European Online Journal of Natural and Social Sciences 2013;
vol.2, No. 3(s), pp. 1397-1406 ISSN 1805-3602


# Evaluating the efficiency of intellectual capital through data envelopment analysis approach (Case study: Automotive industry and component manufacturers)

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## Abstract

The aim of this study was to evaluate the efficiency of intellectual capital of companies listed on Tehran Stock Exchange through Data Envelopment Analysis approach. In this study, the automotive industry and component manufacturers listed in Tehran Stock Exchange were chosen as pilot, and intellectual capital (human, physical, and structural capital) index was used as input index; stock return, return on assets, and return on equity were utilized as output variables for fifteen companies of this industry between 2006 and 2010. Results from the efficiency of intellectual capital indicated that throughout the years of assessment in this study, it was only the brake pad company that had the best performance among the selected companies; this was due to the fact that this company had been able to gain the maximum performance of intellectual capital in the assessed years.

**Keywords:** Human Capital, Physical Capital, Structural Capital, Efficiency, Data Envelopment Analysis.

## Introduction

Intellectual capital is a new issue which has been theoretically addressed throughout the world in the recent years. However, since intellectual capital is considered a valuable source for countries and organizations, its growth rate is rapidly becoming an index of country development; on the other hand, this intangible source has been proposed as one of the sources that mostly adds value to the companies' resources and increases key investment in entrepreneurial growth. According to investigators, intellectual capital is a hidden value that is not visible in financial statements; it is an issue that leads organizations to gain a competitive advantage (e.g.Maditinos *et al*, 2010). Today, the necessity of intellectual capital development and management has become a serious requirement on the national level and in the business arena; by moving towards a knowledge-based economy, this has also led to the change in dominant paradigm of industrial economy. Having intellectual capital and its management is considered the key to success in today's turbulent and challenging arena (e.g.Chen *et al*, 2001). In knowledge-based economy, intellectual capital compared with physical and financial capital is more important for organizations and companies; in a sense, intellectual capital is considered as real capital and one of the most important assets of today's organizations and companies.

One way to optimize the combination of intellectual capital is to use concepts of efficiency and productivity. Efficiency and productivity are criteria which can be used to constantly improve existing conditions. The first step in the efficiency and productivity improvement cycle is measurement. Measurement of efficiency and productivity as a basic system can provide conditions for decision-makers to find out in what condition they are; this way they can better plan to improve the existing conditions. Thus, organizations and companies need to consciously and systematically identify and manage intellectual capital and also evaluate its efficiency and productivity. To this end, the assessment of efficiency and productivity of intellectual capital is of significant importance. Success in any industry requires utilizing the best manufacturing methods and making optimal use of production elements and existing equipment. Therefore, increasing efficiency and productivity in all industries is a confident way to achieve greater economic growth with the same available resources. Due to

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the growing importance of intellectual capital efficiency and productivity in the process of strategic advantage of companies, the researcher aimed to investigate efficiency and productivity of the intellectual capital in automotive industry and component manufacturers between 2006 and 2010.

## Theoretical basis and literature review

### *Review of the related literature*

***Bentis*** (1998) conducted a study entitled "the relationship between investment in intellectual capital and business performance of commercial enterprises"; the results of this study revealed that there was a strong and direct relationship between the amount of investment in intellectual capital and performance indicators for enterprises. Chen *et al.* (2004) examined the relationship among intellectual capital, market value and financial performance; they used Pulic model to measure intellectual capital. Cohen and Kaimenakis (2007) conducted a study entitled "intellectual capital and organizational performance in small and medium knowledge-based organizations". They believe, however, in recent years a number of measures of intellectual capital have been widely developed and used in many organizations. Yet, there are other fundamental requirements to determine the relationships between various features of the intellectual capital existing in small to medium organizations. It is felt that the way these assets affect financial performance must be determined. The findings suggested that the interaction of the specific features of the intellectual capital in these companies is different in some aspects from the patterns observed in studies on big companies. Also, experimental data have provided supporting evidence that certain categories of intellectual capital contributed better organizational performance. Ismaeel (2009) investigated the intellectual capital efficiency and performance of financial sectors of Malaysian companies; to do so, he conducted a case study on a sample of 18 companies in 2007. Results showed that there is a positive relationship between intellectual capital and performance and that in parts of Malaysia, the market value is more created through the employed capital (physical capital) rather than intellectual capital.

In a study, Thomas (2010) explored the income of competitive intellectual capitals and resources and performance of companies in healthcare industry. The purpose of this research was to study the effects of intellectual capital; this was done using the concept of human and customer process control, innovative capitals and the process in performing the firm's plans. Experimental results showed a significant relationship between intellectual capital and firm performance. The results also revealed that the innovative and reformative capacity is considered to be the first procedure and that by the firm's human capital of the value added, the firm's better performance can be achieved. Studying the companies producing racing sail boats in Italy, Costa (2012) evaluated the efficiency and productivity of intellectual capital of 17 companies over 4 years (2005-2008). In this study, DEA techniques were used to assess efficiency and Malmquist index was used to evaluate productivity growth of intellectual capital. Results of the study divided the companies into 4 groups: the group with high competitiveness and quick growth; the group with high competitiveness but slow growth; the group with low competitiveness, but quick growth; and the group with low competitiveness and slow growth. Finally, some recommendations were made to improve efficiency and productivity of inefficient firms in the mentioned industry.

Despite the importance of intellectual capital in various fields, few studies have addressed its efficiency evaluation. Evaluating the efficiency of intellectual capital will allow organizations to move towards improving their weaknesses; also, by maximum use of the capabilities and strengths, they can take ship of organizations' goals in stormy sea of changes to the best beach.

### *Intellectual capital*

***The concept of*** intellectual capital was first considered by Machlup in 1962. Later, the economist John Kenneth Galbraith first used the term intellectual capital in 1969. Before him, Peter Drucker used the term "knowledge workers" (Fival, 1975). Intellectual capital literature shows the intangible value and nature of these resources. The following quotations represent the summary of different definitions proposed in this issue:

Broking (1996): The combination of four main components: market assets, human assets, intellectual property assets and infrastructure assets.

Stwart (1997): Any intellectual element such as knowledge, information, intellectual property and experience that could be used to create wealth.

Smith (1998): Human capital is a set of knowledge, ability and experience of a company's staff that is a transiently and shortly in the company's disposal in the work hours.

Bentis (2000): Relational capital indicates all relationships a company makes with its customers, competitors, materials and goods suppliers, business associations or government.

Today, organizations measure intellectual capital in order to improve internal management, reporting to outside agencies, exchanging this capital, and legal reasons for better accounting. In a knowledge-based organization, where knowledge makes a large part of the value of a product as well as the wealth of an organization, traditional accounting methods which are based on tangible assets as well as the information relating to the previous operations of the organization are inadequate for evaluation of intellectual capital which is the largest and the most valuable asset for them. Thus, intellectual capital approach is more comprehensive for organizations that want to be better aware of their performance value. Different patterns have been used by companies In order to examine this issue at different levels, but the degree of these patterns' acceptance depends on management accuracy and needs of the organization. Some of these models tend to focus on customer capital, while others focus on human capital within the organization. The pattern used in this study was the value added intellectual coefficient (VAIC); this model is part of asset returns model which was proposed by Pulic in 1998. This is an analytical tool to measure companies' performance. This model aims to enhance the ability of managers, shareholders and other stakeholders of the organization, and evaluates created value through intellectual capital of organizations; this model was designed by considering at all resources and major components of organizational resources and was evolved the years after its introduction (e.g. Pulic, 2000).

### *Efficiency*

***The simplest***, yet the most general definition of efficiency were presented by Peter Drucker. According to him, efficiency is doing things properly. Based on the bills passed by Audit Committee of the Auditing Organization, efficiency is the ratio of results obtained by operations (outputs) to resources consumed (inputs). Efficient operation is an operation that supplies the maximum efficiency (output) with a minimum consumption of resources (inputs) by using optimization techniques. According to Katz (1978), efficiency is the ratio of generated inputs to required outputs to generate these outputs. These two things between potential and actual efficiency show how much an organization can generate if it perform optimally. However, the actual efficiency is the real ratio of actual input levels. Actual efficiency is usually smaller than potential efficiency; however it may sometimes be larger. Pires suggests that efficiency means how well an organization can use its resources in order to produce in relation with the best performance in point of time. Another definition of efficiency is the ratio of the actual output to the standard output; in fact, this means the ratio of the amount of work done to the amount of work that must be done. Daft knows efficiency as the amount of resources used to produce a consumed product unit which can be calculated by the ratio of the consumed to the product (e.g. Robins, 1997). Generally, efficiency is how to use resources or how much it costs for the work to be accomplished; it means that to what extent the resources and facilities have been properly utilized.

### *Measuring efficiency through using data envelopment analysis approach*

Data envelopment analysis is a classical non-parametric technique which is based on a mathematical programming which is used for comparing the efficiency evaluation of a set of similar decision making units and its notable advantage is that it does not require a parametric characterization (such as production function) to obtain the efficiency scores (e.g. Siriopoulos & Tziogkidis, 2010). Decision Making Units (DMU) means an organizational unit or a separate organizational unit which is governed by an individual known as "manager", "director" or "officer", provided that this organization or this organizational unit has a system process, i.e. some production factors are used to generate some products. It should be mentioned that after performing DEA models, a set named Reference Set is presented in which it is specified that in order for each inefficient unit to reach efficiency, it should be compared with which efficient unit (e.g. Charnes *et al.*, 1985)

Assuming that there are "n" number of decision making units with "m" inputs and "s" outputs, the relative efficiency of each unit is achieved by solving the following fractional programming model (e.g. Bal *et al*, 2010).

$$Max\ z = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}} \qquad (1)$$

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1 \; j = 1, 2, \ldots, n$$

$$u_r \ge 0,\ r = 1, 2, \ldots, s$$

$$v_i \ge 0,\ i = 1, 2, \ldots, m$$

Where $y_{rj}$ is the $r^{th}$ output for the $j^{th}$ decision making unit; $x_{ij}$ is the $i^{th}$ input for the $j^{th}$ decision making unit; $u_r$ is the allocated weight to $r^{th}$ output; $v_i$ is the allocated weight to $i^{th}$ input and $z$ is the efficiency score of the assessed unit.

In the above model, the efficiency score of each evaluated unit is calculated through dividing the sum

of balanced outputs by the sum of balanced inputs; this score is smaller or equal to 1. If this score is equal to 1 it is considered an efficient unit and if it is less than 1, that unit is considered inefficient. Although day by day the number of data envelopment analysis models is increasing and each looks at a special aspect, all of them are based on a number of basic models that the founders of this approach such as Charnes, Cooper and Rhodes have designed. Among these models, the model proposed by Charnes, Cooper and Rhodes (1978) can be mentioned which called CCR is assuming the Constant Return to Scale (CRS). The mathematical form of this model is defined as follows. The other model is BCC assuming the Variable Return to Scale presented by Banker, Charnes, and Cooper; this model is defined as follows (Bal *et al.*, 2010).

$$
\begin{array}{ll}
CCR & \text{BCC} \\
Max=\sum_{r=1}^{s} u_r y_{ro} & Max=\sum_{r=} u_r y_{ro} + w \\
\sum_{i=1}^{m} v_i x_{io} = 1 & \sum_{i=1}^{m} v_i x_{io} = 1 \\
\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0, & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + w \le 0, \\
u_r \ge 0,\ r = 1, 2, \ldots, s & u_r \ge 0,\ r = 1, 2, \ldots, s \\
v_i \ge 0,\ i = 1, 2, \ldots, m & v_i \ge 0,\ i = 1, 2, \ldots, m \\
 & w \text{ free in sign}
\end{array}
\qquad (2)
$$

Based on the nature of their use, the basic DEA models are divided into two groups: input-oriented models and output-oriented models. By maintaining a constant output level, if it is aimed to minimize the inputs in evaluation process, the nature of the used model is input-oriented. Also, by maintaining a constant output level, if it is aimed to maximize the outputs in evaluation process, the nature of the used model is output-oriented.

## Methodology

In this study, the value added coefficient of intellectual was used as input variable, and return on assets and return on equity were used as output variables in DEA. How it is calculated is as follows.

### *Value Added Intellectual Coefficient (VAIC)*

To measure intellectual capital, the value added intellectual coefficient (VAIC) proposed by Pulic was used. Due to the advantages this model has over the other models, it was used in this study as the model of measuring intellectual capital. Based on Pulic model, the value added intellectual coefficient was calculated according to the following steps.

Step one: calculating the value added (VA):

$$VA=W+I+T+NI \qquad (3)$$

Where VA = Value Added; W = Employees' wages; I = Interest expenses; T = Tax and NI = Net profit after tax.

Step two: Calculating CE (capital employed), HU (human capital), and SC (structural capital):

According to the definition, capital employed (physical capital), human capital, and structural capital are as follows:

1. Capital employed (CE) = value of total net assets

2. Human capital (HU) = Total cost spent for the employees including: direct labor + indirect labor + wages of sale section, marketing and office.

3. Structural capital (SC) = human capital - the value added

Step three: Calculating VACE (value added capital employed):

$$VACE=VACE \qquad (4)$$

This relationship demonstrates the added value generated by the unit of physical capital; physical capital is the total value of the net assets. Pulic assumes that if in a company, each physical capital unit works more efficiently than other company, in this case, the first company performed better in the use of physical capital.

Step four: Calculating VAHU (value added of human capital):

$$VAHU=VA/HU \qquad (5)$$

This relationship indicates how much value is created for employees per each one rial spent.

Step Five: Calculating STVA (capital structure value added):

$$STVA=SC/VA \qquad (6)$$

This relationship shows the amount of structural capital required to make one rial value added; this is also considered as an indicator of the success of capital structure in value creation process.

Step six: Calculating value added intellectual coefficient (VAIC):

$$VAIC=VACA+VAHU+STVA \quad (7)$$

This coefficient is considered as a tool for measuring intellectual capital of Pulic model. It is true that the accounting data is used to calculate this coefficient, but instead of focusing on the company's costs, it focuses on resources that create value for the company. Thus the value added intellectual coefficient which is considered as the independent variable in this study is calculated.

### *Return on assets (ROA)*

The index is used as the financial performance; it is also a component of profitability ratios which is used to identify the strength of profitability of an organization. It represents the ratio of net income (earnings before interest and taxes (EBIT) divided by the book value of total assets.

$$ROA=Pre\text{-}t \,/ average\ A \quad (8)$$

Where Pre = Net profit; t = Taxes and A: average of total assets.

### *Return on equity (ROE)*

This index is a measure of financial performance and also a component of profitability ratios which is used to identify the strength of profitability of an organization; it represents the average ratio of operating income over book value of equity.

$$ROE = Operating\ Income \,/ average\ Efficiency \quad (9)$$

Where OI = Operating income; T = Taxes and E = Average equity.

### *Stock returns ($R_i$)*

All proceeds of shareholders for owning equity shares of a company in a given period are called stock returns. Returns for each investment in companies' shares can be calculated using the following formula.

$$R_i = \frac{(1+x-y)P_t - P_{t-1} - YP_n + DPS_t}{P_{t-1} + YP_n} \quad (10)$$

Where $R_i$: rate of return on i stock in t year; $P_t$: i share price at the end of the year t; $P_{t-1}$: i share price at the beginning of year t; $DPS_t$: i share dividend in year t; $P_n$: nominal value of i share; X: percentage of increase in capital reserves and Y: percentage of increase in capital receivables and cash.

### *Methodology*

The population of the research includes automotive and components manufacturers listed in Tehran Stock Exchange. The sample was selected using knockout systematic sampling based on five criteria as follows:

1. The companies under study must be technical manufacturers listed in Tehran stock exchange, but not a member in OTC or waiting to be listed in Stock Exchange.

2. Detailed information of the annual financial statements of each of these companies with market price of shares at the end of each year must be available in the official panel of Tehran Stock Exchange for the five-year period under study (2006-2010).

3. Companies under study must continuously be a member of Tehran Stock Exchange from one year before the study had begun (2005) until the end of 2010.

4. The selected companies must be profitable for all the five years.

5. The selected companies must have the same end of financial year in order not to violate comparability of financial information.

In this research, automotive industry and component manufacturers listed in Tehran stock exchange were selected as the pilot; the total number of these companies was as the sample size was 15.

In this study, the required information for the review of literature section was gathered from books and technical magazines in English and also from articles extracted from websites and computer information systems (library method). The data required to test the hypotheses were gathered using Stock Exchange reports (i.e. the annual financial statements and explanatory notes) and also through Stock Exchange official website for the five-year period (2006-2010). To calculate the variables, the data was stored in an Excel database. The informing software of Stock Exchange including Rahavard Novin, Tadbirpardaz, and Ardis were also used to complete and control the information. Excell and WinQSB were used to analyze the data as well.

## Results

Reviewing the previous studies and considering experts' ideas, one input index and three primary output indices were chosen for evaluating the relative efficiency of selected automotive industry and component manufacturers listed in Tehran Stock Exchange. There are some limitations using data envelopment analysis. One of these limitations, for example, is that the greater the number of variables, the less discrimination the base models make between efficient and inefficient

units. Also, when the number of organizational units is less than a certain amount, the discrimination power of basic DEA models decreases. Thus, given that the number of selected companies in the sample was 15, and this number makes the population, and also as it was not possible to increase the number of these companies, it was attempted to overcome this problem by reducing the number of input and output variables of DEA models. Therefore, only the intellectual capital was chosen as the input for DEA model input; return on equity (ROE), return on assets (ROA), and stock return (RI) were selected as output for DEA model. First and foremost, it is required to calculate these indices for the selected companies in the period between 2006 and 2010; the final results of the calculation of these indices are presented in following Tables.

**Table 1. Value added intellectual coefficient for the selected company in 2006-2010**

| Company | 2010 | 2009 | 2008 | 2007 | 2006 |
|---|---|---|---|---|---|
| Iran Khodro | 3.082 | 2.914 | 2.427 | 2.56 | 3.454 |
| Pars Khodro | 1.404 | 1.711 | 2.015 | 2.675 | 2.798 |
| Saipa | 1.592 | 1.996 | 4.39 | 5.291 | 6.538 |
| Bahman Group | 2.706 | 6.631 | 4.689 | 5.07 | 5.089 |
| Electric Khodro | 1.612 | 1.795 | 2.008 | 2.107 | 2.35 |
| Charkheshgar | 1.2 | 1.447 | 1.408 | 1.597 | 1.612 |
| Radiator Iran | 1.432 | 1.421 | 1.511 | 2.158 | 1.667 |
| Ringsazi | 1.396 | 1.652 | 1.674 | 1.774 | 1.573 |
| Zamyad | 2.199 | 2.49 | 3.433 | 4.301 | 4.344 |
| Sazeh Puyesh | 3.476 | 2.571 | 3.592 | 3.203 | 3.149 |
| Khavar Spring Manufacturer | 1.704 | 1.924 | 1.728 | 1.376 | 1.523 |
| Break Pad | 1.805 | 1.75 | 1.719 | 2.171 | 1.947 |
| Mehvarsazan | 1.545 | 1.488 | 1.403 | 1.378 | 1.194 |
| Mehrkam Pars | 1.365 | 1.249 | 1.359 | 1.769 | 2.021 |
| Niroo Mohareke | 1.66 | 1.472 | 1.588 | 1.651 | 2.003 |

**Table 2. Indices of return on equity the years 2006-2010**

| Company | 2010 ROE | 2009 ROE | 2008 ROE | 2007 ROE | 2006 ROE |
|---|---|---|---|---|---|
| Iran Khodro | 37.57 | 30.78 | 16.76 | 36.84 | 33.4 |
| Pars Khodro | 9.48 | 28.23 | 29.26 | 36.1 | 40 |
| Saipa | 17.28 | 30.24 | 36.44 | 41.06 | 48.1 |
| Bahman Group | 29.69 | 20.49 | 19.67 | 19.32 | 20.67 |
| Electric Khodro | 22.39 | 24.99 | 42.77 | 38.9 | 45.34 |
| Charkheshgar | 13.46 | 35.06 | 28.75 | 21.74 | 37.72 |
| Radiator Iran | 11.89 | 10.59 | 7.42 | 14.59 | 27.7 |
| Ringsazi | 23.31 | 20.82 | 27.7 | 23.39 | 20.43 |
| Zamyad | 32.97 | 43.36 | 39.58 | 48.28 | 34.37 |
| Sazeh Puyesh | 59.1 | 41.52 | 50.25 | 51.21 | 51.85 |
| Khavar Spring Manufacturer | 14.64 | 26.95 | 17.55 | 5.19 | 0.79 |
| Break Pad | 27.54 | 23.9 | 23.12 | 34.58 | 35.95 |
| Mehvarsazan | 22.75 | 17.01 | 14.67 | 23.47 | 0.22 |
| Mehrkam Pars | 3.21 | 3.18 | 14.78 | 36.11 | 31.15 |
| Niroo Mohareke | 22.71 | 24.01 | 32.17 | 25 | 25.71 |

**Table 3. Indices of return on assets the years 2006-2010**

| Company | 2010 ROA | 2009 ROA | 2008 ROA | 2007 ROA | 2006 ROA |
|---|---|---|---|---|---|
| Iran Khodro | 4.52 | 3.09 | 1.27 | 4.920 | 3.51 |
| Pars Khodro | 2.52 | 10.02 | 13.08 | 17.910 | 14.61 |
| Saipa | 3.7 | 13.96 | 17.42 | 21.390 | 25.29 |
| Bahman Group | 14.37 | 9.04 | 9.81 | 9.980 | 11.44 |
| Electric Khodro | 6.36 | 9.48 | 12 | 12.760 | 19.47 |
| Charkheshgar | 2.92 | 10.33 | 7.74 | 5.760 | 5.88 |
| Radiator Iran | 4.59 | 4.26 | 3.17 | 4.360 | 7.70 |
| Ringsazi | 5.9 | 6.38 | 7.59 | 5.400 | 5.94 |
| Zamyad | 9.03 | 15.18 | 15.72 | 22.060 | 10.05 |
| Sazeh Puyesh | 14.14 | 9.62 | 10.15 | 9.680 | 15.08 |
| Khavar Spring Manufacturer | 6.13 | 8.4 | 6.23 | 1.850 | 0.26 |
| Break Pad | 14.18 | 14.59 | 12.91 | 20.340 | 19.37 |
| Mehvarsazan | 5.27 | 3.92 | 3.13 | 6.410 | 0.04 |
| Mehrkam Pars | 0.82 | 0.92 | 5.14 | 15.620 | 11.96 |
| Niroo Mohareke | 7.14 | 5.51 | 8.31 | 6.680 | 8.51 |

**Table 4. Indices of stock return the years 2006-2010**

| Company | 2010 RI | 2009 RI | 2008 RI | 2007 RI | 2006 RI |
|---|---|---|---|---|---|
| Iran Khodro | 12.95 | 1.35 | 5.71 | 6.250 | 9.74 |
| Pars Khodro | 1.73 | 4.73 | 5.06 | 12.070 | 12.6 |
| Saipa | 7.72 | 4.83 | 7.31 | 11.470 | 9.5 |
| Bahman Group | 10.73 | 6.86 | 5.2 | 9.420 | 3.82 |
| Electric Khodro | 3.12 | 5.41 | 7.94 | 13.770 | 7.1 |
| Charkheshgar | 0.09 | 9.19 | 7.23 | 0.000 | 10.42 |
| Radiator Iran | 3.23 | 0.01 | 11.75 | 11.710 | 0.00 |
| Ringsazi | 5.11 | 6.62 | 7.65 | 10.880 | 9.05 |
| Zamyad | 11.46 | 10.13 | 4.41 | 13.480 | 4.76 |
| Sazeh Puyesh | 4.39 | 2.7 | 6.31 | 13.010 | 8.09 |
| Khavar Spring Manufacturer | 2.77 | 8.32 | 7.54 | 6.540 | 8.11 |
| Break Pad | 4.69 | 6.62 | 6.2 | 13.620 | 8.11 |
| Mehvarsazan | 0.76 | 6.15 | 0.01 | 3.840 | 7.52 |
| Mehrkam Pars | 0.04 | 2.77 | 4.87 | 11.960 | 12.2 |
| Niroo Mohareke | 7.16 | 8.9 | 7.81 | 12.770 | 10.69 |

In the next step, regarding the information presented in Tables 1, 2, 3 and 4 for each company and using the output-oriented CCR DEA technique, the relative performance of intellectual capital for each of the selected companies was determined; the results are summarized in Table 5. The output-oriented method was selected since the companies had a fixed amount of resources; but they were expected to generate maximum output. Thus, their output depended on the activities and resource allocations to different sectors.

**Table 5. Efficiency of intellectual capital of units for the years 2006-2010**

| Number | Company | 2010 | 2009 | 2008 | 2007 | 2006 |
|---|---|---|---|---|---|---|
| 1 | Iran Khodro | 0.811 | 0.436 | 0.410 | 0.705 | 0.436 |
| 2 | Pars Khodro | 0.405 | 0.782 | 0.920 | 0.737 | 0.800 |
| 3 | Saipa | 0.930 | 0.881 | 0.551 | 0.441 | 0.396 |
| 4 | Bahman Group | 0.950 | 0.183 | 0.290 | 0.264 | 0.226 |
| 5 | Electric Khodro | 0.836 | 0.694 | 1.000 | 0.944 | 0.982 |
| 6 | Charkheshgar | 0.660 | 1.000 | 1.000 | 0.667 | 1.000 |
| 7 | Radiator Iran | 0.556 | 0.389 | 1.000 | 0.701 | 0.771 |
| 8 | Ringsazi | 1.000 | 0.631 | 0.861 | 0.813 | 0.904 |
| 9 | Zamyad | 1.000 | 0.817 | 0.674 | 0.574 | 0.370 |
| 10 | Sazeh Puyesh | 1.000 | 0.667 | 0.657 | 0.783 | 0.770 |
| 11 | Khavar Spring Manufacturer | 0.546 | 0.681 | 0.761 | 0.614 | 0.823 |
| 12 | Break Pad | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 13 | Mehvarsazan | 0.866 | 0.651 | 0.491 | 0.834 | 0.974 |
| 14 | Mehrkam Pars | 0.139 | 0.349 | 0.693 | 1.000 | 1.000 |
| 15 | Niroo Mohareke | 0.908 | 0.952 | 0.987 | 1.000 | 0.858 |

As can be seen in Table 5, the efficacy of the automotive industry and component manufacturers listed in Tehran Stock Exchange was in a range between zero and one. Companies with the efficiency value of 1 are considered efficient, and companies with the efficiency value below 1 are considered inefficient. As the calculated weights were optimal weights to maximize the efficiency of the units in data envelopment analysis, it was expected to obtain an efficiency value of 1 for all units. But it can be seen in the table that it is not so and there are significant differences in the observed efficiency of units. For all the years of assessment, it was only the brake pad company that had the best performance among the selected companies. This company was able to gain maximum efficiency of intellectual capital (i.e. full efficiency) in all the years of assessment. In other words, this company was able to make the most of its resources in order to have access to performance output in all these years. Other companies did not operate at optimal scale in efficiency indicators. To be able to show how inefficient units can reach the efficiency, it should be looked at from the input or output view, or combination of both of them. Looking at the output, the outputs of this will increase until the mentioned ratio reaches efficiency. Looking at the outputs, the inputs are somewhat reduced and the outputs increase a little. Looking at the inputs in order to see the reduced rate of them, the obtained efficiency of various models of DEA is multiplied in the initial input values. It is natural that for efficient decision-making units whose efficiencies are 1, there would be no change in inputs and for the rest of the units with efficiency lower than 1, the mount of their proposed input would decrease by multiplying by values of initial inputs. Looking at the outputs to see the increase in outputs, the reverse of obtained efficiency from different models of DEA is multiplied by initial output values. Here too, the output would not change for efficient decision-making units. And for the rest of the units whose efficiency is smaller than 1, the value of proposed outputs would increase by multiplying the efficiency reverse by initial output values.

## Conclusions

The aim of this study was to evaluate the efficiency of intellectual capital of companies listed on Tehran Stock Exchange through Data Envelopment Analysis approach. In this study, the automotive industry and component manufacturers listed in Tehran Stock Exchange were chosen as pilot, and intellectual capital (human, physical, and structural capital) index was used as input index; stock return, return on assets, and return on equity were utilized as output variables for fifteen companies of this industry between 2006 and 2010. The results showed that the brake pad company, Charkheshgar and Mehrkam Pars have an advantage in the relative efficiency of intellectual capital over the other selected companies in this industry. Thus, the companies which experience a lower relative performance in intellectual capital can use the experience of brake pad company,

Charkheshgar, and Mehrkam Pars to close themselves to relative efficiency. This experience which can be used by the low efficiency companies includes employing educated, committed and polite staff, preparing better trained personnel, using proper modern methods of management, being customer oriented and respecting clients, offering variety of services, and using modern information technology and related technologies of their industry. Human capital is considered as a strategic and a key factor in improving the efficiency of selected companies listed on the Tehran Stock Exchange. This is due to the fact that skilled and innovative staff questions the existing conditions for improving processes and later, improved processes leads in improvement of services and production offered to customers. Ultimately, loyal and satisfied customers lead to improved performance and efficiency of the organization. Other suggestions include the following:

• Creating competitive conditions for automotive industry and component manufacturers listed in Tehran Stock Exchange

• Since inefficient companies in automotive industry and component manufacturers listed in Stock Exchange did not perform optimally in output indicators such as measures of return on equity (ROE), return on assets (ROA) and return on equity (RI), managers of the mentioned companies, thus, should pay special attention to this matter when they are making policies, since improvement of these indices would lead to efficiency improvement.

• Scale inefficiency is one of the factors that influence technical inefficiency. This means that most of the companies in automotive industry and component manufacturers do not operate at optimal scale. It is recommended that companies that act in rising returns in relation to the scale increase their activity level and those which act in declining returns decrease their activity level; this way they move towards an optimum scale.

Some suggestions for future research may include the following:

• It is suggested that in other studies the type of returns to scale (increasing, constant, or decreasing) be investigated using BCC model of DEA for the listed companies of automotive industry and component manufacturers and the model be chosen according to returns to scale.

• DEA determines a specific weight to input and output variables in a way to maximum efficiency of the unit under evaluation. According to different coefficients of each input and output, it is better to determine the weight range of input and output by manager's and experts' opinion; it is also better that the evaluation that uses DEA model takes into account weight limitation features.

• To take advantage of the benefits of constant returns to scale (CCR) and avoid its shortcomings, it is suggested to use combined models of BCC-CCR and CCR-BCC.

• In order to compare companies regarding their intellectual capital efficiency in different periods, window data envelopment analysis can be used to determine the rate of performance changes of each unit with respect to time.

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