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Using Analysis of Variance for Measuring Excellence in a Construction Company: Based on the EFQM Model

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ABSTRACT

It has been several years that organizations have used excellence models for achieving some aims such as providing an assessment of the organization, assisting development of strategy, focusing and measuring improvement efforts. There are some excellence models such as EFQM and Malcolm Baldrige that have been developed regionally. The purpose of this paper is to analysis the level of excellence in a construction company in each criteria of the European Foundation for Quality Management (EFQM) excellence model. The main problem of using the different excellence models is the different results that caused managers couldn't understand the real situation of organization clearly. Also implementing same model for different assessment periods provide the different results too. It is because of difference in the condition of assessments such as different specializations of assessors, how to present the organization in site-visits, the quality of declaration preparation, etc., This study presents a method for homogenize the results. Data which is collected from three periods of assessment has been used. Since, it is expected that there is a significant difference in the condition of assessments, Randomized Complete Blocks Design (RCBD) in Analysis of Variance (ANOVA) has been used to homogenize the conditions of experiment. The results of experiments show a significant difference between model criteria in the amount of company's excellence. Using the paired Analysis of Means (ANOM), different criteria have been recognized and results have presented at the end of the paper.

Key words: European foundation for quality management, level of excellence, statistic methods, excellence companies

INTRODUCTION

The European Foundation for Quality Management (EFQM) excellence Model, a non prescriptive framework based on nine criteria, has been used to assess an organization's progress towards excellence. It is based on the premise that: Excellent results with respect to performance, customers, people and society are achieved through leadership driving policy and strategy, that is delivered through people, partnerships and resources and processes. Figure 1 present the EFQM excellence model.

This model does not cover the clinical aspects or the specifics of this field. For that reason, Vallejo *et al.* (2006) in their article aimed to bring the EFQM fundamental concepts of excellence closer to health care, using a specific model as a reference to this field. Also Mehrmanesh and Taghavi (2010) have designed an assessment model based on EFQM Model for quality management. They found some criticisms to EFQM model that are measuring qualitative variables by numbers and assessing activity without offering any improving plan.

People and people result, criteria 3 and 7 of the EFQM Model contain job satisfaction and work motivation. Several studies have shown that job satisfaction is not the only high performance but

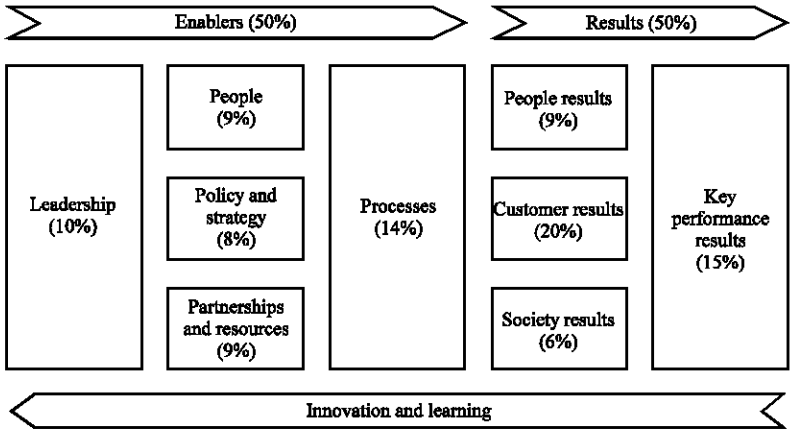

Fig. 1: The EFQM excellence model

it includes high motivation too (Ehrlich, 2006). The researchers has developed an instrument that contains the motivation potentials of the JDS (the job diagnostic survey) Based on an expectancy-value approach. Also, Kirk (1999) has suggested a new quality management excellence model to improve organizations performance base on the EFQM model. In this model customer and people satisfaction and impact on society are achieved through leadership driving policy and strategy, people management and resources. Stahr (2001) has explained an approach to implementation and integrate a culture of quality within the United Kingdom healthcare system. In an effort to achieve his goal he used the EFQM Excellence Model to provide one overarching framework for all their quality initiatives. McCarthy (2005) aimed to determine whether leadership practices vary between German and UK organizations using self-assessment documents submitted by German and UK organizations to the European Foundation for Quality Management (EFQM). Rusjan (2005) has assessed the usefulness of the EFQM excellence model for decision-making on organizational improvement activities. Researcher has done it by studying the procedures of the EFQM model in practice and discussed some methodological issues related to the use of the EFQM model.

Gutierrez *et al.* (2010) in their article proposed a criterion for choosing among alternatives, according to the degree of development required for the elements that structure the alternatives. For this, ANOVA analysis and mean comparison t-tests have used that concluded that quality control is the simplest initiative, followed by ISO 9000 and finally, the EFQM model and Six Sigma methodology. Loh *et al.* (2010) have used ANOVA to determine the significant differences of the physical and mechanical properties of particle board produced from admixtures of rubber wood and Mahang at different proportion levels.

Chung *et al.* (2008) have studied the impact of critical success factors of Total Quality Management (TQM) activities implementation and the impact of TQM activities implementation on business operational performance. Ergulen (2009) has tried to determine the affect of Information Technologies (IT) on the dimensions of TQM in production lines. The results indicated that IT contributes significantly to TQM and to each dimension of TQM. Jain *et al.* (2010) have developed a multidimensional scale to measure service quality of higher education using exploratory factor analysis. It has been concluded that service quality in higher education setting comprises of twelve factors such as visual appeal, outcome, inter personal relationships, curriculum, academic facilities and processes, etc. Ouattara *et al.* (2011) have developed methods for measuring

quality of fruit. It has been shown that the image analysis of histological sections is full of potential solutions allowing understanding the differences in texture and firmness or crispness among the three varieties of apples.

This study has analysis the level of excellence in a construction company in each criteria of the EFQM excellence model. To achieve this objective, section one introduces the problem to be solved and in section two model of problem has been design based on model assumptions.

DESIGN OF MODEL

This company has begun its movement for excellence using the organizational improvement model. It has been assessed by EFQM model including two external assessments by INQA (Iranian National Quality Award) and IPHRD (Institute for Productivity and Human Resource Development) assessors and one period of self assessment. Using the result of these three periods of assessment, in the present study, it is explored that whether there is a significant difference in the amount of excellence of this company in any of nine EFQM criteria.

For this, nine criteria of EFQM excellence model are considered as treatments and the purpose is to analyze significant differences among the scores of these nine criteria. The μ_i shows the mean of the each criterion and the τ_i defines each criteria affect. Hypotheses of model are as below:

$$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 = \mu_7 = \mu_8 = \mu_9 \quad (1)$$
$$H_1: \text{at least one } \mu_i \neq \mu_j$$

In other words:

$$H_0: \tau_1 = \tau_2 = \tau_3 = \tau_4 = \tau_5 = \tau_6 = \tau_7 = \tau_8 = \tau_9 \quad (2)$$
$$H_1: \tau_i \neq 0 \text{ at least one i}$$

Since it is expected that assessments be heterogeneous, randomized complete block design is used. Two external assessments (IPHRD and INQA assessors) and one period of internal self assessment are taken as blocks (nuisance factors). Thus the statistical model is formulated as follows:

$$y_{ij} = \mu + \tau_i + \beta_j + \in_{ij} \begin{Bmatrix} i = 1,2,...,9 \\ j = 1,2,3 \end{Bmatrix} \quad (3)$$

Summarized as:

Problem : Indicating significant difference in amount of company's Excellence in criteria
Treatments : Nine criteria of EFQM
Blocks : Three periods of assessment
Responses : The scores gained in each of the criteria in a period of assessment

Table 1 shows the score of criteria in three different assessment, self assessment IPHRD and INQA assessors. Also, Fig. 2 presents the differences between three assessments. In the Fig. 2 we report the assessors, on the x axis and the score of criteria, on the y axis. As it is shown in Fig. 2,

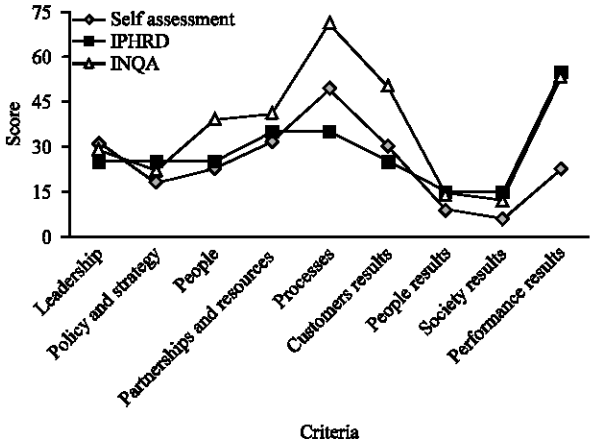

Fig. 2: Result of assessments by three assessors

Table 1: Score of criteria by three assessors

Assessors criteria	Self assessment	IPHRD[1]	INQA[2]
Leadership	31.0	25	29
Policy and strategy	18.0	25	22
People	22.5	25	39
Partnerships and resources	31.5	35	41
Processes	49.0	35	71
Customers results	30.0	25	50
People results	9.0	15	14
Society results	6.0	15	12
Performance results	22.5	55	53

[1]Iranian National Quality Award, [2]Institute for Productivity and Human Resource Development

INQA assessment result shows the higher level of excellence. But which assessment is presenting the real score of company? This is the main question that in this paper tried to answer it. Figure 2 also shows that the score of enables in the company is more than results. It means that this company couldn't use of its ability in a good way.

For solving the model, Minitab 15 software has been used. Result of the three periods of assessment is given to the software as entry and the residuals which are considered the main elements of calculations, are calculated.

Model adequacy checking: Before solving the model it is needed to check the main assumptions of the ANOVA modeling.

Independence assumption: Since, no disciplined and pattern is observed in residuals in time order plot, it can be inferred that observations are independent. Figure 3 shows residuals versus the order of the data.

The normality assumption: Using the normal hypothesis test and normal probability plot of residuals and the histogram of residuals, the normality assumption is checked. Results show that the assumption is met. Figure 4 and 5 show the result of normality test.

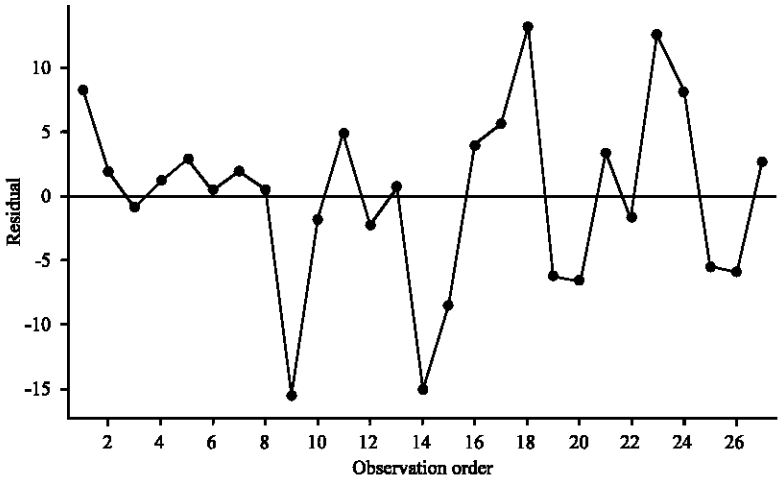

Fig. 3: Residuals versus the order of the data

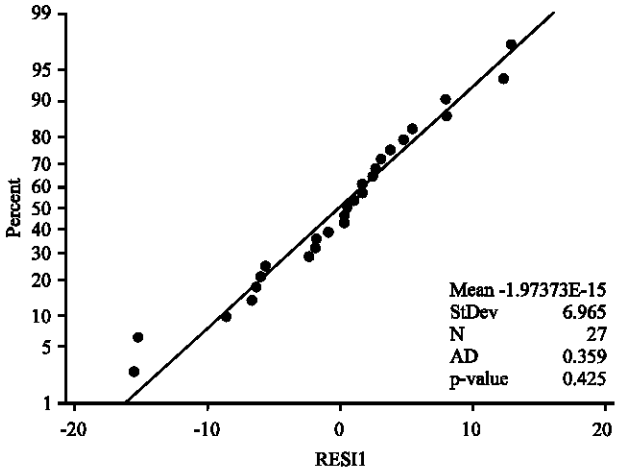

Fig. 4: Normal probability plot of residuals

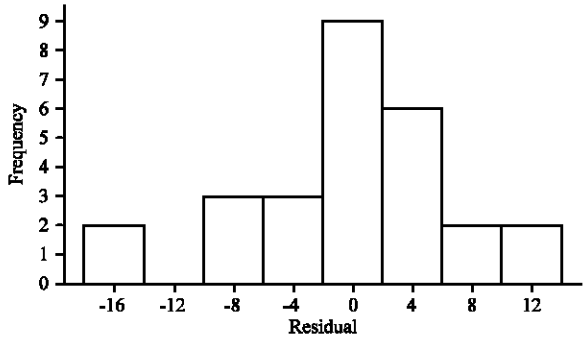

Fig. 5: Histogram of residuals

Equality of variance assumption: This assumption can be tested both using the Bartlett's test and the Levene's test. The statistics of these tests is t student. The results show that the assumptions are met:

$$H_0 : \sigma_1^2 = \sigma_2^2 = \sigma_3^2 = \sigma_4^2 = \sigma_5^2 = \sigma_6^2 = \sigma_7^2 = \sigma_8^2 = \sigma_9^2 \quad (4)$$

$$H_1 : \text{Above not true for at least one } \sigma_1^2$$

Table 2 presents the result of test for equal variance and Fig. 6 shows the residuals histogram with 95% Bonferroni confidence intervals for standard deviations.

Model results: After making sure that the main assumptions are met, model adequacy, the significance of the difference between different criteria of EFQM model is checked. Using randomized complete blocks design and Minitab software, Table 3 presents the output of the model. The results indicate that there is a significant difference between the companies' excellence in different criteria (treatment means). Also, the block design model is a correct choice because there is a significant difference between different periods of assessment.

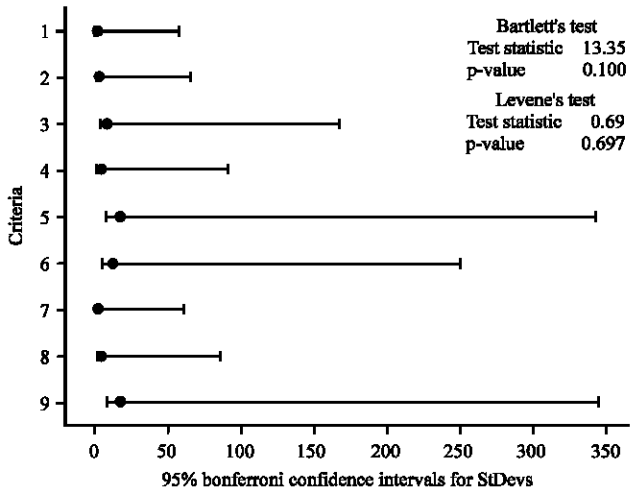

Fig. 6: Residuals histogram

Table 2: Test of equality of variance

Source	DF	SS	MS	F-value	p-value
Criteria	8	4337	542	4.92	0.051
Error	18	1983	110		
Total	26	6319			

S = 10.49, R-Sq = 68.63%, R-Sq (adj) = 54.68%

Table 3: RCBD for assessing company excellence

Source	DF	SS	MS	F-value	p-value
Criteria	8	4336.50	542.063	6.88	0.001
Assessor	2	721.06	360.528	4.57	0.027
Error	16	1261.44	78.840		
Total	26	6319.00			

S = 8.879, R-Sq = 80.04%, R-Sq (adj) = 67.56%

After realizing the significant difference between EFQM criteria, discovering different criteria and analyzing its reasons is important.

RECOGNIZING DIFFERENT CRITERIA

For determining different criteria, the means comparisons methods are used. Figure 7 illustrates the results obtained from paired Analysis of Means (ANOM).

Individual 95% CIs for mean based on pooled StDev are show as:

Level	N	Mean	St Dev	0-----20-----40-----60----
1	3	28.33	3.06	(-----*------)
2	3	21.67	3.51	(------*-----)
3	3	28.83	8.89	(-----*------)
4	3	35.83	4.80	(-----*-----)
5	3	51.67	18.15	(------*-----)
6	3	35.00	13.23	(------*-----)
7	3	12.67	3.21	(-----*------)
8	3	11.00	4.58	(-----*------)
9	3	43.50	18.21	(-----*------)

Pooled StDev = 10.49

It is concluded from Fig. 7 that there is a significant difference between criteria 4, 5, 6 and 9 (top of axis) and criteria 1, 2, 3, 7 and 8 (bottom of axis). This difference can be interpreted in this way that company has gained higher scores in first set of criteria (4, 5, 6 and 9) in comparison with the second set (1, 2, 3, 7 and 8). It means that the company has had a good status in the partnership and resources? processes, customer results criteria and key performance results but in leadership, strategy and policy, people and people result criteria is still in the first stages of the excellence journey and needs to develop and improve these criteria for the sake of approaching its goal, namely an excellence organization. This result is more close to the INQA result. It means that INQA assessment presented the real image of company in excellence level.

Appendix presents the results of all Pair wise comparisons among Levels of Criteria Individual confidence level = 99.75% using Tukey 95% Simultaneous Confidence Intervals.

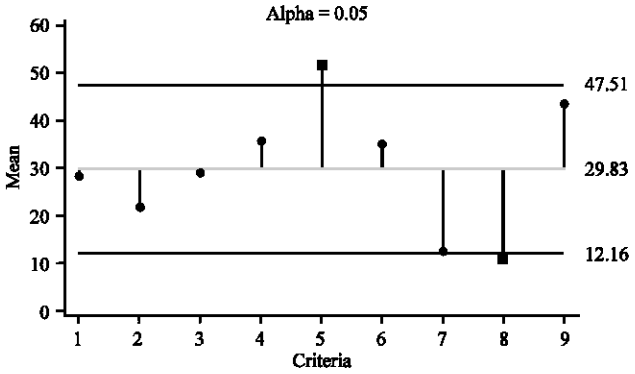

Fig. 7: One way ANOM for response by criteria

CONCLUSION

In this study, the level of excellence in a construction company in each criteria of the EFQM excellence model has been analyzed. Data which is collected from three periods of assessment has been used. Result show that there is a significant difference in the condition of assessments such as different specializations of assessors, how to present the organization in site-visits, the quality of declaration preparation, etc., Randomized Complete Blocks Design (RCBD) in Analysis of Variance (ANOVA) has been used to homogenize the conditions of experiment. The results of experiments show a significant difference between model criteria in the amount of company's excellence. Using the paired Analysis of Means (ANOM), different criteria have been recognized and results have presented at the end of the paper.

APPENDIX

Tukey 95% simultaneous confidence intervals: All Pair wise Comparisons among Levels of Criteria Individual confidence level = 99.75%.

Criteria = 1 subtracted from:

Criteria	Lower	Center	Upper	--------+---------+---------+---------+-
2	-36.72	-6.67	23.39	(------*-------)
3	-29.55	0.50	30.55	(------*-------)
4	-22.55	7.50	37.55	(-------*------)
5	-6.72	23.33	53.39	(-------*------)
6	-23.39	6.67	36.72	(-------*------)
7	-45.72	-15.67	14.39	(------*-------)
8	-47.39	-17.33	12.72	(-------*------)
9	-14.89	15.17	45.22	(-------*------)
				--------+---------+---------+---------+-
				-40 0 40 80

Criteria = 2 subtracted from:

Criteria	Lower	Center	Upper	--------+---------+---------+---------+-
3	-22.89	7.17	37.22	(-------*------)
4	-15.89	14.17	44.22	(-------*------)
5	-0.05	30.00	60.05	(-------*------)
6	-16.72	13.33	43.39	(------*-------)
7	-39.05	-9.00	21.05	(-------*------)
8	-40.72	-10.67	19.39	(------*-------)
9	-8.22	21.83	51.89	(------*-------)
				--------+---------+---------+---------+-
				-40 0 40 80

Criteria = 3 subtracted from:

Criteria	Lower	Center	Upper	--------+---------+---------+---------+-
4	-23.05	7.00	37.05	(-------*------)
5	-7.22	22.83	52.89	(-------*------)
6	-23.89	6.17	36.22	(-------*------)
7	-46.22	-16.17	13.89	(-------*------)
8	-47.89	-17.83	12.22	(-------*------)
9	-15.39	14.67	44.72	(-------*------)
				--------+---------+---------+---------+-
				-40 0 40 80

Criteria = 4 subtracted from:

Criteria	Lower	Center	Upper	--------+---------+---------+---------+-
5	-14.22	15.83	45.89	(-------*------)
6	-30.89	-0.83	29.22	(-------*------)
7	-53.22	-23.17	6.89	(------*-------)
8	-54.89	-24.83	5.22	(-------*------)
9	-22.39	7.67	37.72	(-------*------)
				--------+---------+---------+---------+-
				-40 0 40 80

Criteria = 5 subtracted from:

Criteria	Lower	Center	Upper	--------+---------+---------+---------+-
6	-46.72	-16.67	13.39	(-------*------)
7	-69.05	-39.00	-8.95	(------*-------)
8	-70.72	-40.67	-10.61	(-------*------)
9	-38.22	-8.17	21.89	(-------*------)
				--------+---------+---------+---------+-
				-40 0 40 80

Criteria = 6 subtracted from:

Criteria	Lower	Center	Upper	--------+---------+---------+---------+-
7	-52.39	-22.33	7.72	(------*-------)
8	-54.05	-24.00	6.05	(-------*-------)
9	-21.55	8.50	38.55	(------*-------)
				--------+---------+---------+---------+-
				-40 0 40 80

Criteria = 7 subtracted from:

Criteria	Lower	Center	Upper	--------+---------+---------+---------+-
8	-31.72	-1.67	28.39	(-------*------)
9	0.78	30.83	60.89	(-------*------)
				--------+---------+---------+---------+-
				-40 0 40 80

Criteria= 8 subtracted from:

Criteria	Lower	Center	Upper	--------+---------+---------+---------+-
9	2.45	32.50	62.55	(------*-------)
				--------+---------+---------+---------+-
				-40 0 40

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