DISCRIMINANT ANALYSIS MODEL FOR PREDICTING CONTRACTOR PERFORMANCE IN HONG KONG

by

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DEDICATION

To my beloved wife ALICE CHEUNG, brothers and mother,

who gave me inspiration and support

****

DECLARATION

No portion of the research referred to in this thesis has been submitted in support of an application for another degree or qualification at this or any other university or other institution of learning.

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ABSTRACT

This thesis describes the development of an operational research model for the identification of determinating variables and prediction of contractor performance in Hong Kong. The mathematical technique used is the Discriminant Analysis approach.

The model is also verified with two other analyses namely Multiple Regression Analysis and Unidimensional Scaling Analysis. One of the aims of the research is to betray the underlying factors that influence contractor performance which are measured in the clients' point of view. The second aim is to develop an accurate model for predicting contractor performance used by clients in vetting contractors.

All aspects of the model's development are described, including the quantification of the variables, data collection, analysis of the model results, verification of the model results with other models and testing the model using independent data. Further, the variables adopted in the model are compared with the actual practices in Hong Kong.

The predictive model produced by the study is made up of six variables measuring the three dimensions namely the inherent characteristics of the project, the contractor's internal attributes and the external influence of the project team,

including the complexity of the project, the working experience of the project leaders, the percentage of professionally qualified staff in the company, the past performance of the contractor, the origin of the company and the architect's or client's supervision and control on the quality of work and work progress.

However, the developed models should only be used as part of an assessment process and with caution as there are other unpredictable factors which are not able to quantify and include in the model such as the changing of the company structure and strategy, change in management quality, profitability and the happening of overtrading. Nevertheless, the use of the model to exclude companies from tender lists could accelerate the contractor selection process and spare more time for clients to concentrate on more important issues.

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CHAPTER 1

GENERAL INTRODUCTION

1.1 INTRODUCTION

In Hong Kong, most of the new construction works are let in the form of competitive tendering. Construction clients commonly try to gauge a contractor's potential performance on a past record of finishing on time, to cost and with good quality of work before inviting bids. However, the tendering method can only measure a portion of the cost component as contractors often succeed in obtaining claims for extras. Unfortunately, the other two components, time (completion on time) and quality of work, are even more difficult to assess at the tendering stage. While careful pre-selection may help in judgement, decision making is subjective and often not accurate.

One of the largest housing developers in Hong Kong openly criticised the performance of contractors explaining that it is difficult to rely solely on the present selective tendering process in evaluating contractors' performance and other methods need to be devised to include as much quantitative and objective factors as possible. These aspects form the basis of the research described in this thesis where a quantitative model has been developed.

1.2 AIM AND OBJECTIVES

1.2.1 AIM

The primary aim of this research is to develop a quantitative model able to assess and predict contractor performance in the process of bid evaluation.

1.2.2 OBJECTIVES

1.2.2.1 To develop a formalised and structured approach in the prequalification of contractors.

1.2.2.2 To quantify the subjective elements in performance assessment.

1.2.2.3 To investigate the reasons that ascribe contractor performance.

1.2.2.4 To draw clients' attention to the attributes that can improve contractor performance.

1.3 METHODOLOGY

The mathematical technique of Discriminant Analysis was adopted in the research to evaluate the performance of contractors.

Multiple Regression Analysis and Unidimensional Scaling techniques were used to verify and compare the results.

Because of the complexities of calculation involved, it was impractical to achieve this manually. Therefore the package called 'Statistical Packages for Social Science' (SPSSpc) was used for computation.

The project information was obtained through interviews with the client and the contractor representatives.

1.4 BACKGROUND INFORMATION ON THE CONSTRUCTION INDUSTRY OF HONG KONG

Before going further, it is worth at this stage to introduce the characteristics of the construction industry in Hong Kong:

Hong Kong has become a major financial and industrial centre in the Far East despite its size. Its significance has been strengthened by its strategic location on China's south-eastern coastline, and lies on the edge of the economically important Pacific Basin. Located at the mouth of the Pearl River, Hong Kong is just inside the tropics. It has a total area of 1064 sq. kilometres.

The Territory is covered with mountains and hills which account for 80% of the whole territory. So far only 16% of the total land is built up and this is mainly concentrated on the relatively flat and low-lying parts of Hong Kong Island and the Kowloon Peninsula.[5]

The population reached six millions in 1991 (source from the Census and Statistics Department of Hong Kong). Thus most buildings are high rise structures in order to house the population.

1.4.1 IMPORTANCE OF THE INDUSTRY IN THE ECONOMY

The importance of the construction industry in Hong Kong's economy is demonstrated by the statistics given in Table 1.

The percentage of the construction industry as a percentage of the Gross Domestic Product is expected to rise in the coming few years as Hong Kong has geared up to start an estimated HK$140 billions worth of the Port and Airport Development project.

1.4.2 LEVELS OF EXPENDITURE IN THE PRIVATE SECTORS OF CONSTRUCTION WORKS

The distribution of private and public work sectors are shown in Table 2.

1.4.3 CHANGE IN PRODUCTIVITY OF THE INDUSTRY

Table 1 Construction as a Proportion of Gross Domestic Product

Building & Construction as a Percentage of the total G.D.P.%											
1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
10.5	12.5	12.5	11.7	12.1	11.9	13.2	12.4	10.6	9.8	8.8	8.2

(Source: Census & Statistics Department of Hong Kong)

Table 2 Value of Work Completed at constant Prices at year 1980
(Source: Census & Statistics Department of Hong Kong)

Building & Construction Expenditure 1976-1986 (in HK$ Billion)												
At Constant 1980 Price	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Private	5.7	7.4	7.4	8.3	10.5	11.5	11.9	11.6	11.1	11.4	11.6	12.3
Public	3.7	5.2	6.4	6.1	6.1	6.4	8.5	8.8	8.0	6.2	6.0	6.5
Total	9.4	12.6	13.8	14.4	16.6	17.8	20.4	20.4	19.1	17.6	17.6	18.7
Change %	+13	+34	+10	+4	+15	+8	+14	0	-6	-8	0	+7
Public %	39	41	46	42	37	36	42	43	42	35	34	35

Table 3 shows the number of workers, value of construction works and the average output per worker from 1976- 1989.

Over the thirteen years, the productivity of the industry has increased by 44% due to the use of machines and the highly prefabricated construction methods such as steel frame and curtain walling.

1.4.4 THE LABOUR RECRUITMENT OF THE INDUSTRY

In Hong Kong, the labour recruitment of the industry is overwhelmed with labour-only subcontractors. Main contractors normally maintain a small pool of direct labour on sites to carry out the miscellaneous works such as small amount of re-work, cleaning, setting out, and etc. The rest normally are subletted.

However, as the labour shortage became more severe in the recent years, a few construction firms have turned to directly employed labour because of the difficulties in managing labour-only subcontractors. However, the scale is still very small. Nevertheless, as the Hong Kong government starts to import labour, the use of directly employed labour will inevitably be augmented.

1.4.5 PROCUREMENT METHOD

The procurement method used in Hong Kong is still very traditional. The use of selective tendering dominates the market.

Table 3 Change in Productivity in the Construction Industry from 1976- 1989
(Source: Construction Industry Training Authority of Hong Kong)

Number of workers on construction sites													
1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
48,761	63,010	74,734	85,959	90,498	88,877	82,055	70,611	68,603	66,313	70,808	72,486	76,340	70,503
Value of construction works (HK$ Billion)													
At current prices													
4,689	6,876	8,363	12,339	16,623	19,937	24,787	25,112	24,414	22,970	24,403	30,362	37,352	45,573
At constant prices (1980)													
9,415	12,593	13,838	14,447	16,623	17,880	20,417	20,373	19,110	17,634	17,600	18,633	18,775	19,749
Average output per worker (at constant 1980 price)													
193,085	199,857	185,163	168,068	183,684	201,177	248,821	288,524	278,559	265,921	248,559	257,078	245,939	280,116
Changes in output %													
-	+3.5	-7.4	-9.2	+9.3	+9.5	+23.7	+16	-3.5	-4.5	-6.5	+3.4	-4.3	+13.9
Cummulative changes %													
-	+3.5	-3.9	-13.1	-3.8	+5.7	+29.4	+45.4	+41.9	+37.4	+30.9	+34.3	+30	+44

There have been only a few records of management contracting or design and build contracts and they were normally confined to the very large projects.

1.4.6 FOREIGN CONTRACTORS

The construction of the Mass Transit Railway system in 1976 introduced overseas contractors, which were mainly British, Japanese and French, to Hong Kong. The booming conditions in the early 1980's drew other foreign contractors such as Korean, Mainland Chinese, Australian, and Italian. At the start, such firms mainly concentrated on the civil engineering sector which is machine and technique intensive and comprises mostly directly employed labour. Furthermore, the less complicated management of subcontracts and labour together with relatively little services coordination and small amount of trades contractors involved avoids the need to involve local practice. As these firms entered into the building industry, however the increased complexity of the process of this type of work has tended to affect their performance.

Table 4 shows the number of overseas contractors eligible to tender for public works.[6]

1.4.7 FEATURES OF CONTRACTORS[4]

Most construction companies in the developing countries are sole ownerships, and Hong Kong is not exceptional.

Table 4 <u>The number of overseas contractors eligible to tender for public works</u>

	Year						
	1980	1981	1982	1983	1984	1985	1986
Japan	11	12	12	15	15	16	18
South Korea	3	4	5	6	7	9	10
China	-	2	3	3	4	4	6
United Kingdom	1	6	8	9	10	9	8
France	2	4	4	4	5	7	8
Australia	2	2	2	2	3	2	1
Italy	3	3	3	3	3	3	4
Other	3	4	11	11	19	21	21
Total	25	37	48	53	66	71	76

In the last decade, contractors were unable or unwilling to employ qualified personnel. Their proprietors were also reluctant to delegate responsibility to others, especially where this involved monetary transactions such as the purchase of materials.

Also, owing to their cultural background and the setting of their operations, proprietors of contracting firms had a paternalistic and highly personal management style. Goodwill was important in business relationships. Winning contracts, obtaining materials, arranging for credit from banks and receiving interim payments from clients were rarely straight forward business transactions.

However as the scale of the economy has enlarged and the emergence of large overseas contractors, Hong Kong is experiencing changes from the traditional way of business to a new system. For example, contractors are having to manage their firms more professionally by delegating some reponsibilities, and seeking technical and managerial training or employing qualified personnel. They have begun to realise that contractual rights and relationships with clients have changed from a faithful to confrontational attitude.

1.4.8 SUMMARY

The above description outlines the past and existing market and industry conditions in Hong Kong. These provide some contextual information to the study which are considered vital to understand the background of the research.

CHAPTER 2

REVIEW OF PREVIOUS STUDIES

2.1 INTRODUCTION

In the past, research on the performance of contractors has tended to concentrate on the contractors' business point of view; i.e. the assessment of the productivity, the financial performance, profitability and etc.[2,3,4] with little work done relevant to clients' concerns relating to time, cost and quality.

2.2 PREVIOUS STUDIES

2.2.1 MUSTAFA AND RYAN'S WORK[7]

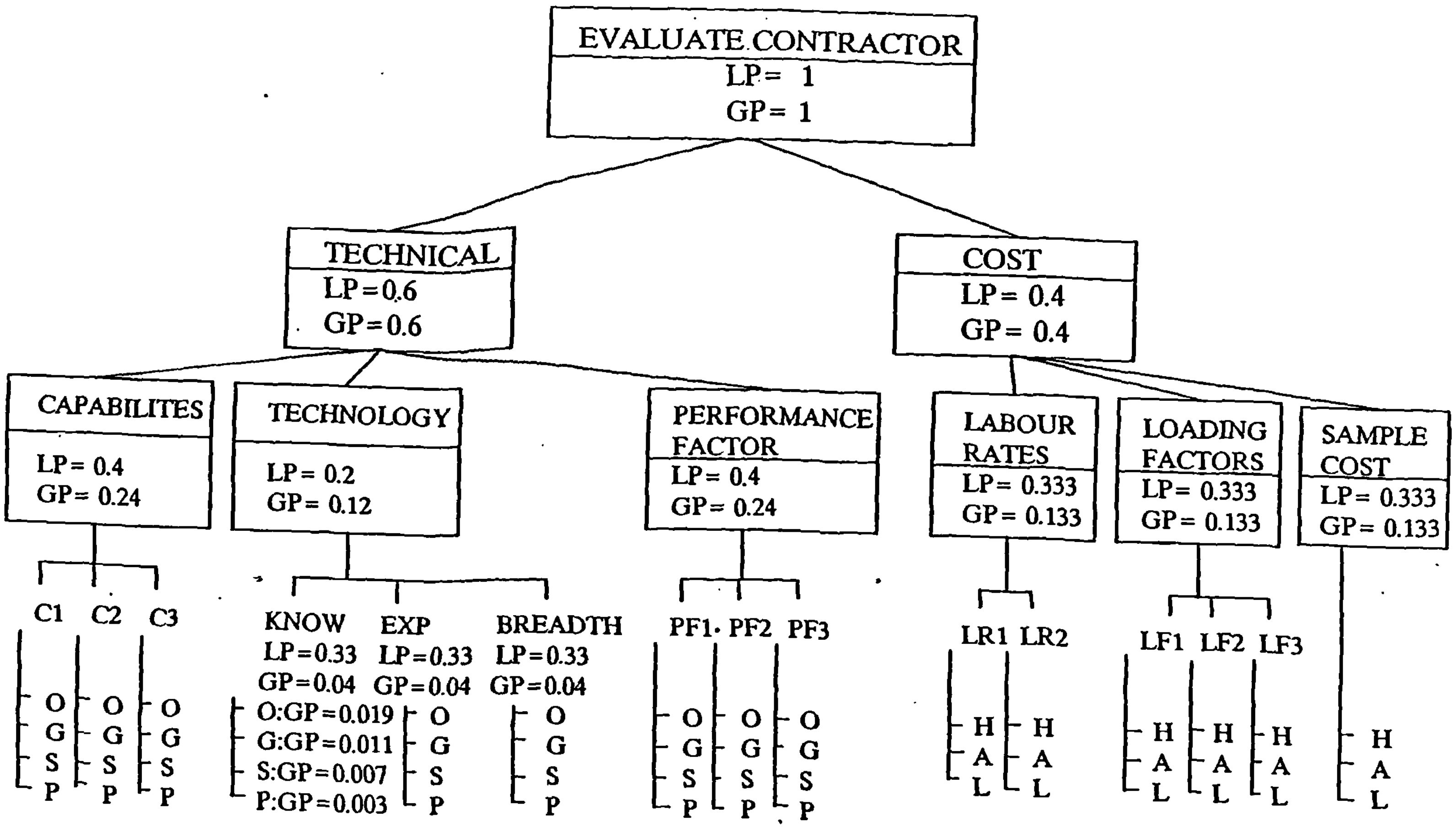
The research concerned the process of evaluating bids characterised by the existence of multiple criterion; some of which were found to be qualitative. They concluded that existing methods used in bid evaluation all have their limitations[7] in so far as most solicitation documents stipulate that the work shall be awarded to the responsible contractor who submits the lowest responsive bid. 'Responsible' and 'responsive' summarise the criteria used in the selection of the contractor, implying that it is not enough to be the lowest bidder for the contractor to be selected.

In their work, it mentioned that the bid evaluation was characterised by multiple quantitative and qualitative criteria. The price of the bid was only one criterion in the evaluation process, and the expected performance was the second. The latter criterion was influenced by many subjective and objective factors.

Mustafa and Ryan et al suggested a number of attributes which they thought would affect the performance namely:

- specific experience suitable for undertaking the work;
- safety record;
- attitudes towards correcting faulty or incomplete work;
- compliance with specification, and contractual requirements in previous work;
- management capability to plan, schedule and execute the work in a timely manner;
- availability of facilities: the availability and application of special equipment and facilities;
- availability of in-house skilled labour;
- financial stability;
- number of years of experience in the related industry;
- reputation and position in the market; and
- quality of products, records.

Their work involved the evaluation of bids by a systematic approach called 'Analytic Hierarchy Process' (AHP) which is very similar to the concept of tree diagram.



0- OUTSTANDING
G- GOOD
S- SATISFACTORY
P- POOR

H- HIGH
A- AVERAGE
L- LOW

LP- LOCAL PRIORTY
GP- GLOBAL PRIORTY

KNOW: KNOWLEDGE
EXP: EXPERIENCE
BREADTH: BREADTH

FIGURE 1 ANALYTIC HIERARCHY PROCESS IN BID EVALUATION

AHP enables decision makers to structure a complex problem in the form of a hierarchy. Each factor and alternative can be identified and evaluated with respect to other related factors. The model is illustrated in Figure 1.

In general, AHP involves the following steps[21]:

2.2.1.1 Breaking down the decision into a hierarchy of decision elements. (In Figure 1, the decision elements are Capabilities:- engineering support, cost-benefit analysis, risk analysis; Technology:- konwledge and understanding of the technology, experience base in specific technologies, breadth or number of technologies in which expertise is stated in the offer; Predictive Performance; Labour Rate; Loading Factors of the Tender; Cost of a Sample Task; and etc.)

2.2.1.2 Allocating relative weights to each element according to the client's and project's requirements.

2.2.1.3 Aggregating the relative weights of the decision elements in order to obtain a numerical outcome; for example, Contractor A may get 0.8 score and Contractor B scores 0.75, C scores 0.5 and thus the contract should be awarded to Contractor A.

This model has the shortfall that the weightings assigned are arbitrary and thus by and large is quite subjective.

2.2.2 NGUYEN'S WORK[8]

Nguyen V. et al also agreed that besides the cost criterion, evaluating tenders usually required two other general criteria based on the contractor's previous experience and the predictive judgement on the contractor's likely performance for the present job.[8]

They further suggested another set of factors thought to affect the contractor's performance, namely:

- technical competence and managerial expertise;
- compliance with specifications in previous undertakings;
- attitude towards correcting faulty or incomplete work;
- safety records;
- ability to meet work schedules; and
- attitude towards claims and counter-claims.

Nguyen suggested the use of fuzzy sets to consider the bid evaluation taking into account 3 main criteria; i.e. cost, past performance, and predictive performance. The method can be illustrated with the following example.

2.2.2.1 EXAMPLE[8]

Suppose there are five tenderers (x_1, x_2, x_3, x_4,x_5) and $\{y_1, y_2, y_3\}$ are the criteria of cost, past performance and predictive performance of equal importance.

In the tender evaluation process, the client holds meetings with partners or associates to exchange individual assessments and opinions on various tenderers. Each partner or interest group presents a rating table for all factors considered on every tenderer. Suppose equal importance, or weights, among the partners or interest groups is used, the aggregation method would then be:

A rating given to tenderer i on account of a criterion j is a binary grade of membership u_{ij}. Aggregation and averaging of k rating values of u_{ij} given by k different decision makers will give the y_2 and y_3 values for contractors x_1 to x_5 in Table 5.

For the cost criterion, the rating can be scaled from a threshold as follows:

Suppose the tenders submitted are:

x_1— \$316,989;

x_2— \$229,311;

x_3— \$244,946;

x_4— \$276,350; and

x_5— \$222,220;

and the panel agreed the desired lowest price, in this instance equal to \$215,553. Then the u values are:

u_1— 0.68; (Bid price x u = Basic price)

u_2— 0.94;

u_3— 0.88;

u_4— 0.78; and

u_5— 0.97.

Then the resulting rating matrix or binary relation is shown in Table 5.

Table 5 Rating Matrix or Binary Relation

	y_1	y_2	y_3
x_1	0.68	0.83	0.90
x_2	0.94	0.89	0.67
x_3	0.88	0.95	0.72
x_4	0.78	0.96	0.79
x_5	0.97	0.77	0.93

The best suited method for multicriteria decision making process in a fuzzy framework is a decision subset D.

$D = y_1$ AND y_2 AND y_3;

$D = \{x_1|0.68,\ x_2|0.67,\ x_3|0.72,\ x_4|0.78,\ x_5|0.77\}$

In decsion subset D, the membership grade of each contractor is obtained by taking the minimum across the respective row in Table 5. From D, it is seen that contractor x_4 is selected on the basis of highest degree of support (=0.78) assigned to x_4, even though contractor x_4 by no means tendered with the lowest bid.

However, the shortfall of the approach is once again the reliance on the subjective judgement of the partners or associates of the client on the predictive performance.

2.2.3 DIEKMANN'S WORK[9]

His approach assumed the existence of n one-dimensional utility functions to transform the attributes of the decision alternatives into preferences. In his method, multiple criteria were identified and assigned weights. Alternative bids were then given scores with respect to each criterion. These scores were multiplied by the weights assigned to the criterion. The sum of the weighted scores of each alternative represented its overall weight. The alternative receiving the highest total weight was selected. The model had the following form:

$$U(x)=¶_1u(x_1) + ¶_2u(x_2) + \ldots + ¶_nu(x_n)$$

where $u(x_i)$ is the single attribute utility function of x_i and $¶_i$ is a scale (or a weight) which indicates the importance of achieving objective x_i.

The shortfall of this method is that most weights and scores are arbitrarily assigned to an arbitrary scale on which the decision makers is making absolute judgements. There is little meaning attached to what an assigned weight represents.

2.2.4 RUSSELL'S WORK[10]

Russell et al have suggested the following decision factors in bid evaluation:

- past performance;
- financial stability;
- status of current work program: to evaluate the contractor's current work load and determine any severe difficulties with on going projects;
- technical expertise: to evaluate technical characteristics of a contractor; and
- project specific criteria: to evaluate whether a candidate contractor can provide unusual expertise or specialised facilities required by the project.

2.2.5 RUSSELL AND SKIBNIEWSKI'S WORK[22]

Russell and Skibniewski et al concluded from their work that contractor prequalification was a decision making process involving a wide range of criteria for which information was often qualitative, subjective and imprecise. The process was largely an art where subjective judgement, based on the individual's experience was employed.

They suggested the following objectives in determining the client's perception on performance:

- Cost of the project
- Time required for completion
- Quality of finished product
- Safety achieved during construction

They also suggested the following decision parameters on contractor performance:

- Experience over last five years in similar construction
- Experience in completion of project in schedule
- Present workload and capability to support project
- Experience and capability of contractor key site management personnel
- Availability of first line supervisors
- Quality control program and quality of work on past projects
- Past owner/ contractor relationship
- Past and present experience on legal suits or claims

A number of bid evaluation models were proposed by them, namely:

2.2.5.1 DIMENSIONAL WEIGHTING

In this process, each decision parameter and its relative weight of importance were determined based on the characteristics of the decision maker. Once the decision parameters were established, the alternatives, in this case the contractors, could be rated with respect to the decision parameters. A contractor's score was calculated as a weighted sum of ratings over all decision parameters. The magnitude or the rank order of the scores could then be used to perform contractor selection.

2.2.5.2 TWO STEP PREQUALIFICATION

An alternative suggested was the two step prequalification model. In the first step, contractors were selected or discarded based on how well they satisfied each of the preliminary screening dimensions which were, say for instance the corporate experience in constructing similar projects; capability of handling such a project; and the financial profile.

The second step utilised the dimensional weighting strategy described with more specific criteria being used to determine the contractor's attractiveness as a bidder.

This method could allow rapid elimination of unwanted contractors. This in turn allowed the owner to focus on the remaining contractors and study their merits and demerits more extensively.

2.2.6.3 DIMENSIONWIDE STRATEGY

This approach was to select the more salient dimensions in measuring contractor competence and all contractors were evaluated with respect to it. If the contractor failed to meet the owner's expectations, he was discarded from the potential bidder list. The rest who passed the first dimension would proceed to the next. Typical decision criteria used in this model included:

- contractor's safety performance;
- prior experience;
- past performance;
- location of home office;
- type of labour employed;
- financial stability and
- longevity.

2.2.6.4 PREQUALIFICATION FORMULA

One example was that the State Departments of Transportation in Ohio of U.S.A. used a formula to restrict the workload of contractor as follows:

> "The maximum work volume must be smaller than the contractor's net current assets (from a current financial statement) multipled by 10."

2.3 SUMMARY

These early methods illustrate fairly useful approaches to the subject of bid evaluation with the results demonstrating some systematic and structured overtures. However, all used subjective judgement, none of which could provide a quantitative model, in assessing or predicting contractor performance. This research thesis concentrates on this shortfall.

This research adopted a mathematical technique called Discriminant Analysis to develop a quantitative model in the form of a formula by which each contractor's predictive performance can be expressed in Z scores. The Z score is a linear scale transformed from multiattribute and multidimensional scales which collectively ascribe the performance behaviour. This approach is new and different from the early studies on contractor performance.

CHAPTER 3

THE TECHNIQUE OF DISCRIMINANT ANALYSIS

3.1 INTRODUCTION

Discriminant analysis , first introduced by Sir Ronald Fisher[13], is a statistical technique designed to distinguish among several mutually exclusive groups based upon linear combinations of the independent, sometimes called predictor, variables.

As in real life, there may be a number of factors ascribing the outcomes of a problem in the social, behavioural and biological sciences. The contributions and the identification of the variables to the outcome is the information that most researchers look for.

The discriminant analysis technique is a useful tool for the assignment of observations from unknown groups or populations to mutually exclusive groups or populations and for finding out the predictive variables and arrange them in the order of importance. With two groups, it is possible to derive one discriminant function that maximizes the ratio of between to within groups sums of squares. Where there are three groups, two discriminant functions can be calculated. The first function, as in the two group case, has the largest ratio of between groups to within groups sums of squares. The second function is uncorrelated with the first and has the next largest ratio. In general, if there are K groups, (K-1) discriminant functions can be computed. They are all uncorrelated with each other and maximize the ratio of between groups to within groups sums of squares, subject to the constraints of being uncorrelated.

3.2 APPLICATION OF THE DISCRIMINANT ANALYSIS IN CONSTRUCTION RELATED RESEARCH

To date the technique has generally not been applied in construction related research works, there being few references to previous research[11,12,14,15]. However of notice, Mason and Abidali[11,12] et al applied the technique in predicting company failure in the construction industry by taking financial ratios as the predictors.

Salomonsson and Flood[15] et al also used the technique to classify building firms in Australia based upon the job area, job complexity, completion time and cost as the predictors.

Skitmore and Marsden[14] et al used the method to investigate the decision making path for different procurement methods based upon the following predictors:

-Speed
-Certainty
-Flexibility

-Quality level

-Complexity

-Risk avoidance and responsibility

-Price competition

The reasons for this technique's lack of citation may be due to complexity and its very advanced nature. In contrast, Multiple Regression Analysis applications are more commonly reported, however, discriminant analysis is more powerful in discriminating two or more number of groups.

3.3 ASSUMPTIONS ABOUT THE DATA IN APPLYING DISCRIMINANT ANALYSIS

For the linear discriminant function to be "optimal", that is, to provide a classification rule that minimizes the probability of misclassification, the following assumptions about the data must be met:

- In each group, the variables must be from multivariate normal distributions.

- The population covariance matrices for all groups must all be equal.

In testing the first assumption, a simple tactic is to examine first the distributions of each of the variables individually.

If the variables are jointly distributed as a multivariate normal, it follows that each is individually distributed normally. Therefore, if any of the variables have markedly non-normal distributions, there is reason to suspect that the multivariate normality assumption is violated. For the second assumption, the SPSS (Statistical Package for the Social Science) has provided a feature, that is the Box's M test to test the equality of the group covariance matrices. A small probability might lead to reject the null hypothesis that the covariance matrices are equal. The test is also sentitive to departures from multivariate normality. That is, matrices tend to be unequal if the normality assumption is violated.

These two assumptions are not always satisfied in practice. However, the technique has been found to be very robust implying that the assumptions need not be strongly adhered to[11].

3.4 RELATIONSHIP TO MULTIPLE REGRESSION ANALYSIS

Two group linear discriminant analysis is closely related to multiple linear regression analysis. The binary grouping variables in the discriminant analysis can be treated as the dependent variable in multiple linear regression analysis and the predictor variables as the independent variables.

However, multiple regression analysis is less powerful than discriminant analysis in the case of binary groupings dependent variables with only 'Yes' or 'No' alternatives. Multiple regression analysis is more suitable to cases where the dependent variable is a continuum[16].

Nevertheless it is not unusual to obtain the same set of dependent variables both in the two group discriminant analysis and the multiple regression analysis and the two sets of coefficients are usually proportional.

3.5 THE GENERAL CONCEPT OF MULTIPLE DISCRIMINANT ANALYSIS

For a two group linear discriminant analysis, the prime objective is to derive a linear function having the significant variables that maximize the between group variation to the within group variation.

The discriminant function has the following form:

$$Z = C_0 + C_1V_1 + C_2V_2 + \dots + C_nV_n$$

where Z = the discriminant score

C_1 to C_n = the weighting coeficients

C_0 = constant

V_1 to V_n = the discriminant variables

The first step in discriminant analysis is to select cases to be included in the computations. Cases containing missing information have to be excluded. When all the cases are ready, the next step is to generate and examine the within groups correlation matrix since interdependencies among the variables will affect most multivariate analysis. The correlation matrix should show whether one variable is directly correlated with another, either negatively or positively. If a very strong correlation exists (over ±0.90), it may be necessary to combine the two criteria, as they may essentially be measuring the same performance factor. A further difficulty with correlations of this magnitude is that any results may be distorted by the presence of multicollinearity.

The third step is going through a large amount of tedious calculation to arrive at the variables found to be significant and their discriminant coefficients, together with a constant.

Ultimately, the effectiveness of the function is measured by the following methods:

3.5.1 PERCENTAGE OF CASES CLASSIFIED CORRECTLY

The percentage of cases classified correctly is one indicator of the effectiveness of the discriminant function. Another indicator of effectiveness of the function is the actual discriminant scores in the group.

3.5.2 THE BETWEEN GROUPS AND WITHIN GROUPS VARIABILITIES

In fact, the coefficients of the discriminant function are chosen so that the ratio of the between groups sum of squares to the within groups sum of squares is as large as possible. Any other linear combination of the predictor variable will have a smaller ratio.

One way to measure the variabilities is the use of the Eigenvalue which is the ratio of the between groups to within groups sums of squares.

$$\text{Eigenvalue} = \frac{\text{Between groups sum of squares}}{\text{Within groups sum of squares}}$$

Large Eigenvalues are associated with 'good' functions.

3.5.3 THE CANONICAL CORRELATION

This is a measure of the degree of association between the discriminant scores and the groups.

In the two groups situation, the canonical correlation is simply the usual Pearson correlation coefficient between the discriminant score and the group variable.

3.5.4 WILKS' LAMBDA

This is the ratio of the within groups sum of squares to the total sum of squares. It is the proportion of the total variance in the discriminant scores not explained by differences among groups.

Small values of lambda are associated with functions that have much variability between groups and little variability within groups. A lambda of 1 occurs when the mean of the discriminant scores is the same in all groups and there is no between groups variability. However, this figure provides little information about the effectiveness of the discriminant function in classification, being mainly a test of the null hypothesis that the population means are equal. Small differences may be statistically significant but still not permit good discrimination among the groups.

3.6 SUMMARY

Using the discriminant analysis, it is able to derive a function which can maximize the groups' difference by means of an index expressed in Z-score. A cut off point is able to be established in the two groups. Thus the group membership can be assigned when the score is known.

The advantages of this approach in performance appraisal are as follows:

a) It is a multivariate approach which can consider the entire profile of all the attributes that affect the dependent variable (in this research, the contractor performance).

b) The interrelationship between attributes can be taken into consideration.

c) The classification tool is a straight forward function which is easy to interpret and use.

d) A quantitative approach is provided which can reduce the effect of subjective judgement in contractor evaluation.

CHAPTER 4

DECISION FACTORS AFFECTING PERFORMANCE AND THEIR QUANTIFICATION

4.1 INTRODUCTION

A builder's overall performance is generally perceived as being related to such factors as quality of workmanship, completion on time, within budget and the builder's attitude when dealing with the client[15] although safety in construction could also be included[22,23]. These factors provide the primary investigation in this study.

First of all, performance needs to be defined. In this research, performance is divided into two groups: good and poor in which 'fair' performance would be categorised into 'good' pool to avoid ambiguity. Clients were asked to classify the contractor performance into the two groups in interviews.

In order to unveil the clients' decision pattern, a set of variables of time, cost and quality was modelled using the Discriminant Analysis technique to generate the Z_1 model to determine if there was indeed any decision making structure and to ascertain the relative weightings of each factor. The study of these factors forms the first part of this chapter.

In the second part, the variables thought to affect contractor performance were investigated. It being believed that contractor performance is multidimensional and a function of a number of attributes; for instance the ability of members in the project, the type of project, etc. Some of the attributes are conceived to be the intrinsic features of the contractor while the others may be the external traits which are out of the contractor's control. Indeed research carried out on bid evaluation has highlighted certain intrinsic factors; however, the external influences have seldom been discussed.

4.2 DATA SELECTION

Firstly, a sample of projects was selected based upon the following criteria:

- Different sizes.
- Different types; e.g. renovation works, foundation works to complicated hospital projects.
- Range of contractors from sole proprietary owned firms to large public companies.

The data was designed according to the following objectives:

- The information must be relevant to the subject according to previous research works.
- Additional variables to be included if thought to be significant in the context of the Hong Kong environment.
- The information must be easily accessable in order not to cause too much inconvenience to the interviewees and thus to maintain the accuracy of data.

- The information must not be so sensitive to cause reluctance to disclose.

4.3 VARIABLES THAT MEASURE THE CLIENT'S SATISFACTION ON CONTRACTOR PERFORMANCE

Historically, project performance has been evaluated in terms of cost, schedule and quality[2,1]. In simple terms, the objectives are to complete the project within time, within budget and to the quality specified. Although some researchers also included safety as the fourth dimension[22]; however, in the context of Hong Kong, there is no system in the private sector to penalize contractors although one of the public clients has started considering that a poor safety record might handicap contractors with respect to invitation to tender.

Some previous research reported by Might and Fisher[18] involving a mail survey of 100 development projects in 30 different firms in the U.S.A. produced the following results relating to contractor performance:

Table 6 Relative Weightings of the Success Criteria in Might and Fisher's Mail Survey

Success Criteria	Relative Weight (%)
Technical Performance (Quality)	54
Cost Performance (Cost)	23
Scheduled Performance (Time)	22
	100

The result suggests that clients tend to be very concerned about quality (the highest weighting) with the weightings of cost and time being comparable in magnitude.

Indicators of this kind, i.e. the three criteria, seemed appropriate for modelling by the Discriminant Analysis method described in Chapter 6. After a full analysis the relative weightings of the 3 factors measured by the standardized discriminant coefficients were found to be:

Table 7 The Standardized Discriminant Coefficients and their Relative weightings in the Z_1 Model

Criteria	Stand. Discriminant Coefficients	Relative Weightings
Time Cost Quality	-0.41669 -0.26144 0.95613	25% 16% 59%
		100%

Comparing the two sets of research results evidently clients seem most concerned about the quality (in Might and Fisher's[18] and this study, the weightings are 54% and 59% respectively). Indeed the weightings of all the three criteria are comparable, the difference being the reverse priority order of the weightings for time and cost factors (in Might and Fisher's[18] and this study, the priorities for time factor are ranked 3 and 2 respectively). However, in Hong Kong the high cost of land rental charges would explain the clients' concern on the time criterion.

The importance given by clients to the quality element may be related to the difficulty in projecting likely quality performance at the time the contract is awarded although the specifications might give some indications. In contrast, time and cost are stipulated precisely in contracts which can be known at the outset in spite of the fact that their exact extent cannot be valuated.

The methods adopted to quantify these three criteria are described in the following pages.

4.3.1 QUALITY

Quality is very difficult to define in the construction industry; for instance, if the specification calls for soil to be compacted to a given density but was not achieved in reality, quality would not be attained and the defect would not show up immediately. Further, there are many trades in a building project which could not be realistically expected to achieve a good quality. Thus ultimately the question is whether the completed work possesses the attributes desired by the owner and designer. These can only be measured subjectively by their comformity to the specifications established for the project[2].

In this study, quality was assessed by ordering clients perceptions on a ranked basis, namely:

Quality of work	Rank
Poor quality compared with the specifications.	1

Slightly poorer than average compared with the specifications.	2
Meet the requirements of the specifications.	3
Slightly better than average compared with the specifications.	4
Good quality compared with the specifications.	5

4.3.2 TIME

This factor was measured by the following ratio:

$$\frac{\text{Actual Completion Time}}{\text{Estimated Contract Duration in the Tender}}$$

This measure is designed to determine the percentage delay of the project caused by the contractor. The accuracy of this factor may be affected by variations, consequently, projects with few variations were selected in order to minimize such effects.

4.3.3 COST

This was measured in the ratio of:

$$\frac{\text{Final Cost of Contract}}{\text{Tender Price}}$$

The main objective here is to identify contractors with a tendency towards inflating prices through claims against the client.

While these last two criteria cannot be determined precisely without access to detailed project information, the crude figures facilitate an indication to be made of the clients' decision pattern in judging performance.

4.4 THE INTRINSIC TRAITS OF CONTRACTOR LIKELY TO AFFECT PERFORMANCE

Researchers[4,7,8,10,22,23,24,25] have suggested a number of internal attributes of contractors thought to affect performance. In this study, nearly all, plus unique elements were included and discussed below.

4.4.1 STAFF TRAINING PROGRAMME

Companies which invest in human resources are normally well established and often appear to have better long term planning policies. Training in management skills may be one of the factors in improving their performance in managing projects and was thus included in the model as a variable defined by the following ratio:

$$\frac{\text{Number of staff members taking management training}}{\text{Total no. of staff}}$$

4.4.2 PLANT OWNERSHIP POLICY

Both Mustafa et al[7] and Russell et al[22] suggested the availability, quantity, quality and suitability of plant would affect contractor performance. Further, construction contracting is a risky business with flucuations of work commonly hindering contractors in the acquisition of fixed assets. Plant ownership trend can provide some indication of the long term planning policies and attitudes especially in fostering good relationships with clients. This factor is designed to measure the availability and quantity of company owned plant and was quantified as follows:

$$\frac{\text{Preceding year's total amount of plant owned}}{\text{Preceding year's turnover}}$$

4.4.3 SIZE OF THE COMPANY

Large companies generally possess more resources and more sophisticated systems of management and because of size, have to live up to a particular public image, thus indirectly affecting performance.

Size in this context was quantified by the number of staff employed as human resources are the main assets of a construction firm. In contrast, works in hand are unreliable as a measure because of the possibility of short term overload. Fixed assets are difficult to include while the turnover of a year does not reflect the size of the company.

4.4.4 QUALITY OF MANAGEMENT TEAM - PROFESSIONAL QUALIFICATIONS

Nguyen and Russell et al mentioned in their works[8,22] that management qualifications and expertise were the criteria for contractor selection. Giege and Selin[24] cited in their interview survey that competent personnel in management and organisation of the project was one of the most important factors for success. Moreover, Russell et al[22] described that the capability of contractor's key site management and technical field personnel was one of the determinants of success.

In the building industry of Hong Kong, many senior management staff in construction firms are promoted from supervisory or trade foreman level and seldom receive professional management training. Some are less adaptive to changing technology than others and sometimes find it difficult to accept new ideas and changed skills. Thus the percentage of staff acquiring professional qualifications could affect the performance behaviour.

The ratio used to quantify this element was chosen to be:

$$\frac{\text{Number of professionally qualified staff}}{\text{Total no. of staff}}$$

4.4.5 QUALITY OF MANAGEMENT TEAM - PROJECT LEADER'S EXPERIENCE

Jaselskis et al and Russell et al mentioned in their works[23,22] that experience of contractor's key site management and technical field personnel was one of the determinants in contractor selection. Jaselskis[23] also specifically cited that the project manager's number of years of experience could affect contractor performance.

A count of the number of years of experience of the project leader in construction contracting was thus selected as the measure in this case.

4.4.6 PAST PERFORMANCE OF THE PROJECT MANAGER

The past performance of the project manager in the eyes of his or her senior may reflect the quality of the project manager which may affect the contractor performance. This was obtained by asking the project manager's superior about the past performance and gauged as follows:

1. Slightly poorer than average
2. Fair
3. Better than average

4.4.7 CONTRACTOR'S EXPERIENCE IN THE TYPE OF JOB

Both Jaselskis et al and Mustafa et al specified in their works[23,7] that the specific experience of the contractor suitable for undertaking the work was one of the criteria in determining success.

Contractors who are familiar with the type of project may manage that potential kind of work more efficiently and thus perform better and this was gauged by the ratio:

$$\frac{\text{Number of similar jobs in a fixed period of time}}{\text{Total no. of jobs in the same period}}$$

4.4.8 CONTRACTOR'S WORK LOAD

Both Jaselskis et al[23] and Russell et al[22] described that the allowable work volume for a contractor had to be limited in bid evaluation. If contractors are overloaded with work, resources and labour availability may be affected and this can be gauged as follows:

$$\frac{\text{Total contract sum in hand}}{\text{Total no. of staff}}$$

In this approach, the workload relative to the staff establishment was used to define the real workload situation since staff is one of the most important resources in the construction industry and the staff establishment normally prescribes the size of a construction firm.

4.4.9 CONTRACTOR'S PAST PERFORMANCE OR IMAGE

Mustafa et al[7] described that reputation and position in the market was one of the criteria in bid evaluation. Russell[10] stated that past performance was important in contractor selection.

Past performance may be one of the factors governing future performance but is difficult to measure objectively. The method adopted in this research ranked the past performance of the contractor in the order from 5 to 1 representing very bad, bad, fair, good and very good respectively of which clients were asked to judge in interviews.

4.4.10 NUMBER OF YEARS IN THE BUSINESS

Longevity is one of the factors to be considered in contractor appraisal[23]. Mustafa et al specifically stated that the number of years of experience in the related industry would be considered in bid appraisal.

Contractors that have survived long in the market may be more reliable, possessing different marketing policies from competitors; e.g. more experience in controlling and managing the local works. Some attempt at gauging this aspect was included in the model as a variable for age of the firm.

4.4.11 ORIGIN OF THE COMPANY

Abdel Salam[25] cited that foreign contractors were faced with a general lack of information concerning both technical and administrative experience in the host country. In addition, most foreign contractors relied on compensating costs through claims. In order to maximize turnover and enter into the market, there was a tendency to tender below the true economic cost of the work. Then too much time and effort were expended on trying to increase the financial return and avoid loss. There was no margin for small expenditures that might improve quality of process, which a good contractor executing work at adequate price would usually undertake, on his own responsibility, in the interest of a good job and his own reputation.

Foreign contractors normally obtained information from their own native embassy staff who mainly dealt with commercial and trade field probably had no practical experience of the construction industry. As a result, they might be unaware of matters that could cause local problems on major projects carried out in whole or in part by expatriates.

Further, overseas contractors may have different management skills compared with the local contractors whose business policies may be influenced by the Chinese culture and the Chinese way of running business. This variable was described by 3 classes; representing overseas contractors, overseas and local joint venture contractors and local contractors.

4.4.12 AMOUNT OF DIRECTLY EMPLOYED LABOUR

Russell et al[22] stated that the type of labour employed was one of the decision factors in assessing the potential performance. Mustafa et al[7] mentioned that the availability of in-house skilled labour would affect contractor performance.

However, direct labour could be easier to manage and may produce higher quality of work when compared with labour only subcontractors, particularly in booming conditions with severe labour shortages.

This effect was measured by the percentage of directly employed labour in the total workforce of the company. This was the ratio of the amount of direct labour over the estimated total number of labour working for the contractor at the moment of interview.

4.4.13 LISTED ON THE STOCK MARKET

Private companies may be very flexible while public companies may be more stable in policy and decision making and some quantification measure was therefore included in the model.
This was gauged by 1 or 2 representing 'yes' or 'no'.

4.4.14 DECISION MAKING CENTRALISED IN HEAD OFFICE OR DE-CENTRALISED TO SITE

This factor was included in order to see whether types of company control affect performance and was gauged by 1, 3 and 2 for centralised, decentralised and mediocrity.

4.4.15 CONTRACTOR IS CLIENT'S SUBSIDIARY FIRM

In Hong Kong, most large developers have subsidiaries or part owned firms and the relationships of subsidiary contractors with clients can be quite close compared to general contractors and was thus included in the model.

This was gauged by 1 and 2 representing 'yes' and 'no'.

4.5 EXTERNAL FACTORS THOUGHT TO AFFECT CONTRACTOR PERFORMANCE

The above are internal attributes of contractors; however, there may be many external influences which were seldom discussed in previous research works which could affect contractor performance such as:

4.5.1 THE ARCHITECT'S PERFORMANCE

The quality of drawings, the number of drawing amendments, variations and the timely issuance of drawings may be important. Clearly these aspects are very difficult to quantify and can only be quantified by subjective ranking; e.g. on a scale 1 to 5 representing very poor to very good respectively.

4.5.2 ARCHITECT'S OR CLIENT'S SUPERVISION AND CONTROL ON QUALITY AND WORK PROGRESS

If the client or architect supervises and controls tightly the quality of work and work progress, contractors may perform better. Early signalling of the client's dissatisfaction on the work progress and the quality of works by issuing architectual instructions and warnings can reduce disputes at the end of the contract.

Again this factor is very difficult to quantify and was measured in rank order 1 to 5 representing very loose to very tight control.

4.5.3 PUNCTUALITY OF PAYMENT BY THE CLIENT

Frequent delays of payments may cause discontent to the contractor resulting in disputes. This was gauged by 1 and 2 representing 'punctual' and 'unpunctual'.

4.5.4 COMPLEXITY OF THE PROJECT

Simple works require little management input while complicated works involve the coordination of complicated electrical and mechanical services and management of nominated specialist subcontractors and the client's requirement may be more stringent. That may affect contractors' performance.

A small survey was carried out in order to rank the levels of complexity. Firstly, six levels of work were derived arbitrarily by the author. Questionnaires were sent to clients asking them to gauge the complexity in ascending order and the Kendall Coefficient of Corcordance[52] was used to test the judges' agreement and was proved to have a high concordance (for details please refer to Appendix 1).

This was quantified in the following manner:

Types of work	Complexity
Foundation works, site formation, slope protection and similar simple civil engineering works which output relies on that of machine and contractors normally use directly employed labour without the trouble of coordinating subcontractors. No electrical and mechanical works are involved.	1
Renovation or alteration works.	2
Factory or domestic housing works which require a little amount of E&M services coordination.	3
Deluxe housing projects or office buildings which require more subcontracting and E&M coordination.	4
Hotel or high class office buildings.	5
Hospital or complicated structures or projects.	6

4.5.5 PROFITABILITY

If the contractor knows, at the outset of the project, that work will be profitable, a more cooperative spirit and willingness to spend a little more to achieve a better quality might prevail. However, on the contrary, contractors may seek every chance of claims and upset the client. This was gauged by the ratio:

$$\frac{\text{Winning tender price}}{\text{Pre-tender estimate}}$$

Both the tender price and the pre-tender estimate were obtained through the interview with the clients.

4.6 SUMMARY

In the first part of this chapter, three variables were described which were thought important in evaluating performance, namely:

- Time
- Cost
- Quality

In the second part, twenty factors conceived affecting performance were included, namely:

Internal Factors

- The staff training programme
- Plant ownership policy
- Size of company
- The percentage of professionally qualified staff
- Project leader's experience
- Past performance of the project manager
- Contractor's experience in the type of job
- Contractor's work load
- Contractor's past performance or image
- Number of years in the business
- Origin of the company
- Amount of directly employed labour
- Listed on the stock market or not
- Decision making centralised in head office or decentralised to site

- Whether the contractor is client's subsidiary firm

External Factors

- Architect's performance
- Architect's or client's supervision and control on the quality of work and work progress
- Punctuality of payment by the client
- Complextity of the project
- Profitability of the project

The Discriminant Analysis model is intended to separate the two groups of performance by maximizing the differentiation among attributes. The list of variables is by no means exhaustive but the most important factors were included and considered in the model.

CHAPTER 5

DATA COLLECTION AND FORMATION OF DATA GROUPS

5.1 INTRODUCTION

This section concerns the methodology of data collection, data types and formation of the data groups used to develop and verify the discriminant model for contractor performance. The data type, the main features of project samples will be discussed in the following pages together with the types of projects chosen which were aimed to produce a fair representation of the population.

5.2 METHODOLOGY OF DATA COLLECTION

Cases were selected on the criteria that a wide spread of the different characteristics of projects was included.

Once cases were selected, contacts were made to ascertain who would be best able to act as key informants about the details of the projects. These individuals were then provided with information outlining the research followed up by personal meetings to establish willingness to participate. Once access had been agreed, an indepth interview was arranged which was based on a structured questionnaire. The nomenclature and role of those interviewed varied considerably, as might be expected including managing directors, project managers, contract managers, property managers, chief architects, chief quantity surveyors, management consultants.

5.3 FORMATION OF DATA GROUPS

In this study, four groups of project samples were chosen as shown in Table 8:

Table 8 Group Size of Projects in the Study

	Groups	Number of Cases
1	'Good Performance' Group	24
2	'Bad Performance' Group	9
	Total:	34
3	Test 'Good Performance' Group	10
4	Test 'Bad Performance' Group	6
	Total:	16

Groups one and two were used for modelling the discriminant function whilst Groups three and four were served for testing and verifying the model.

Groups one and two consist of a total of 34 cases which were collected on a random basis. They were gathered in years of 1989 to 1990.

The test groups three and four were specially selected to include more 'bad' cases for examining the discriminant power of the model. The information required for the test groups were much simplified to contain the significant variables discovered in the discriminant model only. They were collected in year 1991.

5.4 DATA ANALYSIS

Since both the collection of the good and bad performance cases were at random, the 'prior probability' in the modelling which is an estimate of the likelihood that a case belongs to a particular group when no information about it is available, can be estimated by the observed proportions of cases in each group. In this study, nine out of the thirty-four cases belong to the 'bad' group. The prior probabilities of belonging to group 2 (bad) and group 1 (good) are then 0.26 and 0.74 respectively. In other words, the chance that clients can encounter good performance is 74% out of all projects and 26% for poor performance.

5.4.1 TYPES OF PROJECTS

The types of project in the sample groups are shown in Table 9. The modelling groups cases were designed to give a wide spread of different types in order to secure a fair representation of the population.

5.4.2 TYPES OF CONTRACTORS

The types of contractors in terms of their nationality in the sample groups are shown in Table 10. The percentage of foreign contractors in the modelling groups represents more or less their market share in Hong Kong.

Table 9 Types of Projects in the Samples

Types of Project	Number of cases	
	Modelling Groups	Testing Groups
Foundation, site formation, slope protection and similar civil engineering projects.	4	0
Renovation or alteration projects.	4	3
Factory or domestic housing projects.	9	7
Deluxe housing projects or office buildings.	5	5
Hotel or high class office building projects.	7	1
Hospital or complicated structure projects.	5	0

Table 10 Types of Contractors in the Modelling Groups

ORIGIN	NUMBER	
	Modelling Groups	Testing Groups
Foreign Contractors	5	1
Local Contractors	29	15
Total:	34	16

5.4.3 SIZE OF CONTRACTORS

The size of contractor was measured in terms of the number of staff employed (refer to para. 4.4.3 of Chapter 4). Their sizes in the modelling groups are shown in Table 11 which spread over a very large range.

Table 11 Size of Company in the Modelling Group

Number of staff employed	Number of cases
15 or less	5
16 to 99	3
100 to 199	7
200 to 999	14
1000 or above	5
Total:	34

5.4.4 PROJECT SIZE

The sizes of project measured in terms of contract sums are shown in Table 12 which demonstrated that the spread is very extensive.

Table 12 Project Size in the Sample Groups

SIZE	NUMBER OF CASES	
	Modelling Groups	Testing Groups
1 Million or less (HK$)	2	0
Above 1 million up to 10 millions	3	4
Above 10 millions up to 50 millions	6	5
Above 50 millions up to 100 millions	11	3
Above 100 millions up to 500 millions	10	4
Above 500 millions	2	0
Total:	34	16

5.5 SUMMARY

Attempts have been made to include different and a wide spread of types, sizes and other important features of project in the samples. The period of data collection has been confined to within two years for the modelling groups to avoid any changing conditions of the industry which could affect the consistency of the results.

The test groups were designed to obtain a balance in the number of good and bad cases in order to demonstrate the predicting power of the model.

CHAPTER 6

RELATION BETWEEN PERFORMANCE AND TIME, COST & QUALITY

6.1 INTRODUCTION

This section concerns the formulation of the Z_1 model to portray clients' decision profile in determining contractor performance using variables such as time, cost and quality. As discussed in section 4.3 of Chapter 4, cost, schedule and quality were considered as the most important predictors in performance. These three variables were investigated in the model for their underlying structure in performance appraisal.

6.2 DATA ANALYSIS

There were forty-four cases adopted in the analysis. The ways to quantify the variables have been described in Chapter 4. The group means of the three variables, time, cost, and quality, are shown in Table 13.

Table 13 Group Means of Time, Cost and Quality

Group	Time	Cost	Quality
1	1.09584	1.04866	3.21875
2	1.60417	1.07392	1.91667
Total	1.23448	1.05555	2.86364

Table 13 shows that the variable TIME overran by 9.6% in the 'good' group on average while that was 60.49% in the 'bad' group. Also, the budget overran by 4.9% in the 'good' group but 7.4% in the 'bad' group. The quality was slightly above average in the 'good' group but slightly below the 'slightly poor' catagory in the 'bad' group.

The correlation of the three variables are shown in Table 14.

Table 14 Pooled Within Groups Correlation Matrix in the Z_1 Model

	Time	Cost	Quality
Time	1.00		
Cost	-0.03588	1.00	
Quality	0.09256	0.14920	1.00

The small correlations infer that multicollinearity does not upset the model.

6.3 Z_1 MODEL DERIVED

(Details of computer generation of the model are described in Appendix 3.)

The standardized and unstandardized Discriminant Function Coefficients found are shown in Table 15. The magnitude of the unstandardized coefficients is not a good index of relative importance when the varibles differ in the units in which they are measured. However, when the variables are standardized to adjust for the unequal means and standard deviations of independent variable, the relative importance can be measured more accurately. Therefore, the importance of an individual variable can be assessed according to the size of the standardized canonical discriminant function coeffieients in the priority order of quality, time and cost since the values are little distorted by small correlations. The actual signs of the coefficients are arbitrary which are determined by the way of quantification.

Table 15 The Standardized and Unstandardized Canonical Discriminant Function Coefficients in the Z_1 Model

	Standardized Discriminant Function Coefficients	Unstandardized Discriminant Function Coefficients
Time	-0.41669	-0.7132566
Cost	-0.26144	-2.932977
Quality	0.95613	1.760698

Table 7 The Standardized Discriminant Coefficients and their Relative weightings in the Z_1 Model

Criteria	Stand. Discriminant Coefficients	Relative Weightings
Time Cost Quality	-0.41669 -0.26144 0.95613	25% 16% 59%
		100%

The Z_1 model function for time, cost and quality is as follows:

$$Z_1=1.760698*QUALITY - 0.7132566*CON\_TIME - 2.932977*CON\_COST - 1.065610$$

where QUALITY= Quality of work in the rank of:

1 - poor quality compared with the specification.

2 - slightly poorer than average compared with the specification.
3 - meet the requirement of the specification.
4 - slightly better than average compared with the specification.
5 - good quality compared with the specification.

CON_TIME= The ratio of:

$$\frac{\text{Actual completion time}}{\text{Estimated contract duration in the tender}}$$

CON_COST= The ratio of:

$$\frac{\text{Final cost of contract}}{\text{Tender price}}$$

6.3.1 PERCENTAGE OF CASES CLASSIFIED CORRECTLY

The classification power of the model can be gauged by the percentage of cases being assorted correctly. Table 16 illustrates the overall classification results of the model and Table 17 shows the individual classification of the cases and their discriminant scores.

Table 16 <u>Overall Classification Results of the Z_1 Model</u>

Actual Group	Number of Cases	Predicted Group Membership	
		Group 1	Group 2
Group 1	32	31 (96.9%)	1 (3.1%)
Group 2	12	1 (8.3%)	11 (91.7%)

The distribution of the classified cases is illustrated in Figure 2.

From the results, it demonstrates that the effectiveness of

Table 17 Classification Results and the Discriminant Scores of Cases in the Z_1 Model

Case	Actual Group	Discriminant Scores	Classified Group	Classification
1	1	0.7446	1	Correct
2	1	-0.0464	1	Correct
3	1	2.0083	1	Correct
4	2	-3.8920	2	Correct
5	1	0.5703	1	Correct
6	1	-0.2597	1	Correct
7	2	-1.1294	2	Correct
8	1	2.2152	1	Correct
9	2	-1.2506	2	Correct
10	1	0.3967	1	Correct
11	1	0.7667	1	Correct
12	1	0.3911	1	Correct
13	1	0.012	1	Correct
14	1	0.4236	1	Correct
15	1	1.9577	1	Correct
16	1	0.1303	1	Correct
17	1	0.2746	1	Correct
18	1	2.086	1	Correct
19	1	0.3425	1	Correct
20	1	0.5116	1	Correct
21	1	1.8910	1	Correct
22	1	1.6873	1	Correct
23	1	-0.1091	1	Correct
24	2	-1.4663	2	Correct
25	1	1.8261	1	Correct
26	2	-3.3300	2	Correct
27	1	2.1796	1	Correct
28	2	-0.3770	1	Wrong
29	2	-1.4282	2	Correct
30	1	0.6670	1	Correct
31	1	0.5489	1	Correct
32	1	1.2689	2	Wrong
33	1	2.3309	1	Correct
34	1	0.2176	1	Correct
35	1	0.5371	1	Correct
36	1	0.5949	1	Correct
37	1	0.4197	1	Correct
38	1	0.0828	1	Correct
39	1	-0.9368	1	Correct
40	2	-2.0504	2	Correct
41	2	-4.1608	2	Correct
42	2	-2.1185	2	Correct
43	2	-1.1025	2	Correct
44	2	-1.5131	2	Correct

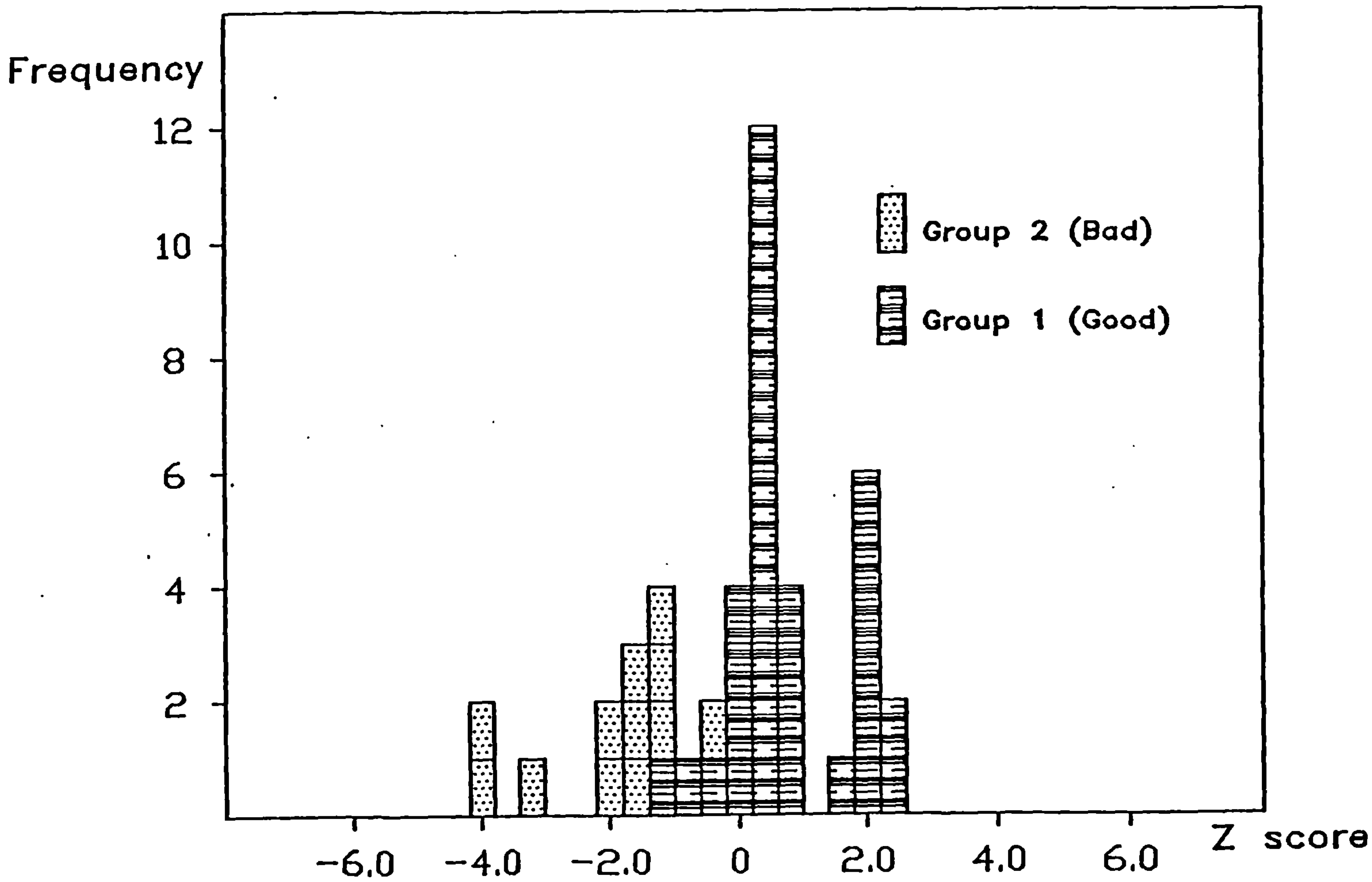


Figure 2 All Groups Stack Histogram for Model Z1

classification of the model is very high. The two groups are well separated by the discriminant model Z_1.

6.3.2 THE BETWEEN GROUPS AND WITHIN GROUPS VARIABILITIES

This is scaled by eigenvalues as described in section 3.5.2 of Chapter 3. Large eigenvalues mean 'good' classification and the eigenvalue is gauged as:

$$\text{Eigenvalue} = \frac{\text{Between groups sum of squares}}{\text{Within groups sum of square}} = 1.54778$$

The value is fairly large and so the classification is considered as good and effective.

6.3.3 THE CANONICAL CORRELATION

This is the correlation which measures the association between the discriminant scores and the groups. The value is 0.779 which is quite high and again this demonstrates that the classification is good.

6.4 SUMMARY AND CONCLUSION

Although there were two cases misclassified in the forty-four cases, the model was demonstrated to be effective in separating the two groups. It is thus believed that clients' judgement on contractor performance has an underlying decision structure. The priority order of importance in their perception is as follows:

1. Quality
2. Time
3. Cost

The relative importance of 'quality' is almost 2.4 times that of the second ranked variable, i.e. time while the relative importance of 'time' is almost 1.6 times that of the last, i.e. cost. The importance given by clients to the quality element may be related to the difficulty in projecting likely quality performance at the time the contract is awarded while the other two variables are stipulated precisely in contracts although their exact extent cannot be ascertained until the completion of a contract.

The magnitude and order of importance of the variables are comparable with the findings of Might and Fisher's[18] mail survey as described in section 4.3 of Chapter 4. The matching of the two research results indicates that the clients' perception on performance is not the consequences of the random and unstructured projections. They share certain commonalities in performance appraisal. It concludes that clients' judgement on performance is trustworthy to be used as a performance indicator.

CHAPTER 7

THE DISCRIMINANT ANALYSIS MODEL

7.1 INTRODUCTION

This Chapter includes a description of the main discriminant model Z_2, and its constituent variables, together with the relationship between the variables and contribution of each variable to the model. The cut-off value for the model is also encompassed.

The derived model included all types of project in the building industry of Hong Kong as described in Table 9 of Chapter 5 which embodies renovation works, building related civil engineering works such as site formation, slope protection and foundation construction, and the construction of high rise buildings. In order to investigate the different effects of different types of project on the prediction model, two sub-models, comprising new works (Z_3 model) and building works (Z_4 model) cases only were also selected from the main model.

There are twenty variables studied namely:

- The staff training programme
- Plant ownership policy
- Size of company
- The percentage of professionally qualified staff
- Project leader's experience

- Past performance of the project manager
- Contractor's experience in the type of job
- Contractor's work load
- Contractor's past performance or image
- Number of years in the business
- Origin of the company
- Amount of directly employed labour
- Listed on the stock market or not
- Decision making centralised in head office or decentralised to site
- Whether the contractor is client's subsidiary firm
- Architect's performance
- Architect's or client's supervision and control on the quality of work and work progress
- Punctuality of payment by the client
- Complextity of the project
- Profitability of the project

The variables were classified into two groups, namely the internal attributes of contracting firms and the external influences of projects. The variables could be further subdivided into subject groups which measure the important characteristics of projects as shown in Figure 3.

The final prediction model produced in the research is made up of six variables, measuring six distinct aspects of the project attributes, namely: the complexity of the project, the percentage of professional staff, the project leader's

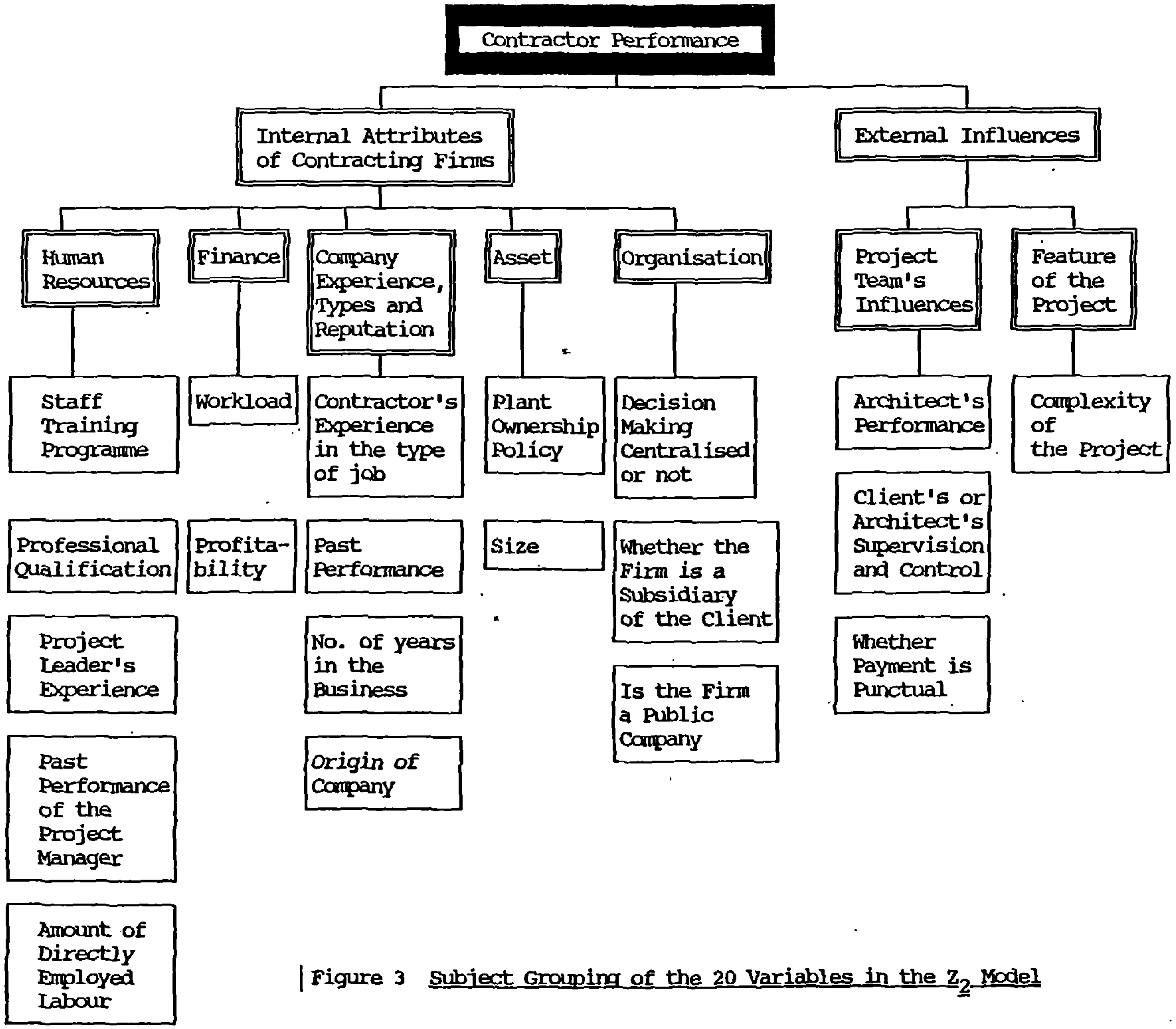


Figure 3 Subject Grouping of the 20 Variables in the Z_2 Model

experience, the past performance of the contractor, the origin of the firm and the architect's and the client's supervision and control on the progress and quality of the project.

7.2 THE RESULTANT MODEL Z_2

(Details of computer generation of the model are described in Appendix 4.)

The following six variables linear function resulted:

$$\begin{aligned} \text{Discriminant function} = & - 0.5616\ (\text{COMPLEX}) \\ & + 11.9324\ (\text{PROF\_STA}) \\ & + 0.0949\ (\text{LEAD\_EX}) \\ & - 1.7845\ (\text{PAST\_PER}) \\ & + 0.8219\ (\text{ORIGIN}) \\ & + 1.0364\ (\text{CONTROL}) - 1.1408 \end{aligned}$$

where

COMPLEX	:	The complexity of the project
PROF_STA	:	Percentage of professional qualified staff
LEAD_EX	:	Project leader's experience
PAST_PER	:	Contractor's past performance or image
ORIGIN	:	Origin of the company
CONTROL	:	Architect's or client's supervision and control on the quality of work and work progress

7.3 THE CONSTITUENT VARIABLES

The constituent variables in the developed model are described in the next few pages.

7.3.1 COMPLEXITY OF PROJECT

As described in Chapter 4, complicated works typically involve the coordination of complex electrical and mechanical services, the management of nominated specialist subcontractors and furthermore clients' requirements are often more stringent. The more complicated the work, the more effort generally required, with increased likelihood of poor performance by all the parties involved.

Surprisingly this factor has hardly ever been pinpointed by researchers in bid evaluation but is inherent in many projects. An appreciation of the importance of complexity can help clients in exercising tighter supervision on the progress and quality of work.

The degree of importance of this variable should be revealed in that clients would choose experienced contractors for the complicated and large projects while keeping the simple and small scale work for small and new contracting firms together with better supervision by the architect or the client on complicated contracts. Evidence that this is the case can be seen in the relatively high correlation between the variables of complexity and the experience of the contractor in similar jobs and client's or architects' control, 0.50214 and 0.62167 respectively (refer to Table 18).

Table 18 Pooled Within Group Correlation Matrix of Variables in the Z_2 Model

	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
COMPLEX	1.000					
PROF_STA	-0.178	1.000				
LEAD_EX	0.039	-0.032	1.000			
PAST_PER	-0.322	0.561	0.346	1.000		
ORIGIN	-0.082	-0.701	0.050	-0.285	1.000	
CONTROL	0.622	-0.227	-0.214	-0.268	0.040	1.000
CONT_EX	-0.502	-0.100	-0.110	0.180	0.143	-0.175

Where COMPLEX: The complexity of project

PROF_STA: The percentage of professional staff

LEAD_EX: The project leader's experience

PAST_PER: The past performance of contractor

ORIGIN: The origin of the firm

CONTROL: The architects' or clients' control and supervision on progress and quality of work

CONT_EX: The experience of the contractor in similar types of job

7.3.2 PERCENTAGE OF PROFESSIONAL STAFF

In Chapter 4, it was suggested that the competence of contractors' staff would influence their performance. Indeed the Z_2 model function indicates that firms with a higher percentage of professional staff have a better chance of achieving good performance, i.e. staff who have had professional training and experience may be more efficient and professional in production and project management and thereby contribute to achieving completion dates, improved quality and cost savings from which clients would finally benefit.

The contribution of this factor to the function was the second most important in terms of standardized discriminant function coefficients (see Table 20). In contrast, however a higher percentage of professional staff may also mean that contractors could have more expertise in claims negotiation. As a result, this negative contribution has reduced the importance of this variable to the function.

Table 19 Unstandardized Discriminant Function Coefficients for the Z_2 Model

Variables	Unstandardized Discriminant Function Coefficients
COMPLEX	-0.5616
PROF_STA	11.9324
LEAD_EX	0.0949
PAST_PER	-1.7845
ORIGIN	0.8219
CONTROL	1.0364
Constant	-1.1408

Table 20 Standardized Discriminant Function Coefficients and their Priority Order of Contribution to the Z_2 Model

Variables	Standardized Discriminant Function Coefficients	Order of Contribution
COMPLEX	-0.8867	4
PROF_STA	0.9110	2
LEAD_EX	0.6372	5
PAST_PER	-1.1000	1
ORIGIN	0.5184	6
CONTROL	0.8870	3

7.3.3 PROJECT LEADER'S EXPERIENCE

The model shows that the more experienced the project leader, the more likely the final outcome would be favourable. This verifies Jaslskis and Russell et al's findings that project leaders' experience correlated positively with the predictive performance.

Nevertheless, the contribution of this variable to the function is not high (see Table 20) in terms of standardized discriminant function coefficients which is quite understandable as only a small part of staff competence is measured.

7.3.4 PAST PERFORMANCE

Most previous research suggests that contractors' past performance to be a very important determinant of predictive performance. Likewise, this study also highlighted that this factor's contribution to the function in terms of standardized discriminant function coefficients is high (see Table 20).

Thus past negative performance could be expected to be repeated with companies forming the habit of managing projects in a characteristic manner, e.g. hard attitude in dealing with clients trying to maximize profits irrespective of the relationship with clients, or standing very firm on claims, etc.

On the contrary, if the policy of a company is to care for quality and clients' relations, this would have a positive contribution to its performance.

7.3.5 ORIGIN OF CONTRACTOR

Local Chinese contractors have their own way of running business and generally prefer commercial settlements rather than bringing the case to arbitration or court. In contrast most overseas contractors in Hong Kong (especially those from the Western countries) are very claim conscious. Further such firms may have difficulties in managing local subcontractors; particularly the labour only employers.

Abdel Salam[25] cited that foreign contractors generally lack knowledge on local problems thereby affecting their performance.

The contribution of this factor to the function in terms of standardized discriminant function coefficients is not very strong (see Table 20). Contractor origin is rarely mentioned in previous research works in bid evaluation, and may be only significant in the Hong Kong context where the society is intermixed with western and eastern cultures with the industrial market typical international where overseas contractors are not prejudiced.

7.3.6 ARCHITECTS' OR CLIENTS' CONTROL AND SUPERVISION

Surprisingly, this factor has also rarely been identified by previous researchers in bid evaluation, when in reality it is a variable which can be controlled by clients. For example where the predictive performance is considered likely to be poor, clients could intervene and try and tighten up supervision.

This factor is shown to be one of the important determinants in performance prediction in the Z_2 model in terms of standardized discriminant coefficients (see Table 20).

7.4 THE CUT-OFF VALUE BETWEEN GROUPS[26]

The derivation of the cut-off value between the two groups is described in the following pages. The mathematical model was explained in Troy's work[26] and will not be discussed in this section.

In order to set the cut-off point mathematically, it is required to ascertain that the distributions of the groups are normal (see Figure 4). As Figure 5 reveals, the distributions of the two groups deviate very little from normality.

The following formulae are abstracted from Troy's work[26]:

$$Z_c = -b \pm \sqrt{(b^2 - 4ac)} \;/\; 2a$$

Where Z_c = The cut-off value between the two groups

$a=(1/4\sigma_2^2 - 1/4\sigma_1^2)$

$b=(\mu_1/2\sigma_1^2 - \mu_2/2\sigma_2^2)$

$c=(\mu_2^2/4\sigma_2^2 - \mu_1^2/4\sigma_1^2 - \log_{10}\mu_1 + \log_{10}\mu_2)$

μ_1, μ_2 = Means of Group 1 & 2 samples
=1.0168, -2.8244 (see Table 21)

σ_1, σ_2 = Standard deviations of Group 1 & 2 samples
=0.9901, 1.0290 (see Table 21)

Thus:

a = -0.0189
b = 1.8522
c = 1.6365

Z_c = The cut-off value = -0.8757

Table 21 Classification Results and the Discriminant Scores of Cases in the Z_2 Model

Case	Actual Group	Discriminant Scores	Classified Group	Classification
1	1	1.7270	1	Correct
2	1	0.6614	1	Correct
3	1	2.9198	1	Correct
4	2	-2.0789	2	Correct
5	1	1.8374	1	Correct
6	1	0.0420	1	Correct
7	2	-1.7774	2	Correct
8	1	-0.0765	1	Correct
9	2	-1.3102	2	Correct
10	1	0.4852	1	Correct
11	1	0.0104	1	Correct
12	1	0.6749	1	Correct
13	1	0.6749	1	Correct
14	1	1.9644	1	Correct
15	1	1.8972	1	Correct
16	1	0.6121	1	Correct
17	1	1.0022	1	Correct
18	1	2.8211	1	Correct
19	1	0.4621	1	Correct
20	1	0.6614	1	Correct
21	1	1.4905	1	Correct
22	1	1.8779	1	Correct
23	1	2.8437	1	Correct
24	2	-3.7487	2	Correct
25	1	0.1870	1	Correct
26	2	-4.3826	2	Correct
27	1	-0.0996	1	Correct
28	2	-3.8130	2	Correct
29	2	-2.7081	2	Correct
30	2	-2.4454	2	Correct
31	1	0.0060	1	Correct
32	2	-3.1556	2	Correct
33	1	1.1756	1	Correct
34	1	-0.4381	1	Correct

μ_1	= Mean of Group 1 sample = 1.0168
μ_2	= Mean of Group 2 sample = -2.8244
σ_1	= Standard deviation of Group 1 sample $= \sqrt{\{\Sigma(Z - Z_{mean})^2/(N-1)\}} = 0.9901$
σ_2	= Standard deviation of Group 2 sample $= \sqrt{\{\Sigma(Z - Z_{mean})^2/(N-1)\}} = 1.0290$

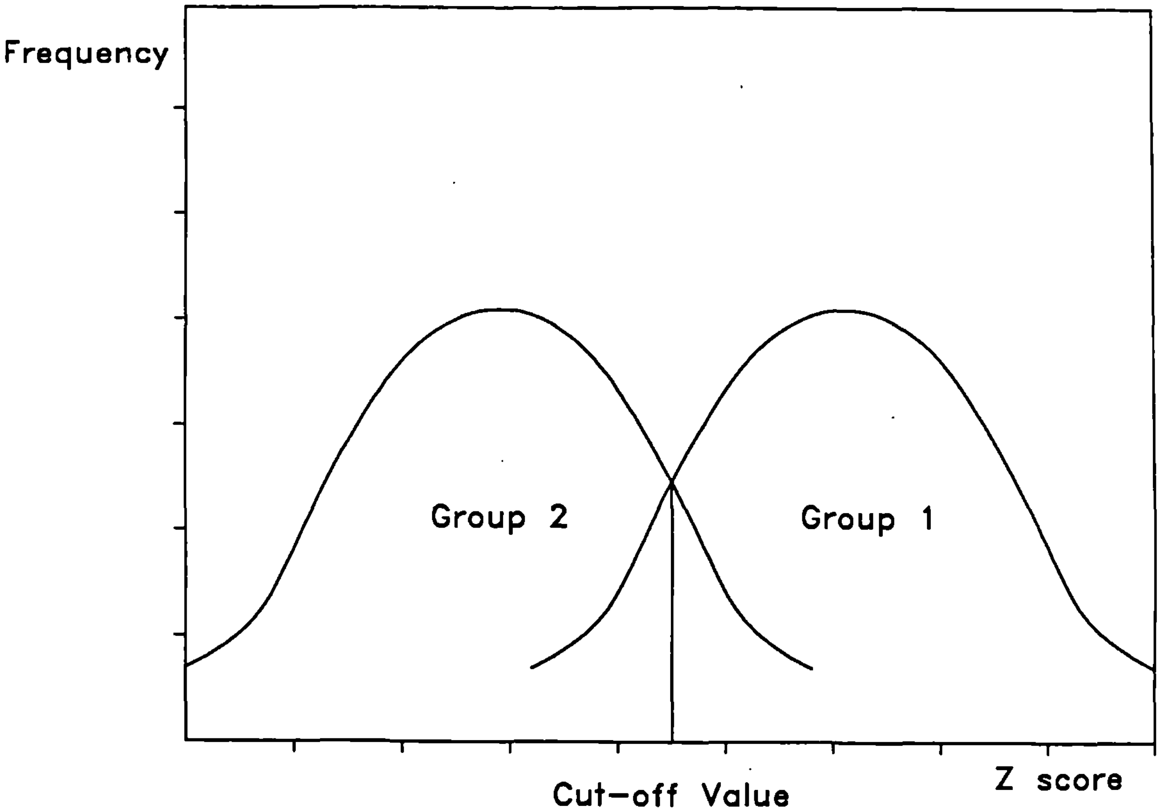


Figure 4 Normality Assumption in Deriving the Cut-off Point for Two Groups

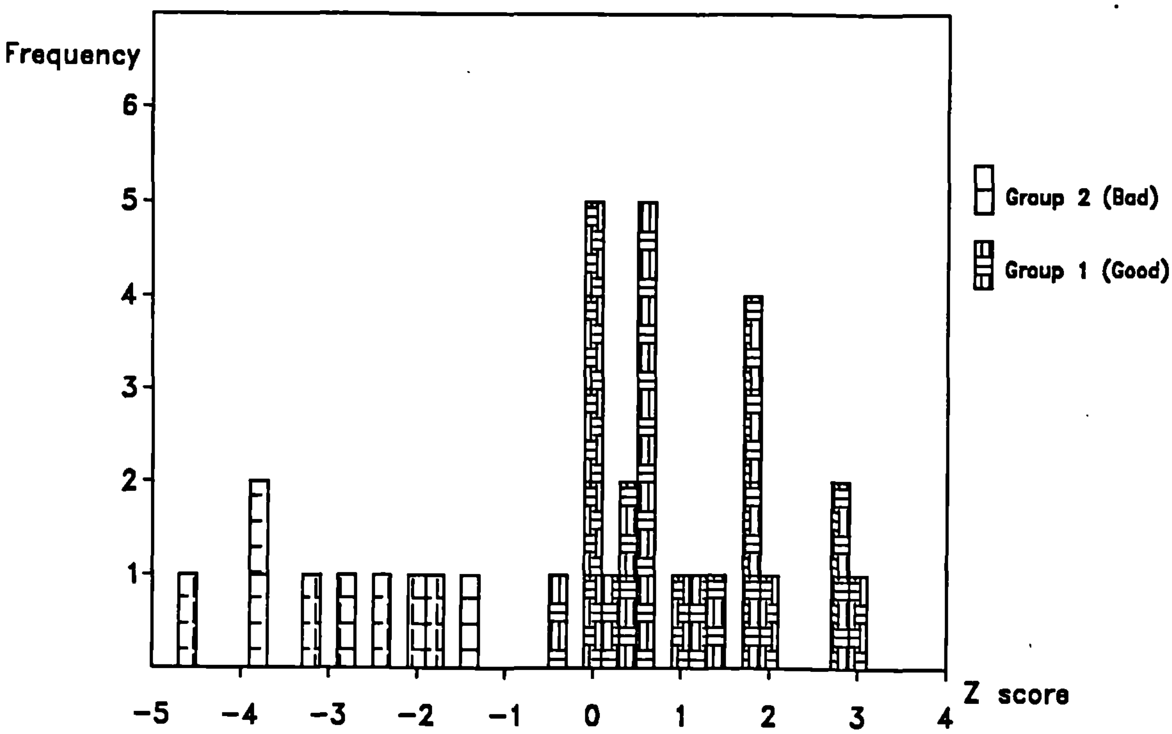


Figure 5 All Groups Stack Histogram for Model Z2

7.5 CLASSIFICATION POWER

The classification power of the Z_2 model is gauged by the following methods:

7.5.1 PERCENTAGE OF CASES CLASSIFIED CORRECTLY

Table 22 illustrates the overall classification results of the model revealing that the overall classification is intact.

Table 22 Overall Classification Results of the Z_2 Model

Actual Group	No. of Cases	Predicted Group Membership	
		Group 1	Group 2
Group 1	25	25 (100%)	0 (0%)
Group 2	9	0 (0%)	9 (100%)

The discriminant scores and the classification of the individual cases are shown in Table 21 and the distributions of frequency of the two groups are illustrated in Figure 5. The results demonstrate that the effectiveness of classification is high and the two groups are well separated by the discriminant model Z_2.

7.5.2 THE BETWEEN GROUPS AND WITHIN GROUPS VARIABILITIES

This is scaled by Eigenvalues as described in Section 3.5.2 of Chapter 3. Large Eigenvalues mean 'good' classification and the

Eigenvalue is gauged as:

$$\text{Eigenvalue} = \frac{\text{Between Groups Sum of Squares}}{\text{Within Groups Sum of Squares}} = 3.05139$$

The value is large enough to be considered that the model is powerful in classification.

7.5.3 THE CANONICAL CORRELATION

This is the correlation which measures the association between the discriminant scores and the groups. The value is 0.868 which is high enough to be believed that classification is good and effective.

7.6 Z_3 MODEL CONSISTING OF NEW WORKS ONLY

Thirty cases falling into the group of new building and new building related civil engineering works selected from the main Z_2 model were applied to generate a sub-model which excluded renovation and alteration works. The purpose of the sub-model is to investigate if there are any differences between the sub-model and the main model.

Table 23 Number of Cases by Group in the Z_3 Model

Performance	No. of Cases
1	22
2	8
Total:	30

7.6.1 THE RESULTANT Z_3 MODEL

(Details of computer generation of the model are described in Appendix 5.)

In this Z_3 study, the six variables found in the Z_2 discriminant function were re-modelled and the following linear function resulted:

$$\begin{aligned}\text{Discriminant function} = & - 0.6347\ (\text{COMPLEX}) \\ & + 9.6270\ (\text{PROF\_STA}) \\ & + 0.0812\ (\text{LEAD\_EX}) \\ & - 1.5578\ (\text{PAST\_PER}) \\ & + 0.7796\ (\text{ORIGIN}) \\ & + 1.0709\ (\text{CONTROL}) - 1.0049\end{aligned}$$

where

COMPLEX : The complexity of the project

PROF_STA: Percentage of professional qualified staff

LEAD_EX : Project leader's experience

PAST_PER: Contractor's past performance or image

ORIGIN : Origin of the company

CONTROL : Architect's or client's supervision and control on the quality of work and work progress

The standardized discriminant function coefficients and their priority order of contribution to the Z_3 and Z_2 discriminant functions are illustrated in Table 24.

From Table 24, it is noticed that the priority orders of COMPLEX and PROF__STA were exchanged. This infers that for new projects, the complexity of a project plays a more important role than when all types of building works are considered in determining contractor performance.

Table 24 Standardized Discriminant Function Coefficients and their Priority Order of Contribution to the Z_3 and Z_2 models

Variables	Z_3 Model		Z_2 Model	
	Standardized Discriminant Function Coefficients	Order of Contribution	Standardized Discriminant Function Coefficients	Order of Contribution
COMPLEX	-0.98426	2	-0.8867	4
PROF_STA	0.76314	4	0.9110	2
LEAD_EX	0.54974	5	0.6372	5
PAST_PER	-0.98495	1	-1.1000	1
ORIGIN	0.50646	6	0.5184	6
CONTROL	0.96312	3	0.8870	3

The classification results, the frequency distribution and the discriminant scores of the cases in the Z_3 model are shown in Table 25 and Figure 6. Both indicate that the classification is good in separating the two groups.

7.6.2 PERCENTAGE OF CASES CLASSIFIED CORRECTLY

Table 26 illustrates the perfect overall classification results of the model.

7.7 Z_4 MODEL CONSISTING OF BUILDING WORKS ONLY

Twenty-six cases falling into the group of building works only selected from the main Z_2 model were applied to generate a

Table 25 Classification Results and the Discriminant Scores of Cases in the Z_3 Model

Case	Actual Group	Discriminant Scores	Classified Group	Classification
1	1	2.9762	1	Correct
2	1	1.8598	1	Correct
3	1	0.1397	1	Correct
4	2	-1.7411	2	Correct
5	1	-0.0717	1	Correct
6	2	-1.1572	2	Correct
7	1	0.5630	1	Correct
8	1	0.1268	1	Correct
9	1	0.7253	1	Correct
10	1	0.7253	1	Correct
11	1	1.7045	1	Correct
12	1	0.9823	1	Correct
13	1	0.9461	1	Correct
14	1	2.9889	1	Correct
15	1	0.4601	1	Correct
16	1	0.6486	1	Correct
17	1	1.6484	1	Correct
18	1	1.8556	1	Correct
19	1	2.5455	1	Correct
20	2	-3.4364	2	Correct
21	1	0.2428	1	Correct
22	2	-4.3456	2	Correct
23	1	-0.1747	1	Correct
24	2	-3.8283	2	Correct
25	2	-2.8234	2	Correct
26	2	-2.2573	2	Correct
27	1	0.1483	1	Correct
28	2	-2.7203	2	Correct
29	1	1.3547	1	Correct
30	1	-0.0858	1	Correct

Table 26 Overall Classification Results of the Z_3 Model

Actual Group	No. of Cases	Predicted Group Membership	
		Group 1	Group 2
Group 1	22	22 (100%)	0 (0%)
Group 2	8	0 (0%)	8 (100%)

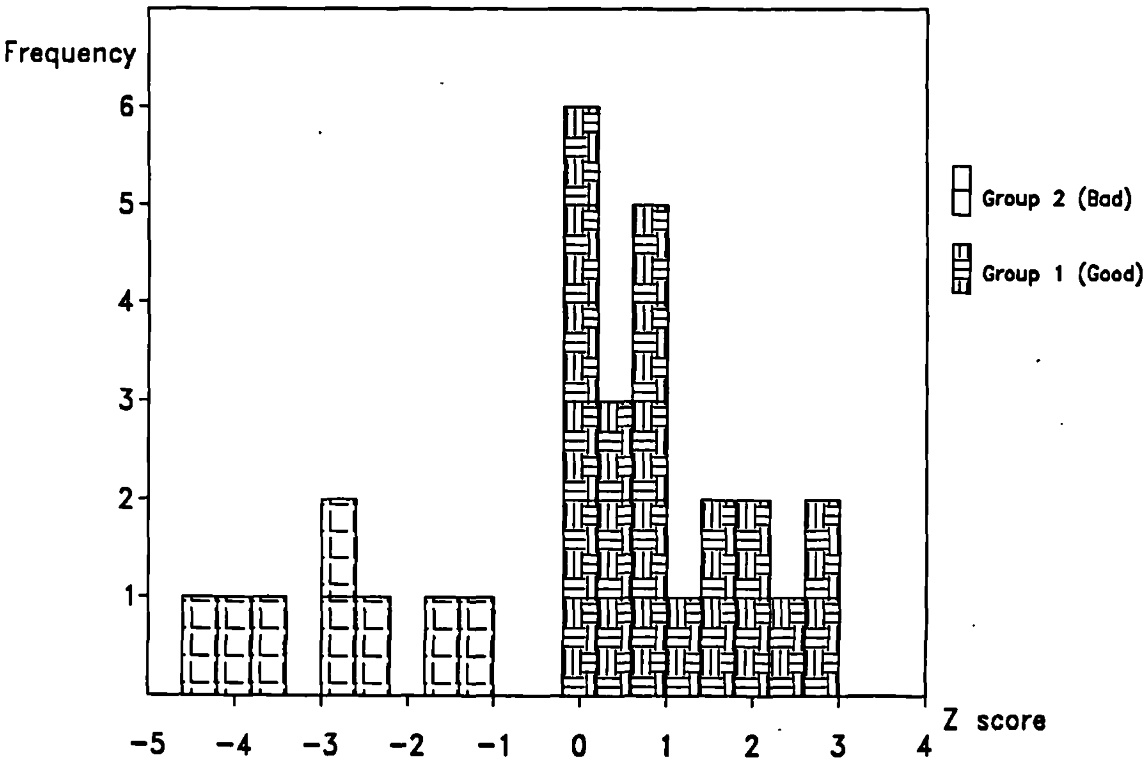


Figure 6 All Groups Stacked Histogram for Model Z3

sub-model which excluded renovation, alteration and civil engineering works. The purpose of the sub-model is to investigate if there are any difference between the sub-model and the main model.

Table 27 Number of Cases by Group in the Z_4 Model

Performance	No. of Cases
1	18
2	8
Total:	26

7.7.1 THE RESULTANT Z_4 MODEL

(Details of computer generation of the model are described in Appendix 6.)

In this Z_4 study, the six variables found in the Z_2 discriminant function were re-modelled and the following linear function resulted:

Discriminant function = - 0.5626 (COMPLEX)
+10.6218 (PROF_STA)
+ 0.0931 (LEAD_EX)
- 1.7666 (PAST_PER)
+ 0.7885 (ORIGIN)
+ 1.0347 (CONTROL) - 0.7053

The standardized discriminant function coefficients and their priority order of contribution to the Z_4 and Z_2 discriminant functions are illustrated in Table 28.

Table 28 Standardized Discriminant Function Coefficients and their Priority Order of Contribution to the Z_4 and Z_2 models

Variables	Z_4 Model		Z_2 Model	
	Standardized Discriminant Function Coefficients	Order of Contribution	Standardized Discriminant Function Coefficients	Order of Contribution
COMPLEX	-0.6857	3	-0.8867	4
PROF_STA	0.5756	5	0.9110	2
LEAD_EX	0.6718	4	0.6372	5
PAST_PER	-1.0436	1	-1.1000	1
ORIGIN	0.4552	6	0.5184	6
CONTROL	0.8874	2	0.8870	3

The results in Table 28 show that the importance of the percentage of professional staff has dropped from rank 2 to 5 while the priority orders of the complexity of project, project leader's experience and architects' or clients' supervision and control have escalated. This infers that for building works, the percentage of professional staff plays a less important role in determining contractor performance. This is perhaps due to the paradoxical nature of this variable that high percentage means better management quality and better claim expertise as explained in Section 7.3.2.

The classification results, the frequency distribution and the discriminant scores of the cases in the Z_4 model are shown in Table 29 and Figure 7. Both indicate that the classification is good in separating the two groups.

Table 29 <u>Classification Results and the Discriminant Scores of Cases in the Z_4 Model</u>

Case	Actual Group	Discriminant Scores	Classified Group	Classification
1	1	2.1629	1	Correct
2	1	0.3836	1	Correct
3	2	-1.5390	2	Correct
4	1	0.1540	1	Correct
5	2	-1.0627	2	Correct
6	1	0.7166	1	Correct
7	1	0.2445	1	Correct
8	1	0.9027	1	Correct
9	1	0.9027	1	Correct
10	1	1.9281	1	Correct
11	1	3.1121	1	Correct
12	1	0.7229	1	Correct
13	1	0.9521	1	Correct
14	1	1.7551	1	Correct
15	1	2.1300	1	Correct
16	1	3.0996	1	Correct
17	2	-3.5017	2	Correct
18	1	0.4867	1	Correct
19	2	-4.2062	2	Correct
20	1	0.1603	1	Correct
21	2	-3.6410	2	Correct
22	2	-2.4880	2	Correct
23	2	-2.1978	2	Correct
24	1	0.2305	1	Correct
25	2	-2.8514	2	Correct
26	1	1.4433	1	Correct

Table 30 Overall Classification Results of the Z_4 Model

Actual Group	No. of Cases	Predicted Group Membership	
		Group 1	Group 2
Group 1	18	18 (100%)	0 (0%)
Group 2	8	0 (0%)	8 (100%)

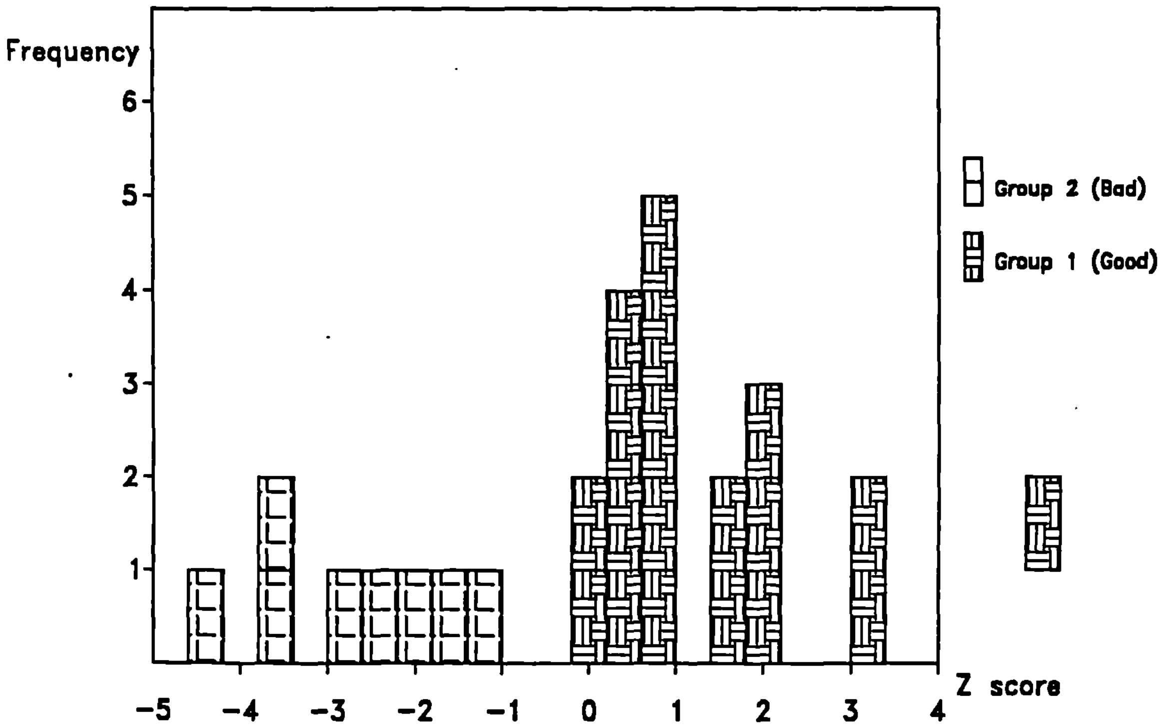


Figure 7 All Group Stacked Histogram for Model Z4

7.7.2 PERCENTAGE OF CASES CLASSIFIED CORRECTLY

Table 30 illustrates the perfect overall classification results of the model.

7.8 COMPARING MODELS Z_2, Z_3 AND Z_4

The above sections demonstrate that the three models are very similar in nature although having a small deviation in the priority order of some predictive variables. Table 31 shows the standardized discriminant function coefficients of the three models.

Table 31 Standardized Discriminant Function Coefficients of Z_2, Z_3 AND Z_4 MODELS

	Standardized Discriminant Function Coefficients		
	Z_2 Model	Z_3 Model	Z_4 Model
Types	All Projects	New Works Only	Building Works Only
No. of Cases	34 cases	30 cases	26 cases
Variables			
COMPLEX	-0.8867	-0.9843	-0.6857
PROF_STA	0.9110	0.7631	0.5756
LEAD_EX	0.6372	0.5497	0.6718
PAST_PER	-1.1000	-0.9850	-1.0436
ORIGIN	0.5184	0.5065	0.4552
CONTROL	0.8870	0.9631	0.8874

It is worth noting that the contribution of the percentage of professional staff drops enormously from model Z_2 to Z_4. This is perhaps due to the paradoxical nature of this variable that high percentage means better management quality and better claim expertise as explained in Section 7.3.2.

Basically the contributions of the predictive variables of the three models follow a very close pattern and their classification results are ideal.

7.9 SUMMARY AND CONCLUSION

The results from applying the linear discriminant analysis technique produced a linear discriminant model made up of six variables measuring the aspects of the personnel characteristics, company reputation, origin of firms, special features of the job and the project team's influences on contracting firms and projects.

There was no misclassification in the model which demonstrated that separation of the two groups was effective. Further, it will be demonstrated in Chapter 10 that the percentage of 'grouped' cases correctly classified by applying the model Z_2 to a test group with 16 cases was found to be 87.5%. Having such a high classification power, it is believed that there is an underlying structure influencing contractor performance.

The priority order of contribution of each factor to the function is as follows:

1. Past Performance
2. Percentage of Professional Staff
3. Client's or architect's supervision and control
4. Complexity of the Project
5. Project Leader's Experience
6. Origin of the Contracting Firm

The results show that the factors, 'Project Leader's Experience' and 'Origin of the Contracting Firm' are the least discriminant of the variables while 'Past Performance' and 'Percentage of Professional Staff' are relatively more important than others.

The cut-off value of the Z_2 model was derived to be at -0.8757 below which performance is more likely to be poor. In the bid evaluation process, clients can consider the tender cost as well as the predictive performance arrived using the Z_2 model. Tenderers with poor predictive performance can be removed from shortlist as quality, time of completion and cost would most likely not meet clients' expectation.

Two sub-models of new works and building works only were also derived to investigate if there are any deviations from the main model. The results demonstrate that the divergence is very small and all the three models have a very good classification power.

The priority order of contribution of each factor to the Z_3 function (consists of new works only) is as follows:

1. Past Performance
2. Complexity of the Project
3. Client's or architect's supervision and control
4. Percentage of Professional Staff
5. Project Leader's Experience
6. Origin of the Contracting Firm

The priority order of contribution of each factor to the Z_4 function (consists of building works only) is as follows:

1. Past Performance
2. Client's or architect's supervision and control
3. Complexity of the Project
4. Project Leader's Experience
5. Percentage of Professional Staff
6. Origin of the Contracting Firm

The only point worth noting is the factor, the percentage of professional staff, whose contribution to the models drops significantly from Z_2 to Z_4. The priorities of the variables, past performance of contractors and the origin of the company, remain unchanged throughout.

CHAPTER 8

INTERVIEW SURVEY TO STRUCTURE CLIENTS' UNSTRUCTURED APPROACH IN CONTRACTOR SELECTION

8.1 INTRODUCTION

Although most clients do not have a structured approach in the contractor selection process, it is believed that there are some criteria relevant to the the selection process. In order to find out the ways that clients handle the process and verify the results with the discriminant model developed, an interview survey was conducted.

The purpose of the survey is to find out the criteria which clients consider in the selection process and the ways they measure the factors. The interviewees were selected amongst the largest clients in Hong Kong which includes the director of the largest public housing organisation which provides more than 50% of the total annual supply of housing in Hong Kong.

8.2 INTERVIEW

The study reported in this Chapter is derived from an interview survey of construction industry clients in Hong Kong, the aim of which was to find out clients' decision patterns and practices upon contractor selection and the ways they gauge the factors. The interview questions are shown in Figure 12.

Figure 12 Form of Interview Questions Used in the Interview Survey

CONTRACTOR SELECTION CRITERIA

1. What are the criteria your organisation adopted in contractor selection besides bidding prices?

___

___

2. How do you assess the past performance of contractors?

___

___

3. Are there any additional screening procedures or requirements for complex projects? And what are they if any?

___

___

4. Do you agree that staff quality will be attributable to contractor performance and if agree how do you measure it ?

___

___

5. Do you agree that the experience of the project manager will be attributable to contractor performance and if agree how do you measure it?

___

___

6. What action would you take if the contractor performance is likely to be poor? Will you exercise tighter project control?

___

___

7. What do you mean by 'tighter' control?

___

___

8. Will you treat overseas contractors differently? Why?

___

___

Since interviewees are the representatives of the large developers, project management consultants and the largest public housing organisation in Hong Kong, they have much experience in the contractor selection process and can reflect clients' actual concern on the determinants of performance. The total number of interviewees in this survey is ten.

8.3 RESULTS

The survey results are summarised in Figure 13, 14, 15, 16, 17, 18, 19.

8.3.1 COMPARING THE SURVEY RESULTS WITH THE DISCRIMINANT MODEL

The discriminant model Z_2 has identified six variables with the strongest contribution to the scale of performance in the following priority order:

- Past performance
- Percentage of professional staff
- Clients' control
- Complexity of the project
- Project leader's experience
- Origin of the contractor

Likewise, the survey discovers that the three most frequently highlighted criteria in contractor selection are past

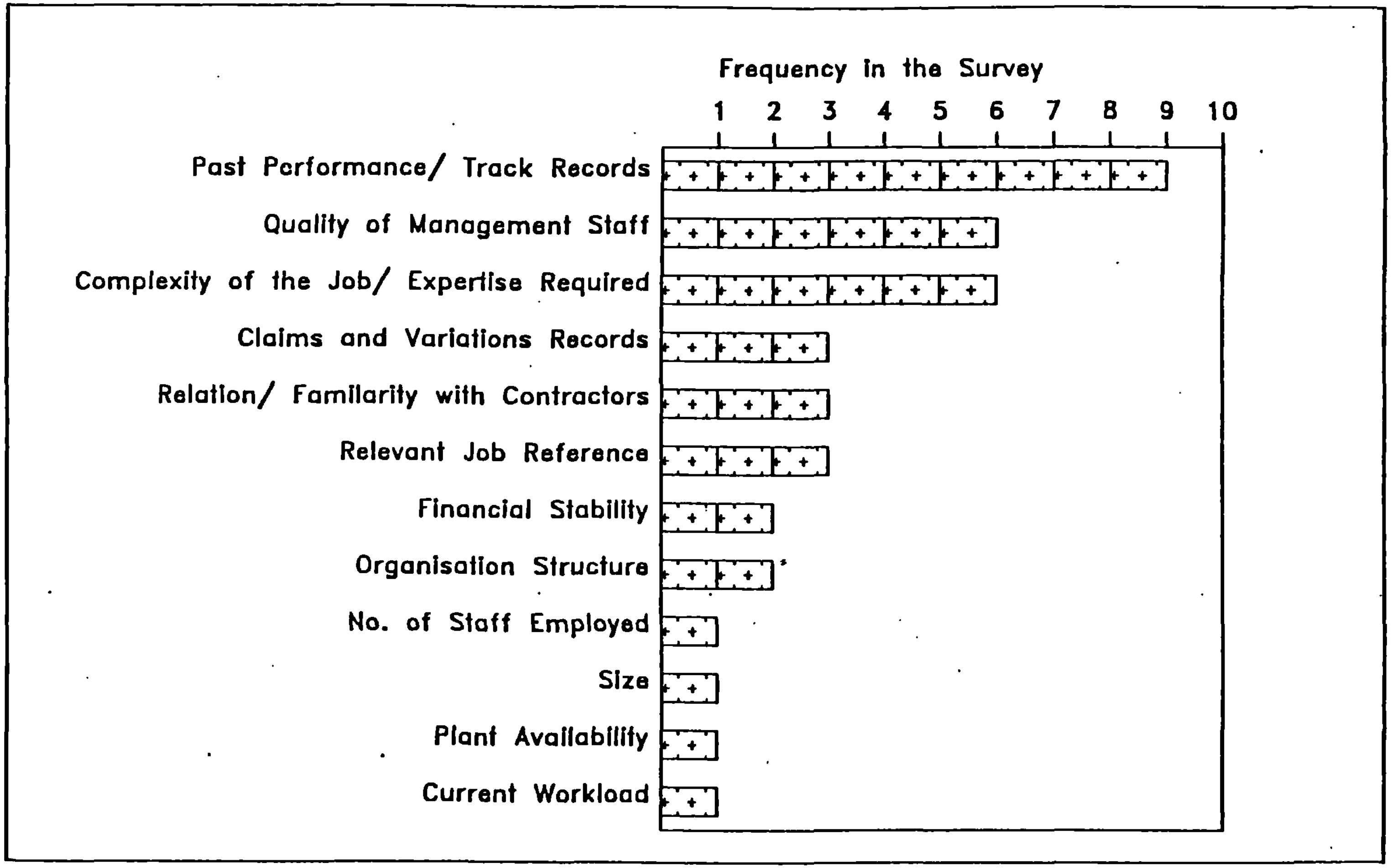


Figure 13 Criteria in Contractor Selection Other Than Bidding Prices

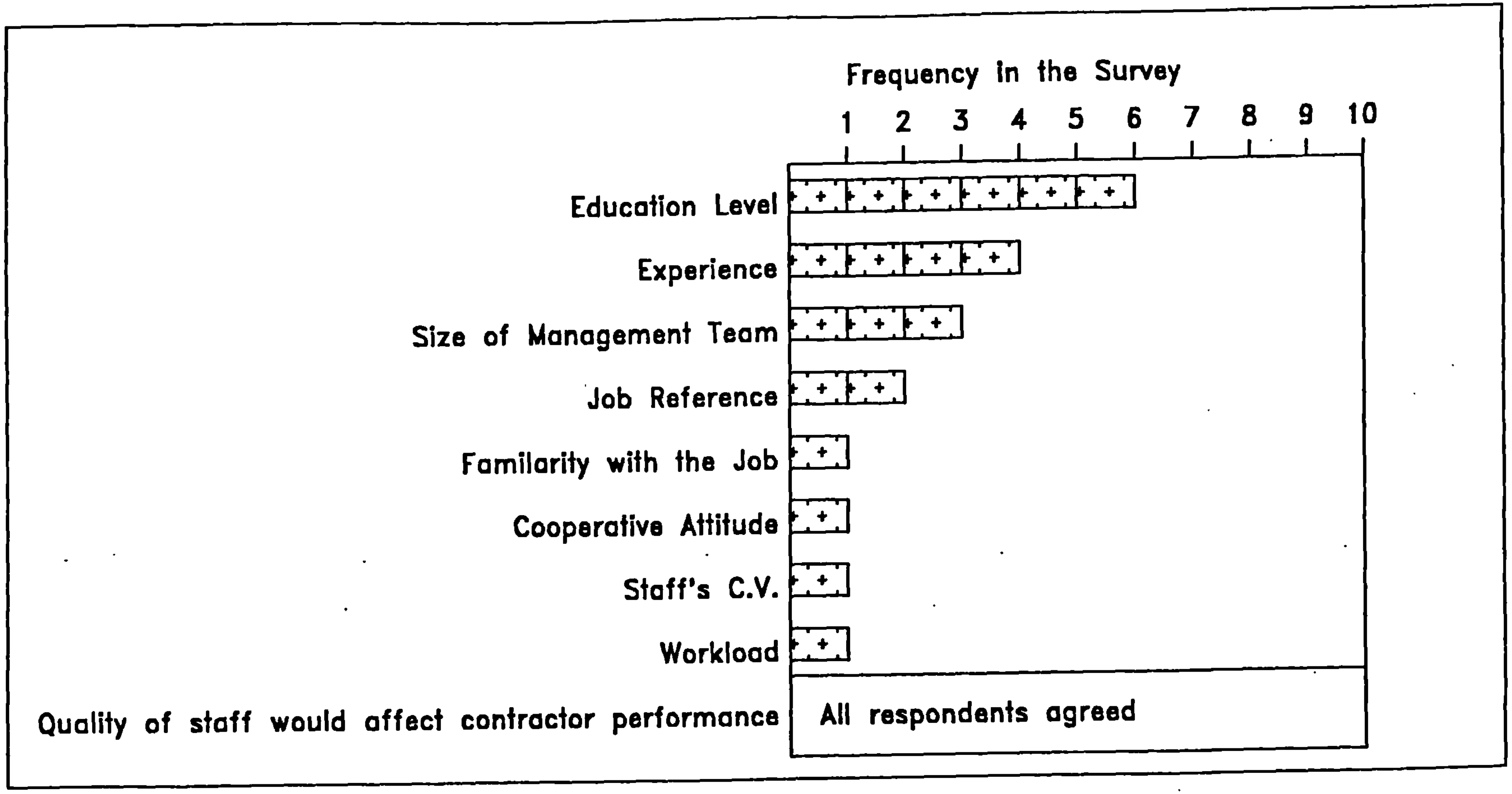


Figure 14 Clients' Perception on Quality of Staff and Its Importance

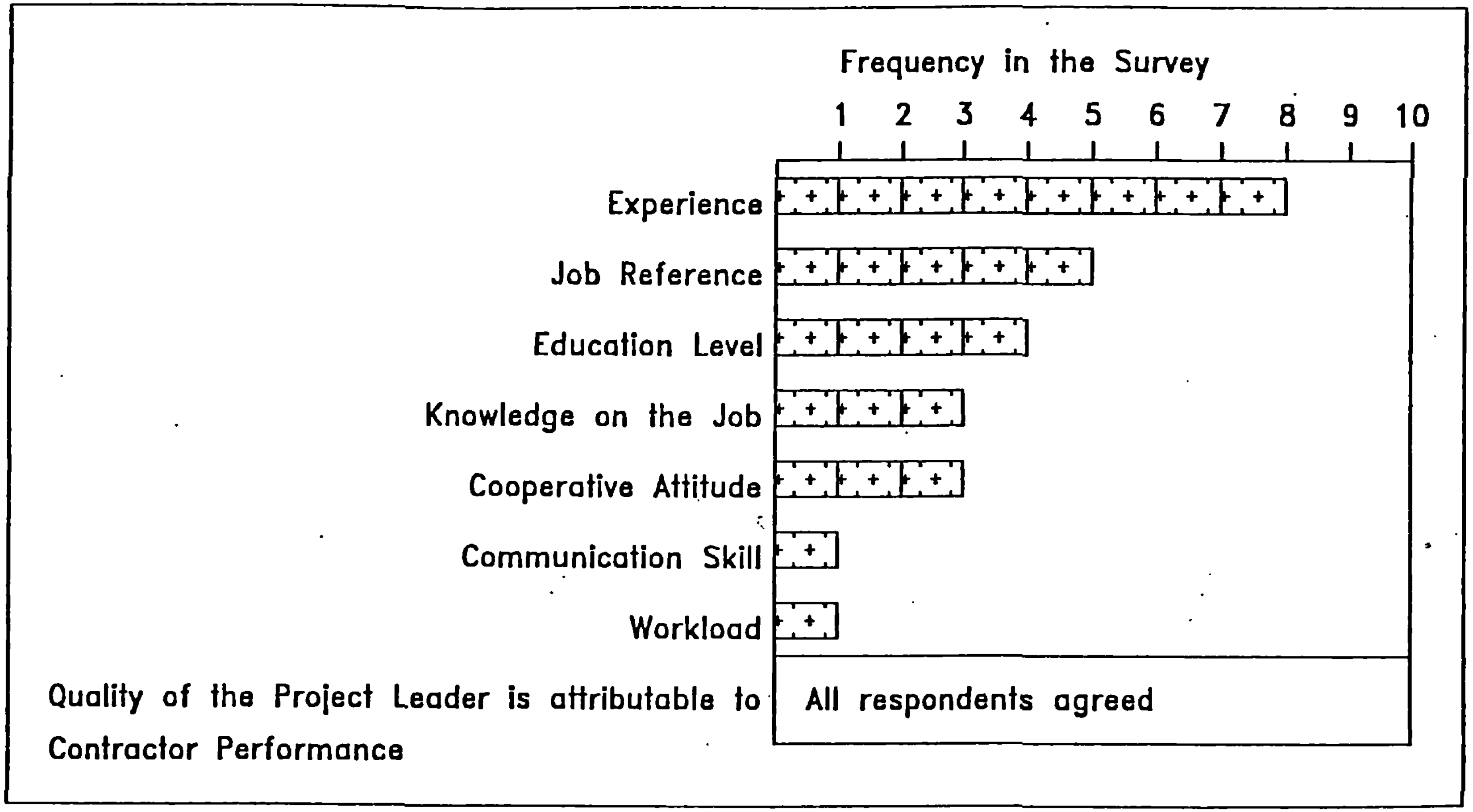


Figure 15 Clients' Perception on Quality of the Project Leader and Its Importance

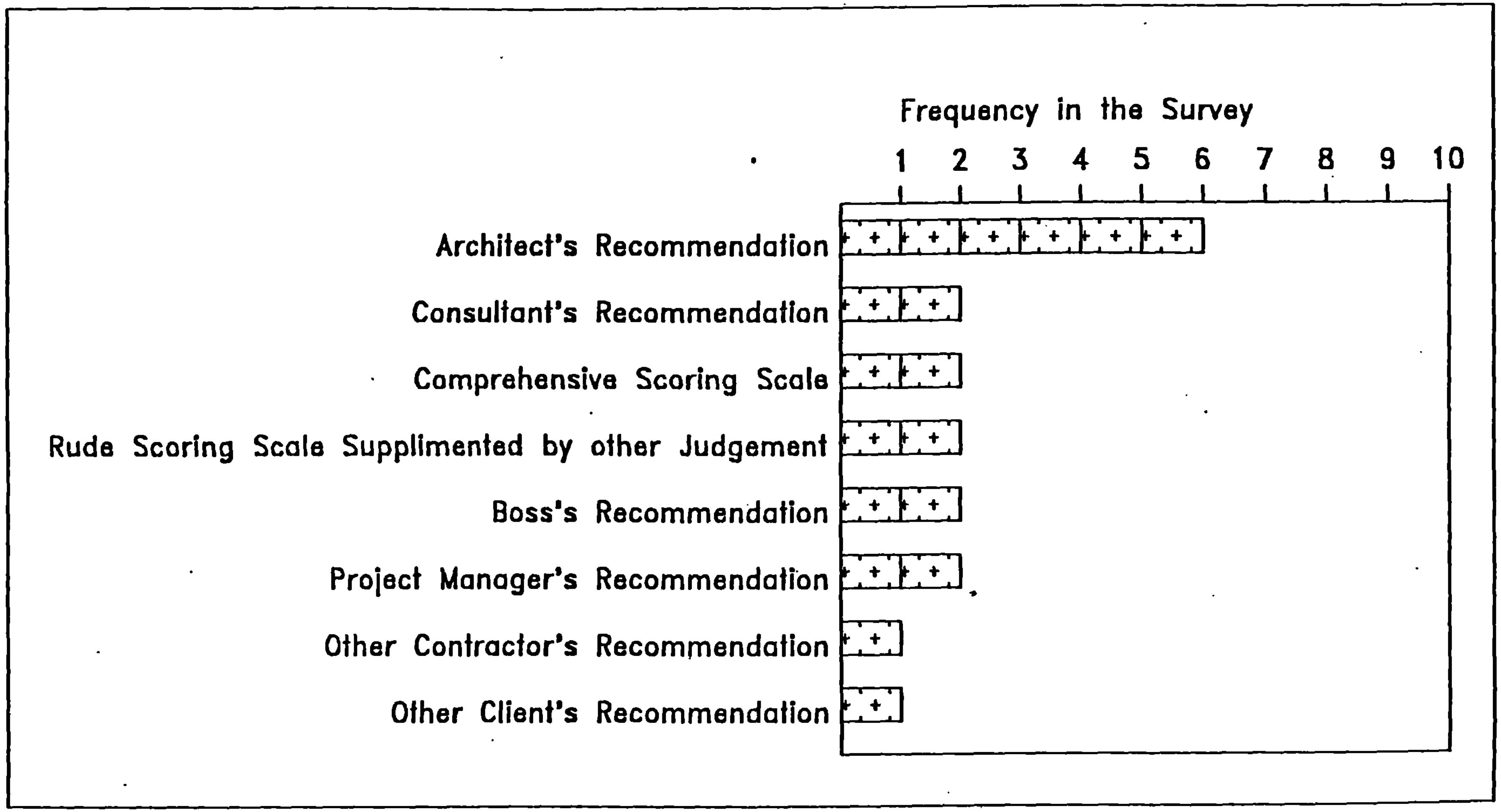


Figure 16 Various Approaches to Measure Past Performance

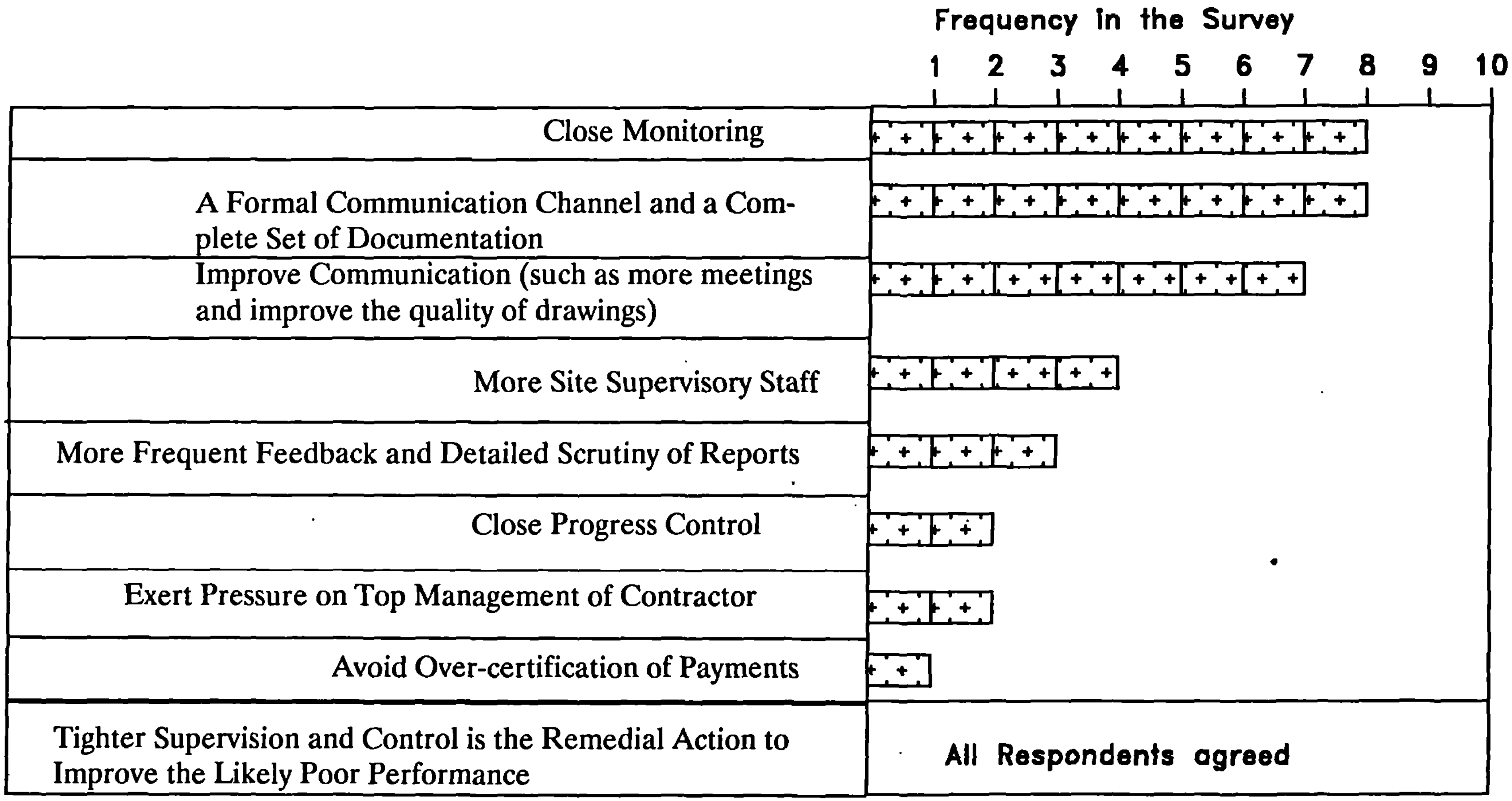


Figure 17 The Ways That Clients Define Tight Control And Its Importance

	INTERVIEWEES									
	1	2	3	4	5	6	7	8	9	10
CLIENTS' ATTITUDE IN DEALING WITH OVERSEAS CONTRACTORS										
Tighter Control and Supervision	#	No Experience	No Experience			No Experience	No Experience	No Experience	N.E.	N.E.
Communicate Formally and Keep Documentation Properly	#									
Avoid Dealing with Overseas Contractors unless a Special Expertise is Required				#						
CLIENTS' PERCEPTION ON OVERSEAS CONTRACTORS										
Claims and Variations Conscious	#	No Experience	No Experience	#	#*	No Experience	No Experience	No Experience	N.E.	N.E.
Like to Play the Contract with Clients and Consultants	#			#	#*					
High Preliminary				#						

*: It is the interviewee's policy not to prejudice overseas contractors

Figure 18 Clients' Attitude and Perception on Overseas Contractor

	INTERVIEWEES										Frequency
	1	2	3	4	5	6	7	8	9	10	1 2 3 4
Financial Capacity/ Stability	#			No Experience	Criteria set at ad hoc basis	No Experience	#	No Specific Screening Procedures	No Experience	#	+ + + + + +
Feasibility of the Proposed Method Statement	#	#	#								+ + + + + +
Feasibility of the Proposed Programme	#	#	#								+ + + + + +
Workload							#			#	+ + + +
Expertise			#							#	+ + + +
Project Leader's C.V.		#									+ +
Quality of Staff										#	+ +

Figure 19 Additional Screening Requirements for Large and Complex Projects

performance, quality of management staff and complexity of the project/ expertise required which corresponds to the model's findings (see Figure 13).

The survey also reveals that all the respondents agreed that the quality of management staff and experience of the project leader could affect contractor performance and the way to remedy the likely poor performance was to exercise tighter supervision and control.

As regards overseas contractors, only three out of the ten interviewees had experience in dealing with them and all the three respondents agreed that overseas contractors were more difficult to deal with as they were more claims and variations conscious and had the know-how to play the contract with clients. In dealing with them, clients would exercise tighter supervision and maintain a more formal communication channel and documentation.

In conclusion, the survey results basically match well with that of the discriminant model. That means that clients are concerned about the determinants of the predictive performance although they do not have a structured approach to assess them.

8.3.2 WAYS TO QUANTIFY VARIABLES

8.3.2.1 QUALITY OF MANAGEMENT STAFF AND THE PROJECT LEADER

The quality of management staff embraces a variety of constituents; however, most are difficult to quantify and collect. The survey shows that the education level is the most frequently highlighted constituent by the respondents and is the easy measurable variable and thus was adopted in building the discriminant model.

Similarly, the quality of the project leader is difficult to define and composed of many determinants. However, experience is most frequently highlighted by respondents in the survey and was adopted in building the discriminant model.

8.3.2.2 PAST PERFORMANCE

The survey shows that there were two out of the ten respondents totally relying on comprehensive performance appraisal systems to assess past performance, another two had rude scoring scales supplimented with human judgements, the rest relied purely on individuals' recommendations. It seems that there was not a unified approach in the assessment.

It is thus recommended, for the purpose of applying the discriminant model for organisations where no comprehensive performance appraisal system exists, that the average of the client's, the architect's and consultant's recommendations gauged in five ranges be adopted; that is good, better than average, fair, poorer than average, poor, is taken to be the assessment of past performance.

In cases where a comprehensive performance appraisal system exists, the five extents (good, better than average, fair, poorer than average, poor) are represented by mark ranges where each range embodies 20% of the total recorded cases.

8.3.2.3 CLIENT'S SUPERVISION AND CONTROL

The survey cannot evidence any systematic approaches to measure this factor; however, clients' perception on 'tighter control' was identified (see Figure 17).

It is thus recommended, for the purpose of applying the discriminant model, that the degree of control is gauged by the number of positive or negative responses to the actions described (refer to Figure 17) and then measured by the following rule:

Action Taken	Type of Control
Most answers are positive	Tight
A few positive answers	Tighter than average
Most answers are neutual	Fair
A few negative answers	Looser than average
Most answers are negative	Loose

Actions:
- -Close supervision
- -Communicate formally and maintain a complete set of documentation as evidence for future disputes
- -More site supervisory staff
- -More frequent feedback and detailed scrutiny of reports
- -Close progress control
- -Exert pressure on the top management of the contractor
- -Avoid over-certification of payments

8.3.3 ADDITIONAL SCREENING REQUIREMENTS FOR LARGE AND/ OR COMPLEX PROJECTS

Besides the general criteria described in the contractor selection process, the survey also identifies the additional screening requirements for large and/ or complex projects (see Figure 19). For these types of projects, clients should examine contractors in more detail.

8.4 SUMMARY AND CONCLUSION

This Chapter has described an interview survey which was aimed comparing the criteria that clients are currently exercising in contractor selection with the developed discriminant model, and to find ways to quantify the variables.

The results demonstrate that the current practice in contractor selection is very close to the factors that the discriminant model has investigated.

As regards the provision of a more quantitative system for evaluating the vaguely defined variables; past performance and the client's control and supervision, this Chapter has recommended the approaches which enable the discriminant model more easy to apply.

CHAPTER 9

COMPARING THE DISCRIMINANT ANALYSIS MODEL WITH MULTIPLE REGRESSION ANALYSIS AND UNIDIMENSIONAL SCALING MODELS

9.1 INTRODUCTION

In this Chapter, two models other than the discriminant analysis approach were developed to verify with the discriminant analysis model namely:

a) Multiple Regression Analysis Model; and
b) Unidimensional Scaling Model.

These two models are less complicated than the discriminant model both in terms of mathematical theroies and computations. Multiple regression closely resembles discriminant analysis as explained in Section 3.4 of Chapter 3. The unidimensional scaling model was designed to scale persons, stimuli, or both persons and stimuli. The main shortfall of the scaling model is the neglect of interrelationship between the predictive variables. These two models will be discussed in the following pages.

9.2 MULTIPLE REGRESSION ANALYSIS MODEL

Researchers in the social sciences, business, policy studies and other areas rely heavily on the use of regression analysis[27]. The frequency with which the technique is employed can be demonstrated by a review of articles in professional journals such as the American Econmics Review, Journal of Policy Analysis and Management, Journal of Marketing, etc.

Multiple linear regression analysis is a method for measuring the effects of several factors concurrently. There are numerous occasions where the use of multiple regression analysis is appropriate, as in social science, there normally are a number of factors determining the outcome of a dependent variable.

The concept of multiple regression analysis is identical to that of simple regression analysis except that two or more independent variables are used simultaneously to explain the dependent variables.

9.2.1 THE REGRESSION MODEL

The regression model is in the following form:

$$C = \alpha + B_1X_1 + B_2X_2 + \ldots + B_nX_n$$

Where α is a constant.

B_n is the coeficients for X_n.

X_n is the independent variable determining the outcome of C.

9.2.2 THE STANDARDIZED COEFFICIENTS

In multiple regression analysis, standardized coefficients are also used as in the discriminant model and interpreted as indicators to measure the contribution of each independent variable to the model. Likewise, coefficients are standardized to a unity standard deviation and a zero mean.

Unlike the discriminant model, standardized coefficients are named as beta coefficients in multiple regression. The standardized coefficients measure the change in the dependent variable (measure in standard deviations) that results from a one-standard-deviation change in the independent variables[27].

Thus,

Beta Coefficient = $B_1 * (S_x/S_y)$

where B_1 is the regression coefficient

S_x is the standard deviation of the independent variable.

S_y is the standard deviation of the dependent variable.

9.2.3 ASSUMPTIONS IN APPLYING THE MODEL

To draw inferences about population values based on sample results, the following assumptions are needed to be met. However, it has been demonstrated that regression analysis is generally robust in the presence of departures from assumptions[30].

9.2.3.1 NORMALITY AND EQUALITY OF VARIANCE

For any fixed value of the independent variable, the distributions of the dependent variables should be normal and have constant variances (see Figure 8).

9.2.3.2 INDEPENDENCE

The data set should be non-collinear or non-multicollinear. More precisely, a set of observations on a collection of independent variables is said to be non-collinear if no one variable is a linear combination of the others.

9.2.3.3 LINEARITY

The mean values of the dependent variable all lie on a straight line, which is the population regression line. An alternative way of stating this assumption is that the linear model is correct.

9.2.4 GOODNESS OF FIT

The coefficient of determination (the R square) is the most commonly used measure of the goodness of fit of a linear model. The R square statistic measures closeness as the percentage of total variation in the dependent variable explained by the regression line.

If the data points were all to lie directly on the regression model, the observed values of the dependent variable would be

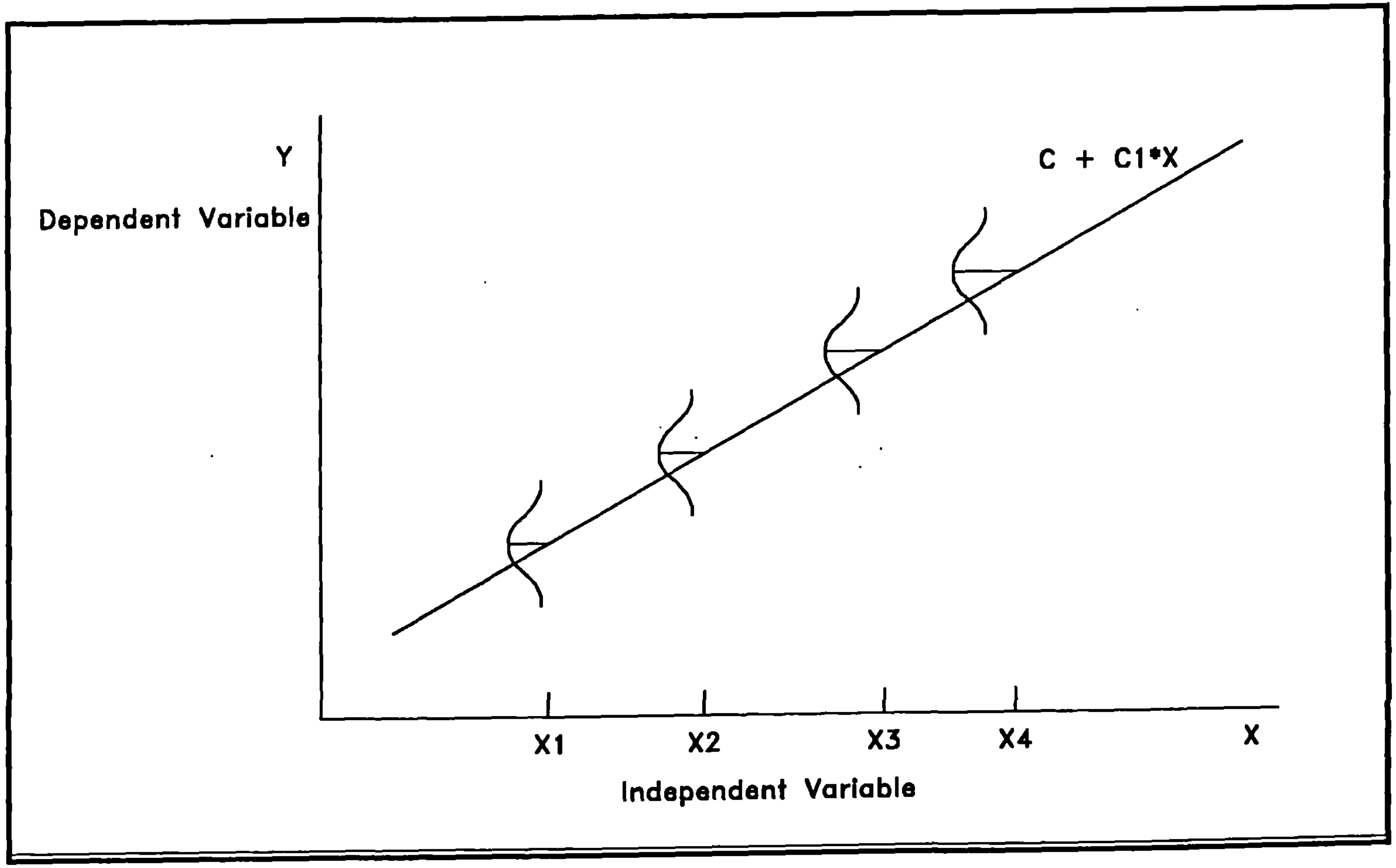


Figure 8 Regression Assumptions

equal to the predicted values, and the R square would be equal to 1. As the independent varaible explains less and less of the variation in the dependent variables, the value R square falls toward zero.

The sample R square tends to be an optimistic estimate of how well the model fits the population. The model usually does not fit the population as well as it fits the sample from which it is derived. The value of the coefficient of determination will never decrease when another variable is added to the regression. Although the additional variable may be of no use whatsoever in explaining variations in the dependent variable, it cannot reduce the explanatory value of the previously included variables. Since including additional variables can never decrease the value of R square and normally increase it, it is common to use the adjusted R square which is adjusted for the number of independent variables used in the regression. Thus it is possible that by adding another independent variable to the regression, the adjusted R square will decrease although R square actually increases. Hence, the statistic adjusted R square is to correct R square to more closely reflect the goodness of fit of the model in the population. The adjusted R square is derived as follows[13]:

$$R_a^2=R^2 - \{p(1-R^2)/(N-p-1)\}$$

Where p is the number of independent variables in the equation

N is the number of observations

For this reason, the adjusted R square is used to determine whether including another independent variable increases the explanatory power of the regression.

9.2.5 STEPWISE REGRESSION

Since decisions regarding which of numerous possible variables to include in a regression equation are difficult, stepwise regression techniques are used to remove the unsignificant variables. These techniques which are most commonly used[13], allow the investigation of different combinations of independent variables. The selection criterion is usually based on the partial correlation coefficient, the coefficient of determination, R square and whether the inclusion of the variable would be significant which is tested by the F distribution.

In the stepwise regression, simple linear regressions using each of all the possible independent variables specified will be generated. The one having the largest partial correlation coefficient and producing the highest R square and meanwhile passing the F-distribution test will be selected. In step 2, the remaining independent variables together with the variable chosen in step 1 will be used to produce different regression results each with two independent variables. The one combination generating the highest R square will be selected. This process continues until all the variables are included in the equation or no remaining variable increases the R square statistic sufficiently to permit the inclusion of additional variables or combinations cannot pass the F-distribution test.

9.2.6 THE RESULTANT MODEL

(Details of computer generation of the model are described in Appendix 7.)

The selection method used in developing the model is the 'stepwise selection' which incorporates both the 'forward selection' and the 'backward elimination' approaches. The first variable is examined to see whether it should be removed according to the removal criterion and then variables not in the equation are examined for entry. The following model is developed:

$$\begin{aligned} PERFORM = &+ 0.36853(PAST\_PER) + 0.1355(COMPLEX) \\ &- 0.22549(CONTROL) - 0.02055(LEAD\_EX) \\ &- 1.42476(PROF\_STA) + 0.92865 \end{aligned}$$

where COMPLEX : The complexity of the project

PROF_STA: Quality of management team-
Professional qualifications

LEAD_EX : Quality of management team-
Project leader's experience

PAST_PER: Contractor's past performance or image

CONTROL : Architect's or client's supervision and control on the quality of work and work progress

9.2.7 THE RELATIVE IMPORTANCE OR CONTRIBUTION OF VARIABLES TO THE MODEL

The order of contribution of variables to the model are shown in Table 33.

Table 32 Unstandardized Partial Regression Coefficients

Varibles	Unstandardized Partial Regression Coefficients
COMPLEX	0.1355
PROF_STA	-1.42476
LEAD_EX	-0.02055
PAST_PER	0.36853
CONTROL	-0.22549
(constant)	0.92865

Table 33 Beta Coefficients (Standardized Regression Coefficients)

Varibles	Beta Coefficients (Standardized Partial Regression Coefficients)	Order of Contribution
COMPLEX	0.48856	2
PROF_STA	-0.24559	5
LEAD_EX	-0.30394	4
PAST_PER	0.64489	1
CONTROL	-0.48198	3

The past performance of contractors is considered as the most important determinant in performance prediction. The complexity of projects is ranked the second and the percentage of professional staff has the least contribution to the model.

9.2.8 COMPARISON BETWEEN THE DISCRIMINANT MODEL AND THE MULTIPLE REGRESSION MODEL

The number of variables in the multiple regression model is reduced from 6 to 5 and the variable ORIGIN is removed when compared with the discriminant model. Although ORIGIN has the next highest contribution to the regression model amongst the variables not falling into the equation, it cannot pass the F-distribution test and have a high probability of F-distribution to enter; i.e. 10.8% comparing with the criterion of 6%. This may be due to the fact that the distribution is highly skew towards the locals because there are only 5 overseas cases amongst the total 34 and the multiple regression model has more stringent criteria in variable selection than that of the discriminant model.

Comparing the two models' standardized coefficients, it reveals that the contribution of the variable PAST_PER is ranked the first in both models. However, PROF_STA falls from the second in the discriminant model to the last in the regression model. This may be due to the high correlation between PROF_STA and ORIGIN and the variable ORIGIN was removed from the regression model.

The contribution ranking of the complexity of projects in the regression model has risen from the fourth in the discriminant model to the second and thus this is considered more important in the regression model.

Meanwhile, it is worth noting that the variable PROF_STA (the percentage of professional staff in the company) has a positive effect on the contractor performance in both models; that is the higher the percentage, the better is the performance.

Table 34 Comparison of the Standardized Coefficients Between Discriminant Model and Multiple Regression Model

	Standardized Coefficients			
	Discriminant Model	Rank	Regression Model	Rank
COMPLEX	-0.8867	4	0.4886	2
PROF_STA	0.9110	2	-0.2456	5
LEAD_EX	0.6372	5	-0.3039	4
PAST_PER	-1.1000	1	0.6449	1
ORIGIN	0.5184	6		
CONTROL	0.8870	3	-0.4820	3

* The signs of the coefficients are arbitrary only.

The variables COMPLEX and CONTROL have the comparable magnitude in both the discriminant model and multiple regression model.

On the whole, the size and ranking of the coefficients in both models do not differentiate too much only with the exception of the variable: 'the percentage of professional staff'.

Table 35 compares the results of the two other discriminant models Z_3 (for new works only), Z_4 (for building works only,

Table 35 Results of The Discriminant Models Z_3 and Z_4 and the Regression Model

Variables	Z_3 Model		Z_4 Model		Regression Model	
	Standardized Coefficients	Order of Contri-bution	Standardized Coefficients	Order of Contri-bution	Beta Coefficient	Order of Contri-bution
COMPLEX	-0.9843	2	-0.6857	3	0.4886	2
PROF_STA	0.7631	4	0.5756	5	-0.2456	5
LEAD_EX	0.5497	5	0.6718	4	-0.3039	4
PAST_PER	-0.9850	1	-1.0436	1	0.6449	1
ORIGIN	0.5065	6	0.4552	6		
CONTROL	0.9631	3	0.8874	2	-0.4820	3

see Chapter 7) and the regression model.

It can be noticed that the variable contribution pattern of the Z_4 discriminant model matches that of the regression model most. It thus is advisable to follow the regression model or the Z_4 discriminant model for building works only.

9.2.9 QUALITY OF CLASSIFICATION

Table 36 shows the results of the regression model for each individual cases of the sample. Since there are binary results only; i.e. '1' for 'good performance and '2' for 'poor performance' in the dependent variable PERFORM, the demarcation value for group 1 and 2 is set to be 1.5.

The overall classification results are summarised in Table 37.

Table 37 The overall Classification Results of the Regression Model

Actual group	No. of cases	Predicted group membership	
		1	2
Group 1	25	25 (100%)	0 (0%)
Group 2	9	0 (0%)	9 (100%)

Percentage of "grouped" cases correctly classified is 100% which demonstrates that the classification of the model is effective

Table 36 Classification Results and the Regression Scores of Cases in the Multiple Regression Model

Case	Actual Group	Regression Scores	Classified Group	Classification
1	1	0.8293	1	Correct
2	1	1.1581	1	Correct
3	1	0.6740	1	Correct
4	2	1.6963	2	Correct
5	1	0.8459	1	Correct
6	1	1.2358	1	Correct
7	2	1.6846	2	Correct
8	1	1.3280	1	Correct
9	2	1.5824	2	Correct
10	1	1.1925	1	Correct
11	1	1.2825	1	Correct
12	1	1.1514	1	Correct
13	1	1.1514	1	Correct
14	1	0.8565	1	Correct
15	1	1.0920	1	Correct
16	1	1.1327	1	Correct
17	1	1.0453	1	Correct
18	1	0.6469	1	Correct
19	1	1.2225	1	Correct
20	1	1.1434	1	Correct
21	1	0.9720	1	Correct
22	1	0.9148	1	Correct
23	1	0.6835	1	Correct
24	2	1.8271	2	Correct
25	1	1.2461	1	Correct
26	2	2.0361	2	Correct
27	1	1.3580	1	Correct
28	2	1.9255	2	Correct
29	2	1.6474	2	Correct
30	2	1.8568	2	Correct
31	1	1.2981	1	Correct
32	2	1.9433	2	Correct
33	1	1.0083	1	Correct
34	1	1.3321	1	Correct

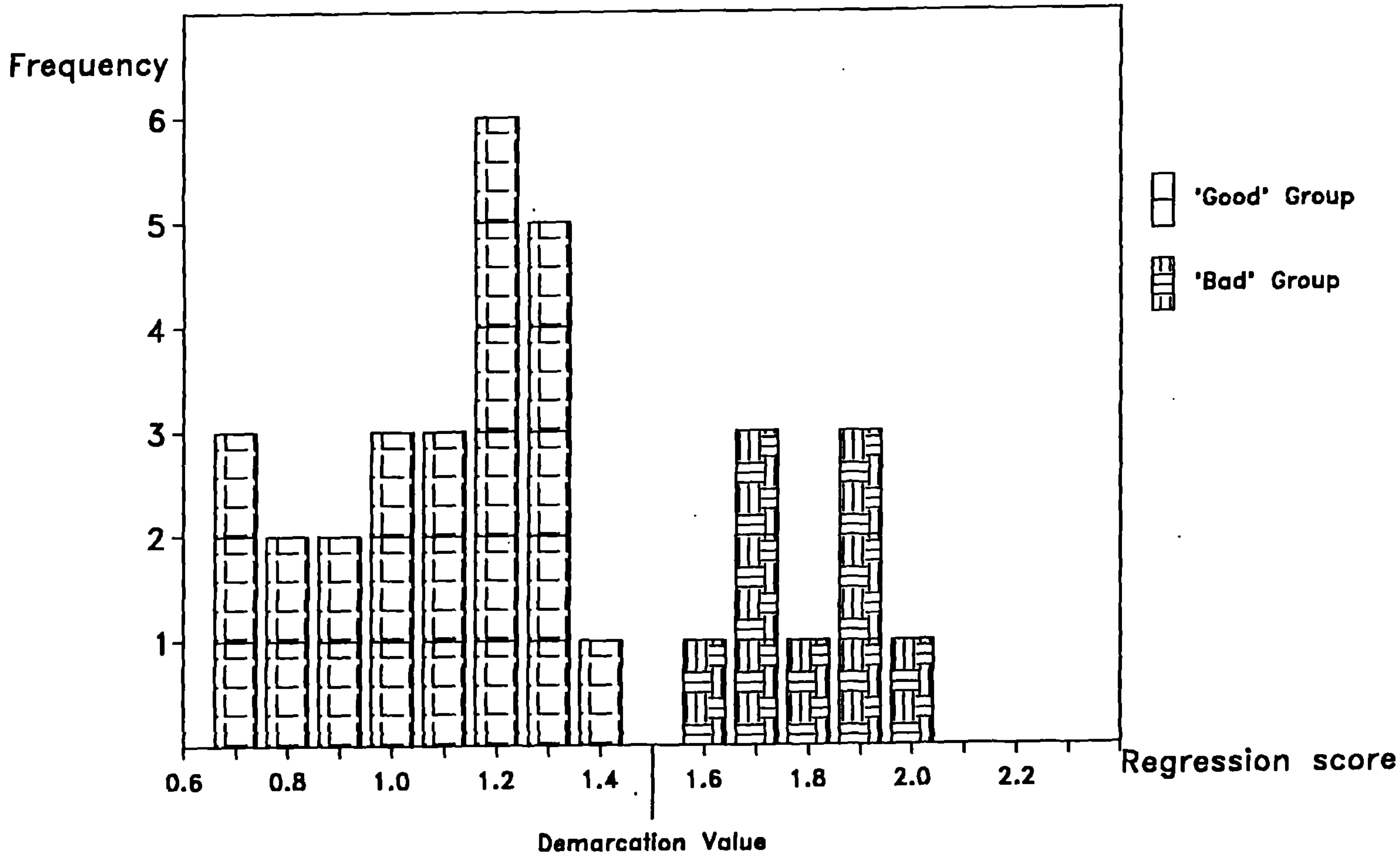


Figure 9 Stacked Histogram for the Regression Model

and good. The frequency distribution of individual cases are illustrated in Figure 9.

9.2.10 GOODNESS OF FIT

Table 38 shows the summary of the regression model.

Table 38 <u>Summary Table of the Regression Statistics</u>

Step	Multiple Regression Coefficient	R square	Adjusted R square	Variable In
1	0.6324	0.3999	0.3812	PAST_PER
2	0.7064	0.4991	0.4667	COMPLEX
3	0.7917	0.6267	0.5894	CONTROL
4	0.8302	0.6892	0.6463	LEAD_EX
5	0.8532	0.7279	0.6793	PROF_STA

Where COMPLEX: The complexity of project

PROF_STA: The percentage of professional staff

LEAD_EX: The project leader's experience

PAST_PER: The past performance of contractor

CONTROL: The architects' or clients' control and supervision on progress and quality of work

The regression statistic R square is 0.7279, indicating that 72.79% of the variation in the performance behaviour is explained by variations in the predictive variables, PAST_PER, COMPLEX, CONTROL, LEAD_EX, and PROF_STA.

9.3 UNIDIMENSIONAL SCALING MODEL

9.3.1 INTRODUCTION TO UNIDIMENSIONAL SCALING

Unlike length, height and time which have the worldwide accepted, defined and measurable scales to measure, some social, political, psychological issues; such as attitudes, preferences and perceptions are very difficult to define and measure; for instance, the government's performance, the voters' preference in election, etc. Scaling is a set of mathematical techniques that enable a researcher to uncover the 'hidden structure' of data bases and form a standard by which the social concepts and psychological perceptions can be measured.

Scaling models may be employed for three related but distinct purposes[31, 32]. First, scaling analysis may perform a hypothesis that there is a single dimension, ideology (e.g., liberalism), that underlies voters' preferences for different political candidates. In this case, the scaling model is used as a criterion to evaluate the relative fit of a given set of observed data to a specific model. Second, scaling may be employed for the purpose of simply describing a data structure, that is, for discovering the latent dimensions underliying a set of obtained observations. This would be the case, for example, if psychologists attempted to specify the dimensions underlying the perceived loudness of various sounds. No hypothesis is necessarily being tested here. Instead, the purpose of the analysis is mainly exploratory. Whether the primary purpose of the analysis is confirmatory (the testing of a specific hypothesis) or exploratory, the technique can be used to derive and construct a scale, in which case it is a scaling method. In this third instance the purpose of scaling is to develop a unidimensional scale on which individuals can be given scores. Their scores on the particular scale can then be related to other measure of interest. Sociologists, for example, may construct a scale for measuring socioeconomic status that can be correlated with a variety of attitudinal and behavioral measures. In this study, a scaling model with scores was derived to measure the performance scale of contractors.

There are a number of scaling models designed to scale persons, stimuli, or both persons and stimuli. In this research, Likert scaling[28] was used which was designed to scale subjects only. In Likert scaling, individuals are presented with a list of statements about a single topic (in this study, the performance of contractors) and are instructed to respond to each statement in terms of their degree of agreement or disagreement. Then the scale is obtained by adding together the response scores of its constituent items to form a 'summative' scale. Alternatively, the term 'linear composite' is used to designate such a scale.

The Likert approach to scaling consists of three interrelated tasks: (1) item construction, (2) item scoring, and (3) item selection. In this study, there are totally 20 independent variables, the first step to do is to derive a univariate correlation table between each variable and the dependent variable PERFORM. Variables having a high correlation, for the purpose of this study, correlation coefficients higher than 0.2, are chosen to form items of the scale. It makes little sense to combine unrelated items into a total sum since undifferentiating items contribute little useful information to the total. Indeed, they may actually decrease the reliability and /or validity of the scale[28].

Weightings are then assigned to each item or variable according to their degree of correlation with the dependent variable PERFORM. However, Sewell and Alwin et al[33,34] arrived at the following conclusion regarding weightings:

> "The problem of assigning weights to items in a scale is one which is rather annoying but not of great practical significance in light of the roughness of most sociometric devices at the present time. Several studies have shown that essentially the same final results are obtained with arbitrary common sense weighting as with more complicated, but still arbitrary, statistical techniques."

Nevertheless, in order to manipulate the scores of the model to fall into a scale of 0 to 100 for the ease of interpretation of the results, equal weightings were assigned.

Finally, for the item selection, the item-to-total correlations were calculated and those having a low value were removed from the final scale because they failed to discriminate between groups. The following sections will describe the process of modelling item construction, item scoring and item selection.

9.3.2 ITEM CONSTRUCTION

In order to decide which variables among the twenty independent variables to be included in the model, it has to remove the unrelated or less related items which may decrease the reliabilty or validity of the scale. Univariate correlation coefficients between the predictive variables and the dependent variable PERFORM (performance) were used to measure their relativeness. Table 39 shows the coefficients.

In the preliminary screening, variables having a coefficient larger than 0.2 are selected and included in the model. From Table 39, it is noticed that ten variables among the twenty fulfil this requirement and they are COMPLEX (the complexity of project), TRAINING (amount of management training provided), PROF_STA (the percentage of professional staff), CONT_EX (the contractor's experience in similar jobs), PAST_PER (the past performance of the contractor), ORIGIN (the origin of the contractor), LISTED (whether the contractor is a public or private firm), CENTRAL (whether decision making is centralised or de-centralised), ARCH_PER (architect performance), and CONTROL (architect/ client's control and supervision).

Table 39 The Univariate Correlation Coefficients Between the Dependent Variable PERFORM and Other Independent Variables

Independent Variables		Correlation Coefficient with the dependent variable PERFORM
COMPLEX	(The complexity of projects)	0.27
TRAINING	(Amount of management training)	-0.252
PLANT	(Plant ownership policy)	-0.054
COM_SIZE	(Size of company)	0.09
PROF_STA	(Percentage of professional staff)	0.227
LEAD_EX	(Project leader's experience)	-0.05
CONT_EX	(Contractor's experience in similar jobs)	-0.208
WORKLOAD	(Contractor's workload)	0.188
PAST_PER	(Contractor's past performance)	0.632
YEAR_BUS	(Number of years in business)	-0.178
ORIGIN	(Origin of contractors)	-0.504
DEL	(Amount of directly employed labour)	0.145
LISTED	(Public or private firm)	0.236
CENTRAL	(Decision centralised or de-centralised)	0.455
SUBSID	(Subsidiary firm of the client or not)	0.095
ARCH_PER	(Architect performance)	-0.384
CONTROL	(Clients' control)	-0.474
PAYMENT	(Punctual payment or not)	0.133
PROFIT	(Profitability)	0.151
PAS_P_PM	(Past performance of the project manager)	0.016

9.3.3 ITEM SCORING

As mentioned in Section 9.3.1, equal weightings of a maximum of 10% were allocated to the ten shortlisted independent variables yielding a maximum of 100% score.

In order to delineate the value of a variable to be good and bad, a cut off value (x value) is defined at which both the chances of falling into good and bad groups are the same as illustrated in Figure 10 with an assumption that all variables are normallly distributed, and their means and standard deviations are used to estimate the x value.

The 10% weighting score was further subdivided according to the attainment level of each variable; for example, if the value of the variable 'TRAINING' is larger than or equal to 0.177 which is the mean of the 'good' group, 10% score will be assigned; if however, the value is between 0.117 to 0.079 which is the demarcation value between the two groups, 6.67% would be allotted and if the value is between 0.079 to 0.068 which is the mean of the 'bad' group, 3.33% would be apportioned; and finally 0% for value below or equal to 0.068 (see Figure 10 for details).

However, this does not apply to certain variables processing binary values; such as 'LISTED' (whether the company has been listed in the stock market) has only 'Yes' and 'No' options and in that case, either 10% or 0% will be assigned.

Variable	Group	Mean	Standard Deviation	X-value
TRAINING	1 2	0.117 0.068	0.098 0.029	0.079

Variable— "TRAINING"

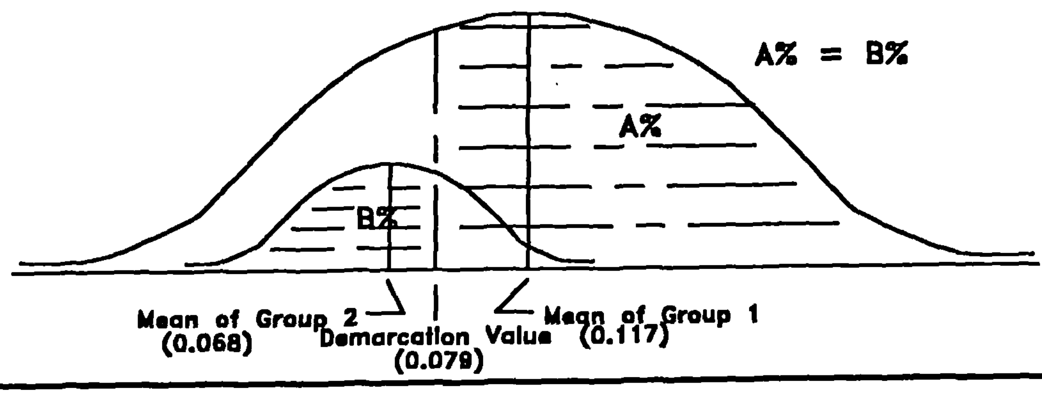


Figure 10 Means of Group 1 & 2 and the Demarcation Value of the Variable 'TRAINING'

The sums of score for each individual case are obtained by summing up the scores of the items. The results are presented in Table 40.

9.3.4 ITEM SELECTION

The next step is to check the item to total correlation to eliminate the undifferenting items which should have a low correlation. The correlations of each variable with the sum of score are shown in Table 41.

Table 41 Correlations of Items with the Total Sum of Score

Items	Correlations to Sum-of-Score
COMPLEX	0.1250
TRAINING	0.2726
PROF_STA	0.7167
CONT_EX	0.1435
PAST_PER	0.7966
ORIGIN	0.7607
LISTED	0.4217
CENTRAL	0.7037
ARCH_PER	0.6731
CONTROL	0.5261

Since none of the above is extremely low, all variables are selected and included in the model.

Table 40 Classification Results and the Scaling Scores of Cases in the Unidimensional Scaling Model

Case	Actual Group	Scaling Scores	Classified Group	Classification
1	1	90	1	Correct
2	1	71.67	1	Correct
3	1	71.67	1	Correct
4	2	45	2	Correct
5	1	53.33	1	Correct
6	1	75	1	Correct
7	2	55	1	Wrong
8	1	50	1	Correct
9	2	55	1	Wrong
10	1	60	1	Correct
11	1	50	1	Correct
12	1	60	1	Correct
13	1	60	1	Correct
14	1	75	1	Correct
15	1	61.67	1	Correct
16	1	55	1	Correct
17	1	35	2	Wrong
18	1	95	1	Correct
19	1	70	1	Correct
20	1	80	1	Correct
21	1	78.33	1	Correct
22	1	65	1	Correct
23	1	75	1	Correct
24	2	18.33	2	Correct
25	1	78.33	1	Correct
26	2	6.67	2	Correct
27	1	65	1	Correct
28	2	21.67	2	Correct
29	2	13.33	2	Correct
30	2	41.67	2	Correct
31	1	51.67	1	Correct
32	2	40	2	Correct
33	1	50	1	Correct
34	1	50	1	Correct

9.3.5 QUALITY OF CLASSIFICATION

The maximum score of the scale is 100%, and thus the mid value, 50%, is taken as the demarcation value between good and bad groups. Table 40 shows the scores and classification of each individual cases. The overall classification results are shown in Table 42. The frequency distribution of scores is illustrated in Figure 11.

Table 42 The Overall Classification Results of the Unidimensional Scaling

Actual group	No. of cases	Predicted group membership	
		1	2
Group 1	25	24 (96%)	1 (4%)
Group 2	9	2 (22.22%)	7 (77.78%)

9.3.6 COMPARISON BETWEEN THE DISCRIMINANT MODEL AND THE UNIDIMENSIONAL SCALING MODEL

The number of variables in the unidimensional scaling model has increased from 6 in the discriminant model to 10. The variables TRAINING, CONT__EX, LISTED, CENTRAL, and ARCH_PER were added and the variable LEAD__EX is removed when compared with the discriminant model. Table 43 compares the variables included in the discriminant and unidimensional models.

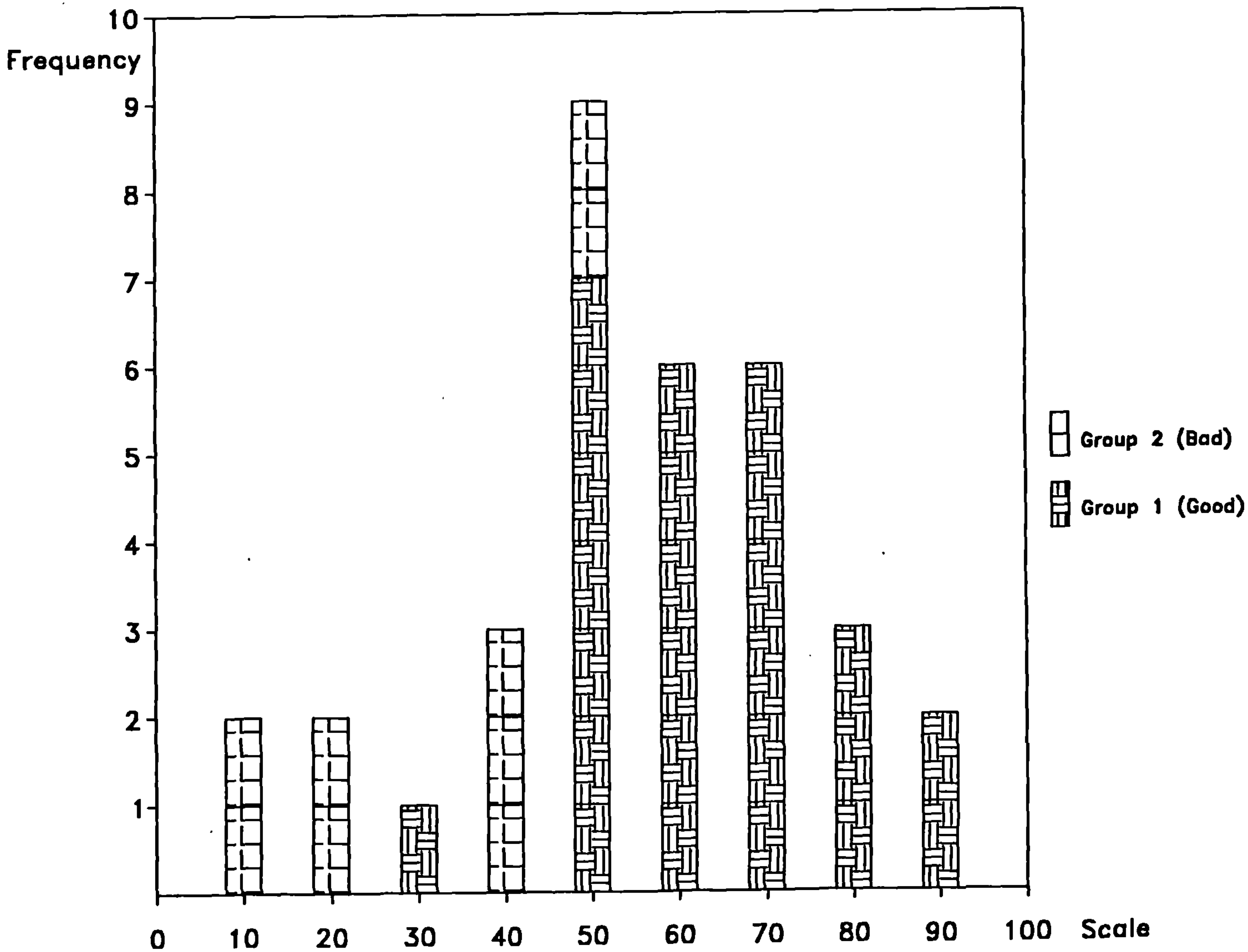


Figure 11 Stacked Histogram for the Unidimensional Scaling Model

Table 43 Variables Included in the Discriminant and Unidimensional Scaling Models

Variables	Discriminant Model	Unidimensional Scaling Model
COMPLEX	*	*
TRAINING	-	*
PROF_STA	*	*
CONT_EX	-	*
PAST_PER	*	*
ORIGIN	*	*
LEAD_EX	*	-
LISTED	-	*
CENTRAL	-	*
ARCH_PER	-	*
CONTROL	*	*

* Included Variable

It can be noticed that the unidimensional scale is much inferior to the discriminant model and the regression model both in terms of the quality of classification and the variables embodied. The reasons would be the neglect of the interrelationship between the independent variables and the much simplified computation and mathematical concept of the unidimensional scale.

9.4. CONCLUSION AND SUMMARY

The discriminant analysis (D.A.), multiple regression analysis (MRA) and unidimensional scaling (A score) techniques were employed to generate three models to classify contractor performance with the 34 cases. The results obtained from the D.A. and MRA are compatible to each other with a small difference in the number of variables selected. In the D.A. model six variables were found to be significant in classification while in the MRA five were obtained which eliminates the variable ORIGIN. This may be due to the fact that the sample was skew towards locals (5 out of 34 are overseas contractors).

In comparing the D.A. model and the unidimensional scale, the variations are large. Firstly, there were ten variables included in the unidimensional scaling model compared with only six in the D.A. model. Secondly the quality of classification of the unidimensional scaling is much inferior to D.A. and MRA. It is because the unidimensional scaling technique has ignored the interrelationship between variables. Each variable in the unidimensional scaling was considered independently but in D.A and MRA the interrelationship of variables was taken into consideration in the variable selection process.

As mentioned in Section 3.4, the D.A. model should have the stronger classification power in the case of binary grouping dependent variable when compared with the MRA model. The unidimensioal scaling is proved to be the weakest amongst the three models due to its simplified approach.

CHAPTER 10

TESTING THE MODELS USING INDEPENDENT DATA

10.1 INTRODUCTION

A discriminant model usually fits the sample from which it is derived better than it will fit another sample from the same population[13]. Thus, the percentage of cases classified correctly by the model is an inflated estimate of the true performance in the population.

There are several ways to obtain a better estimate of the true misclassification rate. One technique is called the leaving-one-out method. It involves leaving out each of the cases in turn, calculating the function based on the remaining n-1 cases, and then classifying the left-out case. Since the case which is being classified is not included in the calculation of the function, the observed misclassification rate is a less biased estimate of the true one. However, as the function is made up of most cases in the sample, the estimate of the misclassification rate is not precise enough.

Another technique is to obtain a test group, then the model can be tested against the test group. Since the sample cases are not used for both estimating the function and testing it, the observed error rate in the 'test' sample should better reflect the function's effectiveness. This approach was adopted in this study.

Hitherto, three models; namely discriminant analysis, multiple regression analysis and unidimensional scaling models, have been described. However, as described in Chapter 9, the unidimensional scaling model has a very high percentage of misclassification and thus was excluded from testing. The test results of the Discriminant and Multiple Regression Models will be described in the following pages.

10.2 TEST DATA GROUPS

In order to prove the validity of the models for each group, two groups of test projects were collected. As described in Table 5 of Chapter 5, the number of cases in the test groups of 'Good Performance' and 'Poor Performance' are 10 and 6 respectively.

In the test groups, more 'Bad' cases were included to examine the discriminant power of the models. It is because when one of the groups is much smaller than the other, a highly correct classification rate can occur even when most of the 'minority' group cases are misclassified; for example, in judging everyone to be disease free in an AIDS screening program, the error rate will be very small since few people actually have infected with AIDS. Thus the 'Poor Performance' group was deliberately enlarged to test the actual validity of the models.

Justify

10.3 VALIDATION OF THE DISCRIMINANT ANALYSIS MODEL

The discriminant analysis model developed is as follows:

$$\begin{aligned}\text{Discriminant function} = &- 0.5616\ (\text{COMPLEX}) \\ &+ 11.9324\ (\text{PROF\_STA}) \\ &+ 0.0949\ (\text{LEAD\_EX}) \\ &- 1.7845\ (\text{PAST\_PER}) \\ &+ 0.8219\ (\text{ORIGIN}) \\ &+ 1.0364\ (\text{CONTROL}) - 1.1408\end{aligned}$$

where

COMPLEX : The complexity of the project

PROF_STA: Percentage of professional qualified staff

LEAD_EX : Project leader's experience

PAST_PER: Contractor's past performance or image

ORIGIN : Origin of the company

CONTROL : Architect's or client's supervision and control on the quality of work and work progress

The results obtained from the independent data groups are shown in Table 44 and 45.

Table 44 Overall Classification Results of the Test Data Groups in the Discriminant Analysis Model

Actual Group	No. of Cases	Predicted Group Membership	
		Group 1	Group 2
Group 1	10	9 (90%)	1 (10%)
Group 2	6	1 (16.7%)	5 (83.3%)

Percent of 'grouped' cases correctly classified: 87.5%

Table 45 Classification Results and the Discriminant Scores of the Test Data Groups in the Discriminant Analysis Model

Case	Actual Group	Discriminant Scores	Classified Group	Classification
1	1	-2.067	2	WRONG
2	1	0.739	1	Correct
3	1	3.048	1	Correct
4	1	4.052	1	Correct
5	1	3.238	1	Correct
6	1	0.509	1	Correct
7	1	2.318	1	Correct
8	1	2.072	1	Correct
9	1	0.844	1	Correct
10	1	-0.384	1	Correct
11	2	0.139	1	WRONG
12	2	-1.795	2	Correct
13	2	-3.473	2	Correct
14	2	-2.931	2	Correct
15	2	-2.369	2	Correct
16	2	-5.347	2	Correct

In the Z_2 model development, there are 25 cases from the 'Good' group and 9 from the 'Bad' group. Thus, the prior probabilities of group 1 (good performance) and group 2 (bad performance) are 73.53% (25/34 * 100%) and 26.47% (9/34 * 100%) respectively. If the classification rate for the 'Good' group is lower than or equal to 74%, it would suspect that the outcome happens only accidentally and the performance is not better than chance. Similarly, if the classification rate for the 'Bad' group is lower than or equal to 26%, it would suspect that the outcome just happens by chance.

In this study, the classification rates for the 'Good' and 'Bad' groups are 90% and 83.3% which are well above 74% and 26% and thus the classification performance is very convincing. It demonstrates a satisfactory prediction power of the model.

10.4 VALIDATION OF THE MULTIPLE REGRESSION ANALYSIS MODEL

The multiple regression analysis model developed is as follows:

$$\begin{aligned}\text{PERFORM} = &+ 0.36853(\text{PAST\_PER}) + 0.1355(\text{COMPLEX}) \\ &- 0.22549(\text{CONTROL}) - 0.02055(\text{LEAD\_EX}) \\ &- 1.42476(\text{PROF\_STA}) + 0.92865\end{aligned}$$

where COMPLEX : The complexity of the project

PROF_STA: Quality of management team-Professional qualifications

LEAD_EX : Quality of management team-Project leader's experience

PAST_PER: Contractor's past performance or image

CONTROL : Architect's or client's supervision and control on the quality of work and work progress

The results obtained from the independent data group are summarised in Table 46 and 47.

Table 46 Overall Classification Results of the Test Data Groups in the Multiple Regression Analysis Model

Actual Group	No. of Cases	Predicted Group Membership	
		Group 1	Group 2
Group 1	10	9 (90%)	1 (10%)
Group 2	6	1 (16.7%)	5 (83.3%)

Percent of 'grouped' cases correctly classified: 87.5%

Table 47 Classification Results and the Multiple Regression Scores of the Test Data Groups in the Multiple Regression Analysis Model

Case	Actual Group	Discriminant Scores	Classified Group	Classification
1	1	1.6969	2	WRONG
2	1	1.1359	1	Correct
3	1	0.5421	1	Correct
4	1	0.6757	1	Correct
5	1	0.5010	1	Correct
6	1	1.1208	1	Correct
7	1	0.7533	1	Correct
8	1	0.8509	1	Correct
9	1	1.0901	1	Correct
10	1	1.3383	1	Correct
11	2	1.1561	1	WRONG
12	2	1.6291	2	Correct
13	2	2.0514	2	Correct
14	2	1.8888	2	Correct
15	2	1.7533	2	Correct
16	2	2.1881	2	Correct

The classification results obtained are same as that of the discriminant model. Thus it concludes that the prediction power of the multiple regression model is satisfactory which verifies the reliability of the discriminant model.

10.5 CONCLUSION AND SUMMARY

The discriminant model was extremely accurate in classifying 87.5% of the sample correctly. The Type I error (i.e. when the case is actually bad but classified into the 'Good' group) was proved to be 16.7% while the Type II error (i.e. when the case is actually good but classified into the 'Bad' group) was 10%. This is significantly better than a pure chance model. The results, therefore, are encouraging.

The multiple regression analysis model has proved to be effective in discriminating between the 'Good' and 'Bad' groups which has counterproved the validity and reliability of the discriminant model.

CHAPTER 11

PERIPHERAL FACTORS NEEDED TO BE TAKEN INTO ACCOUNT WHEN USING THE MODEL

11.1 INTRODUCTION

As revealed in the last Chapter, the test cases no.1 and 11 were found to be misclassified both by the Discriminant Analysis and the Multiple Regression Analysis models. This infers that the models correctly classified 87.5% of the sample projects. Despite of this high percentage of accuracy, the misclassifications highlighted that there were some uncertainties in prediction which could not be explained by the models.

It is the aim of this Chapter to investigate the underlying factors and provide recommendations in exercising the Discriminant Analysis Prediction Model.

11.2 METHODOLOGY

In order to unveil the hidden factors, detailed interviews with the contractors and/or the clients' representatives were intended for the two misclassified cases. However one of the contractors was not willing to disclose the information. The only misclassified case studied was categorized into the 'Bad' group by the models which, however in actual fact, belonged to the 'Good' group.

However, one single case is not adequate to provide a complete picture; thus, two more cases were found and collected over a four month period. In these two cases, the clients had expected a good performance but the contractor performance turned out to be poor. Consequently detailed investigations were carried out and two discriminant scores derived for the two projects. These cases should have fallen into the 'Good' group but in actual, its performance was poor.

11.3 CASE STUDIES

The following pages describe the findings from the detailed investigations of the three mis-catagorised cases.

11.3.1 CASE 1- 'GOOD PERFORMANCE' CASE CLASSIFIED AS 'BAD'

This case was one of the misclassified cases in the testing sample. The detailed interview was conducted in August, 1991 with the contracts manager of the company and the findings are presented as follows:

A) Brief history of the company:

The company was set up in 1985; by which time, it was a joint venture firm between a Japanese contractor and a local company. In 1988, the organisation was re-shuffled and the company re-organised and sub-divided. The joint venture was ended and the company has become a 100% locally owned company. The past image of the contractor was very poor with some records of poorly constructed public housing projects bearing poor quality and delay in completion.

B) Change of management team after re-shuffle:

Since the re-shuffle, more professional staff have been recruited; the percentage of which has increased from 5% to 10%. A few unsatisfactory project managers were dismissed.

C) Change of management system and style:

In the past, they did not have a proper control system and everything was kept in mind rather than on paper. After the re-organisation, a management control system was introduced. Computers have also been adopted in management.

The decision making system was changed from strictly centralized in the past to a more flexible and de-centralized system.

D) Change of subcontractors list:

In the past, the subcontractors had a very close relation with the top management and usually recruited through negotiations rather than from proper competitive tendering. After the re-shuffle, the list of subcontractors was changed and subject to selection through tendering.

E) Workload:

Since the re-organisation, workload has nearly doubled.

F) Profitability:

Losses occurred in the past but profits were evident during the time of the interview.

G) Change in company strategy:

In the past, the objective was to maximise profit but recently more emphasis have been given to improving the quality of work and image.

H) Amount of plant owned:

This remained roughly the same before and after the re-organisation.

I) Size of the company:

The size has not changed.

11.3.1.1 SUMMARY

From the information obtained above, four factors are evident which might affect the "PAST PERFORMANCE" variable used in the model; namely:

- Change of company policy in managing and running projects.
- Improvement in management both in terms of human resources and the system itself.
- Change of the company origin from an overseas and local joint venture to a wholly local firm.
- Improvement in profitability; thus the firm could afford more resources to improve management and quality of work.

11.3.2 CASE 2- 'BAD PERFORMANCE' CASE CLASSIFIED AS 'GOOD'

This is one of the two cases where the client had expected a good performance but the result turned out to be bad. The discriminant score of 0.4622 would, according to the Discriminant Model, fall in the 'Good' catagory; however, the client was not satisfied with performance. The interviews were conducted in January, 1992 with both the general manager of the contractor and the client's representative. The findings are presented as follows:

A) <u>Brief history of the company</u>:

The company was a subsidiary of a large construction firm which had been set up for more than 30 years. The firm had specialised in maintenance works before the split from its mother company in 1987 at which time the mother company went into a joint venture with a Dutch firm. After the split, the firm entered into the new works' market and expanded rapidly.

B) Workload:

The company expanded very fast in term of workload. In 1987, the total contract sum in hand was 200 million Hong Kong dollars but increased to 1000 million dollars in 1991.

C) Delay payment to subcontractors:

Because of rapid expansion, subcontractors' payments were delayed in order to save cash for expansion.

D) Profitability:

The marginal profit dropped due to the keener competition in the new works' market.

E) Project particulars:

The project in question was obtained through a negotiated form of contract. Although the contractor's resources had been fully committed at that time, the offer was accepted in order not to upset the client. Trying to avoid hiring new staff to manage the project, the works were wholly sublet to a third contractor but a few supervisiory staff were still maintained to oversee the project.

11.3.2.1 SUMMARY

From the above information, three possible reasons for reduction in performance are identified as follows:

- The contractor lacked experience in handling new works projects.

- The profitability of the company was falling which might subsequently lead to difficulties for the management.

- Lastly, but the most important, the over-expansion of the company caused in a difficult situation in terms of cash flow and human resources.

11.3.3 CASE 3- 'BAD PERFORMANCE' CASE CLASSIFIED AS 'GOOD'

This is the second case where the client had expected a good performance but the result turned out to be bad. The discriminant score was 0.7387 which, according to the Discriminant Model should fall under the 'Good' catagory; however, the client was not satisfied with this level of performance. The interviews were conducted in February, 1992 with both the contractor's chief quantity surveyor and the client's representative. The findings are presented as follows:

A) Brief history of the company:

The company was a very traditional Chinese contractor set up 30 years ago. The firm was taken over by a large developer and went public in 1990. Top management has also changed since then.

B) Overtrading:

In order to present a favourable image regarding the financial accounts before going public, the company tried to increase turnover in a fairly short period of time and actually won a number of projects in 1990. The high workload forced the company to promote some younger staff to manage projects. Secondly, payments to subcontractors were severely delayed; some of which had been delayed for more than four months and a few subcontractors were preparing legal actions at the time of interview.

C) Project particulars:

In this project, the client complained that the main problem contributing to the poor performance was the lack of experience of the project manager in tackling the waterproofing works which needed much remedial work. Further the confused management and communication systems irritated the client and the architect. The project was also delayed due to poor coordination of subcontractors.

11.3.3.1 SUMMARY

The root problems of the contractor's poor performance are summarised as follows:

- The change of the top management led to an alteration in the company strategy and policy.

- Over-expansion increased competition for resources; both in terms of financial and human. Although in the development of the Discriminant Model, workload was taken as one of the determinants; nevertheless, it is quite difficult to define 'overtrading' in terms of 'workload' since workload has to reach a certain point before overtrading is realized. Further, the maximum manageable workload may vary from company to company due to different structures, organisation and types of work that companies specialise in.

11.4 SUMMARY AND CONCLUSION

From the study of the three cases above, it is probable that the following factors would affect the accuracy in exercising the Discriminant Model; namely:

11.4.1 CHANGE IN COMPANY POLICY AND ATTITUDE

It is recognised both from Cases 1 and 3 that a change in company policy and top management may affect the predictive performance was not previously considered in the development of the model because of the difficulties in quantifying 'changes in attitude and policy'.

Thus in qualifying contractors, this factor needs to be considered by intervewing contractors regarding changes in the company strategy and top management.

11.4.2 CHANGE IN MANAGEMENT QUALITY

Cases 1 and 2 indicated that changes in staff quality and the management system could affect the predictive performance. Again this can be discovered through interviewing contractors and scrutinising the submitted project organisation chart.

The changes in management quality, company strategy and attitude may, in long run, change the 'PAST PERFORMANCE' factor used in the model.

11.4.3 PROFITABILITY

The profitability of the projects themselves was included in the development of the model. However, the overall profitability of companies was not included due to the difficulty and the sensitivity in collecting the information; especially from small private companies.

This factor was demonstrated to be affecting the predictive performance from Cases 1 and 2 as profitable contractors can afford more resources and have more room to improve their quality of work and image while non-profitable contractors may be clinging to maximize the profit. This information can be obtained from the contractor pre-qualification interview.

11.4.4 OVERTRADING

Attempts were made to quantify this factor in the Discriminant Model using the variable 'WORKLOAD'; however the overtrading condition was difficult to determine as not normally be directly proportional to workloads and is usually a situation where the available resources are over-committed. This situation may vary according to different company structures, organisation and trading specialisms.

This factor was demonstrated to be affecting the predictive performance very much in Cases 2 and 3 and can only be revealed at a contractor pre-qualification interview.

In conclusion, the Discriminant Model should only be used as part of an overall assessment of contractors' predictive performance. Any predictions should be interpreted with caution as the model has some peripheral factors which are difficult to be quantified and included. However, the Discriminant Model can confidently be adopted as a quantitative tool in assessing contractor's predictive performance in order to exclude contractors from tender lists and consequently improve the bid evaluation process thereby leaving more time for the clients to concentrate on detailed analysis of the tender.

This Chapter highlighted some peripheral factors which need to be considered in exercising the Discriminant Model to assess contractor performance in the contractor pre-qualification stage.

CHAPTER 12

COMMENTS FROM THREE ORGANISATIONS ON THE DISCRIMINANT VARIABLES

12.1 INTRODUCTION

In order to compare the actual practices to the viability of the discriminant variables of the model, three interviews were conducted with the representatives of the largest public housing client, one of the largest project management consultants and the estate offfice of a tertiary institution in Hong Kong.

In the model, there were six variables identified as significant in describing contractor performance; namely:

1. COMPLEX : The complexity of the project
2. PROF_STA: Percentage of professional qualified staff
3. LEAD_EX : Project leader's experience
4. PAST_PER: Contractor's past performance or image
5. ORIGIN : Origin of the company
6. CONTROL : Architect's or client's supervision and control on the quality of work and work progress

The findings of the interviews are presented in the following pages.

12.2 INTERVIEW 1- PUBLIC HOUSING CLIENT

In this interview, the deputy director mentioned that three extra factors were considered in addition to the bidding price in the contractor selection process; viz.:

12.2.1 PAST PERFORMANCE

A comprehensive past performance track recording system was adopted called PASS (the Performance Assessment Scoring System) described in details in Appendix 8. This system was used to provide an objective measurement of quality. Random sample checks carried out monthly throughout each contract period were administered. The checks contained either PASS or FAIL, without good, average or poor ratings. Full compliance gives a total of 100 points made up as follows:

Structural	35%
Building	35%
External	10%
General Conditions:	20%
	100%

In this performance assessment system, quality was the only dimension measured whereas other factors such as the degree of claim consciousness, completion time and management attitude were not able to describe.

The discriminant variable 'PAST-PER' in the model, which measures more dimensions than just quality alone, can serve similar purposes in judging contractors' track records of quality.

12.2.2 MANAGEMENT CAPABILITY

The education levels of staff and the management organisation structure were the next aspects which assessed the management capability. Furthermore, ISO 9000 was going to be implemented which asked for higher education levels of management staff. Only those contractors succeeding in obtaining accreditation of ISO 9000 would be allowed to tender.

This, to a certain extent, corresponds to the provision of the discriminant variable 'PROF-STA' in the model. It was also pointed out that the experience of project managers 'LEAD-EX' would be attributable to contractor performance but this was not measured directly in the selection process.

12.2.3 FINANCIAL STANDING

The captial liquidity, which may affect contractors' ability in funding the work, was also one of their main concerns.

The financial attribute included in developing the model was the profitability of the project. The liquidity information, however, was too sensitive and difficult to collect especially from small private contractors and thus was not included in the model. Nevertheless, the information can be obtained from the contractor prequalification interview.

12.2.4 OTHER VARIABLES

12.2.4.1 CONTROL

It was agreed that more frequent feedback of reports on contract was required when the project ran into difficulties although this was not measured in the selection process.

12.2.4.2 COMPLEXITY

No attempt was designed to guage this variable in the organisation. This may be due to the standardisation of most public housing designs bearing a constant degree of complexity.

12.3.4.3 ORIGIN

No discrimination was made between local and overseas contractors. The reason behind may be that it was a government subvented organisation which beared public accountability and thus tried to avoid discrimination.

12.3 INTERVIEW 2- ESTATE OFFICE OF A TERTIARY INSTITUTION

The assistant estate officer mentioned in the interview that the following factors were considered on top of the bidding price in contractor selection.

1. Degree of familarity with the contractor. (This corresponds to Ward, Curtis and Chapman[19] et al's findings regarding the quality of the relationships with the contractor concerning impressions of harmony, goodwill and trust or

conversely, of arguments, distrust and conflict.)

2. Claim consciousness of contractors.
3. The technical requirements of the project.
4. The complexity of the job.

12.3.1 PAST_PER & COMPLEX

The first two factors correspond to the discriminant variable PAST-PER since these represent, to a certain extent, the track record of the contractor concerned. Besides that, they have a systematic approach in assessing contractors' track record on quality (refer to Appendix 9 for details) although the system was not as comprehensive as the PASS used by the last organisation.

The latter two correspond to the variable COMPLEX as they measure the complexity of a project.

12.3.2 ORIGIN

Besides the above four factors, it was pointed out that the use of overseas contractors was tried to avoid where possible unless a particular expertise, which was only available from them, was required. It was noted that these contractors were normally more claim conscious, having high preliminaries and the know-how to play with the contract.

12.3.3 PROF_STA & LEAD_EX

Although it was admitted that the staff quality and experience could affect contractor performance, they found it difficult to measure these two aspects. The cooperativeness of staff, familarity with the job, education levels, experience and attitude were considered important in describing staff quality.

12.4 INTERVIEW 3- PROJECT MANAGEMENT CONSULTANT

One of the partners in the consulting firm mentioned that the following factors were considered on top of the bidding price in contractor selection.

1. Past performance which was guaged by peers', other clients', architects' and consultants' recommendations.

   This corresponds to the discriminant variable, PAST-PER, in the model.

2. Quality of management staff which included education levels, experience and types of job experience which were obtained through the pre-qualification interview.

   This corresponds to the discriminant variables, PROF-STA and LEAD-EX, used in the model.

3. Contractors' expertise.

   This is, to a certain extent, measured by the variable COMPLEX in the model although the former measures the contractors' ability to manage complex jobs while the latter measures the job's complexity itself.

As regards overseas contractors, there was no experience in dealing with them.

12.5 SUMMARY AND CONCLUSION

In Interview 1, two out the three assessment criteria adopted by the organisation were measured directly or indirectly by the three discriminant variables; viz. PAST-PER, PROF-STA and LEAD-EX. However, the variables, COMPLEX and ORIGIN were not adopted due to the special nature of the organisation.

In Interview 2, PAST-PER, COMPLEX and ORIGIN were considered, however, they did not measure the quality of management staff.

In Interview 3, PAST_PER, PROF-STA, LEAD-EX were assessed directly while COMPLEX was measured indirectly.

It is not surprising that clients' supervision and control (CONTROL) was not considered by the three organisations as this is a post contract measure. Notwithstanding this, this factor was viewed as a step to improve poor performance by the three organisations.

From the interviews, it reveals that there was not a unified approach in contractor selection in Hong Kong despite of a few common criteria. This infers that the selection processes were designed subjectively according to individuals' perception and organisations' own experience without any theoretical support.

CHAPTER 13

DISCUSSION AND CONCLUSIONS

13.1 INTRODUCTION

In the construction industry, most clients would hope that their projects could be finished on time, within budget, and up to the required quality. The competitive tendering system, however, cannot satisfy these assessment requirements. Some methods are apparently needed which will provide a quantitative indication of contractors' predictive performance to assist clients in making decision objectively and dispassionately.

The purpose of this dissertation was to investigate empirically the characteristics of contractor behaviour in performance and attempt to develop an accurate performance prediction model for the clients of the construction industry. Multiple discriminant analysis was utilized to accomplish this with contractor internal attributes and project characteristics serving as predictive variables.

The study encompassed essentially three parts. The first part included the development of the Discriminant Model. Secondly, the model was tested and verified with two other models; namely the Multiple Regression Analysis Model and the Unidimensional Scaling Model. Finally, a set of peripheral factors was investigated and recommended to suppliment the inadequacy of the Discriminant Model.

13.2 THE DISCRIMINANT ANALYSIS MODEL

In the beginning of this study, the general concept and previous works on this subject were introduced. Based upon the previous studies, a list of decision factors were derived and investigated by the discriminant analysis technique. Two sets of data projects belonging to the two groups were collected and analysed by the model. Then the model produced a formula in the following form indicating the six most important factors in deciding contractor performance:

$$\text{Discriminant function} = -0.5616\ (\text{COMPLEX}) + 11.9324\ (\text{PROF\_STA}) + 0.0949\ (\text{LEAD\_EX}) - 1.7845\ (\text{PAST\_PER}) + 0.8219\ (\text{ORIGIN}) + 1.0364\ (\text{CONTROL}) - 1.1408$$

where

- COMPLEX : The complexity of the project
- PROF_STA: Percentage of professional qualified staff
- LEAD_EX : Project leader's experience
- PAST_PER: Contractor's past performance or image
- ORIGIN : Origin of the company
- CONTROL : Architect's or client's supervision and control on the quality of work and work progress

13.3 VERIFICATION OF THE DISCRIMINANT MODEL USING MULTIPLE REGRESSION AND UNIDIMENSIONAL SCALING MODELS

In the second part of the study, two mathematical models were developed using the same set of data. Firstly, a Multiple

Regression Model was developed and its results were comparable to that of the Discriminant Model which demonstrated the validity of the discriminant analysis approach. Although the Multiple Regression Model is similar to the Discriminant Model, however; as mentioned in Chapter 3 and 9, the discriminant analysis approach has a stronger classification power than the multiple regression analysis approach in the case of binary grouping and thus was preferred.

The Unidimensional Scaling Model was then developed and its classification results were much inferior to those of both the Discriminant and Regression Models. It is because the unidimensional scaling approach has ignored the interrelationship between variables; for example, the percentage of professional staff may affect the past performance of a contractor. Although this approach did not produce any fruitful results, the model showed that there was an underlying structured approach in assessing contractor performance.

13.4 PERIPHERAL FACTORS IN EXERCISING THE DISCRIMINANT MODEL

As there were a few misclassifications, detailed investigation to the misclassified cases was carried out to study the side factors which could not be explained by the models.

The study discovered that the Discriminant Model should be used with care when the following signs appeared:

A) The contractor has a drastic change in company policy and attitude in running and managing projects.

B) The contractor has an abrupt change in management quality both in terms of the staff quality and the management system itself.

C) The profitability of the company is descending or the company is suffering a long period of loss.

D) The company has a strong sign of over-trading.

13.5 RECOMMENDATIONS FOR IMPLEMENTING THE DISCRIMINANT MODEL

There were 34 cases, including 25 cases in the 'Good' group and 9 in the 'Bad' group, used to develop the Discriminant Model. However, the developer or project manager can include information of the newly completed projects in the model and strengthen the data employed in the model development. Consequently the model can grow and perfect itself as more and more project information are embodied.

13.6 SUGGESTION FOR FUTURE STUDY

In this study, all types of works and companies of all sizes were examined. But in the actual construction environment, companies of different sizes or carrying different types and sizes of projects may exhibit different characteristics in performance. Hence, it is recommended that each catagory may be investigated individually.

Further, the model, as mentioned in the last paragraph, can grow as more project information are available. It is possible to develop an expert system package in expanding the model and vetting contractors on tender lists.

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APPENDIX 1

Measuring the Degree of Concordance of Clients on the levels of Complexity of Work

APPENDIX ONE

MEASURING THE DEGREE OF CONCORDANCE OF CLIENTS ON THE LEVELS OF COMPLEXITY OF WORK

A1.1 INTRODUCTION

In order to unveil the levels of complexity of work, a survey was carried out for clients to rank the six pre-set groups of work according to their complexity. Nine replies were collected and a non-parametric statistical technique called the Kendall Coefficient of Concordance was adopted to test the degree of agreement between the clientsees. The levels of complexity of work were then derived in ordinal approach.

A1.2 SURVEY

Twenty questionnaires had been sent out and nine were returned. The results of the survey are shown in Table A.1. From the results, it can be noticed that there is a clear pattern of ranking order as follows:

1- Foundation works, site formation, slope protection and similar simple civil engineering works.
2- Renovation or alteration works.
3- Factory or domestic housing works.
4- Deluxe housing projects or office buildings.
5- Hotel or high class office buildings.
6- Hospital or complicated structures or projects.

Table A.1 Results of Survey on the Levels of Complexity of Work

Types of work	Client									ΣR_i
	1	2	3	4	5	6	7	8	9	
	Ranking									
Foundation works, site formation, slope protection and similar simple civil engineering works	2	1.5	1.5	1	1	2	1	1	1	12
Renovation or alteration works	2	1.5	1.5	2	2	1	2	2	2	16
Factory or domestic housing works	2	3	3	3	3	3	3	3	3	26
Deluxe housing projects or office buildings	4	4	4	4.5	4	4	4	4	4	36.5
Hotel or high class office buildings	5	5	5	4.5	5	5	5	5	5	44.5
Hospital or complicated structures or projects	6	6	6	6	6	6	6	6	6	54

A1.3 KENDALL COEFFICIENT OF CONCORDANCE[52]

A1.3.1 STEP 1

N = the number of entities to be ranked = 6.

K = the number of judges assigning ranks = 9.

The sums of ranks assigned to each entity by K judges are shown in Table A.1 as R_i.

The mean of R_i = (12 + 16 + 26 + 36.5 + 44.5 + 54)/6 = 31.5

S= Sum of squares of the observed deviations from the mean of R_i : $(12 - 31.5)^2 + (16 - 31.5)^2 + (26 - 31.5)^2 + (36.5 - 31.5)^2 + (44.5 - 31.5)^2 + (54 - 31.5)^2 = 1351$

A1.3.2 STEP 2

Adjustment for ties:

Client 1: $T_1 = \Sigma(t^3-t)/12 = (3^3-3) = 24$

Client 2: $T_2 = \Sigma(t^3-t)/12 = (2^3-2) = 6$

Client 3: $T_3 = \Sigma(t^3-t)/12 = (2^3-2) = 6$

Client 4: $T_4 = \Sigma(t^3-t)/12 = (2^3-2) = 6$

$K\Sigma T = 9*(24+6+6+6) = 378$

Compute the Coefficient of Concordance

W = the Coefficient of Concordance = $S/\{(1/12)K^2(N^3-N)-K\Sigma T\}$

$= 1351/\{0.083*81*(216-6)-378\}$

$= 1.307$

A1.3.3 STEP 3- Compute Chi-Square with a degree of freedom of (N-1)

Chi-Square = K(N-1)W

= 9*(6-1)*1.307

= 58.81

A1.4 CONCLUSION

From Chi-Square Tables, it can be found that probability that the value of Chi-Square is greater than or equal to 20.52 for a degree of freedom of 5 is 0.001. Thus having a Chi-Square value of 58.81, it can be concluded with considerable assurance that the agreement among the 9 judges is higher than it would be by chance.

APPENDIX 2

Raw Data of 34 Cases for Model Formulation and 16 Cases for Testing

Case	PAST_PER	YEAR_BUS	ORIGIN	DEL	LISTED	CENTRAL	SUBSID	ARCH_PER	CONTROL	PAYMENT	PROFIT
1	2	3	3	0.150	2	1.0	2	4	4	1	1.070
2	3	5	3	0.200	2	1.0	2	2	4	2	0.940
3	2	20	3	0.200	2	1.0	2	4	3	1	0.950
4	4	8	3	0.000	2	1.5	2	2	3	1	0.923
5	2	15	3	0.050	2	1.0	2	1	5	1	0.869
6	2	10	3	0.000	2	1.0	2	3	4	1	1.070
7	3	18	3	0.116	1	2.0	1	3	1	1	1.000
8	3	18	3	0.134	1	2.0	1	3	3	1	1.000
9	3	18	3	0.084	1	2.0	1	3	2	1	1.000
10	3	18	3	0.096	1	2.0	1	3	3	1	1.000
11	3	18	3	0.127	1	2.0	1	3	2	1	1.000
12	3	18	3	0.102	1	2.0	1	3	3	1	1.000
13	3	18	3	0.080	1	2.0	1	3	3	1	1.000
14	2	40	3	0.000	1	1.0	2	4	3	1	1.000
15	3	3	3	0.150	2	1.5	2	3	4	1	0.878
16	3	15	3	0.250	2	2.0	2	3	3	1	1.007
17	4	12	1	0.565	2	2.0	2	2	3	1	0.783
18	2	51	3	0.033	1	1.5	1	5	5	1	1.000
19	2	40	3	0.000	1	1.0	1	4	4	1	0.934
20	2	51	3	0.033	1	1.5	2	4	4	1	0.981
21	2	40	3	0.000	1	1.0	2	4	4	1	0.970
22	2	40	3	0.000	1	1.0	1	3	5	1	1.000
23	2	51	3	0.033	1	1.5	2	3	5	1	1.020
24	4	34	1	0.150	2	2.0	2	3	3	1	1.170
25	2	51	3	0.033	1	1.0	2	3	4	1	1.055
26	4	13	1	0.150	2	2.0	2	2	2	1	0.937
27	2	40	3	0.000	1	1.0	2	3	4	1	1.400
28	4	13	1	0.130	2	2.0	2	2	3	1	0.950
29	3	34	1	0.500	2	2.0	2	2	3	1	1.300
30	4	18	3	0.086	1	2.0	2	3	4	1	1.097
31	4	15	3	0.133	1	2.0	2	4	4	1	0.949
32	4	12	3	0.030	2	2.0	2	2	3	2	1.000
33	3	12	3	0.030	2	2.0	2	2	4	1	1.300
34	3	12	3	0.030	[illegible]	2.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Case	PERFORM	CON_TIME	CON_COST	QUALITY	COMPLEX	TRAINING	PLANT	COM_SIZE	PROF_STA	LEAD_EX	CONT_EX	WORKLOAD
1	1	0.92	0.96	3	2	0.250	0.500	20	0.000	10	0.90	105000
2	1	1.33	1.13	3	2	0.200	0.025	10	0.100	5	0.75	120000
3	1	1.00	1.11	4	1	0.100	0.040	20	0.100	15	0.30	100000
4	2	1.25	1.26	1	2	0.000	0.050	15	0.067	10	0.00	110000
5	1	1.00	1.00	3	5	0.000	0.000	15	0.000	18	0.25	6667000
6	1	0.93	1.30	3	5	0.200	0.050	12	0.000	10	0.50	4000000
7	2	1.12	0.95	2	3	0.068	0.020	190	0.084	20	0.38	420108
8	1	1.08	1.02	4	4	0.068	0.020	190	0.084	22	0.10	420108
9	2	1.22	0.97	2	3	0.068	0.020	190	0.084	14	0.41	420108
10	1	1.12	1.03	3	3	0.068	0.020	190	0.084	22	0.41	420108
11	1	1.07	0.92	3	2	0.068	0.020	190	0.084	22	0.10	420108
12	1	1.21	1.01	3	3	0.068	0.020	190	0.084	24	0.41	420108
13	1	1.07	0.96	3	3	0.068	0.020	190	0.084	24	0.41	420108
14	1	1.00	1.05	3	2	0.050	0.025	600	0.067	15	0.08	4500000
15	1	1.40	1.03	4	4	0.417	0.000	12	0.250	11	0.33	2000000
16	1	1.00	1.15	3	1	0.000	0.140	50	0.080	12	1.00	3000000
17	1	1.25	1.04	3	1	0.125	0.178	200	0.400	12	0.40	3500000
18	1	1.22	1.03	4	3	0.214	0.011	700	0.036	12	0.70	2286000
19	1	0.87	1.11	3	5	0.050	0.025	600	0.067	6	0.12	4500000
20	1	1.00	1.02	3	5	0.214	0.011	700	0.036	12	0.05	2286000
21	1	1.00	1.15	4	3	0.050	0.025	600	0.067	5	0.30	4500000
22	1	1.08	1.20	4	5	0.050	0.025	600	0.067	10	0.08	4500000
23	1	1.13	1.20	3	6	0.214	0.011	700	0.036	30	0.05	2286000
24	2	1.14	1.06	2	4	0.075	0.017	530	0.151	11	0.05	7925000
25	1	1.42	1.07	4	5	0.214	0.011	700	0.036	7	0.25	2286000
26	2	1.12	1.10	1	5	0.100	0.050	400	0.200	15	0.05	4000000
27	1	1.13	1.02	4	6	0.050	0.025	600	0.067	6	0.04	4500000
28	2	NA	NA	NA	6	0.100	0.050	400	0.200	16	0.40	4000000
29	2	1.30	1.25	3	6	0.075	0.017	530	0.151	15	0.00	7925000
30	2	1.21	1.03	2	6	0.060	0.150	1000	0.090	16	0.00	3000000
31	1	1.00	0.97	3	4	0.060	0.150	1000	0.090	30	0.20	3000000
32	2	NA	1.02	2	4	0.064	0.050	1100	0.055	12	0.85	2450000
33	1	NA	NA	3	3	0.064	0.050	1100	0.055	22	0.85	2450000
34	1	1.00	1.00	4	1	0.064	0.050	1100	0.055	15	0.85	2450000

Case	PERFORM	CON_TIME	CON_COST	QUALITY	COMPLEX	TRAINING	PLANT	COM_SIZE	PROF_STA	LEAD_EX	CONT_EX	WORKLOAD
1	1	1.03	1.00	3	3	NA	NA	NA	0.075	12	NA	NA
2	1	1.11	1.00	2	3	NA	NA	NA	0.067	8	NA	NA
3	1	NA	NA	3	2	NA	NA	NA	0.000	13	NA	NA
4	1	NA	NA	NA	3	NA	NA	NA	0.289	15	NA	NA
5	1	1.33	1.04	3	2	NA	NA	NA	0.000	15	NA	NA
6	1	1.10	0.99	3	4	NA	NA	NA	0.000	9	NA	NA
7	1	1.06	0.98	3	3	NA	NA	NA	0.033	18	NA	NA
8	1	1.17	1.01	3	4	NA	NA	NA	0.060	7	NA	NA
9	1	1.19	1.12	3	4	NA	NA	NA	0.036	8	NA	NA
10	1	0.85	0.95	2	4	NA	NA	NA	0.020	8	NA	NA
11	2	2.00	1.05	2	2	NA	NA	NA	0.000	23	NA	NA
12	2	1.36	NA	1	3	NA	NA	NA	0.051	10	NA	NA
13	2	5.00	1.04	2	3	NA	NA	NA	0.100	8	NA	NA
14	2	1.89	1.10	2	4	NA	NA	NA	0.050	15	NA	NA
15	2	1.00	0.97	2	3	NA	NA	NA	0.050	15	NA	NA
16	2	1.00	1.11	2	5	NA	NA	NA	0.151	11	NA	NA

Case	PAST_PER	YEAR_BUS	ORIGIN	DEL	LISTED	CENTRAL	SUBSID	ARCH_PER	CONTROL	PAYMENT	PROFIT
1	5	NA	3	NA	NA	NA	NA	NA	5	NA	NA
2	2	NA	3	NA	NA	NA	NA	NA	3	NA	NA
3	2	NA	3	NA	NA	NA	NA	NA	5	NA	NA
4	2	NA	3	NA	NA	NA	NA	NA	3	NA	NA
5	2	NA	3	NA	NA	NA	NA	NA	5	NA	NA
6	2	NA	3	NA	NA	NA	NA	NA	4	NA	NA
7	2	NA	3	NA	NA	NA	NA	NA	4	NA	NA
8	2	NA	3	NA	NA	NA	NA	NA	5	NA	NA
9	2	NA	3	NA	NA	NA	NA	NA	4	NA	NA
10	2	NA	3	NA	NA	NA	NA	NA	3	NA	NA
11	3	NA	3	NA	NA	NA	NA	NA	3	NA	NA
12	4	NA	3	NA	NA	NA	NA	NA	4	NA	0.957
13	4	NA	3	NA	NA	NA	NA	NA	2	NA	NA
14	4	NA	3	NA	NA	NA	NA	NA	3	NA	NA
15	4	NA	3	NA	NA	NA	NA	NA	3	NA	NA
16	4	NA	1	NA	NA	NA	NA	NA	2	NA	NA

APPENDIX 3

SPSS(pc) Computer Printout of the Stepwise Procedures in Computing the Z_1 Discriminant Analysis Model

```
DSCRIMINANT /GROUPS PERFORM (1,2) /VARIABLES CON_TIME CON_COST QUALITY /SELECT
INCLUDE (1) /METHOD WILKS /PRIORS SIZE /STATISTICS=all.
```

Since ANALYSIS= was omitted for the first analysis all variables
on the VARIABLES= list will be entered at level 1.

This Discriminant Analysis requires 1364 (1.3K) BYTES of workspace.

- D I S C R I M I N A N T   A N A L Y S I S - - - -

On groups defined by PERFORM CONTRACTOR'S PERFORMANCE

50 (unweighted) cases were processed.
6 of these were excluded from the analysis.
0 had missing or out-of-range group codes.
6 had at least one missing discriminating variable.
0 were excluded by the SELECT= variable.
44 (unweighted) cases will be used in the analysis.

Number of Cases by Group

	Number of Cases		
PERFORM	Unweighted	Weighted	Label
1	32	32.0	
2	12	12.0	
Total	44	44.0	

Group Means

PERFORM	CON_TIME	CON_COST	QUALITY
1	1.09584	1.04866	3.21875
2	1.60417	1.07392	1.91667
Total	1.23448	1.05555	2.86364

Group Standard Deviations

PERFORM	CON_TIME	CON_COST	QUALITY
1	.14246	.08500	.55267
2	1.11621	.09987	.51493

Total	.62113	.08883	.79507

Pooled Within-Groups Covariance Matrix with 42 degrees of freedom

	CON_TIME	CON_COST	QUALITY
CON_TIME	.3412959		
CON_COST	-.1868442E-02	.7945479E-02	
QUALITY	.2936334E-01	.7221974E-02	.2948909

Pooled Within-Groups Correlation Matrix

	CON_TIME	CON_COST	QUALITY
CON_TIME	1.00000		
CON_COST	-.03588	1.00000	
QUALITY	.09256	.14920	1.00000

Correlations which cannot be computed are printed as '.'

Wilks' Lambda (U-statistic) and univariate F-ratio
with 1 and 42 degrees of freedom

Variable	Wilks' Lambda	F	Significance
CON_TIME	.86407	6.607	.0138
CON_COST	.98359	.7009	.4072
QUALITY	.45565	50.18	.0000

Covariance Matrix for Group 1,

	CON_TIME	CON_COST	QUALITY
CON_TIME	.2029472E-01		
CON_COST	.1606865E-03	.7225330E-02	
QUALITY	.2255141E-01	.1094859E-01	.3054435

Covariance Matrix for Group 2,

	CON_TIME	CON_COST	QUALITY
CON_TIME	1.245936		
CON_COST	-.7586894E-02	.9974992E-02	
QUALITY	.4856061E-01	-.3280303E-02	.2651515

Total Covariance Matrix with 43 degrees of freedom

	CON_TIME	CON_COST	QUALITY
CON_TIME	.3858020		
CON_COST	.7811057E-03	.7890207E-02	
QUALITY	-.1056543	.3784355E-03	.6321353

- D I S C R I M I N A N T   A N A L Y S I S - - - -

On groups defined by PERFORM CONTRACTOR'S PERFORMANCE

Analysis number 1

Stepwise variable selection

Selection rule: Minimize Wilks' Lambda
Maximum number of steps.................. 6
Minimum Tolerance Level.................. .00100
Minimum F to enter....................... 1.0000
Maximum F to remove...................... 1.0000

Canonical Discriminant Functions

Maximum number of functions.............. 1
Minimum cumulative percent of variance... 100.00
Maximum significance of Wilks' Lambda.... 1.0000

Prior Probabilities

Group	Prior	Label
1	.72727	
2	.27273	
Total	1.00000	

---------------- Variables not in the analysis after step 0 ----------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
CON_TIME	1.0000000	1.0000000	6.6073	.86407
CON_COST	1.0000000	1.0000000	.70087	.98359
QUALITY	1.0000000	1.0000000	50.176	.45565

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At step 1, QUALITY was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.45565	1	1	42.0		
Equivalent F	50.1759		1	42.0	.0000	

---------------- Variables in the analysis after step 1 ----------------

Variable	Tolerance	F to remove	Wilks' Lambda
QUALITY	1.0000000	50.176	

---------------- Variables not in the analysis after step 1 ----------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
CON_TIME	.9914332	.9914332	4.6694	.40906
CON_COST	.9777397	.9777397	1.6320	.43821

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F statistics and significances between pairs of groups after step 1
Each F statistic has 1 and 42.0 degrees of freedom.

	Group 1
Group 2	50.176 .0000

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At step 2, CON_TIME was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.40906	2	1	42.0		
Equivalent F	29.6145		2	41.0	.0000	

---------------- Variables in the analysis after step 2 ----------------

Variable	Tolerance	F to remove	Wilks' Lambda
CON_TIME	.9914332	4.6694	.45565
QUALITY	.9914332	45.604	.86407

--------------- Variables not in the analysis after step 2 ---------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
CON_COST	.9752493	.9681410	1.6882	.39250

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F statistics and significances between pairs of groups after step 2
Each F statistic has 2 and 41.0 degrees of freedom.

Group	1
2	29.614 .0000

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At step 3, CON_COST was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.39250	3	1	42.0		
Equivalent F	20.6371		3	40.0	.0000	

--------------- Variables in the analysis after step 3 ---------------

Variable	Tolerance	F to remove	Wilks' Lambda
CON_TIME	.9889079	4.6583	.43821
CON_COST	.9752493	1.6882	.40906
QUALITY	.9681410	46.519	.84896

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F statistics and significances between pairs of groups after step 3
Each F statistic has 3 and 40.0 degrees of freedom.

Group	1
2	20.637 .0000

F level or tolerance or VIN insufficient for further computation.

Summary Table

Step	Action Entered	Action Removed	Vars In	Wilks' Lambda	Sig.	Label
1	QUALITY		1	.45565	.0000	QUALITY OF WORK
2	CON_TIME		2	.40906	.0000	RATIO OF ACTUAL AND EST. CONTRACT DURATI
3	CON_COST		3	.39250	.0000	RATIO OF FINAL AND TENDER PRICE

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Classification Function Coefficients
(Fisher's Linear Discriminant Functions)

PERFORM =	1	2
CON_TIME	3.254332	5.200973
CON_COST	125.9233	133.9280
QUALITY	7.507107	2.701759
(constant)	-80.20843	-79.97385

Canonical Discriminant Functions

Function	Eigenvalue	Percent of Variance	Cumulative Percent	Canonical Correlation	:	After Function	Wilks' Lambda	Chi-squared	D.F.	Significance
					:	0	.3924986	37.877	3	.0000
1*	1.54778	100.00	100.00	.7794238	:					

* marks the 1 canonical discriminant functions remaining in the analysis.

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Standardized Canonical Discriminant Function Coefficients

	FUNC 1
CON_TIME	-.41669
CON_COST	-.26144
QUALITY	.95613

Structure Matrix:

Pooled-within-groups correlations between discriminating variables
and canonical discriminant functions
(Variables ordered by size of correlation within function)

	FUNC 1
QUALITY	.87855
CON_TIME	-.31881
CON_COST	-.10383

Unstandardized Canonical Discriminant Function Coefficients

	FUNC 1
CON_TIME	-.7132566
CON_COST	-2.932977
QUALITY	1.760698
(constant)	-1.065610

Canonical Discriminant Functions evaluated at Group Means (Group Centroids)

Group	FUNC 1
1	.74434
2	-1.98489

Test of equality of group covariance matrices using Box's M

The ranks and natural logarithms of determinants printed are those of the group covariance matrices.

Group Label	Rank	Log Determinant
1	3	-10.158298
2	3	-5.730461
Pooled Within-Groups Covariance Matrix	3	-7.164973

Box's M	Approximate F	Degrees of freedom		Significance
77.013	11.425	6,	2686.6	.0000

?

Case Number	Mis Val	Sel	Actual Group	Highest Probability Group	P(D/G)	P(G/D)	2nd Highest Group	P(G/D)	Discriminant Scores...
1		Yes	1	1	.9998	.9910	2	.0090	.7446
2		Yes	1	1	.4291	.9274	2	.0726	-.0464
3		Yes	1	1	.2062	.9997	2	.0003	2.0083
4		Yes	2	2	.0565	.9996	1	.0004	-3.8920

5		Yes	1	1	.8618	.9857	2	.0143	.5703
6		Yes	1	1	.3154	.8771	2	.1229	-.2597
7		Yes	2	2	.3923	.6008	1	.3992	-1.1294
8		Yes	1	1	.1413	.9998	2	.0002	2.2152
9		Yes	2	2	.4628	.6769	1	.3231	-1.2506
10		Yes	1	1	.7281	.9772	2	.0228	.3967
11		Yes	1	1	.9822	.9916	2	.0084	.7667
12		Yes	1	1	.7239	.9768	2	.0232	.3911
13		Yes	1	1	.9150	.9880	2	.0120	.6376
14		Yes	1	1	.7484	.9787	2	.0213	.4236
15		Yes	1	1	.2250	.9997	2	.0003	1.9577
16		Yes	1	1	.5392	.9539	2	.0461	.1303
17		Yes	1	1	.6386	.9684	2	.0316	.2746
18		Yes	1	1	.1797	.9998	2	.0002	2.0860
19		Yes	1	1	.6878	.9736	2	.0264	.3425
20		Yes	1	1	.8160	.9832	2	.0168	.5116
21		Yes	1	1	.2515	.9996	2	.0004	1.8910

Case Number	Mis Val	Sel	Actual Group	Highest Probability Group	P(D/G)	P(G/D)	2nd Highest Group	P(G/D)	Discriminant Scores...
22		Yes	1	1	.3457	.9993	2	.0007	1.6873
23		Yes	1	1	.3934	.9150	2	.0850	-.1091
24		Yes	2	2	.6040	.7905	1	.2095	-1.4663
25		Yes	1	1	.2794	.9995	2	.0005	1.8261
26		Yes	2	2	.1786	.9984	1	.0016	-3.3300
27		Yes	1	1	.1512	.9998	2	.0002	2.1796
29		Yes	2 **	1	.2622	.8382	2	.1618	-.3770
30		Yes	2	2	.5778	.7728	1	.2272	-1.4282
31		Yes	1	1	.9384	.9890	2	.0110	.6670
32		Yes	1	1	.8450	.9848	2	.0152	.5489
33		Yes	1 **	2	.4740	.6877	1	.3123	-1.2689
38		Yes	1	1	.1126	.9999	2	.0001	2.3309
39		Yes	1	1	.5983	.9633	2	.0367	.2176
40		Yes	1	1	.8358	.9843	2	.0157	.5371
41		Yes	1	1	.8812	.9866	2	.0134	.5949
42		Yes	1	1	.7454	.9785	2	.0215	.4197
43		Yes	1	1	.5083	.9478	2	.0522	.0828
44		Yes	1	1	.0927	.5292	2	.4708	-.9368
45		Yes	2	2	.9478	.9489	1	.0511	-2.0504
47		Yes	2	2	.0296	.9998	1	.0002	-4.1608
48		Yes	2	2	.8937	.9572	1	.0428	-2.1185

Case Number	Mis Val	Sel	Actual Group	Highest Probability Group	P(D/G)	P(G/D)	2nd Highest Group	P(G/D)	Discriminant Scores...
49		Yes	2	2	.3775	.5830	1	.4170	-1.1025
50		Yes	2	2	.6371	.8109	1	.1891	-1.5131

Symbols used in Plots

```
Symbol  Group  Label
------  -----  --------------------
  1       1
  2       2
```

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```
     Histogram for Group        1

             Canonical Discriminant Function 1
     16 +                                        +
        |                                        |
        |                                        |
        |                                        |
     12 +                    1                   +
        |                    1                   |
        |                    1                   |
        |                    1                   |
      8 +                    1                   +
        |                    1                   |
        |                    1   1               |
        |                    1   1               |
      4 +                   111  1               +
        |                   111  1               |
        |                   111  11              |
        |                111111 111              |
        X----+----+----+----+----+----+----+----X
       Out -6.0 -4.0 -2.0   .0  2.0  4.0  6.0   Out
  Class   2222222222222222222211111111111111111111
Centroids                     1
```

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```
             Histogram for Group        2

             Canonical Discriminant Function 1
      4 +                                        +
        |                                        |
        |                                        |
```

```
      |                                    |
    3 +              22                    +
      |              22                    |
      |              22                    |
      |              22                    |
    2 +          2  222                    +
      |          2  222                    |
      |          2  222                    |
      |          2  222                    |
    1 +          2 2  222 2                +
      |          2 2  222 2                |
      |          2 2  222 2                |
      |          2 2  222 2                |
      X----+----+----+----+----+----+----+----X
     Out -6.0 -4.0 -2.0   .0  2.0  4.0  6.0   Out
  Class    2222222222222222222211111111111111111111
Centroids                  2
-------------------------------------------------------------------------------------------
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               All-groups stacked Histogram

             Canonical Discriminant Function 1
   16 +                                    +
      |                                    |
      |                                    |
      |                                    |
   12 +                    1               +
      |                    1               |
      |                    1               |
      |                    1               |
    8 +                    1               +
      |                    1               |
      |                    1   1           |
      |                    1   1           |
    4 +              2  111   1            +
      |             22  111   1            |
      |          2    222 2111   11        |
      |          2 2  22111111 111         |
      X----+----+----+----+----+----+----+----X
     Out -6.0 -4.0 -2.0   .0  2.0  4.0  6.0   Out
  Class    2222222222222222222211111111111111111111
Centroids                  2     1
-------------------------------------------------------------------------------------------
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```

```
          X----+----+----+----+----+----+----+----X
        Out -6.0 -4.0 -2.0   .0  2.0  4.0  6.0    Out
  Class    2222222222222222222211111111111111111111
Centroids                 2     1
--------------------------------------------------------------------------------
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Classification Results for cases selected for use in the analysis -

                      No. of     Predicted Group Membership
   Actual Group        Cases          1          2
--------------------  ------     --------   --------
Group        1            32         31          1
                                   96.9%       3.1%

Group        2            12          1         11
                                    8.3%       91.7%

Percent of "grouped" cases correctly classified:  95.45%
--------------------------------------------------------------------------------
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Classification Results for cases not selected for use in the analysis -

                      No. of     Predicted Group Membership
   Actual Group        Cases          1          2
--------------------  ------     --------   --------
Group        1             0          0          0
                                     .0%        .0%

Group        2             0          0          0
                                     .0%        .0%

Percent of "grouped" cases correctly classified:    .00%

Classification Processing Summary
        50 Cases were processed.
         0 Cases were excluded for missing or out-of-range group codes.
         6 Cases had at least one missing discriminating variable.
        44 Cases were used for printed output.
--------------------------------------------------------------------------------
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This procedure was completed at 15:33:37

--------------------------------------------------------------------------------
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FINISH.

End of Include file.
```

APPENDIX 4

SPSS(pc) Computer Printout of the Stepwise Procedures in Computing the Z_2 Discriminant Analysis Model

```
DSCRIMINANT /GROUPS PERFORM (1,2) /VARIABLES COMPLEX TO PROFIT PAS_P_PM
/METHOD WILKS /PRIORS SIZE /STATISTICS=all.
```

Since ANALYSIS= was omitted for the first analysis all variables
on the VARIABLES= list will be entered at level 1.

This Discriminant Analysis requires 14568 (14.2K) BYTES of workspace.

-------- D I S C R I M I N A N T   A N A L Y S I S --------

On groups defined by PERFORM CONTRACTOR'S PERFORMANCE

34 (unweighted) cases were processed.
0 of these were excluded from the analysis.
34 (unweighted) cases will be used in the analysis.

Number of Cases by Group

	Number of Cases		
PERFORM	Unweighted	Weighted	Label
1	25	25.0	
2	9	9.0	
Total	34	34.0	

Group Means

PERFORM	COMPLEX	TRAINING	PLANT	COM_SIZE
1	3.36000	.11704	.05808	411.56000
2	4.33333	.06778	.04711	483.88889
Total	3.61765	.10400	.05518	430.70588

PERFORM	PROF_STA	LEAD_EX	CONT_EX	WORKLOAD
1	.08116	15.08000	.37804	2445461.60000
2	.12022	14.33333	.23811	3361135.11111
Total	.09150	14.88235	.34100	2687845.76471

PERFORM	PAST_PER	YEAR_BUS	ORIGIN	DEL
1	2.56000	24.64000	2.92000	.09714
2	3.66667	18.66667	2.11111	.13844
Total	2.85294	23.05882	2.70588	.10807

PERFORM	LISTED	CENTRAL	SUBSID	ARCH_PER
1	1.40000	1.48000	1.68000	3.16000
2	1.66667	1.94444	1.77778	2.44444
Total	1.47059	1.60294	1.70588	2.97059

PERFORM	CONTROL	PAYMENT	PROFIT	PAS_P_PM
1	3.68000	1.04000	.99906	2.20000
2	2.66667	1.11111	1.04189	2.22222
Total	3.41176	1.05882	1.01040	2.20588

Group Standard Deviations

PERFORM	COMPLEX	TRAINING	PLANT	COM_SIZE
1	1.60416	.09793	.10303	363.42538
2	1.50000	.02926	.04169	363.47092
Total	1.61461	.08757	.09037	359.35047

PERFORM	PROF_STA	LEAD_EX	CONT_EX	WORKLOAD
1	.08198	7.55491	.30068	1828796.17430
2	.05618	3.04138	.29417	2985459.93833
Total	.07719	6.62303	.30109	2182022.12344

PERFORM	PAST_PER	YEAR_BUS	ORIGIN	DEL
1	.65064	16.45165	.40000	.12200
2	.50000	9.31397	1.05409	.14500
Total	.78363	15.00089	.71898	.12753

PERFORM	LISTED	CENTRAL	SUBSID	ARCH_PER
1	.50000	.46726	.47610	.85049
2	.50000	.16667	.44096	.52705
Total	.50664	.45692	.46250	.83431

PERFORM	CONTROL	PAYMENT	PROFIT	PAS_P_PM
1	.85245	.20000	.12851	.64550
2	.86603	.33333	.12496	.66667
Total	.95719	.23883	.12714	.64099

Pooled Within-Groups Covariance Matrix with 32 degrees of freedom

	COMPLEX	TRAINING	PLANT	COM_SIZE
COMPLEX	2.492500			
TRAINING	.2575958E-01	.7406266E-02		
PLANT	-.3700167E-01	.1028317E-02	.8396523E-02	
COM_SIZE	171.5717	-3.989149	-2.885438	132086.3
PROF_STA	-.2147208E-01	.1406259E-02	.1729518E-03	-5.391813
LEAD_EX	.4150000	-.1130129	-.4404667E-01	273.1942
CONT_EX	-.2370842	.2328318E-02	.9993650E-02	-.2216078
WORKLOAD	1615882.	-30407.05	-31533.83	.2304657E+09
PAST_PER	-.3137500	-.5975833E-02	.9131667E-02	12.55708
YEAR_BUS	11.00750	-.2419708E-01	-.5362796	2347.710
ORIGIN	-.8166667E-01	-.5428056E-02	-.4092222E-02	17.94472
DEL	-.5398729E-01	.1126102E-02	.3201524E-02	-14.32466
LISTED	-.2375000	.8029167E-02	.1261042E-01	-47.02917
CENTRAL	-.1610417	-.5877847E-02	-.4345139E-03	23.49139
SUBSID	.4833333E-01	.8808611E-02	.1118319E-01	32.19556
ARCH_PER	-.8666667E-01	.1077278E-01	.1035111E-01	60.25639
CONTROL	.8400000	.1758292E-01	.2811667E-02	80.59833
PAYMENT	-.5291667E-01	.2474444E-02	-.9434722E-03	6.704722
PROFIT	.7749354E-01	-.8114932E-03	-.1245340E-04	11.32974
PAS_P_PM	.2979167	.6007639E-02	.4699306E-02	-10.89306

	PROF_STA	LEAD_EX	CONT_EX	WORKLOAD
PROF_STA	.5829154E-02			
LEAD_EX	-.1634333E-01	45.12000		
CONT_EX	-.2282668E-02	-.2211379	.8943762E-01	
WORKLOAD	18502.74	-3517108.	-193506.5	.4736614E+13
PAST_PER	.2641958E-01	1.433750	.3311792E-01	-243679.2
YEAR_BUS	-.2706217	-14.60250	-2.219947	.1297196E+08
ORIGIN	-.3374694E-01	.2133333	.2690528E-01	-716249.9
DEL	.6944564E-02	.4343396E-01	.2941669E-02	32926.28
LISTED	.1034583E-01	-.8687500	.7106042E-01	193142.9
CENTRAL	.1036535E-01	1.834583	.2803361E-01	-212201.0
SUBSID	.4116389E-02	-.8341667	.1123569E-01	376850.2
ARCH_PER	-.1414153E-01	-.4579167	-.2411264E-01	-228192.8
CONTROL	-.1481417E-01	-1.230000	-.4482333E-01	768910.2
PAYMENT	-.1449444E-02	-.3879167	.3074528E-01	-101143.6
PROFIT	-.2996876E-02	-.2560271E-01	-.3819998E-02	73534.04
PAS_P_PM	.2302361E-01	.9166667E-01	-.3576319E-01	466106.9

	PAST_PER	YEAR_BUS	ORIGIN	DEL
PAST_PER	.3800000			
YEAR_BUS	-5.248750	224.6800		
ORIGIN	-.1108333	-.4183333	.3977778	

DEL	.2969917E-01	-.4857940	-.5275514E-01	.1642012E-01
LISTED	.7500000E-01	-4.293750	-.1208333	.2446667E-01
CENTRAL	.1754167	-1.760833	-.4638889E-01	.1796226E-01
SUBSID	.2541667E-01	-.7045833	-.7555556E-01	.8812778E-02
ARCH_PER	-.1533333	5.211667	.1211111	-.2561993E-01
CONTROL	-.1412500	4.441250	.2166667E-01	-.2539208E-01
PAYMENT	.2416667E-01	-.8220833	.3027778E-01	-.1745139E-03
PROFIT	-.2409917E-01	.6064283	.1663472E-02	-.1284977E-02
PAS_P_PM	.5833333E-01	.1395833	-.1819444	.3509097E-01

	LISTED	CENTRAL	SUBSID	ARCH_PER
LISTED	.2500000			
CENTRAL	-.1458333E-01	.1706944		
SUBSID	.1416667	-.5534722E-01	.2186111	
ARCH_PER	-.1958333	-.3743056E-01	-.8847222E-01	.6119444
CONTROL	.6250000E-02	-.1664583	.1179167	-.1208333E-01
PAYMENT	.2916667E-01	-.1326389E-01	.1694444E-01	-.5013889E-01
PROFIT	-.9185417E-02	-.4680486E-02	.4461181E-02	.6115764E-02
PAS_P_PM	.2083333E-01	.3784722E-01	.1388889E-02	.9722222E-02

	CONTROL	PAYMENT	PROFIT	PAS_P_PM
CONTROL	.7325000			
PAYMENT	.2041667E-01	.5777778E-01		
PROFIT	.2578583E-01	-.3154653E-02	.1629019E-01	
PAS_P_PM	.7083333E-01	-.1319444E-01	-.4361806E-02	.4236111

Pooled Within-Groups Correlation Matrix

	COMPLEX	TRAINING	PLANT	COM_SIZE	PROF_STA	LEAD_EX	CONT_EX
COMPLEX	1.00000						
TRAINING	.18959	1.00000					
PLANT	-.25577	.13040	1.00000				
COM_SIZE	.29902	-.12754	-.08664	1.00000			
PROF_STA	-.17814	.21402	.02472	-.19431	1.00000		
LEAD_EX	.03913	-.19550	-.07156	.11191	-.03187	1.00000	
CONT_EX	-.50214	.09047	.36468	-.00204	-.09997	-.11008	1.00000
WORKLOAD	.47028	-.16235	-.15812	.29137	.11135	-.24058	-.29730
PAST_PER	-.32238	-.11264	.16166	.05605	.56135	.34626	.17964
YEAR_BUS	.46515	-.01876	-.39044	.43096	-.23647	-.14503	-.49522
ORIGIN	-.08202	-.10001	-.07081	.07829	-.70083	.05036	.14265
DEL	-.26686	.10212	.27266	-.30759	.70983	.05046	.07676
LISTED	-.30087	.18660	.27524	-.25880	.27101	-.25867	.47522
CENTRAL	-.24689	-.16531	-.01148	.15645	.32860	.66106	.22689
SUBSID	.06548	.21891	.26102	.18947	.11531	-.26560	.08035
ARCH_PER	-.07017	.16002	.14440	.21194	-.23678	-.08715	-.10307
CONTROL	.62167	.23872	.03585	.25912	-.22671	-.21395	-.17512
PAYMENT	-.13944	.11962	-.04284	.07675	-.07898	-.24026	.42770
PROFIT	.38458	-.07388	-.00106	.24425	-.30754	-.02986	-.10008
PAS_P_PM	.28993	.10726	.07880	-.04605	.46333	.02097	-.18374

	WORKLOAD	PAST_PER	YEAR_BUS	ORIGIN	DEL	LISTED	CENTRAL
WORKLOAD	1.00000						
PAST_PER	-.18163	1.00000					
YEAR_BUS	.39764	-.56804	1.00000				
ORIGIN	-.52181	-.28507	-.04425	1.00000			
DEL	.11806	.37598	-.25292	-.65276	1.00000		
LISTED	.17749	.24333	-.57291	-.38317	.38187	1.00000	
CENTRAL	-.23600	.68876	-.28433	-.17803	.33928	-.07060	1.00000
SUBSID	.37034	.08818	-.10053	-.25622	.14709	.60598	-.28652
ARCH_PER	-.13403	-.31797	.44447	.24548	-.25558	-.50068	-.11581
CONTROL	.41280	-.26773	.34619	.04014	-.23153	.01461	-.47075
PAYMENT	-.19334	.16310	-.22817	.19972	-.00567	.24268	-.13356
PROFIT	.26472	-.30630	.31698	.02066	-.07857	-.14393	-.08876
PAS_P_PM	.32905	.14539	.01431	-.44324	.42075	.06402	.14075

	SUBSID	ARCH_PER	CONTROL	PAYMENT	PROFIT	PAS_P_PM
SUBSID	1.00000					
ARCH_PER	-.24189	1.00000				
CONTROL	.29467	-.01805	1.00000			
PAYMENT	.15077	-.26665	.09924	1.00000		
PROFIT	.07476	.06125	.23606	-.10283	1.00000	
PAS_P_PM	.00456	.01910	.12716	-.08434	-.05251	1.00000

Correlations which cannot be computed are printed as '.'

Wilks' Lambda (U-statistic) and univariate F-ratio
with 1 and 32 degrees of freedom

Variable	Wilks' Lambda	F	Significance
COMPLEX	.92712	2.515	.1226
TRAINING	.93654	2.168	.1506
PLANT	.99705	.9483E-01	.7601
COM_SIZE	.99188	.2621	.6122
PROF_STA	.94865	1.732	.1975
LEAD_EX	.99745	.8177E-01	.7768
CONT_EX	.95669	1.449	.2376
WORKLOAD	.96469	1.171	.2872
PAST_PER	.60006	21.33	.0001
YEAR_BUS	.96820	1.051	.3130
ORIGIN	.74618	10.89	.0024
DEL	.97897	.6876	.4131
LISTED	.94444	1.882	.1796
CENTRAL	.79281	8.363	.0068
SUBSID	.99104	.2894	.5943
ARCH_PER	.85249	5.537	.0249
CONTROL	.77525	9.277	.0046
PAYMENT	.98222	.5792	.4522
PROFIT	.97724	.7452	.3944
PAS_P_PM	.99976	.7715E-02	.9306

Covariance Matrix for Group 1,

	COMPLEX	TRAINING	PLANT	COM_SIZE
COMPLEX	2.573333			
TRAINING	.2473500E-01	.9589623E-02		
PLANT	-.5778000E-01	.1423913E-02	.1061608E-01	
COM_SIZE	128.8317	-6.175857	-6.605630	132078.0
PROF_STA	-.4610167E-01	.1472577E-02	.3506117E-03	-6.352302
LEAD_EX	.5333333E-01	-.1651283	-.6267333E-01	382.2450
CONT_EX	-.2887233	.2611665E-02	.1412691E-01	-10.92865
WORKLOAD	1208410.	-54392.41	-35342.31	.1898272E+09
PAST_PER	-.4600000	-.7648333E-02	.8661667E-02	-5.826667
YEAR_BUS	13.21833	-.5765167E-01	-.6717617	2992.502
ORIGIN	.1966667	-.6633333E-03	-.9993333E-02	17.63000
DEL	-.1122608	.9606817E-03	.4904134E-02	-19.54014
LISTED	-.3583333	.1040000E-01	.1884167E-01	-65.69167
CENTRAL	-.2633333	-.9249167E-02	-.5191667E-03	21.55333
SUBSID	-.4666667E-01	.1176333E-01	.1265167E-01	18.43667
ARCH_PER	-.6000000E-01	.1436833E-01	.1302833E-01	81.40667
CONTROL	.9116667	.2513833E-01	-.3806667E-02	45.72833
PAYMENT	-.5666667E-01	.3456667E-02	-.1378333E-02	-16.73167
PROFIT	.7585250E-01	-.1257732E-02	.1800992E-03	10.21803
PAS_P_PM	.1333333	.2200000E-02	.7400000E-02	-28.99167

	PROF_STA	LEAD_EX	CONT_EX	WORKLOAD
PROF_STA	.6720223E-02			
LEAD_EX	-.3193000E-01	57.07667		

CONT_EX	-.1096715E-02	-.3181700	.9040579E-01	
WORKLOAD	-10300.51	-4241446.	-150049.6	.3344495E+13
PAST_PER	.3349000E-01	2.161667	.4743500E-01	-379830.1
YEAR_BUS	-.4071067	-19.59500	-2.627485	9894557.
ORIGIN	-.2657000E-01	.2566667	-.1830000E-02	-87878.20
DEL	.7986789E-02	.2238417E-01	.9149161E-02	-60214.85
LISTED	.9516667E-02	-.8666667	.9802500E-01	-2609.000
CENTRAL	.1271167E-01	2.355833	.3241750E-01	-350666.6
SUBSID	.2470000E-02	-.8900000	.2818000E-01	257381.4
ARCH_PER	-.1586000E-01	-.7633333	-.2759000E-01	-234285.3
CONTROL	-.1969667E-01	-1.223333	-.3861167E-01	699251.9
PAYMENT	.7850000E-03	-.4200000	.1549833E-01	-96894.23
PROFIT	-.4271552E-02	-.3427583E-01	-.7425858E-03	2706.556
PAS_P_PM	.2055000E-01	-.1833333	-.4659167E-01	242612.2

	PAST_PER	YEAR_BUS	ORIGIN	DEL
PAST_PER	.4233333			
YEAR_BUS	-6.415000	270.6567		
ORIGIN	-.1200000	1.053333	.1600000	
DEL	.5146000E-01	-.9806142	-.3898833E-01	.1488491E-01
LISTED	.5833333E-01	-5.808333	-.5000000E-01	.2723333E-01
CENTRAL	.2408333	-2.570000	-.4333333E-01	.2106542E-01
SUBSID	-.2166667E-01	-.9950000	-.2666667E-01	.8546667E-02
ARCH_PER	-.1766667	6.393333	.9666667E-01	-.2925250E-01
CONTROL	-.2716667	5.630000	.5666667E-01	-.3532833E-01
PAYMENT	.1833333E-01	-.8183333	.3333333E-02	.4285833E-02
PROFIT	-.2486833E-01	.4500850	.1800500E-01	-.6534071E-02
PAS_P_PM	.9166667E-01	-.4250000	-.6666667E-01	.2582500E-01

	LISTED	CENTRAL	SUBSID	ARCH_PER
LISTED	.2500000			
CENTRAL	-.1250000E-01	.2183333		
SUBSID	.1333333	-.6916667E-01	.2266667	
ARCH_PER	-.1916667	-.5916667E-01	-.7166667E-01	.7233333
CONTROL	-.3333333E-01	-.2150000	.6000000E-01	.1166667E-01
PAYMENT	.2500000E-01	-.2000000E-01	.1333333E-01	-.4833333E-01
PROFIT	-.1344167E-01	-.8717500E-02	.2457500E-02	.4010833E-02
PAS_P_PM	.0000000	.2500000E-01	-.1666667E-01	.5000000E-01

	CONTROL	PAYMENT	PROFIT	PAS_P_PM
CONTROL	.7266667			
PAYMENT	.1333333E-01	.4000000E-01		
PROFIT	.2247833E-01	-.2460833E-02	.1651547E-01	
PAS_P_PM	.1083333	-.8333333E-02	-.1332500E-01	.4166667

Covariance Matrix for Group 2,

	COMPLEX	TRAINING	PLANT	COM_SIZE
COMPLEX	2.250000			
TRAINING	.2883333E-01	.8561944E-03		
PLANT	.2533333E-01	-.1584722E-03	.1737861E-02	
COM_SIZE	299.7917	2.570972	8.275139	132111.1
PROF_STA	.5241667E-01	.1207306E-02	-.3600278E-03	-2.510347
LEAD_EX	1.500000	.4333333E-01	.1183333E-01	-53.95833
CONT_EX	-.8216667E-01	.1478278E-02	-.2406139E-02	31.89951
WORKLOAD	2838297.	41549.03	-20108.37	.3523810E+09
PAST_PER	.1250000	-.9583333E-03	.1054167E-01	67.70833
YEAR_BUS	4.375000	.7616667E-01	-.1298333	413.3333
ORIGIN	-.9166667	-.1972222E-01	.1361111E-01	18.88889
DEL	.1208333	.1622361E-02	-.1906306E-02	1.321806
LISTED	.1250000	.9166667E-03	-.6083333E-02	8.958333
CENTRAL	.1458333	.4236111E-02	-.1805556E-03	29.30556
SUBSID	.3333333	-.5555556E-04	.6777778E-02	73.47222
ARCH_PER	-.1666667	-.1388889E-04	.2319444E-02	-3.194444

CONTROL	.6250000	-.5083333E-02	.2266667E-01	185.2083
PAYMENT	-.4166667E-01	-.4722222E-03	.3611111E-03	77.01389
PROFIT	.8241667E-01	.5272222E-03	-.5901111E-03	14.66486
PAS_P_PM	.7916667	.1743056E-01	-.3402778E-02	43.40278

	PROF_STA	LEAD_EX	CONT_EX	WORKLOAD
PROF_STA	.3155944E-02			
LEAD_EX	.3041667E-01	9.250000		
CONT_EX	-.5840528E-02	.6995833E-01	.8653311E-01	
WORKLOAD	104912.5	-1344095.	-323877.1	.8912971E+13
PAST_PER	.5208333E-02	-.7500000	-.9833333E-02	164773.7
YEAR_BUS	.1388333	.3750000	-.9973333	.2220415E+08
ORIGIN	-.5527778E-01	.8333333E-01	.1131111	-2601365.
DEL	.3817889E-02	.1065833	-.1568081E-01	312349.7
LISTED	.1283333E-01	-.8750000	-.9833333E-02	780398.7
CENTRAL	.3326389E-02	.2708333	.1488194E-01	203195.9
SUBSID	.9055556E-02	-.6666667	-.3959722E-01	735256.8
ARCH_PER	-.8986111E-02	.4583333	-.1368056E-01	-209915.6
CONTROL	-.1666667E-03	-1.250000	-.6345833E-01	977885.2
PAYMENT	-.8152778E-02	-.2916667	.7648611E-01	-113891.9
PROFIT	.8271528E-03	.4166667E-03	-.1305224E-01	286016.5
PAS_P_PM	.3044444E-01	.9166667	-.3277778E-02	1136591.

	PAST_PER	YEAR_BUS	ORIGIN	DEL
PAST_PER	.2500000			
YEAR_BUS	-1.750000	86.75000		
ORIGIN	-.8333333E-01	-4.833333	1.111111	
DEL	-.3558333E-01	.9986667	-.9405556E-01	.2102578E-01
LISTED	.1250000	.2500000	-.3333333	.1616667E-01
CENTRAL	-.2083333E-01	.6666667	-.5555556E-01	.8652778E-02
SUBSID	.1666667	.1666667	-.2222222	.9611111E-02
ARCH_PER	-.8333333E-01	1.666667	.1944444	-.1472222E-01
CONTROL	.2500000	.8750000	-.8333333E-01	.4416667E-02
PAYMENT	.4166667E-01	-.8333333	.1111111	-.1355556E-01
PROFIT	-.2179167E-01	1.075458	-.4736111E-01	.1446231E-01
PAS_P_PM	-.4166667E-01	1.833333	-.5277778	.6288889E-01

	LISTED	CENTRAL	SUBSID	ARCH_PER
LISTED	.2500000			
CENTRAL	-.2083333E-01	.2777778E-01		
SUBSID	.1666667	-.1388889E-01	.1944444	
ARCH_PER	-.2083333	.2777778E-01	-.1388889	.2777778
CONTROL	.1250000	-.2083333E-01	.2916667	-.8333333E-01
PAYMENT	.4166667E-01	.6944444E-02	.2777778E-01	-.5555556E-01
PROFIT	.3583333E-02	.7430556E-02	.1047222E-01	.1243056E-01
PAS_P_PM	.8333333E-01	.7638889E-01	.5555556E-01	-.1111111

	CONTROL	PAYMENT	PROFIT	PAS_P_PM
CONTROL	.7500000			
PAYMENT	.4166667E-01	.1111111		
PROFIT	.3570833E-01	-.5236111E-02	.1561436E-01	
PAS_P_PM	-.4166667E-01	-.2777778E-01	.2252778E-01	.4444444

Total Covariance Matrix with 33 degrees of freedom

	COMPLEX	TRAINING	PLANT	COM_SIZE
COMPLEX	2.606952			
TRAINING	.1536364E-01	.7668485E-02		
PLANT	-.3802139E-01	.1105515E-02	.8166210E-02	
COM_SIZE	180.4902	-4.582788	-2.957098	129132.8
PROF_STA	-.1319697E-01	.9777576E-03	.8178788E-04	-4.661848
LEAD_EX	.2566845	-.1022121	-.4106952E-01	254.0856
CONT_EX	-.2572121	.3640091E-02	.9998606E-02	-2.244485
WORKLOAD	1745644.	-38531.37	-32592.41	.2367632E+09

PAST_PER	-.8823529E-01	-.1672727E-01	.6420677E-02	28.22816
YEAR_BUS	9.508021	.3554545E-01	-.5068895	2189.927
ORIGIN	-.2370766	.2727273E-02	-.2188948E-02	5.668449
DEL	-.4428922E-01	.6839394E-03	.3013653E-02	-13.29148
LISTED	-.1782531	.5151515E-02	.1164171E-01	-41.73619
CENTRAL	-.6550802E-01	-.1028788E-01	-.1442959E-02	29.51604
SUBSID	.6595365E-01	.7575758E-02	.1062923E-01	32.63815
ARCH_PER	-.2237077	.1751515E-01	.1161141E-01	48.05169
CONTROL	.6167558	.2706061E-01	.4955437E-02	63.45811
PAYMENT	-.3743316E-01	.1696970E-02	-.1071301E-02	7.532977
PROFIT	.8350490E-01	-.1210000E-02	-.1062843E-03	11.60762
PAS_P_PM	.2932264	.5606061E-02	.4508021E-02	-10.24064

	PROF_STA	LEAD_EX	CONT_EX	WORKLOAD
PROF_STA	.5958500E-02			
LEAD_EX	-.2169697E-01	43.86453		
CONT_EX	-.3309606E-02	-.1934848	.9065388E-01	
WORKLOAD	25114.83	-3547636.	-213337.0	.4761221E+13
PAST_PER	.3428788E-01	1.224599	.1060606E-02	-33083.98
YEAR_BUS	-.3092121	-13.26560	-1.985061	.1148202E+08
ORIGIN	-.3906061E-01	.3279857	.4878788E-01	-843077.0
DEL	.7057674E-02	.3593316E-01	.1693500E-02	39513.02
LISTED	.1212121E-01	-.8823529	.6142424E-01	236256.6
CENTRAL	.1368939E-01	1.709447	.1415152E-01	-120487.3
SUBSID	.4757576E-02	-.8235294	.8151515E-02	383384.9
ARCH_PER	-.1931818E-01	-.3368984	-.3303030E-02	-352671.3
CONTROL	-.2230303E-01	-1.040998	-.1503030E-01	559537.2
PAYMENT	-.8484848E-03	-.3868093	.2781818E-01	-85020.96
PROFIT	-.2570568E-02	-.3123975E-01	-.4906045E-02	79170.17
PAS_P_PM	.2250000E-01	.8556150E-01	-.3530303E-01	456063.0

	PAST_PER	YEAR_BUS	ORIGIN	DEL
PAST_PER	.6140820			
YEAR_BUS	-6.415330	225.0267		
ORIGIN	-.2869875	.5632799	.5169340	
DEL	.3796569E-01	-.5205499	-.5785651E-01	.1626467E-01
LISTED	.1319073	-4.483066	-.1604278	.2593405E-01
CENTRAL	.2731729	-2.263815	-.1203209	.2126493E-01
SUBSID	.4634581E-01	-.8003565	-.8912656E-01	.9355615E-02
ARCH_PER	-.3074866	5.910873	.2335116	-.3077050E-01
CONTROL	-.3618538	5.520499	.1853832	-.3301604E-01
PAYMENT	.3921569E-01	-.8823529	.1782531E-01	.4197861E-03
PROFIT	-.1386408E-01	.5367487	-.5334225E-02	-.8912877E-03
PAS_P_PM	.6149733E-01	.1087344	-.1800357	.3421168E-01

	LISTED	CENTRAL	SUBSID	ARCH_PER
LISTED	.2566845			
CENTRAL	.1069519E-01	.2087790		
SUBSID	.1426025	-.4456328E-01	.2139037	
ARCH_PER	-.2281640	-.1029412	-.9982175E-01	.6960784
CONTROL	-.4812834E-01	-.2557932	.9447415E-01	.1336898
PAYMENT	.3208556E-01	-.6238859E-02	.1782531E-01	-.5882353E-01
PROFIT	-.6616756E-02	-.5496881E-03	.5165775E-02	-.2152406E-03
PAS_P_PM	.2139037E-01	.3877005E-01	.1782531E-02	.6238859E-02

	CONTROL	PAYMENT	PROFIT	PAS_P_PM
CONTROL	.9162210			
PAYMENT	.5347594E-02	.5704100E-01		
PROFIT	.1630125E-01	-.2448307E-02	.1616439E-01	
PAS_P_PM	.6417112E-01	-.1247772E-01	-.4038770E-02	.4108734

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On groups defined by PERFORM CONTRACTOR'S PERFORMANCE

Analysis number 1

Stepwise variable selection

Selection rule: Minimize Wilks' Lambda
Maximum number of steps.................. 40
Minimum Tolerance Level.................. .00100
Minimum F to enter....................... 1.0000
Maximum F to remove...................... 1.0000

Canonical Discriminant Functions

Maximum number of functions.............. 1
Minimum cumulative percent of variance... 100.00
Maximum significance of Wilks' Lambda.... 1.0000

Prior Probabilities

Group	Prior	Label
1	.73529	
2	.26471	
Total	1.00000	

--------------- Variables not in the analysis after step 0 ---------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
COMPLEX	1.0000000	1.0000000	2.5153	.92712
TRAINING	1.0000000	1.0000000	2.1684	.93654
PLANT	1.0000000	1.0000000	.94826E-01	.99705
COM_SIZE	1.0000000	1.0000000	.26210	.99188
PROF_STA	1.0000000	1.0000000	1.7323	.94865
LEAD_EX	1.0000000	1.0000000	.81769E-01	.99745
CONT_EX	1.0000000	1.0000000	1.4488	.95669
WORKLOAD	1.0000000	1.0000000	1.1714	.96469
PAST_PER	1.0000000	1.0000000	21.328	.60006
YEAR_BUS	1.0000000	1.0000000	1.0509	.96820
ORIGIN	1.0000000	1.0000000	10.885	.74618
DEL	1.0000000	1.0000000	.68758	.97897
LISTED	1.0000000	1.0000000	1.8824	.94444
CENTRAL	1.0000000	1.0000000	8.3628	.79281
SUBSID	1.0000000	1.0000000	.28941	.99104
ARCH_PER	1.0000000	1.0000000	5.5370	.85249
CONTROL	1.0000000	1.0000000	9.2769	.77525
PAYMENT	1.0000000	1.0000000	.57919	.98222
PROFIT	1.0000000	1.0000000	.74516	.97724
PAS_P_PM	1.0000000	1.0000000	.77146E-02	.99976

At step 1, PAST_PER was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.60006	1	1	32.0		
Equivalent F	21.3282		1	32.0	.0001	

--------------- Variables in the analysis after step 1 ---------------

Variable	Tolerance	F to remove	Wilks' Lambda
PAST_PER	1.0000000	21.328	

--------------- Variables not in the analysis after step 1 ---------------

Minimum

Variable	Tolerance	Tolerance	F to enter	Wilks' Lambda
COMPLEX	.8960681	.8960681	6.1334	.50094
TRAINING	.9873114	.9873114	.53397	.58990
PLANT	.9738653	.9738653	.66379	.58748
COM_SIZE	.9968585	.9968585	.37359E-01	.59934
PROF_STA	.6848895	.6848895	1.3825	.57444
LEAD_EX	.8801069	.8801069	2.3470	.55783
CONT_EX	.9677283	.9677283	2.4834	.55555
WORKLOAD	.9670098	.9670098	2.2187	.55998
YEAR_BUS	.6773262	.6773262	2.1922	.56043
ORIGIN	.9187325	.9187325	2.4874	.55549
DEL	.8586394	.8586394	.55714	.58946
LISTED	.9407895	.9407895	.38071E-01	.59932
CENTRAL	.5256065	.5256065	.92385E-01	.59828
SUBSID	.9922236	.9922236	.10010E-01	.59986
ARCH_PER	.8988939	.8988939	.50607	.59042
CONTROL	.9283220	.9283220	2.0500	.56284
PAYMENT	.9733995	.9733995	.36550E-04	.60006
PROFIT	.9061802	.9061802	3.3283	.54188
PAS_P_PM	.9788611	.9788611	.20228	.59617

F statistics and significances between pairs of groups after step 1
Each F statistic has 1 and 32.0 degrees of freedom.

	Group 1
Group 2	21.328
	.0001

At step 2, COMPLEX was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.50094	2	1	32.0		
Equivalent F	15.4415		2	31.0	.0000	

--------------- Variables in the analysis after step 2 ---------------

Variable	Tolerance	F to remove	Wilks' Lambda
COMPLEX	.8960681	6.1334	.60006
PAST_PER	.8960681	26.373	.92712

--------------- Variables not in the analysis after step 2 ---------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
TRAINING	.9610922	.8722720	1.0679	.48373
PLANT	.9275793	.8534797	.64058E-01	.49988
COM_SIZE	.8846514	.7952061	.37011	.49484
PROF_STA	.6848806	.6338123	1.1340	.48270
LEAD_EX	.8547418	.7670816	3.1711	.45306
CONT_EX	.7475033	.6921508	.16273	.49824
WORKLOAD	.7778294	.7207664	.15601	.49835
YEAR_BUS	.5885678	.5885678	.31719	.49570
ORIGIN	.8849755	.7983689	1.0193	.48448
DEL	.8349645	.8055525	.93339E-01	.49939
LISTED	.8855802	.8434832	.54253	.49205
CENTRAL	.5249175	.5008948	.37144E-01	.50033
SUBSID	.9823822	.8840717	.17536E-01	.50065
ARCH_PER	.8656155	.7794891	.46280E-01	.50017
CONTROL	.6084737	.5873327	10.262	.37326
PAYMENT	.9649793	.8818337	.45538E-01	.50019
PROFIT	.8150043	.8059096	.96931	.48527
PAS_P_PM	.8522681	.7801825	1.6671	.47457

F statistics and significances between pairs of groups after step 2
Each F statistic has 2 and 31.0 degrees of freedom.

	Group 1
Group	
2	15.442
	.0000

At step 3, CONTROL was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.37326	3	1	32.0		
Equivalent F	16.7910		3	30.0	.0000	

---------------- Variables in the analysis after step 3 ----------------

Variable	Tolerance	F to remove	Wilks' Lambda
COMPLEX	.5873327	15.237	.56284
PAST_PER	.8886833	12.156	.52451
CONTROL	.6084737	10.262	.50094

---------------- Variables not in the analysis after step 3 ----------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
TRAINING	.9386005	.5861746	.21771	.37048
PLANT	.8613095	.5230740	.28220	.36966
COM_SIZE	.8728676	.5597290	.41571E-01	.37273
PROF_STA	.6748524	.5840906	1.5423	.35441
LEAD_EX	.7813500	.5309825	5.8271	.31081
CONT_EX	.7160344	.4425231	.48470E-01	.37264
WORKLOAD	.7548743	.5379633	.66322	.36491
YEAR_BUS	.5874889	.5419057	.35394	.36876
ORIGIN	.8774373	.5617956	.37031	.36855
DEL	.8318044	.5814706	.18263	.37092
LISTED	.8112717	.5101906	2.1784	.34718
CENTRAL	.4037693	.4037693	2.8081	.34031
SUBSID	.8694187	.5385057	.74053	.36397
ARCH_PER	.8656155	.5728975	.33345E-01	.37283
PAYMENT	.9026121	.5572143	.81347	.36307
PROFIT	.8145448	.5432659	.59480	.36576
PAS_P_PM	.8502391	.5261285	1.5127	.35475

F statistics and significances between pairs of groups after step 3
Each F statistic has 3 and 30.0 degrees of freedom.

	Group 1
Group	
2	16.791
	.0000

At step 4, LEAD_EX was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.31081	4	1	32.0		
Equivalent F	16.0764		4	29.0	.0000	

---------------- Variables in the analysis after step 4 ----------------

Variable	Tolerance	F to remove	Wilks' Lambda
COMPLEX	.5309825	19.110	.51562
LEAD_EX	.7813500	5.8271	.37326
PAST_PER	.7664780	16.898	.49191
CONTROL	.5562275	13.273	.45306

--------------- Variables not in the analysis after step 4 ---------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
TRAINING	.9129192	.5262526	.61974	.30408
PLANT	.8606007	.4803946	.17173	.30891
COM_SIZE	.8668520	.5132124	.98718E-05	.31081
PROF_STA	.5923844	.4825447	3.9845	.27209
CONT_EX	.7129001	.4164008	.29506E-02	.31077
WORKLOAD	.7006056	.4623777	.24201E-01	.31054
YEAR_BUS	.5872690	.4950659	.33111	.30717
ORIGIN	.8252934	.4906048	.34413E-03	.31080
DEL	.8254527	.5284908	.33008	.30719
LISTED	.7425928	.4892013	.52563	.30508
CENTRAL	.2623073	.2623073	.75450E-01	.30997
SUBSID	.8069761	.5167999	.39526E-01	.31037
ARCH_PER	.8621542	.5159217	.72456E-03	.31080
PAYMENT	.8437490	.5197775	.70090E-01	.31003
PROFIT	.8139085	.4968155	.56597	.30465
PAS_P_PM	.8378861	.4687735	1.8871	.29118

F statistics and significances between pairs of groups after step 4
Each F statistic has 4 and 29.0 degrees of freedom.

	Group 1
Group 2	16.076 .0000

At step 5, PROF_STA was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.27209	5	1	32.0		
Equivalent F	14.9815		5	28.0	.0000	

--------------- Variables in the analysis after step 5 ---------------

Variable	Tolerance	F to remove	Wilks' Lambda
COMPLEX	.5122598	19.997	.46641
PROF_STA	.5923844	3.9845	.31081
LEAD_EX	.6858678	8.4716	.35441
PAST_PER	.4825447	22.232	.48813
CONTROL	.5274149	15.017	.41802

--------------- Variables not in the analysis after step 5 ---------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
TRAINING	.8109538	.4645754	.13715E-01	.27195
PLANT	.8568320	.4681431	.67574E-01	.27141
COM_SIZE	.8035577	.4462241	.26803	.26941
CONT_EX	.6469050	.4160424	.28450	.26925
WORKLOAD	.6572375	.4585087	.38277	.26829
YEAR_BUS	.5738811	.3786970	.66412	.26556
ORIGIN	.4587421	.3292789	2.7630	.24683
DEL	.4514117	.3239547	.91323	.26319
LISTED	.7297675	.4661655	.83737	.26390

CENTRAL	.2619172	.2619172	.33045E-01	.27176
SUBSID	.8057077	.4678539	.65318E-01	.27143
ARCH_PER	.8593382	.4500598	.16837E-01	.27192
PAYMENT	.7657723	.4161170	.10884	.27100
PROFIT	.7847592	.4703480	.12283	.27086
PAS_P_PM	.6378709	.4509740	.17604	.27033

F statistics and significances between pairs of groups after step 5
Each F statistic has 5 and 28.0 degrees of freedom.

	Group 1
Group 2	14.982
	.0000

At step 6, ORIGIN was included in the analysis.

		Degrees of Freedom		Signif.	Between Groups
Wilks' Lambda	.24683	6	1	32.0	
Equivalent F	13.7312		6	27.0	.0000

--------------- Variables in the analysis after step 6 ---------------

Variable	Tolerance	F to remove	Wilks' Lambda
COMPLEX	.4906048	11.056	.34790
PROF_STA	.3292789	6.9980	.31080
LEAD_EX	.6858599	7.1670	.31235
PAST_PER	.4780581	20.846	.43740
ORIGIN	.4587421	2.7630	.27209
CONTROL	.5273377	12.273	.35903

--------------- Variables not in the analysis after step 6 ---------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
TRAINING	.7823584	.2845318	.34441E-01	.24650
PLANT	.8266384	.3191984	.24564E-02	.24681
COM_SIZE	.8023391	.3119939	.29681	.24404
CONT_EX	.6413423	.3018862	.41651	.24294
WORKLOAD	.4233616	.2955002	.18857	.24505
YEAR_BUS	.5571406	.3292789	.25374	.24444
DEL	.3803947	.2735525	.91026E-01	.24597
LISTED	.5910761	.3149880	.39113E-01	.24646
CENTRAL	.2599279	.2599279	.93921E-01	.24594
SUBSID	.7474988	.3215280	.34427E-01	.24650
ARCH_PER	.8468296	.3288040	.44421E-02	.24679
PAYMENT	.7465063	.3234794	.39329E-02	.24679
PROFIT	.7541791	.3052177	.45363E-03	.24682
PAS_P_PM	.6349894	.2889594	.24770	.24450

F statistics and significances between pairs of groups after step 6
Each F statistic has 6 and 27.0 degrees of freedom.

	Group 1
Group 2	13.731
	.0000

F level or tolerance or VIN insufficient for further computation.

Summary Table

Step	Action Entered	Removed	Vars In	Wilks' Lambda	Sig.	Label
1	PAST_PER		1	.60006	.0001	CONTRACTOR'S PAST PERFORMANCE OR IMA
2	COMPLEX		2	.50094	.0000	COMPLEXITY OF PROJECT
3	CONTROL		3	.37326	.0000	ARCHITECT OR CLIENT SUPERVISION AND
4	LEAD_EX		4	.31081	.0000	PROJECT LEADER'S EXPERIENCE
5	PROF_STA		5	.27209	.0000	MANAGEMENT TEAM'S QUALITY-PROFESSION
6	ORIGIN		6	.24683	.0000	ORIGIN OF THE COMPANY

Classification Function Coefficients
(Fisher's Linear Discriminant Functions)

PERFORM =	1	2
COMPLEX	1.532383	3.689788
PROF_STA	113.3637	67.52847
LEAD_EX	.2260276	-.1383812
PAST_PER	7.275977	14.13054
ORIGIN	18.80951	15.65250
CONTROL	6.785520	2.804390
(constant)	-58.44693	-58.55843

Canonical Discriminant Functions

Fcn	Eigenvalue	Pct of Variance	Cum Pct	Canonical Corr		After Fcn	Wilks' Lambda	Chisquare	DF	Sig
					:	0	.2468	40.573	6	.0000
1*	3.0514	100.00	100.00	.8679	:					

* marks the 1 canonical discriminant functions remaining in the analysis.

Standardized Canonical Discriminant Function Coefficients

	FUNC 1
COMPLEX	-.88670
PROF_STA	.91103
LEAD_EX	.63724
PAST_PER	-1.10002
ORIGIN	.51835
CONTROL	.88703

Structure Matrix:

Pooled-within-groups correlations between discriminating variables
and canonical discriminant functions
(Variables ordered by size of correlation within function)

	FUNC 1
PAST_PER	-.46736
ORIGIN	.33389
CENTRAL	-.32796
CONTROL	.30823
ARCH_PER	.25199
YEAR_BUS	.18871
TRAINING	.18611
WORKLOAD	-.17338
COM_SIZE	-.16209
COMPLEX	-.16050
PROF_STA	-.13319
LISTED	-.10448
PAS_P_PM	-.09851

SUBSID	-.09069
PAYMENT	-.08926
PROFIT	-.08318
DEL	-.04186
LEAD_EX	.02894
PLANT	.02098
CONT_EX	.00501

Unstandardized Canonical Discriminant Function Coefficients

	FUNC 1
COMPLEX	-.5616425
PROF_STA	11.93241
LEAD_EX	.9486742E-01
PAST_PER	-1.784466
ORIGIN	.8218719
CONTROL	1.036417
(constant)	-1.140765

Canonical Discriminant Functions evaluated at Group Means (Group Centroids)

Group	FUNC 1
1	1.01680
2	-2.82444

Test of equality of group covariance matrices using Box's M

The ranks and natural logarithms of determinants printed are those of the group covariance matrices.

Group Label	Rank	Log Determinant
1	6	-6.076040
2	6	-10.344742
Pooled Within-Groups Covariance Matrix	6	-4.779148

Box's M	Approximate F	Degrees of freedom		Significance
75.650	2.4802	21,	855.4	.0003

Case Number	Mis Val	Sel	Actual Group	Highest Probability Group	P(D/G)	P(G/D)	2nd Highest Group	P(G/D)	Discrim Scores
1			1	1	.4776	1.0000	2	.0000	1.7270
2			1	1	.7223	.9991	2	.0009	.6614
3			1	1	.0570	1.0000	2	.0000	2.9198
4			2	2	.4559	.9705	1	.0295	-2.0789
5			1	1	.4119	1.0000	2	.0000	1.8374
6			1	1	.3297	.9906	2	.0094	.0420
7			2	2	.2951	.9116	1	.0884	-1.7774
8			1	1	.2743	.9852	2	.0148	-.0765
9			2	2	.1300	.6316	1	.3684	-1.3102
10			1	1	.5950	.9983	2	.0017	.4852
11			1	1	.3142	.9894	2	.0106	.0104
12			1	1	.7324	.9992	2	.0008	.6749
13			1	1	.7324	.9992	2	.0008	.6749
14			1	1	.3433	1.0000	2	.0000	1.9644
15			1	1	.3786	1.0000	2	.0000	1.8972
16			1	1	.6857	.9989	2	.0011	.6121
17			1	1	.9884	.9998	2	.0002	1.0022
18			1	1	.0712	1.0000	2	.0000	2.8211
19			1	1	.5791	.9981	2	.0019	.4621
20			1	1	.7223	.9991	2	.0009	.6614
21			1	1	.6357	1.0000	2	.0000	1.4905

22	1	1	.3892	1.0000	2	.0000	1.8779
23	1	1	.0677	1.0000	2	.0000	2.8437
24	2	2	.3553	1.0000	1	.0000	-3.7487
25	1	1	.4067	.9946	2	.0054	.1870
26	2	2	.1192	1.0000	1	.0000	-4.3826
27	1	1	.2643	.9839	2	.0161	-.0996
28	2	2	.3229	1.0000	1	.0000	-3.8130
29	2	2	.9074	.9973	1	.0027	-2.7081
30	2	2	.7047	.9926	1	.0074	-2.4454
31	1	1	.3121	.9892	2	.0108	.0060
32	2	2	.7405	.9995	1	.0005	-3.1556
33	1	1	.8739	.9999	2	.0001	1.1756
34	1	1	.1457	.9433	2	.0567	-.4381

Symbols used in Plots

Symbol	Group	Label
1	1	
2	2	

Histogram for Group 1

```
                         Canonical Discriminant Function 1
      8
        |                                                              |
        |                                                              |
F       |                                                              |
r     6 |                                                              |
e       |                                                              |
q       |                              1  1                            |
u       |                              1  1                            |
e     4 |                              1  1     1                      |
n       |                              1  1     1                      |
c       |                              1  1     1                      |
y       |                              1  1     1                      |
      2 |                              1  11    1    1                 |
        |                              1  11    1    1                 |
        |                            1 1111 111 11   11                |
        |                            1 1111 111 11   11                |
        X---------+---------+---------+---------+---------+---------X
       Out      -4.0      -2.0        .0       2.0       4.0       Out
  Class    222222222222222222222222221111111111111111111111111111111111111
Centroids                                       1
```

Histogram for Group 2

```
                         Canonical Discriminant Function 1
      4 |                                                              |
        |                                                              |
        |                                                              |
F       |                                                              |
r     3 |                                                              |
e       |                                                              |
q       |                                                              |
u       |                                                              |
e     2 |          2                                                   |
n       |          2                                                   |
c       |          2                                                   |
y       |          2                                                   |
      1 |       2  2  2 2 2 22 2                                       |
        |       2  2  2 2 2 22 2                                       |
        |       2  2  2 2 2 22 2                                       |
        |       2  2  2 2 2 22 2                                       |
        X---------+---------+---------+---------+---------+---------X
       Out      -4.0      -2.0        .0       2.0       4.0       Out
```

```
  Class    22222222222222222222222222111111111111111111111111111111111111
Centroids                 2
--------------------------------------------------------------------------
```


All-groups stacked Histogram

```
                        Canonical Discriminant Function 1
        8 |                                                           |
          |                                                           |
          |                                                           |
F         |                                                           |
r       6 |                                                           |
e         |                                                           |
q         |                           1  1                            |
u         |                           1  1                            |
e       4 |                           1  1     1                      |
n         |                           1  1     1                      |
c         |                           1  1     1                      |
y         |                           1  1     1                      |
        2 |         2                 1 11     1    1                 |
          |         2                 1 11     1    1                 |
          |      2  2  2 2 2 22 2   1 1111 111 11   11                |
          |      2  2  2 2 2 22 2   1 1111 111 11   11                |
          X---------+---------+---------+---------+---------+---------X
         Out      -4.0      -2.0       .0       2.0       4.0        Out
  Class    22222222222222222222222222111111111111111111111111111111111111
Centroids                 2                   1
```

Classification Results -

Actual Group		No. of Cases	Predicted Group Membership 1	2
Group	1	25	25	0
			100.0%	.0%
Group	2	9	0	9
			.0%	100.0%

Percent of "grouped" cases correctly classified: 100.00%

Classification Processing Summary

34 Cases were processed.
0 Cases were excluded for missing or out-of-range group codes.
0 Cases had at least one missing discriminating variable.
34 Cases were used for printed output.

APPENDIX 5

SPSS(pc) Computer Printout of the Stepwise Procedures in Computing the Z_3 Discriminant Analysis Model

```
DSCRIMINANT /GROUPS PERFORM (1,2) /VARIABLES COMPLEX PROF_STA LEAD_EX PAST_PER
ORIGIN CONTROL /METHOD WILKS /PRIORS SIZE /STATISTICS=all.
```

Since ANALYSIS= was omitted for the first analysis all variables
on the VARIABLES= list will be entered at level 1.

This Discriminant Analysis requires 1904 (1.9K) BYTES of workspace.

- D I S C R I M I N A N T   A N A L Y S I S - - - - - - - -

On groups defined by PERFORM CONTRACTOR'S PERFORMANCE

30 (unweighted) cases were processed.
0 of these were excluded from the analysis.
30 (unweighted) cases will be used in the analysis.

Number of Cases by Group

	Number of Cases		
PERFORM	Unweighted	Weighted	Label
1	22	22.0	
2	8	8.0	
Total	30	30.0	

Group Means

PERFORM	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
1	3.54545	.08464	15.77273	2.59091	2.90909	3.68182
2	4.62500	.12688	14.87500	3.62500	2.00000	2.62500
Total	3.83333	.09590	15.53333	2.86667	2.66667	3.40000

Group Standard Deviations

PERFORM	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
1	1.62502	.08560	7.65899	.66613	.42640	.89370
2	1.30247	.05614	2.74838	.51755	1.06904	.91613
Total	1.59921	.08017	6.66816	.77608	.75810	1.00344

Pooled Within-Groups Covariance Matrix with 28 degrees of freedom

	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
COMPLEX	2.404627					
PROF_STA	-.3375041E-01	.6283499E-02				
LEAD_EX	-.7731331	-.3781940E-01	45.88352			
PAST_PER	-.3648539	.2861972E-01	1.734984	.3997565		
ORIGIN	.3246753E-02	-.3641883E-01	.4480519	-.1363636	.4220779	
CONTROL	.9890422	-.1585430E-01	-1.177354	-.1781656	.1298701E-01	.8088474

Pooled Within-Groups Correlation Matrix

	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
COMPLEX	1.00000					
PROF_STA	-.27457	1.00000				
LEAD_EX	-.07360	-.07043	1.00000			
PAST_PER	-.37213	.57104	.40511	1.00000		
ORIGIN	.00322	-.70718	.10181	-.33197	1.00000	
CONTROL	.70918	-.22239	-.19326	-.31332	.02223	1.00000

Correlations which cannot be computed are printed as '.'

Wilks' Lambda (U-statistic) and univariate F-ratio
with 1 and 28 degrees of freedom

Variable	Wilks' Lambda	F	Significance
COMPLEX	.90781	2.843	.1029
PROF_STA	.94385	1.666	.2074
LEAD_EX	.99633	.1030	.7506
PAST_PER	.64083	15.69	.0005
ORIGIN	.70909	11.49	.0021
CONTROL	.77561	8.101	.0082

Covariance Matrix for Group 1,

	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
COMPLEX	2.640693					
PROF_STA	-.5831602E-01	.7327481E-02				
LEAD_EX	-1.060606	-.4965801E-01	58.66017			

PAST_PER	-.5757576	.3522511E-01	2.521645	.4437229		
ORIGIN	.2424242	-.3003463E-01	.3593074	-.1341991	.1818182	
CONTROL	1.038961	-.2202597E-01	-1.170996	-.3268398	.6493506E-01	.7987013

Covariance Matrix for Group 2,

	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
COMPLEX	1.696429					
PROF_STA	.3994643E-01	.3151554E-02				
LEAD_EX	.8928571E-01	-.2303571E-02	7.553571			
PAST_PER	.2678571	.8803571E-02	-.6250000	.2678571		
ORIGIN	-.7142857	-.5557143E-01	.7142857	-.1428571	1.142857	
CONTROL	.8392857	.2660714E-02	-1.196429	.2678571	-.1428571	.8392857

Total Covariance Matrix with 29 degrees of freedom

	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
COMPLEX	2.557471					
PROF_STA	-.2336207E-01	.6427748E-02				
LEAD_EX	-.9425287	-.4418621E-01	44.46437			
PAST_PER	-.1264368	.3646897E-01	1.487356	.6022989		
ORIGIN	-.1954023	-.4293103E-01	.5977011	-.3218391	.5747126	
CONTROL	.7241379	-.2433793E-01	-.9448276	-.3931034	.2068966	1.006897

- D I S C R I M I N A N T   A N A L Y S I S - - - - - - - -

On groups defined by PERFORM CONTRACTOR'S PERFORMANCE

Analysis number 1

Stepwise variable selection

Selection rule: Minimize Wilks' Lambda
Maximum number of steps.................. 12
Minimum Tolerance Level.................. .00100
Minimum F to enter....................... 1.0000
Maximum F to remove...................... 1.0000

Canonical Discriminant Functions

Maximum number of functions.............. 1

Minimum cumulative percent of variance... 100.00
Maximum significance of Wilks' Lambda.... 1.0000

Prior Probabilities

Group	Prior	Label
1	.73333	
2	.26667	
Total	1.00000	

--------------- Variables not in the analysis after step 0 ---------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
COMPLEX	1.0000000	1.0000000	2.8433	.90781
PROF_STA	1.0000000	1.0000000	1.6657	.94385
LEAD_EX	1.0000000	1.0000000	.10304	.99633
PAST_PER	1.0000000	1.0000000	15.693	.64083
ORIGIN	1.0000000	1.0000000	11.487	.70909
CONTROL	1.0000000	1.0000000	8.1008	.77561

* *

At step 1, PAST_PER was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.64083	1	1	28.0		
Equivalent F	15.6933		1	28.0	.0005	

--------------- Variables in the analysis after step 1 ---------------

Variable	Tolerance	F to remove	Wilks' Lambda
PAST_PER	1.0000000	15.693	

--------------- Variables not in the analysis after step 1 ---------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
COMPLEX	.8615175	.8615175	7.1643	.50645
PROF_STA	.6739127	.6739127	.86547	.62093
LEAD_EX	.8358887	.8358887	2.7418	.58176
ORIGIN	.8897930	.8897930	2.9878	.57698

CONTROL	.9018285	.9018285	1.7650	.60151

F statistics and significances between pairs of groups after step 1
Each F statistic has 1 and 28.0 degrees of freedom.

	Group 1
Group 2	15.693 .0005

* *

At step 2, COMPLEX was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.50645	2	1	28.0		
Equivalent F	13.1562		2	27.0	.0001	

--------------- Variables in the analysis after step 2 ---------------

Variable	Tolerance	F to remove	Wilks' Lambda
COMPLEX	.8615175	7.1643	.64083
PAST_PER	.8615175	21.398	.90781

--------------- Variables not in the analysis after step 2 ---------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
PROF_STA	.6694410	.6237599	.38867	.49899
LEAD_EX	.8289799	.7180710	2.7678	.45772
ORIGIN	.8729903	.7521043	1.4362	.47994
CONTROL	.4942267	.4721352	13.587	.33262

F statistics and significances between pairs of groups after step 2
Each F statistic has 2 and 27.0 degrees of freedom.

Group 1

```
  Group
     2                   13.156
                          .0001

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

At step   3, CONTROL  was included in the analysis.

                                      Degrees of Freedom  Signif.   Between Groups
Wilks' Lambda          .33262          3     1        28.0
Equivalent F          17.3888                3        26.0   .0000

--------------- Variables in the analysis after step   3 ---------------

Variable  Tolerance  F to remove   Wilks' Lambda
COMPLEX    .4721352   21.018          .60151
PAST_PER   .8566052   8.3523          .43948
CONTROL    .4942267   13.587          .50645

--------------- Variables not in the analysis after step   3 ---------------

                      Minimum
Variable  Tolerance  Tolerance  F to enter   Wilks' Lambda
PROF_STA   .6694398   .4704642   .24938           .32934
LEAD_EX    .8001350   .4545938   3.6171           .29058
ORIGIN     .8729884   .4671124   .89875           .32108
------------------------------------------------------------------------------------------------
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F statistics and significances between pairs of groups after step   3
Each F statistic has   3 and      26.0 degrees of freedom.

                Group       1

  Group
     2                   17.389
                          .0000

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

At step   4, LEAD_EX  was included in the analysis.

                                      Degrees of Freedom  Signif.   Between Groups
```

Wilks' Lambda	.29058	4	1	28.0	
Equivalent F	15.2587		4	25.0	.0000

--------------- Variables in the analysis after step 4 ---------------

Variable	Tolerance	F to remove	Wilks' Lambda
COMPLEX	.4545938	21.707	.54288
LEAD_EX	.8001350	3.6171	.33262
PAST_PER	.7180347	11.720	.42680
CONTROL	.4770297	14.380	.45772

--------------- Variables not in the analysis after step 4 ---------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
PROF_STA	.5596452	.4401812	1.6171	.27224
ORIGIN	.7965507	.4423698	.13642	.28894

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F statistics and significances between pairs of groups after step 4
Each F statistic has 4 and 25.0 degrees of freedom.

	Group 1
Group 2	15.259 .0000

* *

At step 5, PROF_STA was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.27224	5	1	28.0		
Equivalent F	12.8316		5	24.0	.0000	

--------------- Variables in the analysis after step 5 ---------------

Variable	Tolerance	F to remove	Wilks' Lambda
COMPLEX	.4543854	19.037	.48818
PROF_STA	.5596452	1.6171	.29058
LEAD_EX	.6689051	5.0339	.32934

PAST_PER	.4401812	12.450	.41346
CONTROL	.4736817	13.777	.42851

--------------- Variables not in the analysis after step 5 ---------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
ORIGIN	.4589571	.3224567	2.2334	.24814

F statistics and significances between pairs of groups after step 5
Each F statistic has 5 and 24.0 degrees of freedom.

	Group 1
Group 2	12.832 .0000

* *

At step 6, ORIGIN was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.24814	6	1	28.0		
Equivalent F	11.6148		6	23.0	.0000	

--------------- Variables in the analysis after step 6 ---------------

Variable	Tolerance	F to remove	Wilks' Lambda
COMPLEX	.4368113	10.732	.36393
PROF_STA	.3224567	3.7814	.28894
LEAD_EX	.6684600	4.1190	.29258
PAST_PER	.4398088	10.863	.36534
ORIGIN	.4589571	2.2334	.27224
CONTROL	.4736647	11.346	.37055

F statistics and significances between pairs of groups after step 6
Each F statistic has 6 and 23.0 degrees of freedom.

Group 1

```
Group
    2                    11.615
                          .0000

F level or tolerance or VIN insufficient for further computation.
```

Summary Table

Step	Action Entered	Removed	Vars In	Wilks' Lambda	Sig.	Label
1	PAST_PER		1	.64083	.0005	CONTRACTOR'S PAST PERFORMANCE OR IMAGE
2	COMPLEX		2	.50645	.0001	COMPLEXITY OF PROJECT
3	CONTROL		3	.33262	.0000	ARCHITECT OR CLIENT SUPERVISION AND CONT
4	LEAD_EX		4	.29058	.0000	PROJECT LEADER'S EXPERIENCE
5	PROF_STA		5	.27224	.0000	MANAGEMENT TEAM'S QUALITY-PROFESSIONAL Q
6	ORIGIN		6	.24814	.0000	ORIGIN OF THE COMPANY

Classification Function Coefficients
(Fisher's Linear Discriminant Functions)

PERFORM =	1	2
COMPLEX	1.769996	4.183717
PROF_STA	104.8577	68.24728
LEAD_EX	.8377672E-01	-.2248458
PAST_PER	9.427000	15.35105
ORIGIN	18.68790	15.72341
CONTROL	6.341327	2.268965
(constant)	-59.61441	-60.17896

Canonical Discriminant Functions

Function	Eigenvalue	Percent of Variance	Cumulative Percent	Canonical Correlation	:	After Function	Wilks' Lambda	Chi-squared	D.F.	Significanc
					:	0	.2481417	34.844	6	.0000
1*	3.02996	100.00	100.00	.8670976	:					

* marks the 1 canonical discriminant functions remaining in the analysis.

Standardized Canonical Discriminant Function Coefficients

	FUNC 1
COMPLEX	-.98426
PROF_STA	.76314
LEAD_EX	.54974
PAST_PER	-.98495
ORIGIN	.50646
CONTROL	.96312

Structure Matrix:

Pooled-within-groups correlations between discriminating variables
and canonical discriminant functions
(Variables ordered by size of correlation within function)

	FUNC 1
PAST_PER	-.43009
ORIGIN	.36797
CONTROL	.30901
COMPLEX	-.18307
PROF_STA	-.14012
LEAD_EX	.03485

Unstandardized Canonical Discriminant Function Coefficients

	FUNC 1
COMPLEX	-.6347252
PROF_STA	9.627276
LEAD_EX	.8115704E-01
PAST_PER	-1.557821
ORIGIN	.7795574
CONTROL	1.070890
(constant)	-1.004874

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Canonical Discriminant Functions evaluated at Group Means (Group Centroids)

Group	FUNC 1
1	1.01408
2	-2.78871

Test of equality of group covariance matrices using Box's M

The ranks and natural logarithms of determinants printed are those of the group covariance matrices.

Group Label	Rank	Log Determinant
1	6	-6.164931
2	6	-10.725307
Pooled Within-Groups Covariance Matrix	6	-4.793984

Box's M	Approximate F	Degrees of freedom		Significance
70.309	2.1427	21,	654.9	.0022

Case Number	Mis Val	Sel	Actual Group	Highest Probability Group	P(D/G)	P(G/D)	2nd Highest Group	P(G/D)	Discriminant Scores...
1			1	1	.0498	1.0000	2	.0000	2.9762
2			1	1	.3977	1.0000	2	.0000	1.8598
3			1	1	.3819	.9927	2	.0073	.1397
4			2	2	.2948	.9034	1	.0966	-1.7411
5			1	1	.2776	.9839	2	.0161	-.0717
6			2	2	.1028	.5036	1	.4964	-1.1572
7			1	1	.6519	.9985	2	.0015	.5630
8			1	1	.3749	.9924	2	.0076	.1268
9			1	1	.7727	.9992	2	.0008	.7253
10			1	1	.7727	.9992	2	.0008	.7253
11			1	1	.4899	1.0000	2	.0000	1.7045
12			1	1	.9747	.9997	2	.0003	.9823
13			1	1	.9458	.9997	2	.0003	.9461
14			1	1	.0483	1.0000	2	.0000	2.9889
15			1	1	.5796	.9978	2	.0022	.4601
16			1	1	.7147	.9989	2	.0011	.6486
17			1	1	.5259	1.0000	2	.0000	1.6484
18			1	1	.4001	1.0000	2	.0000	1.8556
19			1	1	.1257	1.0000	2	.0000	2.5455
20			2	2	.5172	.9998	1	.0002	-3.4364
21			1	1	.4405	.9951	2	.0049	.2428
22			2	2	.1195	1.0000	1	.0000	-4.3456
23			1	1	.2345	.9764	2	.0236	-.1747
24			2	2	.2985	1.0000	1	.0000	-3.8283

25	2	2	.9723	.9983	1	.0017	-2.8234
26	2	2	.5951	.9852	1	.0148	-2.2573
27	1	1	.3866	.9930	2	.0070	.1483
28	2	2	.9455	.9974	1	.0026	-2.7203
29	1	1	.7334	.9999	2	.0001	1.3547
30	1	1	.2714	.9830	2	.0170	-.0858

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Symbols used in Plots

```
Symbol  Group  Label
------  -----  --------------------
  1        1
  2        2
     Histogram for Group       1

             Canonical Discriminant Function 1
      8 +                                        +
        |                                        |
        |                                        |
        |                                        |
      6 +                1                       +
        |                1                       |
        |                1 1                     |
        |                1 1                     |
      4 +                1 1                     +
        |                1 1                     |
        |                111                     |
        |                111                     |
      2 +                111 11 1                +
        |                111 11 1                |
        |                11111111                |
        |                11111111                |
        X----+----+----+----+----+----+----+----X
       Out -6.0 -4.0 -2.0   .0  2.0  4.0  6.0    Out
  Class   2222222222222222222111111111111111111111
Centroids                     1
```

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Histogram for Group 2

Canonical Discriminant Function 1

```
     4 +                                    +
       |                                    |
       |                                    |
       |                                    |
     3 +                                    +
       |                                    |
       |                                    |
       |                                    |
     2 +           2                        +
       |           2                        |
       |           2                        |
       |           2                        |
     1 +        222 22 22                   +
       |        222 22 22                   |
       |        222 22 22                   |
       |        222 22 22                   |
        X----+----+----+----+----+----+----+----X
      Out -6.0 -4.0 -2.0    .0  2.0  4.0  6.0    Out
 Class    2222222222222222222211111111111111111111
Centroids              2
```

```
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                All-groups stacked Histogram

               Canonical Discriminant Function 1
     8 +                                    +
       |                                    |
       |                                    |
       |                                    |
     6 +                  1                 +
       |                  1                 |
       |                  1 1               |
       |                  1 1               |
     4 +                  1 1               +
       |                  1 1               |
       |                  111               |
       |                  111               |
     2 +             2    111 11 1          +
       |             2    111 11 1          |
       |        222 22 22 11111111          |
       |        222 22 22 11111111          |
        X----+----+----+----+----+----+----+----X
      Out -6.0 -4.0 -2.0    .0  2.0  4.0  6.0    Out
```

```
  Class    22222222222222222221111111111111111111111
Centroids                    2        1
--------------------------------------------------------------------------------
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Classification Results -

                      No. of     Predicted Group Membership
   Actual Group        Cases          1          2
-------------------  ------   --------   --------
Group      1             22         22          0
                                 100.0%        .0%

Group      2              8          0          8
                                    .0%     100.0%

Percent of "grouped" cases correctly classified: 100.00%

Classification Processing Summary
        30 Cases were processed.
         0 Cases were excluded for missing or out-of-range group codes.
         0 Cases had at least one missing discriminating variable.
        30 Cases were used for printed output.
--------------------------------------------------------------------------------
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This procedure was completed at 17:18:21
--------------------------------------------------------------------------------
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FINISH.

End of Include file.
```

APPENDIX 6

SPSS(pc) Computer Printout of the Stepwise Procedures in Computing the Z_4 Discriminant Analysis Model

```
DSCRIMINANT
/GROUPS PERFORM (1,2) /VARIABLES COMPLEX PROF_STA LEAD_EX PAST_PER
ORIGIN CONTROL /METHOD WILKS /PRIORS SIZE /STATISTICS=all.
```

Since ANALYSIS= was omitted for the first analysis all variables on the VARIABLES= list will be entered at level 1.

This Discriminant Analysis requires 1904 (1.9K) BYTES of workspace.

D I S C R I M I N A N T   A N A L Y S I S

On groups defined by PERFORM CONTRACTOR'S PERFORMANCE

26 (unweighted) cases were processed.
0 of these were excluded from the analysis.
26 (unweighted) cases will be used in the analysis.

Number of Cases by Group

	Number of Cases		
PERFORM	Unweighted	Weighted	Label
1	18	18.0	
2	8	8.0	
Total	26	26.0	

Group Means

PERFORM	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
1	4.11111	.06817	16.27778	2.50000	3.00000	3.88889
2	4.62500	.12688	14.87500	3.62500	2.00000	2.62500
Total	4.26923	.08623	15.84615	2.84615	2.69231	3.50000

Group Standard Deviations

PERFORM	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
1	1.18266	.05336	8.39331	.61835	.00000	.83235
2	1.30247	.05614	2.74838	.51755	1.06904	.91613
Total	1.21845	.05985	7.10320	.78446	.73589	1.02956

Pooled Within-Groups Covariance Matrix with 24 degrees of freedom

	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
COMPLEX	1.485532					
PROF_STA	-.9461806E-03	.2936057E-02				
LEAD_EX	-2.080440	.1050174E-01	52.10359			
PAST_PER	-.2135417	.1471354E-01	2.338542	.3489583		
ORIGIN	-.2083333	-.1620833E-01	.2083333	-.4166667E-01	.3333333	
CONTROL	.6707176	-.8751736E-02	-1.742477	-.1302083	-.4166667E-01	.7355324

Pooled Within-Groups Correlation Matrix

	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
COMPLEX	1.00000					
PROF_STA	-.01433	1.00000				
LEAD_EX	-.23647	.02685	1.00000			
PAST_PER	-.29659	.45967	.54843	1.00000		
ORIGIN	-.29606	-.51810	.04999	-.12217	1.00000	
CONTROL	.64165	-.18833	-.28147	-.25701	-.08415	1.00000

Correlations which cannot be computed are printed as '.'

Wilks' Lambda (U-statistic) and univariate F-ratio
with 1 and 24 degrees of freedom

Variable	Wilks' Lambda	F	Significance
COMPLEX	.96059	.9846	.3310
PROF_STA	.78684	6.502	.0176
LEAD_EX	.99136	.2092	.6515
PAST_PER	.54437	20.09	.0002
ORIGIN	.59091	16.62	.0004
CONTROL	.66614	12.03	.0020

Covariance Matrix for Group 1,

	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
COMPLEX	1.398693					
PROF_STA	-.1778431E-01	.2847324E-02				

LEAD_EX	-2.973856	.1577451E-01	70.44771			
PAST_PER	-.4117647	.1714706E-01	3.558824	.3823529		
ORIGIN	.0000000	.1306145E-16	.0000000	.0000000	.0000000	
CONTROL	.6013072	-.1345098E-01	-1.967320	-.2941176	.0000000	.6928105

Covariance Matrix for Group 2,

	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
COMPLEX	1.696429					
PROF_STA	.3994643E-01	.3151554E-02				
LEAD_EX	.8928571E-01	-.2303571E-02	7.553571			
PAST_PER	.2678571	.8803571E-02	-.6250000	.2678571		
ORIGIN	-.7142857	-.5557143E-01	.7142857	-.1428571	1.142857	
CONTROL	.8392857	.2660714E-02	-1.196429	.2678571	-.1428571	.8392857

Total Covariance Matrix with 25 degrees of freedom

	COMPLEX	PROF_STA	LEAD_EX	PAST_PER	ORIGIN	CONTROL
COMPLEX	1.484615					
PROF_STA	.5775385E-02	.3582185E-02				
LEAD_EX	-2.156923	-.8163077E-02	50.45538			
PAST_PER	-.7692308E-01	.2875692E-01	1.895385	.6153846		
ORIGIN	-.3138462	-.2856615E-01	.5107692	-.2892308	.5415385	
CONTROL	.5000000	-.2484000E-01	-1.280000	-.4400000	.2400000	1.060000

- D I S C R I M I N A N T A N A L Y S I S - - - - - - - -

On groups defined by PERFORM CONTRACTOR'S PERFORMANCE

Analysis number 1

Stepwise variable selection

Selection rule: Minimize Wilks' Lambda
Maximum number of steps.................. 12
Minimum Tolerance Level.................. .00100
Minimum F to enter....................... 1.0000
Maximum F to remove...................... 1.0000

Canonical Discriminant Functions

Maximum number of functions.............. 1
Minimum cumulative percent of variance... 100.00
Maximum significance of Wilks' Lambda.... 1.0000

Prior Probabilities

Group	Prior	Label
1	.69231	
2	.30769	
Total	1.00000	

---------------- Variables not in the analysis after step 0 ----------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
COMPLEX	1.0000000	1.0000000	.98457	.96059
PROF_STA	1.0000000	1.0000000	6.5017	.78684
LEAD_EX	1.0000000	1.0000000	.20917	.99136
PAST_PER	1.0000000	1.0000000	20.087	.54437
ORIGIN	1.0000000	1.0000000	16.615	.59091
CONTROL	1.0000000	1.0000000	12.028	.66614

* *

At step 1, PAST_PER was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.54437	1	1	24.0		
Equivalent F	20.0873		1	24.0	.0002	

---------------- Variables in the analysis after step 1 ----------------

Variable	Tolerance	F to remove	Wilks' Lambda
PAST_PER	1.0000000	20.087	

---------------- Variables not in the analysis after step 1 ----------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
COMPLEX	.9120351	.9120351	3.0828	.48003
PROF_STA	.7887015	.7887015	.15858	.54065
LEAD_EX	.6992200	.6992200	6.3414	.42672

ORIGIN	.9850746	.9850746	6.5942	.42308
CONTROL	.9339455	.9339455	2.9970	.48162

F statistics and significances between pairs of groups after step 1
Each F statistic has 1 and 24.0 degrees of freedom.

	Group 1
Group 2	20.087 .0002

* *

At step 2, ORIGIN was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.42308	2	1	24.0		
Equivalent F	15.6818		2	23.0	.0001	

---------------- Variables in the analysis after step 2 ----------------

Variable	Tolerance	F to remove	Wilks' Lambda
PAST_PER	.9850746	9.1240	.59091
ORIGIN	.9850746	6.5942	.54437

---------------- Variables not in the analysis after step 2 ----------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
COMPLEX	.7999433	.7999433	.62039	.41147
PROF_STA	.5720743	.5720743	.92025	.40609
LEAD_EX	.6853254	.6767880	3.5263	.36463
CONTROL	.9203920	.9131206	3.1409	.37022

F statistics and significances between pairs of groups after step 2
Each F statistic has 2 and 23.0 degrees of freedom.

Group 1

Group

2	15.682
	.0001

* *

At step 3, LEAD_EX was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.36463	3	1	24.0		
Equivalent F	12.7783		3	22.0	.0000	

---------------- Variables in the analysis after step 3 ----------------

Variable	Tolerance	F to remove	Wilks' Lambda
LEAD_EX	.6853254	3.5263	.42308
PAST_PER	.6767880	13.596	.58997
ORIGIN	.9654997	3.7462	.42672

---------------- Variables not in the analysis after step 3 ----------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
COMPLEX	.7982218	.6259238	.40460	.35774
PROF_STA	.5297124	.4919228	1.9207	.33408
CONTROL	.8969336	.6628083	3.6244	.31096

F statistics and significances between pairs of groups after step 3
Each F statistic has 3 and 22.0 degrees of freedom.

	Group 1
Group 2	12.778
	.0000

* *

At step 4, CONTROL was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.31096	4	1	24.0		
Equivalent F	11.6331		4	21.0	.0000	

---------------- Variables in the analysis after step 4 ----------------

Variable	Tolerance	F to remove	Wilks' Lambda
LEAD_EX	.6678582	4.0020	.37022
PAST_PER	.6628083	7.3692	.42008
ORIGIN	.9561471	3.7288	.36618
CONTROL	.8969336	3.6244	.36463

---------------- Variables not in the analysis after step 4 ----------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
COMPLEX	.4966453	.4966453	4.2590	.25637
PROF_STA	.5026165	.4919065	2.8244	.27248

F statistics and significances between pairs of groups after step 4
Each F statistic has 4 and 21.0 degrees of freedom.

	Group 1
Group 2	11.633 .0000

* *

At step 5, COMPLEX was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.25637	5	1	24.0		
Equivalent F	11.6026		5	20.0	.0000	

---------------- Variables in the analysis after step 5 ----------------

Variable	Tolerance	F to remove	Wilks' Lambda
COMPLEX	.4966453	4.2590	.31096
LEAD_EX	.6649367	3.5918	.30241

PAST_PER	.6250881	8.6452	.36719
ORIGIN	.8337800	.66473	.26489
CONTROL	.5580627	7.9082	.35774

--------------- Variables not in the analysis after step 5 ---------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
PROF_STA	.4979703	.4603865	2.7911	.22353

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F statistics and significances between pairs of groups after step 5
Each F statistic has 5 and 20.0 degrees of freedom.

	Group 1
Group 2	11.603 .0000

* *

At step 6, ORIGIN was removed from the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.26489	4	1	24.0		
Equivalent F	14.5696		4	21.0	.0000	

--------------- Variables in the analysis after step 6 ---------------

Variable	Tolerance	F to remove	Wilks' Lambda
COMPLEX	.5695338	8.0299	.36618
LEAD_EX	.6778561	4.6523	.32357
PAST_PER	.6697130	13.584	.43623
CONTROL	.5704559	10.332	.39521

--------------- Variables not in the analysis after step 6 ---------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
PROF_STA	.6516212	.4618141	1.2705	.24907
ORIGIN	.8337800	.4966453	.66473	.25637

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F statistics and significances between pairs of groups after step 6
Each F statistic has 4 and 21.0 degrees of freedom.

	Group 1
Group 2	14.570
	.0000

* *

At step 7, PROF_STA was included in the analysis.

		Degrees of Freedom			Signif.	Between Groups
Wilks' Lambda	.24907	5	1	24.0		
Equivalent F	12.0600		5	20.0	.0000	

---------------- Variables in the analysis after step 7 ----------------

Variable	Tolerance	F to remove	Wilks' Lambda
COMPLEX	.5290974	8.9806	.36090
PROF_STA	.6516212	1.2705	.26489
LEAD_EX	.6001996	5.7110	.32019
PAST_PER	.4618141	13.936	.42261
CONTROL	.5269143	11.408	.39113

---------------- Variables not in the analysis after step 7 ----------------

Variable	Tolerance	Minimum Tolerance	F to enter	Wilks' Lambda
ORIGIN	.6371765	.4603865	2.1704	.22353

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F statistics and significances between pairs of groups after step 7
Each F statistic has 5 and 20.0 degrees of freedom.

Group 1

Group

2	12.060
	.0000

* *

At step 8, ORIGIN was included in the analysis.

		Degrees of Freedom		Signif.	Between Groups
Wilks' Lambda	.22353	6	1	24.0	
Equivalent F	10.9999		6	19.0	.0000

---------------- Variables in the analysis after step 8 ----------------

Variable	Tolerance	F to remove	Wilks' Lambda
COMPLEX	.4920543	4.1607	.27248
PROF_STA	.4979703	2.7911	.25637
LEAD_EX	.5993354	5.0523	.28297
PAST_PER	.4603865	12.112	.36603
ORIGIN	.6371765	2.1704	.24907
CONTROL	.5268576	9.0303	.32977

F statistics and significances between pairs of groups after step 8
Each F statistic has 6 and 19.0 degrees of freedom.

Group	1
Group	
2	11.000
	.0000

F level or tolerance or VIN insufficient for further computation.

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Summary Table

Step	Action Entered	Removed	Vars In	Wilks' Lambda	Sig.	Label
1	PAST_PER		1	.54437	.0002	CONTRACTOR'S PAST PERFORMANCE OR IMAGE
2	ORIGIN		2	.42308	.0001	ORIGIN OF THE COMPANY
3	LEAD_EX		3	.36463	.0000	PROJECT LEADER'S EXPERIENCE
4	CONTROL		4	.31096	.0000	ARCHITECT OR CLIENT SUPERVISION AND CONT
5	COMPLEX		5	.25637	.0000	COMPLEXITY OF PROJECT

6	ORIGIN	4	.26489	.0000	ORIGIN OF THE COMPANY
7	PROF_STA	5	.24907	.0000	MANAGEMENT TEAM'S QUALITY-PROFESSIONAL Q
8	ORIGIN	6	.22353	.0000	ORIGIN OF THE COMPANY

Classification Function Coefficients
(Fisher's Linear Discriminant Functions)

PERFORM =	1	2
COMPLEX	4.459446	6.642191
PROF_STA	96.03139	54.82136
LEAD_EX	.1847489	-.1763594
PAST_PER	8.776058	15.63000
ORIGIN	18.11079	15.05179
CONTROL	5.380530	1.366030
(constant)	-62.90948	-63.87885

Canonical Discriminant Functions

Function	Eigenvalue	Percent of Variance	Cumulative Percent	Canonical Correlation	:	After Function	Wilks' Lambda	Chi-squared	D.F.	Significance
					:	0	.2235317	31.462	6	.0000
1*	3.47364	100.00	100.00	.8811744	:					

* marks the 1 canonical discriminant functions remaining in the analysis.

Standardized Canonical Discriminant Function Coefficients

	FUNC 1
COMPLEX	-.68571
PROF_STA	.57555
LEAD_EX	.67184
PAST_PER	-1.04358
ORIGIN	.45521
CONTROL	.88742

Structure Matrix:

Pooled-within-groups correlations between discriminating variables
and canonical discriminant functions

(Variables ordered by size of correlation within function)

	FUNC 1
PAST_PER	-.49087
ORIGIN	.44643
CONTROL	.37984
PROF_STA	-.27926
COMPLEX	-.10867
LEAD_EX	.05009

Unstandardized Canonical Discriminant Function Coefficients

	FUNC 1
COMPLEX	-.5625999
PROF_STA	10.62183
LEAD_EX	.9307522E-01
PAST_PER	-1.766595
ORIGIN	.7884532
CONTROL	1.034732
(constant)	-.7052658

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Canonical Discriminant Functions evaluated at Group Means (Group Centroids)

Group	FUNC 1
1	1.19377
2	-2.68598

Test of equality of group covariance matrices using Box's M

The ranks and natural logarithms of determinants printed are those of the group covariance matrices.

Group Label	Rank	Log Determinant
1	5	(singular)
2	6	-10.725307
Pooled Within-Groups Covariance Matrix	6	-5.839023

NOTE 10473
NOT ENOUGH NON-SINGULAR GROUP COVARIANCE MATRICES FOR DSC--At least two are required for a test to be performed.

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Case Number	Mis Val	Sel	Actual Group	Highest Probability Group	P(D/G)	P(G/D)	2nd Highest Group	P(G/D)	Discriminant Scores...
1			1	1	.3325	1.0000	2	.0000	2.1629
2			1	1	.4178	.9945	2	.0055	.3836
3			2	2	.2514	.9060	1	.0940	-1.5390
4			1	1	.2984	.9867	2	.0133	.1540
5			2	2	.1045	.6029	1	.3971	-1.0627
6			1	1	.6332	.9985	2	.0015	.7166
7			1	1	.3425	.9906	2	.0094	.2445
8			1	1	.7710	.9993	2	.0007	.9027
9			1	1	.7710	.9993	2	.0007	.9027
10			1	1	.4627	1.0000	2	.0000	1.9281
11			1	1	.0551	1.0000	2	.0000	3.1121
12			1	1	.6378	.9985	2	.0015	.7229
13			1	1	.8091	.9994	2	.0006	.9521
14			1	1	.5746	1.0000	2	.0000	1.7551
15			1	1	.3492	1.0000	2	.0000	2.1300
16			1	1	.0567	1.0000	2	.0000	3.0996
17			2	2	.4147	.9999	1	.0001	-3.5017
18			1	1	.4796	.9963	2	.0037	.4867
19			2	2	.1284	1.0000	1	.0000	-4.2062
20			1	1	.3014	.9870	2	.0130	.1603
21			2	2	.3396	1.0000	1	.0000	-3.6410
22			2	2	.8430	.9974	1	.0026	-2.4880
23			2	2	.6254	.9920	1	.0080	-2.1978
24			1	1	.3354	.9900	2	.0100	.2305
25			2	2	.8686	.9994	1	.0006	-2.8514
26			1	1	.8030	.9999	2	.0001	1.4433

Symbols used in Plots

Symbol	Group	Label
1	1	
2	2	

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Histogram for Group 1

```
          Canonical Discriminant Function 1
     8 +                                         +
       |                                         |
       |                                         |
       |                                         |
     6 +                                         +
       |                                         |
       |                    1                    |
       |                    1                    |
     4 +                   11                    +
       |                   11                    |
       |                   11  1                 |
       |                   11  1                 |
     2 +                  111 11  1              +
       |                  111 11  1              |
       |                  111 11  1              |
       |                  111 11  1              |
       X----+----+----+----+----+----+----+----X
     Out -6.0 -4.0 -2.0   .0  2.0  4.0  6.0   Out
Class    2222222222222222222211111111111111111111
Centroids                   1
```

```
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          Histogram for Group       2

          Canonical Discriminant Function 1
     4 +                                         +
       |                                         |
       |                                         |
       |                                         |
     3 +                                         +
       |                                         |
       |                                         |
       |                                         |
     2 +          2                              +
       |          2                              |
       |          2                              |
       |          2                              |
     1 +        2 2 22222                        +
       |        2 2 22222                        |
       |        2 2 22222                        |
       |        2 2 22222                        |
       X----+----+----+----+----+----+----+----X
```

```
     Out -6.0 -4.0 -2.0   .0  2.0  4.0  6.0    Out
 Class   2222222222222222222211111111111111111111
Centroids                2
```

```
            All-groups stacked Histogram

          Canonical Discriminant Function 1
     8 +                                        +
       |                                        |
       |                                        |
       |                                        |
     6 +                                        +
       |                                        |
       |                    1                   |
       |                    1                   |
     4 +                    11                  +
       |                    11                  |
       |                    11  1               |
       |                    11  1               |
     2 +         2         111 11  1            +
       |         2         111 11  1            |
       |       2 2 22222   111 11  1            |
       |       2 2 22222   111 11  1            |
        X----+----+----+----+----+----+----+----X
     Out -6.0 -4.0 -2.0   .0  2.0  4.0  6.0    Out
 Class   2222222222222222222211111111111111111111
Centroids                2        1
```

Classification Results -

Actual Group	No. of Cases	Predicted Group Membership 1	2
Group 1	18	18 100.0%	0 .0%
Group 2	8	0 .0%	8 100.0%

Percent of "grouped" cases correctly classified: 100.00%

```
Classification Processing Summary
        26 Cases were processed.
         0 Cases were excluded for missing or out-of-range group codes.
         0 Cases had at least one missing discriminating variable.
        26 Cases were used for printed output.
------------------------------------------------------------------------------------------------------
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This procedure was completed at 17:09:29

------------------------------------------------------------------------------------------------------
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FINISH.

End of Include file.
```

APPENDIX 7

SPSS(pc) Computer Printout of the Stepwise Procedures in Computing the Multiple Regression Analysis Model

```
SET /MORE OFF.
REGRESSION /VARIABLES PERFORM COMPLEX TO PROFIT PAS_P_PM /DESCRIPTIVES=all
/SELECT INCLUDE EQ 1 /STATISTICS=all /CRITERIA pin(0.06) /DEPENDENT PERFORM
/METHOD STEPWISE.
```

****** MULTIPLE REGRESSION ******

Listwise Deletion of Missing Data
Selecting only Cases for which INCLUDE EQ 1

	Mean	Std Deviati	Variance	Label
PERFORM	1.265	.448	.201	CONTRACTOR'S PERFORMANCE
COMPLEX	3.618	1.615	2.607	COMPLEXITY OF PROJECT
TRAINING	.104	.088	.008	STAFF TRAINING PROGRAMME
PLANT	.055	.090	.008	PLANT OWNERSHIP POLICY
COM_SIZE	430.706	359.350	129132.759	SIZE OF THE COMPANY
PROF_STA	.092	.077	.006	MANAGEMENT TEAM'S QUALITY-PROFESSIONAL Q
LEAD_EX	14.882	6.623	43.865	PROJECT LEADER'S EXPERIENCE
CONT_EX	.341	.301	.091	CONTRACTOR'S EXPERIENCE IN THE TYPE OF J
WORKLOAD	2687845.765	2182022.123	4761220547176.9	CONTRACTOR'S WORK LOAD
PAST_PER	2.853	.784	.614	CONTRACTOR'S PAST PERFORMANCE OR IMAGE
YEAR_BUS	23.059	15.001	225.027	NUMBER OF YEARS IN THE BUSINESS
ORIGIN	2.706	.719	.517	ORIGIN OF THE COMPANY
DEL	.108	.128	.016	AMOUNT OF DIRECTLY EMPLOYED LABOUR
LISTED	1.471	.507	.257	LISTED IN THE STOCK MARKET
CENTRAL	1.603	.457	.209	CENTRALISED OR DECENTRALISED DECISION MA
SUBSID	1.706	.462	.214	WHETHER THE CONTRACTOR IS THE CLIENT'S S
ARCH_PER	2.971	.834	.696	ARCHITECT'S PERFORMANCE
CONTROL	3.412	.957	.916	ARCHITECT OR CLIENT SUPERVISION AND CONT
PAYMENT	1.059	.239	.057	PUNCTUALITY OF PAYMENT BY CLIENT
PROFIT	1.010	.127	.016	RATIO OF TENDER PRICE OVER PRE-TENDER ES
PAS_P_PM	2.206	.641	.411	PAST PERFORMANCE OF PROJECT MANAGER

N of Cases = 34

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****** MULTIPLE REGRESSION ******

Correlation, Covariance, 1-tailed Sig, Cross-Product:

	PERFORM	COMPLEX	TRAINING	PLANT	COM_SIZE	PROF_STA	LEAD_EX
PERFORM	1.000	.270	-.252	-.054	.090	.227	-.050
	.201	.195	-.010	-.002	14.504	.008	-.150
	.999	.061	.075	.380	.306	.099	.388
	6.618	6.441	-.326	-.073	478.647	.258	-4.941
COMPLEX	.270	1.000	.109	-.261	.311	-.106	.024
	.195	2.607	.015	-.038	180.490	-.013	.257
	.061	.999	.270	.068	.037	.276	.446
	6.441	86.029	.507	-1.255	5956.176	-.436	8.471
TRAINING	-.252	.109	1.000	.140	-.146	.145	-.176
	-.010	.015	.008	.001	-4.583	.001	-.102
	.075	.270	.999	.215	.206	.207	.159
	-.326	.507	.253	.036	-151.232	.032	-3.373
PLANT	-.054	-.261	.140	1.000	-.091	.012	-.069
	-.002	-.038	.001	.008	-2.957	.000	-.041
	.380	.068	.215	.999	.304	.474	.350
	-.073	-1.255	.036	.269	-97.584	.003	-1.355
COM_SIZE	.090	.311	-.146	-.091	1.000	-.168	.107
	14.504	180.490	-4.583	-2.957	129132.759	-4.662	254.086
	.306	.037	.206	.304	.999	.171	.274
	478.647	5956.176	-151.232	-97.584	4261381.059	-153.841	8384.824
PROF_STA	.227	-.106	.145	.012	-.168	1.000	-.042
	.008	-.013	.001	.000	-4.662	.006	-.022
	.099	.276	.207	.474	.171	.999	.406
	.258	-.436	.032	.003	-153.841	.197	-.716
LEAD_EX	-.050	.024	-.176	-.069	.107	-.042	1.000
	-.150	.257	-.102	-.041	254.086	-.022	43.865
	.388	.446	.159	.350	.274	.406	.999
	-4.941	8.471	-3.373	-1.355	8384.824	-.716	1447.529
CONT_EX	-.208	-.529	.138	.367	-.021	-.142	-.097
	-.028	-.257	.004	.010	-2.244	-.003	-.193
	.119	.001	.218	.016	.454	.211	.293
	-.926	-8.488	.120	.330	-74.068	-.109	-6.385

**** MULTIPLE REGRESSION ****

	PERFORM	COMPLEX	TRAINING	PLANT	COM_SIZE	PROF_STA	LEAD_EX
WORKLOAD	.188	.495	-.202	-.165	.302	.149	-.245
	183624.367	1745643.604	-38531.370	-32592.410	236763189.747	25114.828	-3547635.544
	.144	.001	.126	.175	.041	.200	.081
	6059604.118	57606238.941	-1271535.216	-1075549.535	7813185261.647	828789.330	-117071972.941
PAST_PER	.632	-.070	-.244	.091	.100	.567	.236
	.222	-.088	-.017	.006	28.228	.034	1.225
	.000	.348	.082	.305	.286	.000	.090
	7.324	-2.912	-.552	.212	931.529	1.132	40.412
YEAR_BUS	-.178	.393	.027	-.374	.406	-.267	-.134
	-1.198	9.508	.036	-.507	2189.927	-.309	-13.266
	.156	.011	.440	.015	.009	.063	.226
	-39.529	313.765	1.173	-16.727	72267.588	-10.204	-437.765
ORIGIN	-.504	-.204	.043	-.034	.022	-.704	.069
	-.162	-.237	.003	-.002	5.668	-.039	.328
	.001	.123	.404	.425	.451	.000	.349
	-5.353	-7.824	.090	-.072	187.059	-1.289	10.824
DEL	.145	-.215	.061	.261	-.290	.717	.043
	.008	-.044	.001	.003	-13.291	.007	.036
	.207	.111	.365	.068	.048	.000	.406
	.273	-1.462	.023	.099	-438.619	.233	1.186
LISTED	.236	-.218	.116	.254	-.229	.310	-.263
	.053	-.178	.005	.012	-41.736	.012	-.882
	.090	.108	.257	.073	.096	.037	.066
	1.765	-5.882	.170	.384	-1377.294	.400	-29.118
CENTRAL	.455	-.089	-.257	-.035	.180	.388	.565
	.093	-.066	-.010	-.001	29.516	.014	1.709
	.003	.309	.071	.422	.155	.012	.000
	3.074	-2.162	-.340	-.048	974.029	.452	56.412

SUBSID	.095	.088	.187	.254	.196	.133	-.269
	.020	.066	.008	.011	32.638	.005	-.824
	.297	.310	.145	.073	.133	.226	.062
	.647	2.176	.250	.351	1077.059	.157	-27.176
ARCH_PER	-.384	-.166	.240	.154	.160	-.300	-.061
	-.143	-.224	.018	.012	48.052	-.019	-.337
	.012	.174	.086	.192	.183	.042	.366
	-4.735	-7.382	.578	.383	1585.706	-.637	-11.118

*** * * * MULTIPLE REGRESSION * * * ***

	PERFORM	COMPLEX	TRAINING	PLANT	COM_SIZE	PROF_STA	LEAD_EX
CONTROL	-.474	.399	.323	.057	.184	-.302	-.164
	-.203	.617	.027	.005	63.458	-.022	-1.041
	.002	.010	.031	.374	.148	.041	.177
	-6.706	20.353	.893	.164	2094.118	-.736	-34.353
PAYMENT	.133	-.097	.081	-.050	.088	-.046	-.245
	.014	-.037	.002	-.001	7.533	-.001	-.387
	.226	.292	.324	.390	.311	.398	.082
	.471	-1.235	.056	-.035	248.588	-.028	-12.765
PROFIT	.151	.407	-.109	-.009	.254	-.262	-.037
	.009	.084	-.001	-.000	11.608	-.003	-.031
	.197	.008	.270	.479	.074	.067	.417
	.283	2.756	-.040	-.004	383.051	-.085	-1.031
PAS_P_PM	.016	.283	.100	.078	-.044	.455	.020
	.004	.293	.006	.005	-10.241	.023	.086
	.465	.052	.287	.331	.401	.003	.455
	.147	9.676	.185	.149	-337.941	.743	2.824

*** * * * MULTIPLE REGRESSION * * * ***

CONT_EX	WORKLOAD	PAST_PER	YEAR_BUS	ORIGIN	DEL	LISTED

PERFORM	-.208	.188	.632	-.178	-.504	.145	.236
	-.028	183624.367	.222	-1.198	-.162	.008	.053
	.119	.144	.000	.156	.001	.207	.090
	-.926	6059604.118	7.324	-39.529	-5.353	.273	1.765
COMPLEX	-.529	.495	-.070	.393	-.204	-.215	-.218
	-.257	1745643.604	-.088	9.508	-.237	-.044	-.178
	.001	.001	.348	.011	.123	.111	.108
	-8.488	57606238.941	-2.912	313.765	-7.824	-1.462	-5.882
TRAINING	.138	-.202	-.244	.027	.043	.061	.116
	.004	-38531.370	-.017	.036	.003	.001	.005
	.218	.126	.082	.440	.404	.365	.257
	.120	-1271535.216	-.552	1.173	.090	.023	.170
PLANT	.367	-.165	.091	-.374	-.034	.261	.254
	.010	-32592.410	.006	-.507	-.002	.003	.012
	.016	.175	.305	.015	.425	.068	.073
	.330	-1075549.535	.212	-16.727	-.072	.099	.384
COM_SIZE	-.021	.302	.100	.406	.022	-.290	-.229
	-2.244	236763189.747	28.228	2189.927	5.668	-13.291	-41.736
	.454	.041	.286	.009	.451	.048	.096
	-74.068	7813185261.647	931.529	72267.588	187.059	-438.619	-1377.294
PROF_STA	-.142	.149	.567	-.267	-.704	.717	.310
	-.003	25114.828	.034	-.309	-.039	.007	.012
	.211	.200	.000	.063	.000	.000	.037
	-.109	828789.330	1.132	-10.204	-1.289	.233	.400
LEAD_EX	-.097	-.245	.236	-.134	.069	.043	-.263
	-.193	-3547635.544	1.225	-13.266	.328	.036	-.882
	.293	.081	.090	.226	.349	.406	.066
	-6.385	-117071972.941	40.412	-437.765	10.824	1.186	-29.118
CONT_EX	1.000	-.325	.004	-.440	.225	.044	.403
	.091	-213337.023	.001	-1.985	.049	.002	.061
	.999	.030	.490	.005	.100	.402	.009
	2.992	-7040121.768	.035	-65.507	1.610	.056	2.027
WORKLOAD	-.325	1.000	-.019	.351	-.537	.142	.214
	-213337.023	4761220547176.9	-33083.975	11482016.014	-843077.041	39513.017	236256.599

.030	.999	.457	.021	.001	.212	.112
-7040121.768	157120278056838	-1091771.176	378906528.471	-27821542.353	1303929.550	7796467.765

*** * * * M U L T I P L E R E G R E S S I O N * * * ***

	CONT_EX	WORKLOAD	PAST_PER	YEAR_BUS	ORIGIN	DEL	LISTED
PAST_PER	.004	-.019	1.000	-.546	-.509	.380	.332
	.001	-33083.975	.614	-6.415	-.287	.038	.132
	.490	.457	.999	.000	.001	.013	.027
	.035	-1091771.176	20.265	-211.706	-9.471	1.253	4.353
YEAR_BUS	-.440	.351	-.546	1.000	.052	-.272	-.590
	-1.985	11482016.014	-6.415	225.027	.563	-.521	-4.483
	.005	.021	.000	.999	.385	.060	.000
	-65.507	378906528.471	-211.706	7425.882	18.588	-17.178	-147.941
ORIGIN	.225	-.537	-.509	.052	1.000	-.631	-.440
	.049	-843077.041	-.287	.563	.517	-.058	-.160
	.100	.001	.001	.385	.999	.000	.005
	1.610	-27821542.353	-9.471	18.588	17.059	-1.909	-5.294
DEL	.044	.142	.380	-.272	-.631	1.000	.401
	.002	39513.017	.038	-.521	-.058	.016	.026
	.402	.212	.013	.060	.000	.999	.009
	.056	1303929.550	1.253	-17.178	-1.909	.537	.856
LISTED	.403	.214	.332	-.590	-.440	.401	1.000
	.061	236256.599	.132	-4.483	-.160	.026	.257
	.009	.112	.027	.000	.005	.009	.999
	2.027	7796467.765	4.353	-147.941	-5.294	.856	8.471
CENTRAL	.103	-.121	.763	-.330	-.366	.365	.046
	.014	-120487.339	.273	-2.264	-.120	.021	.011
	.281	.248	.000	.028	.017	.017	.398
	.467	-3976082.176	9.015	-74.706	-3.971	.702	.353
SUBSID	.059	.380	.128	-.115	-.268	.159	.609
	.008	383384.898	.046	-.800	-.089	.009	.143
	.371	.013	.236	.258	.063	.185	.000
	.269	12651701.647	1.529	-26.412	-2.941	.309	4.706

ARCH_PER	-.013	-.194	-.470	.472	.389	-.289	-.540
	-.003	-352671.340	-.307	5.911	.234	-.031	-.228
	.471	.136	.003	.002	.011	.049	.000
	-.109	-11638154.235	-10.147	195.059	7.706	-1.015	-7.529
CONTROL	-.052	.268	-.482	.384	.269	-.270	-.099
	-.015	559537.191	-.362	5.520	.185	-.033	-.048
	.385	.063	.002	.012	.062	.061	.288
	-.496	18464727.294	-11.941	182.176	6.118	-1.090	-1.588

* * * * M U L T I P L E R E G R E S S I O N * * * *

	CONT_EX	WORKLOAD	PAST_PER	YEAR_BUS	ORIGIN	DEL	LISTED
PAYMENT	.387	-.163	.210	-.246	.104	.014	.265
	.028	-85020.955	.039	-.882	.018	.000	.032
	.012	.178	.117	.080	.280	.469	.065
	.918	-2805691.529	1.294	-29.118	.588	.014	1.059
PROFIT	-.128	.285	-.139	.281	-.058	-.055	-.103
	-.005	79170.167	-.014	.537	-.005	-.001	-.007
	.235	.051	.216	.053	.372	.379	.282
	-.162	2612615.522	-.458	17.713	-.176	-.029	-.218
PAS_P_PM	-.183	.326	.122	.011	-.391	.419	.066
	-.035	456063.020	.061	.109	-.180	.034	.021
	.150	.030	.245	.475	.011	.007	.356
	-1.165	15050079.647	2.029	3.588	-5.941	1.129	.706

* * * * M U L T I P L E R E G R E S S I O N * * * *

	CENTRAL	SUBSID	ARCH_PER	CONTROL	PAYMENT	PROFIT	PAS_P_PM
PERFORM	.455	.095	-.384	-.474	.133	.151	.016
	.093	.020	-.143	-.203	.014	.009	.004
	.003	.297	.012	.002	.226	.197	.465

	3.074	.647	-4.735	-6.706	.471	.283	.147
COMPLEX	-.089	.088	-.166	.399	-.097	.407	.283
	-.066	.066	-.224	.617	-.037	.084	.293
	.309	.310	.174	.010	.292	.008	.052
	-2.162	2.176	-7.382	20.353	-1.235	2.756	9.676
TRAINING	-.257	.187	.240	.323	.081	-.109	.100
	-.010	.008	.018	.027	.002	-.001	.006
	.071	.145	.086	.031	.324	.270	.287
	-.340	.250	.578	.893	.056	-.040	.185
PLANT	-.035	.254	.154	.057	-.050	-.009	.078
	-.001	.011	.012	.005	-.001	-.000	.005
	.422	.073	.192	.374	.390	.479	.331
	-.048	.351	.383	.164	-.035	-.004	.149
COM_SIZE	.180	.196	.160	.184	.088	.254	-.044
	29.516	32.638	48.052	63.458	7.533	11.608	-10.241
	.155	.133	.183	.148	.311	.074	.401
	974.029	1077.059	1585.706	2094.118	248.588	383.051	-337.941
PROF_STA	.388	.133	-.300	-.302	-.046	-.262	.455
	.014	.005	-.019	-.022	-.001	-.003	.023
	.012	.226	.042	.041	.398	.067	.003
	.452	.157	-.637	-.736	-.028	-.085	.743
LEAD_EX	.565	-.269	-.061	-.164	-.245	-.037	.020
	1.709	-.824	-.337	-1.041	-.387	-.031	.086
	.000	.062	.366	.177	.082	.417	.455
	56.412	-27.176	-11.118	-34.353	-12.765	-1.031	2.824
CONT_EX	.103	.059	-.013	-.052	.387	-.128	-.183
	.014	.008	-.003	-.015	.028	-.005	-.035
	.281	.371	.471	.385	.012	.235	.150
	.467	.269	-.109	-.496	.918	-.162	-1.165
WORKLOAD	-.121	.380	-.194	.268	-.163	.285	.326
	-120487.339	383384.898	-352671.340	559537.191	-85020.955	79170.167	456063.020
	.248	.013	.136	.063	.178	.051	.030
	-3976082.176	12651701.647	-11638154.235	18464727.294	-2805691.529	2612615.522	15050079.647

*** * * *   M U L T I P L E   R E G R E S S I O N   * * * ***

	CENTRAL	SUBSID	ARCH_PER	CONTROL	PAYMENT	PROFIT	PAS_P_PM
PAST_PER	.763	.128	-.470	-.482	.210	-.139	.122
	.273	.046	-.307	-.362	.039	-.014	.061
	.000	.236	.003	.002	.117	.216	.245
	9.015	1.529	-10.147	-11.941	1.294	-.458	2.029
YEAR_BUS	-.330	-.115	.472	.384	-.246	.281	.011
	-2.264	-.800	5.911	5.520	-.882	.537	.109
	.028	.258	.002	.012	.080	.053	.475
	-74.706	-26.412	195.059	182.176	-29.118	17.713	3.588
ORIGIN	-.366	-.268	.389	.269	.104	-.058	-.391
	-.120	-.089	.234	.185	.018	-.005	-.180
	.017	.063	.011	.062	.280	.372	.011
	-3.971	-2.941	7.706	6.118	.588	-.176	-5.941
DEL	.365	.159	-.289	-.270	.014	-.055	.419
	.021	.009	-.031	-.033	.000	-.001	.034
	.017	.185	.049	.061	.469	.379	.007
	.702	.309	-1.015	-1.090	.014	-.029	1.129
LISTED	.046	.609	-.540	-.099	.265	-.103	.066
	.011	.143	-.228	-.048	.032	-.007	.021
	.398	.000	.000	.288	.065	.282	.356
	.353	4.706	-7.529	-1.588	1.059	-.218	.706
CENTRAL	1.000	-.211	-.270	-.585	-.057	-.009	.132
	.209	-.045	-.103	-.256	-.006	-.001	.039
	.999	.116	.061	.000	.374	.479	.228
	6.890	-1.471	-3.397	-8.441	-.206	-.018	1.279
SUBSID	-.211	1.000	-.259	.213	.161	.088	.006
	-.045	.214	-.100	.094	.018	.005	.002
	.116	.999	.070	.113	.181	.311	.487
	-1.471	7.059	-3.294	3.118	.588	.170	.059
ARCH_PER	-.270	-.259	1.000	.167	-.295	-.002	.012
	-.103	-.100	.696	.134	-.059	-.000	.006
	.061	.070	.999	.172	.045	.495	.474

	-3.397	-3.294	22.971	4.412	-1.941	-.007	.206
CONTROL	-.585	.213	.167	1.000	.023	.134	.105
	-.256	.094	.134	.916	.005	.016	.064
	.000	.113	.172	.999	.448	.225	.278
	-8.441	3.118	4.412	30.235	.176	.538	2.118

* * * * M U L T I P L E R E G R E S S I O N * * * *

	CENTRAL	SUBSID	ARCH_PER	CONTROL	PAYMENT	PROFIT	PAS_P_PM
PAYMENT	-.057	.161	-.295	.023	1.000	-.081	-.082
	-.006	.018	-.059	.005	.057	-.002	-.012
	.374	.181	.045	.448	.999	.325	.323
	-.206	.588	-1.941	.176	1.882	-.081	-.412
PROFIT	-.009	.088	-.002	.134	-.081	1.000	-.050
	-.001	.005	-.000	.016	-.002	.016	-.004
	.479	.311	.495	.225	.325	.999	.390
	-.018	.170	-.007	.538	-.081	.533	-.133
PAS_P_PM	.132	.006	.012	.105	-.082	-.050	1.000
	.039	.002	.006	.064	-.012	-.004	.411
	.228	.487	.474	.278	.323	.390	.999
	1.279	.059	.206	2.118	-.412	-.133	13.559

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

Beginning Block Number 1. Method: Stepwise

Variable(s) Entered on Step Number 1.. PAST_PER CONTRACTOR'S PAST PERFORMANCE OR IMAGE

Multiple R .63241 Analysis of Variance

R Square	.39994	R Square Change	.39994		DF	Sum of Squares	Mean Square
Adjusted R Square	.38119	F Change	21.32817	Regression	1	2.64667	2.64667
Standard Error	.35227	Signif F Change	.0001	Residual	32	3.97097	.12409

F = 21.32817 Signif F = .0001

Condition number bounds: 1.000, 1.000

Var-Covar Matrix of Regression Coefficients (B)
Below Diagonal: Covariance Above: Correlation

	PAST_PER
PAST_PER	.00612

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	PAST_PER	PERFORM	COMPLEX	TRAINING	PLANT	COM_SIZE	PROF_STA	LEAD_EX	CONT_EX	WORKLOAD
PAST_PER	1.00000	-.63241	.06974	.24376	-.09067	-.10024	-.56684	-.23595	-.00450	.01935
PERFORM	.63241	.60006	.31406	-.09776	-.11170	.02674	-.13186	-.19970	-.21096	.20016
COMPLEX	-.06974	.31406	.99514	.09166	-.25426	.31807	-.06636	.04046	-.52878	.49414
TRAINING	-.24376	-.09776	.09166	.94058	.16180	-.12120	.28282	-.11872	.13915	-.20637
PLANT	.09067	-.11170	-.25426	.16180	.99178	-.10015	-.03967	-.09001	.36707	-.16354
COM_SIZE	.10024	.02674	.31807	-.12120	-.10015	.98995	-.22488	.08311	-.02120	.30389
PROF_STA	.56684	-.13186	-.06636	.28282	-.03967	-.22488	.67869	-.17619	-.14495	.16008
LEAD_EX	.23595	-.19970	.04046	-.11872	-.09001	.08311	-.17619	.94433	-.09809	-.24092
CONT_EX	.00450	-.21096	-.52878	.13915	.36707	-.02120	-.14495	-.09809	.99998	-.32464
WORKLOAD	-.01935	.20016	.49414	-.20637	-.16354	.30389	.16008	-.24092	-.32464	.99963
YEAR_BUS	-.54574	.16682	.35450	-.10597	-.32444	.46096	.04231	-.00475	-.43705	.34023
ORIGIN	-.50937	-.18168	-.23974	-.08085	.01249	.07300	-.41508	.18906	.22766	-.54725

DEL	.37989	-.09521	-.18859	.15384	.22705	-.32810	.50158	-.04709	.04240	.14934
LISTED	.33224	.02559	-.19474	.19710	.22415	-.26255	.12161	-.34135	.40117	.22014
CENTRAL	.76292	-.02730	-.03559	-.07115	-.10412	.10328	-.04433	.38487	.09944	-.10609
SUBSID	.12788	.01380	.09724	.21822	.24273	.18356	.06078	-.29902	.05796	.38237
ARCH_PER	-.47031	-.08664	-.19887	.12509	.19665	.20742	-.03337	.05000	-.01103	-.20282
CONTROL	-.48241	-.16899	.36543	.20524	.10103	.23285	-.02840	-.05038	-.04998	.25856
PAYMENT	.20953	8.224E-04	-.08246	.13221	-.06864	.06677	-.16480	-.29398	.38591	-.15909
PROFIT	-.13915	.23886	.39708	-.14260	.00337	.26801	-.18305	-.00427	-.12754	.28269
PAS_P_PM	.12243	-.06190	.29186	.12972	.06672	-.05673	.38534	-.00873	-.18347	.32844

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	YEAR_BUS	ORIGIN	DEL	LISTED	CENTRAL	SUBSID	ARCH_PER	CONTROL	PAYMENT	PROFIT
PAST_PER	.54574	.50937	-.37989	-.33224	-.76292	-.12788	.47031	.48241	-.20953	.13915
PERFORM	.16682	-.18168	-.09521	.02559	-.02730	.01380	-.08664	-.16899	8.224E-04	.23886
COMPLEX	.35450	-.23974	-.18859	-.19474	-.03559	.09724	-.19887	.36543	-.08246	.39708
TRAINING	-.10597	-.08085	.15384	.19710	-.07115	.21822	.12509	.20524	.13221	-.14260
PLANT	-.32444	.01249	.22705	.22415	-.10412	.24273	.19665	.10103	-.06864	.00337
COM_SIZE	.46096	.07300	-.32810	-.26255	.10328	.18356	.20742	.23285	.06677	.26801
PROF_STA	.04231	-.41508	.50158	.12161	-.04433	.06078	-.03337	-.02840	-.16480	-.18305
LEAD_EX	-.00475	.18906	-.04709	-.34135	.38487	-.29902	.05000	-.05038	-.29398	-.00427
CONT_EX	-.43705	.22766	.04240	.40117	.09944	.05796	-.01103	-.04998	.38591	-.12754
WORKLOAD	.34023	-.54725	.14934	.22014	-.10609	.38237	-.20282	.25856	-.15909	.28269
YEAR_BUS	.70216	-.22576	-.06477	-.40855	.08608	-.04557	.21562	.12119	-.13193	.20549
ORIGIN	-.22576	.74054	-.43747	-.27118	.02236	-.20289	.14972	.02365	.21054	-.12924
DEL	-.06477	-.43747	.85569	.27516	.07509	.11004	-.11052	-.08720	-.06582	-.00211
LISTED	-.40855	-.27118	.27516	.88961	-.20728	.56609	-.38352	.06104	.19555	-.05649
CENTRAL	.08608	.02236	.07509	-.20728	.41795	-.30843	.08878	-.21681	-.21703	.09670
SUBSID	-.04557	-.20289	.11004	.56609	-.30843	.98365	-.19855	.27509	.13458	.10565
ARCH_PER	.21562	.14972	-.11052	-.38352	.08878	-.19855	.77881	-.05948	-.19666	-.06748
CONTROL	.12119	.02365	-.08720	.06104	-.21681	.27509	-.05948	.76728	.12447	.06682
PAYMENT	-.13193	.21054	-.06582	.19555	-.21703	.13458	-.19666	.12447	.95610	-.05147
PROFIT	.20549	-.12924	-.00211	-.05649	.09670	.10565	-.06748	.06682	-.05147	.98064
PAS_P_PM	.07812	-.32829	.37199	.02519	.03897	-.00964	.06925	.16365	-.10716	-.03252

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	PAS_P_PM
PAST_PER	-.12243
PERFORM	-.06190
COMPLEX	.29186
TRAINING	.12972
PLANT	.06672
COM_SIZE	-.05673
PROF_STA	.38534
LEAD_EX	-.00873
CONT_EX	-.18347
WORKLOAD	.32844
YEAR_BUS	.07812
ORIGIN	-.32829
DEL	.37199
LISTED	.02519
CENTRAL	.03897
SUBSID	-.00964
ARCH_PER	.06925
CONTROL	.16365
PAYMENT	-.10716
PROFIT	-.03252
PAS_P_PM	.98501

Variables in the Equation

Variable	B	SE B	95% Confdnce Intrvl B		Beta	SE Beta	Correl	Part Cor	Partial	Tolerance	T
PAST_PER	.36139	.07825	.20200	.52079	.63241	.13694	.63241	.63241	.63241	1.00000	4.61
(Constant)	.23367	.23128	-.23743	.70478							1.01

* * * * M U L T I P L E   R E G R E S S I O N * * * *

Equation Number 1   Dependent Variable..   PERFORM   CONTRACTOR'S PERFORMANCE

------ in -------		------------------ Variables not in the Equation ------------------						
Variable	Sig T	Variable	Beta In	Partial	Tolerance	Min Toler	T	Sig T
PAST_PER	.0001	COMPLEX	.31559	.40641	.99514	.99514	2.477	.0189
(Constant)	.3199	TRAINING	-.10394	-.13013	.94058	.94058	-.731	.4704
		PLANT	-.11262	-.14479	.99178	.99178	-.815	.4214
		COM_SIZE	.02701	.03469	.98995	.98995	.193	.8480
		PROF_STA	-.19429	-.20663	.67869	.67869	-1.176	.2486
		LEAD_EX	-.21148	-.26529	.94433	.94433	-1.532	.1357
		CONT_EX	-.21096	-.27234	.99998	.99998	-1.576	.1252
		WORKLOAD	.20023	.25844	.99963	.99963	1.490	.1465
		YEAR_BUS	.23757	.25699	.70216	.70216	1.481	.1488
		ORIGIN	-.24533	-.27254	.74054	.74054	-1.577	.1249
		DEL	-.11127	-.13287	.85569	.85569	-.746	.4610
		LISTED	.02876	.03502	.88961	.88961	.195	.8466
		CENTRAL	-.06531	-.05451	.41795	.41795	-.304	.7632
		SUBSID	.01403	.01797	.98365	.98365	.100	.9210
		ARCH_PER	-.11125	-.12674	.77881	.77881	-.711	.4822
		CONTROL	-.22025	-.24905	.76728	.76728	-1.432	.1622
		PAYMENT	8.6022E-04	.00109	.95610	.95610	.006	.9952
		PROFIT	.24357	.31138	.98064	.98064	1.824	.0778
		PAS_P_PM	-.06284	-.08052	.98501	.98501	-.450	.6560

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* * * * M U L T I P L E   R E G R E S S I O N * * * *

Equation Number 1   Dependent Variable..   PERFORM   CONTRACTOR'S PERFORMANCE

Variable(s) Entered on Step Number 2..   COMPLEX   COMPLEXITY OF PROJECT

Multiple R   .70644   Analysis of Variance

R Square   .49906   R Square Change   .09911   DF   Sum of Squares   Mean Square

Adjusted R Square	.46674	F Change	6.13344	Regression	2	3.30257	1.65129
Standard Error	.32701	Signif F Change	.0189	Residual	31	3.31507	.10694

F = 15.44154 Signif F = .0000

Condition number bounds: 1.005, 4.020

Var-Covar Matrix of Regression Coefficients (B)
Below Diagonal: Covariance Above: Correlation

	PAST_PER	COMPLEX
PAST_PER	.00530	.06974
COMPLEX	1.7948E-04	.00125

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	PAST_PER	COMPLEX	PERFORM	TRAINING	PLANT	COM_SIZE	PROF_STA	LEAD_EX	CONT_EX	WORKLOAD
PAST_PER	1.00489	.07008	-.65442	.23733	-.07285	-.12253	-.56219	-.23879	.03256	-.01528
COMPLEX	.07008	1.00489	-.31559	-.09211	.25551	-.31962	.06668	-.04066	.53136	-.49655
PERFORM	.65442	.31559	.50094	-.12669	-.03145	-.07364	-.11092	-.21247	-.04408	.04421
TRAINING	-.23733	.09211	-.12669	.93214	.18522	-.15049	.28893	-.12245	.18786	-.25188
PLANT	.07285	-.25551	-.03145	.18522	.92681	-.01888	-.05662	-.07968	.23197	-.03728
COM_SIZE	.12253	.31962	-.07364	-.15049	-.01888	.88829	-.20367	.07018	.14781	.14595
PROF_STA	.56219	-.06668	-.11092	.28893	-.05662	-.20367	.67427	-.17349	-.18021	.19303
LEAD_EX	.23879	.04066	-.21247	-.12245	-.07968	.07018	-.17349	.94268	-.07659	-.26101
CONT_EX	-.03256	-.53136	-.04408	.18786	.23197	.14781	-.18021	-.07659	.71901	-.06207
WORKLOAD	.01528	.49655	.04421	-.25188	-.03728	.14595	.19303	-.26101	-.06207	.75426
YEAR_BUS	-.52090	.35623	.05494	-.13862	-.23387	.34765	.06595	-.01917	-.24868	.16420
ORIGIN	-.52617	-.24092	-.10602	-.05876	-.04876	.14963	-.43106	.19881	.10027	-.42820

DEL	.36667	-.18951	-.03569	.17121	.17886	-.26783	.48901	-.03943	-.05782	.24299
LISTED	.31860	-.19569	.08705	.21504	.17440	-.20030	.10863	-.33343	.29770	.31684
CENTRAL	.76043	-.03576	-.01607	-.06787	-.11321	.11466	-.04670	.38631	.08052	-.08841
SUBSID	.13469	.09771	-.01688	.20927	.26757	.15248	.06726	-.30298	.10963	.33409
ARCH_PER	-.48425	-.19984	-.02388	.14341	.14584	.27098	-.04663	.05809	-.11670	-.10408
CONTROL	-.45681	.36721	-.28432	.17159	.19440	.11605	-.00404	-.06524	.14419	.07711
PAYMENT	.20375	-.08286	.02685	.13981	-.08970	.09312	-.17029	-.29063	.34209	-.11815
PROFIT	-.11133	.39902	.11354	-.17918	.10482	.14110	-.15657	-.02041	.08346	.08552
PAS_P_PM	.14288	.29329	-.15401	.10283	.14130	-.15002	.40480	-.02060	-.02839	.18352

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	YEAR_BUS	ORIGIN	DEL	LISTED	CENTRAL	SUBSID	ARCH_PER	CONTROL	PAYMENT	PROFIT
PAST_PER	.52090	.52617	-.36667	-.31860	-.76043	-.13469	.48425	.45681	-.20375	.11133
COMPLEX	-.35623	.24092	.18951	.19569	.03576	-.09771	.19984	-.36721	.08286	-.39902
PERFORM	.05494	-.10602	-.03569	.08705	-.01607	-.01688	-.02388	-.28432	.02685	.11354
TRAINING	-.13862	-.05876	.17121	.21504	-.06787	.20927	.14341	.17159	.13981	-.17918
PLANT	-.23387	-.04876	.17886	.17440	-.11321	.26757	.14584	.19440	-.08970	.10482
COM_SIZE	.34765	.14963	-.26783	-.20030	.11466	.15248	.27098	.11605	.09312	.14110
PROF_STA	.06595	-.43106	.48901	.10863	-.04670	.06726	-.04663	-.00404	-.17029	-.15657
LEAD_EX	-.01917	.19881	-.03943	-.33343	.38631	-.30298	.05809	-.06524	-.29063	-.02041
CONT_EX	-.24868	.10027	-.05782	.29770	.08052	.10963	-.11670	.14419	.34209	.08346
WORKLOAD	.16420	-.42820	.24299	.31684	-.08841	.33409	-.10408	.07711	-.11815	.08552
YEAR_BUS	.57588	-.14035	.00241	-.33918	.09876	-.08021	.28646	-.00898	-.10255	.06404
ORIGIN	-.14035	.68279	-.48291	-.31810	.01378	-.17947	.10181	.11168	.19067	-.03357
DEL	.00241	-.48291	.81994	.23825	.06835	.12846	-.14821	-.01794	-.08144	.07315
LISTED	-.33918	-.31810	.23825	.85151	-.21424	.58512	-.42244	.13255	.17941	.02122
CENTRAL	.09876	.01378	.06835	-.21424	.41667	-.30496	.08167	-.20374	-.21998	.11090
SUBSID	-.08021	-.17947	.12846	.58512	-.30496	.97415	-.17912	.23939	.14264	.06685
ARCH_PER	.28646	.10181	-.14821	-.42244	.08167	-.17912	.73907	.01355	-.21314	.01188
CONTROL	-.00898	.11168	-.01794	.13255	-.20374	.23939	.01355	.63309	.15475	-.07899
PAYMENT	-.10255	.19067	-.08144	.17941	-.21998	.14264	-.21314	.15475	.94926	-.01857
PROFIT	.06404	-.03357	.07315	.02122	.11090	.06685	.01188	-.07899	-.01857	.82219
PAS_P_PM	-.02585	-.25797	.42730	.08230	.04941	-.03816	.12757	.05648	-.08297	-.14898

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	PAS_P_PM
PAST_PER	-.14288
COMPLEX	-.29329
PERFORM	-.15401
TRAINING	.10283
PLANT	.14130
COM_SIZE	-.15002
PROF_STA	.40480
LEAD_EX	-.02060
CONT_EX	-.02839
WORKLOAD	.18352
YEAR_BUS	-.02585
ORIGIN	-.25797
DEL	.42730
LISTED	.08230
CENTRAL	.04941
SUBSID	-.03816
ARCH_PER	.12757
CONTROL	.05648
PAYMENT	-.08297
PROFIT	-.14898
PAS_P_PM	.89941

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce	Intrvl B	Beta	SE Beta	Correl	Part Cor	Partial	Tolerance	T
PAST_PER	.37397	.07282	.22545	.52249	.65442	.12743	.63241	.65282	.67800	.99514	5.135
COMPLEX	.08753	.03534	.01545	.15961	.31559	.12743	.26995	.31482	.40641	.99514	2.477
(Constant)	-.11886	.25760	-.64424	.40652							-.461

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

------ in -------

Variable	Sig T
PAST_PER	.0000
COMPLEX	.0189
(Constant)	.6477

------------------ Variables not in the Equation ------------------

Variable	Beta In	Partial	Tolerance	Min Toler	T	Sig T
TRAINING	-.13591	-.18540	.93214	.93214	-1.033	.3097
PLANT	-.03394	-.04616	.92681	.92681	-.253	.8019
COM_SIZE	-.08290	-.11039	.88829	.88829	-.608	.5475
PROF_STA	-.16450	-.19085	.67427	.67427	-1.065	.2954
LEAD_EX	-.22539	-.30919	.94268	.93864	-1.781	.0851
CONT_EX	-.06131	-.07345	.71901	.71552	-.403	.6895
WORKLOAD	.05862	.07193	.75426	.75088	.395	.6956
YEAR_BUS	.09540	.10229	.57588	.57588	.563	.5775
ORIGIN	-.15527	-.18128	.68279	.68279	-1.010	.3207
DEL	-.04353	-.05569	.81994	.81994	-.306	.7621
LISTED	.10223	.13328	.85151	.85151	.737	.4671
CENTRAL	-.03856	-.03517	.41667	.41667	-.193	.8485
SUBSID	-.01733	-.02417	.97415	.97415	-.132	.8955
ARCH_PER	-.03231	-.03925	.73907	.73907	-.215	.8311
CONTROL	-.44910	-.50487	.63309	.63309	-3.204	.0032
PAYMENT	.02828	.03893	.94926	.94926	.213	.8325
PROFIT	.13809	.17692	.82219	.82219	.985	.3327
PAS_P_PM	-.17123	-.22944	.89941	.89941	-1.291	.2065

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Variable(s) Entered on Step Number 3.. CONTROL ARCHITECT OR CLIENT SUPERVISION AND CONT

Multiple R	.79167		
R Square	.62674	R Square Change	.12769
Adjusted R Square	.58941	F Change	10.26246
Standard Error	.28694	Signif F Change	.0032

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	3	4.14755	1.38252
Residual	30	2.47010	.08234

F = 16.79103 Signif F = .0000

Condition number bounds: 1.580, 12.396

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

Var-Covar Matrix of Regression Coefficients (B)
Below Diagonal: Covariance Above: Correlation

	PAST_PER	COMPLEX	CONTROL
PAST_PER	.00542	-.15287	.49698
COMPLEX	-3.843E-04	.00117	-.41820
CONTROL	.00240	-9.364E-04	.00430

XTX Matrix

	PAST_PER	COMPLEX	CONTROL	PERFORM	TRAINING	PLANT	COM_SIZE	PROF_STA	LEAD_EX	CONT_EX
PAST_PER	1.33450	-.19488	.72155	-.44927	.11353	-.21312	-.20627	-.55928	-.19172	-.07148
COMPLEX	-.19488	1.21788	-.58003	-.48050	.00742	.36826	-.25231	.06434	-.07850	.61500
CONTROL	.72155	-.58003	1.57956	.44910	-.27103	-.30706	-.18331	.00637	.10305	-.22776
PERFORM	.44927	.48050	-.44910	.37326	-.04963	.05585	-.02152	-.11273	-.24177	.02067
TRAINING	-.11353	-.00742	.27103	-.04963	.88563	.13253	-.18195	.29002	-.10476	.14878
PLANT	.21312	-.36826	.30706	.05585	.13253	.86712	-.05452	-.05538	-.05964	.18769
COM_SIZE	.20627	.25231	.18331	-.02152	-.18195	-.05452	.86702	-.20294	.08213	.12138
PROF_STA	.55928	-.06434	-.00637	-.11273	.29002	-.05538	-.20294	.67424	-.17390	-.17929
LEAD_EX	.19172	.07850	-.10305	-.24177	-.10476	-.05964	.08213	-.17390	.93596	-.06173
CONT_EX	.07148	-.61500	.22776	.02067	.14878	.18769	.12138	-.17929	-.06173	.68617
WORKLOAD	.07092	.45182	.12180	.07884	-.27278	-.06096	.13182	.19352	-.25306	-.07963
YEAR_BUS	-.52738	.36144	-.01419	.05090	-.13619	-.23111	.34930	.06589	-.02009	-.24664
ORIGIN	-.44558	-.30570	.17641	-.05586	-.08903	-.08306	.12916	-.43035	.21032	.07483

DEL	.35372	-.17911	-.02834	-.04375	.17608	.18437	-.26454	.48889	-.04128	-.05373
LISTED	.41423	-.27257	.20936	.14657	.17911	.13370	-.22460	.10947	-.31978	.26751
CENTRAL	.61342	.08241	-.32181	-.10756	-.01265	-.05065	.15201	-.04800	.36532	.12693
SUBSID	.30742	-.04114	.37812	.09062	.14439	.19407	.10860	.06879	-.27831	.05511
ARCH_PER	-.47447	-.20770	.02140	-.01780	.13974	.14168	.26850	-.04655	.05948	-.11979
PAYMENT	.31542	-.17263	.24444	.09635	.09787	-.13722	.06476	-.16931	-.27468	.30684
PROFIT	-.16833	.44484	-.12478	.07806	-.15777	.12908	.15558	-.15707	-.02855	.10145
PAS_P_PM	.18363	.26053	.08921	-.12865	.08753	.12396	-.16037	.40516	-.01478	-.04125

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	WORKLOAD	YEAR_BUS	ORIGIN	DEL	LISTED	CENTRAL	SUBSID	ARCH_PER	PAYMENT	PROFIT
PAST_PER	-.07092	.52738	.44558	-.35372	-.41423	-.61342	-.30742	.47447	-.31542	.16833
COMPLEX	-.45182	-.36144	.30570	.17911	.27257	-.08241	.04114	.20770	.17263	-.44484
CONTROL	-.12180	.01419	-.17641	.02834	-.20936	.32181	-.37812	-.02140	-.24444	.12478
PERFORM	.07884	.05090	-.05586	-.04375	.14657	-.10756	.09062	-.01780	.09635	.07806
TRAINING	-.27278	-.13619	-.08903	.17608	.17911	-.01265	.14439	.13974	.09787	-.15777
PLANT	-.06096	-.23111	-.08306	.18437	.13370	-.05065	.19407	.14168	-.13722	.12908
COM_SIZE	.13182	.34930	.12916	-.26454	-.22460	.15201	.10860	.26850	.06476	.15558
PROF_STA	.19352	.06589	-.43035	.48889	.10947	-.04800	.06879	-.04655	-.16931	-.15707
LEAD_EX	-.25306	-.02009	.21032	-.04128	-.31978	.36532	-.27831	.05948	-.27468	-.02855
CONT_EX	-.07963	-.24664	.07483	-.05373	.26751	.12693	.05511	-.11979	.30684	.10145
WORKLOAD	.74487	.16529	-.44180	.24517	.30069	-.06360	.30493	-.10573	-.13699	.09514
YEAR_BUS	.16529	.57575	-.13877	.00215	-.33730	.09587	-.07682	.28665	-.10036	.06291
ORIGIN	-.44180	-.13877	.66308	-.47974	-.34148	.04972	-.22170	.09942	.16337	-.01964
DEL	.24517	.00215	-.47974	.81944	.24201	.06258	.13525	-.14783	-.07706	.07091
LISTED	.30069	-.33730	-.34148	.24201	.82376	-.17159	.53500	-.42528	.14701	.03775
CENTRAL	-.06360	.09587	.04972	.06258	-.17159	.35111	-.22792	.08602	-.17017	.08548
SUBSID	.30493	-.07682	-.22170	.13525	.53500	-.22792	.88363	-.18424	.08412	.09671
ARCH_PER	-.10573	.28665	.09942	-.14783	-.42528	.08602	-.18424	.73878	-.21645	.01357
PAYMENT	-.13699	-.10036	.16337	-.07706	.14701	-.17017	.08412	-.21645	.91143	7.413E-04
PROFIT	.09514	.06291	-.01964	.07091	.03775	.08548	.09671	.01357	7.413E-04	.81234
PAS_P_PM	.17664	-.02505	-.26794	.42890	.07048	.06758	-.05952	.12636	-.09678	-.14193

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	PAS_P_PM
PAST_PER	-.18363
COMPLEX	-.26053
CONTROL	-.08921
PERFORM	-.12865
TRAINING	.08753
PLANT	.12396
COM_SIZE	-.16037
PROF_STA	.40516
LEAD_EX	-.01478
CONT_EX	-.04125
WORKLOAD	.17664
YEAR_BUS	-.02505
ORIGIN	-.26794
DEL	.42890
LISTED	.07048
CENTRAL	.06758
SUBSID	-.05952
ARCH_PER	.12636
PAYMENT	-.09678
PROFIT	-.14193
PAS_P_PM	.89437

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	SE Beta	Correl	Part Cor	Partial	Tolerance	T
PAST_PER	.25674	.07364	.10635	.40712	.44927	.12886	.63241	.38891	.53700	.74935	3.487
COMPLEX	.13327	.03414	.06354	.20299	.48050	.12310	.26995	.43541	.58037	.82110	3.903
CONTROL	-.21010	.06559	-.34405	-.07616	-.44910	.14019	-.47407	-.35733	-.50487	.63309	-3.204
(Constant)	.76696	.35715	.03757	1.49635							2.147

------ in -------

Variable	Sig T
PAST_PER	.0015
COMPLEX	.0005
CONTROL	.0032
(Constant)	.0400

------------------ Variables not in the Equation ------------------

Variable	Beta In	Partial	Tolerance	Min Toler	T	Sig T
TRAINING	-.05604	-.08632	.88563	.60150	-.467	.6443
PLANT	.06441	.09817	.86712	.59231	.531	.5993
COM_SIZE	-.02482	-.03783	.86702	.61793	-.204	.8399
PROF_STA	-.16720	-.22472	.67424	.55605	-1.242	.2242
LEAD_EX	-.25831	-.40904	.93596	.62857	-2.414	.0223
CONT_EX	.03013	.04085	.68617	.56526	.220	.8273
WORKLOAD	.10585	.14953	.74487	.62520	.814	.4221
YEAR_BUS	.08841	.10981	.57575	.55018	.595	.5565
ORIGIN	-.08425	-.11229	.66308	.61202	-.609	.5476
DEL	-.05339	-.07911	.81944	.63270	-.427	.6723
LISTED	.17793	.26433	.82376	.61246	1.476	.1507
CENTRAL	-.30635	-.29712	.35111	.35111	-1.676	.1045
SUBSID	.10256	.15780	.88363	.57426	.861	.3965
ARCH_PER	-.02409	-.03389	.73878	.61005	-.183	.8564
PAYMENT	.10571	.16518	.91143	.60786	.902	.3745
PROFIT	.09610	.14177	.81234	.62550	.771	.4468
PAS_P_PM	-.14384	-.22266	.89437	.62954	-1.230	.2286

* * * * M U L T I P L E   R E G R E S S I O N * * * *

Equation Number 1   Dependent Variable..   PERFORM   CONTRACTOR'S PERFORMANCE

Variable(s) Entered on Step Number 4..   LEAD_EX   PROJECT LEADER'S EXPERIENCE

				Analysis of Variance			
Multiple R	.83018				DF	Sum of Squares	Mean Square
R Square	.68919	R Square Change	.06245				
Adjusted R Square	.64632	F Change	5.82713	Regression	4	4.56083	1.14021

Standard Error	.26632	Signif F Change	.0223	Residual	29	2.05681	.07092
				F = 16.07636	Signif F = .0000		

Condition number bounds: 1.591, 21.030

Var-Covar Matrix of Regression Coefficients (B)
Below Diagonal: Covariance Above: Correlation

	PAST_PER	COMPLEX	CONTROL	LEAD_EX
PAST_PER	.00481	-.13786	.47380	-.16907
COMPLEX	-3.037E-04	.00101	-.42177	-.07332
CONTROL	.00201	-8.186E-04	.00373	.08445
LEAD_EX	-8.482E-05	-1.686E-05	3.7325E-05	5.2349E-05

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	PAST_PER	COMPLEX	CONTROL	LEAD_EX	PERFORM	TRAINING	PLANT	COM_SIZE	PROF_STA	CONT_EX
PAST_PER	1.37377	-.17881	.70044	-.20483	-.49879	.09207	-.22534	-.18944	-.59490	-.08412
COMPLEX	-.17881	1.22446	-.58867	-.08387	-.50078	-.00137	.36326	-.24542	.04976	.60982
CONTROL	.70044	-.58867	1.59090	.11010	.47571	-.25949	-.30050	-.19235	.02552	-.22096
LEAD_EX	-.20483	-.08387	.11010	1.06842	.25831	.11193	.06373	-.08775	.18580	.06596
PERFORM	.49879	.50078	-.47571	-.25831	.31081	-.07669	.04044	-3.07E-04	-.15765	.00473
TRAINING	-.09207	.00137	.25949	-.11193	-.07669	.87391	.12586	-.17275	.27056	.14187
PLANT	.22534	-.36326	.30050	-.06373	.04044	.12586	.86332	-.04928	-.06647	.18376
COM_SIZE	.18944	.24542	.19235	.08775	-3.07E-04	-.17275	-.04928	.85981	-.18767	.12680
PROF_STA	.59490	-.04976	-.02552	-.18580	-.15765	.27056	-.06647	-.18767	.64193	-.19076
CONT_EX	.08412	-.60982	.22096	-.06596	.00473	.14187	.18376	.12680	-.19076	.68209
WORKLOAD	.12276	.47305	.09394	-.27038	.01347	-.30111	-.07709	.15403	.14650	-.09633

YEAR_BUS	-.52327	.36313	-.01640	-.02147	.04571	-.13844	-.23239	.35106	.06216	-.24796
ORIGIN	-.48867	-.32333	.19957	.22471	-.00153	-.06549	-.06965	.11070	-.39127	.08871
DEL	.36218	-.17564	-.03289	-.04410	-.05441	.17146	.18174	-.26091	.48123	-.05645
LISTED	.47973	-.24575	.17416	-.34166	.06397	.14332	.11332	-.19654	.05006	.24642
CENTRAL	.53859	.05177	-.28159	-.39031	-.01320	.02824	-.02737	.11995	.01988	.15102
SUBSID	.36443	-.01780	.34748	-.29735	.01873	.11323	.17633	.13302	.01708	.03675
ARCH_PER	-.48665	-.21268	.02795	.06355	-.00243	.14640	.14547	.26328	-.03550	-.11587
PAYMENT	.37168	-.14959	.21420	-.29347	.02539	.06712	-.15473	.08886	-.22034	.28873
PROFIT	-.16248	.44724	-.12792	-.03050	.07069	-.16096	.12726	.15808	-.16238	.09957
PAS_P_PM	.18666	.26177	.08758	-.01579	-.13246	.08587	.12301	-.15907	.40241	-.04223

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	WORKLOAD	YEAR_BUS	ORIGIN	DEL	LISTED	CENTRAL	SUBSID	ARCH_PER	PAYMENT	PROFIT
PAST_PER	-.12276	.52327	.48867	-.36218	-.47973	-.53859	-.36443	.48665	-.37168	.16248
COMPLEX	-.47305	-.36313	.32333	.17564	.24575	-.05177	.01780	.21268	.14959	-.44724
CONTROL	-.09394	.01640	-.19957	.03289	-.17416	.28159	-.34748	-.02795	-.21420	.12792
LEAD_EX	.27038	.02147	-.22471	.04410	.34166	-.39031	.29735	-.06355	.29347	.03050
PERFORM	.01347	.04571	-.00153	-.05441	.06397	-.01320	.01873	-.00243	.02539	.07069
TRAINING	-.30111	-.13844	-.06549	.17146	.14332	.02824	.11323	.14640	.06712	-.16096
PLANT	-.07709	-.23239	-.06965	.18174	.11332	-.02737	.17633	.14547	-.15473	.12726
COM_SIZE	.15403	.35106	.11070	-.26091	-.19654	.11995	.13302	.26328	.08886	.15808
PROF_STA	.14650	.06216	-.39127	.48123	.05006	.01988	.01708	-.03550	-.22034	-.16238
CONT_EX	-.09633	-.24796	.08871	-.05645	.24642	.15102	.03675	-.11587	.28873	.09957
WORKLOAD	.67645	.15986	-.38494	.23401	.21423	.03518	.22968	-.08964	-.21126	.08742
YEAR_BUS	.15986	.57532	-.13425	.00127	-.34416	.10371	-.08279	.28793	-.10626	.06230
ORIGIN	-.38494	-.13425	.61582	-.47047	-.26962	-.03237	-.15916	.08605	.22509	-.01322
DEL	.23401	.00127	-.47047	.81762	.22791	.07869	.12297	-.14521	-.08917	.06965
LISTED	.21423	-.34416	-.26962	.22791	.71450	-.04677	.43992	-.40495	.05317	.02800
CENTRAL	.03518	.10371	-.03237	.07869	-.04677	.20852	-.11929	.06281	-.06296	.09663
SUBSID	.22968	-.08279	-.15916	.12297	.43992	-.11929	.80087	-.16656	.00244	.08823
ARCH_PER	-.08964	.28793	.08605	-.14521	-.40495	.06281	-.16656	.73500	-.19900	.01538
PAYMENT	-.21126	-.10626	.22509	-.08917	.05317	-.06296	.00244	-.19900	.83082	-.00764
PROFIT	.08742	.06230	-.01322	.06965	.02800	.09663	.08823	.01538	-.00764	.81146

PAS_P_PM	.17264	-.02536	-.26461	.42825	.06543	.07335	-.06391	.12730	-.10112	-.14238

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	PAS_P_PM
PAST_PER	-.18666
COMPLEX	-.26177
CONTROL	-.08758
LEAD_EX	.01579
PERFORM	-.13246
TRAINING	.08587
PLANT	.12301
COM_SIZE	-.15907
PROF_STA	.40241
CONT_EX	-.04223
WORKLOAD	.17264
YEAR_BUS	-.02536
ORIGIN	-.26461
DEL	.42825
LISTED	.06543
CENTRAL	.07335
SUBSID	-.06391
ARCH_PER	.12730
PAYMENT	-.10112
PROFIT	-.14238
PAS_P_PM	.89414

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

---------- Variables in the Equation ----------

Variable	B	SE B	95% Confdnce Intrvl B		Beta	SE Beta	Correl	Part Cor	Partial	Tolerance	T
PAST_PER	.28504	.06934	.14322	.42685	.49879	.12134	.63241	.42556	.60676	.72793	4.111
COMPLEX	.13889	.03177	.07391	.20387	.50078	.11456	.26995	.45256	.63025	.81668	4.371
CONTROL	-.22256	.06109	-.34750	-.09762	-.47571	.13058	-.47407	-.37716	-.56034	.62857	-3.643
LEAD_EX	-.01747	7.23529E-03	-.03226	-2.66776E-03	-.25831	.10701	-.05049	-.24990	-.40904	.93596	-2.414
(Constant)	.96829	.34180	.26922	1.66736							2.833

------ in ------- ---------- Variables not in the Equation ----------

Variable	Sig T
PAST_PER	.0003
COMPLEX	.0001
CONTROL	.0010
LEAD_EX	.0223
(Constant)	.0083

Variable	Beta In	Partial	Tolerance	Min Toler	T	Sig T
TRAINING	-.08776	-.14715	.87391	.59954	-.787	.4378
PLANT	.04685	.07808	.86332	.58980	.414	.6817
COM_SIZE	-3.570E-04	-.00059	.85981	.61202	-.003	.9975
PROF_STA	-.24559	-.35295	.64193	.51946	-1.996	.0557
CONT_EX	6.9291E-03	.01026	.68209	.56508	.054	.9571
WORKLOAD	.01992	.02939	.67645	.62346	.156	.8775
YEAR_BUS	.07946	.10811	.57532	.54063	.575	.5696
ORIGIN	-2.491E-03	-.00351	.61582	.56769	-.019	.9853
DEL	-.06655	-.10794	.81762	.62805	-.575	.5702
LISTED	.08953	.13575	.71450	.58967	.725	.4745
CENTRAL	-.06329	-.05184	.20852	.20852	-.275	.7856
SUBSID	.02339	.03755	.80087	.57416	.199	.8438
ARCH_PER	-3.308E-03	-.00509	.73500	.58963	-.027	.9787
PAYMENT	.03056	.04997	.83082	.60749	.265	.7931
PROFIT	.08711	.14076	.81146	.62071	.752	.4581
PAS_P_PM	-.14815	-.25128	.89414	.62520	-1.374	.1804

**** MULTIPLE REGRESSION ****

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

Variable(s) Entered on Step Number 5.. PROF_STA MANAGEMENT TEAM'S QUALITY-PROFESSIONAL Q

Multiple R .85318 Analysis of Variance

R Square	.72791	R Square Change	.03872
Adjusted R Square	.67932	F Change	3.98445
Standard Error	.25359	Signif F Change	.0557

	DF	Sum of Squares	Mean Square
Regression	5	4.81706	.96341
Residual	28	1.80059	.06431

F = 14.98154 Signif F = .0000

Condition number bounds: 1.925, 37.127

Var-Covar Matrix of Regression Coefficients (B)
Below Diagonal: Covariance Above: Correlation

	PAST_PER	COMPLEX	CONTROL	LEAD_EX	PROF_STA
PAST_PER	.00611	-.14626	.38661	-.25651	-.53515
COMPLEX	-3.464E-04	9.1816E-04	-.41956	-.05917	.05603
CONTROL	.00176	-7.398E-04	.00339	.08790	.02525
LEAD_EX	-1.416E-04	-1.266E-05	3.6113E-05	4.9854E-05	.21891
PROF_STA	-.02985	.00121	.00105	.00110	.50947

****** MULTIPLE REGRESSION ******

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	PAST_PER	COMPLEX	CONTROL	LEAD_EX	PROF_STA	PERFORM	TRAINING	PLANT	COM_SIZE	CONT_EX
PAST_PER	1.92507	-.22492	.67679	-.37702	-.92673	-.64489	.34280	-.28693	-.36337	-.26091
COMPLEX	-.22492	1.22832	-.58670	-.06947	.07751	-.48856	-.02234	.36841	-.23088	.62461
CONTROL	.67679	-.58670	1.59192	.11748	.03976	.48198	-.27025	-.29785	-.18489	-.21338
LEAD_EX	-.37702	-.06947	.11748	1.12220	.28944	.30394	.03362	.08296	-.03343	.12117
PROF_STA	-.92673	.07751	.03976	.28944	1.55780	.24559	-.42147	.10354	.29236	.29717
PERFORM	.64489	.48856	-.48198	-.30394	-.24559	.27209	-.01025	.02412	-.04640	-.04212
TRAINING	-.34280	.02234	.27025	-.03362	.42147	-.01025	.75988	.15387	-.09365	.22227
PLANT	.28693	-.36841	.29785	-.08296	-.10354	.02412	.15387	.85644	-.06871	.16401

COM_SIZE	.36337	.23088	.18489	.03343	-.29236	-.04640	-.09365	-.06871	.80494	.07103
CONT_EX	.26091	-.62461	.21338	-.12117	-.29717	-.04212	.22227	.16401	.07103	.62541
WORKLOAD	-.01301	.48440	.09977	-.22797	.22821	.04945	-.36285	-.06192	.19686	-.05279
YEAR_BUS	-.58087	.36795	-.01393	-.00347	.09683	.06098	-.16464	-.22595	.36923	-.22949
ORIGIN	-.12606	-.35366	.18401	.11146	-.60952	-.09763	.09942	-.11017	-.00369	-.02757
DEL	-.08379	-.13835	-.01375	.09519	.74965	.06377	-.03137	.23157	-.12022	.08655
LISTED	.43335	-.24187	.17615	-.32717	.07798	.07626	.12222	.11850	-.18191	.26129
CENTRAL	.52017	.05331	-.28080	.39607	.03096	-.00832	.01986	-.02531	.12576	.15693
SUBSID	.34860	-.01647	.34816	-.29241	.02660	.02293	.10604	.17810	.13802	.04183
ARCH_PER	-.45376	-.21544	.02654	.05328	-.05530	-.01115	.16136	.14180	.25290	-.12642
PAYMENT	.57588	-.16667	.20544	-.35725	-.34325	-.02872	.15999	-.17754	.02444	.22325
PROFIT	-.01200	.43465	-.13437	-.07750	-.25295	.03081	-.09252	.11045	.11061	.05131
PAS_P_PM	-.18627	.29296	.10358	.10069	.62688	-.03363	-.08373	.16468	-.04142	.07736

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*** * * * M U L T I P L E R E G R E S S I O N * * * ***

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	WORKLOAD	YEAR_BUS	ORIGIN	DEL	LISTED	CENTRAL	SUBSID	ARCH_PER	PAYMENT	PROFIT
PAST_PER	.01301	.58087	.12606	.08379	-.43335	-.52017	-.34860	.45376	-.57588	.01200
COMPLEX	-.48440	-.36795	.35366	.13835	.24187	-.05331	.01647	.21544	.16667	-.43465
CONTROL	-.09977	.01393	-.18401	.01375	-.17615	.28080	-.34816	-.02654	-.20544	.13437
LEAD_EX	.22797	.00347	-.11146	-.09519	.32717	-.39607	.29241	-.05328	.35725	.07750
PROF_STA	-.22821	-.09683	.60952	-.74965	-.07798	-.03096	-.02660	.05530	.34325	.25295
PERFORM	.04945	.06098	-.09763	.06377	.07626	-.00832	.02293	-.01115	-.02872	.03081
TRAINING	-.36285	-.16464	.09942	-.03137	.12222	.01986	.10604	.16136	.15999	-.09252
PLANT	-.06192	-.22595	-.11017	.23157	.11850	-.02531	.17810	.14180	-.17754	.11045
COM_SIZE	.19686	.36923	-.00369	-.12022	-.18191	.12576	.13802	.25290	.02444	.11061
CONT_EX	-.05279	-.22949	-.02757	.08655	.26129	.15693	.04183	-.12642	.22325	.05131
WORKLOAD	.64302	.14567	-.29565	.12419	.20281	.03064	.22578	-.08154	-.16098	.12448
YEAR_BUS	.14567	.56930	-.09637	-.04533	-.34901	.10179	-.08444	.29137	-.08492	.07803
ORIGIN	-.29565	-.09637	.37733	-.17715	-.23911	-.02025	-.14875	.06442	.09079	-.11220
DEL	.12419	-.04533	-.17715	.45686	.19038	.06378	-.11017	-.11860	.07601	.19138
LISTED	.20281	-.34901	-.23911	.19038	.71060	-.04832	.43859	-.40219	.07035	.04066
CENTRAL	.03064	.10179	-.02025	.06378	-.04832	.20790	-.11982	.06391	-.05614	.10165
SUBSID	.22578	-.08444	-.14875	.11017	.43859	-.11982	.80042	-.16561	.00831	.09254

ARCH_PER	-.08154	.29137	.06442	-.11860	-.40219	.06391	-.16561	.73304	-.21118	.00640
PAYMENT	-.16098	-.08492	.09079	.07601	.07035	-.05614	.00831	-.21118	.75519	-.06337
PROFIT	.12448	.07803	-.11220	.19138	.04066	.10165	.09254	.00640	-.06337	.77039
PAS_P_PM	.08080	-.06433	-.01933	.12658	.03405	.06089	-.07462	.14955	.03701	-.04059

*** * * * M U L T I P L E R E G R E S S I O N * * * ***

Equation Number 1 Dependent Variable.. PERFORM CONTRACTOR'S PERFORMANCE

XTX Matrix

	PAS_P_PM
PAST_PER	.18627
COMPLEX	-.29296
CONTROL	-.10358
LEAD_EX	-.10069
PROF_STA	-.62688
PERFORM	-.03363
TRAINING	-.08373
PLANT	.16468
COM_SIZE	-.04142
CONT_EX	.07736
WORKLOAD	.08080
YEAR_BUS	-.06433
ORIGIN	-.01933
DEL	.12658
LISTED	.03405
CENTRAL	.06089
SUBSID	-.07462
ARCH_PER	.14955
PAYMENT	.03701
PROFIT	-.04059
PAS_P_PM	.64187

*** * * * M U L T I P L E R E G R E S S I O N * * * ***

Equation Number 1   Dependent Variable.. PERFORM   CONTRACTOR'S PERFORMANCE

-- Variables in the Equation --

Variable	B	SE B	95% Confdnce Intrvl B		Beta	SE Beta	Correl	Part Cor	Partial	Tolerance	T
PAST_PER	.36853	.07816	.20843	.52863	.64489	.13677	.63241	.46480	.66527	.51946	4.715
COMPLEX	.13550	.03030	.07343	.19757	.48856	.10925	.26995	.44082	.64547	.81412	4.472
CONTROL	-.22549	.05819	-.34468	-.10630	-.48198	.12438	-.47407	-.38201	-.59084	.62817	-3.875
LEAD_EX	-.02055	7.06073E-03	-.03501	-6.08772E-03	-.30394	.10443	-.05049	-.28692	-.48195	.89110	-2.911
PROF_STA	-1.42476	.71377	-2.88685	.03733	-.24559	.12304	.22661	-.19677	-.35295	.64193	-1.996
(Constant)	.92865	.32607	.26072	1.59658							2.848

------ in -------

Variable	Sig T
PAST_PER	.0001
COMPLEX	.0001
CONTROL	.0006
LEAD_EX	.0070
PROF_STA	.0557
(Constant)	.0082

----------------- Variables not in the Equation -----------------

Variable	Beta In	Partial	Tolerance	Min Toler	T	Sig T
TRAINING	-.01348	-.02253	.75988	.48083	-.117	.9076
PLANT	.02816	.04997	.85644	.49475	.260	.7969
COM_SIZE	-.05764	-.09914	.80494	.47867	-.518	.6089
CONT_EX	-.06735	-.10211	.62541	.49166	-.533	.5981
WORKLOAD	.07691	.11823	.64302	.51939	.619	.5413
YEAR_BUS	.10711	.15494	.56930	.39718	.815	.4222
ORIGIN	-.25873	-.30469	.37733	.37733	-1.662	.1080
DEL	.13959	.18088	.45686	.35870	.956	.3477
LISTED	.10732	.17344	.71060	.45676	.915	.3683
CENTRAL	-.04000	-.03496	.20790	.20790	-.182	.8571
SUBSID	.02864	.04913	.80042	.48149	.256	.8002
ARCH_PER	-.01521	-.02496	.73304	.45332	-.130	.8977
PAYMENT	-.03803	-.06336	.75519	.42297	-.330	.7440
PROFIT	.03999	.06729	.77039	.51941	.350	.7287
PAS_P_PM	-.05240	-.08048	.64187	.46082	-.420	.6781

End Block Number   1   PIN =   .060 Limits reached.

**** MULTIPLE REGRESSION ****

Equation Number 1   Dependent Variable.. PERFORM   CONTRACTOR'S PERFORMANCE

Summary table

Step	MultR	Rsq	AdjRsq	F(Eqn)	SigF	RsqCh	FCh	SigCh		Variable	BetaIn	Correl	
1	.6324	.3999	.3812	21.328	.000	.3999	21.328	.000	In:	PAST_PER	.6324	.6324	CONTRACTOR'S PAST PERFORMANCE
2	.7064	.4991	.4667	15.442	.000	.0991	6.133	.019	In:	COMPLEX	.3156	.2700	COMPLEXITY OF PROJECT
3	.7917	.6267	.5894	16.791	.000	.1277	10.262	.003	In:	CONTROL	-.4491	-.4741	ARCHITECT OR CLIENT SUPERVISI
4	.8302	.6892	.6463	16.076	.000	.0625	5.827	.022	In:	LEAD_EX	-.2583	-.0505	PROJECT LEADER'S EXPERIENCE
5	.8532	.7279	.6793	14.982	.000	.0387	3.984	.056	In:	PROF_STA	-.2456	.2266	MANAGEMENT TEAM'S QUALITY-PRO

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APPENDIX 8

Introduction to the Performance Assessment Scoring System (PASS) of the Hong Kong Housing Authority[48]

1/1 INTRODUCTION

1/1.1 Housing Authority introduced its own independent list of Building Contractors in April 1990.

1/1.2 In managing the Authority's list, the main principle to be followed is that Contractors who perform to the required standard, will have more tendering opportunities than those who do not. This requires the establishment of an objective means of assessing performance standards.

1/1.3 For many years, Housing Department has operated a performance assessment system which is based on the project staff's rating of the contractor's level of achievement under the headings of materials, structure, labour, progress, safety etc. Although the system has served well, it does not measure attainment against a common scale of preset standards.

1/1.4 A new Performance Assessment Scoring System (PASS) has been developed to measure performance output directly against defined standards and to provide a fair means of comparing the performance of individual contractors.

1/1.5 At the Building Committee meeting of 16th February 1990, PASS was approved for use on Housing Authority Contracts.

1/1.6 PASS will also be used to guide contractors on aspects which require improvement and will be a practical continuous assessment tool in persuading, training and instructing contractors to improve their performance.

1/1.7 *It is considered that the assessment of a contractor's overall performance should be based not only on his PASS score but also on some measure of his management capability and capacity.*

1/1.8 *Management capability relates to the contractor's organisational input on his contracts. It is useful to monitor input for deciding the contractor's capacity in undertaking the additional work-load which would arise out of new contracts as well as for diagnostic purposes.*

1/1.9 *Management input aspects will eventually be covered by the contractor's Quality Management Schedule (QM Sch) and will in time be assessed objectively by the HK Quality Assurance Agency (HKQAA) in their half-yearly routine surveillance visits following a contractor's certification to ISO 9002. However, the Contractor's management input at the site level will be assessed by the project team on a quarterly basis on individual contracts.*

1/1.10 *It is considered that the output scores and input rating should not be combined due to their different natures.*

1/1.11 The overall performance reports, *considering both PASS Output and Management Input,* will be used as an aid in deciding whether or not to promote or downgrade a company and also in awarding preferential tendering opportunities.

1/2 ABOUT PASS

1/2.1 The Singapore Construction Industry Development Board's quality assessment scheme, which has been in successful operation for several years, has been the principal source of reference.

1/2.2 PASS classifies a building's construction in terms of four main aspects : structural work; architectural work, other obligations and external works. The system, focusing on quality, scores performance against predetermined standards and tolerance levels which are assessed at several sample locations. The scores are then added up to give a total. The maximum possible score is 100 points.

1/2.3 At a particular sampling location, the construction work which is to be assessed, is judged as complying or not complying with the stated standards. The assessment is a simple yes/no exercise. There is no provision for partial attainment of standards. To give a fair assessment, several locations are sampled to give an even measure of the overall standard.

1/2.4 In addition to an objective measure of workmanship and quality, there is a need to monitor progress accurately and fairly. Delays to individual contracts must be identified so that timely corrective action can be taken. A system which identifies contractors who consistently fail to meet established programmes will enable the CPRC to recommend appropriate disciplinary action and provide a further tool for the LMC in deciding tendering eligibility, as part of the overall assessment of a contractor. Such a system will be introduced during the next financial year.

1/2.5 The system is better than the existing performance assessment system in several respects. It is particularly good in directly assessing compliance against standards rather than representing an overall impression. It is therefore directly related to site supervisory functions. It has the added advantage of allowing the contractor to be informed immediately of good or bad performance.

1/2.6 It should be noted that PASS is not intended to replace the normal checks, inspections and tests to be carried out by the "Architect" or to reduce his overall authority or powers under the contract. PASS is, nevertheless, seen as a complementary, but limited, checking system for the various aspects.

1/3 ASPECTS OF PASS

1/3.1 Monthly Assessment

The PASS Monthly Assessment is divided into four aspects, plus a separate assessment of progress.

(a) Structural Work is allotted 35 percent of the total score. The factors included in this aspect are falsework, formwork, reinforcement, concrete practice, concrete quality and finished concrete. The quality standards and tolerances are given in Part 2.

(b) Architectural Work deals mainly with components and finishes. The 35 percent allotted to architectural work is distributed among several factors, including floor, wall, windows, installation of components, plumbing installation, structural window openings and application of spatterdash. The quality standards and tolerances are given in Part 3.

(c) External Works is given 10 percent of the total assessment. The factor covered by this aspect is drainage. The quality standards and tolerances are given in Part 4.

(d) General Obligations are the contractors's duties and responsibilities under the contract. The 20 percent allowed for this aspect is assessed with respect to the factors of safety and general obligations. The quality standards are given in Part 5.

1/3.2 Substantial Completion Assessment

At Substantial Completion, all projects will be checked by a Substantial Completion Assessment (SCA) as a round up of the previous monthly assessments. Details of SCA will be issued later.

1/3.3 *Maintenance Assessment*

A Maintenance Assessment (MA) will be carried out during the Maintenance Period. This assessment aims at checking how the building functions after occupation. Details of MA will be issued later.

1/4 PRACTICAL DETAILS OF PASS MONTHLY ASSESSMENT

1/4.1 When to carry out the Assessment

Assessment to be conducted monthly. *Assessment dates for 1991 are shown in the Schedule at item 1/4.11.*

1/4.2 Resources

Introduction of PASS will make some increased demands on project staff time. This may be compensated by the fact that the system is more directly related to the ongoing site supervision functions and this checking would have to be carried out in any event.

1/4.3 Who is to carry out the Assessment

The assessment will be done by the project team members, with the assistance of the site staff and in the presence of the contractor's authorised representative.

1/4.4 Locations

(a) The system is wholly based on the principle of examining workmanship at random sampling locations. The concept of a location as an identifiable discrete area of the building is essential to an understanding of the scheme.

(b) To improve consistency and to encourage a systematic assessment, locations are further subdivided into spots which are themselves constituent parts (walls, ceilings etc.) of the location. Spots are therefore usually defined as particular elements or areas within the location.

(c) The main aspects of work (e.g. structural, architectural, etc.) are broken down into factors which are assessed in turn at each spot. They have to be broken down into discrete items which have definite standards. These standards are based on specification standards. Very important items are marked *.

(d) *The total number of sampling locations for all aspects are to be doubled for contracts with more than 4 standard blocks.*

1/4.5 Method of Assessment

(a) Particular locations are selected on the day of assessment. There should not be any advance notice of the sampling locations. *However, half a day's advance notice may be given to the Contractor's representative to ensure that he could make himself available during the assessment. For details, please refer to item 1/6 showing assessment checklist for PASS monthly assessment.*

(b) The records of test results such as those on concrete and some other tests are also used in the assessment.

(c) The assessment team will usually be concentrating on a particular aspect (e.g. Architectural work) and will proceed to the first sampling location.

(d) On reaching the sampling location the team will examine each factor that is included in the aspect being assessed. If the assessment standards are satisfied, that factor will be given a positive tick (✓) on the standard assessment form. If not, a cross (X) is entered.

(e) The team then moves on to cover the other sampling locations. The overall score will be an expression of how many factors complying with standards out of the total number sampled. This is explained in more detail below.

1/4.6 Choice of Sample Locations

(a) For structural work, falsework formwork, reinforcement, concreting procedures and finished concrete, locations at various stages of work will be selected at random. Concrete quality and practice is assessed for the assessment period as a whole.

(b) Sample locations for Architectural Work will be selected to cover different areas of the domestic blocks and a wide range of construction activities will be assessed.

(c) For assessment of external works and other obligations, the assessment team will walk around the site stopping at pre-selected random locations in areas of activity in order to assess the situation against preset standards.

For consistency of documentation, project teams shall complete the "Sampling Location Record" shown in item 1/7.

1/4.7 Unperformed Aspects/Factor of Work

There will be stages of the work when the full range of all aspects/factors of work cannot be assessed because the work is not in progress at the time of assessment. In order to ensure that PASS measure the performance of the contractor direct, only those works assessed will be used to determine the overall PASS score.

1/4.8 Range of Sample and Assessment of Sequential Work in Progress

For structural aspects, other obligations and external works, the range of the samples is comparatively easy to assess. For Architectural finishes, work in progress at a particular location is sequential, e.g. concreting -> door frames -> blockwork -> fittings -> plastering -> tiling -> glazing -> doors -> painting -> cleaning and the whole process can extend over a significant period - often exceeding one year for an individual flat. For this reason, the Architectural sample location will be spread on a random basis throughout a range of floors where work is in progress. Each month different sample locations will be chosen at random. *To determine the available range of floors for sampling locations for architectural assessment, a "progress record" shown in item 1/8 shall be completed prior to selection of locations.*

1/4.9 Completion of Forms

On completion of an inspection, the forms will be completed and initialled by members of the project team and the contractor's authorised representative. After each site assessment, the forms will be despatched to HAHQ for entry into a computerised data base.

1/4.10 Use of Instruments

PASS involves the use of levels and other site equipment such as auto plumb, straight edges, plumb-lines and alignment strings. For details, please refer to item 1/6.4 on GD/14/1.7.1991.

1/4.11 Proposed Schedule of PASS Assessment / Score Processing / HDCPRC (NW) and LMC Dates

Month during which assessment takes place	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PASS assessments on site (last full working week in general)	Between 25/2/91 to 1/3/91	Between 25/3/91 to 28/3/91	Between 29/4/91 to 3/5/91	Between 27/5/91 to 31/5/91	Between 24/6/91 to 28/6/91	Between 29/7/91 to 2/8/91	Between 27/8/91 to 30/8/91	Between 30/9/91 to 4/10/91	Between 28/10/91 to 1/11/91	Between 25/11/91 to 29/11/91	Between 30/12/91 to 3/1/92
Last date for forwarding PASS or quarterly old format(*) reports to TS unit	4/3/91 (*)	2/4/91	6/5/91	3/6/91 (*)	1/7/91	5/8/91	2/9/91 (*)	7/10/91	4/11/91	2/12/91 (*)	6/1/92
Month during which PRE-PRC (or LMC) actions take place	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
TS unit enters raw scores into database	5/3/91 to 6/3/91	3/4/91 to 4/4/91	7/5/91 to 8/5/91	4/6/91 to 5/6/91	2/7/91 to 3/7/91	6/8/91 to 7/8/91	3/9/91 to 4/9/91	8/10/91 to 9/10/91	5/11/91 to 6/11/91	3/12/91 to 4/12/91	7/1/92 to 8/1/92
Triggered reports from TS unit to CA's and consultants for comments 'not adverse' reports from TS unit to CA's for information	6/3/91	10/4/91	8/5/91	5/6/91	3/7/91	7/8/91	4/9/91	10/10/91	6/11/91	4/12/91	
Last date for consultants to return comments to CA/6	9/3/91	13/4/91	11/5/91	8/6/91	6/7/91	10/8/91	7/9/91	13/10/91	9/11/91	7/12/91	
Last date for CA's to forward comments to TS unit Issue PRC agenda	13/3/91	17/4/91	15/5/91	12/6/91	10/7/91	14/8/91	11/9/91	17/10/91	13/11/91	11/12/91	
PRC(NW) meeting consider reports from previous month Add PRC's rating to reports and score-league	(Feb. scores) 22/3/91 9:30am	(Mar. scores) 26/4/91 9:30am	(Apr. scores) 24/5/91 9:30am	(May scores) 21/6/91 9:30am	(Jun. scores) 19/7/91 9:30am	(Jul. scores) 23/8/91 9:30am	(Aug. scores) 20/9/91 9:30am	(Sep. scores) 25/10/91 9:30am	(Oct. scores) 22/11/91 9:30am	(Nov. scores) 20/12/91 9:30am	
Score-league to LMC (and issue LMC agenda where appropriate)	20/3/91	29/4/91	27/5/91	2/7/91	22/7/91	27/8/91	1/10/91	28/10/91	25/11/91	31/12/91	
LMC meeting	4/4/91 3:00pm			5/7/91 2:30pm			4/10/91 2:30pm			3/1/92 2:30pm	

1/5 SCORING SYSTEM

1/5.1 As indicated previously, for the assessment system to be objective and systematic, the whole process has to be broken down into specific blocks or items which can be assessed against pre-determined standards. This breakdown is further illustrated in the glossary diagrams in Part 10 but can be typically summarised as follows :-

(a) The assessment is by aspect of work.

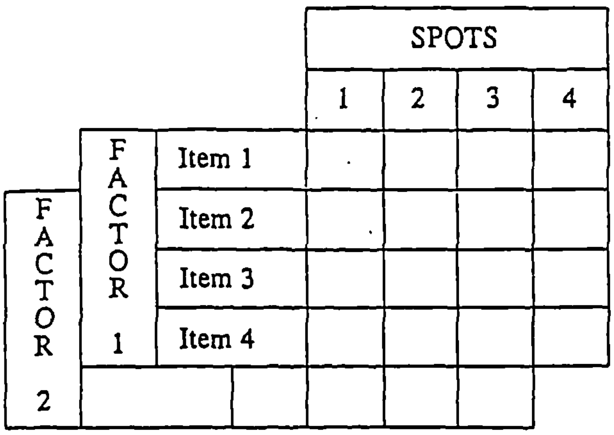
(b) At pre-selected parts of the building called locations.

(c) Location scores are built up by assessments of factors.

(d) Spots, which are discrete elements within each location are chosen for factor assessments.

(e) Each factor is broken down into specific items which have definite pre-determined standards.

1/5.2 The breakdown can be modelled like this :-



1/5.3 An understanding of this model helps an appreciation of the scoring system as a whole.

1/5.4 For each factor, spot failure is usually marked by :-

			SPOT	
FACTOR	Items	1	√	F
		2	X	
		3	X	
		4	√	

a) failure of 2 items

			SPOT	
FACTOR	Items	1*	X(*)	F
		2*	√	
		3	√	
		4	√	

b) failure of a * item

			SPOT	
FACTOR	Items	1	√	F
		2	√	
		3	X(2)	
		4	√	

c) an item failing its tolerance by more than twice its MPD

			SPOT	
FACTOR	Items	1	NA	F
		2	X	
		3	NA	
		4	NA	

d) *failure of one item which is the only assessed item amongst N/A items*

1/5.5 This criteria permits some degree of scoring tolerance which is necessary for differentiating different levels of performance. This scoring is reflected by a Scoring Index A which is defined as :-

(a) For Structural Work, Architectural Work and External Works :-

$$\frac{\text{No. of spots passed}}{\text{No. of spots assessed}}$$

(b) For Other Obligations a slightly different approach is adopted :-

$$\frac{\text{No. of locations passed}}{\text{No. of locations assessed}}$$

1/5.6 This scoring approach alone was found in early trials to be not sufficiently discriminating. Another parallel was introduced and known as Scoring Index B which is defined as :-

$$\frac{\text{No. of items passed}}{\text{No. of items assessed}}$$

This is necessary to pick up patterns of item failure which are not covered by spot assessment alone :-

(a) A particular item fails consistently at all spots.

(b) Over-failure of the failed spot (e.g. failed spot with more than 2 failed items).

1/5.7 Therefore, the overall factor score is calculated by the following formula.

Factor Score = Allotted Points x Scoring Index A x
Scoring Index B.

1/5.8 The scoring system is further explained graphically at 1/5.9 and on an example of the scoring system as shown at 1/5.10.

1/5.9

Scoring Matrix | Scoring Formula | Remarks

FACTOR

Items / Spot

Items	1	2	3	4
1	√	X	√	√
2	X	√	X	√
3	X	√	√	√
4	X	√	√	√
	F	P	P	P

Collection

Assessment by Project Team

Note: For Other Obligations there are slight differences in layout but the principle remains the same.

FACTOR

Vertical Scoring

√	X	√	√
X	√	X	√
X	√	√	√
X	√	√	√
F	P	P	P

Collection

Scoring Index A

$$= \frac{P}{(P + F)}$$

Note

F = { 2X
{ * item
{ twice MPD

Vertical Scoring to determine local performance at assessment spot.

For further details of Failure Criteria, see later sections.

FACTOR

Item Scoring

√	⊗	√	√
⊗	√	⊗	√
⊗	√	√	√
⊗	√	√	√
F	P	P	P

Collection

Scoring Index B

$$= \frac{\surd}{(\surd + X)}$$

Item Scoring to determine overall performance across all items.

Factor Score = Allotted Point x Scoring Index A x Scoring Index B

$$= \text{Allotted Point} \times \left(\frac{P}{P + F}\right) \times \left(\frac{\surd}{\surd + X}\right)$$

1/5.10 Example

Factor : Allotted Point = 7										
Location		Spot	1		2		3		4	
1	Item / Standard	1	X		X		✓		✓	
		2	X	F	✓	P	X	P	✓	P
		3	✓		✓		✓		X	
2	Item / Standard	1	X		X		X		X	
		2	X	F	✓	P	✓	P	✓	P
		3	✓		✓		✓		✓	
3	Item / Standard	1	✓		✓		✓		✓	
		2	✓	P	✓	P	✓	P	✓	P
		3	✓		✓		✓		✓	
4	Item / Standard	1	✓		✓		✓		✓	
		2	✓	P	✓	P	N/A	P	✓	P
		3	✓		✓		✓		✓	
5	Item / Standard	1	✓		✓		✓		✓	
		2	✓	P	N/A	P	✓	P	✓	P
		3	✓		✓		✓		✓	

$$\text{Factor Score} = \text{Allotted Point} \times \left(\frac{P}{P + F}\right) \times \left(\frac{\checkmark}{\checkmark + X}\right)$$

$$= 7 \times \frac{18}{20} \times \frac{48}{58}$$

$$= 6.3 \times \frac{48}{58}$$

$$= 5.2$$

N/A entries represent items not being performed by contractor and hence are not assessed.

1/6 ASSESSMENT CHECKLIST FOR PASS MONTHLY ASSESSMENT

1/6.1 Assessment Procedure

1/6.1.1 Preparation in Office

(i) PA and SE to observe assessment date stipulated by TS/1 ☐

(ii) PA and/or SE to give notification of date and time of assessment to the Contractor's Authorized Representative no more than half a day before the assessment ☐

Person Contacted	Date	Time

(iii) PA to liaise with SE, BSI & COW ☐

1/6.1.2 Preparation on Site

(i) PA or SE to check preparation work by COW & check presence of COW ☐

(ii) PA or SE to check presence of Contractor's Authorized Representative ☐

(iii) PA to check presence of SE & BSI for OO Assessment ☐

(iv) PA or SE to check availability of Assessment Equipment ☐

(v) PA or SE to select assessment location and keep records ☐
   (a) By drawing lot: or
   (b) By computer

(vi) PA to check availability of specification references ☐

1/6.1.3 Assessment

(i) Assess "General Obligations" by record check (PA, SE, BSI & COW) ☐

(ii) Assess "General Site Safety" (PA, SE, BSI & COW) ☐

(iii) Assess "Block Related Safety" (PA, SE, BSI & COW) ☐

(iv) Assess "External Works (Drainage)" (PA & COW) ☐

(v) Assess Structural Works (SE & COW) ☐

(vi) Assess Architectural Works (PA & COW) ☐

(vii) Enter Scores immediately at the assessment spot (PA/SE) ☐
   (a) By manual method
   (b) By hand-held computer

1/6.1.4 Completion (by PA except for Structural Works; by SE for Structural Works)

(i) Complete Monthly Score Sheet ☐

(ii) Complete Comment Sheet ☐

(iii) Sign Score Sheets and Comment Sheets ☐

(iv) Send Score Sheets and comment sheets through PC on site to the headquarter to TS/1 for Data Processing before the due date of each month. ☐

1/6.2 Assessment

Assessment of the following aspects :-

[ ] Structural

[ ] Architectural

[ ] External Works

[ ] Other Obligations

will be carried out on works as found on site. Works in progress but not yet completed will be assessed on the basis of the works carried out so far.

1/6.3 Equipment

[ ] Laser Leveller

[ ] Digital Measurement Probe

[ ] String and Plumbline

[ ] Measuring Tape

[ ] 600mm Long Spirit Level

[ ] 1200mm Long Spirit Level

[ ] Wire Brush

[ ] Coins ($5.00 and 10¢ Coins)

[ ] Hand-held Computer

[ ] Score Sheets

[ ] Straight Edge

[ ] Feeler Gauge

[ ] Steel Set Square

[ ] Mirror

[ ] Binoculars

[ ] Screw Driver

All equipment for PASS, except coins, hand-held computer and equipment for air/water test, can be obtained from SLS/C.

1/7 SAMPLING LOCATION RECORD

Name of Project : Date :

Contractor :

Block Type :

1/7.1 Structural Assessment (Working Floor) :-

Location	1	2	3	4
Block				
Floor	/F	/F	/F	/F
Flat No.	Flat	Flat	Flat	Flat

1/7.2 Structural Assessment (Finishing Floor) :-

Block No. :

Location	1	2	3	4
Floor	/F	/F	/F	/F
Flat No.	Flat	Flat	Flat	Flat

1/7.3 Architectural Assessment :-

Block No. :

Location	1 Flat	2 Flat	3 Flat	4 Stair-case	5 Corridor	6 Structural Window Opening	7 Application of Spatterdash	
Floor	/F	/F	/F	/F	/F	/F	/F	/F
Flat/Wing	Fl/	Fl/	Fl/	W/	W/	W/	W/	W/

1/7.4 External Works Assessment (Drainage) :-

Location	1	2	3	4	5
Between					

1/7.5 General Site Safety :-

Location	1	2	3	4	5
Point					

1/7.6 Block Related Safety* :-

Block No. :

Location	Lower Zone			Middle Zone			Higher Zone		
	1 Ground Floor	2	3	4	5	6	7	8	9 (Working Floor)
Floor	G/F	/F	/F	/F	/F	/F	/F	/F	/F
Wing	W/	W/	W/	W/	W/	W/	W/	W/	W/

* Each location for Block Related Safety shall preferably be on a different floor where such choice exists. At least one location in each zone shall include a wing with a temporary refuse chute.

1.8 PROGRESS RECORD - ARCHITECTURAL FACTORS

Name of Project : Date :

Contractor :

Block Type : Block No.:

Progress Record

COW shall complete the Progress Record to determine the available range of floors for Sampling Locations..

Completed floors available for checking for each factor

Location 1 - Flat (Kitchen)

1.	Check floor and internal walls in kitchen	from /F	to /F
2.	Check balcony door and walls	from /F	to /F
3.	Check 2 nos. windows and external walls outside those windows	from /F	to /F
4.	Check plumbing installation	from /F	to /F
5.	Check cooking bench and sink unit	from /F	to /F

Location 2 - Flat (Bathroom)

1.	Check floor and internal walls in bathroom	from /F	to /F
2.	Check 3 nos. windows and external walls outside those windows	from /F	to /F
3.	Check plumbing installation	from /F	to /F
4.	Check 2 items of sanitary ware	from /F	to /F

Location 3 - Flat (Living Room)

1.	Check floor and internal walls in living room	from /F	to /F
2.	Check 3 nos. windows and external walls outside the windows	from /F	to /F
3.	Check 2 nos. door and frame	from /F	to /F
4.	Check plumbing installation	from /F	to /F

1.8 PROGRESS RECORD - ARCHITECTURAL FACTORS

Name of Project : Date :

Contractor :

Block Type : Block No.:

Progress Record

COW shall complete the Progress Record to determine the available range of floors for Sampling Locations..

Completed floors available for checking for each factor

Location 1 - Flat (Kitchen)

1. Check floor and internal walls in kitchen	from /F	to /F
2. Check balcony door and walls	from /F	to /F
3. Check 2 nos. windows and external walls outside those windows	from /F	to /F
4. Check plumbing installation	from /F	to /F
5. Check cooking bench and sink unit	from /F	to /F

Location 2 - Flat (Bathroom)

1. Check floor and internal walls in bathroom	from /F	to /F
2. Check 3 nos. windows and external walls outside those windows	from /F	to /F
3. Check plumbing installation	from /F	to /F
4. Check 2 items of sanitary ware	from /F	to /F

Location 3 - Flat (Living Room)

1. Check floor and internal walls in living room	from /F	to /F
2. Check 3 nos. windows and external walls outside the windows	from /F	to /F
3. Check 2 nos. door and frame	from /F	to /F
4. Check plumbing installation	from /F	to /F

APPENDIX 9

University's Panel of Contractors- Monitoring of Contractors' Performance[49]

ESTATES OFFICE

University's Panel of Contractors
Monitoring of Contractors' Performance

Summary notes of meeting held on 2nd April 1992 at 3.30 p.m. involving MM/AJK/HSS/KW

The meeting was called to discuss the decision of University's Tenders Board of 27th June 1991 which proposed actions as follows:-

> "Guidelines for Delisting of Contractors
>
> It was agreed that the guidelines should be prepared by the Estates Officer before the end of 1991. Members supported the Estates Officer's emphasis on safety in the drawing up of these guidelines and agreed that these safety measures in construction works are very important and should be taken up by the Estates Officer with the Environmental Health and Safety Committee. It was also recommended that more training in this respect should be given to all appropriate personnel within the University."

NOTED that the current monitoring format used by both Building Maintenance and Development Divisions are based on ICAC's recommendations of many years past i.e. Building Maintenance's Annex D and Development Division's Annex A & Annex B are in accordance with ICAC's recommendations.

AGREED that Development Division's Annex B is probably slightly more appropriate and should now be used for all reporting by Building Maintenance, E & M and Development Divisions on the University's Panel of Contractors. However, to this standard format should be added a further category, namely, 'Adherence to Safety and Health Requirements'.

Minor Works - this is intended to refer to works generally falling under $0.75 Million in line with U.P.G.C.'s requirement that any works above this figure require the appointment of quantity surveyor consultants.

Major Works - this is intended to refer to individual contracts exceeding $0.75 Million in value and in accordance with A.S.D.'s list (category A) not exceeding $6 Million per contract.

For anything larger than the above, i.e. major development projects undertaken by Development Division and development section of E & M Division, the formal reporting on the contractor's performance would be the responsibility of the architect involved i.e. architect consultants employed by the University or by the Estates Office Development Division where the architectural consultancy is done in-house.

.../2

The standard format to be used for major works should be Development Division's Annex A but it was not felt necessary to include the wealth of detail shown on page 2 of Annex A. In similar fashion to Annex B agreed this Annex A should also include a section on 'Adherence to Safety and Health Requirements'.

Frequency of Reporting

It was felt that there should be a differentiation in frequency of reporting between maintenance works and new works and probably also a differentiation according to the size of contract value. Small maintenance contracts for example in the region of $50,000 to $100,000 may require a reporting form to be filled in weekly as the contract period may only be a matter of few weeks whereas for larger-scale projects it would probably suffice to report on a 3-monthly basis.

Issuance of Warnings to Contractors

In line with what is done in the Housing Authority it was felt that the procedures should be along the following lines i.e. to issue the first warning with a time limit for compliance followed by a second warning again with a time limit; failure to comply would result in the contractor being summoned to the Estates Office to explain/justify his lack of response or improvement.

Suspension

AGREED that there is merit in adopting a system of suspension in similar way as the Housing Authority and other major employers of contractors. In this system, the contractor who is not performing is not totally removed from the List or Panel of Contractors but is barred for a specific time period from tender. A suspension period is normally 3 to 6 months after which the contractor automatically rejoins the List/Panel perhaps with his subsequent performance being more carefully scrutinised to ensure compliance.

Interview of Contractors

For warning and suspension procedures, felt that it is ultimately up to the Division Heads to set out guidelines for who should be responsible for interview of contractors. Again, the value of the contract should determine the appropriate level of staff required but in general terms it was felt that at least two Estates Office staff members need to be involved both in the issuance of warnings and in the interview of contractors e.g. a proposal to issue a warning would have to be part of a recommendation upward for approval. Similarly the interview of a contractor should be the person involved with the job plus his immediate superior officer.

.../3

Summary/Conclusion

These proposals for monitoring of contractors' performance would be reported back as required to Tenders Board for approval. Assuming that Tenders Board are in agreement then such monitoring procedures to be put in place for review of contractors' performance for 1992/93 commencing from 1st July 1992.

Division Heads are therefore required to ensure that adequate administration procedures are to be in place for routine review with these routine reviews forming part of the annual review of contractors' performance for submission to the Estates Officer and onward submission to Tenders Board for deletion or addition of contractors to existing lists.

Contract Completion Report

Name of Contractor

Contract No. ____________ Brief Description of Work ____________

____

PART I (To be completed by Inspecting Officer)

Assessment of Contractors Performance

	Very Good	Good	Fair	Poor	Bad
Standard of Workmanship					
Rate of Progress					
Adherence to Contractual Obligations/Instructions					
Contractors Organisation					
Overall Assessment					

General Comment on Contractors Performance ____________

____

____

Certification

I certify that I have inspected the works on ____________ and that they have been completed to my satisfaction.

Signed ____________

Date ____________

PART II (To be completed by Officer in charge of the Project)

	Very Good	Good	Fair	Poor	Bad
Overall Assessment of Contractor's Work					

General Comments

Certification

I certify that I have inspected the above works on ____________ and that they have been completed to my satisfaction.

Signed ____________

Date ____________

REPORT ON CONTRACTORS PERFORMANCE (6 months)	RESTRICTED (ADMIN.)

ESTATES OFFICE
UNIVERSITY OF HONG KONG

FROM ______ TO ______

A CONTRACTOR ______

______ GROUP ______

NO. ______

CONTRACT NO. & TITLE ______

______

CATEGORY OF WORK ______

______

COMMENCEMENT DATE ______

PORTION	CURRENT DUE DATE FOR COMPLETION	ESTIMATED DATE FOR COMPLETION
WHOLE		

B CONTRACT SUM $ ______ ESTIMATED FINAL CONTRACT SUM $M ______

Estimated Value of Work Done as at end of Last Report $M ______
Estimated Value of Work in this Quarter $M ______
Estimated Value of Work Outstanding $M ______
Other Matters Allowed for in Est. Final Cont. Sum $M ______

C	ASPECTS OF PERFORMANCE	VG	G	S	A	P	VB	E
1	ORGANISATION							
2	GENERAL OBLIGATION							
	Site Safety							
	Other Obligations							
3	RESOURCES							
	Labour							
	Plant							
	Materials							
4	WORKMANSHIP							
	Structure							
	Services							
	Finishes							
5	PROGRESS							
	OVERALL ASSESSMENT							

CLAIMS	NO.	CLAIMED	ASSESSED	DISPUTE OR UNRESOLVED
END OF LAST PERIOD		$M	$M	$M
THIS PERIOD		$M	$M	$M

COMMENTS:-

D REMARKS:-

This Report *NOT ADVERSE/ADVERSE

PREPARED BY

______
ARCHITECT/CONSULTANTS
(SUPERVISING OFFICER)

DATE ______

ENDORSED BY

______
( )

DATE ______

1.0	STANDARD OF ORGANISATION	VG	G	S	A	P	VB
1.1	adequacy and management ability of site supervisory staff						
1.2	adequacy of planning						
1.3	adequacy of supervision						
1.4	degree of co-operation						
1.5	technical knowledge of site supervisory staff						
1.6	adequacy of site staff's executive authority						
1.7	support provided by head office to overcome any deficiency						
1.8	control over sub-contractors						
1.9	attention to measurement matters/adequacy of records and accounts						

2.0	COMPLIANCE WITH GENERAL OBLIGATIONS	VG	G	S	A	P	VB
2.1	attention to safety						
2.2	cleanliness of site						
2.3	care of the works						
2.4	avoidance of nuisance/damage to general public & neighbours						
2.5	compliance with insurance requirements						
2.6	cooperation with utilities and care of utility apparatus						
2.7	cooperation with other authorised contractors						
2.8.	compliance with instructions						
2.9	compliance with enactments e.g. noise						
2.10	submission of temporary works design						
2.11	adequacy/submission of operational and maintenance-manuals						
2.12	adequacy of notice for examination of works						
2.14	payment of nominated sub-contractors						
2.15	compliance with particulars related to sub-letting						

3.0	ADEQUACY OF RESOURCES	VG	G	S	A	P	VB
3.1	adequacy of labour						
3.2	skill of personnel						
3.3	adequacy of materials						
3.4	standard of materials						
3.5	storage of materials						
3.6	adequacy of plant						
3.7	suitability and state of plant						

4.0	WORKMANSHIP	VG	G	S	A	P	VB
4.1	standard of temporary works						
4.2	standard of workmanship, earthworks						
4.3	standard of workmanship, structural						
4.4	standard of workmanship, finishes						
4.5	standard of workmanship (others)						

5.0	PROGRESS	VG	G	S	A	P	VB
5.1	adequacy of programme						
5.2	adherence to programme						
5.3	updating of programme						
5.4	suitability of method and sequence of working						
5.5	achievement in period						
5.6	action taken to mitigate delay/catch up with programme						

Inspection Report (to be completed weekly)

Name of Contractor: ______________________________

Contract No. ______________ Brief Description of Work ______________

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Date of Commencement of Work ______________________

Date of this Report ______________________________

Estimated Date of Completion ______________________

Total Value of Contract __________________________

Estimated Value of Work completed to date ______________

Report on Contractor's Performance since last Report

	Very Good	Good	Fair	Poor	Bad
Standard of Workmanship					
Rate of Progress					
Adherence to Contractual Obligation/Instruction					
Contractor's Organisation					

N.B. A 'bad' in any of above would normally necessitate a written warning to Contractor from the Estates Officer.

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General Comments/Instructions to Contractor

Signed ______________ Date __________
S.E.A.

Noted by ______________ Date __________
M.O.