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SUMMARY

Measurement/quantification is a core skill of the quantity surveyor and such skills need to be placed within a more appropriate educational framework to ensure their continuing relevance. This paper reports on a study that sought firstly, to identify the characteristics associated with measurement/quantification skills and secondly, to weight or rank their relative importance. A total of thirty seven characteristics associated with a person undertaking the measurement task were identified following a search of available literature and a series of taped interviews with practitioners. These were then classified and grouped together into a model structured according to the fundamental requirements of educationally soundness, technically soundness and personally soundness. Twenty one representative characteristics of this model were then rated for importance by 77 undergraduate quantity surveying students and 30 qualified quantity surveyors working in private practice.

The resulting analysis enabled the subsets of the characteristics of measurement skill to be ranked in the following order of importance:- ability to formulate and solve problems, sufficient knowledge of salient aspects of the task, good intellect, ability to activate responses, adequate construction capability, ability to transmit information, good character, practical capability and good physical characteristics. This ranking allowed the proposed model of the characteristics of measurement skills to be weighted to show that educational soundness was more important than technical and personal soundness.

Keywords: Quantity surveying, quantification skills, skills

modelling, education, training.

INTRODUCTION

Measurement and quantification are well established activities in the construction industry and their applications are well known. Project cost and price forecasts, for example, rely heavily on the measurement and quantification of the likely construction work involved. Since Napoleonic times, the UK construction industry has used bills of quantities as the basis of its procurement and cost information systems. For these systems to work effectively, the people involved in measurement and quantification have to have special characteristics. Normally these people are either quantity surveyors or contractors' estimators.

The development of appropriate quantification skills is therefore a fundamental requirement for many involved in the construction process. The construction management functions of estimating, purchasing, planning, quantity surveying and site management, for example, have been found to comprise seventeen different tasks that demand quantification skills (Pasquire, 1991). Furthermore, Eccles (1992) has suggested that, even in the absence of the traditional bills of quantities, these quantification skills will still be needed to produce the necessary "quantified schedules" used by contractors.

What is not fully understood is the nature of the skills that are necessary to carry out the measurement task in an adequate manner. What do these skills consist of, and how are they acquired? It is argued that the skills necessary for the quantification task have a continuous relevance to many involved in the construction procurement process. How can such skills be identified? The answers to these questions have an important bearing on the way practitioners work and especially the education and training of novices.

Quantity surveyors are, by definition, likely to have the best developed skills in quantification in the UK and so were chosen for our research. Based on these considerations, a sample of 77 student quantity surveyors and 30 practising quantity surveyors was studied. The data collected from a structured schedule of questions was classified by LSD (least significant difference) analysis of variance. This grouped characteristics of equal weight and allowed the data to be classified into a weighted model. From this it was possible to show the most important perceived attributes to be the ability to solve problems ('educational soundness'), acquire sufficient knowledge ('technical soundness') and a possess a good intellect, logical thought and numerical skills ('personal soundness'). A conceptual model is proposed to indicate how the grouped and weighted characteristics of a person undertaking the quantification task may be collectively grouped and named for future analyses of this kind.

The subject matter of this paper is concerned with the identification, and relative importance, of the perceived individual skill characteristics involved in measurement. The development of a model of measurement skills is described which, when tested, allows a weighted model to be advanced that reflects the relative importance of the individual skills involved.

As these results have implications for the way that quantification studies are presented within courses of formal education, some recommendations are made concerning the delivery of studies in a workshop environment that develops problem solving abilities utilising numeracy, communication and organisational skills.

POTENTIAL CHARACTERISTICS ASSOCIATED WITH QUANTIFICATION SKILLS

According to Fletcher & Bannister (1931), the "essential" attributes of a person quantifying construction work are: thorough knowledge of building construction; acquaintance with the ordinary rules of mensuration; knowledge of the customs of each trade; tact; patience; accuracy; energy; common sense; initiative; and imagination to visualise building design details. Willis & Newman (1988) in their standard text on quantity surveying add to this the ability to write clearly, take care, think logically and possess a sound knowledge of building materials.

Mudd (1984) described many qualities considered to be associated with contractors estimators'. These are very similar to Fletcher & Bannister and Willis & Newman with the addition of: a good basic numerate education; experience on site; ability to read and interpret drawings; a neat, methodical and tidy habit; ability to cope with vast amounts of paper work; curiosity; confidence; and the flexibility to pick up useful information. In addition, Skitmore's (1985) work with practising quantity surveyors in early design-stage estimating found four further perceived characteristics: good organisational ability; intuition; application; and aptitude.

Of these 26 characteristics, only 14 are specifically related to the individual undertaking the quantification task. Also, 10 of these characteristics were identified only by Bannister and Fletcher before 1931 and may reflect practises that are now outdated. The first stage of the research, therefore, was to check the current status of these characteristics regarding the measurement task. This involved conducting unstructured interviews with eight quantity surveying practitioners holding senior positions in practices in the Greater Manchester area. Each practitioner was encouraged to express his own views of the skills, abilities or characteristics required to perform the quantification function.

Analysis of the interview transcripts generally confirmed the perceived desirability of all the characteristics, except "energy", identified in the literature although sometimes with a slightly different terminology. Thus the characteristics confirmed as relevant by the practitioners were: knowledge of construction; good written communication skills; appropriate personality factors; accuracy; the ability to think in a logical manner; thoroughness; flexibility to use past solutions appropriately; neatness and tidiness; imagination and visualisation of construction details; feel for numbers; practical awareness; good attitude to work; understand design drawings; learn from experience; an enquiring disposition; ability to take short cuts; knowledge of new and differing materials; good perception and judgement; awareness of the importance of feedback; ability to decide on appropriate measurement levels; organise tasks; pay attention to detail; and take decisions.

In addition, the practitioners' provided a further 14 relevant characteristics: speed; teamwork orientation; ability to concentrate; ability to analyse information; keyboard skills; knowledge of the methods of measurement; good attitude to people; good powers of verbal expression; good memory; understanding of the constraints on clients; ability to draw; learn from published works; maintain own standards; and learn from others. Table 1 lists the characteristics identified above and gives each characteristic's own reference number.

CLASSIFICATION OF POTENTIAL CHARACTERISTICS

In the absence of any previously published classificational work on the subject, we referred to models already established for three other occupations: architects, accountants and civil engineers (see Table 1).

Lawson (1972) suggested that architectural skills can be combined into a model that represents technical, social, artistic, analytical and managerial abilities. Our intuition was that our characteristics numbered 1,7,12,14,16,19,30,34,35,37 are technical, 2,3,11,15,20,22,27,31 are social, 5,6,8,9,10,32,33, are analytical, and 13,23 are managerial. We were unable to classify the remaining 10 characteristics under this system.

Solomon and Berridge (1974) considered skills in their work on the relevant education and training of accountants. These were classified as numeracy, personal integrity, good general intelligence and communication skills. In this case our intuition was that our characteristics 4,6,11,24,37 are associated with numeracy, 3,13,31,36 with personal integrity, 5,17,20,21,22,28,32 with intelligence, 2,9,15,27,34 with communicative ability. In this case, we were unable to classify the remaining 16 characteristics.

Blockley and Robertson (1983) proposed an hierarchically arranged model of what they considered to be the attributes of good civil engineers, claiming it to be equally applicable outside the field of civil engineering. Their model consists of 113 characteristics linked by a set of logically connected propositions. The three main skill areas identified by Blockley and Robertson were technical soundness, educational soundness and personal soundness. Here our intuition was that characteristics 1,12,14,16,19,21,22,30,33,34, 35,37 are concerned with technical soundness, 2,4,5,6,7,8,11,15, 18,20,23,24,25,26,27,28,32,36 with education, and 3,9,10,13,17, 25,29,31 with personal qualities (with no unclassified characteristics).

The intuitive ease with which Blockley & Robertson's basic classification was applied to our list of quantification skills, together with their claims for the model's generality, resulted in our decision to adopt this system in this research. The thirty seven previously identified characteristics of measurement skill were grouped accordingly (see Table 1) and an outline conceptual model advanced containing the three main subsets of characteristics of technical soundness, educational soundness, and personal soundness.

As Blockley & Robertson point out, different occupations place different emphasis on the importance of individual characteristics. Having decided on the general structure of the model, perceived relative importance of the characteristics is clearly an empirical issue. The next stage therefore was to estimate the weights of the various characteristics as a measure of their individual and grouped or subsetted importance.

DATA COLLECTION

Subjects

It has been said that, in the appraisal of skills, the skilled activity should be (1) discussed almost *ad nauseam* with the individuals who practice it, as well as those for whom they are responsible, and (2) examined by observing the development of trainees (Singleton, 1978). In view of this, it was considered appropriate to gather views from experts and novices of different levels of ability. Data was therefore collected from both practising chartered quantity surveyors and two groups of trainee quantity surveyors. One group of trainee quantity surveyors was studying in the second year and another group was studying in the fourth year, of a five year part-time degree course in quantity surveying.

Group A comprised thirty seven part-time quantity surveying students studying first level quantification in parallel with working in quantity surveying organisations at a junior level. Group B comprised forty part-time quantity surveying students studying second level quantification in parallel with working in quantity surveying organisations. These were working at a slightly more senior level than those Group in A. Group C comprised thirty practising quantity surveyors who were visited in their offices in the North West of England between April 1990 and April 1991. The subjects in Group C were selected through personal contacts of the authors. These were recommended by senior personnel within their organisation as the persons most often quantifying building work for inclusion in bills of quantities.

Questionnaire design

An "interview and rank order schedule" (Kerlinger, 1969) was used to collect data from the different subject groups. Early versions of the questionnaire, using the full set of 37 characteristics, were tested in a series of pilot studies. These studies indicated that, because of time constraints, schedule would have to be limited to questions concerning a subset of the characteristics. Kerlinger's work on questionnaire length indicated that approximately 20 representative characteristics (RCs) would be appropriate.

As Table 1 shows, a total of 12, 18 and 7 of the set of 37 potential characteristics are concerned with the subsets of technical, educational and personal soundness respectively. To reflect the numbers of characteristics within each subset proportionally over the questionnaire schedule, a total of 7, 10 and 4 RCs were allocated to each of the three respective skill groupings. This produced a questionnaire schedule that contained a total of twenty one RCs for rating by the subjects within the sample frame. The actual questions used in the questionnaire schedule were determined by reference to the Blockley and Robertson (1983) hierarchical model of the characteristics of a good civil engineer. The full hierarchical model contained the following sub groupings within each main subset of characteristics:- 1. Construction capability, and sufficiency of knowledge **(Technical Soundness)**, 2. Communication, formulation and solution of problems, organisation of the task, appreciation of the context of the task, and numeracy **(Educational Soundness)**, 3. Good character, intellect, and physical characteristics **(Personal Soundness)**. Table 2 shows the thirty seven characteristics of measurement skill located within the sub groupings of each of the main subsets. The questionnaire schedule was then structured to reflect the proportion of characteristics of measurement skill located within each sub grouping. Of course, by limiting the size of the questionnaire in this way it was not possible to gain data on all the 37 potential characteristics contained in the original model and a sub-set of 21 representative characteristics (RCs) was eventually examined, some of the RCs covering more than one potential characteristic (see last column in Table 1). The resulting full schedule of 21 RCs used in the survey are summarised in Table 3. Each question in the questionnaire was designed to elicit an importance level rating (ILR) from each subject relating to a RC.

Procedure

The questionnaire was then used to obtain data from each of the groups of subjects. Basically identical procedures were used in the collection of the data from the differing groups, consisting of:

1. A general introductory informal discussion with the subjects concerning the nature and purpose of the project and the people and institutions involved. Time was also taken to ensure that subjects were at ease with the scope and range of RCs to be rated.

2. Subjects were then asked to rate the RCs on their importance in contributing to the measurement task. **The order of the RCs was randomised for each subject to eliminate as far as possible any bias in their responses**. Some clarificational questions were occasionally asked by subjects and these were answered by the interviewer in as consistent a manner as possible.

3. Each subject was given the opportunity to comment or add to the list of RCs that they were presented with.

The total time taken for each of the interviews ranged between fifteen and twenty minutes and it was generally found that this was an appropriate period for maintaining interest and motivation. Each subject was asked to rate on a scale between 1 (low) and 7 (high) the importance of each of the listed RCs. No information was given to the subjects on the results of the interview and, as far as the authors are aware, no communication between subjects took place.

DATA ANALYSIS

Importance Level Ratings generally

The mean and standard deviation of the ILRs for each RC for each group of subjects is shown in Table 3. Singleton's (1978) model for the appraisal of practical skills calls upon the investigator to compare the opinions of groups of practitioner's at differing stages of expertise. In our case, the subject groupings A to C represented increasing levels of experience and therefore assumed expertise. Table 4 shows the most frequent highest and lowest rated RCs for each subject group. The three separate groups of subjects showed some measure of agreement on which the RCs should be rated as more important than others. Of the top seven ratings, six RCs (15, 7, 4, 13, 12 and 2) were common across all subject groups.

The placing of these RCs within the importance rating of the different groups varied and no firm conclusions could be drawn from the positioning of the RCs other than that the RCs listed above could all be said to be of perceived importance.

Table 4 also shows that some measure of agreement on which RCs should be rated as the least important. Of the bottom seven ratings, five RCs (5, 3, 19, 17 and 18) were common across all subject groups.

Test for homogeneity across subject groupings

Various analyses were made using the SPSS/PC+ statistical analysis package (Nie *et al*, 1975). These were firstly, to test for significant differences in ILRs between subject groups and, secondly, to identify clusters of RCs with similar ILRs.

A oneway analyses of variance was conducted for each of the 21 RCs to test for differences between the mean ILRs of three groups of respondents. This revealed the existence of significant differences (at the 5% level) between the groups for five (RC 1, 9, 14, 15 and 21) 5 out of the 21 ILRs - 4 more than would be expected to occur by chance alone. On this evidence it was decided to proceed further with the analysis using subject group C - the most experienced group - alone, as the subjects clearly could not be regarded as homogeneous across all three groups.

RC clusters

A oneway LSD (least significant differences) analysis of variance was carried out for each of the three skill groups of Technically Soundness, Educational Soundness and Personal Soundness to identify RCs with similar ILRs.

Table 5 gives the results that show the ranked RCs in decreasing order of importance within each group.

DISCUSSION

An interesting aspect of this study is the apparent unanimity across the subject groupings on the most and least important RCs, despite the conclusive lack of homogeneity generally. The six RCs agreed as **most important** by all the subject groups were 'logical and systematic structuring of thoughts' (15), 'knowledge of methods of measurement' (13), 'uses maths to quantify accurately' (7), 'knowledge of construction methods' (12), 'visualises construction in three dimensions' (4), 'decisive and enquiring (2). The five RCs agreed as **least important** were 'knowledge of construction materials' (18), 'judges the quality of information' (17), 'possesses appropriate personality traits (19), 'draws or sketches construction details' (3), 'fitness, coordination, agility and dexterity' (5). In Blockley and Robertson's terminology, the groups of subjects saw the ideal measurer as numerate and able to formulate and solve problems, as well as having a knowledge of construction and of methods of measurement, rather than having a good character, good physical characteristics, or able to sketch construction details.

Reference to Table 1 shows these RCs to be evenly distributed across the three educational, technical and personal skill groups. The analysis of the experienced subject group C (Table 5) over all the RCs however clearly showed the perceived superiority of the educational and technical skill groups over the personal skill group, with the educational group ranked slightly above the technical group.

The results of the LSD test indicated that, although the recorded differences in sample ILR means, several of these within each skill group were close enough to be grouped together and thus form appropriate sub-groups (Table 5). As a result it was possible to suggest the model shown in diagrammatic form in Fig. 1 which gives the groupings and weightings of the RCs required by a person undertaking the quantification task. Fig. 1 clearly indicates the perceived importance of the RCs in descending order from top to bottom of the diagram, showing that the educational RCs of 'logical approach' and 'numeracy' are the most highly rated followed by the technical RCs of 'knowledge of methods of measurement', 'learning skill' and 'knowledge of construction'.

Conveniently, three sub-groups were identified for each of the three main groups. After some thought we were able to devise appropriate names for these nine sub-groups (termed 'attributes' here) and these are showed in Table 6. The grouped attributes of measurement skill characteristics are represented in a conceptual model in Fig. 2 which indicates both their interrelationship and their relative hierarchical position.

SUMMARY AND CONCLUSIONS

Quantification skills are required by all construction management personnel involved in either the generation or utilisation of construction cost information. In particular, quantification skills have been identified as core skills of the quantity surveyor. This paper seeks to contribute to the debate on core skills required by construction professionals, by identifying, classifying and quantifying the characteristics that influence the performance of the quantification function.

Thirty seven individual potential characteristics were identified, partly by reference to the existing body of knowledge and partly by unstructured discussions with quantity surveying practitioners. Blockley and Robertson's (1983) hierarchical skills model was then used to classify the individual characteristics into three main skill groupings, namely, technical, educational, and personal soundness. Further empirical evidence was gathered from three experientially different groups of subjects to weight a representative sample of these characteristics within each skill grouping. This weighted skills model is presented in diagrammatic form in Fig. 1 which shows that educational soundness ranked slightly above the technical soundness group and both are ranked above the personal soundness group.

As a result of the analysis of the data it was also possible to observe that the most important 'educational' attribute was the ability to solve problems; the most important 'technical' attribute was the acquisition of sufficient knowledge; and the most important personal attribute was the development of a good intellect, logical thought and numeracy. A conceptual model was proposed in Fig. 2 which suggested how the grouped and weighted characteristics of a person undertaking the quantification task could be collectively grouped and named.

These rankings of contributory characteristics have significance for those academics and practitioners who are involved in the education and training of future personnel involved in quantifying building works. In academic courses, the time devoted to quantification studies is continually being reduced and so the ranking will enable the time available for the teaching of quantification studies to be prioritised into the main skill area of "educational soundness" and in particular the ability to structure thoughts in a logical manner and to use mathematics to calculate accurately. However, the individual ratings of the actual characteristics of a person competent in quantifying building works that were used within the survey indicate that no one single skill area can be relied upon to cover all the important characteristics needed by the practitioner. Indeed the first seven characteristics listed by the study group are drawn evenly from each of the three main skill areas.

The results and observations reached above on characteristic identification and importance ratings are clearly inhibited by the size of the sample of practitioners surveyed. Further evidence needs to be collected before any firm conclusions can be reached. However, we feel it is reasonable to suggest that the way in which quantification studies are taught should concentrate less on transferring knowledge and more on developing an ability to formulate and solve problems that would call upon skills such as numeracy, communication and organisation. These skills may be better developed by changing the emphasis in the delivery of quantification studies within courses of higher education away from formal lecture and practice sessions towards a strategy which sets up a framework for learning opportunities in a workshop environment. In so doing the more important skills identified above may then be better developed. The possession of these skills, not only by quantity surveyors but by other members of the construction team, should ensure that quantification, in whatever form it is required, can take place with maximum efficiency.

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Fig 1: Proposed Model of Weighted Characteristics of Measurement Skills

Fig 2: The Conceptual Model of the Grouped Attributes of Measurement Skill Characteristics

Potential Characteristic	Architects	Accountants	Civil Engineers	Rep Char No

1. Knowledge of construction	Technical	-	Technical	12
2. Written communication skills	Social	Communication	Educational	9
3. Personality traits	Social	Integrity	Personal	19
4. Accuracy	-	Numbers	Educational	7
5. Logical thought	Analytical	Intelligence	Educational	15
6. Thoroughness	Analytical	Numbers	Educational	-
7. Adapts past solutions	Technical	-	Educational	-
8. Analyses information	Analytical	-	Educational	17
9. Neat and tidy presentation	Analytical	Communication	Personal	5
10. Imagination	Analytical	-	Personal	4
11. Numeracy	Social	Numbers	Educational	7
12. Practical awareness	Technical	-	Technical	-
13. Attitude to work	Managerial	Integrity	Personal	-
14. Understands designs	Technical	-	Technical	8
15. Good verbal skills	Social	Communication	Educational	9
16. Learns from experience	Technical	-	Technical	14
17. Inquiring	-	Intelligence	Personal	2
18. Able to take short cuts	-	-	Educational	-
19. Knowledge of materials	Technical	-	Technical	18
20. Perception/confidence	Social	Intelligence	Educational	11
21. Learns from published works	-	Intelligence	Technical	14
22. Learns from others	Social	Intelligence	Technical	14
23. Organises	Managerial	-	Educational	10
24. Attention to detail	-	Numbers	Educational	-
25. Decisiveness	-	-	Educational	-
26. Speed	-	-	Educational	20
27. Teamwork orientation	Social	Communication	Educational	6
28. Concentration	-	Intelligence	Educational	1
29. Keyboard skills	-	-	Personal	5
30. Knowledge of methods of measurement	Technical	-	Technical	13
31. Attitude to people	Social	Integrity	Personal	-
32. Memory	Analytical	Intelligence	Educational	-
33. Understands constraints	Analytical	-	Technical	-
34. Drawing skill	Technical	Communication	Technical	3
35. Feedback	Technical	-	Technical	-
36. Maintains standards	Educational	Integrity	Educational	21

37. Judges appropriate measurement levels	Technical	Numbers	Technical	16

Table 1: Comparison with other occupations

Charas Nr.	Sub Set / Group	% Sub Set Group	Nr. of Quest ion	Quest Nr in Survey
Technical soundness (Maximum 7Nr. Questions)				
12,14,19 33,34,35 37	Construction Capability	58	4.08/4	3,8,16 18
1,16,21 22,30	Knowledge	42	2.92/3	12,13, 14
Educational soundness (Maximum 10Nr. Questions)				
2,15	Communication	11	1.1/1	9
5,7,20 28,32	Problem formulation and solution	28	2.8/3	1,11,15
6,8,18 23,24,25 26,27	Organisation	44	4.4/4	6,10,17 20
36	Context Appreciation	6	0.6/1	21
4,11	Numeracy	11	1.1/1	7
Personal Soundness (Maximum 4Nr. Questions)				
3,13,17 31	Character	57	2.3/2	2,19
10	Intellect	14	0.5/1	4
9,29	Physical characteristics	29	1.2/1	5

Table 2: Rationale to Questionnaire Structure

Nr.	Representative Charact.	Group A		Group B		Group C	
		Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
(1)	Concentration	4.95	1.16	5.55	0.92	5.23	0.99
(2)	Decisiveness	5.78	1.14	5.72	1.18	5.83	0.90
(3)	Drawing skill	3.35	1.14	3.35	1.46	3.67	1.56
(4)	Spacial awareness	6.22	1.07	5.80	1.23	5.80	1.11
(5)	Fitness, agility & dexterity	1.41	0.82	1.63	1.04	1.37	0.70
(6)	Teamwork orientation	5.59	1.13	5.10	1.39	5.37	1.08
(7)	Numeracy	6.24	0.82	5.92	0.98	6.03	1.11
(8)	Analytical approach	5.05	1.06	5.15	1.13	5.17	0.90
(9)	Communication	4.92	1.34	4.00	1.50	4.57	1.12
(10)	Organisation	5.38	1.19	4.92	1.46	5.20	1.19
(11)	Judgement & intuition	5.22	0.99	5.15	0.94	5.40	0.88
(12)	Knowledge of construction methods	5.89	1.13	5.97	0.88	6.00	0.77
(13)	Knowledge of methods of measurement	6.14	1.14	5.82	1.12	6.07	0.81
(14)	Learning ability	4.49	1.31	4.38	1.43	5.80	1.11
(15)	Logical approach	6.38	0.82	5.70	1.10	6.20	0.75
(16)	Assesses closeness of match between past solutions & present needs	4.73	1.20	4.60	1.09	4.73	1.18
(17)	Judges quality of information	4.27	1.08	4.32	1.17	4.60	1.14
(18)	Knowledge of construction materials	4.43	1.42	4.40	1.42	4.83	1.34
(19)	Personality traits	3.59	1.58	3.25	1.82	3.90	1.47
(20)	Speed	5.16	1.52	4.71	1.31	5.43	1.31
(21)	Corrects errors thoroughly	6.08	0.94	5.25	0.99	5.43	1.31

Table 3: Average ratings of representative characteristics

Highest Rated RCs	Lowest Rated RCs
Subject Group A 15.Logical approach 7. Numeracy 4. Spacial awareness 13. Knowledge of methods of measurement 21. Corrects errors thoroughly 12. Knowledge of construction methods 2. Decisiveness	*Subject Group A* 16. Assesses closeness of match between past solutions & present needs 14. Learning ability 18. Knowledge of construction materials 17. Judges quality of information 19. Personality traits 3. Drawing skill 5. Fitness, agility and dexterity
Subject Group B 12. Knowledge of construction methods 7. Numeracy accurately 13. Knowledge of methods of measurement 4. Spacial awareness 2. Decisiveness 15. Logical approach 1. Concentration	*Subject Group B* 18. Knowledge of construction materials 14. Learning ability 17. Judges quality of information 9. Communication 3. Drawing skill 19. Personality traits 5. Fitness, agility and dexterity
Subject Group C 15. Logical approach 13. Knowledge of methods of measurement 7. Numeracy 12. Knowledge of construction methods 2. Decisiveness 4. Spacial awareness 14. Learning ability	*Subject Group C* 18. Knowledge of construction materials 16. Assess closeness of match between past solutions & present needs 17. Judges quality of information 9. Communication 19. Personality traits 3. Drawing skill details 5. Fitness, agility and dexterity

Table 4: The Highest and Lowest Rated RCs

Nr	Rep Char	Rank Pos	Avg	Homogenous Subset
Technical Soundness (Group 1)				
(13)	Knowledge of methods of measurement	2	6.07	---+
(12)	Knowledge of construction methods	4	6.00	| 1
(14)	Learning ability	7	5.80	---+
(8)	Analytical approach	14	5.17	---+
(18)	Knowledge of construction materials	15	4.83	| 2
(16)	Assesses closeness of match between past solutions & present needs	16	4.73	---+
(3)	Drawing skill	20	3.67	---- 3
	Group 1	2	5.17	
Educational Soundness (Group 2)				
(15)	Logical approach	1	6.20	---+ 1
(7)	Numeracy	3	6.03	---+
(21)	Corrects errors thoroughly	8	5.43	---+
(20)	Speed	9	5.43	|
(11)	Judgement & intuition	10	5.40	| 2
(6)	Teamwork orientation	11	5.37	|
(1)	Concentration	12	5.23	|
(10)	Organisation	13	5.20	---+
(17)	Judges quality of information	17	4.60	---+
(9)	Communication	18	4.57	---+ 3
	Group 2	1	5.36	
Personal Soundness (Group 3)				
(2)	Decisiveness	5	5.83	---+ 1
(4)	Spacial awareness	6	5.80	---+
(19)	Personality traits	19	3.90	---- 2
(5)	Fitness, agility & dexterity	21	1.37	---- 3
	Group 3	3	4.23	

Table 5: Multiple Range Test for homogeneous sub-sets within main skill areas

Group	Attribute	Representative Characteristic
Technical Soundness	*Knowledge*	Knowledge of methods of measurement Knowledge of construction methods Learning ability
	Construction capability	Knowledge of materials Analytical approach Assesses the closeness of match between past solutions & present need
	Practical capability	Drawing skill
Educational Soundness	*Problem formulation and solution*	Logical approach Numeracy
	Response activation	Speed Corrects errors thoroughly Teamwork orientation Judgement and intuition Concentration Organisation
	Information transmission	Communication Judges quality of information
Personal Soundness	*Intellect*	Spacial awareness Decisiveness
	Character	Personality traits
	Physical characteristics	Fitness, agility & dexterity

Table 6: The Grouped Attributes of Measurement Skill Characteristics

Fortune, Chris and Skitmore, Martin R. (1994) Quantification skills in the construction industry. *Construction Management and Economics* 12(1):pp. 79-88.