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Exploratory Factor-Item Analytic Approach for Construction Project Cost Overrun using Oblique Promax Rotation for Predictors Determination

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Abstract— ***Adapting innovations in construction project management can proliferate the production of high-quality projects which are known as vital contributors to the socio-economic development of a country. This study was conducted to provide a new approach to cost estimation that would help prevent cost overrun problem during project implementation. Preliminary data collection through literature review and interview led to the determination of qualitative information pertaining to the most frequently encountered cost-influencing conditions and issues, which were adopted to develop the Cost-influencing Factor Assessment Questionnaire, following an Exploratory Factor Analysis through Principal Axis Factoring Method and Oblique Promax Rotation Method to uncover the latent underlying cost-influencing factors for building projects. The survey data were validated through the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO>0.5) and the Bartlett test of sphericity (p<0.05), which indicate the suitability of the data for Factor Analysis. Scree Plot Analysis and Parallel Analysis suggested that 9 factors should be extracted, which were then named according to the shared concepts of the items clustered under each factor. After extensive data screening and analysis, the validity and reliability requirements for scale construction were met, and a new set of items categorized into 9 cost-influencing factors were obtained, establishing the Project Cost Assessment Instrument. A mathematical model was developed through multiple linear regression analysis which showed that 4 out of 9 factors were significant predictors for residential project cost, and these were Project Scale, Equipment Management, Site Condition, and Client Collaboration. The validity of the model was ascertained by means of graphical and mathematical validation, proving the mathematical model's good prediction accuracy.***

Index Terms— ***Construction Project Management, Factor Analysis, Mathematical Model, Project Cost.***

1. INTRODUCTION

Construction projects are known as the basic building blocks for the socio-economic development of a country. Construction industry success has been associated with other industries' progress. The increasing demand for construction commodities, such as cement, steel, and sand from the construction brings enormous impact on the growth of the material production industry at the same time [1]. Acknowledging the impact of a construction project on the nation's overall growth suggests that there is a strong need to ensure the quality of the management approach throughout the implementation process. Hence, it is essential nowadays to create new techniques and adopt innovations so that we can look for relevant solutions to one of the most frequently encountered problems in the construction that is cost overrun.

Cost overrun problem has been connected with the improper cost-estimating procedure. However, it is believed that the procedure itself becomes questionable in today's environment. The traditional ways of cost management system such as simplified budgeting in cost estimation and cost process, which follow specific rules and simple parameters based on quantities, sizes, types, and other linear factors, are insufficient as a concrete basis for a project cost proposal [2]. This is because of uncertainties, like weather conditions, changes in economic condition, design modifications, soil conditions, and client changing decisions can generate vast impact on the construction cost which may require additional works, that can be as crucial as the works indicated in the contract [2].

In addition, complexity is one of the underlying reasons that prompt cost-related problems in a construction project. Project change, unforeseen site condition, project duration, third party condition, heavy traffic, and multiple contracts can further stimulate complex projects which would require a much longer time and a higher needed cost [3]. Furthermore, the social costs can comprise up to four times the construction cost of a particular project, including traffic, economic situation, pollution and ecological and social condition [4].

To bring this information altogether, external cost-influencing conditions and issues can be categorized into four factors, Scope of the Contract, Environment and Circumstantial Factors, Project Risks and Management and Techniques [5].

Cost-related problems in the construction have been attributed to unforeseen conditions that are not technically considered during the conceptual stage of the project implementation. These are generally incalculable in nature and cannot be determined through the traditional cost-estimation procedure that we adopted in the project implementation. To address this problem, this study aimed to develop a regression model that would help describe the mathematical relationship between the project cost and these

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qualitative cost-influencing information by exploring the underlying relevant factors using factor-item analytic approach.

2. STATEMENT OF THE PROBLEM

The main objective of this research is to create a cost predictive mathematical model for residential projects through Multiple Linear Regression Analysis associated with Exploratory Factor Item-analytic approach to determine the cost-influencing factors.

Specifically, this study aimed to answer the following questions:

1. Determine the most frequently encountered cost-influencing conditions and issues by undertaking expert consultation and critical review on established construction project management theories.
2. Develop and administer the Cost-influencing Factors Assessment Questionnaire (CFAQ) to measure the extent to which the obtained conditions and issues affect a building project cost.
3. Utilize Factor Analysis to extract the latent underlying cost-influencing factors and to develop and validate the Project Cost Assessment Instrument (PCAI).
4. Design a regression mathematical model to delineate the relationship between the extracted factors and residential project cost using the developed instrument.
5. Assess the effectiveness of the developed mathematical model by conducting residential project assessment in Davao City.

3. METHODOLOGY

Both descriptive qualitative and applied quantitative research were used in this study. Data gathering was conducted through a series of interview, literature review and survey. Specifically, a 5-point Likert scale was utilized in measuring the level of significance of each cost-influencing conditions and issues contained in the questionnaire. Prior to the utilization of the proposed assessment instrument, reliability test and three validity tests were verified in different phases of this research and these were Content Validity, Construct Validity and Criterion Validity.

Content validity describes the extent to which the item of a given measure represents the underlying content domain it was intended to measure [6]. Construct validity test refers to how well the score in the test relates to observable behavior in the ways predicted by the theory underlying the construct [7]. Lastly, Criterion-related validity test is used to determine how well scores on one measure predict scores on the other measure of interest [7].

The methodology of this study was confined into six phases (see Fig. 1), explaining all the statistical approach, formulas and instruments adopted for the data gathering and result extraction. These were: Phase 1 Collection and Organization of Cost-influencing Conditions and Issues; Phase 2 Development of the Cost-influencing Factor Assessment Questionnaire (CFAQ); Phase 3 Data Collection Analysis and Interpretation; Phase 4 Development of the Project Cost Assessment Instrument (PCAI); Phase 5 Development of the Cost Predictive Mathematical Model; and Phase 6 Evaluation of the Cost Predictive Mathematical Model.

Phase 1: Collection and Organization of Cost-influencing Conditions and Issues

This phase involved gathering of relevant information pertaining to the cost-influencing conditions and issues frequently encountered during the implementation of building projects. This involved literature review and interviews participated by construction managers. The acquired information was critically and individually analyzed, grouped and categorized to form the CFAQ.

Phase 2: Development of the CFAQ

The validity and the reliability of the questionnaire were examined through content validity and internal consistency test, respectively. Most importantly, a pilot study was conducted prior to the actual and final survey using the CFAQ. Content validity was verified through simultaneous consultation of experts in the field of study. Afterwards, a pilot survey using a small sample size was enacted to measure the internal consistency of the CFAQ wherein construction managers, who have experience in building construction were asked to participate in either direct or online interview.

Phase 3: Data Collection Analysis and Interpretation

The finalized CFAQ was employed in the actual survey simultaneously participated by 200 construction managers, and contractors who have established experience in building constructions. The respondents were asked to rate each item in the questionnaire, using a 5-point Likert Scale to measure the extent to which the specific cost-influencing conditions and issues are significant and influential to the overall construction cost of a building project. The survey result was tabulated, followed by factor analysis in which the underlying factors were extracted and determined.

Factor Analysis was used in various researches, most especially in studies with large datasets. Its primary function is to group different measures that describe common concept into one factor or component [8]. Factor analysis offers several alternatives for extraction and rotation method. In this study, Principal Axis Factoring method was used for factor extraction, while the Scree Plot and Parallel Analysis were used to identify the relevant factors among the extracted factors.

Rotation method in Factor Analysis is essential as it helps to simplify the presentation of the structured solution by changing the unrotated factor and increasing the understanding of each factor so that it will become easier to interpret. Primarily, it was assumed that the extracted factors were correlated, and thus Oblique Rotation Method was used [9]. This can be done in two ways, Promax and Direct Oblimin. Though these two rotation methods can produce nearly the same result, Promax is preferred because of its conceptual and computational simplicity [10].

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Phase 4: Development of the PCAI

The extracted factors were adopted to develop the PCAI. Prior to that, both two types of Construct Validity, the Convergent and Discriminant (Divergent) Validity were examined, in which item analysis and data screening were conducted by consecutively removing items with factor loading value of less than 0.5 [11]. Item deletion was carefully implemented with simultaneous verification through the Scree Plot, KMO and Bartlett's Test of Sphericity, Correlation Matrix, Internal Consistency, and the Pattern Matrix, making sure that all the criteria were maintained satisfied.

Convergent and Discriminant validity of the instrument can be assessed through the Average Variance Extracted (AVE). To measure the convergent validity of a factor, AVE must be larger than 0.5 [12].

On the other hand, measuring the Discriminant Validity includes the computation of the square root of AVE (√AVE) which should be larger than the correlation values of the specific factor with any of the other factors by simply inspecting the Factor Correlation Matrix [12].

The formula for AVE is given below:

$$AVE = \frac{\sum(f_i)^2}{\sum(f_i)^2 + \sum \varepsilon_i} \qquad (1)$$

Where f_i is the factor loading of each measurement item, and ε_i is the error variance.

Phase 5: Development of the Cost Predictive Mathematical Model

At this stage, Criterion-related Validity Test was enacted to assess the performance of the PCAI in predicting residential project cost. Generally, a mathematical regression model was developed, describing the mathematical relationship between the extracted factors and residential project costs.

Initially, the PCAI was utilized to assess 20 residential projects in Davao City. Selected projects were categorized as Mid Cost Projects. These were selected randomly from construction companies and thoroughly evaluated by construction managers who were the same people involved with the implementation of these projects.

Likert Scale, specifically a summated scale, was adopted in the assessment, to quantify the extent to which a particular item in the PCAI had a significant contribution to the overall construction cost of the corresponding residential project. There were various studies [13,14] used a summated rating scale for regression analysis especially in dealing with ordinal and qualitative predictors. Using a summated scale instead of restricting the coefficient to 1-5 value can give a wider range of manifestation of the relevant cost-influencing factors. Factors with a summated score have more values than their individual components, and thus appropriate for regression analysis.

Multiple Regression Analysis was thereafter employed to generate the mathematical model, using the summated score from the assessment result as the independent variable while the determined actual cost of the respective project as the dependent variable.

Phase 6: Evaluation of the Cost Predictive Mathematical Model

The regression model was validated through plot and mathematical validation wherein Out-of-Sample validation was mainly considered. 8 residential projects excluded in the derivation of the model were selected and assessed using the previously developed PCAI.

The observed and predicted values were compared through a line graph. On the other hand, mathematical validation involved the computation of the Average Validity Percentage (AVP) and Mean Absolute Percentage Error (MAPE).

The AVP was computed using the following equation [15,16]:

$$AVP = 1 - AIP$$

$$AIP = \frac{\sum_{i=1}^{n} \left|1 - \left(\frac{E_i}{C_i}\right)\right|}{n} \, x\, 100 \qquad (2)$$

Where, AIP is the Average Invalid Percentage, Ei is the Predicted Cost, Ci is the Observed Cost and n is the number of observations.

The Mean Absolute Percentage Error (MAPE) was computed using the equation below:

$$MAPE = \frac{\sum_{i=1}^{n} \frac{|E_i - C_i|}{C_i}}{n} \, x\, 100 \qquad (3)$$

4. RESULTS

The first objective of the study involved the development and validation of the CFAQ. The questionnaire was designed based on the cost-influencing conditions and issues specified in Cheng's established study, which were categorized into four factors, such as the Scope of the Contract, Environmental and Circumstantial Factors, Project Risks, and Management and Techniques [5]. The indicators that confined into these factors were not fully included as some of them might not be relevant to the study's current setting. Hence, both the content validity and reliability test were carefully verified.

Initially, there were 85 extracted information and most of these items were taken from previous studies [4,5] and actual experiences of interviewed construction managers. Provided that the majority of the items or cost-influencing conditions and issues were extracted from established theories might indicate the Content Validity of the gathered information. However, a panel of construction experts was still asked to assess each item in the questionnaire to verify the applicability of the data within the context of building construction project. Generally, they were encouraged to give suggestions and opinions on the clarity, conciseness and consistency of the data obtained.

Critical analysis showed that most of the items were rated applicable and relevant by the evaluators. Some of these items were not considered to be included, however, since the evaluators found them redundant. Experts also introduced new conditions and issues to be included in the questionnaire and recommended that all abstruse statements be refined at the same time. The CFAQ was drafted based on the content validity examination.

The internal consistency measures the reliability of the questionnaire. A pilot survey was participated by 20 respondents which is equivalent to 10% of the sample size adopted in the actual survey [17].

Computing for the internal consistency using the tabulated pilot survey results uncovered the Cronbach's Alpha value [18] for each subgroup in the CFAQ. The result showed an acceptable level of internal consistency, above the minimum threshold of 0.70 [19] for all the four cost-influencing categories, as shown in Table I: Scope of the Contract (α=0.860); Environmental and Circumstantial Factor (α=0.816); Project Risks (α=0.890); and Management and Techniques (α=0.914).

TABLE I: RELIABILITY TEST RESULT

Costs-influencing Factors	Cronbach's Alpha
Scope of the Contract	0.860
Environmental and Circumstantial Factor	0.816
Project Risks	0.890
Management and Techniques	0.914

CFAQ was finalized based on the result of content validity and reliability test, which established the second objective of the study. After data screening and item analysis, 75 items were retained and included in the questionnaire. As shown in Table II, Management and Techniques had the highest number of items (n=30), which means that construction cost is mostly affected by the construction implementation and processes based on the literature review and expert consultation.

TABLE II: COST-INFLUENCING FACTORS ASSESSMENT QUESTIONNAIRE

Costs-influencing Factors	No. of Items
Scope of the Contract	18
Environmental and Circumstantial Factor	12
Project Risks	15
Management and Techniques	30
Total No. of Items	75

The third objective of the study involved administering a survey using the final CFAQ to 200 construction managers who have work experience in building construction. The data from the final survey result were tabulated and afterward subjected to Exploratory Factor Analysis. Most importantly, the PCAI was developed by adopting the extracted factors, and at the same time making the structured solution of the factor loading matrix in conformity with the construct validity requirements.

Before using Factor Analysis, it was first made sure that the obtained data were appropriate for factor analysis. There were two important conditions that must be met: the sample size is adequate, and the correlation matrix is not an identity matrix. Checking for the data suitability showed that Kaiser-Meyer-Olkin value was 0.925, above the minimum value, 0.5 which signified that the 200 samples were adequate [20]. In addition, the Bartlett test of sphericity is statistically significant ($p<0.05$) indicating that the correlation matrix was not an identity matrix which confirmed the factorability of the data [21]. The two requirements mutually attested the appropriateness of the survey result for Factor Analysis.

To investigate the relationship between the extracted factors, the Factor Correlation Matrix was obtained. It showed that most factors have a correlation value above 0.32 [9], suggesting that Oblique Promax was the appropriate rotation method to obtain the structured solution.

After checking all analysis requirements, Scree analysis was then employed to extract the underlying factors. Scree Plot (see Fig. 2) revealed nine important underlying factors for extraction. A simultaneous extraction procedure using Parallel Analysis was also performed through the available syntax file developed by O'Connor [22], which confirmed and validated the number of relevant factors suggested by the scree analysis.

The 9 extracted factors were determined and named based on the shared concept of the retained items under each factor. They were named as: Project Administration (PA), Project Interruption (PI), Contract Scope (CS), Bid Document Preparation (BDP), Project Scale (PS), Financial Competency (FC), Equipment Management (EM), Site Condition (SC) and Client Collaboration (CC).

The adaptation of the extracted factors in the PCAI must concur with the construct validity requirements for scale construction. This was done by rigorous item and data analysis which resulted in the exclusion and removal of some items.

Rerunning again the Factor Analysis allowed the verification of new set of items that strongly converged into every 9 factors. Oblique Promax Rotation was again initiated to come up with a new structured solution, describing the newly structured clustering of items with a factor loading value of above 0.5 [11].

Table III shows the revised Pattern Matrix of the 9 extracted factors, showing the new factor loading values of all items, after extensive data analysis to satisfy the construct validity requirements

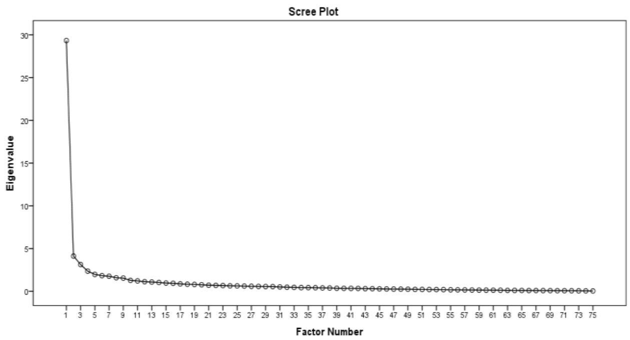

Fig. 2. Scree Plot.

The convergent validity was verified through the direct computation of AVE. Using the equation for construct validity (1), AVE values for all extracted factors were above the recommended level, 0.5 (see Table IV), implying that all the clustered items strongly converged into the same factor,

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which implied shared concepts and commonalities in between.

TABLE III: PATTERN MATRIX

	Factor								
	PA	PI	CS	BDP	PS	FC	EM	SC	CC
1.1	.93								
1.2	.90								
1.3	.83								
1.4	.80								
1.5	.69								
1.6	.63								
1.7	.62								
1.8	.54								
2.1		.89							
2.2		.66							
2.3		.65							
2.4		.64							
3.1			.87						
3.2			.74						
3.3			.71						
3.4			.64						
4.1				.85					
4.2				.81					
4.3				.80					
5.1					.90				
5.2					.83				
5.3					.61				
6.1						.86			
6.2						.71			
6.3						.64			
7.1							.90		
7.2							.84		
7.3							.65		
8.1								.88	
8.2								.83	
8.3								.52	
9.1									.86
9.2									.57

Extraction Method: Principal Axis Factoring
Rotation Method: Promax with Kaiser Normalization
Only Loading > 0.5 Displayed

TABLE IV: CONSTRUCT VALIDITY TEST RESULT

Extracted Costs-influencing Factors	AVE	√AVE
PA	0.568	0.753
PI	0.512	0.715
CS	0.550	0.741
BDP	0.668	0.817
PS	0.624	0.790
FC	0.551	0.742
EM	0.643	0.802
SC	0.580	0.762
CC	0.530	0.728

The computed √AVE values were compared with the factor correlation values. Table V shows the Factor Correlation Matrix, wherein the diagonal values are the computed √AVE. The table shows that values are larger than the correlation values of the specific factor with any factor in the matrix, proving the Discriminant Validity of the PCAI.

After a thorough and extensive validation process, the Project Cost Assessment Instrument was finalized, and thus determined the third objective of the study. It contained 9 factors and a total of 33 item questions (see Fig. 3): PA(n=8), PI(n=4), CS(n=4), BDP(n=3), PS(n=3), FC(n=3), EM(n=3), SC(n=3) and CC(n=2).

TABLE V: FACTOR CORRELATION MATRIX

Factor	PA	PI	CS	BDP	PS	FC	EM	SC	CC
PA	0.75								
PI	.566	0.72							
CS	.644	.432	0.74						
BDP	.609	.492	.500	0.82					
PS	.415	.347	.537	.356	0.79				
FC	.488	.540	.423	.408	.361	0.74			
EM	.616	.523	.587	.535	.422	.477	0.80		
SC	.449	.562	.470	.359	.409	.467	.461	0.76	
CC	.352	.315	.429	.356	.266	.436	.309	.275	0.73

PCAI was used for residential project cost assessment. After which, Linear Regression Analysis using Backward Elimination was executed to determine the best combination of variables that were statistically significant ($p<0.05$). Coefficients with significant value exceeding 0.05 confidence interval were removed, the analysis was resumed, and a variable was deleted one at a time until the final significant variables were acquired. Four factors, as shown in Table VI, were remained statistically significant.

TABLE VI: COEFFICIENTS

Mode 6	Coefficients (10^5) B	Sig.	Collinearity Statistics VIF
(Constant)	35.02777	.000	
PS	.76124	.000	1.762
EM	-.46658	.013	1.452
SC	.70000	.001	1.463
CC	-.60496	.025	1.084

When predicting residential project cost, it was found out that Project Scale (B=0.76124), Equipment Management (B=-0.46658), Site Condition (B=0.70000) and Client Collaboration (B=-0.60496) are significant predictors at

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$p<0.05$. VIF for all coefficients were less than 5% which indicates the absence of multicollinearity between the 4 variables. Furthermore, the coefficient of correlation (R=0.843) was above 0.8, implying strong association while the coefficient of determination (R^2=0.711) was above 0.6, and thus deemed satisfactory [23]. In addition, the normal P-P Plot (see Fig. 4) shows that the Standardized Residual follow the diagonal line, implying that the data are normally distributed.

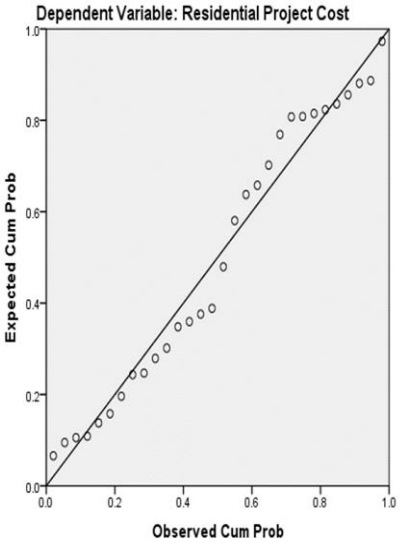

Fig. 4. Normal P-P Plot of Regression Standard Residual

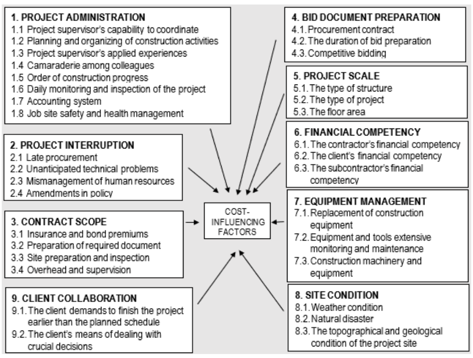

Fig. 3. Extracted Factors used in the Project Cost Assessment Instrument

The fourth objective of this study, the cost predictive mathematical model for Residential Project Cost (RPC) was finally obtained, as shown below:

$$RPC = 76124(\boldsymbol{PS}) - 46658(\boldsymbol{EM}) + 70000(\boldsymbol{SC}) - 60496(\boldsymbol{CC}) + 3502777 \qquad (4)$$

The model shows that Equipment Management and Client Collaboration have a negative beta coefficient, which denotes an inverse relationship with the Residential Project Cost.

For the fifth objective of the study, the derived mathematical model was tested through Out-of-Sample test, wherein a new data set was used. Two approaches were introduced to validate the model, graphical and mathematical validation.

Using the derived model (4), the predicted costs of the sample were computed and compared with the observed costs.

First, the graphical presentation (see Fig. 5) describes the relationship between the observed and predicted value. The line graph reveals that the predicted value lies around the observed values, indicating that the two values are very close and there is indeed a good prediction accuracy of the model.

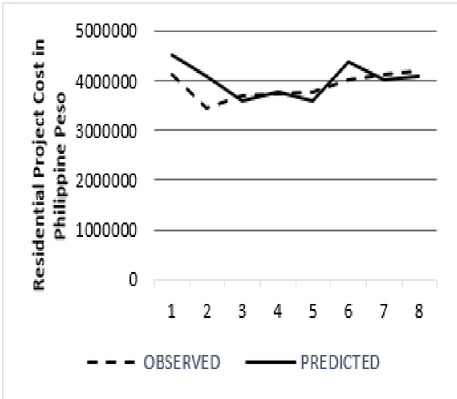

Fig. 5. Plot Validation

For the mathematical evaluation, the Average Validity Percentage (AVP) and the Mean Absolute Percentage Error (MAPE) were determined.

Table VII shows the predicted model was almost 93.5% accurate based on the computation of AVP using equation (2). On the other hand, the Mean Absolute Percentage Error (MAPE) was also computed using the equation (3). The result shows that the MAPE value was 6.54% which was less than 10%, implying accurate prediction based on the classification: less than 10% - accurate prediction; 10-20% - good prediction; 20%-50% - acceptable prediction; and more than 50% - inaccurate prediction [24].

TABLE VII: MATHEMATICAL VALIDATION

Observed, C_i (PHP)	Predicted, E_i (PHP)	AVP	MAPE
4,123,751.86	4,527,768.50	90.20%	9.80%
3,436,202.00	4,080,346.60	81.25%	18.75%
3,705,310.00	3,597,806.60	97.09%	2.90%
3,743,376.02	3,774,033.00	99.18%	0.82%
3,769,819.00	3,573,309.80	94.79%	5.21%
4,021,332.21	4,386,205.20	90.93%	9.07%
4,125,320.10	4,009,191.80	97.18%	2.82%
4,202,630.00	4,079,165.80	97.06%	2.94%
Result		93.45%	6.54%

5. CONCLUSION

The main purpose of the study was to delineate the relationship between the residential project cost and

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qualitative cost-influencing factors through mathematical representation. However, there has been no established methodologies on determining the numerical equivalence of these factors in the real world. Therefore, this study introduced the Project Cost Assessment Instrument to provide a profound insight into the effect of these conditions on the financial aspect of a building construction project.

The first objective of the study, which was to determine the most commonly encountered cost-influencing conditions and challenges in building construction was achieved through extensive literature review and interview. Cost-influencing factors can be categorized into four aspects, Scope of the Contract, Environmental and Circumstantial Factors, Project Risks, and Management and Techniques. These are qualitative data and immeasurable in nature, which convey unanticipated impact on building construction project and can stimulate financial problem as a cost overrun.

The Cost-influencing Factors Assessment Questionnaire was developed based on the initially collected information, which guided the second objective of the study. The CFAQ established content validity and reliability by conducting series of interviews and expert consultations, revealing Cronbach's alpha values above the recommended level.

The significant contribution of this study is the determination of the 9 Cost-influencing Factors of building projects. Factor Analysis through Principal Axis Factoring Extraction and Promax Rotation Method uncovered 9 important underlying factors, based on the Scree Plot and Parallel Analysis. These factors were named as, Project Administration, Project Interruptions, Contract Scope, Bid Document Preparation, Project Scale, Financial Competency, Equipment Management, Site Condition and Client Collaboration.

The extracted factors were adopted to form the PCAI, which was used in the assessment of residential projects, resulting in the development of a mathematical regression model.

It was therefore concluded that only 4 out of 9 factors were found statistically significant in predicting residential project cost, and these were Project Scale, Equipment Management, Site Condition, and Client Collaboration. However, only two factors, Equipment Management and Client Collaboration, were identified to have a negative Beta coefficient, signifying a negative relationship with the residential project cost. Thus, this study ended with a realization that employing equipment and machinery and establishing constant communication with the client may provide a solution to cost overrun problem in building construction.

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