Application of Analytic Hierarchy Process in Prioritization of Critical Success Factors of TQM

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Abstract

The study describes the use of Analytic Hierarchy Process (AHP) for the prioritization of critical success factors of TQM (CSFs of TQM). The use of multi attribute decision analysis for supporting the qualitative data analysis (analytic hierarchy process) has been considered the foremost technique for examining the manager's needs and the weightings of preferences from the panel of three levels of managers (top, middle, low) for each CSFs of TQM in the most objective way available. Two rounds of Delphi surveys were conducted. A significant consensus on the weighted evaluation of the six CSFs of TQM and the consistency ratio were obtained from twenty oil and gas managers. The results vividly reveal that AHP is a powerful and appropriate technique for deriving objective opinions in a rather subjective area such as the multi-attribute model for the prioritization of the CSFs of TQM.

The results of qualitative data analysis (using MFEP) indicate that training to improve products/services provides the first priority (the weighted evaluation 0.184; 0.224; and 0.169 for top level managers, middle kevel managers, and low level managers); followed by Quality Improvement, Top Management Commitment, Supplier Involvement, Cross-Functional Relationships among SBUs, and Supervisory Leadership.

In addition, the qualitative data analysis (using AHP) also provides a set of sufficiently consistent CSFs of TQM was obtain after the second round of Delphi questionnaire. The result of consistency ratio (CR) shows that the managers had highly satisfactory in assessing the prioritization of CSFs of TQM (CR = 0.0456). Therefore, these CSFs of TQM were supported the results from the quantitative data analysis.

Oil and gas managers in Indonesia can use these qualitative data results in concert with other critical quality management practices to help them in there word-class company initiatives. The researcher recommended the use of Delphi method as an objective and rigorous determining consensus. Researchers can also use this method to combine qualitative and quantitative research approaches into mixed methodology or triangulation.

Keywords*: Delphi Method, Qualitative Data Analysis, Critical Success Factors of TQM, Multifactor Evaluation Process, Analytic Hierarchy Process, and NVivo.*

Qualitative Data Analysis Using Delphi Method and Analytic Hierarchy Process (AHP)

Decision making under certainty using AHP is designed for situations in which ideas, feelings, and emotions are quantified based on subjective judgment (the managers' perspectives) to provide a numeric scale or prioritizing decision alternative [Saaty, 1991]. The following four steps illustrate the AHP methodology [Saaty, 1991].

Step 1: The Structure of the Decision Problem of the Study

The structure of the decision problem of the study summarizes in Figure 1. The relevant criteria and alternatives are structured in the form of a hierarchy, where the higher the level, the more strategic decision. The conceptualization of the six CSFs of TQM can be used by the managers at the SBU level as a communication tool to better understand and promote consensus regarding the appropriate role of critical success factors of TQM in their companies.

Step 2: Pairwise Comparisons Matrices of Interdependent CSFs of TQM and Building Consensus Using the Policy Delphi Method

a. Pairwise Comparisons Matrices of Interdependent CSFs of TQM

A nine-point ratio measurement scale developed by Saaty [1991] is used to make the comparisons (see Table 1).

Table 1. Preference Scale for Pairwise Comparisons

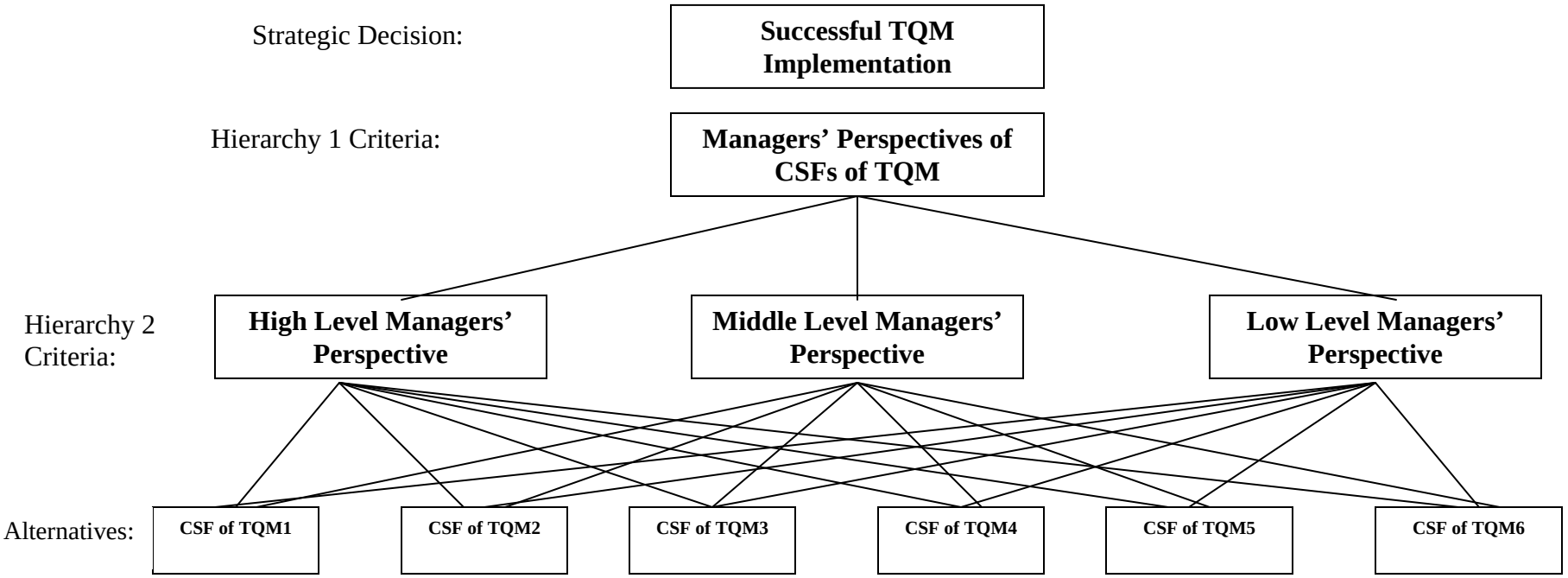
Numerical Value	Definition	Explanation
1	Equally Preferred (Equally Important)	Two factors contribute equally to the objective
3	Moderately Preferred (Moderately more Important)	Experience and judgment slightly favor one factor over the other
5	Strongly Preferred (Strongly more Important)	Experience and judgment strongly favor one factor over another
7	Very Strongly Preferred (Very Strongly more Important)	A factor is strongly favored and its dominance is demonstrated in practice
9	Extremely Preferred (Extremely more Important)	Reserved for situations where the difference between the items being compared is so great that they are in the verge of not being directly comparable
2,4,6,8	Intermediate Values	To reflect compromise between two adjacent judgments

Source: Taylor III, 2002; Grembergen, 2001; Render & Stair, 2000; and Saaty & Vargas, 1991.

b. Building Consensus Using the Policy Delphi Method

In order to obtain the most valuable opinions, only managers who met all the sampling criteria were selected. The twenty managers of the panels represent a wide distribution of professional people, with five from high level managers, seven from middle level managers, and eight from low level managers. The composition of this group of managers provides a balanced view for the Delphi survey. A list of the panel members and their position in the corresponding oil and gas companies is given in Table 2, although the names of the managers and their companies are faked to respects their anonymity.

Figure 1 the Structure of the Decision Problem Using AHP



Source: Taha, 2003 with modifications

Table 2 List of the Panel of Managers for the Delphi Method

Name	Position	Types of Companies	Companies Currently Work for
I. High Level Managers			
1. Mr A	Vice President	PSC	AA Company
2. Dr. B	Vice Chairman	State Owned Company	BB Executive Agency
3. Dr. C	Chairman	State Owned Company	CC Regulatory Body
4. Mr. D	Manager	State Owned Company	DD Quality Department
5. Mr. E	Manager	PSC	EE Operations Department
II. Middle Level Managers			
6. Mr. F	Assistant to Senior Vice President	PSC	AA Company
7. Mr. G	Team Manager	State Owned Company	DD Company
8. Dr. H	Portfolio Investment Manager	State Owned Company	BB Company
9. Mr. I	Senior Manager	PSC	FF Company
10. Mr. J	Team Manager	State Owned Company	HH Company
11. Mr. K	Team Manager	State Owned Company	DD Company (Quality Department)
12. Mrs. L	Manager	PSC	GG Company (Human Resource)
III. Low Level Managers			
13. Mr. M	Quality Expert	PSC	EE Company
14. Mr. N	Senior Planning, Analysis, & Assessment	PSC	GG Company
15. Mr. O	Head of Supervisor	PSC	FF Company
16. Mr. P	Team Leader	State Owned Company	DD Company
17. Mrs. Q	Team Leader	PSC	AA Company
18. Mrs. R	Engineer	State Owned Company	CC Regulatory Body
19. Mr. S	Engineer	State Owned Company	BB Executive Agency
20. Mrs. T	Team Leader	State Owned Company	HH Company

c. Format of Delphi Rounds

From the Delphi round one questionnaire it has found that the rank of prioritization of CSFs of TQM obtained were sufficiently consistent with the result of MFEP analysis. The ranks were recorded into six as indicated in Table 3.

Table 2. The Criterion Influence the Choice of CSFs of TQM: Frequency Distribution and Percentage

CSFs of TQM	% of managers who stated the criterion as either very important or important	To what extent do you think the criterion influence the choice of successful TQM implementation			Total Value; (%)	Rank
		Very Important (Scale = 5)	Important (Scale = 3)	Not Important (Scale = 1)		
1. CSF of TQM1: Quality Improvement	100%	14	6	0	88 (19.4%)	2
2. CSF of TQM2: Supervisory Leadership	80%	2	14	4	56 (12.3%)	6
3. CSF of TQM3: Supplier Involvement	85%	8	9	3	70 (15.4%)	4
4. CSF of TQM4: Top Management Commitment	100%	12	8	0	84 (18.5%)	3
5. CSF of TQM5: Training to Improve Products/Services	100%	18	2	0	96 (21,1%)	1
6. CSF of TQM6: Cross Functional Team Relationships among SBUs	80%	4	12	4	60 (13.2%)	5
				TOTAL VALUE	**454 (100%)**	

In the second round of the Delphi questionnaire, managers were asked to provide their opinion that they considered to influence the pairwise comparisons of CSFs of TQM. The priority questions allow the managers to prioritize the CSFs of TQM according to pairwise comparisons among the CSFs of TQM. In the questionnaire, list of CSFs of TQM that had been found from the first round of Delphi results were included for their reference. These were: Quality Improvement, Supervisory Leadership, Supplier Involvement, Top Management Commitment, Training to Improve Products/Services, and Cross Functional Team Relationships among SBUs.

Table 4 shows that CSF of TQM 1 is strongly to very strongly preferred (6) for CSF of TQM 3, but CSF of TQM 3 is moderately preferred (3) over CSF of TQM 6. Notice that any CSF of TQM compared against itself, such as CSF of TQM 1 compared to CSF of TQM 1, must be “equally preferred” with a preference value of 1. Thus, the values along the diagonal of the matrix must be 1s. The remaining pairwise comparisons matrices for the other six CSFs of TQM have been developed by this study as follows:

Table 4 Pairwise Comparisons Matrix to Perform for CSFs of TQM

No	CSFs or TQM	CFS of TQM1	CFS of TQM2	CFS of TQM3	CFS of TQM4	CFS of TQM5	CFS of TQM6
1	CFS of TQM1	1.000	7.000	2.000	1.000	1.000	6.000
2	CFS of TQM2	0.143	1.000	0.333	1.000	0.200	1.000
3	CFS of TQM3	0.500	3.000	1.000	1.000	0.500	2.000
4	CFS of TQM4	1.000	1.000	1.000	1.000	0.333	2.000
5	CFS of TQM5	1.000	5.000	2.000	3.000	1.000	6.000
6	CFS of TQM6	0.167	1.000	0.500	0.500	0.167	1.000
	Total	**3.810**	**18.000**	**6.833**	**7.500**	**3.200**	**18.000**

Step 3: Evaluations for CSFs of TQM

After the researcher has completed the matrix of pairwise comparisons, the researcher can start to compute the evaluation for CSFs of TQM. The researcher starts by converting the numbers in the matrix of pairwise comparisons to decimals to make them easier to work with [Render & Stair, 2000]. The researcher then gets the column totals which shown in Table 5. Once the column totals have been determined, the numbers in the matrix are divided by their respective column totals as follows (see Table 14):

Table 5. Evaluations for CSFs of TQM (Column Total and Row Averages Values) Using AHP

No	CSFs or TQM	CFS of TQM1	CFS of TQM2	CFS of TQM3	CFS of TQM4	CFS of TQM5	CFS of TQM6	Raw Averages
1	CFS of TQM1	0.262	0.389	0.293	0.133	0.313	0.333	0.287
2	CFS of TQM2	0.038	0.056	0.049	0.133	0.063	0.056	0.066
3	CFS of TQM3	0.131	0.167	0.146	0.133	0.156	0.111	0.141
4	CFS of TQM4	0.262	0.056	0.146	0.133	0.104	0.111	0.135
5	CFS of TQM5	0.262	0.278	0.293	0.400	0.313	0.333	0.313
6	CFS of TQM6	0.044	0.056	0.073	0.067	0.052	0.056	0.058

To determine the priorities for CSFs of TQM, the researcher simply finds the average of the various rows from the matrix of numbers. The results are displayed in Table 6. As we can see, the factor evaluation for CSF of TQM 5 is 0.313. For CSF of TQM 1, CSF of TQM 4, CSF of TQM 2, CSF of TQM 3, and CSF of TQM 6, the factor evaluations are 0.287; 0.135; 0.066; 0.141; and 0.058.

To arrive at the consistency ratio, the researcher begins by determining the weighted sum vector. This is done by multiplying the factor evaluation number for each of CSF of TQM times the first row of the original pairwise comparisons matrix. The researcher multiplied the second factor evaluation times the second row, the third factor evaluation times the third row, the fourth factor evaluation times the fourth row, the fifth factor evaluation times the fifth row, and the sixth factor evaluation times the sixth row of

the original matrix of pairwise comparisons. Then the researcher sums these values over the rows.

Table 6. Consistency Ratio of AHP

	Row Averages Value (1)		**Pairwise Comparison Value row 1 (2)**	**The Result (1) x (2)**
1	0.287	x	1.000	0.2872
2	0.066	x	7.000	0.4588
3	0.141	x	2.000	0.2817
4	0.135	x	1.000	0.1355
5	0.313	x	1.000	0.3131
6	0.058	x	6.000	0.3468
	Weighted Sum Vector 1			**1.8231**
No	**Row Averages Value (1)**		**Pairwise Comparison Value row 2 (2)**	**The Result (1) x (2)**
1	0.287	x	0.143	0.0411
2	0.066	x	1.000	0.0655
3	0.141	x	0.333	0.0469
4	0.135	x	1.000	0.1355
5	0.313	x	0.200	0.0626
6	0.058	x	1.000	0.0578
	Weighted Sum Vector 2			**0.4094**
No	**Row Averages Value (1)**		**Pairwise Comparison Value row 3 (2)**	**The Result (1) x (2)**
1	0.287	x	0.500	0.1436
2	0.066	x	3.000	0.1966
3	0.141	x	1.000	0.1408
4	0.135	x	1.000	0.1355
5	0.313	x	0.500	0.1566
6	0.058	x	2.000	0.1156
	Weighted Sum Vector 3			**0.8887**
No	**Row Averages Value (1)**		**Pairwise Comparison Value row 4 (2)**	**The Result (1) x (2)**
1	0.287	x	1.000	0.2872
2	0.066	x	1.000	0.0655
3	0.141	x	1.000	0.1408
4	0.135	x	1.000	0.1355
5	0.313	x	0.333	0.1043
6	0.058	x	2.000	0.1156
	Weighted Sum Vector 4			**0.8489**
No	**Row Averages Value (1)**		**Pairwise Comparison Value row 5 (2)**	**The Result (1) x (2)**
1	0.287	x	1.000	0.2872
2	0.066	x	5.000	0.3277
3	0.141	x	2.000	0.2817
4	0.135	x	3.000	0.4065
5	0.313	x	1.000	0.3131
6	0.058	x	6.000	0.3468
	Weighted Sum Vector 5			**1.9630**

(Continued)

Table 6 Continued

No	Row Averages Value (1)		Pairwise Comparison Value row 6 (2)	The Result (1) x (2)
1	0.287	x	0.167	0.0479
2	0.066	x	1.000	0.0655
3	0.141	x	0.500	0.0704
4	0.135	x	0.500	0.0677
5	0.313	x	0.167	0.0522
6	0.058	x	1.000	0.0578
	Weighted Sum Vector 6			**0.3616**

Step 4: Consistency Vector

The next step is to determine the consistency vector. This is done by dividing the weighted sum vector by the factor evaluation values determined previously (see Table 7).

Table 7 Consistency Vector of AHP

Weighted Sum Vector		Divided by	Raw Average		Consistency Vector
1	1.8231	:	0.287	=	6.3474
2	0.4094	:	0.066	=	6.2471
3	0.8887	:	0.141	=	6.3105
4	0.8489	:	0.135	=	6.2659
5	1.9630	:	0.313	=	6.2687
6	0.3616	:	0.058	=	6.2554
				λ	**6.2825**

After the researcher found the consistency vector, the researcher need to compute for two more terms, lambda (**λ)** and the consistency index (CI), before the final consistency ratio can be computed. The value for lambda is simply the average value of the consistency vector (see Table 7, lambda = 6.2825). The formula for CI is:

CI = (λ - n)/ (n-1), where n is the number of items (CSFs of TQM) being compared. The results of the calculations are as follows: CI = (6.2825– 6)/(6-1) = 0.0565. If CI = 0, it means the three level managers would be perfectly consistent interviewee. Because the three level managers are not perfectly consistent, the next question is the degree of inconsistency that is acceptable. An acceptable level of consistency is determined by comparing the CI to a random index, RI, which is the consistency index of a randomly generated peirwise comparisons matrix. The RI has the values shown in Table 8 depending on the number of items (CSFs of TQM), n, being compared. In this study, n = 6 because the researcher is comparing six CSFs of TQM.

Table 8 RI Values for n Items Being Compared

n	RI
1	0
2	0
3	0.58
4	0.90
5	1.12
6	**1.24**
7	1.32
8	1.41
9	1.45
10	1.51

Source: Taylor III, 2002; Render & Stair, 2000; and Saaty & Vargas, 1991

The degree of consistency for the pairwise comparisons in the decision criteria matrix is determined by computing the ratio of CI to RI (the consistency ratio or CR). CR = CI/RI = 0.0565/1.24 = 0.0456. In general, the degree of consistency is satisfactory if CI/RI < 0.10, which in this study it is. If CI/RI > 0.10, then there are probably serious in consistencies and the AHP results may not be meaningful. The consistency ratio (CR) tells us how consistent the three level managers are with their answers. Because the consistency ratio is 0.0456 (< 0.10), the three level managers' answers about the prioritization of CSFs of TQM are relatively consistent. Table 9 summarizes the prioritization of CSFs of TQM from the three level managers using MFEP and AHP analyses.

Table 9 the Prioritization or Rank of CSFs of TQM Based on the Three Level Managers' Perspective Using MFEP and AHP Analyses (A Qualitative Approach)

Rank	High Level Managers	Middle Level Managers	Low Level Managers
1	CSF of TQM 5 (Training to Improve Products/Services	CSF of TQM 5 (Training to Improve Products/Services	CSF of TQM 5 (Training to Improve Products/Services
2	CSF of TQM 1 (Quality Improvement)	CSF of TQM 1 (Quality Improvement)	CSF of TQM 1 (Quality Improvement)
3	CSF of TQM 3 (Supplier Involvement)	CSF of TQM 4 (Top Management Commitment)	CSF of TQM 4 (Top Management Commitment)
4	CSF of TQM 4 (Top Management Commitment)	CSF of TQM 3 (Supplier Involvement)	CSF of TQM 3 (Supplier Involvement)
5	CSF of TQM 6 (Cross-Functional Relationships among SBUs)	CSF of TQM 6 (Cross-Functional Relationships among SBUs)	CSF of TQM 6 (Cross-Functional Relationships among SBUs)
6	CSF of TQM 2 (Supervisory Leadership)	CSF of TQM 2 (Supervisory Leadership)	CSF of TQM 2 (Supervisory Leadership)

DISCUSSION

The results of qualitative data analysis (using MFEP) indicate that training to improve products/services provides the first priority (the weighted evaluation 0.184;

0.224; and 0.169 for top level managers, middle kevel managers, and low level managers); followed by Quality Improvement, Top Management Commitment, Supplier Involvement, Cross-Functional Relationships among SBUs, and Supervisory Leadership.

In addition, the qualitative data analysis (using AHP) also provides a set of sufficiently consistent CSFs of TQM was obtain after the second round of Delphi questionnaire. The result of consistency ratio (CR) shows that the managers had highly satisfactory in assessing the prioritization of CSFs of TQM (CR = 0.0456). Therefore, these CSFs of TQM were supported the results from the quantitative data analysis.

CONCLUSION

To obtain set of CSFs of TQM for the Indonesia's oil and gas industry has been determined by this study (a qualitative research approach). The prioritization exercise using Delphi method enables the managers to specify their requirements according to the companies' experiences in implementing TQM. The first-and second-round Delphi interviews were completed by the three levels of managers experienced. Given that the managers in this study were very busy people in leadership positions, it was important to use a procedure that facilitates participation.

The policy Delphi method is a systematic method for obtaining, exchanging, and developing informed opinion on the prioritization of CSFs of TQM. The method includes a multistage process involving the MFEP measurement of opinion (first-round) followed by an AHP measurement opinion (second-round). The Delphi method was demonstrated to be appropriate for obtaining the prioritization of CSFs of TQM for the Indonesia's oil and gas industry in which a consensus has to be reach.

Several difficulties were encountered in conducting the Delphi technique. First, the Delphi method is extremely demanding of resources, relying as it does on continuing close contact with the managers' participants. Therefore it is not particularly suitable for use in research projects with a restricted time frame [Chan *et al*., 2001]. Second, the selection of the panel of managers is central to the success of the Delphi method. Panel members must be willing and able [Robinson, 1991 in Chan *et al*., 2001]. It is important that panel managers treat the work seriously, and devote the time necessary to provide thoughtful and reasoned responses to the questions. Third, as with all Delphi studies, the wording of the questions and the presentation format of the survey were extremely important [Robinson, 1991 in Chan *et al*., 2001].

In the current study, some efforts were made to make the questionnaire simple and yet sufficient to convey the objectives of the study to the panel of managers. Moreover, Corotis *et al.* [1981] in Chan *et al*. [2001] reported that the principle difficulties were in maintaining the high level of response and in reaching and implementing a consensus. It is very important to keep the whole panel of managers responding to each round of Delphi. Any drop out of the panel of managers would be very undesirable for the Delphi techniques. Because of the extensive commitment the managers needed to spend over the two rounds of questionnaires, there is a relatively high tendency for the respondents to withdraw in the successive rounds of the Delphi [McKenna, 1994 in Chan *et al.*, 2001]. The study was undertaken with relative success in that response rate of 80% was achieved. The 80% response rate achieved in this study is relatively high and considered to be acceptable for the purposes of this research.

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