

Article

Selection Model of Subcontractor Relationships by Using Discriminant Analysis

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Abstract. Subcontractors usually handle some parts of special works in construction projects. The development of the subcontractor's relationship is one of the main issues to ensure the project's success. Many existing models were proposed for evaluating the subcontractor prequalification and performance, but a selection model of subcontractor relationships was still neglected for supporting the decision-making of the main contractor. Currently, main contractors use only their experience and personal preference to choose the type of subcontractor relationships. These practices can reduce the opportunities for finding a suitable subcontractor who could add more value to future explorative work. Moreover, if they mismatch the relationship type with the subcontractor, the main contractors will work with a poor-performance subcontractor. Thus, this wrong selection has hindered the benefit of a long-term relationship subcontractor. This study developed a selection model of subcontractor relationships to solve the problem. The methodology of this research collected data from the primary contractor's assessment of 15 projects, with 93 subcontractors based on factors influencing the current relationship type. Then, the selection model of subcontractor relationships was developed by using discriminant analysis. As a result, time control in planning, work quality, cooperation, and trust factors that influenced the outcome of the model development, were able to classify subcontractors into short-term or long-term relationships. The finding result was also validated and shown at an acceptable level. Therefore, the model development could support the decision-making of the main contractor in choosing the type of subcontractor relationship.

Keywords: Short-term relationship, long-term relationship, subcontractor, main contractor, discriminant analysis.

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1. Introduction

Nowadays, a complicated design is developed by the architect and requires a special skill for handling the construction works for the client. However, some main contractors still have limited capability in construction [1]. They always use subcontractors who can handle and accomplish these special works in the construction projects. Normally, the subcontractor provides the construction services like supplied manpower, equipment, tools, or designs to the main contractor. When the competition increases in the construction market, the subcontractor has become an essential partner in the main contractors' value chain [2]. As a result, possessing many good cooperative subcontractors is a success for the main contractor in sustainable development.

The subcontracted work is seen as a great method for organizing the construction activities that main contractors have decentralized their works to the subcontractors [3]. Moreover, the relationship is believed to occur during a couple of construction projects after the subcontractor has worked with the main contractor. A previous study of the subcontractor relationship has suggested that the main contractor should change from a traditional relationship to a cooperative and collaborative relationship [4]. In addition, this cooperative relationship

will lead the main contractor forward to have a long-term relationship with the subcontractor.

2. Overview of Subcontractor Relationships

The main contractor generally chooses subcontractors in two main stages namely subcontractor selection, and subcontractor relationship selection. First, the objective of subcontractor selection was occurred at the beginning of the project and aimed to choose a good subcontractor for giving the subcontracted work, so the main contractor examined each subcontractor depending on the prequalification factors [5]. Then, after working on a couple of projects, the main contractor could understand the subcontractor's performance which was influenced by time, quality, safety, and cost of the project [2]. Moreover, the relationship between the main contractor and subcontractor was greatly improved by working with the same subcontractor for a few projects. That is why the main contractor wished to have a good partner of a subcontractor who could provide significant productivity of construction in the future. Thus, decision-making for having a long-term relationship with subcontractors was initially developed for evaluating each subcontractor [6]. In summary, the development of the subcontractor relationship was shown in Fig. 1.

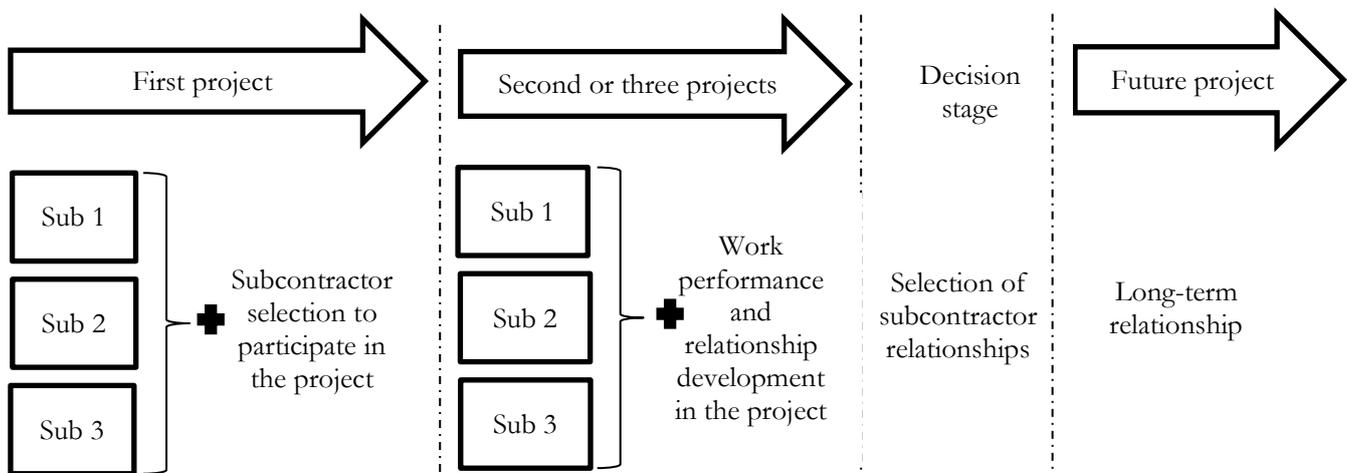


Fig. 1. Development of subcontractor relationship.

The model for selecting the type of subcontractor relationships could use for evaluating the subcontractor who worked with the main contractor for a couple of construction projects. The result of the model could allow the main contractor to classify the subcontractors into two types' namely a short-term relationship and a long-term relationship. The meaning of both key terms is explained in the following section.

First, the meaning of long-term relationship (LTR) does not only consider terms of duration but also includes collaborative activity which has a long-term orientation [7]. This long-term orientation has been defined by various authors. Kelly et al. [8] defined the long-term orientation

as the interdependence of each party that was expected to be gained the outcome in the future. A long-term relationship is a mutual commitment, in which both parties work together to increase profitability [9]. In addition, long-term relationship (LTR) was explained as consistency of organization interaction between the main contractor and subcontractor. To ensure future productivity, many main contractors should not only depend on their internal capabilities but also create a relationship network with the outside companies in the competitive market [10, 11]. Therefore, the main contractor should be able to determine the potential

subcontractor in LTR development which could obtain a lot of benefits in the future project.

Second, although having a potential subcontractor for a long-term relationship is very important in real practice, some of the subcontractors are still having poor performance and should be chosen for a short-term relationship. The meaning of a short-term relationship is described as a situation, in which the main contractor needs a subcontractor on some special occasions although the subcontractor does not have some factors such as no commitment or distrust in the subcontracted work. Moreover, the poor performance of the subcontractor could lead to a part of negative image and create a great amount of dissatisfaction with the project goals of the main contractor [12, 13].

Finally, when the main contractor is a key person to manage and coordinate many critical activities in the construction project, their roles, and perceptions for making the subcontractor relationship are important. Handfield and Nichols [14] mentioned that relationship issue is a fragile and tenuous factor. The poor relationship also leads to shortening the business in construction between other parties. Furthermore, the success of the construction project depends on main contractors who make partnerships with competent subcontractors [15, 16]. If main contractors fail to address the appropriate subcontractor relationship, they will not gain the benefits that can contribute to the organization. Therefore, the selection model of subcontractor relationship types is a concerning matter in the main contractor decision-making.

3. Current Practice for Selecting the Types of Subcontractor Relationships

Main contractors generally choose the relationship types with subcontractors depending on only their interests, and personal preferences [2]. In some main contractor companies, the executive level may use their power to designate subcontractors in their decision-making [29]. Moreover, without a selection model for determining the types of subcontractor relationships, it can reduce opportunities for the main contractor and subcontractor to engage in future explorative work [5].

Furthermore, the main contractors may work with a poor-performance subcontractor, if they mismatch the subcontractor for a long-term relationship. Therefore, this common practice can hinder the benefit of subcontractors that will be discovered in long-term relationships.

Currently, main contractors still do not have an appropriate model for determining the types of subcontractor relationships. At the early stage of the construction project, some main contractors select the subcontractor based on subjective judgment and the lowest bid price of the subcontractor. Moreover, some existing models were developed to choose suitable subcontractors to handle the work. Table 1 shows the model developments of subcontractor selection.

Second, during the construction stage, many different models could help main construction in subcontractor performance appraisal, as shown in Table 2. Those models have a high potential for improving the quality of subcontractor performance evaluation. To determine the suitable subcontractor for a long-term relationship, the main contractor will need to establish a model for choosing the relationship types of subcontractors because this model is not the same as the model for selecting subcontractors at the prior stage and evaluating the subcontractor performance during the construction stage. The proposed model does not only require the subcontractor performance factors but also combines with the subcontractor relationship factors which have been found in previous studies.

Finally, the successful level of future construction projects may depend on the main contractor's decision-making in selecting a good subcontractor to have a long-term relationship. In addition, the advantage of making a long-term relationship can reduce the time and cost of the project because the main contractor does not need to select a new subcontractor for every new project. With the correct choice of main contractors, it could sustain good construction productivity in the future. Moreover, it will be easy and convenient for the main contractor to choose a suitable type of subcontractor relationship. As a result, the research purpose of this paper aims to establish a selection model of subcontractor relationships.

Table 1. Model developments of subcontractor selection.

Authors	Proposed model
Albino and Gravelli [17]	A neural network approach
Okoroh and Torrance [18]	A knowledge-based expert system using fuzzy logic
Tserng and Lin [19]	An accelerated subcontracting and procuring (ASAP)
Luu and Sher [20]	A case-based reasoning procurement advisory system
Ko et al. [21]	A subcontractor performance evaluation model (SPEM)
Arslan et al. [22]	A web-based subcontractor evaluation system (WEBSSES)
El-Mashaleh et al. [23]	A data Envelopment Analysis (DEA)

Table 2. List of proposed methods for subcontractor performance appraisal.

Authors	Proposed model
Balakrishnan [24]	A simple system for evaluation
Wang [25]	Factor-based path analysis
Chung and Ng [26]	A generic procedure for subcontractor appraisal
NG [27]	Balanced Scorecard approach
Nassar [28]	Analytical hierarchy process (AHP)

4. Research Methodology

Based on the main objective of this research, a selection model of subcontractor relationships was developed into two main parts. First, the main contractors were asked their opinion about critical factors that should be used to evaluate subcontractors for selecting the types of relationships. Due to the finding result of the relative important index (RII), ten influencing factors out of 20 factors were discovered as the key factors for choosing the types of subcontractor relationships. Those factors were commitment, cooperation, monitoring, work experience, resources, work quality, coordination, trust, honesty, and time control in planning. The detailed information of the first part result was presented in the paper elsewhere. This paper only presented the second part of model development.

In the second part, the ten factors were considered as the inputs which were used for developing a model for selecting the types of subcontractor relationships. These factors were designed as a questionnaire and conducted by interviewing the main contractor companies in Cambodia building construction such as apartments, hotels shopping malls, office buildings, and hospitals. Next, the discriminant analysis was selected to develop a selection model of subcontractor relationships.

4.1. Questionnaire Design

From the result of the first part, the questionnaire was developed by 10 influencing factors of subcontractor relationships. Based on these factors, the main contractors were asked to evaluate their subcontractors in relationship development. The scale applied to these questions was the Likert scale and it was ranked from 5 to 1 (5= Very agree, 4= Agree, 3= Neutral, 2= Disagree, 1= Very disagree). Table 3 shows an example of the questionnaire design. The data collection was conducted by using an interview with project managers and directors of main contractor companies who were responsible for selecting the subcontractor in the construction project. Each project manager and director were asked to choose the types of current relationships with their subcontractors. Moreover, those subcontractors were responding to the subcontracted works such as earthworks, structural works, finishing works, and MEP work. Based on the interview with 11 project managers and 4 directors of 15 projects, 93 subcontractors were collected. Then, this paper presented the development process of the proposed model with discriminant analysis.

Table 3. Example of questions that were used to evaluate the subcontractor.

Factors	Very agree	Agree	Neutral	Disagree	Very disagree
<i>1. Work Quality</i> Does the subcontractor have performed a good quality of work?					
<i>2. Time control in planning</i> Do you agree that the subcontractor has properly controlled the time as in project planning?					
<i>3. Work experience</i> Do you agree that the subcontractor has enough experience to become a long-term subcontractor?					
<i>4. Honesty</i> Do you agree that a subcontractor is an honest person for working in a long run?					

4.2. The Procedure of Discriminant Analysis

To develop a selection model, six main stages of the discriminant procedure are needed to determine in this study. The detailed information about each stage was explained in the following section.

1. **Objective of discriminant analysis:** The main contractor was interested to see the types of subcontractor relationships whether short-term or long-term relationship. The inquiry followed the obvious need by main contractor management to strive for a better understanding of decision making.
2. **Research design for discriminate analysis:** The independent variables were known as 10 important factors of subcontractor relationship which were perceived by main contractor opinion. In addition, the dependent variables were grouped into short-term and long-term relationships. The research would use the rating score on each independent variable of subcontractor evaluation.
3. **Sample size:** The total sample was divided into one half for an analyzing sample and the other half was used for a testing sample. Some authors suggested using an 85-15 or 60-40 split [30]. Based on 93 sampling data, 79 sampling data were used to develop a discriminant function. 14 sampling data were applied for testing the discriminant function.
4. **Assumption of discriminant analysis:** In discriminant analysis, the assumption used Box's M test to evaluate the significant differences between dependent variables [31].
5. **Determination of discriminant function:** The stepwise method is used to determine the function with a large number of independent variables. The stepwise approach defined the discriminant function by following a sequential process of adding or deleting variables.
6. **Validation of the discriminant results:** This stage involved the validation of the discriminant result. This process assured that the result had validity both internal and external. There were two validities of discriminant analysis such as internal and external. Internal validity was known as a testing sample. It was established to assess whether the discriminant function passed the acceptable level or not and it was not used in the determination process.

5. Result of a Model Development

Four variables (X_{10} , X_4 , X_1 , and X_2) were identified as significant discriminators based on their Wilks' lambda and minimum Mahalanobis D^2 values. Moreover, the discriminant function for classifying the type of subcontractor relationships was obtained by using the unstandardized discriminant coefficients and presented in Eq. (1). The overall model fit was reported under the heading of canonical discriminant functions and showed that the discriminant function is highly significant (0.000) with a canonical correlation of 0.847. Table 4 provided the overall result of the discriminant analysis.

$$\text{Discriminant function (Z)} = -10.263 + 0.773X_1 + 0.346X_2 + 0.882X_4 + 0.896X_{10} \quad (1)$$

The group centroid for short-term relationships (group 1) was -2.008 whereas the group centroid for long-term relationships (group 2) was 1.229. The determination of the cutting score was used to compare with the evaluation of each subcontractor in the particular group whether a short-term or long-term relationship. So, the cutting score became a weighted average of the two group centroids score and was calculated in the following Eq. (2).

The result of the cutting score was obtained at around -0.3895. As a result, classifying a subcontractor into a short-term relationship (group 1) when its discriminant score was less than -0.3895. Then, classifying a subcontractor into a long-term relationship (group 2) when its discriminant score was greater than -0.3895. Moreover, we also compared the classification between actual and predicted group membership values of the analysis and validation sample.

$$Z_{CE} = (Z_A + Z_B)/2 = (1.229 - 2.008)/2 = -0.3895 \quad (2)$$

Through discriminant analysis, the classification accuracy of the model was estimated at 98.7 percent from predictive accuracy and 83.75% for holdout samples. This implied that the percent of correct classification was 98.7%, which denoted a reasonable association between the independent variables and the dependent variables. Table 5 shows the result of the classifications, and Table 6 contains the discriminant scores for each observation as well as the actual and predicted group membership values.

Table 4. Summary of Canonical Discriminant Functions.

Overall Model Fit: Canonical Discriminant Functions				
Function	Eigenvalue	Percent of Variance		Canonical Correlation
		Function %	Cumulative %	
1	2.533	100.0	100.0	0.847

Overall Model Fit: Canonical Discriminant Functions			
Independent Variables		Discriminant Function	
		Unstandardized	Standardized
X ₁	Work quality	0.773	0.492
X ₂	Time control in planning	0.346	0.273
X ₄	Cooperation	0.882	0.642
X ₁₀	Trust	0.896	0.647
	Constant	-10.263	

Group Means (Centroids) of Discriminant Functions	
Category	Functions
Short-term relationship	-2.008
Long-term relationship	1.229

Table 5. Classification Results

Category			Predicted Group Membership		Total
			1. Short-term relationship	2. Long-term relationship	
Estimation Sample	Count	1. Short-term relationship	30	0	30
		2. Long-term relationship	1	48	49
	%	1. Short-term relationship	100	0	100.0
		2. Long-term relationship	2.04	97.96	100.0
Cross-validated	Count	1. Short-term relationship	30	0	30
		2. Long-term relationship	1	48	49
	%	1. Short-term relationship	100	0	100.0
		2. Long-term relationship	2.04	97.96	100.0
Holdout Sample	Count	1. Short-term relationship	6	0	6
		2. Long-term relationship	0	8	8
	%	1. Short-term relationship	100	0	100.0
		2. Long-term relationship	0	100	100.0

- 98.7% of selected original grouped cases (estimation sample) correctly classified.
- 85.7% of selected cross-validated grouped cases correctly classified.
- 100% of handout grouped cases correctly classified

Table 6. Predictions for Individual Cases in the Two-Group Discriminant Analysis.

ID	Actual Group	Discriminant Z Score	Predicted Group	ID	Actual Group	Discriminant Z Score	Predicted Group
Analysis Sample							
1	2	0.429	2	21	2	3.449	2
5	2	1.216	2	22	2	1.671	2
13	2	0.979	2	25	1	-0.799	1
19	2	0.443	2	26	1	-1.695	1
33	2	0.552	2	24	2	0.979	2
34	2	1.434	2	28	1	-0.69	1
62	2	2.676	2	27	2	1.325	2
84	2	3.876	2	30	2	0.552	2
91	1	-1.695	1	31	2	-0.263	2
2	1	-1.226	1	32	2	2.221	2
3	1	-1.226	1	36	2	1.311	2
4	2	2.567	2	38	1	-3.241	1
6	2	0.761	2	39	1	-1.226	1
7	2	0.633	2	37	2	1.671	2
8	2	0.443	2	40	2	0.415	2
9	2	1.202	2	42	1	-2.814	1
10	2	2.098	2	43	1	-3.696	1
12	2	0.32	2	45	1	-3.35	1
15	2	0.566	2	41	2	2.553	2
16	2	1.875	2	46	2	0.443	2
18	2	3.103	2	47	2	0.789	2
20	2	2.567	2	48	2	2.98	2
50	1	-0.799	1	74	1	-1.226	1
51	1	-2.454	1	75	1	-0.989	1
49	2	-0.107	2	72	2	2.084	2
52	2	0.789	2	77	2	-0.121	2
55	1	-0.799	1	78	2	1.216	2
53	2	0.083	2	80	1	-2.8	1
58	1	-2.245	1	81	1	-2.013	1
60	1	-2.454	1	82	1	-1.681	1
61	1	-3.241	1	83	1	-1.586	1
57	2	1.671	2	79	2	-0.093	2
66	2	-0.567	1	85	1	-0.813	1
67	1	-3.004	1	87	1	-3.004	1
68	1	-2.8	1	88	1	-2.345	1
63	2	0.979	2	86	2	2.553	2
69	2	0.192	2	89	2	1.434	2
70	2	0.083	2	92	1	-1.572	1
71	2	1.325	2	90	2	0.775	2
73	1	-2.814	1				
Hold out samples							
14	1	-1.022	1	56	2	1.875	2
11	2	0.538	2	76	2	1.202	2
17	2	2.33	2	93	2	2.084	2
23	2	0.443	2	29	1	-1.226	1
35	2	0.552	2	44	1	-1.226	1
59	1	-1.24	1	54	1	-0.799	1
65	1	-0.989	1	64	2	2.098	2

5.1 Result of Model Validation

Although all of the measures of classification accuracy are seemed to be high, the evaluation still process requires a comparison to the classification by chance. This classification by chance does not need discriminant function and uses to understand the improvement of the discriminant model. Because the overall sample is still small around 93 for estimation and hold out samples, we will use the overall sample to establish the comparison standards.

Our research study, which has 36 and 57 of the group size 1 and 2 in the whole sample size, is unequal group sizes, the researcher has to determine the maximum chance factor and proportional chance factor. First, the proportional chance factor assumes that the costs of misclassification are equal. The proportional chance factor is shown in Eq. (3).

$$\text{CPRO} = p^2 + (1-p)^2 \quad (3)$$

where CPRO = proportional chance factor;
P = proportion of firms in group A;
1-P = proportion of firms in group B.

The group size 1 of short-term relationship constitutes 38.7 percent of the analysis sample (36/93) and group size 2 of long-term is the remained 61.3 percent (57/93). we could see the proportional chance value was $0.525 ((0.613)^2 + (1-0.613)^2 = 0.525)$.

Next, with the greatest probability of occurrence in the group for all observation, the percentage correctly classified is determined by the maximum chance factor. It reflects our most conservative standard and assumes no difference in the cost of misclassification as well. Because group 2 (long-term relationship) is the largest group at 61.3 percent of the sample, our model would be accurate classification if the value is greater than 61.3 percent and it was acceptable too, so we choose the maximum chance criterion as the standard of evaluation.

To attempt to assure practical significance, the achieved classification accuracy must exceed the selected comparison standard by 25 percent. Thus, we must select a comparison standard, calculate the threshold, and compare the achieved hit ratio. All of the classification, which were included analysis sample (98.7 percent), holdout sample (100 percent), and cross-validation (85.7 percent), were higher than the proportional chance criterion of 52.5 percent and the maximum chance criterion of 61.3 percent. Thus, all three hit ratios also exceeded the suggested threshold of these values (comparison standard plus 25 percent), which in this case were 65.625 percent ($52.5\% \times 1.25 = 65.625\%$) for the proportional chance and 76.625 percent ($61.3\% \times 1.25 = 76.625\%$) for the maximum chance. Therefore, all levels of classification including analysis sample, holdout sample, and cross-validation indicated an acceptable and accuracy.

Last, the analysis was needed to measure the classification accuracy of Press's Q which depended on a random process in Eq. (4).

$$\text{Press's Q} = \frac{[N - (nk)]^2}{N(K - 1)} \quad (4)$$

where N = Total sample size;
n = Number of observations correctly classified in Table 6;
K = number of groups

From the result of Eq. (5) and (6), we could get both values of Press's Q exceeding the critical value of 6.63. Therefore, the classification accuracy for the analysis and holdout sample was passed the classification accuracy expected by chance.

For the analysis sample, we could calculate Press's Q is:

$$\text{Press's Q analysis sample} = \frac{[79 - (78 \times 2)]^2}{79(2-1)} = 75.05 \quad (5)$$

For the holdout sample, we could calculate Press's Q is:

$$\text{Press's Q holdout sample} = \frac{[14 - (14 \times 2)]^2}{14(2-1)} = 14 \quad (6)$$

Finally, four main variables were effectively used to develop the discriminant function.

6. Results and Discussions

In the model development, four main factors were confirmed by data analysis. These factors were trust, cooperation, work quality, and time control in planning. This finding gave more understanding of the factors which the main contractor used to select the types of subcontractor relationships. The meaning of these factors was explained in the following section.

First, trust was analyzed as the most essential factor in selecting subcontractor relationships (unstandardized weight = 0.896). The main contractor normally looks to find a subcontractor who was a trusted person for giving the work and became a good partner in the future. Moreover, some of the respondents (C₄ and C₁₄) have mentioned that trust creates a long-term relationship, they were not afraid that subcontractors may run away from them and cause more troubles in construction with their irresponsibility. This trust factor could be influenced not only by subcontractor performance toward the main contractor but also main contractor's behavior toward the subcontractor. Moreover, trust was found as one of the main factors that should implement to achieve a strategic relationship in the future. When both parties had mutual trust in each other, it could help to quickly solve the problem and create credible signals of a long-term

relationship [32]. Therefore, the trust factor may contribute by both the main contractor and subcontractor.

Second, cooperation was listed in the second rank and many respondents agreed that this factor was important in selecting subcontractor relationships. Eighty percent of respondents required a subcontractor who was willing to join or participate in the work requirement. Respondent C₉ shared his experience of this factor when he was working with a project owner on one project and that the project owner had higher work requirements. So, every time that guy saw the progress of work, he kept insisting to see the finishing result of some parts in that project works like structural and floor finishing works. Then, during that time, Respondent C₉ could understand his subcontractors well by seeing their cooperation in the work like adding some more workers and working overtime without complaint. Thus, in his opinion, this cooperation factor would influence his perception of selecting a subcontractor for a long-term partner. Other respondents like C₁₄ and C₂₂ mentioned that the cooperative work of subcontractors in construction could bond the relationship between them and subcontractors and they also could measure the reliability of those subcontractors. Furthermore, the results agreed with Mudzvokorwa and his research teams who found that project teams should cooperate and communicate to all concerned parties, whenever there was an imminent problem related to their work [33]. Therefore, the subcontractor who tried to participate and helped the main contractor as cooperate for finishing the project successfully would be noticed in the future project.

Third, work quality was analyzed as the third rank and given significant consideration for the main contractor in selecting subcontractor relationships. Moreover, the most of respondents were agree that if a subcontractor could produce a high or acceptable quality of work, they would consider giving the work to the subcontractor in the next project or not. Thus, the main contractor also needed to check the quality of subcontractor work which had to match the standard requirement. From the result, some of the respondents especially project managers placed this factor as the most important factor for selecting a subcontractor relationship because it would reflect their achievement of work for the company and they were afraid that if the project owner did not satisfy with their work quality, it would affect their reputation in the contractor company. In addition, the contractor company could lose its reputation in the competitive market. So, they would like to select the subcontractor who had a good performance in the work quality of construction [34]. Last, this factor was not only satisfying the main contractor but also fulfilling the client's needs as mentioned in the contract.

Fourth, time control in planning was the fourth factor in selecting the types of subcontractor relationships. Most of the main contractors considered timing as money, so they were concerned with the time management in the project after giving the work to the subcontractor. Moreover, time planning was one of the key factors in

construction management for the main contractor company. Many main contractors agreed to work with a subcontractor who could finish the work on time. Most main contractors mentioned that if subcontractors had a poor time planning for construction work, it would severely cost them because they would be fined by the owner and also needed to spend more budgets on the unfinished work. Moreover, the contractors should also consider the planning work of the subcontractor carefully to avoid problems of project delay and a financial crisis during a project [33]. Therefore, the main contractor would like to work with any subcontractors who had effective time planning and could finish the given work faster with the quality standard too.

Although, other six factors including experience, resource, commitment, honesty, monitoring, and coordination has been highlighted by previous researchers, these factors did not include in the decision model for selecting between short-term and long-term relationship strategy. From the statistical result of discriminant analysis, these four factors could have enough power in decision making to define the subcontractor in short-term or long-term relationship. From the practical implementation, the model requires data on the subcontractor's characteristics only four main factors for deciding the type of relationship.

The reason is that some influences on relationship development between subcontractor and main contractor. they could use to support the subcontractor management in the future. Therefore, to ease the contractor decision, result of these four factors could have enough power in decision making to define the subcontractor in short-term or long-term relationship.

After evaluating the type of the subcontractor relationship, this model also could use to understand the strengths and weaknesses of each subcontractor area that needed to improve for working with the main contractors in the future. From the result of the data set, we could explain that:

- Subcontractor number 84 was evaluated in this model and got the value $(5 \times .773) + (4 \times .346) + (5 \times .882) + (5 \times .896) - 10.263 = 3.876 > -0.3895$ so it shown that this subcontractor could go for long-term relationship. Among these four factors, three of them got the maximum score equal to 5, and only time control in planning got 4 scores so it meant that this subcontractor was still poor in time control for planning a little bit while the other factors were good performance.
- Subcontractor number 31 was evaluated in this model and got the value $(4 \times .773) + (2 \times .346) + (4 \times .882) + (3 \times .896) - 10.263 = -0.263 > -0.3895$ so this subcontractor was capable to go for long-term relationship with main contractor too. Among these four factors, time control in planning was a poor factor in this subcontractor and trust was also at a medium level. However, work quality and cooperation had a better performance which could satisfy the main contractor.

- Subcontractor number 43 was evaluated in this model and got the value $(3 \times .773) + (2 \times .346) + (2 \times .882) + (2 \times .896) - 10.263 = -3.696 < -0.3895$ so it meant that this subcontractor was in short-term relationship whereas three of four factors got poor score=2 and only work quality, which got 3 scores, were accepted in medium level by main contractor. Thus, this subcontractor should improve more in their work with main contractors like time control in planning, cooperation, and trust.
- Subcontractor number 50 was evaluated in this model and got the value $(4 \times .773) + (3 \times .346) + (3 \times .882) + (3 \times .896) - 10.263 = -0.799 < -0.3895$ so it meant that this subcontractor was chosen as short-term relationship, which there were three of four factors, got medium score=3 and only work quality got a better score= 4. To increase the work productivity, the main contractor encouraged subcontractors to look at their previous performance which required not only work quality but also other three factors like time control in planning, cooperation, and trust. Therefore, it would satisfy the main contractor for having a long-term relationship with the subcontractor.

7. Conclusions

Possessing a good subcontractor for the long run is a great success for the main contractor in the construction business, so this research is interested to find out how to select the type of subcontractor relationships. The main elements of this model found 4 main variables namely time control in planning, trust, work quality, and cooperation. As a result, the discriminate analysis provided the accuracy percentage of estimating sample is 98.7 % whereas the accuracy percentage in the holdout sample is 100 %. Thus, this method has given a high level of accuracy that could support the decision-making of the main contractor in choosing the type of subcontractor relationships. In addition, the main contractor has an alternative tool to help the strategic decision on relationship rather than the user personal subjective.

After developing this model, it would be useful not only for the main contractor who wishes to have a long-term relationship subcontractor but also could provide feedback to some subcontractors who pass a short-term relationship that they need to improve their weakness areas for becoming a good subcontractor in a long-term relationship. Last, the result of this study will compare the accuracy level between discriminant analysis and neural networks in a future study [35]. Thus, we could determine the optimal method which has a lower error than another as a model for choosing the type of subcontractor relationship.

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