2%, 21.8%, 21.9%, and 14.7%, respectively.

The analysis of the path coefficients in the inner structural model revealed that the relationship between the safety commitment (SC) factor and the implementation of the safety management system (SMS) in construction projects was the most significant among all constructs. This indicates that a firm commitment to safety from senior management, in terms of manpower, cost allocation, and explicit safety goals, is essential for successful SMS implementation.

This study emphasizes the importance of various factors in the successful implementation of an SMS in building construction projects. The findings highlight that safety commitment, project management, safety requirements and incentives, competency profiles, and employee participation are all crucial elements for effective SMS implementation.

The strongest effect was observed for safety commitment, underscoring the significance of senior management's clear dedication to safety, particularly in resource allocation. This aligns with previous research suggesting that management commitment is vital for enhancing an organization's safety performance [14, 15]. However, providing appropriate resources and support is also crucial for successful SMS implementation. A comprehensive safety management system necessitates hierarchical synergy, encompassing commitment and active participation from all organizational strata, including both managerial and non-managerial personnel, to ensure effective implementation and sustained success [49]. This research finding validates that, during the COVID-19 pandemic, combination of management's commitment to safety and employee involvement can effectively safeguard workers' health and wellbeing, even within the complex and dynamic systems of organizational and environmental contexts [50].

Project Management has evolved as a distinct discipline, with a parallel branch developed in safety and social sciences, encompassing Safety Science and Accident Analysis and Prevention, contributing valuable insights to safety management system [51].This study reflects the a significant effect of project management on SMS implementation, with effective communication, teamwork, and subcontractor control being essential attributes. This result aligns with expectations, as efficient project management can significantly enhance the likelihood of successful SMS implementation [18-20].

Safety requirements and incentives, along with the competency profiles of safety managers, were identified as essential factors. These findings emphasize the importance of establishing clear safety goals, providing incentives for adherence to safety protocols, and ensuring that safety managers possess the necessary skills and expertise [9, 13, 22, 23]. Additionally, Previous research has also demonstrated that Occupational Safety and Health (OSH) requirements and budgeting are often underemphasized in contract documents; however, to ensure effective implementation of safety management systems, safety needs must be adequately budgeted for, as implementation incurs costs. This can be achieved by incorporating safety as a permanent feature in all project bills of quantity [52].

Preceding research finding indicated that safety risk management indirectly influences flight safety performance through its impact on airport personnel competence in Indonesian Airport. This aligns with the study's finding that competency profiles directly and positively impact the safety management system in construction project[53].

Lastly, employee participation emerged as a significant factor in SMS implementation, emphasizing the need to engage employees in promoting safety awareness, reporting hazards, and participating in safety initiatives. This result is supported by previous studies demonstrating the positive impact of employee involvement on safety management systems and workgroup processes [21]. Similarly, research conducted during the COVID-19 lockdown revealed that enhanced employee engagement led to more effective implementation of safety management systems in the workplace[54].

In the evaluation process, the MDM principle [48] was used to identify the impact levels of critical factors on SMS implementation. The final evaluation result for public building construction was 0.495, placing it at the fourth (IV) level, indicating a poor range. Similarly, the final evaluation result for SMS implementation in private building construction was 0.489, also in the fourth (IV) level, indicating a poor range.

Analysis revelated that all five latent factors (EP, PM, SR, SC, CP) are inclined towards the poor range in public construction projects, indicating a need for greater focus on all constructs and their items to improve SMS implementation. In private construction projects, the factors EP, PM, SR, and CP are also in the poor range, while SC factors are in the fair range. This suggests that selected private construction projects need to focus more on EP, PM, SR, and CP and their items over SC to attain effective SMS implementation.

TABLE X
SPEARMAN'S CORRELATIONS

Spearman's rho	Contractor/Rep.	Client/Rep.	Consultant/Rep.
Contractor/Rep.	1	0.868**	0.798**
Sig. (2-tailed)	-	0.000	0.001
N	24	24	24

To check the monotonic relationship between (client, consultant and contractor) representative view, a null hypothesis is set up at 5% level of significance (α=0.05). The corresponding Spearman's correlation coefficients (ρ) and p-value were obtained and are discussed below.

H0: *The opinions of client, consultant, and contractor representatives regarding the critical factors for effective Safety Management System (SMS) implementation in Nepal's construction projects exhibit no monotonic relationship.*

H1: *The opinions of client, consultant, and contractor representatives regarding the critical factors for effective Safety Management System (SMS) implementation in Nepal's construction projects exhibit monotonic relationship.*

Above Table X shows a strong positive correlation between (client, consultant and contractor) representative with value 0.868 between client and contractor, 0.798 between contractor and consultant and 0.861 between consultant [55]. These values reflects that there is significant monotonic relationship between (client, consultant and contractor) representative opinion on critical factors for proper implementation of the Safety Management System in construction projects in Nepal.

VI. CONCLUSION

To the best of our knowledge, this study is the first to utilize SEM-PLS modeling to demonstrate the relationship between SMS implementation and its critical factors in construction projects in Nepal. The entire hypothesis set were positively affected, as indicated by positive path coefficients in each relationship. Among all relationships, it is concluded that safety commitment factors have the highest impact on the proper implementation of SMS, with a t-value of 5.127 and a beta value of 0.219. Project management factors have the second highest impact, with a t-value of 3.600 and a beta value of 0.218. Similarly, safety requirements and incentive factors have the third highest impact, with a t-value of 2.556 and a beta value of 0.147.

Therefore, it is crucial for construction professionals to focus on these critical aspects and thoroughly analyze their corresponding indicators. This focus is vital, as these factors significantly impact the successful execution of Safety Management Systems in construction projects.

According to the evaluation matrix output obtained through the implementation of the MDM principle, both private and public construction projects fall into the poor range of SMS implementation based on the impact of critical factors. This finding indicates that both selected public and private construction projects need to place more emphasis on all constructs and their respective items for more effective and improved implementation of SMS.

VII. IMPLICATION

A. Methodological Implications:

The study's use of Conceptual Structural Equation Modelling (SEM) with Partial Least Squares (PLS) provides a strong methodological foundation for investigating crucial elements impacting Safety Management System (SMS) adoption in Nepalese building projects. This method identified "safety commitment factors" as critical, underlining their importance with a path coefficient of 0.219 and a t-value of 5.127. Furthermore, the Evaluation Matrix facilitated a systematic assessment of SMS across project types, increasing methodological rigor and providing actionable insights to improve safety procedures within the industry.

B. Managerial Implications:

For Nepalese construction managers and stakeholders, identifying "safety commitment factors" as the primary influencers of SMS effectiveness gives clear managerial imperatives. These findings highlight the necessity of building a strong safety culture and leadership commitment within construction businesses. Managers should prioritize investments in training programs, safety standards, and organizational rules that encourage and sustain all employees' commitment with safety. Furthermore, the discrepancies in SMS implementation between public and private building projects necessitate specialized management solutions. Collaboration between sectors could enhance knowledge sharing and the adoption of best practices, thereby enhancing overall safety performance. To avoid risks and improve project outcomes, managers are encouraged to examine and update SMS frameworks on a regular basis, based on current research and developing industry norms. Likewise, the contract should stipulate a dedicated safety budget to ensure the appropriate allocation of resources for implementing and maintaining required safety measures throughout the project lifecycle.

C. Theoretical Implications:

This study improves the understanding of SMS application in construction, particularly in developing countries like Nepal, by utilizing SEM-PLS to identify structural links between essential components. It promotes theoretical frameworks on organizational safety culture and leadership influence, with a focus on "safety commitment factors" and their effect on safety culture, organizational behavior, and operational outcomes. These findings strengthen the theoretical foundation for future research on adapting safety management techniques across multiple global construction environments. This study emphasizes its broad relevance by informing effective SMS strategies customized to various industry situations.

VIII. LIMITATION AND DIRECTION FOR FUTURE RESEARCH

Each type of research study has its own limitation. The results of this study may not be universally applicable to all construction companies worldwide. To assess its outcomes in diverse circumstances, further research will be necessary to advance, validate, and improve its suitability. The present study considers only five dimensions of critical factors based on a limited review of the literature. Similar future studies could be conducted by considering additional dimensions, exploring broad literature range, and integrating various theories. A comparative study between developed and developing nations could provide a more comprehensive understanding of the global situation for this type of research.

APPENDIX

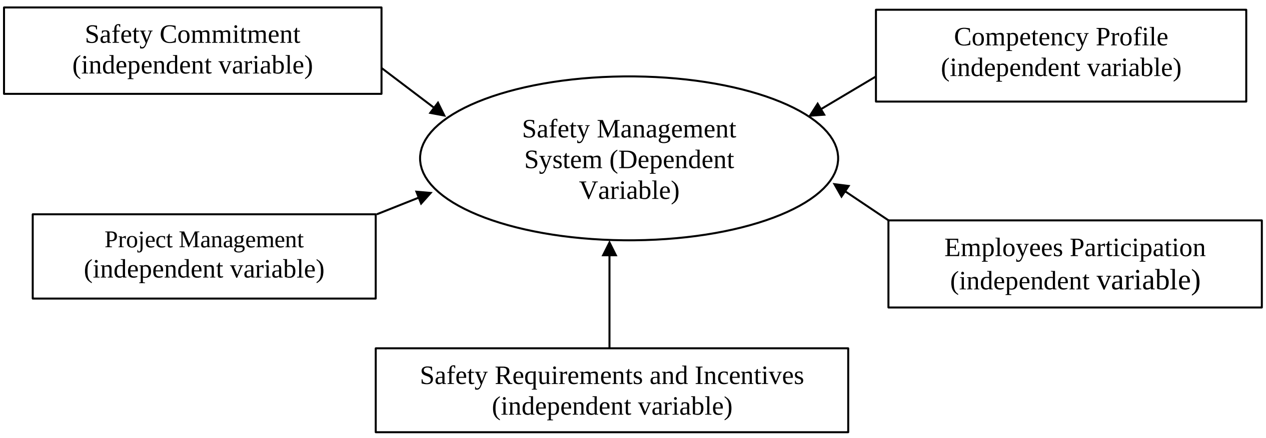

Fig 1: Conceptual Model

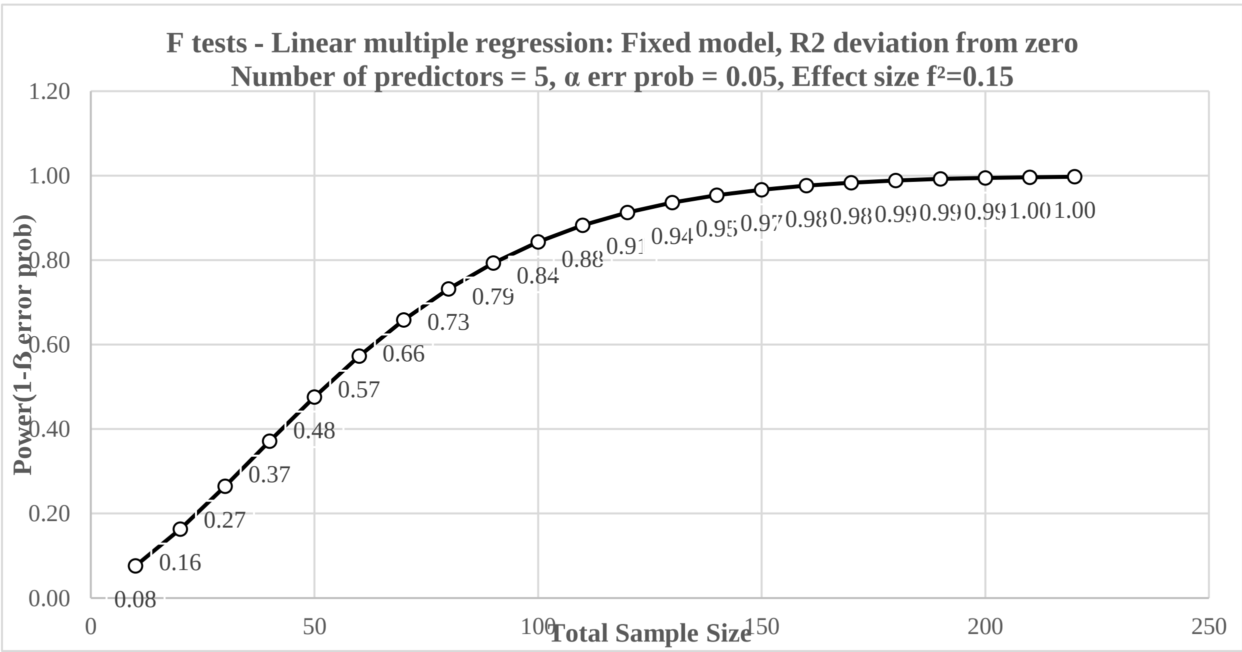

Fig 2: Sample size adequacy

Table 1: KMO and Barlett’s Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.879
Bartlett's Test of Sphericity	Approx. Chi-Square	2147.253
	Df	231
	Sig.	0.000

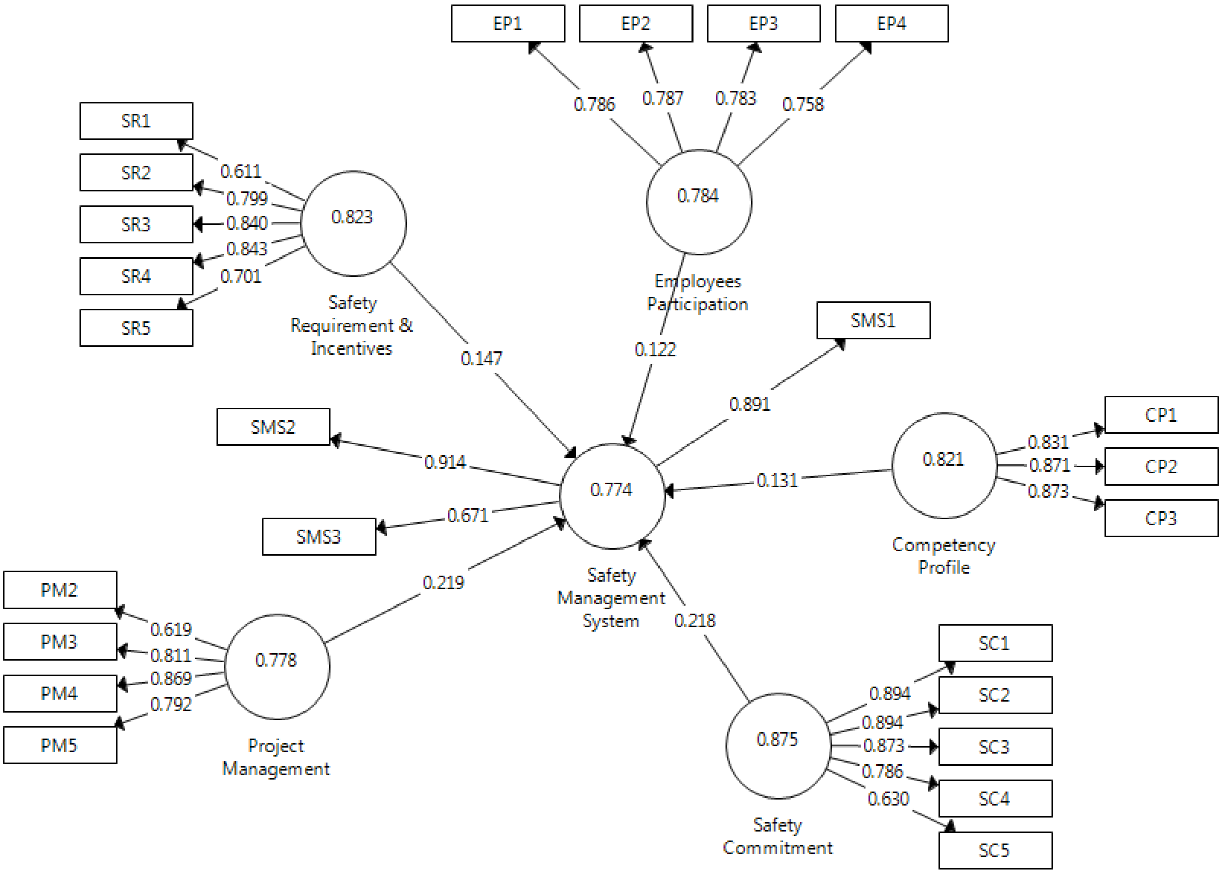

Fig 3: Measurement Model Showing Cronbach’s alpha and indicator loadings

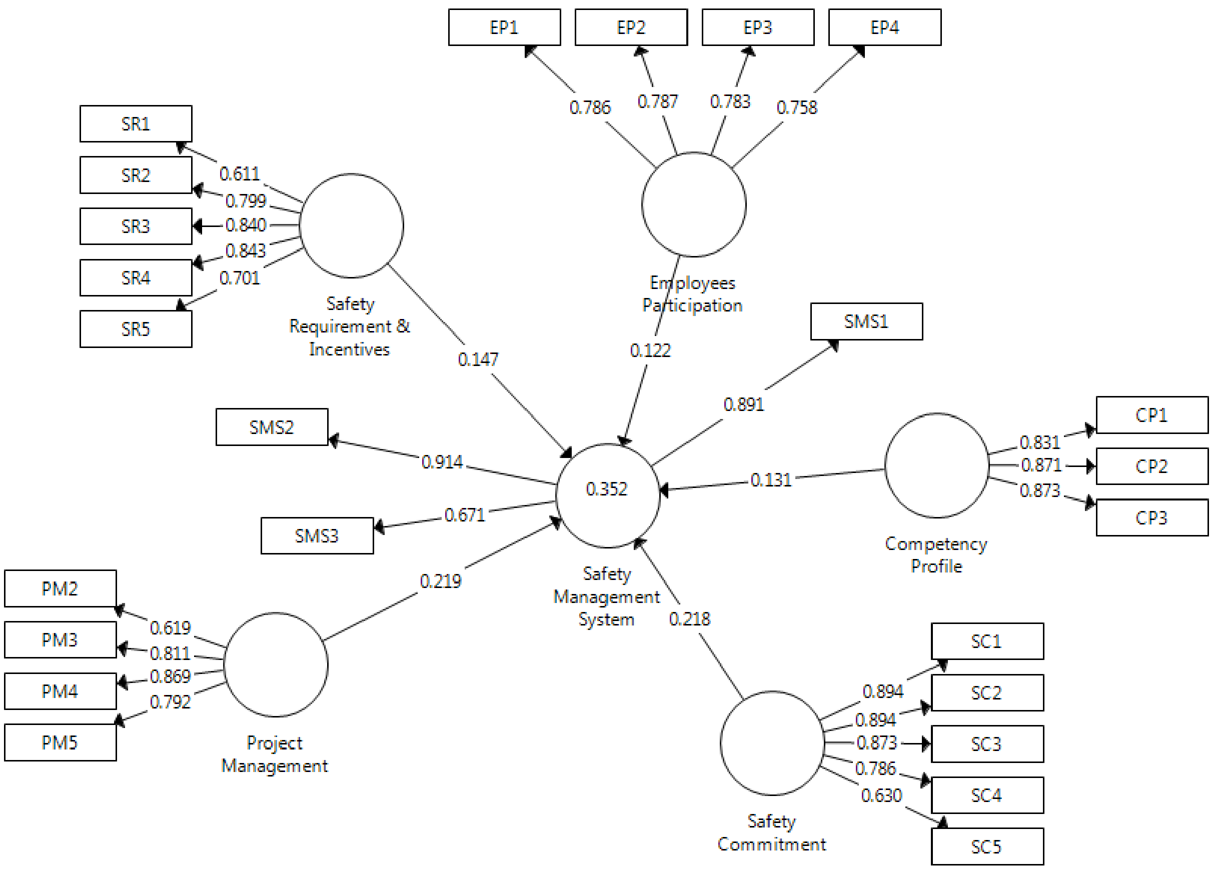

Fig 4: Coefficient of determination (R^2) of dependent construct

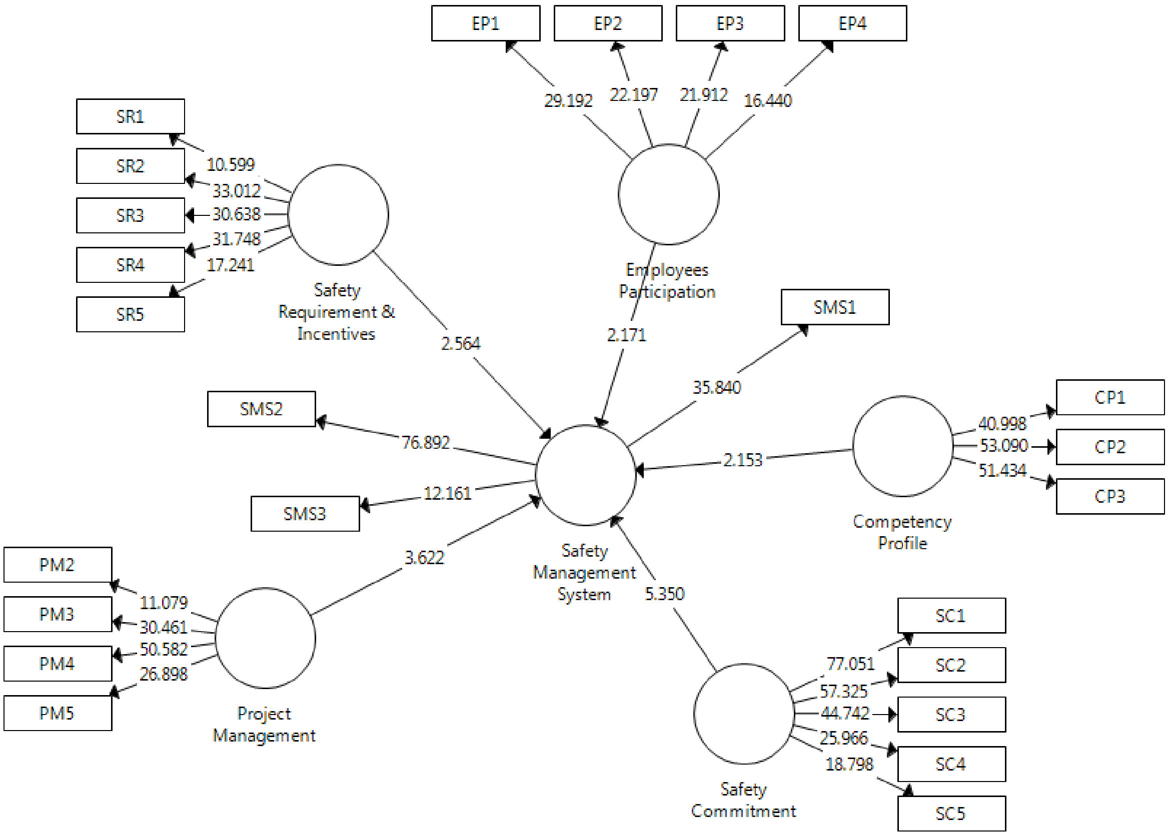

Fig 5: Structural Model showing T-values

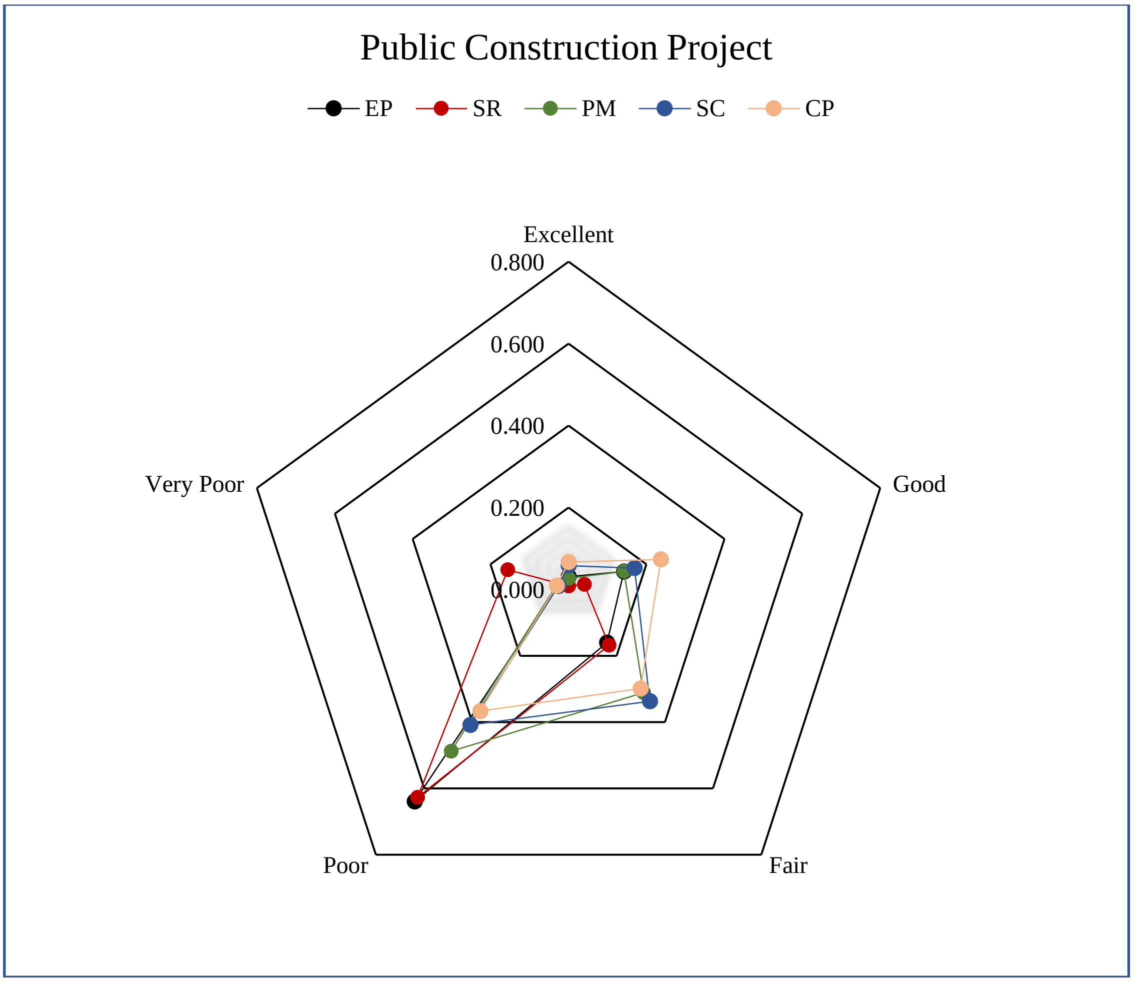

Fig 6: Evaluation result of five latent factors for SMS implementation regarding public construction projects

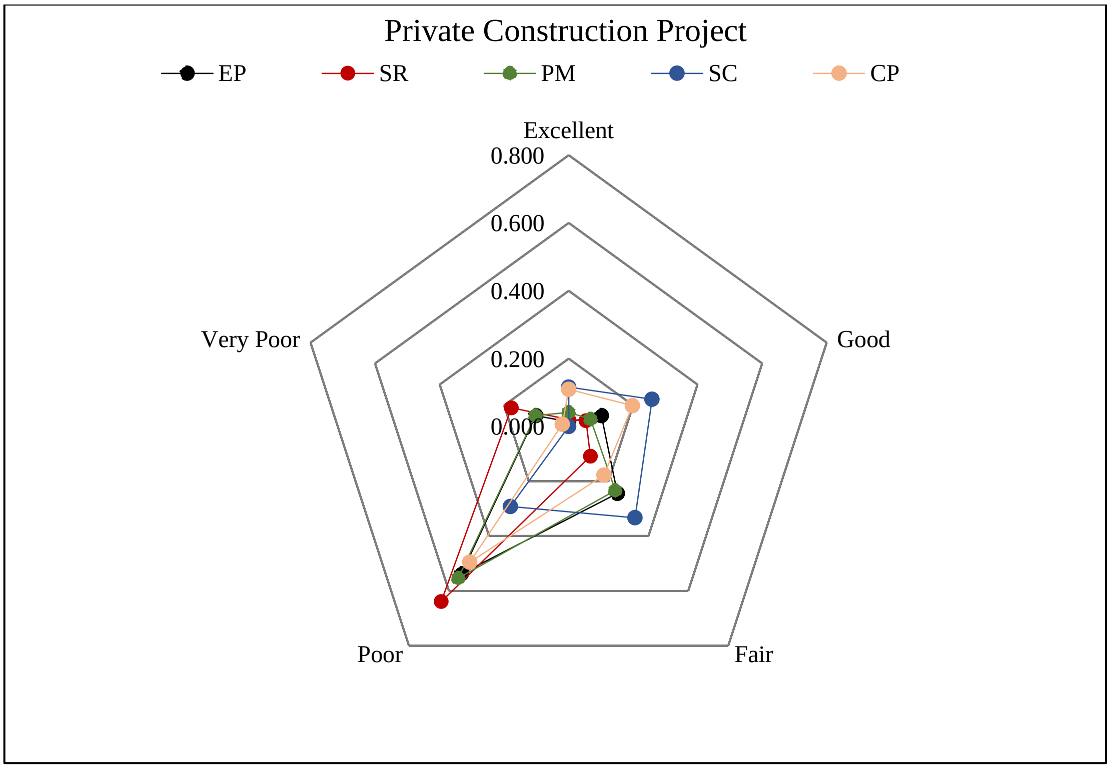

Fig 7: Evaluation result of five latent factors for SMS implementation regarding private construction projects

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