



Case Study

Integrated performance evaluation method study and performance based department ranking: a case study



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Abstract

Enterprise companies, which make future strategic plan, need to view overall performance. In this direction, monitoring decision-making unit (DMU) performances is a critical issue. Therefore, it should be fair and consistent performance evaluation and prepared open and clear reports. To handle with these requirements, this study focusses on establishing a comprehensive method of performance evaluations (PE). Five main stages exist as a framework of the study. Firstly, right PE tool are selected in terms of strategic frame of companies. In this study, we examine balanced scorecard (BSC) approach that considers not only financial but also non-financial topics to watch overall performance. BSC has key performance indicators (KPI) that show objectives and actualizations belonging to related DMU, and BSC also provides proper and summary reports including different perspectives. The next step is determination of KPI's weights. Analytic hierarchy process (AHP) is applied to determine KPI priorities. Because BSC evaluates DMU'S separately, it does not provide satisfied comparison among different DMU's. In here, we propose data envelopment analyses (DEA) that is linear program based non-parametric approach. However, DEA works correctly for only homogeneous DMU's. As a third step, classification process is applied to ensure homogeneity. Then, using BSC KPI's as outputs and DMU budgets as input, DEA model is run for each class. As a last step, we separate DMUs into categories using efficiency score obtained from fourth stage. To determine category numbers, Hierarchical Clustering Analyze (AHCA) method is used and group elements are selected with applying K-Means Clustering Analyze technique. At the end, a case study is given to show how developed model is applied within a company that uses only BSC tool for PE currently. It could be said that this integrated methodology is more efficient and reliable for decision-making process.

Keywords Performance evaluation · Balanced scorecard · Data envelopment analyze · Clustering analyze

1 Introduction

In recent years, global competition enforces companies measuring and management of performance more than past because today higher numbers of competitors exist, so details determine the success. Therefore, upper management of companies should be careful more while taking important decisions. However, if they do not consider into company overall capabilities, strengths or weakness,

their success chances get worse. Therefore, they want to view state of affair. This is possible only with following strategic goals compliance.

Strategic goals determine the company direction, so companies spend more time to establish right strategy to obtain long run success. In this direction, they need to trace compliance of the strategy. It is one of main consideration for companies. The other related topic is that follow-up the goals or actualization of them are not only

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management issue but also whole employees. Sub-departments or branches should also act in scope of the goals. However, departments or employees do not interiorize easily. Therefore, a requirement appears to focus targets by dividing tasked oriented goals related to firm objectives.

In order to report these strategic goal compliance level, different types of performance evaluation tools (PETs) are developed in the literature. Using these tools, firms could measure actual performance of the goals, reflects strengths and weakness. From upper management to lowest hierarchical employee, similar methods should be applied to create performance management culture. It requires to develop alive, consistent, easy tracing.

On the other hand, PETs also ensure both overall and related performance measurements. If sub-departments show insufficient performance then company takes improvement action to enforce with some actions, hiring employee, increasing resources for example. In contrast, when a department demonstrates higher level of success, then it should be awarded to hold up motivation.

Moreover, choosing right performance evaluation strategy supports decision making processes. It facilitates review master plan continuously, making investments, eliminate bottlenecks and improvements, determining real objectives and increase employee motivation levels.

This study is the result of the idea how the performance could be managed comprehensively. Therefore, we propose a general performance management approach including effectivity and efficiency aspects. BSC and AHP provide to watch effectivity of the departments and satisfy strategical and operational tracking. On the other hand, DEA and Clustering techniques ensure to measure departments efficiency and compare them. Grouping departments ensure to solve problems for low-performed departments and award for high-performed departments. As a result, a pilot study is applied for an enterprise company, and results are shared in the study.

In the next chapters, related literature review is presented. After, determined methods are introduces to understand the methodology. To demonstrate working mechanism of the developed methodology, a pilot study is shown. Furthermore, we discuss the results and comment on conclusion. Reference studies could be obtained at the end of the paper.

2 Literature review

In this study, we examined more than 30 studies that has been published for recent years mostly. We consider the different aspects of the problem and combine our findings to develop new comprehensive method.

In the literature, performance evaluation issue appeared long time ago. Until today there were thousands of studies to cover the necessities with many different tools. It is important point is that Ercil [1] says PETs should be chosen in terms of company strategy. According to Ercil [1], three types of theorem, Billiard, Football and Sail, exist for a business with respect to four aspects, environment, structure, interaction and competition. For example, a business strategy is in conformance with Football approach, it could be said that, its environment is static, organization structure is complex, interaction level is multisided, and it is directly affected by the competition. For the football theorem, trend analyses and forecasting techniques are advised to manage the performance, and SMART, BSC or any other similar tools are suitable.

As a strategic performance management, we examined BSC approached. Kaplan and Norton [2] introduced BSC firstly. BSC has four dimension, Finance, Customer, Internal Process, Learning & Growth. Using BSC provides balanced performance management, measuring departments' performance in terms of strategic goals and easy understandable reports for upper management. Kala and Bagri [3] and Neves and Lourenco [4] says non-financial issues are as important as financial issues and BSC provides balance management. Moreover, Güner [5] claimed that Non-Financial issues are as important as financial issues. Therefore, non-financial issues are called as premise KPIs, and financials are posterior. Güner [5] also mentioned about easy report functionality of BSC because different types of KPIs could be reported by BSC. Anugrah et al. [6] discussed that BSC and EFQM are more suitable model than Performance Pyramid, Performance Prism, KBEMS according to strategic management approach. They also claim that AHP could be used to determine KPI weights within the BSC.

Sehhat et al. [7], Önder et al. [8], Tunay and Akhisar [9] used AHP and TOPSIS methods together to evaluate performance. They used AHP to determine KPI weights and TOPSIS to rank DMUs. They imply past performance evaluation methods only consider financial issues, but other issues are also important for long term success. Senel [10] also studied on integrated AHP and TOPSIS methods. He said that MCDM methods are technically successful, but they ignore DMU differences and resource usage. In addition, MCDM methods work for limited numbers of DMU. Seçme et al. [11] took into consideration non-financial issues. They used FAHP which consider decision maker sights to determine KPI weights and TOPSIS to rank. Furthermore, Çağıl [12] studied performance evaluation on finance sector using by ELECTRE which makes comparison among decision making units (DMU's) in terms of dominance relations.

Different studies exist for the right numbers of KPI in the literature. Storey [13] said that a few KPIs are enough. Niven [14] suggested different numbers according to dimension 3 or 4 for Finance, 5–8 Customer, 5–10 for Internal Process, 3–6 for Learning and Growth. Kaplan and Norton [15] claimed that 15–25 KPIs are enough in a report. Frigo and Krumwiede [16] discussed that 9 or 10 KPIs should be reported but large numbers of KPI could be followed. Furthermore, Golpîra [17] determined KPI priorities using by “5 Point Likert” and “Factor Analyze”. Seven KPIs are determined as outputs. Related inputs are chosen related to outputs, and groups are ranked by K-Means Clustering techniques. Najafi and Aryanezhad [18] used AHP to determine KPI weights. They categorized BSC KPIs as input and output for DEA. They also explained differences between BSC and DEA.

Many studies include both BSC and DEA methods. Kádárová et al. [19] showed that BSC is enough for Compliance with Strategic Goals and Whole Picture of company, but not sufficient for related performance, resource usage. Therefore, to deal with that, it is suggested to integrate BSC and DEA. Dolasinski et al. [20] claimed that because BSC does not provide department rankings, it should be integrated by DEA. They used output-oriented DEA technique, including BSC KPIs as outputs, to determine smart objectives for ineffective DMUs. Furthermore, in the study of Cheng et al. [21], DMUs are evaluated for each BSC dimensions, providing KPIs, by DEA. It shows strengths and weakness aspects. Basso et al. [22] classified BSC KPIs as input and output. DMUs are evaluated for each BSC dimension by DEA. After, according to first step, second DEA is applied to calculate overall performance.

Before applying DEA methods, one of the major rule is the homogeneity for each DEA groups. Samoilenko and Osei-Bryson [23] recommended management view to classify DMUs. Okursoy and Özdemir [24] used K-Means technique to determine class members. After, each class are evaluated by CCR and BCC. They showed that evaluation with classification leads better results than evaluation without classification. Gomes et al. [25] remarked that technology and infrastructure could be used for classification. In the study, after first application of DEA for each class, classes are compared with DEA also. Obtained efficiency scores are used as adjustment factor. Acer and Timor [26] applied output-oriented DEA to maximize output with determined input level. They ensured homogeneity Single-Link Hierarchical Clustering and Wards Clustering (among clusters).

Rouyendegh [27] used DEA method to measure efficiency. DEA results (efficient/not efficient) are not enough for fair comparison. Using results, Intuonistic Fuzzy TOPSIS(IFT) method is applied to full ranking. Thanks to IFT, decision makers could affect ranking

process. Pala and Aksaraylı [28] applied input oriented CCR to determine optimal input level with fixed output level, and clustered DMUs by Hierarchical Clustering. Kassani et al. [29] also used DEA for performance evaluation. They determine cluster numbers by Agglomerative Hierarchical Clustering Analyze (AHCA) and cluster by Self Organizing Map (SOM) technique. Omrani et al. [30] ensures homogeneity using by Fuzzy C-Means (FCM) Clustering Analyze. Shapley and Core Values corrected the results. Girginer et al. [31] claimed that DEA and Clustering methods are applied separately, and results show similarity.

We categorized literature reviewed in terms of performance evaluation method. It could be seen at the Table 1.

Table 1 Literature review categorization

Authors/contents	MCDM	BSC	DEA	Clustering
Çağıl [12]	X			
Seçme et al. [11]	X			
Sehhat et al. [7]	X			
Önder et al. [8]	X			
Tunay and Akhisar [9]	X			
Senel [10]	X	X		
Ercil [1]		X		
Kaplan and Norton [2]		X		
Kala and Bagri [3]		X		
Neves and Lourenco [4]		X		
Güner [5]		X		
Anugrah et al. [6]	X	X		
Epstein and Wisner [34: 5]		X		
Storey [12: 325]		X		
Niven [14: 151]		X		
Kaplan and Norton [15: 201]		X		
Frigo and Krumwiede [16: 51]		X		
Golpira [17]		X	X	X
Najafi and Aryanezhad [18]	X	X	X	
Kádárová et al. [19]		X	X	
Dolasinski et al. [20]		X	X	
Cheng et al. [21]		X	X	
Basso et al. [22]		X	X	
Samoilenko and Osei-Bryson [23]			X	X
Okursoy and Özdemir [24]			X	X
Gomes et al. [25]			X	X
Acer and Timor [26]			X	X
Pala et al. [28]			X	X
Kassani et al. [29]			X	X
Omrani et al. [30]			X	X
Girginer et al. [31]			X	X
Rouyendegh [27]			X	X

3 Methodology

5 step solution methodology is proposed to cover all demands on performance management for a company. BSC is the first step of the proposal. Then, AHP is used for determination of KPI weights. To ensure homogeneity among DMUs, classification step is applied thirdly. After, DEA method is run for DMU class to compare and rank the departments. Lastly, DMUs are categorized by the Hierarchical and K-Means Clustering Analysis techniques in terms of efficiency scores.

3.1 Balanced scorecard (BSC)

BSC tool is developed by Kaplan and Norton [2]. They claimed that if a business do not balance different management aspects then it will not arrive the long run success. Although many studies on performance management focus only finance issues, they also recommend

focusing on Customer, Internal Process and Learning and Growth dimensions (Fig. 1).

BSC has four dimensions and each dimension includes dimensions, KPIs, evaluation term, strategic goal, actualization score, KPI weight, KPI direction, objective scores, unit of measurement (UoM), KPI performance score and department performance score within only one report illustrated at Fig. 2.

3.2 Analytic hierarchy process (AHP)

AHP procedure discovered by Saaty [32] is mainly used to compare DMUs and determine prioritization weights in terms of relative KPIs.

In the procedure, similar KPIs are grouped firstly because less number of decision items lead to more accurate results. Then, Using Saaty's one to nine scale, pairwise comparison is made (Table 2).

After calculations, pairwise comparison matrix is created. Then using pairwise comparison matrix, Eigenvector

Fig. 1 BSC dimensions

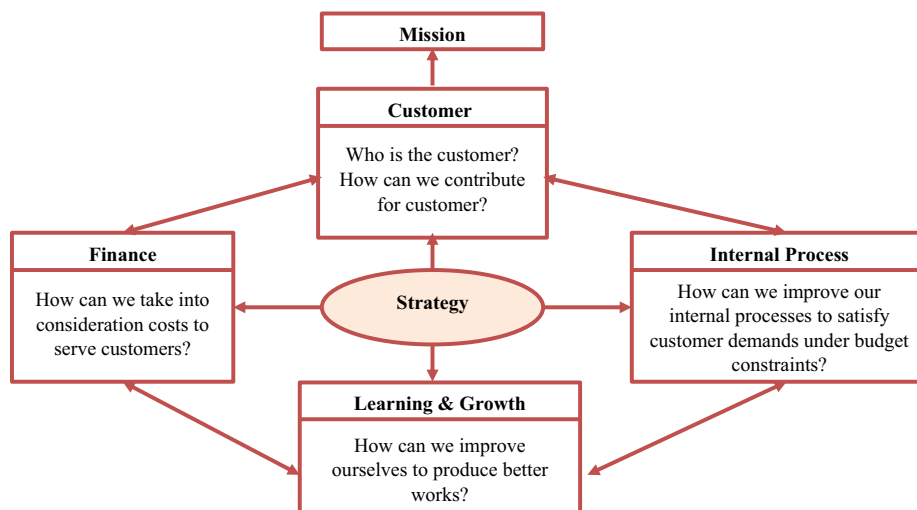


Fig. 2 Sample BSC

Ara.18		Strategic Goal	Actual	Weight	Direction	Objective	UoM	Score
• FİNANSAL BOYUT								94,50%
• Gösterge 1		Dimension			≤		TL	93,25%
• MÜŞTERİ BOYUTU								
• Gösterge 2		KPI			≤		Mday	100,00%
• İŞ SONUÇLARI BOYUTU								
• Gösterge 3					≤		Mday	100,00%
• ÇALIŞAN BOYUTU								
• Gösterge 4					≤		%	89,01%
• Gösterge 5					≥		%	100,00%

Table 2 One to nine scale of Saaty

Priority	Lowest				Normal				Highest
Rank	1	2	3	4	5	6	7	8	9

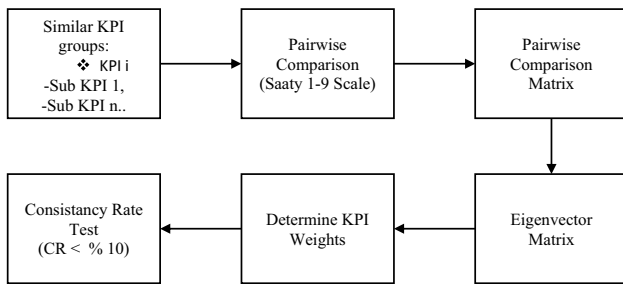


Fig. 3 AHP procedure

Matrix values are measured. With respect to some calculations, weights of KPIs are determined lastly.

After determination of the final scores, it is needed to be corrected the methodology results. Therefore, the Consistency Rate Test is applied. When the consistency rate is less than ten percent, it could be said that the results are consistent. Otherwise, the process should be revised.

A flow chart of the process is given at the Fig. 3.

3.3 Classification

For the next step, to apply DEA procedure, DMUs should be homogene. It means that they have similar job tasks. Therefore, we classify DMUs in terms of DMU job title or specialty area, Manufacturing Engineering, Program Management, Production Planning, etc.

The most important issue to collect the right information about DMUs job tasks. Different methods could be applied. For example, company Information management system gives the necessity information or decision maker can decide which DMUs would be evaluated together. On the other hand, clustering techniques are also used to classification in the literature.

3.4 Data envelopment analysis (DEA)

Data envelopment analysis (DEA) is developed by Charnes et al. [33]. This non-parametric method, based on linear programming, is generally used for measuring and ranking performance of related DMUs.

The original formula of DEA is given from Formula 1 to Formula 4. Model elements include parameters and decision variables for “n” DMUs. Parameters consist of “m” which is the number of inputs, “s” which is the number of outputs, x_{ij} which is the consumed input amount, y_{ij} which is the produced output amount for jth DMU. On the

other hand, u_r and v_i are the decision variables that mean weights for inputs and outputs. In this direction, the model aims maximum outputs using minimum inputs under constraint that provides efficiency score do not pass the maximum efficiency score of 1.

$$Max \left\{ h_0 = \frac{\sum_{r=1}^s u_r y_{r0}}{\sum_{i=1}^m v_i x_{i0}} \right\} \tag{1}$$

$$\frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1 \quad j = 1 \dots n \tag{2}$$

$$u_r \geq 0 \quad r = 1 \dots s \tag{3}$$

$$v_i \geq 0 \quad i = 1 \dots m \tag{4}$$

To solve this model, it was linearized by the Simplex algorithm, from Formula 5 to Formula 9. This new model is called as CCR because Charnes, Cooper and Rhodes discovered first [33]. In this model, h_0 is the objective value which shows the efficiency of observed DMU 0. When inputs of observed DMU are equal to 1, then model will be output oriented and h_0 will maximize. In contrast, when outputs are equal to 1, then model will be input oriented and h_0 will minimize.

$$Max h_0 = \sum_{r=1}^s u_r y_{r0} \tag{5}$$

$$\sum_{i=1}^m v_i x_{i0} = 1 \tag{6}$$

$$\sum_{r=1}^s u_r y_{rj} - \sum_{i=1}^m v_i x_{ij} \leq 0 \quad j = 1 \dots n \tag{7}$$

$$u_r \geq 0 \quad r = 1 \dots s \tag{8}$$

$$v_i \geq 0 \quad i = 1 \dots m \tag{9}$$

3.5 Clustering

In the study, we propose a solution to another necessity of the performance management issue, grouping. Since low performed departments need improvements

and high performed departments want to get rewarded, fair categorization should be made. In terms of literature review, K-Means Clustering is selected the most applicable method for our problem. To apply K-Means Clustering, we used Single-Linkage Agglomerative Hierarchical Clustering Analyze to determine “k” used for category numbers.

In the study, there exists two types of clustering. Firstly, Single-Linkage Agglomerative Hierarchical Clustering Analyze is applied.

- Whole data are obtained as one cluster.
- Clusters are combined according to distances among clusters.
- Combination process is made with Nearest Neighborhood distance and determined unit of measure such as Euclidean distance, Chebuchev distance, etc.
- Process continues until determined iteration number or obtained determined cluster number.

In the next step, using determined number of cluster, K-Means Clustering is used to determine cluster members.

- Firstly, determine number of clusters “k”.
- Randomly select k data points for the clusters.
- Compute the sum of the squared distance w/w data points and clusters
- Assign each data point to the closest cluster.
- Process continues until determined iteration number or no change to clusters.

4 Case study

Developed model was applied for an Enterprise Company. As a pilot, we selected five similar departments with eight KPIs to create a performance management methodology and compare their performance.

4.1 BSC

When company is examined, given at the Fig. 4, in terms of strategic theorem approach, we say that company is in the Football Theorem. Therefore, we propose BSC approach. In the Table 3, there exist KPI results for five departments.

4.2 AHP

Pairwise Comparison Matrix is prepared as shown at the Table 4 in terms of specialist views. The study is run by Microsoft Excel. Results are shared at the Table 5. Consistency rate of the AHP procedure is the 0.03 that is sufficient for correction (Table 5).

4.3 Classification

Since Pilot departments are similar, then classification is not necessary. DMUs are homogene.

4.4 DEA

DEA results are given at the table below. Output oriented procedure is applied. Budget rates are inputs and BSC KPIs

Fig. 4 Strategic theorem examination

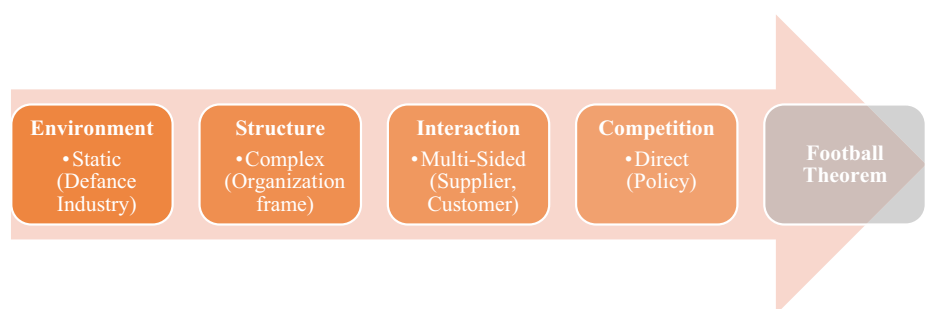


Table 3 BSC results

Dept./KPI	G1	G2	G3	G4	G5	G6	G7	G8
B1	0.54	0.03	0.56	0.97	0.99	0.89	0.97	1
B2	0.81	1	1	0.75	0.9	0.85	0.84	0.61
B3	0.98	1	1	0.97	0.65	0.61	0.75	1
B4	0.44	0.26	0.47	0.8	0	0.67	0.72	0.5
B5	0.6	1	0.82	1	0.635	0.755	0.92	0.5

Table 4 Pairwise comparison matrix

KPI	G1	G2	G3	G4	G5	G6	G7	G8
G1	1	6	8	4	8	8	6	6
G2	1/6	1	1	1/2	2	3	2	2
G3	1/8	1	1	1/4	1	1	1/2	1/2
G4	1/4	2	4	1	4	5	3	3
G5	1/8	1/2	1	1/4	1	1	1/2	1/2
G6	1/8	1/3	1	1/5	1	1	1	1
G7	1/6	1/2	2	1/3	2	1	1	1
G8	1/6	1/2	2	1/3	2	1	1	1

Table 5 AHP results

KPI	Weights (%)
G1	44.0
G2	9.9
G3	4.9
G4	18.3
G5	4.4
G6	4.9
G7	6.8
G8	6.8

are outputs. The study is run by CPLEX OPL. Process Time: 1 s (Table 6).

4.5 Clustering

4.5.1 Single-linkage AHCA

DEA efficiency results are used as inputs. The study is run by IBM SPSS Statistics Subscription. Single Linkage (Nearest Neighbor) method and «Squared Euclidean» distance is used. With respect to Single-Linkage AHCA, 3 category is the appropriate for performance grouping. Dendrogram analyze helps to see how the categorization is made (Fig. 5).

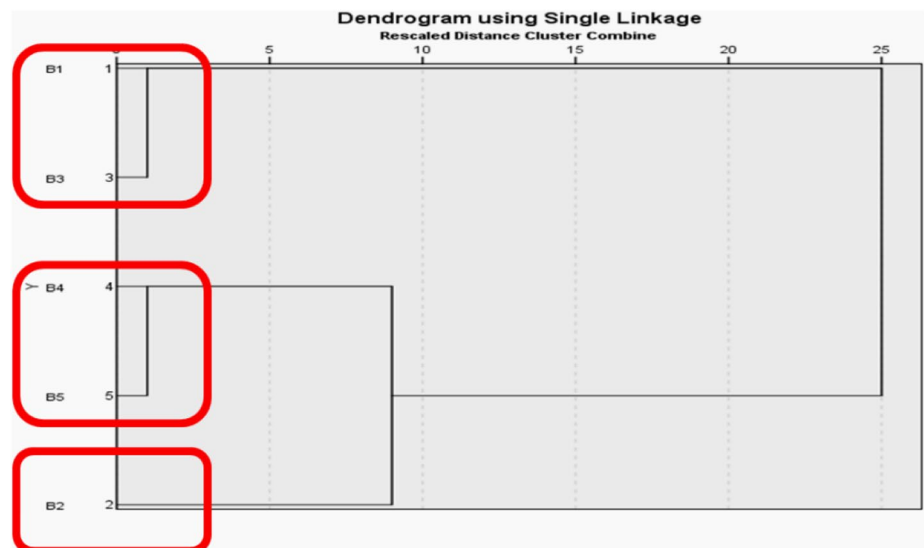
Table 6 DEA results

Dept.	Efficiency	Reference set	Efficiency scores
B1	Not efficient	B3	1.01
B2	Not efficient	B3	1.21
B3*	Efficient	–	1
B4	Not efficient	B3	1.33
B5	Not efficient	B3	1.36

4.5.2 K-means clustering analyse

Although Single-Linkage AHCA method is also used for categorization, we only use to determine “k” number because similar problems are solved by K-Means

Fig. 5 Dendrogram analyze



Clustering Analyse in the literature. As a result of previous steps, “k” equal to 3 obtained by AHCA and DEA efficiency scores are used as inputs. The study is run by IBM SPSS Statistics Subscription (Table 7).

As a result of case study, whole results are shown at the Table 8.

5 Conclusion

In this paper, we propose comprehensive performance evaluation methodology to cover all performance evaluation requirements for enterprise companies having sub-departments or branches. It can be considered that this study exists two major concern, effectivity and efficiency. BSC approach is used as a strategical performance management because BSC provides to see whole picture of company/department performance within one report. BSC includes different types of dimensions, Finance, Customer, Internal Operations and Learning and Growth basically, and each dimension has KPIs for evaluation. To weight these KPIs, AHP is used. The first two step reflect the effectivity scores which mean individual performance of departments. Furthermore, before comparing departments/DMUs to detect efficiency scores, classification stage is applied thirdly to provide homogeneity among DMUs. After, we apply DEA to measure relative performance. DEA used resource consumptions as an input and Thanks to DEA, departments are

Third and Fourth stage ensures to efficiency scores. At the end, department are categorized in terms of success groups created by clustering analyses. This study is implemented for an enterprise company and result are shared within the study.

According to results, we present the effectivity and efficiency oriented rankings for making comparison. In general, firms make effectivity analyze following some KPI results for example weighted BSC score. However, when we take into consideration resource consumption (budget) and related performance, although department numbers are low, there are important changes on the ranks and group members. A summary table is given below. Both group members and DMU rankings changed after application DEA and Clustering methods. If it is preferred, we recommend both effectivity and efficiency ranks. For instance, firms could prefer average category of both effectivity and efficiency rankings. B1 is in the C category based on Effectivity and A category based on Efficiency so it could be accepted B category (Table 9).

In the next studies, other DEA methods (Fixed weight CCR-O, BCC, etc.) will be tried and results will be compared. Moreover, Different techniques (fuzzy C-Means, Game Theory) will be studied for classification and clustering. Results will be examined. All in all, a decision-making platform will be developed to apply real sized problems.

Table 7 Cluster membership analyze

Cluster membership			
Case number	Birim	Cluster	Distance
1	B1	3	0.010
2	B2	2	0.000
3	B3	3	0.000
4	B4	1	0.030
5	B5	1	0.000

Table 9 Result comparison

Rank	Effectivity		Efficiency	
	Dept.	Group	Dept.	Group
1	B3	A	B3	A
2	B2	B	B1	A
3	B5	B	B2	B
4	B1	C	B4	C
5	B4	C	B5	C

Table 8 General results

Dept.	BSC-AHP Weighted BSC Score (%)	DEA			Clustering	
		Efficiency	Referance set	Score	Cluster	Group
B1	67	Not efficient	B3	1.01	3	A
B2	82	Not efficient	B3	1.21	2	B
B3*	93	Efficient	–	1	3	A
B4	50	Not efficient	B3	1.33	1	C
B5	75	Not efficient	B3	1.36	1	C

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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