Volume 1, Number 3, 2012

International Journal of Research in Industrial Engineering

journal homepage: www.nvlscience.com/index.php/ijrie

A New Method to Organizational Ranking: Integrating BSC and DEA

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A R T I C L E   I N F O

Article history :
Received:
August 10, 2012
Revised:
October 28, 2012
Accepted:
December 15, 2012

Keywords :
Balanced Scorecard,
DEA,
Ranking method.

A B S T R A C T

Nowadays, managers tend to compare their organizations with the others as well they want to have benchmarks. Benchmarking should be based on correct updated organizational critical factors. Balanced scorecard (BSC) is the tool to translate the organizational strategic goals into the operational critical factors by its strategy map. It individually may not use as the tool for organizational comparison. Data envelopment analysis (DEA) is essentially used to evaluate decision making units (DMUs) from the best possible relative efficiency. But it's incapable of defining its input and output indexes efficiently. So, in this paper the most important strategic factors obtained from BSC are employed as the input data for DEA. This may lead us to a comprehensive benchmarking method to attain the reliable appropriate results for each organization in each period. Finally, the proposed method is practically tested and the results are illustrated in the following paragraphs.

1. Introduction

The BSC model is a widely used method for organizational performance measurement. The method is first introduced by R. Kaplan in 1980 and by Kaplan and Johnson in 1987 [1]. But its university based idiom was denoted by Kaplan and Norton in 1992 [2, 3]. Despite, it is not completely emphasized on balanced measurement and related factors in any publication of Kaplan and Norton, Cobbole, and Lawrie [4] highlighted it in 2003 and finally, the strategy plan is used to complete the model in 2004 [3, 6].
The model is based on four fundamental factors: (1) Financial (2) Internal business process (3) Customer (4) Innovation and learning to found a relation between strategic goals and operational controls which are illustrated in Fig. 1 [2-6]. The model is establishes balance between financial and nonfinancial, short term and long term and internal and external goals. It balances the anterior and posterior factors in some cause and effect chains [7].
The key practical steps involved in developing a BSC are: (1) Develop organization mission, vision and strategy (2) Confirm the BSC role in performance management framework (3) Select the scorecard viewpoint (4) Review suitable background materials (5) Conduct executive interviews (6) Create strategy map (7) Gather feedback (8) Improve performance measures (9) Develop initiatives (10) Develop the continuing implementation plan [5, 6].

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Data envelopment analysis (DEA) was introduced by Charnes, Cooper, and Rhodes [8], often evaluates decision making units (DMUs) from the best possible relative efficiency [9]. Myoungand Sang [10] used DEA to define the time path of returns to scale of all publicly held U. S. computer companies over the time period 1980-1991.Runsheng [11] discussed a new approach to productive efficiency evaluation in forest products industries, using DEA. Sevcovic et al. [12] proposed DEA for the assessment of efficiency of a large structured network of bank branches in Slovakia. Emrouznejad and Banker [13] introduced the theory and application of DEA to efficiency and productivity measurement. Henderson and Zelenyuk [14] and Yang [15] used the DEA for assessing Latvian and Canadian bank branch operating efficiency. Malhotra [16] illustrated the application of DEA to analyze the financial performance of the 7 largest retailers in the United State by benchmarking a set of financial ratios of a firm against its peers. Sepehrdoust [17] introduced the DEA method for efficiency measurement of housing sector in Iran. Wen-Chih and Chen-Fu [18] used the DEA for measuring the performance of wafer fabrication operations in Taiwan. Lee et al. [19] used the DEA for measuring efficiency in the Malaysian banking industry. Rahimi et al. [20] applied the DEA to analysis of the efficiency and optimal consumption of resources in selected hospitals in Urmia province.

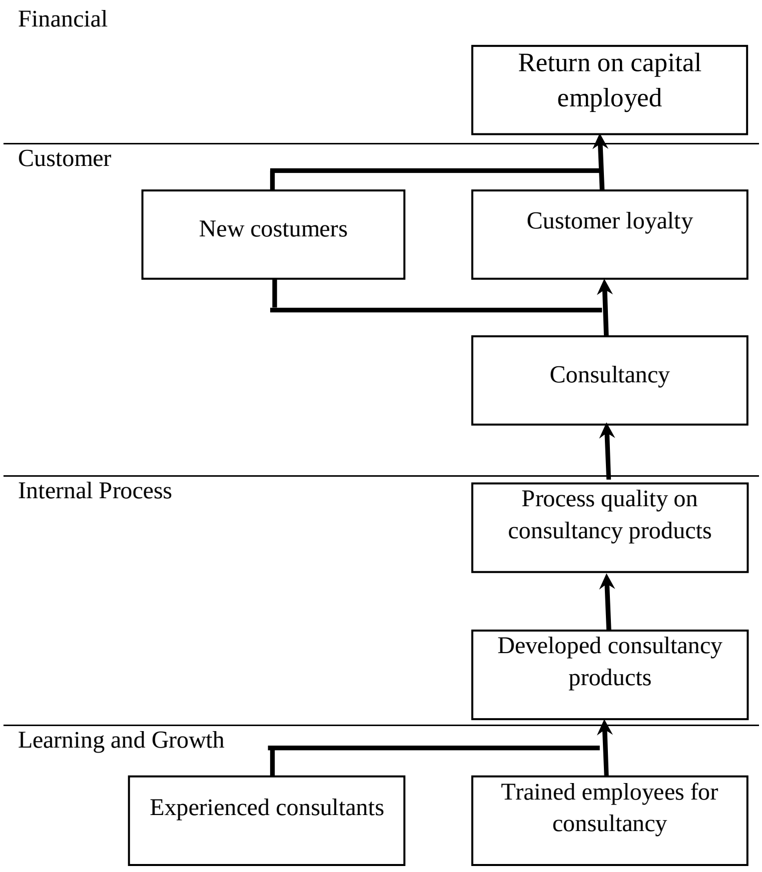

Figure 1. Fundamentals of BSC and its Cause-and-effect relationships

Entani, et al. [21] and Wang, et al. [22] developed a model to consider both the optimistic and pessimistic points, until Wang and Luo [9] proposed their model based on the relative closeness (RC) to the ideal DMU (IDMU) that uses the two distinctive efficiencies as well as the TOPSIS model in multi-attribute decision making (MADM). Then the RC factor may be used for overall ranking of all DMUs, easily [9, 23].

One of the most important drawbacks of the DEA is its weakness on identifying factors to rank the DMUs. In this paper, the BSC method is used to determine two or three most important factors in any field of its four basic fundamental factors. The factors are then used as the input data for the DEA method to rank complex organizations and enhance the reliability and flexibility of the method for benchmarking.

2. Proposed Method

The DEA has no tools to finding effective factors, especially in the field of organizational ranking and this weakness may decrease its reliability. In this paper, the strategy map that is established by BSC is used to solve this weakness by defining most relevant factors as the input of the following DEA model:

Assume that there are n DMUs to be evaluated. Each of them consumes m inputs, denoted by $x_{ij}(i=1,...,m, j=1,...,n)$, to produce s outputs denoted by $y_{rj}(i=1,...,s, j=1,...,n)$. Then, an IDMU may be defined as a virtual DMU that can use the least inputs, $x_i^{\min}(i=1,...,m)$, to produce the most outputs, $y_r^{\max}(r=1,...,s)$, while an anti-ideal DMU (ADMU) may defined as a DMU, which consume the most inputs, $x_i^{\max}(i=1,...,m)$, to generate the least outputs, $y_r^{\min}(r=1,...,s)$. To completing the model, the LP model shown in Eq. (1) and Eq.(2) must be solved for all DMUs such as DMU0 to calculate the $\theta_{j0}^*, \varphi_{j0}^*$, where j0 is the DMU under evaluation (denoted by DMU0), u_r, v_i are decision variables, ε is the non-Archimedean infinitesimal, θ_{IDMU}^* is the optimum efficiency of IDMU that may calculated by Eq. (3) and φ_{ADMU}^* is the worst efficiency of the ADMU that may calculated by Eq. (4). Then the final ranking is achieved by Eq. (5).It is clear that the bigger the RC_{j0} value is the-better-the-performance of DMU_0.

3. Empirical Example and Conclusion

The data for this study are collected in winter 2011 in Kermanshah, Iran. The data included 53 creditable performance indexes that factor analyzing in SPSS software classifies them into four levels of factors. Data are classified as: (1) 10 financial indexes, (2) 7 internal business process indexes, (3) 7 customer Indexes, (4) 24 innovation and learning indexes. This classification is shown in Table 1. The indexes which are selected to construct the organizational strategic map are recognized by asterisks.

Indexes are given to experts to give a privilege to them according to organizational predefined strategies. Consequently, Five Point Likert and Factor analysis methods are used to demonstrate the classification. Then the most important indexes in each four levels are chosen. After linking the factors in BSC procedure, the strategy map is given as shown in Fig. 2. One can see that the output of the BSC method is the indexes which are cited as the important relative critical factors of organization. These indexes are used as the outputs for the DEA method. Seven inputs which are strongly related to these outputs are also selected and the real data are collected from the 10 sub-organization of the Kermanshah Water Regional Organization as shown in Table 1. Finally, DEA is used to rank these sub-organization using factors which are indicated in strategy map. The results are illustrated in Table 2.

What is indicated in column five (RC) of Table 3 shows the difference of the sub-organizations. So managers not only can clearly recognize the differences between their organizations and the others, but also the related distances can show the intensity of these differences. This information helps the manager to have a better view to perceive the position of his/her organization and enhance an ability to compare it with other similar ones in terms of the organizational strategic goals that may change and updated over its life cycle. This ranking is based on the same other organizations that make it possible and acceptable for any of them. The ranking shows that DMU_2 is the better one. In addition, the distance among the index RC of 4^{th} DMU to 10^{th} one is not as important as what is seen in first three DMUs.

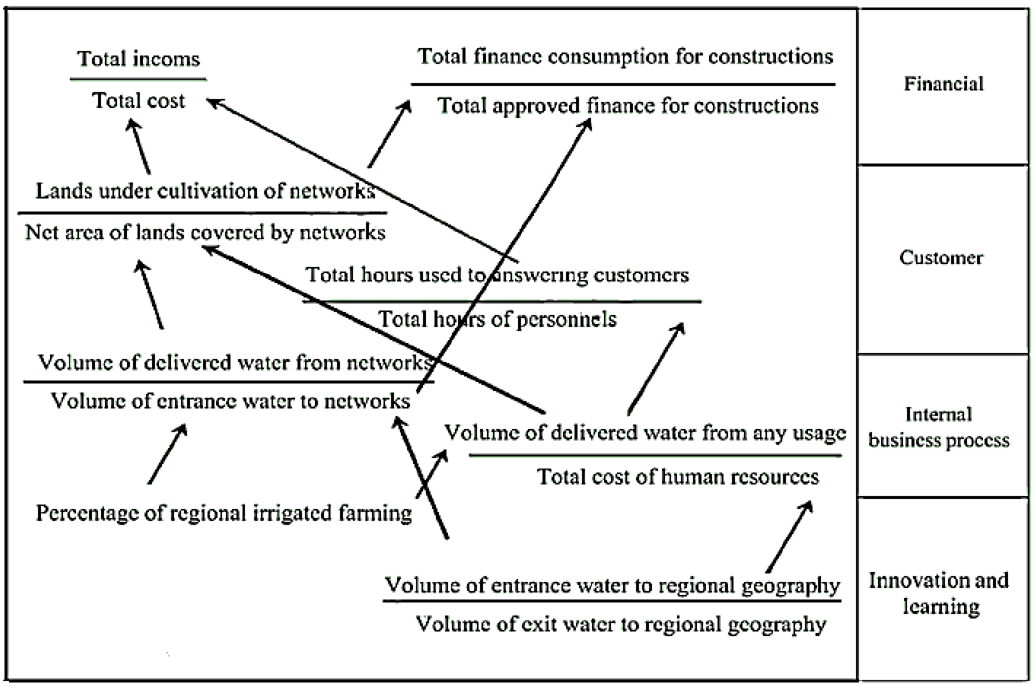

Figure 2. Strategy map of Kermanshah Regional Water Organization

$$
\begin{aligned}
Max \quad & \theta_{j0} = \sum_{r=1}^{s} u_r y_{rj0} \\
S.T. \quad & \sum_{i=1}^{m} v_i x_{ij0} = 1 \\
& \sum_{r=1}^{s} u_r y_j^{\max} - \sum_{i=1}^{m} v_i (\theta_{IDMU}^{*} \ x_i^{\min}) = 0 \\
& \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \qquad j = 1, \ldots, n \\
& u_r, v_i \ge \varepsilon \qquad \forall r, i
\end{aligned} \tag{1}
$$

$$
\begin{aligned}
Min \quad & \varphi_{j0} = \sum_{r=1}^{s} u_r y_{rj0} \\
S.T. \quad & \sum_{i=1}^{m} v_i x_{ij0} = 1 \\
& \sum_{r=1}^{s} u_r y_j^{\min} - \sum_{i=1}^{m} v_i (\varphi_{IDMU}^{*} \ x_i^{\max}) = 0 \\
& \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \qquad j = 1, \ldots, n \\
& u_r, v_i \ge \varepsilon \qquad \forall r, i
\end{aligned} \tag{2}
$$

$$
\begin{aligned}
Max \quad & \theta_{IDMU} = \sum_{r=1}^{s} u_r y_r^{\max} \\
S.T. \quad & \sum_{i=1}^{m} v_i x_i^{\min} = 1 \\
& \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \qquad j = 1, \ldots, n \\
& u_r, v_i \ge \varepsilon \qquad \forall r, i
\end{aligned} \tag{3}
$$

$$
\begin{aligned}
Min \quad & \varphi_{ADMU} = \sum_{r=1}^{s} u_r y_r^{\min} \\
S.T. \quad & \sum_{i=1}^{m} v_i x_i^{\max} = 1 \\
& \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \qquad j = 1, \ldots, n \\
& u_r, v_i \ge \varepsilon \qquad \forall r, i
\end{aligned} \tag{4}
$$

$$
RC_{j0} = \frac{\varphi_{j0}^{*} - \varphi_{ADMU}^{*}}{(\varphi_{j0}^{*} - \varphi_{ADMU}^{*}) + (\theta_{IDMU}^{*} - \theta_{j0}^{*})} \tag{5}
$$

Table 1. Data classification and indexes illustration

No.	Category	Index	No.	Category	Index
***1**	Finan.	Total income / Total cost	25	Innov.	Total water used in industrial fields / Total water delivered for industries
2	Finan.	Gross benefit / Total cost	26	Innov.	Total water used in industrial fields / Total water delivered for industries
3	Finan.	Budget percent fulfilled	27	Innov.	Total recovered water / Total proved budget
4	Finan.	Total income / Total assets	28	Innov.	Total recovered water / Total proved budget
***5**	Finan.	T. finance consumption for con. / T. approved finance for con.	29	Innov.	T. recovery of under ground water / T. recoverable under ground water
6	Finan.	Gross benefit / Total assets	*30	Innov.	V. of enterance water to area / Total leaving water from area
7	Finan.	Actual ROI / Forcasted ROI	31	Innov.	Mean time of projects actual time / Mean time of projects planed time
8	Finan.	Assigned budget / Approved budget	32	Innov.	Total volume of recovered rainfall / Total rainfall volume
10	Finan.	Total regulated water of dams / Total assets of dams	33	Innov.	Mean stoping time of devel. projects
***11**	In. B.P.	Vol. of delivered water from any usa / Total cost of human resources	34	Innov.	Total water usage / Total water need
***12**	In. B.P.	V. of delivered water from networks / V. of interance water to networks	35	Innov.	Total used potential of the area / Total potential of the area
13	In. B.P.	Mean time of payment to contructo	36	Innov.	Total absorbed civil budget / Total approved civil budget
14	In. B.P.	Recovery perecent of used water	37	Innov.	Total water usage / Total water
15	In. B.P.	Nomber of networks customer / Nomber of contructs	38	Innov.	Percentage of U. G. water pollution
16	In. B.P.	V. of under ground water for agri. us / Total volume of water for agri. usa	39	Innov.	Percen. of pollution of surface water
17	In. B.P.	productivity	40	Innov.	Percentage of irrigating lands
***18**	Cust.	Lands under cultivation of networl / Net area of lands covered by netwo	41	Innov.	Mean quality of water / Mean standard quality
***19**	Cust.	Total hours used to answering cust. / Total hours of personels working	42	Innov.	Men cost of IT developement projects / Total cost of IT systems
20	Cust.	Total delivered water based on cont / Total delivered water	*43	Innov.	Perce. of regional irrigated fatming
21	Cust.	Total delivered water for agricultur / Total delivered water	44	Innov.	Total industrial production / Total delivered water to industries
22	Cust.	Total delivered water for industries / Total delivered water	45	Innov.	T. recovered water of ind. waste wate / Total delivered water to industries

Table 1. Continued

23	Cust.	Total delivered water for agricultur / Total cultivated lands	46	Innov.	Total tuned water by dams / Total assets of dams
24	Cust.	Mean education of customers	47	Innov.	Total investment on R & *D*

Table 2. Inputs and outputs data for 10 sub-organization of Kermanshah Water Regional Org.

	DMU	**X_1**	**X_2**	**X_3**	**X_4**	**X_5**	**X_6**	**X_7**	
1	DMU_1	46963	54	990	169934.1	75357	273600	16	
2	DMU_2	37570.4	9	99	118953.87	52749.9	164160	16	
3	DMU_3	16437.05	12.6	264	101960.46	45214.2	68400	14	
4	DMU_4	16437.05	32.4	330	33986.82	33910.65	54720	14	
5	DMU_5	18785.2	7.92	231	254901.15	22607.1	76608	14	
6	DMU_6	28177.8	6.48	198	169934.1	33910.65	109440	16	
7	DMU_7	37570.4	14.04	264	339868.2	15071.4	191520	16	
8	DMU_8	11740.75	16.74	330	254901.15	36171.36	54720	14	
9	DMU_9	7044.45	13.68	429	169934.1	37678.5	41040	12	
10	DMU_{10}	14088.9	13.14	165	84967.05	16578.54	27360	14	
	Max	46963	54	990	339868.2	75357	273600	16	
	Min	7044.45	6.48	99	33986.82	15071.4	27360	12	
	DMU	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8
1	DMU_1	3	0.148148148	0.007595767	9.185965736	0.34	0.508632244	0.86	16
2	DMU_2	0.75	0.333333333	0.005086451	6.450145506	0.2	0.537696944	0.56	16
3	DMU_3	0.4	0.047619048	0.00356536	9.505477587	0.23	0.406905795	0.57	14
4	DMU_4	0.333333333	0.032716049	0.00604561	2.376369397	0.19	0.565146938	0.39	14
5	DMU_5	0.514705882	0.116161616	0.0042048	7.311905836	0.26	0.339088163	0.56	14
6	DMU_6	0.384615385	0.114197531	0.002351071	4.558749455	0.39	0.429511673	0.67	16
7	DMU_7	0.133333333	0.196581197	0.006103741	10.04864774	0.23	1.449601895	0.56	16
8	DMU_8	0.609756098	0.05734767	0.006076614	9.820710263	0.19	0.635790305	0.48	14
9	DMU_9	0.928571429	0.097953216	0.00795747	3.830045914	0.18	0.345869926	0.56	12
10	DMU_{10}	0.304878049	0.04718417	0.004702141	4.616946257	0.25	0.439273302	0.45	14
	Max	3	0.333333333	0.00795747	10.04864774	0.39	1.449601895	0.86	16
	Min	0.133333333	0.032716049	0.002351071	2.376369397	0.18	0.339088163	0.39	12

Table 3. DEA Results

	DMU	φ*(ADMU)	ϴ*(IDMU)	RC	rank
1	DMU_1	1	1	0.0792	4
2	DMU_2	1.5478	1	0.1237	1
3	DMU_3	1	0.6503	0.0767	7
4	DMU_4	1	0.5968	0.0763	8
5	DMU_5	1	0.7576	0.0775	6
6	DMU_6	1	0.5958	0.0763	9
7	DMU_7	1	0.4565	0.0754	10
8	DMU_8	1	0.8932	0.0784	5
9	DMU_9	1.1951	1	0.0956	3
10	DMU_{10}	1.3021	1	0.1043	2
11	IDMU	-	10.9358	-	-
12	ADMU	0.1449	-	-	-
			$\epsilon = 0$		

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