Principal Prequalification Criteria In Thailand
: A Study on Electric Supply Projects

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This study identified key prequalification criteria to be considered in Thai construction Industry. For the purpose, statistical analyses were conducted on prequalification factors of the Electricity Generating Authority of Thailand (EGAT). The pre-defined criteria of EGAT included contractor's *experience, financial capabilities, key personnel, equipment capabilities, past performance, current work load, construction capability, business condition, capacity of company*, and *litigation history*. Insights into the significance of these criteria were then obtained through numerous interviews and questionnaires with the owner and contractors. The results from this study revealed that criteria rating of both the owner and the contractors are quite similar. Results also revealed that prequalification criteria could be grouped into four principal components labeled as ***abilities, capacities, reliability***, and ***compatibility*** in general.

Key Words: prequalification, criteria, public energy construction, Thailand

1. INTRODUCTION

During the past decade, the Thai construction industry has faced various problems while it has played an important role in supporting the rapid growth of the economy. The situation is reflected by, for example, financial failure, project delay, increasing accident rates, and so on. In addition, globalization has progressed, and the whole construction industry has been in the needs to quickly adjust traditional procurement methods to effective and accountable ways. Among the necessary changes, establishment of prequalification system is one of the most important things to be considered for the "healthy" growth of the industry.

"Prequalification involves screening and qualifying contractors according to a given set of criteria based on experience, skill, reputation, financial stability, responsibility, and so on to determine competence to perform the work if awarded the contract[1)]." "Its objective is to ensure that the contractor's characteristics and capabilities match the requirements of the project under consideration[2)]."

Prequalification criteria are critical in choosing suitable contractors. This premise underlies research efforts completed by some researchers. For example, Russell and Skibniewski states that factors considered in the development of prequalification criteria relates to "type of owner (public and private), owner objective, scope of work, resource required, project constraints, and contracting strategy[3)]."

An effective prequalification process not only serves owners, but also is important for contractors. On the owner's side, "it reduces risk in the choice of contractors for making decisions and attracts responsible contractors[4)]". On the contractor's side, it works as a form of external auditing of the contractor's abilities and assures that the bidding will not include low prices with inadequate experiences of the bidders. Furthermore, it functions as an incentive "because preparing the bid requires substantial investment of effort and money so the potential contractor can ensure that his bid is not rejected[5)]."

In Thailand, individual owners employ different prequalification criteria. Some emphasize low bid, technical superiority, or financial capabilities, and others put more values on expertise and experiences of contractors. Even if the owners have their own criteria, prequlification practices are not sometimes consistent even within their organizations. Moreover, logical discussions have not been made with regard to importance of prequalification system in Thailand. Under these situations, insights into prequalification research are expected to have tremendous contribution to the society.

2. OBJECTIVE

The objectives of this study are as follows:

1) Analyze differences in the criteria rating between the owner and contractors, using EGAT's pre-determined prequalification criteria.
2) Analyze if EGAT's criteria could be grouped to identify principal prequalification criteria in general.

3. METHODOLOGY

This study has explored the current prequalification practices within EGAT, which is a large semi-public organization that is responsible for the whole electric supply projects in Thailand. Analyses into the principal prequalification criteria were then conducted by questionnaires and interviews with EGAT personnel and their contractors.

In the first step, EGAT's prequalification system[6] was pictured with the help of key personnel who have been prequalification committee within the organization before. Second, series of interviews and questionnaires were conducted among the owner and contractors who have bided EGAT's projects before. Finally, statistical analyses were conducted to rank the criteria from both the owner and the contractor point of view, and group them into principal prequalification criteria.

EGAT's prequalification criteria were known to consist of eleven major areas as follows:

(1) Business conditions
(2) Experience
(3) Capacity of Company
(4) Current Work Load
(5) Past Performance
(6) Financial Capabilities
(7) Key Personnel Capabilities
(8) Equipment Capabilities
(9) Construction Capabilities
(10) Management Capabilities
(11) Litigation History

These major criteria include sub-factors as shown in Figure-1. Description of the criteria is also given in Table-1.

Then, questionnaires were conducted to identify which of the criteria appeared to have significant importance in order. Inputs from EGAT personnel and the contractors were compiled so that each criteria was subjectively rated using a range of "not important" measured as a value of 1 to "very important" considered as 5. The same information was also obtained for the sub-criteria.

Fifteen and thirty questionnaires were sent out to people within EGAT and contractors, respectively. The number of individuals who responded to the questionnaire was 14 (response rate of 93%) from the owner and 27 (response rate of 90%) from the contractor, respectively (Table-2).

Finally, response data from these questionnares were analyzed statistically. First, the mean values of the criteria rating were computed to rank the criteria in order (refer to appendix-II). Accordingly, *two-sample hypothesis testing* was conducted to see if there are statistical differences in the criteria rating between the owner and the contractors (refer to appendix-III). Finally, *factor analysis* was employed to determine if the eleven major criteria could be statistically correlated to principal prequalification factors (refer to appendix-IV). In doing such analyses, statistical software of *SPSS* (ver. 6) was used. A summary of the results can be found in the next sections.

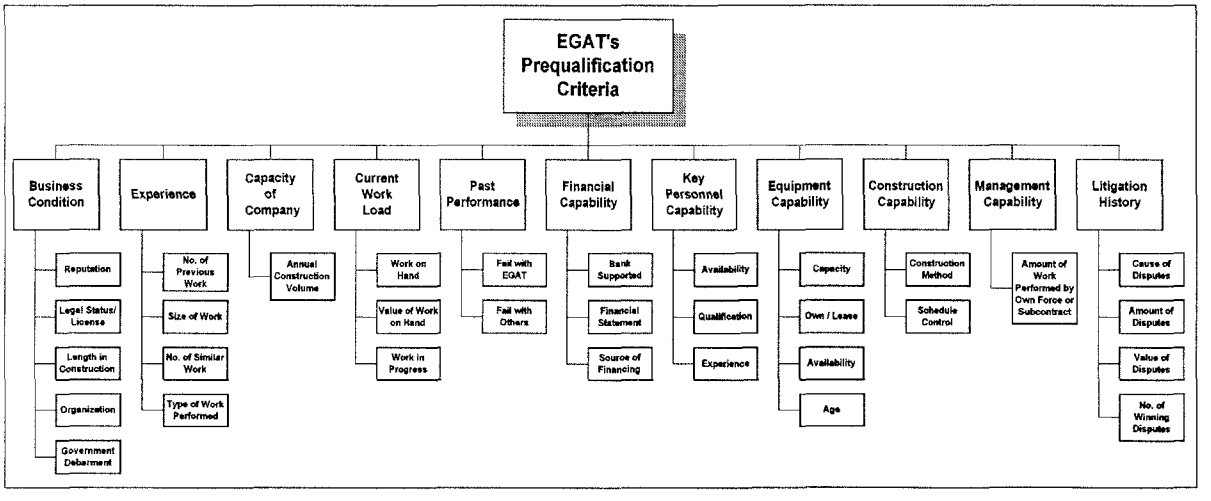

Figure 1 : Prequalification Criteria (EGAT, 1995)

Table 1: Definition of Prequalification Criteria for Electric Supply Projects in Thailand

Criteria	Descriptions
Business Condition	The general information of company, such as name, address, status of company (cooperative or single) is usually requested. The following items are used as an indication for this criterion; 1) Reputation: It refers to size of company (number of employee), membership of trade/specialist associations, and well-known name. ; 2) License and length in construction under same company name. ; 3) Organizational structure: It indicates the level of management, decision-making, and communication process. ; 4) Debarment from government: Some companies may be prohibited by government in some areas or some types of works.
Experience	Experience ensures that the firm will have sufficient knowledge and capability to smoothly execute works. Experience can be focused on the four aspects. First is the number of success of the previous project. Second is the size and complexity of project most often undertaken. Third and forth are the numbers of similar project performed and type of work, respectively.
Capacity of Company	Capacity imposed quantity of works which contractor has ever undertaken. Past construction volume in each year mirrors a company's trading with an increase representing growth. Annual increases may be associated with positive management, which increase profitability and expand company activities.
Current Work Load	Current workload implies current status of the company in number of work on hand that is undertaking. Current work load may be considered according to the following items as the inherent number of works, value of those work, work in progress (estimated completion date for those works) which it refer to the quantity of remaining works.
Past Performance	As past performance expresses failure of work execution of contractor from the previous works, it is used as a guide of anticipating performance of the company in the upcoming works. Poor performance means failure to meet requirements such as schedule, cost, and quality so, past performance with own EGAT and other owners need to be considered.
Financial Capabilities	Financial capability indicates whether a contractor company has the necessary financial resources to execute the project. The following items are considered on this criterion as; 1) Bank supported: Bank credit indicates relationship of contractor with bank in terms of short term or long term loan, interest rate, and borrowing capacity. ; 2) Financial statement represents a statement of the financial position. It includes asset holding, liabilities, liquidity, and profit. ; 3) In case of a large project, contractor may get money from many ways to meet the financial requirements. Other sources mentioned will be considered in current status (e.g., name, and address), amount of loan, and duration of borrowing.
Key Personnel Capabilities	Key personnel mean both owner and person who administer and supervise on the construction site. This criterion is used to determine whether the contractor has key management sufficient for handling the project. Therefore, it will be concentrated on availability, qualification (degree, age), Experience of them which it refer to both number of past project completed and years with current company.
Equipment Capabilities	Equipment is significant in order that it also affect work performance. Suitable employing equipment will facilitate workers to perform work easier resulting in reduced completion time, and improved quality. The following items of equipment resource should be realized as its capacity, condition (own or lease), availability, and age.
Construction Capabilities	The level of technology is a measure of construction ability and specialist of contractor. It depends on the project objectives. For example, time, advance construction method and high technology may be better old technology. The following items express this criterion as construction method and schedule control system (i.e., CPM, S-Curve).
Management Capabilities	Some works necessitate to be subcontracted. Reasons for using subcontractors include short-term overload, inconvenient geographical location of project, or lack of specialist capacity. This criterion is used to assess elements such as the ability to coordinate the work, and real performance (percentage of work performed by owned company or by subcontract).
Litigation History	The objective of this criterion is to see the litigation tendency. In details, this criterion is not considered only quantitative evaluation. It has to see whether contractor is defendant or plaintiff. The following items are considered as cause, amount, value (both cost for compensation and penalty), and the number of winning disputes and claims.

Table 2: Characterization of sample

Organization type	Survey source	Total number of questionnaires sent to interview	Number of questionnaires responded	Percentage of questionnaires responded
Owner	The Electricity Generating Authority of Thailand (EGAT)	15	14	93
Contractor	List from owner, located in Bangkok	30	27	90
Total sample		45	41	91

4. RESULTS

4.1 Criteria Ranking

The ranking order towards the criteria from both the owner's and the contractors' views are shown in Table-4 and –5, respectively. The mean values in the tables are arithmetic means of points given by the respondents. By the definition of input data, the higher the value, the more important the criteria are thought to be.

The results show that both owners and the contractors rated the ***experience*** the highest and ***financial capabilities*** the second highest. It is not surprising to see why both the owner and the contractors ranked these criteria highly. It is likely that *experience* is essential because of "uniqueness" or specialty type of works for EGAT. According to interviews, both the owner and the contractors have expressed the difficulties in finishing EGAT's projects without past experiences. Similarly, *financial capabilities* were also thought to be very important. This is because many of current problems in Thai construction industry such as delay or interruption of projects have arisen from financial problems of not only owners, but also contractors.

Similarly, ***key personnel capabilities, equipment capabilities,*** and ***construction capabilities*** are also ranked to be the same by both sides, in the fourth, fifth, and sixth rank, individually. It should be understood that the shortage of capable and experienced engineers, and availability and capacity of construction equipment are said to be serious problems in Thai construction industry. Therefore, the respondents may have had perceptions that these criteria were relatively important in Thailand.

It is interesting to see that the contractors rated ***current workload*** as the third important criteria while the owner ranked it in the seventh. In other words, the owner has put less importance on this criterion than the contractors. This result indicates that contractors realize full efficiency of operation could not be achieved when they have too much work beyond their capacity. Although the owner gives less importance on exiting workload on contractor's hand, they may need to put more attention on this criterion.

On the contrary to contractors' rating, the owner rated ***past performance*** (3^{rd} rank) higher than the contractors did (7^{th} rank). According to interviews, it was found that contractors didn't worry about the evaluation of past performance because they knew no such historical records existed. It was also pointed out that some contractors even try to bribe owner's officials to neglect this criterion. Contractor's failure to finish projects directly relates to owner's loss, and it is likely that these "cultural conditions" make the owner sensitive to contractor's failure indicated by the performance of completed projects.

Both the owner and the contractors ranked ***business condition*** and ***capacity of company*** relatively low. While these criteria are regarded relatively important as prequalification in some countries, it can be seen that owners in Thailand do not pay much attention on these criteria. It is quite natural to understand that owners may not be interested in *capacity of company* designated by, for example, annual contract volume because it does not necessarily represent "goodness" of the company. Instead, other parameters such as turnover by overtrading, profitability or liquidity of the company should be the key variables considered for prequalification.

Management capabilities and ***litigation histories were*** also ranked low. In general, owners record disputes and claims from contractors in detail, and any contractors that have raised problems leading to legal suits are thought to be "bad." This, in turn, means that contractors may not be able to survive if he is given such bad reputation. Therefore, *litigation* associated with management capabilities can not be serious problems in Thailand.

Up to this point, differences were investigated by observing mean differences of points using the owner and the contractors' evaluation. This type of analysis is not in itself entirely conclusive. Therefore, the results in Table-4 and -5 need further scrutiny to see whether the observed differences in the mean values between two groups are statistically different. For this, two-sample tests were performed to signify evidence against the hypothesis that the differences may be regarded as due to sampling errors and accordingly either reject or accept the hypothesis. The level of significance at 5% level was used as a measurement of the strength of evidence that a difference existed in doing the statistical test.

Table-5 shows criteria that proved to be statistically different. These included the followings: *capacity of a company*, *current work load,* and *construction capabilities* (indicated by a superscript (*) in Table-5.) The results indicated that owner considered these three criteria were less important than contractors did.

Table-3. Criteria Ranking by Owner

Owner		
Rank	Prequalification Criteria	Mean
1	Experience	4.57
2	Financial Capability	4.28
3	Past Performance	4.14
4	Key Personnel Capability	3.78
5	Equipment Capability	3.71
6	Construction Capability	3.28
7	Current Work Load	3.14
8	Management Capability	3.07
9	Litigation History	3.00
10	Business Condition	2.85
11	Capacity of Company	2.57

Table-4. Criteria Ranking by Contractor

Contractor		
Rank	Prequalification Criteria	Mean
1	Experience	4.70
2	Financial Capability	4.59
3	Current Work Load	4.33
4	Key Personnel Capability	4.18
5	Equipment Capability	4.11
6	Construction Capability	3.92
7	Past Performance	3.88
8	Capacity of Company	3.51
9	Business Condition	3.48
10	Management Capability	3.25
11	Litigation History	2.62

Table-5. Significance Test on Mean Rating between Owner and Contractor Evaluation

Criteria	Overall Mean	Standard		± 95% Conf.	95% Conf. Limits		t-value	Level of Signif.	Significant at 5% level
		Dev.	Error		Lower	Upper			
(1) Business Condition	3.26	1.25	0.19	0.38	2.89	3.65	-1.56	0.131	Not Significant
(2) Experience	4.65	0.57	0.09	0.18	4.48	4.83	-0.69	0.492	Not Significant
(3) *Capacity of Company*	3.19*	1.12	0.18	0.34	2.85	3.54	-2.77	0.009	**Significant**
(4) *Current Work Load*	3.92*	0.96	0.15	0.29	3.63	4.22	-4.64	0.000	**Significant**
(5) Past Performance	3.97	0.88	0.14	0.27	3.71	4.24	0.87	0.388	Not Significant
(6) Financial Capabilities	4.48	0.64	0.10	0.20	4.29	4.68	-1.48	0.146	Not Significant
(7) Key Personnel Capabilities	4.04	0.71	0.11	0.22	3.83	4.26	-1.76	0.085	Not Significant
(8) Equipment Capabilities	3.97	0.76	0.12	0.23	3.74	4.21	-1.62	0.113	Not Significant
(9) *Construction Capabilities*	3.70*	0.93	0.15	0.28	3.42	3.99	-2.19	0.035	**Significant**
(10) Management Capabilities	3.19	0.98	0.15	0.30	2.90	3.50	-0.58	0.567	Not Significant
(11) Litigation History	2.75	1.09	0.17	0.33	2.42	3.09	1.03	0.308	Not Significant

Note : (*) Significance at 0.05, and t-value from statistical table at 0.05 level is 2.021.

3.2 Criteria Grouping

The final step of this research was to analyze if the eleven criteria work together in influencing the owner and contractors' decision in prequalification. This was accomplished by analyzing results from the set of obtained data as used in the previous section using *principal component factor analysis*.

First, correlation analysis is shown in Table-6 to see if "the data matrix does not suffer from multicollinearity or singularity[7]." The determinant of the correlation matrix is 0.016, which is greater than the required 0.00001. Thus, the data matrix does not suffer from such problems. Also, the Kaiser-Meyer-Olkin measure of sampling adequacy is found to be 0.501, which is greater than 0.5, therefore, "it is confirmed that the sampling adequacy is acceptable[8]".

The results of the factor analysis are shown in Table-7, including eigenvalues, percentage of variances, and the cumulative percentage of variances. An eigenvalue is a measure of standardized variance with a mean of zero and standard deviation of one. A factor with an eigenvalue of less than one is less important, thus it can be ignored. As a result, four factors of ***business condition, experience, capacity of a company*** and ***current workload***, the eigenvalues of which are greater than one, were chosen to be important to compute the factor-loadings of all the variables on these four factors.

Factor loading is simply the correlation coefficient between an original variable and a factor. Thus the higher the absolute value of the loading, the more the variable contributes to the factor. Table-8 includes the results. It also contains the communaliities that show how much of the variance in the variables has been accounted for by the four factors. A close examination of the communalities reveals that the four factors in the analysis account for more than 60% of the variance in all the variables except for only one variable, or *business condition*. Thus, it suggests that the factor analysis has been quite effective.

The initial results in Table-8 include unrotated factors, and indicate the relationship between the factors. To obtain factor-loadings that are easier to interpret than those shown in Table-8, a *varimax rotation* has then been carried out to minimize the number of factors on which the variables have high loadings. The results are shown in Table-9.

After the rotation, it first became clear that ***key personnel, equipment, construction,*** and ***financial capabilities*** substantially contributed to factor-1. In other words, these four variables were identified to be grouped into one category. Similarly, it was found that ***past performance, business condition, management capability,*** and ***capacity of company*** were loaded on factor-2. In the same way, ***experience*** and ***current workload*** were loaded on factor-3, and ***litigation history*** was loaded on factor-4 by itself.

Figure-2 summarizes the results of factor analysis in a "principal prequalification criteria diagram." This figure expresses the many to single relationships between variables toward the four principal prequalification criteria. In the figure, the identified principal criteria were labeled as ***ability, capacity, reliability,*** and ***compatibility***, individually. For the sake of clarity, *ability* can be regarded as requirements related to contractor's "competence" to do the job. *Capacity* involves both experiences and current workload, thus, it may relate to contractors' "prerequisites" in accepting projects. *Reliability* relates to "excellence" and quality of company's resources. Finally, *compatibility* is regarded as the harmonious "attitude" of contractors in doing jobs.

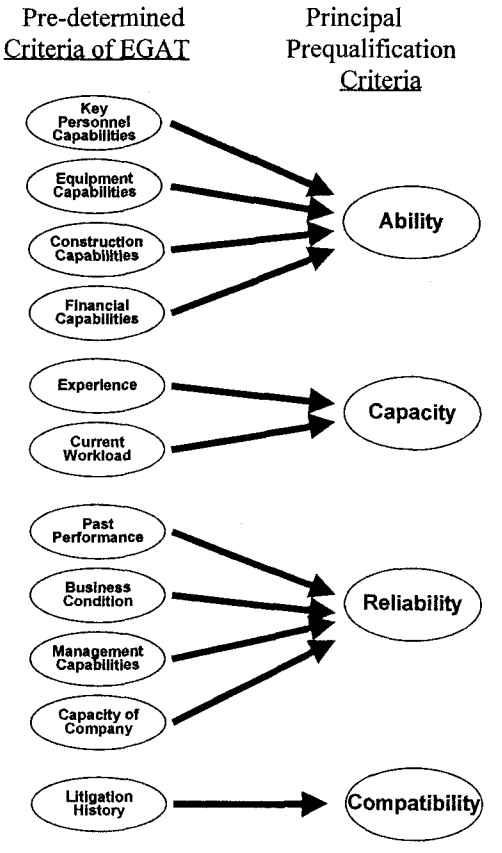

Figure 2: Principal prequalification criteria

Table-6: Correlation Matrix showing Relationship between Owner-Contractor Criteria

Criteria	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Business Condition	1.000	-	-	-	-	-	-	-	-	-	-
(2) Experience	-0.218	1.000	-	-	-	-	-	-	-	-	-
(3) Capacity of Company	0.426	0.105	1.000	-	-	-	-	-	-	-	-
(4) Current Work Load	-0.004	0.361	0.222	1.000	-	-	-	-	-	-	-
(5) Past Performance	0.234	-0.066	0.257	-0.091	1.000	-	-	-	-	-	-
(6) Financial Capability	0.397	-0.216	0.457	-0.021	0.155	1.000	-	-	-	-	-
(7) Key Person. Capability	0.269	0.103	0.271	0.079	0.082	0.501	1.000	-	-	-	-
(8) Equipment Capability	0.218	0.209	0.211	0.169	0.074	0.387	0.750	1.000	-	-	-
(9) Const. Capability	0.004	0.323	0.200	0.199	-0.376	0.205	0.327	0.380	1.000	-	-
(10) Mgn't Capability	0.406	-0.189	0.123	-0.011	0.411	0.324	0.383	0.343	0.174	1.000	-
(11) Litigation History	0.012	0.103	-0.307	-0.017	0.097	-0.040	-0.211	0.083	-0.022	0.279	1.000

Table 7: Initial Statistical of Principal Component Factor Analysis

Factor	Eigenvalues	Percentage of Variance	Cumulative Percentage of Variance
Business Condition	**3.089**	28.1	28.1
Experience	**1.985**	18.1	46.1
Capacity of Company	**1.408**	12.8	58.9
Current Work Load	**1.191**	10.8	69.8
Past Performance	0.883	8.0	77.8
Financial Capability	0.661	6.0	83.8
Key Personnel Capability	0.589	5.4	89.2
Equipment Capability	0.552	5.0	94.2
Construction Capability	0.292	2.7	96.9
Mgnagement Capability	0.213	1.9	98.8
Litigation History	0.131	1.2	100.0

Table-8: Factor-Loadings before Varimax Rotation

Variables	Factors				Achieved Communalities
	Factor 1	Factor 2	Factor 3	Factor 4	
Key personnel Capabilities	**0.798**	0.185	-	-0.254	0.737
Equipment Capabilities	**0.745**	0.287	0.268	-0.148	0.732
Financial Capabilities	**0.726**	-0.187	-0.180	-0.198	0.634
Management Capabilities	**0.610**	-0.362	0.463	-	0.719
Capacity of Company	**0.599**	-	-0.515	0.411	0.794
Business Condition	**0.589**	-0.399	-0.122	0.115	0.535
Experience	-	**0.708**	0.213	0.446	0.748
Construction Capabilities	0.413	**0.636**	0.093	-0.279	0.662
Past Performance	0.286	**-0.586**	0.135	0.546	0.742
Litigation History	-0.058	-0.129	**0.857**	0.103	0.766
Current Work Load	0.176	0.523	-	**0.544**	0.601
Eigenvalues	3.088	1.985	1.408	1.191	-
Percentage of Variance	28.1	18.1	12.8	10.8	-
Cumulative % of Variance	28.1	46.1	58.9	69.8	-

Table-9: Factor-Loadings after Varimax Rotation

Variables	Factors				Achieved Communalities
	Factor 1	Factor 2	Factor 3	Factor 4	
Key personnel Capabilities	**0.839**	0.185	-	-0.254	0.737
Equipment Capabilities	**0.816**	0.287	0.268	-0.148	0.732
Construction Capabilities	**0.657**	-0.187	-0.180	-0.198	0.662
Financial Capabilities	**0.627**	-0.362	0.463	-	0.634
Past Performance	-0.124	**0.839**	-	0.148	0.742
Business Condition	0.329	**0.614**	-0.156	-0.156	0.535
Management Capabilities	0.489	**0.535**	-0.144	0.415	0.719
Capacity of Company	0.274	**0.517**	0.297	-0.601	0.794
Experience	0.069	-0.182	**0.835**	0.110	0.748
Current Work Load	0.068	0.062	**0.762**	-0.104	0.601
Litigation History	-	0.120	0.076	**0.863**	0.766
Eigenvalues	3.088	1.985	1.408	1.191	-
Percentage of Variance	28.1	18.1	12.8	10.8	-
Cumulative % of Variance	28.1	46.1	58.9	69.8	-

4. CONCLUSION

The study analyzed the overall mean ratings of EGAT's (the Electricity Generating Authority of Thailand) criteria from the owner and the contractor's evaluation. The results showed that they gave similar rankings to *experiences, financial capabilities, key personnel capabilities, equipment capabilities,* and *construction capabilities.*

Differences were found in *past performance*, for which that the owner put more importance. Another difference between the owner and the contractors' view was found in the attitude toward *current workload*, on which contractors put more attention. Neither of *business conditions* and *capacity of company* were regarded very important by both sides.

The analysis also examined statistically significant differences in the ratings. The result shows that the difference was found in *capacity of a company, current workload,* and *construction capabilities*, for which the owner considered less important than contractors did.

The major purpose of this study was to identify principal qualification criteria to be recognized in Thai construction industry. This research identified four principal prequalification factors that might be given attention as important prequalification criteria in Thai construction. These factors are *ability, capacity, reliability,* and *compatibility.*

Results from this study have shown some interesting findings about prequalification criteria that may be useful in aiding owners and contractors in Thailand. The results may also be interesting to those in foreign countries in their reviewing current prequalification procedures and providing them with suggestions of changes.

Finally, the results of this research, although not entirely startling, have indicated that research in prequalification in Thailand is a fertile area to pursue on a large scale. Future research will include development of prequalification system that could be used by various public owners.

Appendix I. REFERENCES

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Appendix-II. Mean Value

The following equation was used to calculated the mean values of the criteria rating.

$$Mean\ Value(\bar{X}) = \frac{x_1 + x_2 + x_3 + \ldots\ldots\ldots + x_n}{N} \quad (1)$$

where $\bar{X}$ = mean value in each criterion rating, x_i = scores rated by each respondent (owners and contractors), N = number of respondents.

Appendix-III. Two-sample Hypothesis Test

To see the statistical difference between the owner and contractor's rating, the following hypothesis test is conducted.

$$\text{Hypothesis: } H_o : \mu_1 - \mu_2 = 0 \quad (2)$$

where μ_1 = population mean of owner's rating, and μ_2 = population mean for contractors' rating. The hypothesis indicates that both the owner and contractors assign similar mean values for the criteria. In other words, both the owner and the contractors are not significantly different in their ratings.

Then, t-statistics is computed as follows.

$$\text{The t-statistics: } t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{s^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \quad (3)$$

Where $s^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$, n_1 = number of responds from owner, n_2 = number of responds from contractors, $\bar{x}_1$ = mean value of owner's rating, $\bar{x}_2$ = mean value of contractors' rating, s_1 = standard deviation of owner's rating, s_2 = standard deviation of contractors' rating, and $(n_1 + n_2 - 2)$ = degrees of freedom.

Finally, the hypothesis is accepted if,

$$+t_{0.05/2} \le t \le -t_{0.05/2} \quad (4)$$

where $t_{0.05/2}$ = t-value from the t-distribution table for a significance level 0.025, which is 2.021 when the degrees of freedom is 39. Otherwise, the hypothesis is rejected.

Appendix-IV. Factor Analysis

The factor analysis used in section 3.2 was conducted using the following seven steps.

Step 1: Calculating correlation (Table-6).
After the variables were measured on an interval scale, the correlation matrix was constructed using the following equation.

$$r_{mn} = \frac{\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{N}(x_i - \bar{x})^2 \sum_{i=1}^{N}(y_i - \bar{y})^2}} \quad (1)$$

where r_{mn} = the correlation between mth variable (x) and nth variable (y), and N = the number of data from all respondents. The values of r_{mn} range between –1 and +1.

Step 2: Testing sample adequacy.
To ensure the suitability of the data for this analysis, the determinant of the correlation matrix was calculated by the following equation.

$$D = det(r) = \begin{vmatrix} r_{11} & r_{12} & .. & r_{1n} \\ r_{21} & r_{22} & .. & r_{2n} \\ .. & .. & .. & .. \\ r_{n1} & r_{n2} & .. & r_{nn} \end{vmatrix} > 0.00001 \quad (2)$$

where n = total number of correlation coefficients.
In this step, the data sample size was also measured using Kaiser-Meyer-Olkin (KMO) method as shown below.

$$KMO = \frac{\sum\sum_{m \neq n} r_{mn}^2}{\sum\sum_{m \neq n} r_{mn}^2 + \sum\sum_{m \neq n} a_{mn}^2} > 0.5 \quad (3)$$

where r_{mn} and a_{mn} = the simple and the partial correlation coefficients between variables m and n, respectively.

Step 3: Choosing method of factor analysis.
There are basically two ways to conduct factor analysis: "general" factor analysis and *principal components factor analysis* (PCFA). In this study, PCFA is selected because it considers the total variance in the data in determining the minimum number of factors.

Step 4: Determining the number of factors (Table-7).
The number of factors extracted by factor analysis depends on eigenvalues that represent the total variance associated with the factors. The variance that contributes to the extraction of principal components is one. Therefore, a component with an eigenvalue of less than one is less important.

Step 5: Creating factor matrix (Table-8).
After determining the number of factors, the *factor loading* was calculated. The factor loading indicates how much weight is assigned to each factor, and factors with large coefficients (in absolute values) are closely related to the variables. The relation between factors and variables was represented by the following equation.

$$X_i = b_{i1}F_1 + b_{i2}F_2 + b_{i3}F_3 + \ldots\ldots\ldots\ldots + b_{im}F_m \quad (4)$$

where X_i = the ith variable, b_{ij} = multiple regression coefficient of variable i on factor j, F_m = the factors, m = the number of factors.
The communalities was obtained by the following equation.

$$Communalities = (coeff_1)^2 + (coeff_2)^2 + (coeff_3)^2 + (coeff_4)^2 \quad (5)$$

where $coeff_i$ = the correlation coefficient between variable and factor i.
From Table-8., for example, it is known that $(0.599)^2 + (0)^2 + (-0.515)^2 + (0.411)^2 = (0.794)$ or 79% of the variance in "Capacity of Company" is accounted for.

Step 6: Rotating factors (Table-9).
The *varimax rotation* has the effect of minimizing the number of factors on which the variables have high loading.

タイ国の公共工事で用いられる資格審査要因の抽出

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本研究は、タイ国における入札時の資格審査事項に関する分析を行ったものである.例として，タイ国エネルギー供給公社(EGAT)の資格審査項目をとりあげ，インタビューと質問状による統計分析を行い，一般的な資格審査要因の抽出を行うことを試みた．与えられたデータの分析範囲内で，受注者の「能力(ability)」「容量(capacity)」「信頼性(reliability)」および「協調性(compatibility)」が，タイ国における重要な資格審査要因ではないかという結論が得られた.

タイ国においては，公共工事における資格審査システムは改良・改善していく余地が多いと考えられるが，得られた結果は，将来，公共工事の発注者がそれぞれの資格審査システムをより効果的なものに作り変えていく際の参考となるものと考えられる．また，本研究の結果は，日本など諸外国がタイ国の公共工事に参加する場合の資格要件を理解する上でも，興味のあるものと考えられる.