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TQ-SMART: Total Quality- Self Monitoring & Assessment Rating Tool

Nicholas Chileshe
Senior Lecturer, School of Environment and Development
Sheffield Hallam University, Sheffield, UK

Henry .O. Nyongesa
Reader in Intelligent Systems, School of Computing & Management Sciences
Sheffield Hallam University, Sheffield, UK

Paul . A. Watson
Principal Lecturer, School of Environment and Development
Sheffield Hallam University, Sheffield, UK

Abstract
This paper presents the development of TQ-SMART, a model designed for assessment and monitoring levels of advancement in Total Quality Management (TQM), in Construction-related small and medium-sized organisations. Many small and medium sized organisations opt not to adopt TQM principles, while inherently exhibiting some of the quality initiatives. This study was designed to assess the levels of advancement of implementation constructs in both TQM and non-TQM organisations. The result of the study show that while TQM deploying organisations were more advanced in the observation of the deployment constructs, non-TQM organisations exhibited marked levels of achievement of implementation constructs. Though various assessment models exists, and literature has examined issues such as organisations needing to identify the unused capabilities, there is lack of formal methods of working out the unused capabilities or conducting empirical studies.

Keywords
TQM, Decision Making, Relative Advancement Index, Fuzzy Logic, Assessment

1. Introduction

Usage of the assessment methods based on awards such as the EFQM Model, Malcolm Baldridge National Quality Award (MBNQA) Model are widely reported by various researchers (Pannirselvan *et al* , 1998; Li & Yang, 2003; Watson & Chileshe, 2003a, and Watson & Chileshe, 2003b). However the application has mainly been to large organisations. For example Samuelson & Nilsson (2002) reported on self-assessment practices in large organisations. Where SMEs have tried to use the assessment models, others have questioned the concept of entering such an award. This omission of SMEs in the assessment mechanism was thought to lead to an ineffective analysis of the application problem. This research redresses the imbalance by presenting model designed to be used both as an assessment and monitoring tool for constructional related small and medium sized organisations. It can be used by organisations currently implementing Total Quality Management (TQM) to monitor their levels of advancement in terms of observing and measuring the implementation constructs. It's equally applicable to non-TQM organisations in assessing the inherent level or status of TQM quality initiatives. According to research by (Mohd, 2000), numerous implementation frameworks found were not suitable and were not systematically

developed for SMEs. The frameworks could be classified into three types; Consultant based, Academic based and Award based, which are mostly descriptive and prescriptive models. Where the models are tailored for SMEs, none focus on how to work out the used capabilities. The TQ:SMART model on the other hand, is more robust and easy to apply, and appeals to both TQM and Non-TQM organisations.

2. Definition of Self-Assessment

The generic definition of self-assessment is a comprehensive, systematic and regular review of an organisation's activities and results referenced against the EFQM excellence model. The self-assessment process allows the organisation to discern clearly its strengths and areas in which improvement can be made and culminates in planned improvement weakness

2.1 Definition of TQ:SMART

- Total Quality (TQ): The completeness in the observation and deployment of the ten implementation constructs
- Self (S) : The organisation carries out the procedure, which can then be compared against the validated model such as the EFQM
- Monitoring (M) : Existing levels of quality initiatives in TQM deploying organisations
- Assessment (A) : Evaluation of the TQM advancement, determination of existing quality initiative levels in meeting the requirement
- Rating (R) : Classification of Organisations into different levels of commitment according to the Y value based on the fuzzy scoring system
- Tool (T) : Mechanism or Instrument for carrying out the assessment and monitoring activities. The tool has been evaluated in the validation process within 10 organisations

3. Observations and Analysis

Qualitative data was collected based on the following ten implementation constructs, namely, Training (TR), Employee Empowerment (EE), Executive Commitment (EC), Quality Philosophy (QP), Customer Focus (CF), Supplier Focus (SF), Measurement (ME), Benchmarking (BM), Open Organisation (OO) and Zero Defects (ZD). A survey methodology was employed of 350 questionnaires with a response rate of 22.22%. The analyses are based on the remaining 63 organisations of which 20 were TQM deploying and 43 Non-TQM deploying organisations. Respondents assigned values in a range of [1 ... 5], where 1 implies 'have not begun implementation' and 5 implies 'highly advanced in implementation'. The *relative advancement index* (RAI) derived to summarize the advancement of each implementation construct was computed as

$$\text{RAI} = \frac{Xi}{A} \quad \text{.....} \quad \text{(Equation 1.0)}$$

Where: Xi = mean assigned to the construct and A = the highest weight (5). Subsequent advancement indices were then used to rank the perceived advancement / importance of all variables. Secondly the *weighted average (WA)* was calculated / derived from multiplying the relative advancement index by the individual response from the organisation and dividing by the average response.

4. Application of Fuzzy Reasoning to Assessment Rating

The fundamental idea behind fuzzy logic is based on the observation that human thinking is not just two-valued or multi-valued logic, but logic with continuous degree of truth. Fuzzy logic uses degrees of membership in sets rather than a strict (yes/no) membership. The degree of membership is the possibility (expressed as a number between 0 and 1) of a particular value belonging to a fuzzy set (Zadeh, 1974).

Accordingly, complex-computing tasks can be made simpler if the questions have imprecise or fuzzy answers rather than precise or crisp ones. It provides a remarkably simple way to draw definite conclusions from vague, ambiguous or imprecise information.

The assessment problem is addressed as a fuzzy constraint satisfaction problem. Constraints are mathematical tools used to model decision-making problems. Classical constraint satisfaction is comprised of boolean (yes/no) or hard constraints. Fuzzy constraint satisfaction relaxes the constraints to allow intermediate degrees of satisfaction. For example, on survey questionnaires it is commonly expected to offer qualitative answers, such as, “definitely disagree” or “moderately agree”. On a numeric scale of 1 to 5, a “moderately agree” answer would correspond to the fuzzy number, "about 3". This is illustrated in the Figure 1, below.

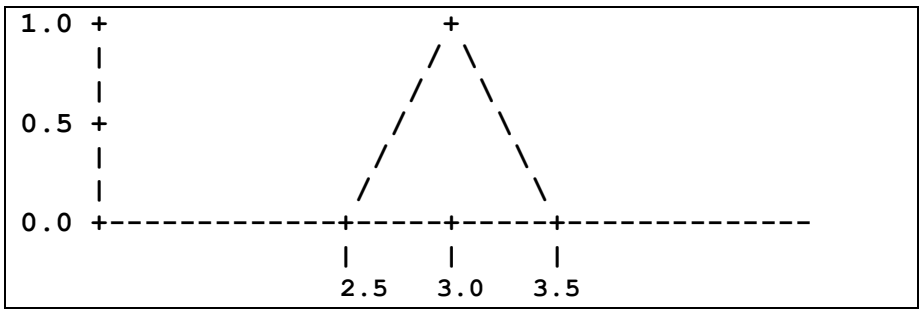

Figure 1: Fuzzy Set for “about 3” or “moderately agree”.

The next step in solving a constraint satisfaction problem is to apply an instantiation of all input variables, and determine the degree to which all constraints will be satisfied. Several techniques have been proposed for this step, which are essentially variations of conjunctions and disjunctions from classical logic. The minimum operator is a common t-norm operator for solving conjunction of several constraints:

$$C_{t-norm} \underset{=}{def} \min(a_1, a_2, \cdots a_n) \quad \text{..... (Equation 2.0)}$$

The degree of advancement of each variable will be used in fuzzy integration to evaluate any alternative.

4.1 Conversion of Ratings to Fuzzy Scores

This utilises the fact that the ideal value (maximum or minimum) is outside the range of scores. Each attribute value is made relative to an ideal maximum attribute value as follows:

$$\frac{X - X_{min}}{X_{max} - X_{min}} \quad \text{.....(Equation 3.0)}$$

Where X is an attribute value, X_{min} is the minimum attribute value and X_{max} is the maximum attribute value.

When the above occurs then all attribute values are related to the maximum. This will result in the scores (which are fuzzy) being transformed to sets of fuzzy set scores in the range 0 to 1 This is the Fuzzy Set Method usually employed. For example, for the variable Executive Commitment with a mean value of 4.10, the possible maximum score is 5.0 and minimum is 1.0, therefore the fuzzy score is computed as follows

$$\frac{4.10 - 1.0}{5.0 - 1.0} = 0.775$$

The same method is applied for the remaining constructs and the values (see table 1, columns 4 & 7) are plotted to produce either the TQM Advancement Chart (Figure 2 & 3).

Table 1: Mean, Rank Values & Fuzzy Scoring for TQM and non-TQM organisations

Implementation Construct	TQM Organisations (N =20)			Non TQM (N = 43)		
	Mean[a]	RAI[b]	Fuzzy [c] Score (0-1)	Mean	RAI	Fuzzy Score
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1. Executive Commitment	4.10	0.820	0.775	2.92	0.584	0.480
2. Adopting the philosophy	3.27	0.654	0.568	2.50	0.500	0.375
3. Customer Focus	3.80	0.760	0.700	3.06	0.612	0.515
4. Supplier Focus	3.07	0.614	0.518	2.50	0.500	0.375
5. Benchmarking	2.60	0.520	0.400	2.12	0.424	0.280
6. Training	2.65	0.530	0.413	2.55	0.510	0.387
7. Open Organisation	3.17	0.634	0.543	2.93	0.586	0.483
8. Employee Empowerment	3.05	0.610	0.513	2.23	0.446	0.308
9. Zero Defects	3.43	0.686	0.608	2.92	0.584	0.480
10. Measurement	3.05	0.610	0.512	2.11	0.422	0.278

[a] Mean Score obtained from descriptive analysis using SPSS
[b]Relative Advancement Index computed from equation 1.0
[c]Fuzzy score derived from equation 3.0

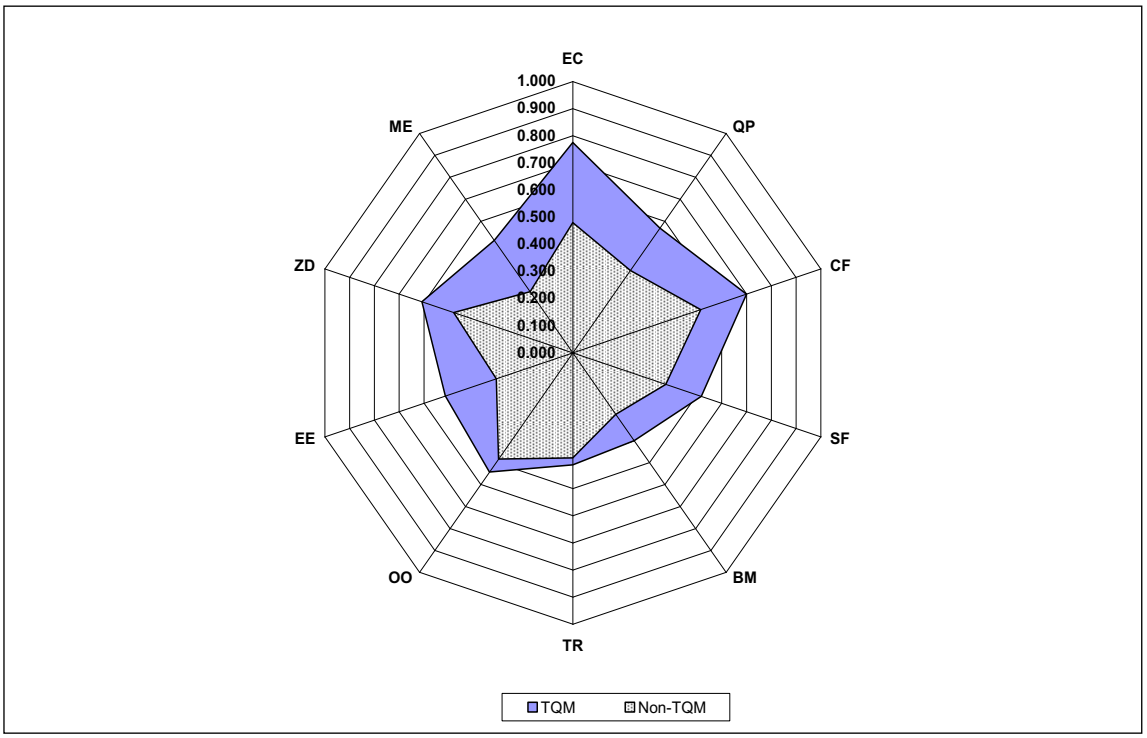

Fig 2: TQM Advancement Chart based on Fuzzy Scoring

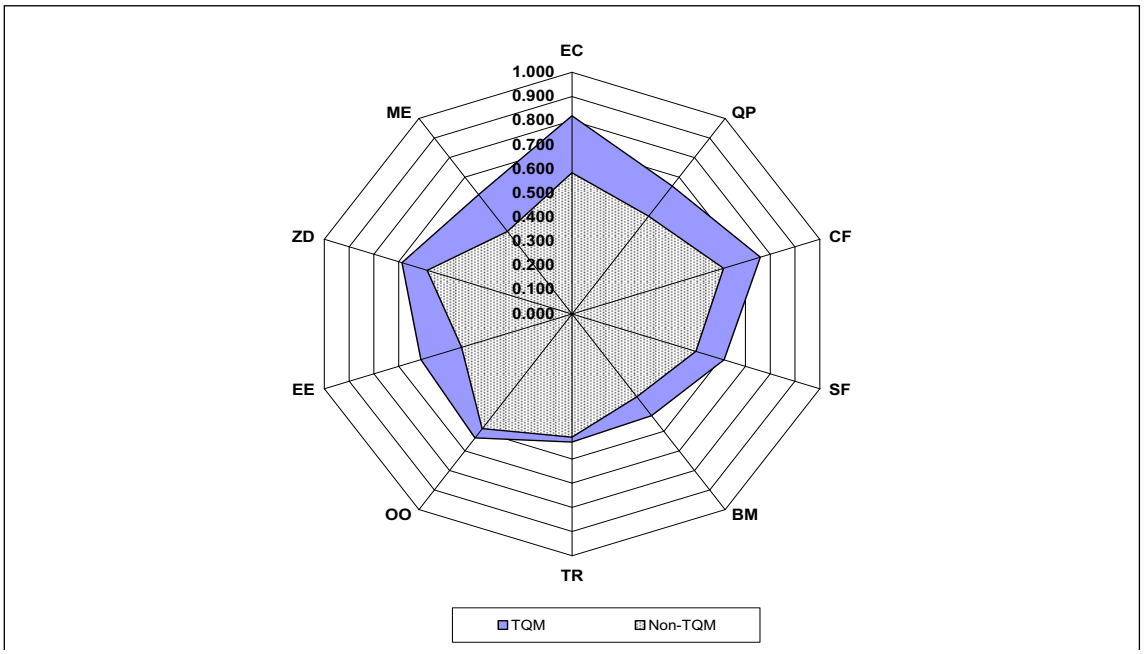

Fig 3: TQM Advancement Chart based on Relative Advancement Indices (RAI)

Figures 2 & 3 shows a visualisation of the comparison in the achievement of implementation constructs by TQM and non-TQM organisations surveyed in this study. It is evident that there was a marked difference in the self-assessment of achievement of implementation constructs by the two groups of organisations. However, the study there was a significant level of achievement of TQM implementation constructs by non-TQM organisations. More so, there was little difference in the achievement levels of Open Organisation (OO) and Training (TR) constructs. A comparison of the ratings using the fuzzy scores, on the other hand, shows a significant reduction in the levels of achievement. It is also shown that there was a more even difference across all implementation constructs, which would suggest a more cautious and realistic measurement of achievements.

5. Discussion

Although the sample of this study (63) was limited, the findings represent a snapshot of the reality of TQM achievement by declared TQM and non-TQM organisations. However, the use of quantitative approaches normally requires a large number of cases representing the population of interest, in order to determine the statistical significance of results. Thus, while the result cannot be generalised at this stage further research should confirm the findings of this study.

6. Conclusions

An application of fuzzy reasoning to rating of the deployment of TQM within small and medium sized organisations has been presented in this paper. Qualitative measures are growing and becoming increasingly important to quality processes. TQM relies on such measures as customer satisfaction, employee commitment, team performance, supplier co-operation, and organisation's reputation, (Shepherd & Helms, 1995). Valid measurement is the sine qua non of science. Without sound measurement techniques there is no science and possibly no concrete evidence of TQM success, therefore the application of fuzzy logic to the comparison of organisation's TQM deployment advancement will rectify the anomaly. The other significant contribution is in identifying the unused capabilities enabling the deployment constructs to be levelled. The study also demonstrates that Organisations claiming to be TQM could be no different from those stating not to. The proposed classification based on the advancement indices is of practical importance as it provides a more robust and clear picture of the state of the

organisation in terms of implementing the TQM constructs. As evident from the various definitions propagated by the Quality Managers, there is no formal definition of what constitutes TQM, therefore one organisation could concentrate of the customer focus construct and pay less attention to benchmarking. Constructional practitioners will be able to use this model to evaluate their TQM implementation so as to target improvement areas. The application of the relative advancement index will prove particularly useful as benchmarks for comparison with other TQM deploying organisations. The Commitment and Advancement indices generated by the TQ: SMART Model serves as an assessment and monitoring mechanism for TQM deployment organisations at the same time as an assessment mechanism for non-TQM deploying organisations wishing to identify their existing levels of quality initiatives. Quality Manager's can use this model well as Senior Management to assess their strengths and weaknesses on the deployment constructs necessary for the effective implementation of TQM

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