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Critical Success Factors of TQM: Regression Analysis versus Structural Equation Modelling Approach

Dr Nicholas Chileshe
Senior Lecturer, Faculty of Development and Society, School of Environment and Development
Sheffield Hallam University, Sheffield, S1 1WB, UK

Abstract
Despite numerous implementation frameworks (Yusof and Aspinwall, 2000) for TQM existing within the manufacturing and service literature, those found were not suitable and were not systematically developed for SME's. Furthermore, little research has been undertaken to determine if these frameworks can be applied to UK Construction related SMEs. This can be inferred as the question of what TQM "really is" has not interested the academia to a large extent (Hellsten and Klefsjo, 2000). The data collection carried out in the descriptive stage was used with the specific aims of testing the adequacy of the TQM concepts developed in relation to the phenomenon, and the hypothesised linkages among the TQM concepts. Structural Equations Modelling (SEM) approach was employed using the AMOS software to translate these identified relationships into structural equations. This enabled the identification of the contributory effect of each of the Ten Deployment constructs towards effective implementation of TQM. By applying the extension to the basic measurement model to include modelling systematic shared variance among indicators, evidence about the extent of bias that could not be obtained using traditional approaches such as partial correlation and multiple regressions was obtained. The factor loadings were used to determine the unit contributions of each construct towards TQM. In additional to testing the validity and reliability of the structural model through Confirmatory Factor Analysis (CFA), the structural equation modelling (SEM) was utilised to verify the construct validity of scales and to test relationships among variables and unobservable variables. SEM was used to determine the relative influence of each of the ten deployments constructs on the quality manager's perception of the overall TQM deployment. Knowledge of the interactions among the ten deployment constructs can be a valuable diagnostic tool in addressing the effectiveness of each initiative alone to further enhance competitive success.

Keywords: Construction Industry, Critical Success Factors, SEM, TQM

INTRODUCTION

According to Yusof and Aspinwall (2000), various quality management implementation frameworks as identified in literature can be classified into three types; Consultant, Academic and Award based of which mostly are descriptive and prescriptive models. As observed by Curkovic (2003), it is critical that researchers link theoretical concepts to empirical indicants. Tan and Wisner (2004) articulate the argument further when they compared previous studies as identified in this study (Anderson et al, 1994; Flynn et al, 1995; Black and Porter, 1996, and Ahire et al, 1996) which despite identifying various practices, little attention was paid to whether these practices of quality management shared common variance-covariance characteristics that defined an individual construct. This study contributes to that body of knowledge by demonstrating the inter relations among the factors as used by Powell (1995) and refined by Chileshe (2004). Usage of Structural Equation Modelling technique enabled the objective to be achieved as indicated by Chileshe (2004; 2005). The confirmatory stage of the study could be equated to the second step in the development of empirical theory, which was enhanced in the depiction of relationships in diagram form thus providing a visual aid for the interpretation and development of theory.

STRUCTURAL EQUATION MODELLING (SEM) APPROACH

The structural equation modelling (SEM) approach consists of two parts, the measurement and structural model. According to Cheng (2001), the structural model stage of analysis involves the evaluation of the relationship between the latent constructs. The measurement model involves parameter estimating. A brief description of each part is explained as follows:

1.

2. **Parameter Estimating** generates the unstandardized estimates, which could be unanalysed association between factors or measurement errors. The factor loadings are interpreted as unstandardized regression coefficients that estimate the direct effects of the factors on the indicators (Kline, 1985). The parameters that will be calculated first are the weighted mean, and variance for each composite measure. Then the maximised reliability coefficients, in the form suggested by Werts et al (1978). The results of parameter estimating can be summarised as factor loadings and Inter-factor loadings, which in turn can be used to test the reliability, validity and criterion, related issues.

3.

Model Testing involves the demonstration of re-specification, through the modification of an initial CFA model with mediocre or poor fit to the data. Several models are tested ranging from testing for a single factor, where TQM is hypothesised as one factor to a multifactor model (i.e. the ten factor model.). Outputs of the model testing include c_2, GFI, (c_2 /df), TLI, AGFI, NFI, CFI, RMSEA

4.

Second Order Approach (SOA)

Structural Equation: = G x + S... Equation 1.0

(10 x 1) = (10 x 1) (1 x 1) + (10 x 1)

The structural equation links the ten quality management factors to the latent factor "Total Quality Management" **x.** These ten factors are shown in Figures 1.0 and 2.0 as Executive Commitment (EC), Quality Philosophy (QP), Customer Focus (CF), Supplier Focus (SF), Benchmarking (BM), Training (TR), Open Organisation (OO), Employee Empowerment (EM), Zero Defects (ZD) and Measurement (ME).

First Order Approach (FOA)

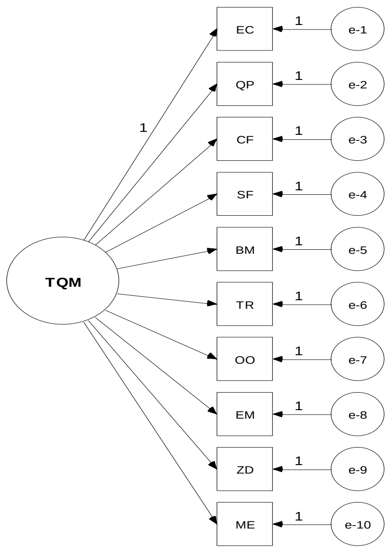
Measurement Equation: y = Ly h + e .... Equation 2.0

(34 x 1) = (34 x 10) (10 x 1) (34 x 1)

The measurement equation links observed indicators y to their respective hypothesized quality factors **h**. First order factors are given by **Ly** while second-order factor loadings are given by G

Global Model = Structural Model + Measurement Model

The hypothesised overall TQ-SMART model (Chileshe et al, 2003) is portrayed in Figure 1.0 in Structural Equation Modelling (SEM) notation. The single headed arrows leading from the second-order of TQM (F_{11}) to each of its underlying first order factors (F_1, F_{11}; F_2, F_{11}; F_3, F_{11}; F_4, F_{11}; F_5, F_{11}; F_6, F_{11}; F_7, F_{11}; F_8, F_{11} F_9, F_{11}; and F_{10}, F_{11}) are regression paths that indicated the prediction of the TQM Executive Commitment, (F1), TQM Adopting the Quality Philosophy (F2), TQM Customer Focus (F3), TQM Supplier Focus (F4), TQM Benchmarking (F5), TQM Training (F6), TQM Open Organisation (F7), TQM Employee Empowerment (F8), TQM Zero Defects (F9), and TQM Measurement (F10) from a higher order TQM factor. They also represent second-order factor loadings denoted as $\mathbf{q}_{11}$ through $\mathbf{q}_{101}$ on Figure 1.0. The results of which are presented in Table 1.0. There is also a residual disturbance term associated with each first-order factor (D_1, D_2, D_3, D_4, D_5, D_6, D_7, D_8, D_9 and D_{10}). These represent residual errors in the prediction of the first-order factors from the higher order factor of TQM. Due to the limitation of the paper, the full global model linking the measurement and structural model is not shown in this paper.



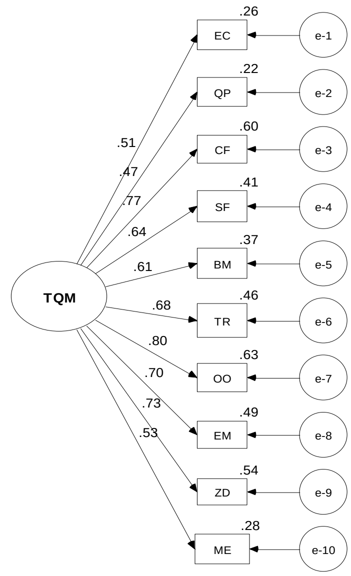


Figure 1.0: Model of the Second-Order Confirmatory Factor Analysis

Figure 2.0: Results of the Second-Order Confirmatory Factor Analysis Model (Full Sample, n = 63)

The loading on the first variable (EC) in Figure 1.0 is fixed to 1.0 to scale the latent variable. With this loading fixed, the one factor model has 20 free parameters, including 9 remaining factor loadings and 19 variances (of 10 measurement errors denoted as e-$_1$ through e-$_{10}$ and latent variable). With 10 observable variables, there are [10(10+1)]/2 =55 observations, thus the degrees of freedom = 55 - 20 = 35.

This approach draws heavily from Curkovic (2003) as used in examining a four factor of Environmental Responsible Manufacturing (ERM). F_1 through F_{10} are constructs, which are approximated units, which by their very nature, cannot be observed directly, Handfield and Melnyk (1998). In testing the theory, the researcher is testing a statement of a predicted relationship between the units observed or approximated in the real world. Thus constructs (h_1 to h_{10}) are related to each other by propositions, while variables are related by hypotheses. Expressed more formally, the Second Order CFA model portrayed in Figure 1.0 hypothesized a priori that

- TQM can be conceptualised in terms of the ten factors
- each observed variable will have non zero loading for all other factors
- error terms (E_1 through E_{10}) associated with each observable variables will be uncorrelated
- The ten first-order factors will be correlated

F_{11}	=	Factor 11	=	TQM (2nd Order Factor)
F_1	=	Factor 1	=	TQM Executive Commitment (1st Order Factor)
F_2	=	Factor 2	=	TQM Quality Philosophy (1st Order Factor)
F_3	=	Factor 3	=	TQM Customer Focus (1st Order Factor)
F_4	=	Factor 4	=	TQM Supplier Focus (1st Order Factor)
F_5	=	Factor 5	=	TQM Benchmarking (1st Order Factor)
F_6	=	Factor 6	=	TQM Training (1st Order Factor)
F_7	=	Factor 7	=	TQM Open Organisation (1st Order Factor)
F_8	=	Factor 8	=	TQM Employee Empowerment (1st Order Factor)
F_9	=	Factor 9	=	TQM Zero Defects (1st Order Factor)

F_{10} = Factor 10 = TQM Measurement (1st Order Factor)

5. MODEL TESTING

The modified TQ-SMART model is represented in Figures 1.0 and 2.0 according to the Linear Structural Relationships (LISREL) notation. The ellipses contain the name of the latent variables while the rectangles contain the measure used to explain each construct (Forza and Filipini, 1998). For example the 'Executive Commitment' is represented by latent variable F1 while the measure used to explain this construct are indicated by variables V_1 to V_3 with their associated errors E_1 to E_3. Table 2.0 presents the results of the SEM and Regression Approaches.

Table 1.0: Structural Equation Modelling Approach				**Table 2.0: Regression Approach**				
Path	Factor Loading	Standardised Regression Weights (SRW)	Squared Multiple Correlations (SMC)	Model	Multiple R	SMC R^2	Adjusted R^2	St Error of the Estimate
TQM - F1	q_{11}	0.542	0.294	1	.422a	.178	.137	.43598
TQM - F2	q_{21}	0.515	0.265	2	.510b	.260	.181	.42462
TQM - F3	q_{31}	0.806	0.650	3	.521c	.271	.131	.43732
TQM - F4	q_{41}	0.720	0.518	4	.622d	.387	.225	.41314
TQM - F5	q_{51}	0.602	0.363	5	.694e	.481	.301	.39234
TQM - F6	q_{61}	0.751	0.564	6	.801f	.641	.470	.34152
TQM - F7	q_{71}	0.834	0.695	7	.812g	.660	.459	.34505
TQM - F8	q_{81}	0.746	0.557	8	.838h	.703	.474	.34032
TQM - F9	q_{91}	0.797	0.635	9	.853i	.727	.471	.34123
TQM - F10	q_{101}	0.569	0.324	10	.872j	.760	.468	.34229

The above results in Table 1.0 are for the second-order factor loadings of TQM constructs, which can also be represented, in a graphical format as shown in Figure 2.0. The results are slightly different as the values used in the second order analysis took the average scores of the variables assigned to each factor. Table 2.0 contains the standardised coefficients for the structural relationships. All but one of the parameters shown in Figure 1.0 are found to be both of the hypothesized sign and statistically significant. Open Organisation (F7) appears to be strongly linked to TQM ($q_{71} = 0.834$)

Demonstration of Inter-Factor Relationships using SEM

The above results in Table 2.0 can also be represented in a graphical format as shown in Figure 2.0. The results are slightly different as the values used in the second order analysis took the average scores of the variables assigned to each factor. The factor loadings are also used to generate the inter-factor correlations, which are presented in Table 3.0. For example, from the factor loadings shown in Table 1.0, the path from TQM to Factor 1 (Executive Commitment) and 2 (Adopting the Quality Philosophy) illustrated as q_{11} and q_{21} are 0.542 and 0.515 respectively. This can further be shown as follows;

$$TQM \rightarrow F1 = 0.542, \quad TQM \rightarrow F2 = 0.515$$

Thus the path between F1 and F2 can be computed as follows; 0.542*0.515 = **0.279**, and that between F2 and F3 can be calculated as **0.415** ($q_{21} * q_{31} = 0.515 * 0.806$). This shows that the relationship between the TQM and its associated constructs at each level is stronger than within the constructs themselves. The full results of the inter-factor correlations are shown in Table 3.0

SEM: Goodness-of-fit measures for comparison of multitrait-multi-method models. The standardised parameters for the Multitrait-multi-method model are displayed in Figure 3.0. Each set of standardised measurement coefficient shows the relative influence of a concept variable and an error variable or a measured variable. The square of a standardised coefficient shows the proportion of observed variance to the specified causes, the error term. For example, TQM contributes 26% (0.51^2) of the unit variance of Executive Commitment. According to Cheng (2001), the structural model stage of analysis involves the evaluation of the relationship between the latent constructs. Table 3.0 presents the relationship among the first-order factors, which can be used to infer the relative strength of relationship among the factors (variables) by their path loadings.

Table 3.0: Inter-Factor Correlations (F)

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	1.00									
F2	**.279**	1.00								
F3	.437	**.415**	1.00							
F4	.390	.371	.580	1.00						
F5	.326	.310	.486	.434	1.00					
F6	.407	.387	.605	.541	.452	1.00				
F7	.452	.429	**.672**	.600	.502	.626	1.00			
F8	.404	.384	.601	.537	.449	.560	.622	1.00		
F9	.432	.410	.642	.574	.480	.599	.665	.595	1.00	
F10	.308	.293	.458	.409	.343	.427	.474	.424	.453	1.00

The highest correlation between Customer Focus (F3) and Open Organisation (F7) as (F = 0.672) and each of the other constructs suggests that when employees have an open culture, more empowered, they'll interact more with meeting the customer's requirements. According to Cortina (2002), these structural coefficients in SEM are meant to represent the relationship among constructs.

REGRESSION APPROACH

Regression: For this study, the F-to-enter and F-to-remove values used were 0.05 and 0.01 respectively. Using a similar approach as adopted by Kontoghiorghes and Gudgel (2004), the generated regression models as shown in Table 2.0 were cross-validated by also calculating the Herzberg's adjusted R^2 value and comparing it to R^2 in order to determine shrinkage and the predictive power of the regression model. The adjusted R^2 value provides an indication of how well the model generalises. Ideally this value should be the same or very close to the value of the squared multiple correlation R^2 (Field, 2000). For model 10 in Table 2.0, the difference between the values is 0.760-0.486 = 0.274 (27.4%). This shrinkage means that if the ten-factor model were derived from a sample, it would account for approximately 27.4% less variance in the outcome.

Convergent validity: Convergent validity refers to the degree to which the different approaches to construct measurement are similar to (converges on) other approaches that it theoretically should be similar to. Three techniques are utilised for assessing Convergent Validity are 1.) Statistical significance of the loadings at a given alpha (i.e. p=0.05), 2. Average Variance Extracted (AVE) and 3. Reliability (standardised loadings)

1. Statistical Significance: The convergent validity analysis was performed in ten stages using the stepwise regression method. In the first model only variables belonging to the Executive Commitment constructs were included. This was termed as Model 1. Test statistics showed that this model was inconsistent with sample data. The root mean square residual (RMSR) was very high (RSMR = 0.190). The residual sum of squares represents the total difference between the model and the observed data. (Field, 2000). All the models apart from No. 6 are insignificant ($p > 0.001$) and the F-ratio are not high values. The interpretation of this data is that it is difficult to predict whether an organisation is implementing TQM or not. Furthermore from Table 2.0, it is evident that when only Executive Commitment is used as a predictor, this becomes a simple correlation between Executive Commitment and implementing TQM (0.422)

2. Average Variance Extracted: Discriminant validity is demonstrated if the average variance for each construct (within-construct variance) is greater than the squared correlations between constructs (between-construct variance). Discriminant validity among the ten elements of TQM was examined using Fornell and Larcker's (1981) techniques. A ten factor correlated model representing each of the ten elements was used to examine discriminant validity, and is schematically shown in Fig 2.0. Convergent validity was supported as the entire factor loading (q_{11} through q_{101}) for each individual indicator (Table 2.0a) to its respective construct was positive (greater than 0.50) indicating that all the 10 constructs were significant determinants of the TQM

DISCUSSION OF THE REGRESSION APPROACH

Table 2.0 presents the results of the ten stepwise regression models. Interestingly enough, the strongest was the 10 Construct Model Summary of Regression Analysis, which included all the factors as shown in Figures 1.0 and 2.0. This reports the strength of the relationship between the model and the dependent variables. The multiple (R) correlation coefficients, is the linear correlation between the observed and Model-predicted values of the dependent model. Its large value indicates a strong relationship. The interpretation of the Model 5 in Table 2.0 is that if the sample were drawn from the population, then the expected variance would be R_2 less the adjusted R_2 value, which would be 0.694-0.481=0.213. This means that the variance from the sample would be 21.3 per cent. As the R_2 states how much of the variance in Y is accounted for by the regression model from the sample, it can be concluded that the ten-construct model as hypothesised is the better option, as it can explain above the recommended variance (> .70). The second model indicated in Table 2.0 includes the three variables each for the executive commitment and adopting the quality philosophy constructs. The value of the squared multiple correlation is ($R_2 = .260$) which means that executive commitment and adopting the quality philosophy constructs accounts for 26.0 per cent of the variation in implementing TQM. As the two (six) predictors are included in this model, the value increases from 0.178 or 17.8 per cent to 0.26 or 26.0 per cent, thus the inclusion of more predictors explains quite a large amount of variation. Furthermore the data collected found a strong association between the implementation of TQM and the independent variables. Table 2.0 shows that the explained variation (R_2) improves from 17.8 percent for the executive commitment construct as the only one in the model to 76.0 per cent for a 10-construct model incorporating all the factors. The above results confirms that there is a positive relation between the implementation of TQM and adoption of the ten deployment constructs as suggested by the R square value of 0.760 and adjusted value of 0.468.

SUMMARY OF DISCUSSION - SEM versus Regression Analysis

Table 3.0 also indicates that there are moderately large correlations among the five core dimensions of benchmarking, zero defects, measurement, customer focus and supplier focus. Table 3.0 provides a direct picture of the relationship between the various TQM practices. This helps give a better understanding about the positive fit among the practices. As supported by Woon (2000), where the correlation among the TQM constructs provides an indication of the extent to which they reinforce one another in the TQM effort.

Based on Structural Equation Modelling using the AMOS Software, the structural analysis produced "factor loadings" that represented the strength of causal connection between the models independent and dependent variables (constructs). The factor loadings could be used to determine the unit contributions of each construct towards business and organisation performance. In additional to testing the validity and reliability of the TQ-SMART through Confirmatory Factor Analysis (CFA), the structural equation modelling (SEM) was utilised to verify the construct validity of scales and to test relationships among variables and unobservable variables. SEM was used to determine the relative influence of each of the ten deployments constructs on the quality manager's

CONCLUSIONS

This study has moved from anecdotes, consultant based awards to a testable model and specific research hypotheses, linking the theoretical concepts of TQM to empirical indicants. The structural model in Figures 2.0 and 3.0 can be effectively used by decision makers to measure the levels of TQM implementation by UK Construction related SMEs. This is possible, as the critical weight factors or factor loadings established, highlights the importance of each of the constructs and their associated activities. Therefore, the conceptual framework conveys a message of how limited Quality Management resources should be allocated (Flynn and Saladin, 2001). Additionally, according to Tan and Wisner (2004), knowledge of the interactions among the ten deployment constructs, can be a valuable diagnostic tool in addressing the effectiveness of each initiative alone to further enhance competitive success.

One of the rationale of SEM usage is that, since science typically views theory validation as coming from predictive verification (Deductive Approach), of expected theoretically results based on empirical evidence, the SEM casual models used throughout the study provided an explanatory description of casual relationships among the TQM, Business and Organisation Performance constructs, plus a manipulation capabilities for diagnosing the key changes necessary for system improvements, and for predicting the impacts of potential change actions (Anderson and Vastag, 2003).

One of the purposes of this study was to contribute to the Quality Management, theory building efforts in services, particularly construction. This was achieved in the following ways: This study contributes to the existing body of knowledge on TQM by answering some of the questions left unanswered both on the conceptual and empirical lines by various researchers. Filippini (1997) identifies these as the components of total quality and their measurements, (SEM) and the relations between these. This paper demonstrates the causal relationships between the ten TQM deployment constructs through the factor loadings. The conclusion drawn from the regression analysis is that TQM is best implemented on a holistic approach rather than a piece meal approach.

Another important conclusion that stems from the results of this study is one area found wanting in TQM research, that is the difficulty at arriving at a theory which highlights the various concepts of TQM by measuring them and then correlating theses concepts to quality performance. This can be achieved through the application of Advanced Structural Equation Modelling techniques as advocated by Williams et al (2003). This research further contributes to TQM knowledge by maintaining the convergent and discriminant validity of Quality Management. This extends the work of Hackman and Wageman (1995) that raised the following question; "Is there such a thing as TQM"?. In assessing the distinctiveness of TQM, the two comparison groups were considered, TQM and non-TQM deploying UK Constructional related SMEs, however, as foreseen by Hackman and Wageman (1995), despite passing the discriminant validity test, TQM is close to failing the test when one considers emerging initiatives as identified in this study, by organisations which claim not to be TQM yet, address some principles of TQM. On the other hand, it would be difficult to demonstrate the aforementioned through usage of tradition methods such a regression analysis.

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