MODELLING CLIENT SATISFACTION LEVELS: A COMPARISON OF MULTIPLE REGRESSION AND ARTIFICIAL NEURAL NETWORK TECHNIQUES

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The performance of contractors is known to be a key determinant of client satisfaction. Here, clients' satisfaction is defined in several dimensions identified using factor analysis techniques. Based on clients' assessment of contractor performance, a number of satisfaction models are presented, developed using multiple regression (MR) and artificial neural network (ANN) techniques. The MR models identified that various attributes of the contractor, project and client were found to significantly influence satisfaction levels. Results of the ANN modelling were similar, however the importance of independent variables was found to be different. The models demonstrate accurate and reliable predictive power as confirmed by validation tests. While the MR models tend to be more accurate for specific dimensions of client satisfaction, the ANN models were found to be superior for models of average satisfaction and overall satisfaction. The MR models suggest that contractors have more effect on client satisfaction than the ANN models. Contractors could use the models to help improve their performance leading to more satisfied clients. This will also promote the development of harmonious working relationships within the construction project coalition.

Keywords: artificial neural networks, performance criteria, multiple regression analysis, satisfaction, performance assessment, questionnaire survey

INTRODUCTION

U.K. contractors have long been criticized for their failure to fulfil the needs of their clients (Latham, 1994; Egan, 1998). In a broader sense, contractors should also perform to the satisfaction of other PC participants (e.g. architects) in order to sustain harmonious working relationships, since these are essential if projects are to be successful (Baker *et al.*., 1988; Smith and Wilkins, 1996; Egan, 1998). There is a need therefore, to investigate contractor performance from the viewpoint of other PC participants (especially clients), from which models for predicting levels of client satisfaction can be developed. This will help to improve performance and enhance satisfaction for the betterment of overall project performance. This paper describes the development of such models using both multiple regression (MR) and artificial neural network (ANN) techniques, which are presented, compared and contrasted.

CONCEPTUAL MODEL OF PERFORMANCE ASSESSMENT

Satisfaction is regarded as an internal frame of mind, tied only to mental interpretations of performance levels (Oliver, 1997). That is, a performance assessor (e.g. client or architect) will have their own psychological interpretation of the performance of others (e.g. contractors). This psychological process is subjective and

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difficult to interpret. Based on this theorem, a conceptual model of performance assessment has been developed (refer to Figure 1).

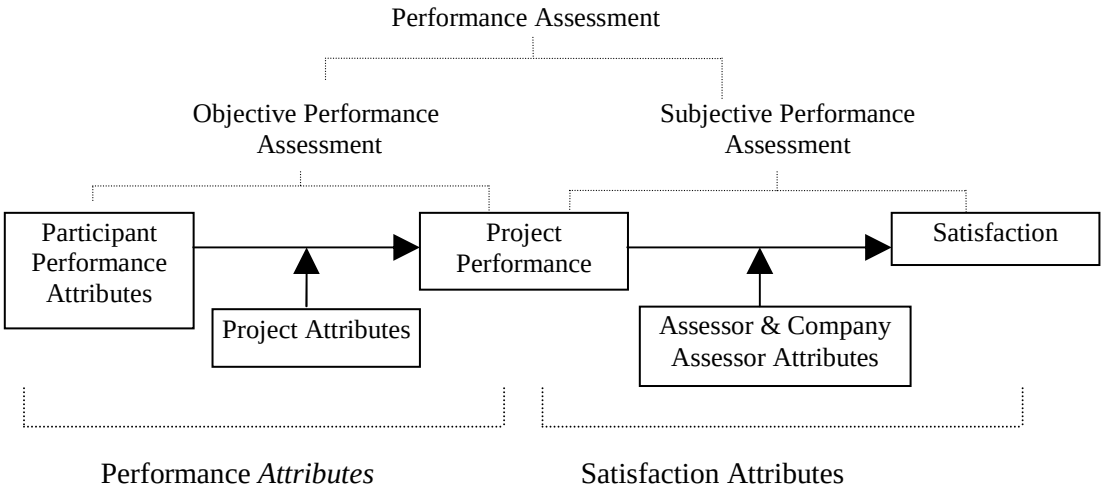

Figure 1: Conceptual model of performance assessment

Conceptually, performance assessment (in terms of levels of satisfaction) can be influenced by two major attributes, those of the performer (i.e. performance attributes) and those of the assessor (i.e. satisfaction attributes). Satisfaction attributes are differentiable from performance attributes mainly due to their unique nature; they being inherent within an individual (i.e. assessor). That is, performance attributes may reflect on both participants and projects, and will influence both participant and project performance. In contrast, satisfaction attributes reflect solely on the assessor and influence their performance assessment and as such are beyond the control of the performer. For full description of these attributes, readers may wish to refer to Soetanto and Proverbs (2001). Here, satisfaction is measured using predetermined performance criteria determined through interviews with twelve experienced clients and supported by detailed literature review in the domain of (contractor) performance. For further detailed description of these interviews, methods of analysis adopted, and full list of performance criteria, refer to Soetanto *et al.* (2001a, b).

The questionnaire

To capture the main modelling data, a questionnaire was developed based on the attributes and performance criteria identified. Respondents (i.e. clients) to the survey were asked to relate all answers to a recent (i.e. within 2 years) UK building project in which they were involved (referred to as the 'case project'). This strategy was designed in order to capture a true and realistic reflection of clients' (i.e. assessors') satisfaction / dissatisfaction feelings. To protect the confidentiality of other parties involved in these case projects, respondents were not asked to identify projects, nor name other participants.

The survey

Following implementation of a pilot survey to help develop and refine the questionnaire, a UK-wide questionnaire survey of clients was conducted. Distribution involved 536 experienced U.K. private and public clients, defined as those who regularly procure construction works from the industry. Private clients consisted of

developers, retailers and financial institutions. Retailers and financial institutions were identified from the listing of Key British Enterprises (Dun and Bradstreet, 1998) representing the top U.K. retailers and financial institutions. Developers were identified from the Estates Gazette (1999). Public clients, i.e. local authorities or City Councils, were identified from the Municipal Year Book (Lauren Hill, 1999). Overall, seventy-seven responses were received representing a 14.4% response rate.

Satisfaction measures

In this research, satisfaction is measured using an interval scale (i.e. scale 0-10) which assumes that satisfaction is a matter of degree, not an all or none property. To measure an abstract concept such as satisfaction, the concept should be defined at an operational (i.e. lower) level, which is observable and directly measurable. If the relationship between the abstract concept and the operational definition of satisfaction (i.e. performance criteria) is strong, the measurement instrument can be considered as valid and reliable to represent the abstract concept (Carmines and Zeller, 1979).

To derive the client satisfaction measures, the factor analysis technique was applied to the performance criteria of 50 responses (i.e. case projects). The main purpose was to determine the number of common factors (i.e. satisfaction dimensions) that would satisfactorily produce the correlations among the observed variables (Kim and Mueller, 1978). Five dimensions of client satisfaction were obtained from this process.

The scores of the performance criteria under each dimension were then averaged to obtain the satisfaction measure (i.e. factor score). The factor score serves as an index of attitude towards a particular dimension of satisfaction under investigation (Torbica, 1997). From the original 48 performance criteria, 28 were included in one of the five factors (i.e. dimensions).

These five factors were meaningfully and logically interpreted as ‘quality of service and attitude of contractor’ (satisfaction measure-1 or *satis1*), ‘main performance criteria and completion’ (*satis2*), ‘performance in preliminary stage’ (*satis3*), ‘performance of site personnel’ (*satis4*), ‘performance in resource management’ (*satis5*). Additionally, two further measures were derived from the mean of *satis1* to *satis5* (*avesat*), and the overall satisfaction of contractor performance derived from one question in the questionnaire (*totsat*). *Totsat* is unique because it represents an individual (i.e. generic) satisfaction score as expressed by clients.

The validity and reliability of satisfaction measures were confirmed using various statistical techniques (e.g. correlation analysis). For a full description of the methodology employed, readers may wish to consult Soetanto and Proverbs (2001).

MODELLING TECHNIQUES

Two modelling techniques were employed to relate the independent with the dependent variables, namely multiple regression (MR) and artificial neural network (ANN) techniques. They are now discussed in the following.

Multiple regression technique

The MR technique was chosen due to its ability to predict levels of satisfaction. Moreover, preliminary data examination showed a degree of linear relationship between dependent and independent variables. That is, MR represented an appropriate methodology for data of this nature (Lewis-Beck, 1993). The stepwise method for inclusion / exclusion of independent variables was utilized.

Artificial neural network technique

ANNs are particularly suitable for analogy-based decision problems prevalent in construction (Moselhi *et al.*, 1991). Given the 'soft' nature of satisfaction and the involvement of subjective judgements, the data was expected to be noisy, biased, complex and non-linear. Moreover, there are a large number of attributes (i.e. input variables) which must be considered in parallel (Moselhi *et al.*, 1991.). That is, ANN provided an alternative, but somewhat appropriate technique for modelling given the nature of the data. *NeuroSolutions* neural network simulation environment version 3.02 consultants level was used (NeuroDimension, 1999) to develop the ANN models. Multilayer Perceptron (MLP), an ANN paradigm commonly used for general classification and regression problems, was used here. To optimize the modelling, a two-stage development process was adopted. Sensitivity analysis was applied (NeuroDimension, *ibid*.) to identify important independent variables, which were included in the second stage. This yielded a simpler model to those developed from the previous stage. This final model could then be used to predict client satisfaction levels. For the purpose of brevity, only the second stage models (i.e. final models) are presented and discussed.

CLIENT SATISFACTION MODELS

In total, seven models for each technique were developed to predict levels of client satisfaction based on contractor performance.

Multiple regression models

In order to assess the MR models as a whole, *importance weights* (IWs) for the independent variables were established. These weights being products of the standardized coefficient (β) of the independent variables in absolute terms and the standard deviation of the dependent variable and being comparable across several models. Then, the *total importance weight* (TIW) of the independent variables was obtained by adding the *importance weights* (IWs) of the variables in each relevant model (refer to Table 1). These variables could then be ranked according to their TIWs and categorized as either extremely important ($TIW \geq 2.0$), highly important ($1.0 \leq TIW < 2.0$), medium importance ($0.1 \leq TIW < 1.0$) or some importance ($TIW < 0.1$) (last column of Table 1).

Artificial neural network models

For the ANN models, a sensitivity factor for each variable included was produced. To obtain an overall picture of the variables used in the models, these variables were accumulated, their sensitivity factors summed and then ranked according to their total sensitivity factors (TSFs) (refer to Table 2). The variables were then categorized as for the MR models, i.e. extremely important ($TSF \geq 2.0$), highly important ($1.0 \leq TSF < 2.0$), medium importance ($0.1 \leq TSF < 1.0$) and some importance ($TSF < 0.1$) (fourth column).

Table 1: Summay of independent variables' total importance weights (TIWs) derived from clients' assessment of contractor performance

Independent Variables	Satisfaction Measures							TIW	Ranking	Importance Category
	satis1	*satis2*	*satis3*	*satis4*	*satis5*	*avesat*	*totsat*			
COATPPQU	0.404	0.533	0.625	0.586		0.653	0.638	3.440	1	extremely important
COATTHS	0.534					0.578	0.520	1.632	2	highly important
COATTQC	0.376		0.434		0.485			1.295	3	highly important
PRVARCO				0.415		0.328	0.462	1.206	4	highly important
COATFISI		0.498			0.428			0.927	5	medium importance
PRVARSE	0.468	0.448						0.915	6	medium importance
COATTSP		0.375		0.526				0.900	7	medium importance
PRBUDMO				0.309			0.446	0.755	8	medium importance
COATTTR					0.724			0.724	9	medium importance
PRDURPL	0.339						0.350	0.690	10	medium importance
COPAYCO2	0.344					0.313		0.657	11	medium importance
COSELCO2			0.488					0.488	12	medium importance
PRTBD3	0.253					0.204		0.457	13	medium importance
PRCONWE			0.328					0.328	14	medium importance
RSCO24		0.314						0.314	15	medium importance
PRTBD0							0.304	0.304	16	medium importance
PRSTO						0.195		0.195	17	medium importance

Discussion of the MR models

The models identified seventeen independent variables as useful predictors. One variable was classified as ‘extremely important’, namely past performance of contractor in terms of cost, time and quality (CLATPPQU). This suggests that contractors whose track records are good, are more likely to satisfy their clients.

Three variables were classified as ‘highly important’, namely (i) health and safety past performance and policy (COATTHS), (ii) quality control policy (COATTQC), and (iii) the extent of variations caused by contractor (PRVARCO). While COATTHS and COATTQC positively influence satisfaction, PRVARCO negatively influences satisfaction. This indicates that health and safety is a highly important factor for clients, more so than quality. Contractors should maintain high levels of safety, quality and attempt to reduce variations if they are to satisfy their clients.

Variables classified as ‘medium importance’ comprised contractor, project and respondent attributes. Contractor attributes were (i) financial soundness and experience in type and size of project (COATFISI), (ii) qualification and experience of site personnel (COATTSP), (iii) formal training regime for site personnel (COATTTR), (iv) cost reimbursement method of contractor payment (COPAYCO2), and (v) contractor selected through negotiation (COSELCO2). Financially sound contractors, experienced in similar projects are more likely to satisfy their clients. COATTSP and COATTTR highlight the importance of site personnel to contractor performance and hence client satisfaction. Contractors being paid by cost reimbursement methods and selected through negotiation derive higher levels of client satisfaction.

Project attributes classified as 'medium importance' were (i) severity of variations (PRVARSE), (ii) project overbudget cost (PRBUDMO), (iii) planned project duration (PRDURPL), (iv) residential projects (PRTBD3), (v) the extent to which the project is constrained by weather conditions (PRCONWE), (vi) public building projects (PRTBD0), and (vii) number of storeys (PRSTO). It is not really surprising that clients are dissatisfied when projects are completed overbudget and incur many variations. Interestingly, larger projects were found to raise satisfaction levels. This may be connected to the prestige associated with such projects, and the need to involve well resourced and experienced contractors whose performance may be superior to smaller firms. Client satisfaction was found to be higher on residential projects than compared to public building projects. PRCONWE suggests adverse weather conditions may hamper contractor performance and hence negate client satisfaction.

Table 2: Aggregate of sensitive independent variables' total sensitivity factors (TSFs derived from clients' assessment of contractor performance

Attributes	Total sensitivity factor	Ranking	Importance category
COPERCL	2.5879	1	extremely important
COSELCO	2.5704	2	extremely important
PRTBD	2.3719	3	extremely important
PRTPR	2.3474	4	extremely important
PRROU	1.9608	5	highly important
PRDUROV	1.9335	6	highly important
COPAYCO	1.9046	7	highly important
PRBUDOV	1.6765	8	highly important
PRVARCO	0.5799	9	medium importance
COATTSI	0.5079	10	medium importance
COWL	0.3771	11	medium importance
COATTQC	0.3730	12	medium importance
COATTPP	0.3650	13	medium importance
COATTQU	0.2775	14	medium importance
COATTBU	0.2633	15	medium importance
COATTHS	0.1802	16	medium importance
RSCON2	0.1554	17	medium importance
COATTTR	0.1228	18	medium importance
PRCONWE	0.0832	19	some importance
RSCON4	0.0600	20	some importance
PRCOMDE	0.0576	21	some importance
COATTSP	0.0564	22	some importance
COATTSC	0.0484	23	some importance
PRINT	0.0348	24	some importance
COATTFI	0.0237	25	some importance
RSSATCO	0.0094	26	some importance

One respondent (i.e. client) attribute representing the perception of the assessor was found to be of 'medium importance', namely 'claim consciousness, never complete projects on time, and contractual attitude of contractors' (RSCO24). Clients who have such perceptions are likely to suffer lower satisfaction levels. This suggests that some degree of subjectivity is prevalent in client's performance assessment.

Discussion of the ANN models

Four variables were classified as 'extremely important', namely (i) any previous working relationship with the contractor's site personnel (COPERCL), (ii) method of

contractor selection (COSELCO), (iii) type of building (PRTBD), and (iv) type of project (PRTPR). Here, well established working relationships with the contractors' site personnel would produce higher satisfaction levels. Further, the procurement of the contractor must be carefully considered. Due to its adversarial nature, the competitive tendering approach is likely to discourage good performance and hence lower satisfaction levels. In this case, a contractor selection methodology based on negotiation would encourage higher satisfaction levels. These two variables suggest that long term relationships encourage higher client satisfaction levels. It is interesting to note that building type and project type influence satisfaction levels. They are considered uncontrollable attributes which can not be altered.

'Highly important' variables comprised (i) project procurement route (PRROU), (ii) overrun (PRDUROV), (iii) method of contractor payment (COPAYCO), and (iv) overbudget (PRBUDOV). Long term, relationship based procurement routes, such as partnering and strategic alliances would have advantages over traditional competitive tendering routes. Moreover, contractors should also maintain their attempt to deliver projects on time and on budget whilst noting that these issues are not considered most important by clients. The lump sum method of payment may discourage satisfaction in contrast to, for example, cost reimbursement. Here, method of contractor payment should be carefully considered and negotiated before project commencement.

Variables categorized as 'medium importance' were dominated by contractor performance attributes. These included (i) experience with project size (COATTSI), (ii) current workload (COWL), (iii) quality control policy (COATTQC), (iv) general past performance of contractor (COATTPP), (v) past performance in quality of construction (COATTQU), (vi) past performance in project budget (COATTBU), (vii) health and safety policy (COATTHS), and (viii) formal training regime (COATTTR). Moreover, contractors should attempt to reduce the number of variations since these have an adverse effect on satisfaction (PRVARCO). Interestingly, one respondent attribute representing the client's general perception of contractors regarding claim consciousness (RSCON2) was included here. That is, clients who perceive contractors to be claim conscious, are less likely to be satisfied.

Variables with 'some importance' included a mixture of project attributes, contractor attributes and respondent attributes. Project attributes were (i) the extent to which the project is constrained by weather conditions (PRCONWE), (ii) design complexity (PRCOMDE), and (iii) contractor and architect interaction prior to on site work (PRINT). Inclement weather may influence contractor performance and hence client satisfaction levels. Complex designs demand higher levels of contractor performance which will ultimately impact client satisfaction. Early interaction between architects and contractors fosters effective levels of buildability, improves communication and the development of working relationships, and thereby improving performance levels.

Contractor performance attributes with 'some importance' included (i) the qualification and experience of site personnel (COATTSP), (ii) past performance in terms of adherence to schedule (COATTSC), and (iii) financial soundness (COATTFI). Respondent (i.e. client) attributes included (i) general perception regarding contractual attitude of contractor (RSCON4) and (ii) the overall satisfaction arising from contractor performance in general (RSSATCO). That is, those clients who perceive contractors to adopt a contractual attitude, are likely to suffer lower satisfaction levels. Conversely, clients with a high perception of contractor performance in general, are more likely to yield higher satisfaction levels.

MODEL VALIDATION AND COMPARISON

To confirm the robustness (in term of accuracy and consistency) of the models in predicting satisfaction levels, the models were validated using a hold-back sample of 27 case projects.

The predictive performance of the models was assessed by examining the residual (i.e. the difference between the actual and the models' predicted satisfaction levels). These were measured using two prediction performance measures, i.e. mean absolute deviation (MAD) and mean absolute percentage error (MAPE) (Kvanli *et al.*, 1996). While MAD indicates the mean absolute deviation of the predicted levels from the actual levels, MAPE indicates the mean absolute percentage of that deviation from the actual levels. Using these measures, it could be concluded that a model yields predicted values with an average deviation of ± MAD, which is MAPE % from actual levels. For data of this nature, MAD of 1.5 to 2.0 and MAPE of 30 to 35% are considered acceptable. MAD of less than 1 and MAPE of less than 20% indicate good predictive performance. The performance of the models was also tested using chi-square (χ^2) analysis and Pearson's correlation coefficient (Edwards, 1999).

A comparison of the results of these tests for both the MR and ANN models is presented in Table 3. Results confirmed their validity and reliability.

Table 3: Comparisons of MR and ANN models validation of clients' assessment of contractor performance

	Satisfaction model														AVERAGE	
	satis1		*satis2*		*satis3*		*satis4*		*satis5*		*avesat*		*totsat*			
	MR	ANN	MR	ANN	MR	ANN	MR	ANN	MR	ANN	MR	ANN	MR	ANN	MR	ANN
MAD	1.24	1.32	1.41	1.27	0.92	1.00	0.91	1.15	0.95	1.00	1.03	0.83	1.37	1.26	**1.12**	**1.12**
MAPE (%)	22.3	23.6	32.4	27.9	16.0	19.5	19.0	23.6	19.4	17.8	19.8	15.7	26.7	23.3	**22.2**	**21.6**
Chi-square test																
Calc. Chi-square	9.73	12.12	13.72	12.60	5.90	6.32	5.94	9.04	6.86	9.24	7.30	6.02	13.42	10.29	**8.98**	**9.38**
***Tab.* = 38.885**																
Correlation test																
Corr. Coefficient	0.52	0.51	0.51	0.57	0.69	0.71	0.77	0.59	0.63	0.61	0.54	0.68	0.45	0.63	**0.59**	**0.61**
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	**0.00**	**0.00**
Preferred Model	●			●	●		●		●			●		●		●

For each satisfaction measure, the performance of the MR and ANN models was compared based on the magnitude of MAD and MAPE (i.e. in terms of accuracy and consistency) to enable the best model to be selected. Generally, the MR models were more accurate for the dimensions of satisfaction (*satis1* to *satis5*) than the ANN models (*satis2* was the exception here). In contrast, for *avesat* and *totsat*, the ANN models were more superior than the MR models. It is worth noting that average MAD for both models are the same (i.e. 1.12), but MAPE and correlation coefficient indicate that the ANN models are better (refer to Table 3, column 'AVERAGE'), albeit this difference was marginal.

In both techniques, the independent variables identified consist of project attributes, contractor performance attributes and respondent (i.e. assessor) attributes. Hence, this suggests the validity of the performance assessment model presented in Figure 1, i.e.

that satisfaction levels are dependent on performance and satisfaction attributes. Hence, subjectivity is to some extent prevalent in performance assessment. The majority of variables identified by the MR technique were also identified using the ANN technique. The ANN models required more variables than the MR models. Moreover, it can be observed that several variables in the ANN models were classified as 'some importance', but none of the variables in the MR models were classified in this category. Moreover, levels of importance for the variables were found to differ between the two techniques.

A comparison of the importance of variables in both techniques revealed that contractors seem to have more impact on client satisfaction in the MR models. In the MR models, four contractor performance attributes (i.e. COATPPQU, COATTHS, COATTQC and PRVARCO) were considered either extremely or highly important. In the ANN models, variables classified as 'extremely important' were found to be largely beyond the control of contractors (e.g. procurement route, method of payment, etc.). In sum, while the importance of contractor performance attributes should not be overlooked, clients should also pay particular attention to key project attributes, since these have a highly significant impact on their levels of satisfaction.

CONCLUSIONS

Based on a UK wide questionnaire survey of clients, multiple regression (MR) and artificial neural network (ANN) models have been developed to predict several dimensions of client satisfaction resulting from the performance of contractors. For this research, both the MR and the ANN techniques were found to be appropriate, given the nature of the problem (i.e. satisfaction being a matter of degree) and characteristics of the data (complex, non-linear and noisy).

For the MR models, the past performance of contractors in terms of cost, time and quality was identified as the most important independent variable. This suggests that contractors whose track records are good, are more likely to satisfy their clients. Moreover, health and safety, quality control, and the variations caused by contractors were also found to be of importance. These suggest that contractors should pay more attention to issues such as safety and quality, rather than focusing on cost.

In the ANN models, the most important (i.e. extremely and highly important) independent variables identified suggest that long term relationships encourage higher client satisfaction levels. Additionally, uncontrollable project attributes, i.e. types of building and project, also significantly influence satisfaction levels. Moreover, contractors should maintain their attempt to deliver projects on time and on budget. Methods of payment to contractors should be carefully considered and negotiated before project commencement.

Subsequent tests confirmed the validity of the models. In terms of accuracy and consistency, the MR models were more accurate for the various dimensions of client satisfaction, whereas the ANN models were superior for models of average satisfaction and overall satisfaction. As a whole, the ANN models were found to be marginally better.

Independent variables identified included project attributes, contractor performance attributes and respondent (i.e. client) attributes. This suggests that subjectivity is to some extent prevalent in performance assessment. The majority of independent variables were identified by both the MR and ANN models, however, levels of importance varied between the two techniques. Contractors appeared to have more

impact on client satisfaction in the MR models. In sum, contractors should focus on those attributes found to be significant in order to continuously improve performance and enhance client satisfaction.

In summary, the models developed could be used by contractors to predict and therefore improve levels of client satisfaction by improving their own performance. This ultimately would help to create a performance-enhancing environment leading to harmonious working relationships between PC participants, thus ensuring continuous performance improvement for the betterment of all involved.

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