Journal Pre-proof

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PII: S0149-7189(18)30396-3

DOI: https://doi.org/10.1016/j.evalprogplan.2019.101762

Reference: EPP 101762

To appear in: *Evaluation and Program Planning*

Received Date: 12 December 2018

Revised Date: 6 October 2019

Accepted Date: 20 November 2019

Please cite this article as: Sarraf F, Nejad SH, Improving performance evaluation based on balanced scorecard with grey relational analysis and data envelopment analysis approaches: Case study in water and wastewater companies, *Evaluation and Program Planning* (2019), doi: https://doi.org/10.1016/j.evalprogplan.2019.101762

Improving performance evaluation based on balanced scorecard with grey relational analysis and data envelopment analysis approaches: Case study in water and wastewater companies

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Highlights

- We compared DEA and grey relational analysis approaches based on balance scorecard in water and wastewater companies.
- Grey relational analysis is proposed to measure the performance of water and wastewater companies.
- This method allows managers to identify weaknesses of the organization to improve the performance for each perspective in balanced scorecard.

ABSTRACT

Various approaches are used to measure the firms' performance. Grey relational analysis is one of the multiple attribute decision-making methods and data envelopment analysis is used to calculate the efficiency. Regarding the importance of water and wastewater companies' services, the present study, evaluates the performance and rank these companies by using grey relational analysis and data envelopment analysis approaches based on balanced scorecard criteria. Besides, balanced scorecard considers all levels of organization. In this research, statistical population includes thirty-five municipal water and wastewater companies in Iran for the year 2017. In order to ascertain grey relational grade, fuzzy normalization method was used then by subtracting normalized numbers from one, reference sequences obtained and in the next step, grey relational coefficient was calculated and finally, grey relational grade was determined by multiplying relative weight from Shannon entropy to relational coefficients. In order to assess companies' efficiency in data envelopment analysis, after ascertaining input and output indices, with the assumption of constant returns to scale and output-oriented viewpoint, the efficiency scores were calculated. Also, to rank efficient units Anderson-

Petersen model implemented. Results demonstrated that, grey relational analysis is a more accurate method to measure the performance of water and wastewater companies.

Key Words: Grey Relational Analysis, Data Envelopment Analysis, Balanced Scorecard, Water and Wastewater Companies

1. Introduction

Performance measurement defined as the process of quantifying the efficiency and effectiveness of a past action (Neely, Adams, & Kennerley, 2002). It has been used extensively in public sector in the last two decades (Speklé & Verbeeten, 2014). In many countries, Public sector is responsible for the major part of water and sewage services (Consciência Silvestre, 2012). Moreover, efficient management of water firms is necessary for sustainable municipal water processes (Molinos-Senante, Porcher, & Maziotis, 2018). So, assessing the performance of water industry is needed broadly due to its environmental, economic and social benefits (Nogueira Vilanova, Magalhães Filho, & Perrella Balestieri, 2015).

One of the performance measurement methods that have been considered extensively in the recent years is balanced scorecard (BSC). BSC is a strategic planning tool developed by Kaplan and Norton in 1992. It is a promising approach for providing a deep and precise understanding of the past and current status of companies. BSC consists both financial and non-financial aspects (Glykas, Valiris, & Chytas, 2011; Dehghanbaghi, Varmazyar, & Afkhami, 2016).

In order to measure the performance of an organization, various criteria are used: such as effectiveness, efficiency, productivity, profitability, etc. In many complicated systems, many parameters affect the system simultaneously. Therefore, in decision-making process we encounter multiple criteria. Various methods used in solving multi criteria tasks such as analytic hierarchy process, the technique for order of preference by similarity to ideal solution (TOPSIS), data envelopment analysis and so on (Yoon & Hwang, 1995). However, sometimes the grey relationships between indicators, lack of sufficient and clear information or difficulty of collecting experimental and practical data are the problems researchers face in some systems. Thus, to avoid data aggregation and wasting resources, grey relational analysis is an appropriate approach in these conditions (Lin, Chen, & Liu, 2004).

In addition, data envelopment analysis is a commonly non-parametric method to calculate the efficiency of decision-making units (DMU's). Efficiency means how well an organization uses its inputs to achieve outputs (Charnes, Cooper, & Rhodes, 1978).

The purpose of this paper is to evaluate performance of water and wastewater companies with data envelopment analysis and grey relational analysis methods based on balanced scorecard criteria; and by comparing results obtained from two methods, better approach proposed to assess the these companies. Finally some recommendations are proposed to enhance efficiency and sustainability in water sector.

2. Literature review

2.1. Balance Score Card (BSC)

Traditional Performance measurement methods mainly focused on financial goals and other aspects of organization were not considered too much. In 1992, Kaplan and Norton proposed Balanced Scorecard (BSC) at “Harvard Business Review”. A comprehensive approach helps organizations to implement the strategy management system. BSC evaluates firm’s performance through four perspectives: financial, customer, internal, and learning and growth. These four perspectives have cause-and-effect relationships. It means that improving customer satisfaction, innovative products, using new technology and employee training can affect financial performance. BSC is a multi-dimensional method that moves from traditional financial indices towards a balanced structure (financial and non-financial, short-term and long-term objectives) (Kaplan & Norton, 1996). BSC perspectives defined as follows:

2.1.1. Financial perspective

Financial perspective is a dominant aspect that is related to firm's profitability. It shows company's status in the past. To measure financial elements, operating income, sales growth, returns on investment and so on are utilized. This aspect only shows the status of company in the past, whereas balanced scorecard is a past and prospective strategic plan. As mentioned above, every measurement in balanced scorecard is a part of cause-and-effect relation and ending in financial aims. It shoes the effectiveness of three other aspects. In many firms, financial issues like risk reduction, productivity, increase revenue can come up with the essential connection among four aspects (Niven, 2002).

2.1.2. Customer perspective

Customer perspective considers to the measures related targeting customers and market share. Managers should recognize these two elements. It enables them to create strategies in accordance with target customers in terms of their needs and expectations. Some of outcome measures are market share, customer satisfaction, retention, and acquisition (Agrawal, Singh, & Murtaza, 2016).

2.1.3. Internal operations

Internal operations perspective deals with operational activities to satisfy customer expectations and demands. These could involve short-term and long-term objectives. Organizations should identify the internal processes that have great effects on customers and shareholders satisfaction. Organizations ought to consider to delivery to retain customers in target market. Also using technology and waste reduction, productivity, after-sales services and innovation are part of value chain activities in preserving current and future needs (Kalender & Vayvay, 2016; Kaplan & Norton, 1992).

2.1.4. Company learning and growth perspective

Learning and growth component is the most impalpable performance driver. It focuses on culture and staff skills. In order to improve organization performance, managers are responsible for developing employee capabilities. These measures include employee training, growth, satisfaction and enhancement. (Agrawal, Singh, & Murtaza, 2016). The BSC four categories illustrated in Figure 1.

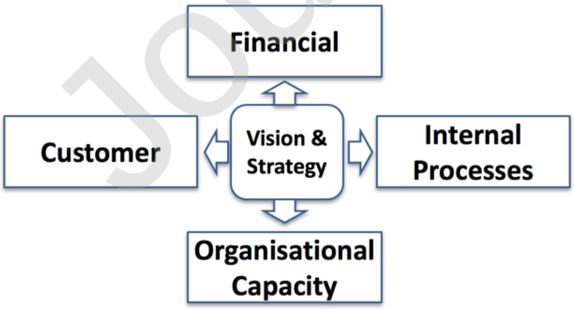

Figure. 1. Four Perspectives of Balanced Scorecard (Kaplan & Norton, 1996)

2.2. Grey theory

During decision-making process, decision makers try to collect information as much as possible through surveys. So, for reaching a prudent decision, gathering all information would be impossible; decisions are usually made in a grey process, without the whole information (Deng, 1989). Grey system theory first proposed by Professor Deng in 1982 to deal with situations with partly known and partly unknown information. Many systems classified into three types (white system, black system and grey system). Information in white systems is known. A system with unknown information is a black system and a system whose information is not completely clear or unclear is grey system (Lin, Chen, & Liu, 2004). Actually, grey system is an assessment tool in case there is uncertain and incomplete data. Grey theory used in many fields such as engineering, management and so on. There are some techniques including grey relational analysis, grey control, grey forecasting and decision-making. The concept of grey systems is shown in Figure 2.

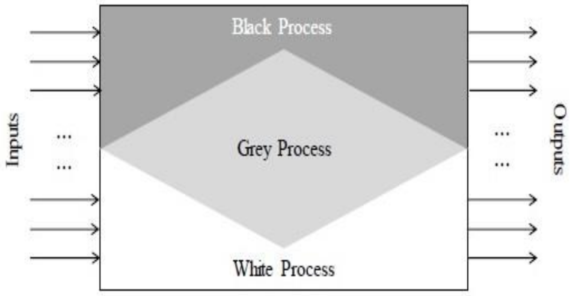

Figure. 2. Grey systems (Lin, Chen, & Liu, 2004)

Grey relational analysis (GRA) introduced by Professor Deng from Huazhong university of Science and Technology, is the most widely used part of grey system theory. GRA is appropriate for solving complicated interrelationships between multiple factors and variables. It is also used in solving Multiple Attribute Decision Making (MADM) problems. GRA solves these problems by integrating various performance attribute values in one single value (Kuo, Yang, & Huang, 2008). Detailed grey relational analysis procedures presented in the following section:

2.2.1. Data normalization

There are four steps in GRA method. The first step is data pre-processing. It is usually required when a data sequence unit is different from others. Data pre-processing is a method of transferring the original data sequence to a comparable sequence. So, to avoid incorrect results in analysis, data must be normalized and become free from any unit before applying the other steps. This processing is called grey relational generation (Hisa, Chen, & Chang, 2004). In order to normalize data for GRA few formulas are employed. The determination of which formula should be used, is depend on the characteristics of data sequences, for instance: Equation (1) is used for the higher the better attributes and equation (2) is used for the lower the better attributes.

$$x^{*}(k) = \frac{x_i^0 - \min x_i^0(k)}{\max x_i^0 - \min x_i^0(k)} \qquad (1)$$

$$x^{*}(k) = \frac{\max x_i^0(k) - x_i^0(k)}{\max x_i^0 - \min x_i^0(k)} \qquad (2)$$

Where,

$i = 1,...m; \quad k = 1,...n.$

m is number of experimental data items

n is the number of parameters

$x_i^O(k)$ is the original sequence

$x_i^*(k)$ is the sequences after data preprocessing

$\min x_i^0(k)$ and $\max x_i^0(k)$ are the smallest and the largest value of $x_i^O(k)$

2.2.2. Reference sequences

After data normalization procedure, using Eq. (1) and (2) all values scaled between zero and one. Therefore, an alternative will be the best choice if all of its values are closest to or equal to one. (Kuo, Yang, & Huang, 2008).

2.2.3. Grey relational coefficient

In this step, grey relational coefficient is calculated. It shows degree of grey relation between the referential sequence and other calculated sequences. Deng (1989) proposed mathematical equation for grey relational coefficient as follows:

$$\xi_i(k) = \frac{\Delta\, min + \rho\Delta max}{\Delta_{0,i}(k) + \rho\Delta max} \qquad (3)$$

Where,

$\Delta_{0,i}$= Deviation sequences of the reference sequence and comparability sequence

$$\Delta_{0,j} = \left\| x_0^*(k) - x_i^*(k) \right\| \qquad (4)$$

$$\Delta\min = \min\min \left\| x_0^*(k) - x_j^*(k) \right\| \quad ; \forall j \epsilon i \forall k \qquad (5)$$

$$\Delta\max = \max\max \left\| x_0^*(k) - x_j^*(k) \right\| \quad ; \forall j \epsilon i \forall k \qquad (6)$$

x_0^* is the k the reference sequence, and x_i^* is the k comparative sequence and ρ is distinguished coefficient where ρ∈ [0,1] that can help make better distinction between normalized reference series and normalized comparative series. It could be adjusted by decision maker exercising judgment, and different distinguishing coefficients usually produce different results in GRA. In general, ρ is equal 0.5 because it offers moderate distinguishing effect and stability (Lin, Lu, & Lewis, 2007). Moreover, based on mathematic proof, the value change of ρ will only change the relational coefficient magnitude but it will not change grey relational grade ranking (Chiang, Tsai, & Wang, 2002).

2.2.4. Grey relational grade

Grey relational grade defined as the numerical measure of similarity between two sequences such as reference sequence and comparability sequence. Where *n* is the number of process responses. The grey relational grade distributed between zero and one. After averaging grey relational coefficients, grey relational grade obtained by using formula below:

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n} \xi_i(k) \qquad (7)$$

As mentioned before, the reference sequence x_0 (k) indicates the best performance that can be attaining among comparability sequences x_i (k). Therefore, if a comparability sequence has highest grey relational grade with reference sequence, it means that comparability sequence is the closest to reference sequence and that alternative has the best performance (Fung, 2003).

2.3. Shannon entropy weight

Entropy concept has been widely used in physical and social sciences. The idea of information entropy first proposed by Shannon in 1948 in his paper called a mathematical theory of communication. It can be considered as a criterion for uncertainty about an event related to a discrete probability distribution. Entropy measures the expected information contained in a certain message as opposed to the part of the message that is determined. Entropy idea can be employed in decision making, because it evaluates available contrasts in a range of data and explicates the intrinsic information that convey to decision maker (Hwang & Yoon, 1981). As an uncertainty measure of information volume in a system or process, Shannon entropy plays an important role in information theory. It indicates that the information volume of each piece of information is directly connected to its uncertainty degree. To ascertain weight through Shannon entropy, there are procedures that presented in the following:

Step 1 is the normalization of decision matrix arrays (performance indexes) to gain possible outcomes p_{ij}:

$$P_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}; \ \forall \mathrm{i,j} \tag{8}$$

Step 2 is computation of possible outcomes entropy measurement by using the following equation:

$$E_j = -k \sum_{i=1}^{m} [p_{ij} \ln p_{ij}]; \ \forall j \tag{9}$$

In which k = 1/Ln (m) and K is a constant.

$$d_j = 1 - E_j \quad ; \ \forall \mathrm{j} \tag{10}$$

Step 3 is defining of objective weight based on the entropy concept:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad ; \ \forall \mathrm{j} \tag{11}$$

Step 4 is calculating the general form of the entropy weight, if the decision maker allocates subjective weight w_j. By considering w_j, Eq. (11) transforms into the following:

$$w'_j = \frac{\lambda_j w_j}{\sum_{j=1}^{n} \lambda_j w_j} \quad ; \ \forall \mathrm{j} \tag{12}$$

In which subjective and objective weights (λ_j and w_j) are integrate to construct the general form of Shannon entropy weight w_j (Shannon, 1948).

2.4. Data envelopment analysis

Data envelopment analysis (DEA) is a widely known technique to measure efficiency among decision-making units (DMUs) (Charnes, Cooper, & Rhodes, 1978). DEA utilized widely in many sectors such as banking, transportation, agriculture and so on (Liu, Lu, Lu, & Lin, 2013). The basic efficiency measure in DEA was outputs to inputs ratio, but this was only applicable for a single input and output. In 1957, Farrell developed this basic concept and proposed efficiency frontier analysis (Farrell, 1957).

Twenty years later in 1978, Charnes, Cooper and Rhodes were able to convert the envelopment analysis concept from its graphical form to a linear programming model that does not limited the number of inputs or outputs. Their so-called CCR model measures all DMUs efficiency without assigning prior weights for inputs and outputs (Aldamak & Zolfaghari, 2017). The concept of CCR model assigns virtual weights to inputs and outputs and employs linear programming to determine DMUs maximum efficiency; this process repeated for all DMUs. CCR model presented in the following:

$$h_k = max\ \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}}$$

$$s.t.$$

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, j = 1,2,\ldots,n \qquad (13)$$

$$u_r \geq 0, v_i \geq 0$$

Where:

Y_{rk} = the amount of the r*th* output produced by the k*th* firm, x_{ik} = the amount of the i*th* input used by the k*th* firm, Y_{rj}= the amount of the r*th* output produced by the j*th* firm, x_{ij} = the amount of the i*th* input used by the j*th* firm, u_r = the weight given to the r*th* output, v_i = the weight given to the i*th* input, n= number of firms, s= number of outputs, m= number of inputs.

This model is based on the constant return to scale (CRS) assumption. The principle of CRS model is maximization of weighted sum of outputs to weighted sum of inputs ratio. Any firms compared to others should have an efficiency score 1 or less, with either zero or positive weights (Charnes, Cooper, & Rhodes, 1978).

DEA models have two orientations: input-oriented and output-oriented. Input-oriented models are used if a DMU can reduce its inputs while keeping the outputs at their current levels. Output-oriented emphasis on increase of outputs to improve efficiency while keeping the inputs at their current levels (Charnes & Cooper, 1985). CCR output-oriented linear programming model is as follows:

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

$$subject\ to:$$

$$\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} \geq 0 \quad j = 1, \ldots n \qquad (14)$$

$$\sum_{r=1}^{s} u_r y_{rk} = 1$$

$$u_r \geq 0, v_i \geq 0$$

2.4.1. Super-efficiency Model

Traditional CCR model has poor discrimination in comparing efficient DMUs. Super-efficiency technique proposed in 1993 by Andersen and Petersen to rank efficient units. In Andersen-Petersen (AP) method, efficient units could be ranked and their efficiency score would be greater than one while the score of inefficient DMUs remains the same (Alder, Friedman, & Sinuany-Stern, 2002; Andersen & Petersen, 1993). The output-oriented super-efficiency AP model described by the Formula below:

$$\begin{aligned}
&\min\ f_k \\
&\text{subject to:} \\
&\sum_{j=1, j\neq k}^{n} v_j x_{ij} \leq f_k x_{ik} \quad i = 1, \dots, m \\
&\sum_{j=1, j\neq k}^{n} v_j y_{rj} \geq y_{rk} \qquad r = 1, \dots, m \\
&v_j \geq 0; j = 1, \dots, n, j \neq k
\end{aligned} \tag{15}$$

2.5. Water and Wastewater Companies

Water and wastewater department established in the Ministry of Energy in 1989. The law of water and wastewater companies' formation enacted in 1990. Thirty companies were founded in different cities between 1990 and 1993. With the population growth and organizational structure expansion in some cities such as Tehran, Mashhad and …, other firms formed in the following years. The number of municipal water and wastewater firms increased to thirty-five and all of them are government-owned. Their main responsibilities are to build and develop the water supply networks and wastewater treatment systems based on national and international standards. From the main objectives of these companies, it can be mentioned to rising public awareness on water conservation, environmental principles, occupational safety and health program implementation, continuous improvement of organizational structure, human resources development by providing training courses, enhancing customer service quality and increase their satisfaction (NWWEC, 2012). In research methodology section, the names of companies, number of employees, number of customers shown in table 1.

On the subject of assessing the performance of water industry in Iran, it could be mentioned to Ebrahimi Nourali, Davoodabadi, & Pashazadeh (2014) research that measured the efficiency of 35 water & wastewater companies (WWCs) by using data envelopment analysis method from 2008 to 2011. They used operating costs, number of employees and number of water connections as inputs and volumes of water billed and number of customers as outputs. Results showed that average efficiency in the four years with constant return to scale (CRS) was 77% and under variable return to scale (VRS) was 88%. In addition, both of grey approach and data envelopment analysis as well as balanced scorecard have been used separately in many studies and a small number of investigations applied two evaluation models, which described in the following:

Davis & Albright (2004) conducted a study on the performance of an American bank based on balanced scorecard. They performed balanced scorecard in four branches. After two years, they compared the results of these four branches with another four branches that still using traditional indicators and realized that there is a significant relationship between the implementation of balanced scorecard and performance improvements in these branches.

Chang (2006) used a grey system approach to rank commercial banks in Taiwan. Financial ratios used as research indices. Their study examined effective features on these banks' performance. Results indicated that grey system approach could measure the performance better than the common statistical methods, such as regression analysis, factor analysis and other multivariate statistical methods, since there is no limit to the amount of data in this model.

Kuo, Yang, & Huang (2008) proposed grey relational analysis for solving MADM problems. They chose two cases in their research, facility layout and dispatching rules selection problem. They used GRA, DEA, TOPSIS and SAW to solve the problems. For facility layout 18 alternative and 6 performance attributes and for selecting dispatching rules, 9 alternatives and 7 attributes were considered. For the two cases, the results of comparisons showed that GRA is the most efficient for solving MADM problem among these four approaches.

Ip, Hu, & Xia (2009) used grey relational method to evaluate water quality of Han Jiang River in china. They proposed method included some properties that had more precise and higher grading of water quality. Their empirical method demonstrated that grey relational method is a helpful tool for incomplete hydrological data analysis.

Kadarova, Durkacova, Teplicka, & Kadar (2015) aimed to measure the performance of organizations in a comprehensive manner and they determined the efficiency of industrial enterprises by integrating data envelopment analysis and balanced scorecard. They suggested that data envelopment analysis should be used to measure quantitative and balanced scorecard to qualitative criteria in order to provide a comprehensive picture of financial performance as well as social and human aspects in organizations.

Chen & Jia (2016) analyzed environmental performance in industrial zones in China with DEA approach between 2008 and 2012. They selected thirty provinces as samples and considered labor, energy and fixed assets as inputs and gross domestic product, sulfur dioxide and solid waste produced as outputs. Results showed that, except some provinces, environmental performance was low in most of regions and did not grow significantly after 2012. They suggested that Chinese government should take steps to increase environmental performance and development of industrial heterogeneous.

Basso, Casarin, & Funari (2018) integrated DEA method with balanced scorecard in the museums. They carried out this approach in two stages. In the first stage, they defined an appropriate DEA model for each BSC component and calculated the efficiency scores. Then, they combined the scores in an overall performance measure. They considered the obtained efficiency scores as outputs and a single constant input for the second stage. They suggested that calculating the efficiency of each component separately could help museums managers to find strengths and weaknesses of the organization.

3. Research Methodology

3.1. Sample and data collection

This study is an applied as purpose and causal-comparative as research type. Documentary method used to examine the current situation and descriptive method used in terms of data collection. Statistical population includes thirty-five municipal water and wastewater companies in Iran. Companies' names and number of employees and customers demonstrated in table 1.

Required data and ratios in table 3 collected from action Plan journal that published every year by National Water & Wastewater Engineering Company of Iran (NWWEC). Period of this research is 2017. With regard to theoretical foundations and the main purpose of this research, following hypothesis presented:

H_1: The performance measurement of water and wastewater companies based on grey relational analysis is more accurate than data envelopment analysis.

In the following, the hypothesis has been tested by methods, which described above.

3.2. Statistical methods

In order to calculate grey relational grade, five steps are required. In the first step, it is necessary to normalize data and then in the next step, by subtracting normalized numbers from one, reference sequence will be achieved. In the third step, grey relational coefficient is calculated and in the fifth one, relational coefficients multiplied by relative weights and numbers summed for each company. Thus, final grade will be obtained. The number of indices in this paper is fourteen. Fuzzy normalization method used to standardize the data and relative weights of indices calculated by Shannon entropy method. All procedures done by excel spreadsheet. Figure 3 shows grey relational analysis methodology based on balance scorecard perspectives in this research.

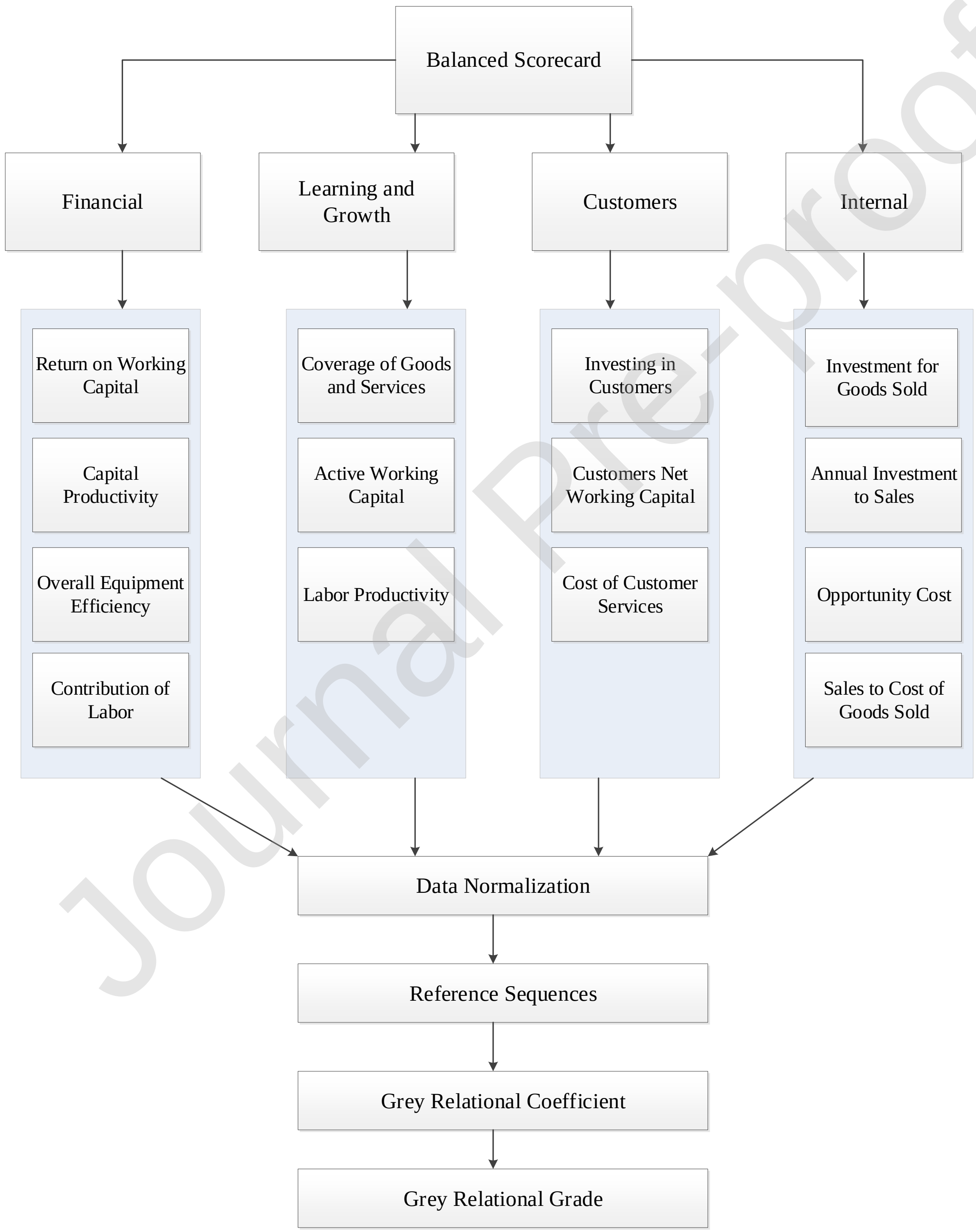

Figure. 3. Flow chart of GRA methodology in this paper

In this paper, CCR model used as the first and fundamental DEA model to determine companies' efficiency. Given the fact that this industry is reliant on government, it is necessary to increase its outputs with specified input level, output-oriented, and constant returns to scale model have been used. For the selection of input indices, items such as cost, investment, assets and for outputs, sales, profits (losses) and added value were considered. Finally, fourteen indices selected with expert consultation, which seven indices as outputs and seven as inputs were chosen. Also, Condition of determining the efficiency (number of inputs + number of outputs) *2 ≥ the number of DMUs observed. DEA Solver has been used for CCR and in the next step, AP model implemented by lingo software. After calculating efficiency, results obtained from two methods compared with each other and better method has been recommended. Table 2 presented the indices used in this paper.

4. Results

4.1. Grey relational analysis statistical method

4.1.1. Data normalization

Initially, data have been normalized and fuzzy method is used. After that, data placed in spaces between zero and one. Results of data normalization shown in Table 3.

4.1.2. Reference sequences

After normalizing, in the second step, reference sequence is calculated. As already stated, it is necessary to subtract normalized data from one to obtain the distance between desired value and each index.

4.1.3. Grey relational coefficient

In the third step, grey relational coefficient is calculated. The formula is described in Equation 3. The obtained coefficients are presented in Table 4.

4.1.4. Relative Weights

As mentioned previously, relative weights of indices in this study have been calculated by using Shannon entropy method. Table 5 shows the relative weights.

4.1.5. Grey relational grade

In the final step, by multiply grey relational coefficients in relative weight and sum up numbers, final grey grade will be obtained. Results demonstrated in table 6. Also, grey relational grade for each BSC perspective presented separately in table 7 and figure 4.

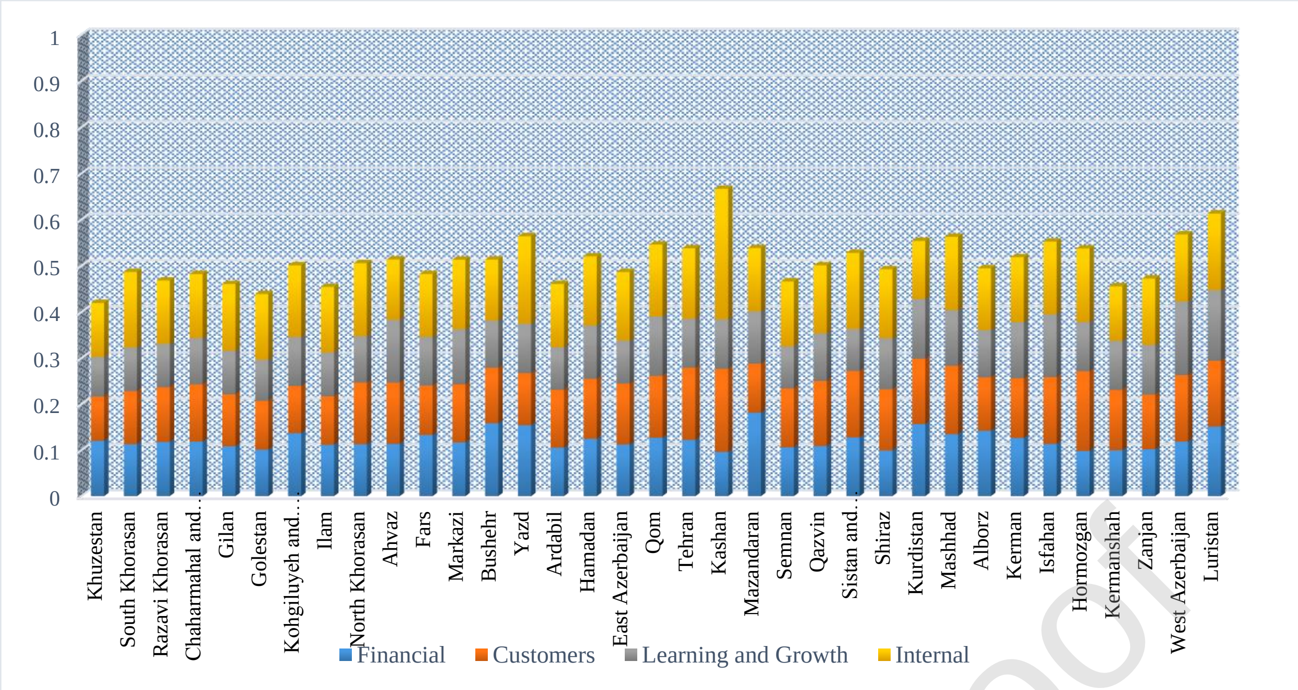

Figure. 4. Grey relational grade for each BSC perspective

As shown above, Khuzestan with a score of 0.42 and Kashan with a score of 0.667 got the lowest and highest ranks respectively; Luristan also has better performance than other companies do. Eighteen firms ranked between 0.5 and 0.59. Fifteen ranked less than 0.5, which indicates their poor performance in 2017. Among BSC components, learning and growth has the lowest grade on average.

4.2. Data envelopment analysis statistical results

As mentioned, CCR as basic model of DEA has been used to determine companies' efficiency; given the fact that this industry should increase its outputs with constant inputs, output-oriented approach and constant return to scale are used. Efficiency rates demonstrate in table 8. To rank efficient units Anderson-Petersen (AP) model is implemented. Table 9 presents the results for efficient DMUs.

According to the results in table 8, Khuzestan with score of 0.501 has the lowest efficiency among all DMUs. Seventeen companies ranked one. In the next step, AP model performed for these 17 units. It was determined that Kashan, Luristan and Yazd obtained highest efficiency. These units have higher grey rates too and Qom with 1.0296 has lowest rate among efficient firms.

5. Discussion and conclusion

In this study, thirty-five municipal water and wastewater companies selected as statistical population, and grey relational analysis and data envelopment analysis approaches selected based on balanced scorecard criteria as performance measurement tools. In grey analysis, numbers were normalized, then reference sequence and the grey coefficient calculated, and by multiplying relative weight to relational coefficients, the final grey relational grade obtained. In data envelopment analysis method, indices are classified into inputs and outputs. Companies' efficiency calculated with output-oriented and constant return to scale approaches. AP method implemented for efficient units. Finally, firms ranked by two approaches.

Results demonstrate that both approaches could be used to evaluate water and wastewater companies, but grey relational analysis is able to measure the performance of these companies more accurate and closer to reality. Therefore, the research hypothesis is confirmed. GRA range is between 0.42 and 0.667. Half of the firms rank between 0.5 and 0.59. Although efficient units have higher grey rates, they have relative better performance but not the best. The result is compatible with Kuo, Yang, & Huang (2008) research, that in solving MADM problems, grey relational analysis is outperform DEA. In fact, there are some limitations in DEA. First, it is preferable that the number of DMUs exceeds the number of inputs and outputs two or three times, but GRA does not make assumptions about the number of indicators. In addition, DEA categorizes DMUs to only efficient and inefficient units, whereas by using GRA, we could have a full rank of DMUs and a better distinction among them (Kuo, Yang, & Huang, 2008). Furthermore, GRA is able to determine the score of each BSC perspective separately.

Determining solution strategies for sustainable management is an important challenge in urban water sector. It is essential that policymakers make informed decisions to enhance the long-term technical and economic sustainability. Results of this paper provide useful prospects for researchers, urban planners, and policymakers due to a number of reasons. First, the methodology used in this paper, helps in the identification of factors that affect productivity and efficiency change over time, which could help regulators and managers to define measures that can be employed to improve the performance. However, due to the limitation of indices selection in DEA, some indicators were not considered such as non-revenue water, water losses, and annual water sales and so on. Second, the comparison of companies' performance over a period of time allows policymakers to perceive the impacts of their decisions. Finally, BSC enables managers to better understand the cause-and-effect relationships between variables. They can see how improvements in each component lead to better performance in others. Although the basic balanced scorecard model does not consider to environmental and social aspects, it has high potential to integrate sustainable components with organizational management system. So, sustainable balanced scorecard is suggested for future researches to help companies promote their efficient and sustainable management.

In the end, national water governance needs to be established which provides regulatory frameworks and public policies in water resources management. It is crucial to achieve economic (water prices), environmental (water losses) and social (drinking water and wastewater treatment) efficiency by good water governance. In fact, water governance integrates sustainable management of water resources and services into socioeconomic development on the one hand; and engages stakeholders to contribute in a meaningful way for water policy design on the other hand. This would enhance transparency and accountability in this industry. With the implementation of all above issues effectively, an important step could be taken towards sustainable development goals.

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Biography

Fatemeh Sarraf is an Assistant Professor in Azad University, South Tehran Branch within accounting courses. Also she is a financial consultant and member pf Iranian Association of Certified Public Accountants. Her research interests include artificial neural network, fuzzy and grey systems.

Table 1

Companies' name, number of employees and customers

No	Company Name	Number of Employees	Number of Customers	No	Company Name	Number of Employees	Number of Customers
1	Khuzestan	1120	917086	19	Tehran	4943	2859785
2	South Khorasan	199	237332	20	Kashan	132	170817
3	Razavi Khorasan	610	900540	21	Mazandaran	1117	647458
4	Chaharmahal and Bakhtiari	214	365948	22	Semnan	268	300299
5	Gilan	584	748923	23	Qazvin	228	472480
6	Golestan	396	309801	24	Sistan and Baluchestan	496	389709
7	Kohgiluyeh and. Boyer-Ahmad	282	197034	25	Shiraz	533	645380
8	Ilam	259	210059	26	Kurdistan	320	678327
9	North Khorasan	145	245940	27	Mashhad	561	1539139
10	Ahvaz	318	642664	28	Alborz	509	556401
11	Fars	987	722741	29	Kerman	542	565260
12	Markazi	318	482001	30	Isfahan	1015	1780155
13	Bushehr	269	322457	31	Hormozgan	341	304566
14	Yazd	405	457128	32	Kermanshah	515	720534
15	Ardabil	343	445233	33	Zanjan	270	292699
16	Hamadan	366	615450	34	West Azerbaijan	493	990814
17	East Azerbaijan	967	1838837	35	Luristan	423	613946
18	Qom	270	428237				

Table 2
Research indices

Perspectives	Indices	Input/Output	Formula	Perspectives	Indices	Input/Output	Formula
Financial	Return on Working Capital	Output	Net Profit (Loss)/ Working Capital	Customers	Investing In Customers	Input	Total Assets/ Number of Customers
	Overall Equipment Efficiency	Output	Added Value/ Net Equipment		Customer's Net Working Capital	Input	Working Capital/ Number of Customers
	Capital Productivity	Output	Added Value/ Equity+ Total Debts		Cost Of Customer Services	Input	Labor Costs/ Number of Customers
	Contribution of Labor	Input	Labor Costs/ Added Value	Internal	Investment For Goods Sold	Input	Total Assets/ Sales Volume
Learning And Growth	Coverage Of Goods And Services	Output	Wastewater Disposal Volumes+ Water Sales/ Number of Employees		Annual Investment To Sales	Input	Investment In A Year/ Total Sales
	Active Working Capital	Input	Working Capital/ Number of Employees		Opportunity Cost	Output	Produced Water Volume - Water Sales Volume/ Water Sales Volume
	Labor Productivity	Output	Added Value/ Number of Employees		Sales To Cost Of Goods Sold	Output	Total Sales/ Cost of Goods Sold

Table. 3
Data normalization

Criteria	Financial	Financial	Financial	Financial	Learning and growth	Learning and growth	Learning and Growth	Customer	Customer	Customer	Internal	Internal	Internal	Internal
Indices	Return on Working Capital	Overall Equipment Efficiency	Capital Productivity	Contribution of Labor	Coverage of Goods and Services	Active Working Capital	Labor Productivity	Investing in Customers	Customer's Net Working Capital	Cost of Customer Services	Investment for Goods Sold	Annual Investment to Sales	Opportunity Cost	Sales to Cost of Goods Sold
Khuzestan	0.494	0.6	0.66	0.367	0.231	0	0.741	0.319	0	0.342	0.148	0.004	0.115	0.129
South Khorasan	0.497	0.78	0.298	0.407	0.093	0.224	0.874	0.245	0.428	0.702	0.418	0.57	0.519	0.199
RazaviKhorasan	0.497	0.78	0.468	0.393	0.123	0.226	0.852	0.113	0.486	0.798	0.283	0.251	0.442	0.211
Chaharmahal and Bakhtiari	0.506	0.79	0.468	0.403	0.228	0.357	0.872	0.059	0.587	0.842	0.143	0.152	0.731	0.17
Gilan	0.506	0.7	0.234	0.38	0.312	0.236	0.782	0.27	0.461	0.626	0.245	0.175	0.808	0.129
Golestan	0.514	0.17	0.34	0.351	0.085	0.349	0.677	0.175	0.432	0.572	0.153	0.242	0.769	0.047
Kohgiluyeh and. Boyer-Ahmad	0.553	0.87	0.681	0.558	0.051	0.502	0.93	0.254	0.612	0.248	0.289	0.419	0.731	0.135
Ilam	0.519	0.64	0.404	0.371	0.045	0.412	0.794	0.231	0.498	0.47	0.256	0.096	0.808	0.152
North Khorasan	0.783	0.57	0	0.352	0.255	0.577	0.65	0.181	0.721	0.862	0.325	0.451	0.731	0.129
Ahvaz	0.535	0.73	0.362	0.358	1	0.402	0.657	0.237	0.646	0.864	0.112	0	0.654	0.275
Fars	0.544	0.8	0.723	0.437	0	0.524	0.914	0.124	0.625	0.519	0.18	0.132	0.692	0.146
Markazi	0.331	0.74	0.596	0.383	0.536	0.664	0.807	0.138	0.773	0.753	0.072	0.226	0.885	0.281
Bushehr	1	0.46	0.787	0.353	0.298	0.592	0.645	0.225	0.724	0.657	0.162	0.175	0.519	0.152
Yazd	0.494	1	0.936	0	0.134	0.312	1	0.136	0.482	0.703	0.168	0.148	0.962	1
Ardabil	0.566	0.48	0.255	0.346	0.185	0.479	0.571	0.224	0.644	0.784	0.32	0.126	0.673	0.053
Hamadan	0.284	0.84	0.681	0.424	0.267	0.651	0.888	0.105	0.764	0.828	0.194	0.305	0.788	0.211
East Azerbaijan	0.505	0.76	0.319	0.36	0.327	0.25	0.728	0.258	0.547	0.876	0.39	0.235	0.75	0.164
Qom	0.417	0.88	0.617	0.442	0.508	0.744	0.894	0.307	0.825	0.755	0.229	0.043	1	0.269
Tehran	0.509	0.9	0.362	0.489	0.353	0.337	0.911	1	0.333	0	0.346	0.267	0.788	0.287
Kashan	0.39	0.55	0.021	0.337	0.241	0.85	0	0.909	0.922	0.644	1	1	0.846	0
Mazandaran	0.679	0.93	0.872	1	0.056	0.588	0.966	0.193	0.701	0.354	0.091	0.26	0.577	0.193
Semnan	0.572	0.49	0.277	0.342	0.109	0.495	0.559	0.264	0.641	0.794	0.384	0.173	0.673	0.041
Qazvin	0.587	0.54	0.319	0.344	0.564	0.501	0.541	0.137	0.689	0.951	0.15	0.13	0.904	0.152
Sistan and Baluchestan	0.987	0.3	0.085	0.338	0.118	0.583	0.345	0.733	0.706	0.57	0.648	0.244	0.885	0.064
Shiraz	0.385	0.49	0.234	0.351	0.315	0.729	0.65	0.288	0.833	0.737	0.234	0.307	0.769	0.181
Kurdistan	0.421	0.82	1	0.453	0.522	0.717	0.921	0	0.793	0.948	0	0.065	0.481	0.275
Mashhad	0.51	0.94	0.574	0.588	0.604	0.437	0.947	0.154	0.679	1	0.265	0.325	0.846	0.363
Alborz	0.91	0	0.787	0.342	0.558	0.574	0.351	0.272	0.706	0.543	0.056	0.045	0.769	0.123
Kerman	0.433	0.78	0.702	0.393	0.207	0.8	0.841	0.26	0.905	0.618	0.253	0.112	0.75	0.228
Isfahan	0.435	0.84	0.319	0.373	0.644	0.835	0.782	0.379	0.868	0.824	0.265	0.076	1	0.263
Hormozgan	0.047	0.73	0.234	0.351	0.389	0.641	0.611	0.95	0.77	0.528	0.519	0.226	0.846	0.281
Kermanshah	0.324	0.36	0.404	0.345	0.382	0.704	0.488	0.202	0.802	0.774	0.163	0.09	0	0.053
Zanjan	0	0.66	0.447	0.381	0.166	0.631	0.813	0.188	0.758	0.614	0.188	0.226	0.769	0.146
West Azerbaijan	0.453	0.8	0.511	0.382	0.685	1	0.799	0.161	0.924	0.861	0.128	0.177	0.827	0.263
Luristan	0.462	0.93	0.809	0.735	0.265	0.991	0.957	0.115	1	0.785	0.208	0.276	1	0.31

Table 4
Grey relational coefficients

Criteria	Financial	Financial	Financial	Financial	Learning and growth	Learning and growth	Learning and Growth	Customer	Customer	Customer	Internal	Internal	Internal	Internal
Indices	Return On Working Capital	Overall Equipment Efficiency	Capital Productivity	Contribution Of Labor	Coverage of Goods and Services	Active Working Capital	Labor Productivity	Investing in Customers	Customer's Net Working Capital	Cost of Customer Services	Investment for Goods Sold	Annual Investment to Sales	Opportunity Cost	Sales to Cost of Goods Sold
Khuzestan	0.497	0.556	0.595	0.441	0.394	0.333	0.659	0.423	0.333	0.432	0.37	0.334	0.361	0.365
South Khorasan	0.499	0.694	0.416	0.457	0.355	0.392	0.799	0.398	0.466	0.627	0.462	0.538	0.51	0.384
Razavi Khorasan	0.499	0.694	0.484	0.452	0.363	0.392	0.772	0.36	0.493	0.712	0.411	0.4	0.473	0.388
Chaharmahal and Bakhtiari	0.503	0.704	0.484	0.456	0.393	0.437	0.796	0.347	0.548	0.76	0.368	0.371	0.65	0.376
Gilan	0.503	0.625	0.395	0.446	0.421	0.396	0.696	0.407	0.481	0.572	0.398	0.377	0.723	0.365
Golestan	0.507	0.376	0.431	0.435	0.353	0.434	0.608	0.377	0.468	0.539	0.371	0.397	0.684	0.344
Kohgiluyeh and. Boyer-Ahmad	0.528	0.794	0.611	0.531	0.345	0.501	0.877	0.401	0.563	0.399	0.413	0.463	0.65	0.366
Ilam	0.51	0.581	0.456	0.443	0.344	0.46	0.708	0.394	0.499	0.485	0.402	0.356	0.723	0.371
North Khorasan	0.697	0.538	0.333	0.436	0.402	0.542	0.588	0.379	0.642	0.784	0.426	0.477	0.65	0.365
Ahvaz	0.518	0.649	0.439	0.438	1	0.455	0.593	0.396	0.585	0.786	0.36	0.333	0.591	0.408
Fars	0.523	0.714	0.644	0.47	0.333	0.512	0.853	0.363	0.571	0.51	0.379	0.365	0.619	0.369
Markazi	0.428	0.658	0.553	0.448	0.519	0.598	0.722	0.367	0.688	0.669	0.35	0.392	0.813	0.41
Bushehr	1	0.481	0.701	0.436	0.416	0.551	0.585	0.392	0.644	0.593	0.374	0.377	0.51	0.371
Yazd	0.497	1	0.887	0.333	0.366	0.421	1	0.367	0.491	0.627	0.375	0.37	0.929	1
Ardabil	0.535	0.49	0.402	0.433	0.38	0.49	0.538	0.392	0.584	0.698	0.424	0.364	0.605	0.346
Hamadan	0.411	0.758	0.611	0.465	0.406	0.589	0.817	0.358	0.679	0.744	0.383	0.418	0.702	0.388
East Azerbaijan	0.503	0.676	0.423	0.439	0.426	0.4	0.648	0.403	0.525	0.801	0.45	0.395	0.667	0.374
Qom	0.462	0.806	0.566	0.473	0.504	0.661	0.825	0.419	0.741	0.671	0.393	0.343	1	0.406
Tehran	0.505	0.833	0.439	0.495	0.436	0.43	0.849	1	0.428	0.333	0.433	0.406	0.702	0.412
Kashan	0.45	0.526	0.338	0.43	0.397	0.769	0.333	0.846	0.865	0.584	1	1	0.765	0.333
Mazandaran	0.609	0.877	0.796	1	0.346	0.548	0.936	0.383	0.626	0.436	0.355	0.403	0.542	0.383
Semnan	0.539	0.495	0.409	0.432	0.359	0.498	0.531	0.405	0.582	0.708	0.448	0.377	0.605	0.343
Qazvin	0.548	0.521	0.423	0.433	0.534	0.501	0.521	0.367	0.617	0.911	0.37	0.365	0.839	0.371
Sistan and Baluchestan	0.975	0.417	0.353	0.43	0.362	0.545	0.433	0.652	0.63	0.538	0.587	0.398	0.813	0.348
Shiraz	0.448	0.495	0.395	0.435	0.422	0.649	0.588	0.413	0.75	0.655	0.395	0.419	0.684	0.379
Kurdistan	0.463	0.735	1	0.478	0.511	0.639	0.864	0.333	0.707	0.906	0.333	0.348	0.491	0.408
Mashhad	0.505	0.893	0.54	0.548	0.558	0.47	0.904	0.371	0.609	1	0.405	0.426	0.765	0.44
Alborz	0.847	0.333	0.701	0.432	0.531	0.54	0.435	0.407	0.63	0.522	0.346	0.344	0.684	0.363
Kerman	0.469	0.694	0.627	0.452	0.387	0.714	0.759	0.403	0.84	0.567	0.401	0.36	0.667	0.393
Isfahan	0.469	0.758	0.423	0.444	0.584	0.752	0.696	0.446	0.791	0.74	0.405	0.351	1	0.404
Hormozgan	0.344	0.649	0.395	0.435	0.45	0.582	0.562	0.909	0.685	0.514	0.51	0.392	0.765	0.41
Kermanshah	0.425	0.439	0.456	0.433	0.447	0.628	0.494	0.385	0.716	0.689	0.374	0.355	0.333	0.346
Zanjan	0.333	0.595	0.475	0.447	0.375	0.575	0.728	0.381	0.674	0.564	0.381	0.392	0.684	0.369
West Azerbaijan	0.478	0.714	0.506	0.447	0.613	1	0.713	0.373	0.868	0.782	0.364	0.378	0.743	0.404
Luristan	0.482	0.877	0.724	0.654	0.405	0.982	0.921	0.361	1	0.699	0.387	0.408	1	0.42

Table 5
Relative weights

Research Indices	Relative Weight	Research Indices	Relative Weight
Return on working capital	0.066	Investing in Customers	0.11
overall equipment efficiency	0.04	customer's net working capital	0.05
Capital productivity	0.074	Cost of Customer services	0.08
contribution of Labor	0.047	Investment for goods sold	0.071
Coverage of goods & services	0.071	Annual investment to sales	0.152
active working capital	0.082	opportunity cost	0.051
labor productivity	0.046	Sales to cost of goods sold	0.06

Table 6
Grey relational grade for each BSC perspective

No	Company Name	Grey Grade	No	Company Name	Grey Grade
1	Khuzestan	0.42	19	Tehran	0.538
2	South Khorasan	0.487	20	Kashan	0.667
3	Razavi Khorasan	0.469	21	Mazandaran	0.539
4	Chaharmahal and Bakhtiari	0.482	22	Semnan	0.467
5	Gilan	0.461	23	Qazvin	0.501
6	Golestan	0.439	24	Sistan and Baluchestan	0.528
7	Kohgiluyeh and. Boyer-Ahmad	0.501	25	Shiraz	0.493
8	Ilam	0.455	26	Kurdistan	0.554
9	North Khorasan	0.506	27	Mashhad	0.563
10	Ahvaz	0.514	28	Alborz	0.495
11	Fars	0.483	29	Kerman	0.519
12	Markazi	0.514	30	Isfahan	0.553
13	Bushehr	0.514	31	Hormozgan	0.538
14	Yazd	0.564	32	Kermanshah	0.456
15	Ardabil	0.461	33	Zanjan	0.473
16	Hamadan	0.521	34	West Azerbaijan	0.568
17	East Azerbaijan	0.487	35	Luristan	0.613
18	Qom	0.546			

Table 7
Grey relational grade

No	Company Name	Financial	Customers	Learning and Growth	Internal	No	Company Name	Financial	Customers	Learning and Growth	Internal
1	Khuzestan	0.12	0.097	0.086	0.117	19	Tehran	0.122	0.157	0.106	0.153
2	South Khorasan	0.113	0.116	0.095	0.164	20	Kashan	0.096	0.181	0.107	0.282
3	Razavi Khorasan	0.118	0.119	0.094	0.137	21	Mazandaran	0.182	0.107	0.113	0.137
4	Chaharmahal and Bakhtiari	0.119	0.124	0.101	0.138	22	Semnan	0.106	0.128	0.091	0.141
5	Gilan	0.109	0.113	0.095	0.144	23	Qazvin	0.109	0.142	0.104	0.147
6	Golestan	0.101	0.106	0.089	0.142	24	Sistan and Baluchestan	0.128	0.145	0.091	0.165
7	Kohgiluyeh and. Boyer-Ahmad	0.137	0.103	0.107	0.155	25	Shiraz	0.099	0.133	0.111	0.149
8	Ilam	0.112	0.106	0.095	0.142	26	Kurdistan	0.157	0.142	0.129	0.126
9	North Khorasan	0.113	0.134	0.101	0.158	27	Mashhad	0.135	0.149	0.12	0.159
10	Ahvaz	0.113	0.134	0.136	0.131	28	Alborz	0.142	0.116	0.103	0.134
11	Fars	0.133	0.108	0.106	0.136	29	Kerman	0.127	0.13	0.122	0.141
12	Markazi	0.117	0.126	0.12	0.151	30	Isfahan	0.114	0.146	0.136	0.158
13	Bushehr	0.159	0.121	0.102	0.132	31	Hormozgan	0.098	0.174	0.106	0.16
14	Yazd	0.154	0.113	0.107	0.189	32	Kermanshah	0.1	0.131	0.107	0.118
15	Ardabil	0.105	0.126	0.092	0.137	33	Zanjan	0.102	0.119	0.108	0.144
16	Hamadan	0.125	0.131	0.115	0.15	34	West Azerbaijan	0.119	0.145	0.159	0.145
17	East Azerbaijan	0.112	0.133	0.093	0.149	35	Luristan	0.151	0.143	0.153	0.166
18	Qom	0.127	0.135	0.129	0.156						

Table 8
Efficiency rates in CCR model

No	Company Name	Efficiency Rate	No	Company Name	Efficiency Rate
1	Khuzestan	0.501	19	Tehran	1
2	South Khorasan	0.993	20	Kashan	1
3	RazaviKhorasan	0.863	21	Mazandaran	1
4	Chaharmahal and Bakhtiari	0.902	22	Semnan	0.855
5	Gilan	0.9	23	Qazvin	1
6	Golestan	0.61	24	Sistan and Baluchestan	0.976
7	Kohgiluyeh and Boyer-Ahmad	0.868	25	Shiraz	0.871
8	Ilam	0.681	26	Kurdistan	1
9	North Khorasan	1	27	Mashhad	1
10	Ahvaz	1	28	Alborz	1
11	Fars	0.973	29	Kerman	1
12	Markazi	0.87	30	Isfahan	1
13	Bushehr	1	31	Hormozgan	1
14	Yazd	1	32	Kermanshah	0.726
15	Ardabil	0.849	33	Zanjan	0.856
16	Hamadan	0.88	34	West Azerbaijan	1
17	East Azerbaijan	0.99	35	Luristan	1
18	Qom	1			

Table 9

Efficiency rates in AP model

No	Company Name	Efficiency Rate	No	Company Name	Efficiency Rate
1	North Khorasan	1.0771	10	Kurdistan	1.5818
2	Ahvaz	1.1155	11	Mashhad	2.6713
3	Bushehr	1.2081	12	Alborz	1.5258
4	Yazd	6.0068	13	Kerman	1.2221
5	Qom	1.0296	14	Isfahan	2.3539
6	Tehran	1.0636	15	Hormozgan	1.2701
7	Kashan	12.624	16	West Azerbaijan	2.3126
8	Mazandaran	1.1298	17	Luristan	5.702
9	Qazvin	1.1899			