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Mathematical model to rank companies provider EFQM with context - dependent data envelopment analysis (case study: Iran auto industry)

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Abstract: Regarding to necessity of performance appraisal issue and accessing to Quality management, it is tried to design a model in order to rank organizations employing both quality and quantity in appraisal - (EFQM) European Foundation for Quality management and Data Envelopment Analysis (DEA) model - favoring the advantages of both the method and minimizing their disadvantages. In the present study, the obtained data from the study, is investigated using the models of EFQM and DEA. The results from this research indicate that ranking by context - dependent DEA is significantly different from the ranking made by Quality management model. In this regard GAMS (generalized analyzing method software) software had been used.

Key words: performance appraisal, Quality management, context-dependent DEA, EFQM.

INTRODUCTION

The main purpose of the EQA was recognizing the organizational excellence in European companies since 1991. Westlund (2001) argued that the EFQM Excellence Model is a framework behind this award and it has clearly become the most commonly applied model in Europe for TQM. Hillman et al., (1994) mention that self-assessment means a comprehensive and regular review of an organization's activities and results alongside the criteria of the model. Porter and Tanner (1996) argued that undertaking a self-assessment process against the EFQM Excellence Model provides an objective, complete measure of strengths of an organization and improvement areas, and gives rise to the establishment and implementation of action plans, integrated in business planning. Van der Wiele et al., (2000) mention that the self-assessment process also allows a methodology to be adopted that will assess progress towards excellence on a regular basis by providing a comparison of scores from assessment to path the real achieved improvement. Schmidt and Zink, (1998) argued that the majority of the academic literature on self - assessment has concentrated on the main Quality/Excellence award models and comparison of their criteria, and the relationship between award winners and business results. Another work that has done by Ritchie and Dale (2000) has concentrated on the self-assessment process with respect to issues such as deciding the assessment approach, the management of the process, the resource required, and selecting performance measurements. Since the launch of the EFQM Model in 1991, thousands of European organizations have used the model as a framework for assessing their performance. But to date, little use has been made of the criteria underpinning the model together with the data collected to build and develop decision models and associated analysis tools for supporting the self-assessment process. In this paper, we have used DEA approach in order to build a decision model that helps the Saipa Group strategic managers to goal setting for each criteria of EFQM business model. One of the main problems after conducting each assessment is how the companies can benchmark the best practices in nine criteria and which companies should be selected as benchmark. In the following we explain the modeling process. The Data shown in Table1 are the percentage scores for each of the nine elements, five Enablers criteria -as Inputs and four Results criteria - as Outputs. Data of the Business Excellence Model for 46 companies are assessed by the Holding company Assessment Teams.

Data envelopment analysis (DEA) is a mathematical programming model for performance appraisal of Decision Making Units (DMUs). It is a technique which is used on all collected observations to measure efficiency. Charnes, cooper, Roudes (1978) developed CCR model (Charnes & Cooper, 1962). In this model, units with one efficiency size are called efficient. All sets of efficient unit are from efficiency border.

It is clear that the omission or adding one inefficient unit and also efficiency border. Inefficient can improve with increasing output levels or reducing input levels and reaching to efficiency border. And with emphasizing on this assumption that input must have the least amount and output must have the most amount

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(Charnes & Cooper, 1978), Seiford & Zhu, provided layer borders for step by step increasing the efficiency of evaluated units increasing the efficiency of evaluated units which its base work was CCR radical model (Seiford &Zhu, 2003). Donnelly, Mike(2000) in his article with the little of "A radical Scoring System for the EFQM" had been dealt with investigate and building a new ranking method based on EFQM. DEA model.

Chen, Morita, Zhu had been used from context - dependent data envelopment analysis model in their article by the little of "A slack - based measure of efficiency in context."

Following this global trend, Iranian industry leaders have introduced the EFQM practice to their supply chain in order to improve its supply base competitiveness during the last four years. The raised question is whether the EFQM model can be combined with mathematical model such as DEA in order to generate a new ranking method and develop or facilitate the benchmarking process. To answer this question, we, firstly refer to the EFQM basic model and DEA method and then make a mathematical model based on the combination of the EFQM conceptual model and DEA mathematical model. Finally, by using the collected data from EFQM assessment in Iranian automotive industry, we run the model and draw a Road Map to help executive managers identify benchmark companies.

In this research at first, decision making units stratifies using context - dependent model and each layer of units is ranking using Anderson - Peterson model until a new mathematical model for ranking the companies providing EFQM is provided which is all accepted.

MATERIALS AND METHODS

The population of this research is the subset companies of the studied automobile - maker group which in this research among this set, 43 companies had been selected which itself had been had the sub set of automobile - maker organization provider EFQM.

With regard to shaping the first remarkable award of quality such as Deming award in 1951 in Japan and Malcom Baldrige award in America in 1987and acquired achievement in Japanese and American organization, 14 well - known European companies assembled together in Brookcle, Belgic, in 1988 and established a foundation with the title of "European Quality Management the mission of this foundation"

The mission of this foundation was defined as "creating progressive force in order to sustainable quality in European" and its landscape was "European quality management in the world".

Efficiency model EFQM is a non - prescriptive model which had been formed from 9 measures. These measures are the core and heart of this model and consider as the appraisal base of an organization.
The measures of EFQM model are divided into two groups.

A- Enablers: They had been had first five measure of this model and they are some factors which enable organization to reach high results.

B- Results: They are results which an efficient organization access to them in various area and they are indicating the achievement from suitable performing of enablers.

In EFQM model, the measures have 1000 score all together (500 score for enablers and 500 score for results).

In other words, if an organization succeeded to completely operate this model in its organization, can receive 1000 score (Najmi, 2009).

In figure 1, you can see these measures, interaction manner and the relation with each other and each one score.

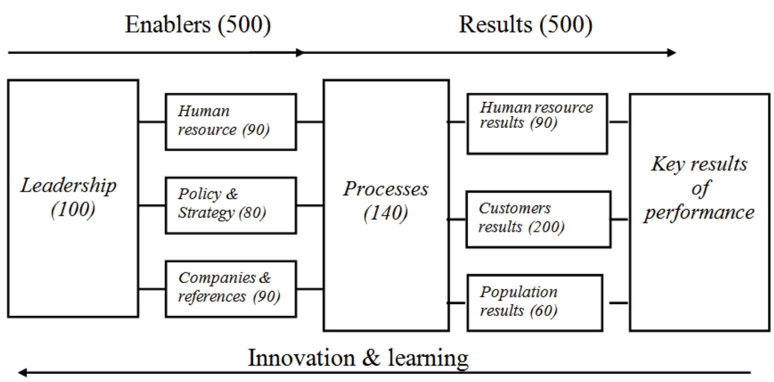

Fig. 1: show of EFQM model Najmi, M. Hoseini, S. Efficiency model of EFQM from idea to action , P. 22.

In BCC & CCR models which place on efficiency border, their maximum efficiency is equal to 1 (one) which in this case the studied unit itself as a combine with coefficient 1 (one) had been considered as itself appraisal criterion, but suggestive model of Anderson - Peterson do not allow this situation.

In other words, they reject being reference of decision - maker unit for the unit itself.

More important, formulating various AP model such as CCR and BCC are corresponding to them.The mathematical programming problem may thus be stated as:

$$\max h_0(u,v) = \sum_r u_r y_{r0} / \sum_i v_i x_{i0}$$

Subject to

$$\sum_r u_r y_{rj} / \sum_i v_i x_{ij} \le 1 for j = 1,2,...,n$$

$u_r, v_i \ge 0$ for all i and r

A fully rigorous development would replace $u_r, v_i \ge 0$ with $\frac{u_r}{\sum_{i=1}^{m} v_i x_{i0}}, \frac{u_r}{\sum_{i=1}^{m} v_i x_{i0}} \ge \varepsilon > 0$ where is a non-Archimedean element smaller than any positive real number. See Arnold *et al.,* (Ritchie, 2000). This condition guarantees that solutions will be positive in these variables. The above ratio form yields an infinite number of solutions; if (u^*, v^*) is optimal, then $(\alpha u^*, \alpha v^*)$ is also optimal for α > 0. However, the transformation developed by Charnes and Cooper (1962) for linear fractional programming selects a representative solution [i.e., the solution (u,v) for which $\sum_{i=1}^{m} v_i x_{i0} = 1$] and yields the equivalent linear programming problem in which the change of variables from (u,v) to (μ,v) is a result of the Charnes-Cooper transformation:

(LP_0)

$$\max z = \sum_{r=1}^{s} \mu_r y_{r0}$$

Subject to

$$\sum \mu_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0$$

$$\sum_{i=1}^{m} v_i x_{i0} = 1$$

$$\mu_r, v_i \ge 0$$

For which the LP dual problem is:

(DLP_0)

$$\theta^* = \min \theta$$

Subject to

$$\sum_{j=1}^{n} x_{ij} \lambda_j \le \theta x_{i0}, i = 1,2,...,m;$$

$$\sum_{j=1}^{n} y_{rj} \lambda_j \ge y_{r0}, r = 1,2,...,s;$$

$$\lambda_j \ge 0, j = 1,2,...,n.$$

The dual problem of (LP_0) is expressed with a real variable θ and a non-negative vector $\lambda = (\lambda_1,...,\lambda_n)^T$ of variables. The result of this model for inefficient units are equal with CCR model, but for efficient units. It produce the score higher than 1 or equal with it, which in this case, efficient units is ranking with the score higher than one or equal with it.

In other words, when the target function of an efficient units is investigating, the limitation of that unit will be omitted inter the limitation of model until the rank of concerned unit specify among the efficient units (Naderi, Sadeghi, 2004). Banker et al., (1984) extended the earlier work of charnes et al., (1978) by providing for variable returns to scale (VRS). Tone (2001) introduced the so-called slacks-based measure (SBM) which is invariant to the units of measurement and is monotone increasing in each input and output slack.

With being consonant of output, units raise higher, so for purpose we had been entered the input inversely.

Results:

In this research, at first, efficiency had been calculated with output oriented CCR model and then, companies classified in 5 layers using context – dependent model and finally, the efficiency of companies had been calculated with Anderson – Peterson model and ranking had been taken place.

As be observed, Companies 1, 6 and 9 are in the first layer and their presentation points, respectively are 2.24 and 1.58 and 1.39، which rank first, second and third are devoted to. All these companies are on the efficient frontier, they can be as reference units, or template for other companies in the same layer or lower layers are considered. The second layer, companies 12 and 19 and four are located. They rated performance are 1.67 and 1.51 and 1.4, that respectively, ranking first, second and third in this layer are allocated. As can be seen, in this layer a number of companies are on the efficient frontier and the lower number of efficient boundaries. This means that, some companies that are located on the efficient frontier should be modeled for companies to use the first layer and others in the lower layers of the border have been efficient for the modeling of the companies that should be in the second layer on the efficient frontier are in use. Companies 10 and 18 and 7 with a score of 1.55 and 1.51 and efficiency 1.37, respectively rank is first, second and third is in the third layer. Suggested strategies for companies that are located in this layer are: The companies that are located on the efficient frontier, companies that are in the second layer should be modeled for use. This point is important because techniques based on generalized data envelopment analysis (context-dependent DEA), Companies should be modeled to consider a layer above its current level. The analysis for the other layers can also be examined.

DEA model with the current methods used in the Iran's car industry (Technique EFQM) were compared. Results from the ranking DEA and EFQM models in the table above are shown. Be Consideration that, Company No. 1 with a 24.2 efficiency rating is a member of the first layer, Using DEA, earned the first rank, but using the EFQM and 383.5 points won the fifth rank. Another example, Company number 19 with a 1.51 2.efficiency ranking that is a member of the second layer, using the DEA is the sixth ranking, But using the EFQM method and 209 points are ranked ninth. By analyzing and comparing the two ranking methods we can be received significant difference exists between these two techniques. DEA Method is empowerment tool for understanding company presentation because this method for determine presentation and company efficiency, Input and output sources are analyzed and Try to be companies limited resources be used to produce output. In fact be shown that compared with the reference companies, companies should determine the inputs to produce output levels. But the EFQM model lacks the capacity and the only companies based on algebraic sum empowerment points and results are ranked.

Table 1: initial and transformed input & output of the companies.

Company	initial inputs					out puts				Transformed input				
	I1	I2	I3	I4	I5	O1	O2	O3	O4	I1	I2	I3	I4	I5
1	40	40	35	40	25	20	20	10	30	0.025	0.025	0.020	0.025	0.040
2	25	20	25	20	25	10	10	10	30	0.040	0.050	0.040	0.050	0.040
3	20	20	20	20	25	15	15	10	20	0.050	0.050	0.050	0.050	0.040
4	20	20	15	25	25	15	10	5	30	0.050	0.050	0.067	0.040	0.040
5	25	20	30	20	25	20	15	10	20	0.040	0.050	0.033	0.050	0.040
6	25	35	20	25	40	20	15	10	30	0.040	0.029	0.050	0.040	0.025
7	20	25	25	25	20	10	10	0	20	0.050	0.040	0.040	0.040	0.050
8	15	15	15	20	20	20	30	5	25	0.067	0.067	0.067	0.050	0.050
9	25	15	30	25	30	15	20	15	30	0.040	0.067	0.033	0.040	0.033
10	25	25	25	15	20	5	10	10	10	0.040	0.040	0.040	0.067	0.050
11	15	10	25	25	20	10	10	5	10	0.067	0.100	0.040	0.040	0.050

Table 1: Continue

12	15	15	25	25	25	10	10	15	15	0.067	0.067	0.040	0.040	0.040
13	10	10	10	20	10	0	0	0	15	0.100	0.100	0.100	0.050	0.100
14	15	30	20	10	40	5	15	5	10	0.067	0.033	0.050	0.100	0.025
15	30	10	30	10	25	5	15	5	25	0.033	0.100	0.033	0.100	0.040
16	15	10	20	20	25	25	25	15	20	0.067	0.100	0.050	0.050	0.040
17	20	15	20	20	25	10	15	5	20	0.050	0.067	0.050	0.050	0.040
18	15	10	25	20	30	10	5	10	15	0.067	0.100	0.040	0.050	0.033
19	30	30	20	20	25	20	15	10	20	0.033	0.033	0.050	0.050	0.040
20	15	15	20	15	20	20	15	5	15	0.067	0.067	0.050	0.067	0.050
21	25	25	15	20	15	15	10	5	15	0.040	0.040	0.067	0.050	0.067
22	10	10	20	20	30	5	5	5	10	0.100	0.100	0.050	0.050	0.033
23	20	20	15	20	20	10	10	10	20	0.050	0.050	0.067	0.050	0.050
24	5	5	10	10	15	5	5	10	10	0.200	0.200	0.100	0.100	0.067
25	25	20	25	20	30	5	5	5	10	0.040	0.050	0.040	0.050	0.033
26	20	10	20	20	20	20	10	5	20	0.050	0.100	0.050	0.050	0.050
27	10	5	15	10	20	15	10	5	5	0.100	0.200	0.067	0.100	0.050
28	20	15	15	15	20	15	15	10	20	0.050	0.067	0.067	0.067	0.050
29	20	25	15	15	15	10	20	15	20	0.050	0.040	0.067	0.067	0.067
30	15	10	10	15	5	0	0	5	20	0.067	0.100	0.100	0.067	0.200
31	10	15	15	10	15	5	10	0	15	0.100	0.067	0.067	0.100	0.067
32	10	5	10	15	25	5	5	0	5	0.100	0.200	0.100	0.067	0.040
33	10	5	10	10	25	10	10	0	15	0.100	0.200	0.100	0.100	0.040
34	20	15	15	15	25	10	10	5	15	0.050	0.067	0.067	0.067	0.040
35	5	10	5	10	10	5	5	5	10	0.200	0.100	0.200	0.100	0.100
36	20	15	25	15	25	15	15	0	20	0.050	0.067	0.040	0.067	0.040
37	15	15	10	10	20	10	10	5	10	0.067	0.067	0.100	0.100	0.050
38	20	15	30	20	25	20	20	5	20	0.050	0.067	0.033	0.050	0.040
39	20	10	30	15	35	5	5	5	25	0.050	0.100	0.033	0.067	0.029
40	15	15	15	15	20	10	10	10	25	0.067	0.067	0.067	0.067	0.050
41	10	10	15	10	20	5	5	5	10	0.100	0.100	0.067	0.100	0.050
42	10	10	20	15	20	5	15	5	15	0.100	0.100	0.050	0.067	0.050
43	5	5	10	10	20	15	5	0	10	0.200	0.200	0.100	0.100	0.050

In this conceptual-mathematical model, we In this conceptual-mathematical model, I have shown that the DEA mathematical model can be combined with conceptual EFQM Business Excellence Model to produce an optimal ranking as a new ranking based on the EFQM score and help the benchmarking process. This paper reports finding of a survey and case study research on the application of the DEA to the ranking method of EFQM Business Excellence Model in Iran's Automotive Industry. This paper assesses the usefulness and power of the DEA technique to recognize a new scoring system in order to compare the classical ranking method with the EFQM business model. We used this method to identify meaningful exemplar companies for every criterion of the EFQM model and then design a road map based on the realistic targets in each criterion which is currently being achieved by exemplar companies. The research indicates that the DEA approach is a powerful tool to analyze the latent knowledge of the scores generated from the conducting self-assessments. have shown that the DEA mathematical model can be combined with conceptual EFQM Business Excellence Model to produce an optimal ranking as a new ranking based on the EFQM score and help the benchmarking process. This paper reports finding of a survey and case study research on the application of the DEA to the ranking method of EFQM Business Excellence Model in Iran's Automotive Industry. This paper assesses the usefulness and power of the DEA technique to recognize a new scoring system in order to compare the classical ranking method with the EFQM business model. We used this method to identify meaningful exemplar companies for every criterion of the EFQM model and then design a road map based on the realistic targets in each criterion which is currently being achieved by exemplar companies. The research indicates that the DEA approach is a powerful tool to analyze the latent knowledge of the scores generated from the conducting self-assessments.

Conclusion:

Efficiency measurement has been a subject of tremendous interest as organizations have struggled to improve productivity. Reasons for this focus were best stated fifty years ago by Farrell (1957) in his classic paper on the measurement of productive efficiency.

The Excellence Model was introduced to Iranian companies in 2000 and the first countrywide assessment of the EFQM, as a selected framework of Iranian authorities, was conducted in 2002. The most profound impact of the Quality Management and Excellence Practice on organizational performance has been in the Iranian Steel making and Automotive Industry. Mentioned industries have clearly proved the possibility of old manufacturing businesses revitalization and it will continue showing the improvements in quality and productivity. Recently, Iranian automotive companies have started action plans on assessing their affiliated companies in order to improve productivity and launch TQM, using EFQM tools.

In ranking with EFQM model, the total score from criterions are specifying the rank, and those companies with higher input and reference with higher input and reference will acquire higher ranks. While in ranking with context - dependent data, at first, the companies which are closer to each other are categorizing in the same layer and then the ranking will be take place with Anderson Peterson model and all companies with different input and output will place in the same condition, and due to references and input permit the smaller

Table 2: the efficiency and rank of companies in various layers.

	Second layer			First layer		
company	efficiency	Model AP	Rank of each	efficiency	Model AP	Rank of each
1	1.0000	2.2464	1			
2	0.8317			1.0000	1.3783	4
3	0.6756			1.0000	1.0000	11
4	0.8125			1.0000	1.4063	3
5	0.8850			1.0000	1.3673	5
6	1.0000	1.5861	2			
7	0.4815			0.9280		
8	1.0000	1.0714	4			
9	1.0000	1.3902	3			
10	0.7011			0.9394		
11	0.3738			0.7000		
12	0.9852			1.0000	1.6750	1
13	0.2500			0.4000		
14	0.9950			1.0000	1.3399	6
15	0.7420			1.0000	1.2838	8
16	1.0000	1.0714	4			
17	0.6271			0.8742		
18	0.6667			0.9524		
19	0.9804			1.0000	1.5152	2
20	0.6667			0.8000		
21	0.4688			0.7500		
22	0.3333			0.5277		
23	0.6144			0.8453		
24	0.3284			0.3980		
25	0.3786			0.5289		
26	0.6667			1.0000	1.0000	11
27	0.4491			0.6000		
28	0.5683			0.7972		
29	0.9375			1.0000	1.2375	9
30	0.2488			0.4478		
31	0.2723			0.4388		
32	0.2014			0.2500		
33	0.4097			0.6187		
34	0.4268			0.6382		
35	0.1536			0.2113		
36	0.6600			0.8734		
37	0.3389			0.4545		
38	0.9023			1.0000	1.3333	7
39	0.9082			1.0000	1.1494	10
40	0.5177			0.7483		
41	0.2209			0.3483		
42	0.4962			0.6323		
43	0.3750			0.6000		

	Third layer			4^{th} layer			5^{th} layer		
company	efficiency	Model AP	Rank of each	efficiency	Model AP	Rank of each	efficiency	Model AP	Rank of each
1									
2									
3									
4									
5									
6									
7	1.0000	1.3777	3						
8									

Table : Continue

9									
10	1.0000	1.5529	1						
11	1.0000	1.0438	11						
12									
13	0.6000			1.0000	1.1206	6			
14									
15									
16									
17	1.0000	1.3062	6						
18	1.0000	1.5152	2						
19									
20	1.0000	1.3358	5						
21	1.0000	1.3616	4						
22	0.6424			1.0000	1.0000	8			
23	1.0000	1.3039	7						
24	0.5000			1.0000	1.0000	8			
25	0.7329			1.0000	1.5672	2			
26									
27	0.7767			1.0000	1.4975	3			
28	1.0000	1.2979	9						
29									
30	0.7463			1.0000	1.2487	5			
31	0.6219			1.0000	1.0000	8			
32	0.3333			0.5000			1.0000	1.4925	2
33	0.7500			1.0000	1.0000	8			
34	0.8249			1.0000	1.4826	4			
35	0.2500			0.5000			1.0000	1.0000	3
36	1.0000	1.3000	8						
37	0.6613			1.0000	1.0000	8			
38									
39									
40	1.0000	1.1363	10						
41	0.4370			0.6600			1.0000	2.9851	1
42	0.9653			1.0000	2.0100	1			
43	0.7500			1.0000	1.0571	7			

Table 3: the compare of ranking from two EFQM, DEA model.

Company	Score	EFQM Rank	company	efficiency	layer	DEA Rank
5	546	1	1	2.246	1	1
7	522.5	2	6	1.586	1	2
4	476.5	3	9	1.39	1	3
6	475	4	8.16	1.079	1	4
1	383.5	5	12	1.675	2	5
10	239	6	19	1.515	2	6
13	230.5	7	4	1.406	2	7
9	210.5	8	5	1.378	2	8
19	209	9	2	1.367	2	9
38	203	10	14	1.339	2	10
2	196.5	11	38	1.333	2	11
8	194	12	15	1.283	2	12
3	186.5	13	29	1.237	2	13
36	176.5	14	39	1.149	2	14
29	176	15	3.26	1	2	15
17	175	16	10	1.552	3	16
12	167.5	17	18	1.515	3	17
28	166.5	18	7	1.377	3	18
39	163.5	19	21	1.361	3	19
26	163	20	20	1.335	3	20
23	160.5	21	17	1.306	3	21
20	160	22	23	1.303	3	22
21	156.5	23	36	1.3	3	23
25	156	24	28	1.297	3	24
40	154.5	25	40	1.136	3	25
18	153	26	11	1.043	3	26
14	149	27	42	2.01	4	27
34	148.5	28	25	1.567	4	28
11,15	143	29	27	1.497	4	29

Table 3: Continue

42	137.5	30	34	1.482	4	30
37	120	31	30	1.248	4	31
33	118.5	32	13	1.12	4	32
31	112.5	33	43	1.057	4	33
22	110.5	34	37.33.31.22	1	4	34
27	108.5	35	41	2.985	5	35
41	101	36	32	1.492	5	36
43,32	93.5	37	35	1	5	37
30	85.5	38				
24	83.5	39				
16	81.5	40				
35	73	41				

The following table(3) is indicating the difference of two ranking model which are provided in this research.

companies to acquire higher rank than bigger companies. In fact, this kind of ranking, first provide a possibilities to all companies to place in a more equality ranking and second, the companies with low efficiency can operate layer by layer strategy and recipes for increasing performance until reach to higher companies in performance perspective.

Consequently, ranking with context - dependent data envelopment analysis have significance different comparing to ranking with Quality management model. In fact, using context – dependent data envelopment analysis will disappear the interact ional and mutual effectives between the variables and index in evaluation and the weakness of relationship between the criterion in EFQM model.

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