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CONSTRUCTION QUALITY ASSESSMENT SYSTEM (CONQUAS): THE SINGAPORE EXPERIENCE

Patrick TI Lam
Lecturer, Hong Kong Polytechnic University, Hong Kong

Albert PC Chan
Associate Professor, Hong Kong Polytechnic University, Hong Kong

Wilson CY Shea
Quantity Surveyor, Levett & Bailey, Hong Kong

ABSTRACT

In the quest for quality management of construction, different countries have devised their own systems for assessing and benchmarking contractors' quality performance. In this regard, Singapore is the forerunner since the then Construction Industry Development Board (now renamed as Building Construction Authority) developed a Construction Quality Assessment System (the CONQUAS) in the 1980s and this system has become the model for others to follow. Hong Kong, for example, has drawn reference from CONQUAS to develop its own quality assessment scheme for use in the public housing sector, whilst UK is now adopting CONQUAS as her official measure for construction quality.

This paper explains the mechanics of "CONQUAS 21", which is the latest version of the quality assessment system in Singapore for the twentieth-first century. It also presents an analysis of contractors' quality performance based on this new scheme and its predecessor. This research is part of the team's efforts to investigate the efficacy of such assessment schemes.

KEYWORDS

CONQUAS, Quality Assessment, Private Sector, Public Sector, Efficacy.

1. INTRODUCTION

Construction outputs account for sizeable portions of many economies in the world. In terms of sheer size, Singapore is a small (with land area of only 683 sq. km and a population of slightly over 4 million) but compact economy. Its GDP per capita in 1998 was at US$22,250, compared with the United States at US$29,240 in the same year (Singapore Department of Statistics, 2001). About 90 per cent of the population owns their homes in this "Garden City State" and like Hong Kong, Singapore is a regional hub of multi-national businesses. Amidst the recent economic downturn, although the share of construction output has shrunk from 7.4 per cent of GDP in 1999 to an estimated 5.8 per cent in 2000 (Singapore Department of Statistics, 2001), the construction industry is still regarded as one of the pillars and an important contributor of the domestic economy. This sets the background of "*Construction 21"* – a recent move to re-invent the construction industry in Singapore towards the twentieth-first century. One of the targets of this move is to enhance the quality of construction to enable even better standard of living and increase competitiveness of Singapore as a whole (Ministry of Manpower, 1999).

Before one can talk about improving construction quality, one has got to measure it. Despite the abstractness of this attribute, Singapore is the pioneer in devising its Construction Quality Assessment Scheme (CONQUAS). Even dating back to the 1980s, Singapore started to measure construction quality with this system, initially on public sector projects and then gradually adopted it for use in the private sector as well. In the early years of operation of this assessment scheme, the progress of quality improvement was slow, with the industry average score commencing from 67.9 in 1989 and rising only to 71.3 in 1995 (Ofori, et al, 1996). Despite the doldrums of the scoring situation in the early years, the usefulness of the scheme in depicting quality standards attracted the attention of the Hong Kong Housing Authority, which began to develop its own Performance Assessment Scoring System (PASS) after studying the CONQUAS in 1990 (Kam, et al, 1997). With the benchmarking tool in place, the Singapore government, through the then Construction Industry Development Board as its think-tank, launched various quality driving schemes which include the Premium scheme and mandatory ISO9000 certification for public sector projects (Low, et al, 1996). In the year 2000, the average CONQUAS score has reached 77.8 and the system has evolved into the so-called "CONQUAS 21" in line with the "*Construction 21*" initiative mentioned above (BCA, 2000).

This paper introduces the mechanics of the CONQUAS 21 and presents the results of an analysis, which is aimed at predicting the potential efficacy of the new scheme based on actual scores recorded under the predecessor scheme.

2. OBJECTIVES OF CONQUAS

The predecessor of the current Building Construction Authority (BCA) in Singapore, then known as the Construction Industry Development Board (CIDB), designed the CONQUAS based on procedures then used by the Housing Development Board and a major Japanese contractor (Low, et al, 1996). BCA now states that CONQUAS is designed with the following objectives (BCA, 2000):

(a) To have a standard quality assessment system for construction projects.
(b) To make quality assessment objective by:
 -measuring constructed works against workmanship standards and specification,
 -using a sampling approach to suitably represent the whole project.
(c) To enable quality assessment to be carried out systematically within reasonable cost and time.

To ensure that the objectives are met, the BCA carried out trials on the system to fine-tune the new testing techniques and assessment standards. The minimum standards were derived from discussions with major public sector agencies, developers, consultants and contractors based on the general specifications used in their projects (BCA, 2000).

3. MECHANICS OF CONQUAS

3.1 Scope of Assessment

The previous CONQUAS weighted Structural Works, Architectural Works and External Works in the ratio of 40: 50: 10 respectively. Structural Works covered formwork, reinforcement, concrete quality and finished concrete, etc. Architectural Works covered floors, walls, ceilings, doors, windows, services and roofs, etc. External Works covered pedestrian walkways, drains, playgrounds, swimming pools, etc. (Low, et al, 2001)

The new CONQUAS 21 has replaced External Works with Mechanical and Electrical (M & E) Works. External Works are now incorporated under Architectural Works. The revised weightings are as shown in Table 1:

Table 1: Weightings in CONQUAS 21

Components	Commercial, Industrial, Institution & Others	Condominium & Others	Public Housing	Landed Properties
Structural Works	30%	35%	45%	40%
Architectural Works	50%	55%	50%	55%
M &E Works	20%	10%	5%	5%
CONQUAS Score	100%	100%	100%	100%

(Source: BCA, 2000)

For Structural Work assessment under CONQUAS 21, structural steel and pre-stressed concrete are covered if each constitutes more than 20 per cent of the total construction cost. Laboratory tests (on strength of concrete and steel reinforcement) as well as non-destructive tests on concrete cover are conducted. For Architectural Works, the new CONQUAS 21 introduces a water-tightness test for external walls and windows as well as tests on adhesion of internal wall tiles. The new category of M & E assessments cover electrical works, air-conditioning and mechanical ventilation works, fire protection works, sanitary and plumbing works and other basic fittings (BCA, 2000).

3.2 Timing of Assessment

Structural works are assessed during construction since the works would not be accessible upon completion. Site inspection for architectural works is carried out at the completion stage of the building. For M & E works, assessment is carried out before works are embedded or concealed. These include conduits and pipes which are concealed. For surface mounted works, such as fire alarm control panels, hose-reels and air-handling units, inspection is carried out after installation (BCA, 2000). External Works were assessed upon completion under the previous CONQUAS scheme (Low, et al, 2001).

3.3 Sampling

Since it is impractical to assess all parts of a building, a sampling system is adopted for assessment. The intensity of sampling is usually based on the gross floor area (GFA) subject to certain specified minimum and maximum criteria. For example, at least 60 concrete cubes (but no more than 100) at an intensity of 1 sample per 500 sq. m of GFA have to be taken for compressive strength tests. Similarly, guidelines are given for inspecting or testing architectural works and M & E works. Before the assessment, the exact locations for sampling are selected by the assessors based on drawings. Samples are supposed to be distributed as uniformly as possible (BCA, 2000).

3.4 Independence of Assessors

All assessments are performed by BCA officials, who are supposed to have completed BCA's CONQUAS training and calibration programmes to ensure competency and consistency in their assessments (BCA 2000). As such, they can be regarded as independent since they are not part of the project team. It is also a practice that assessors rotate to inspect different projects at different times and they usually work in pairs (De Saram, 2002).

3.5 Assessment Approach

Standard proforma with check-boxes are used by assessors, who indicate "pass" or "fail" against the items as they carry out the inspection from one location to the other. No re-assessment will be done for the same item after rectification, hence contractors are encouraged to do things right the first time. The score is computed based on the proportion of passing items over the total number of assessed items (BCA, 2000).

4 ANALYSIS OF CONTRACTORS' PERFORMANCE

4.1 Background

In a recent research, De Saram (2002) points out that structural works usually score higher compared with architectural works. The explanation proposed implies that progressive improvements would result since inspections for structural works are carried out during construction, whereas architectural works are only inspected upon completion. The purpose of this analysis is to investigate the validity of this claim by examining the relative significance of the component scores to the overall CONQUAS score, using actual scores released by the BCA.

4.2 Methodology

Since the number of projects scored by CONQUAS 21 to date is not as numerous as those scored under the previous scheme, the data set used for the following analysis is taken from the previous CONQUAS scheme. Owing to the similarities of the two versions of assessment (except for those new features of CONQUAS 21 as mentioned in 3.1), the results of the present analysis are believed to be applicable to those scores assessed under the new scheme.

Ten contractors are chosen from the public housing list and private housing list respectively based on the criteria that the number of projects scored under CONQUAS is at least 3 (max. 10) for private contractors and at least 7 (max. 19) for public contractors. In terms of time, the scores were taken between 1992 and 2001 (i.e., those projects scored under the previous CONQUAS). The means of Structural Works scores, Architectural Works scores and External Works scores are computed respectively for each contractor. Then a pair-wise comparison is made for each contractor between the means in the following manner: (1) Structural Works scores vs. Architectural Works scores; (2) Architectural Works scores vs. External Works scores and (3) Structural Works scores vs. External Works scores.

The paired T-test based on dependent samples is applied to the pairs of means of component scores achieved by each contractor. The component scores for the same project are dependent since they are achieved by the same contractor with presumably the same quality assurance measures and management team. T-test is appropriate since the number of projects scored under the name of each contractor is less than 30 and the population variance is not known. A 0.05 significance level was chosen for one-tail T-test to give 95 per cent confidence on the results.

The following hypotheses are set up for testing purpose:
H_0 = The means of the 2 component scores are the same (i.e., the difference between the 2 means is zero)
H_1 = The mean of the 1st component scores is larger than the mean of the 2^{nd} component scores in the pair-wise test.

Upon running the tests for 10 contractors in the private sector and the 10 different contractors in the public sector, some interesting patterns have been observed. Table 2 shows an example of the T-test results generated by the Microsoft Excel software, using the data set as shown in the Appendix. Only one such table is shown due to the limitation on the length of this paper. The conclusions drawn on the hypotheses are summarized in Table 3.

Table 2: An example of T-Test Analysis for a Private Housing Contractor "A"

	Structural Score (1^{st} component score)	Architectural Score (2^{nd} component score)
Mean	79.633	72.944
Variance	26.920	30.643
Observation	9.000	9.000
Pearson Correlations	-0.338	
Hypothesized Mean Difference	0.000	
Df	8.000	
T Stat	2.287	
P(T<=t) one-tail	0.026	
T Critical one-tail	1.860	
Decision Approach:One tail	*2.287>1.860 Hence H_1 cannot be rejected*	

4.3 Interpretation of Result

Table 3: Summary of Tests of Hypothesis for Private and Public Housing Scores

Pair-wise Comparison	Struct. Score Vs. Arch. Score	Arch. Score Vs. Ex. Works Score	Struct. Score Vs. Ex. Works Score
Private Housing Contractors (10 Nos)			
Ho cannot be rejected	1	10	8
H1 cannot be rejected	9	0	2
Public Housing Contractors (10 Nos)			
Ho cannot be rejected	0	10	0
H1 cannot be rejected	10	0	10

Private Sector Housing

(1) Structural Works scores vs. Architectural Works scores – 9 contractors out of 10 have their projects scored in such a way that H_1 cannot be rejected and only 1 contractor has his project scored in such a way that H_0 cannot be rejected, meaning that there is statistical significance that the means of Structural Works scores exceed the means of Architectural Works scores;

(2) Architectural Works scores vs. External Works scores – all 10 contractors have their projects scored in such a way that H_0 cannot be rejected, meaning that there is statistical significance that the means of Architectural Works scores are more or less equal to the means of External Works scores;

(3) Structural Works scores vs. External Works scores – 8 contractors out of 10 have their projects scored in such a way that H_0 cannot be rejected and the remaining 2 contractors have their projects scored in such a way that H_1 cannot be rejected, meaning that there is statistical significance that the means of Structural Works scores are more or less equal to the means of External Works scores.

4.4 Public Sector Housing

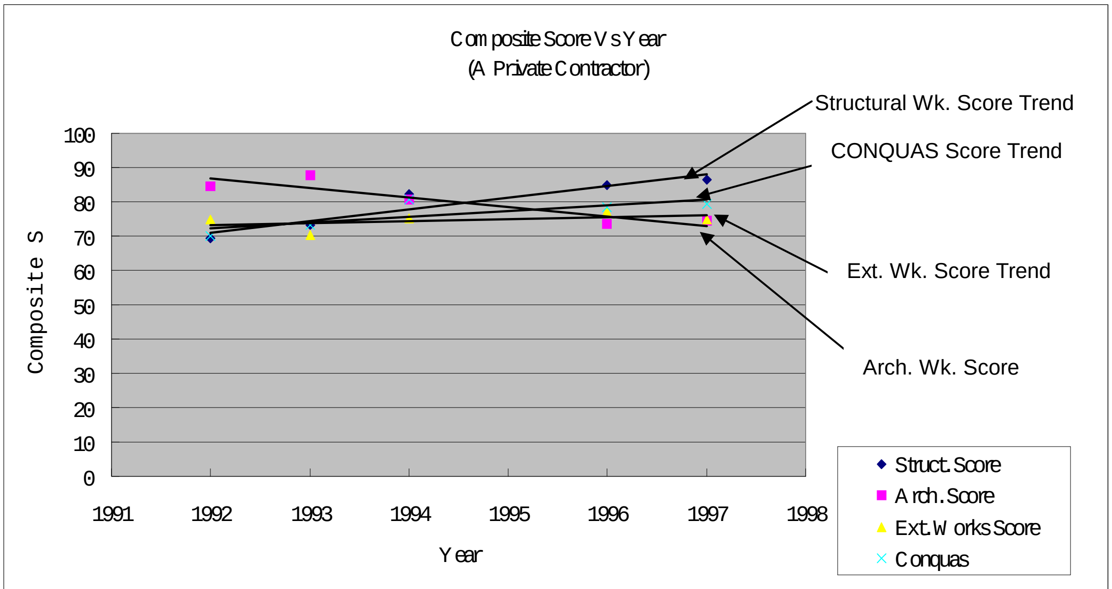
(1) Structural Works scores vs. Architectural Works scores – all 10 contractors have their projects scored in such a way that H_1 cannot be rejected, meaning that there is statistical significance that the means of Structural Works scores exceed the means of Architectural Works scores;

(2) Architectural Works scores vs. External Works scores – all 10 contractors have their projects scored in such a way that H_0 cannot be rejected, meaning that there is statistical significance that the means of Architectural Works scores are more or less equal to the means of External Works scores;

(3) Structural Works scores vs. External Works scores – all 10 contractors have their projects scored in such a way that H_1 cannot be rejected, meaning that there is statistical significance that the means of Structural Works scores exceed the means of External Works scores.

4.5 Significance of Findings

In light of the inferences drawn in 4.3.1 and 4.3.2, it can be concluded that Structural Works scores are predominant in both private and public sector housing projects. This conclusion is in line with the observations made by De Saram (2002), which suggest that Structural Works scores are comparatively higher than Architectural Works scores. This is counter-balanced to some extent by the lower weightage assigned by the BCA for Structural Works scores (as mentioned above, the previous CONQUAS scheme carried the weightages of 40:50:10 for Structural Works: Architectural Works: External Works). The BCA states that the weightage system is a compromise between the cost proportions of the three components in the various buildings and their aesthetic consideration (BCA, 2000). Therefore, it is believed that the higher weightage given to architectural works may well have been intended to highlight the importance of visible quality attributes in the overall CONQUAS score. The lower weightage for structure does not imply that structure is less important but only that the basic requirements for structure are safety, integrity and durability, which are not visible quality aspects. Even taking into account the counter-balancing effect of the higher architectural weightages, there can still be rare occasions whereby the predominance of the Structural Works scores affects the overall CONQUAS score. An illustration of this possibility is shown in Fig. 1 below, which shows a somewhat rising trend for the overall CONQUAS score despite a drop in the Architectural Works score for one of the private housing contractors (say “B”). This is due to the rising trend for the Structural Works scores of this contractor (see also the Appendix).



Source of data: BCA, Singapore

Figure 1: An Example Showing the Effect of Predominance of the Structural Works Scores

Another less significant finding is that for public housing works, the Structural Works scores also prevail over the External Works score. Coupled with the much lower weightage (10 per cent) assigned for External Works, the Structural Works scores again influence the overall CONQUAS score much more than that of External Works, which nevertheless have more visible quality attributes.

5. CONCLUSION

The above analysis shows the empirical predominance of the Structural Works score as a component score in the CONQUAS system. Although the data is limited to those obtainable from the previous assessment scheme, it is believed that the same effect would prevail for the new CONQUAS 21 scheme, which is based on similar assessment mechanics (except for those attributes identified in 3.1). As a matter of design, the weightage system for CONQUAS 21 (as shown in Table 1) logically emphasizes Architectural Works scores in preference to Structural Works scores in similar proportions to those under the previous CONQUAS system. However, based on the above analysis, it is reasonable to infer that the CONQUAS 21 scores are subjected to similar bias towards rewarding the structural performance of contractors, despite this being made up of relatively invisible quality attributes. Apart from the possible explanation due to recurrent inspections of structural works as postulated by De Saram (2002), the comparatively straightforward and less prolific assessment standards for structural works (vis-à-vis the architectural works) might have contributed to this empirical uplift. Since data for the new CONQUAS 21 scheme is not yet abundant enough to carry out similar analysis, it waits to be seen if correct interpretation of contractors' overall quality performance (both in the inherent and visible sense) can be brought about by the new scheme to make CONQUAS 21 a credible quality benchmark for the construction industry. In any case, it is hoped that this paper has thrown some light on the efficacy of quality measurements based on Singapore's experience as a pioneer.

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7. APPENDIX

Scores of private housing contractor “A” as analysed in Table 2

Project	Yr.	Struct	Arch	Ext.Wk	CONQUAS
1	1993	67.7	76.4	92.9	74.6
2	1994	77.1	78.6	87.5	78.9
3	1995	78.6	66.8	73.5	72.2
4	1996	81.1	67.8	84.4	74.8
5	1997	82.2	77.3	55.5	77.1
6	1997	80.2	77.5	87.5	79.6
7	1997	82.4	78.1	80	80
8	1999	86.5	66.9	77.5	75.8
9	2000	80.9	67.1	58.3	71.7

Scores of private housing contractor “B” as depicted in Fig. 1

Project	Yr.	Struct	Arch	Ext.Wk	CONQUAS
1	1992	69.3	84.6	75	70
2	1993	73.1	87.8	70.2	73.1
3	1994	82.1	80.6	75.1	80.5
4	1996	84.8	73.5	77.1	78.4
5	1997	86.6	74.4	75	79.3

(Source of data: BCA, Singapore)