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# Evaluation of Relative Efficiency and Performance of Companies Using Data Envelopment Analysis (DEA) Approach

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**ABSTRACT**

The aim of this research is to create the portfolio of efficient companies using Data Envelopment Analysis (DEA) technique to gain a return beyond the average return of market. For this purpose, input-oriented and output-oriented models were used under constant returns to scale (CCR) and variable returns to scale (BCC). Also, in this research the hypothesis "*the portfolio composed of small companies has a better performance than the average of industry"* was discussed. The results of the research indicate that in case of using CCR method, it is not possible to gain a return beyond the average return of market; however, it is possible to do so if BCC method is used. The performance of the portfolio created using this method was also appropriate. In the end, the portfolio composed of small companies had the return beyond the average return of market and had an appropriate performance.



## 1. Introduction

Stock selection in an investment portfolio has always been highly important. Sahoo[1] enumerates stock selection process for invertors at three stages:

i. Determining the rate of resistance against different types of risks

ii. Selecting profitable securities with high security coefficient

iii. And adjusting a portfolio with respect to its performance (Sahoo *et al*., 2008)

However, this is not the end of stock selection for investors. As there are securities with multiple input and output data, it is complicated to determine the efficient securities. However, it can be improved using the quantitative methods.

Although the portfolio management methods are different, the objectives pursued by decision-makers are very similar. Cooper *et al.* in 1997 stated three major goals for selecting portfolio, which specify decision-making process: 1- Effectiveness 2- Efficiency 3- Balance (Cooper *et al.*, 1997)

In this research, Data Envelopment Analysis is used for selecting portfolio. This technique enables us to overcome two drawbacks of Markowitz Model. Data Envelopment Analysis method is the comparison of inputs and outputs of a series of decision-making units with efficiency appraisal related to them. To select portfolio, decision-making units are stocks and/or securities. In this technique, a decision-making unit is considered ***efficient*** when no other decision-making units would be able to create a higher amount of output using the same or lower amount of input; alternatively, when no other decision-making unit would be able to create the same or higher amount of output using fewer inputs. If these conditions are not met, that unit will be considered as an inefficient unit. The advantage of using data envelopment analysis as an efficiency evaluation method is not only due to its ability in comparing several inputs as well as inputs, but further is due to the differentiation between efficient and inefficient units.

**Research Background**

In 2006, Paul Na *et al.* used a combined method to evaluate the efficiency of a portfolio. They believed that only the *mean* and *variance* of «risk return» are not sufficient for this issue. Therefore, they entered another statistical variable, i.e. ***skewness***, together with the above two variables into the non-parametric model of data envelopment analysis. By converting it into a non-linear structure, regarding the correlation between units and the effect of diversification, they measured their performances to reduce risk and improve return of portfolio. With respect to the obtained results, these researchers made this method more appropriate and efficient than the other common methods in measuring performance and efficiency of portfolio (Paul Na *et al.* 2006).

In a research conducted by Chinta in Taiwan in 2008, the efficiency and effectiveness of 28 brokers of internet securities from 2003 to 2005 were studied using efficiency evaluation methods. The results indicated that by applying efficiency evaluation methods, seven companies had effectiveness in their activities, five companies had efficiency, and only two companies were recognized to be both effective and efficient. He used the data such as salary, wages, operating costs, fixed assets, and advertising costs for input variables. He used operating and non-operating income and fees paid in cash for output variables.

Jennifer Powers *et al.* used data envelopment analysis to select securities from a list including 185 securities. Among them, 14 and 4 securities were appraised as the *efficient* and *relatively efficient* securities, respectively. Eight variables were used in their study. Five output variables are one-year, three-year, five-year, ten-year returns and income per share. Price to Earnings (P/E) ratio, Beta coefficient and sigma coefficient were used as the input variables in this research. They studied

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resistance of efficient securities under unstable conditions; that is, how securities can remain efficient at the time of unfavorable changes. Powers and McMillan believe that one of the advantages of their adopted method, that is data envelopment analysis, is that it is possible to calculate discount and premium rates of inefficient securities to convert them into efficient securities. At the end of these two studies, they emphasize that to apply this method practically in an investment, ***weight coefficients*** should definitely be taken into account (Jennifer Powers *i.e.*, 2000).

In a research, Lopes *et al.*, in 2008 used efficiency evaluation methods as stock selection strategy in Brazil Stock Market. They used P/E ratio per share, beta coefficient and variability of return per share as input variable; they used income of each share, 12- 36- and 60-month return as the output variables of efficiency evaluation method in a 10-year or 12-year period interval. They realized that the portfolio created using efficiency evaluation methods in proportion to two indices of Brazil market has led to a better performance (Lopez *et al.*, 2008).

Malhotra *et al.* in 2007 used data envelopment analysis technique to evaluate bonds. They selected 2 financial ratios (long-time debts/total capital and total debit/total capital) as the input of the model and 6 financial ratios (frequencies of interest coverage before interest and tax, frequencies of interest coverage before interest and tax and before depreciation of tangible and intangible assets, net cash/total debit, free cash/total debit, capital and income/sale return) as the output of the model. Researchers' view in selecting input and output ratios was based on the fact that these ratios show borrower's financial ability for paying principal and interest of a debt. There were 34 companies as decision-making units and the results showed that 8 of them were more efficient than other companies in terms of the ability to pay the principal and interest of debt (Malhotra *et al.*, 2007).

A research titled "Stock Selection" was conducted in Taiwan in 2008 by Chen using efficiency evaluation quantitative models. The research aimed to create a portfolio to compare the rate of return with the average rate of market return and to examine if the created portfolio has more return using these methods? In addition, he examined if size effect strategy is suitable for stock selection or not? This research uses variables of average salary of stockholders and sale costs as input variables and income, operating profit and net profit as output variables. The results of the project showed that *size effect strategy* is a suitable strategy to select stock in Taiwan Stock Exchange and the created portfolio using efficiency evaluation methods gained more return than market indices.

**Statistical Population & Sample**

The statistical population of the present research includes companies listed in Tehran Stock Exchange (TSE); according to the official website of Tehran Exchange, by 1388, all the listed companies included 449 companies classified in 16 industries. The present research uses census method. In other words, the companies with the following specifications were considered as research samples:

• Their audited financial information during 2001-2007 should be available.

• They had to be profitable during the research period

• For the items to be comparable, the fiscal period of the companies should end by 19 March.

• According to the condition of efficiency evaluation model (Mehregan, 2004, p.74) where

Number of units, (number of companies in industry) ≥ 3 (number of input variables + number of output variables) ≥3 (3+3) = 18

We select industries that have more than 18 companies in their subcategory. With respect to the above conditions, basic metals, machineries and equipment, chemical products, food and drink products, drug materials and products, and cement, lime and plaster industries were studied.

**Testing of Research Hypotheses**

The following Table is related to food and drink industry in 2007, which is included as a sample. The first column of the Table contains the names of companies, which were active in that year. The relative efficiencies of the companies were calculated in the second and third columns of the Table using input-oriented and output-oriented CCR model of data envelopment analysis. The companies with the efficiency score of 1 in this model are shown with hatched background. The efficiencies of the companies were calculated in the third and fourth columns of the Table using input-oriented and output-oriented BCC model and the companies with the efficiency score of 1 are shown with hatched background. Column five of the Table contains efficiencies of these companies in the end of the fiscal year. In column six of the Table, the companies were divided into two categories of SMALL and BIG based on the variable of average value at the final period of industry. In the last row of the Table, the average return of the companies with efficiency of 1 was calculated in each model of data envelopment analysis technique. The average return of the small-sized companies was calculated in the last column of the Table. This way, a Table is prepared for each industry for each year from 2001 to 2007.

In the following Table, 2 to 8 returns obtained from creating a portfolio using each data envelopment analysis method and company size variable in each industry were placed against the average return. *Name of industry* was shown in the first column of each Table, *efficiencies of the portfolios created by data envelopment analysis* were shown in the second, third, fourth, and firth column fourth. The average of industry efficiency in the end of the fiscal period is shown in sixth column, respectively. Efficiency of the created portfolio using size variable is shown in the last column. Total efficiency of industries in each portfolio is shown in the last row of the Table. In each Table, the created portfolio is compared with the average return of an industry. If this efficiency exceeds the average return of an industry, we will show that by hachure.

The above Tables show that the portfolio created using input-oriented and output-oriented CCR model had 19 times out of 42 comparisons (6 industries in 7 fiscal years from 2001 to 2007) and the portfolio created using input-oriented, and output-oriented BCC model had 26 times out of 42 comparisons better performance with the average return of industries. Portfolio of small companies had 33 times out of 42 comparisons better performance than the average return of industries. It seems that CCR Model creates a better return corresponding to the average return of industry, whereas BCC Model created a return higher than the one of industry. It also seems that there is an appropriate size effect strategy for investing in Tehran Stock Exchange.

**Results of Wilcoxon Test**

Wilcoxon signed-rank test was used to study and evaluate performance of BCC and CCR portfolio with the average return of industries.

| company | Input-oriented CCR | Output-oriented CCR | Input-oriented BCC | Output-oriented BCC | Return2007 | Size effect |
|---|---|---|---|---|---|---|
| behpak | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0 | SMALL |
| behnoush | 1.0000 | 1.0000 | 1.0000 | 1.0000 | -0.35 | BIG |
| Western Azerbaijan pegah | 0.4476 | 0.4476 | 0.4589 | 0.4492 | -1.51 | SMALL |
| Isfahan pegah | 0.7768 | 0.7768 | 0.7779 | 0.7818 | -56.97 | BIG |
| Khorasan pegah | 1.0000 | 1.0000 | 1.0000 | 1.0000 | -50.41 | BIG |
| Behshar indust | 0.3094 | 0.3094 | 1.0000 | 1.0000 | -6.55 | BIG |
| Dashte morghab | 0.7444 | 0.7444 | 0.7473 | 0.7679 | -52.83 | SMALL |
| Pars vegtabale oil | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0 | SMALL |
| Jahan vegtabale oil | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 17.59 | SMALL |
| Salemin | 0.5747 | 0.5747 | 0.7423 | 0.6739 | -21.86 | SMALL |
| Shahd iran | 0.6249 | 0.6249 | 0.6292 | 0.6292 | -8.95 | SMALL |
| Sanati pars minoo | 0.3941 | 0.3941 | 0.3972 | 0.6192 | -18.75 | BIG |
| Keshte piazar | 0.8106 | 0.8106 | 1.0000 | 1.0000 | -2.33 | SMALL |
| Kesht o sanat gorgan | 0.7170 | 0.7170 | 0.7973 | 0.7750 | 181.82 | SMALL |
| keivan | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 2.02 | SMALL |
| gorji | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 39.63 | SMALL |
| Pak diary | 0.9338 | 0.9338 | 1.0000 | 1.0000 | -4.13 | BIG |
| Kalber diary | 0.7492 | 0.7492 | 0.7829 | 0.7711 | 7.79 | SMALL |
| mahran | 0.8094 | 0.8094 | 0.8532 | 0.8643 | 18.21 | SMALL |
| Minoo khoramdare | 0.5452 | 0.5452 | 0.5758 | 0.8443 | 0 | SMALL |
| nab | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 207.07 | SMALL |
| Nosh mazandaran | 0.7043 | 0.7043 | 0.8439 | 0.8057 | Return 2006 | SMALL |
| Portfolio’s return | 12.37 | 12.37 | 7.54 | 7.54 | 2.04 | 15.53 |

**Table 2 compare of results of portfolio's return with average return in 2001**

| **Industry** | **input-oriented portfolio’s return CCR** | **output-oriented portfolio’s return CCR** | **input-oriented portfolio’s return BCC** | **output-oriented portfolio’s return BCC** | **Average return of industry end of the term** | **Size effect of portfolio’s return** |
|---|---|---|---|---|---|---|
| Basal metals | 40.89 | 40.89 | 33.13 | 33.13 | 27.61 | 48.21 |
| Machines and equipment | 0.29 | 0.29 | 9.21 | 9.21 | 9.61 | 7.05 |
| Chemical products | 27.48 | 27.48 | 24.62 | 24.62 | 42.47 | 45.54 |
| Food and drinking products | 11.31 | 11.31 | 14.98 | 14.98 | 12.42 | 15.98 |
| Medical products | 87.44 | 87.44 | 68.9 | 68.9 | 56.78 | 50.87 |
| Cement | 112.42 | 112.42 | 107.88 | 107.88 | 127.15 | 124.29 |
| Average | 41.37 | 41.37 | 39.33 | 39.33 | 41.36 | 44.39 |

**Table 3 compare of results of portfolio's return with average return in 2002**

| **Industry** | **input-oriented portfolio’s return CCR** | **output-oriented portfolio’s return CCR** | **input-oriented portfolio’s return BCC** | **output-oriented portfolio’s return BCC** | **Average return of industry end of the term** | **Size effect of portfolio’s return** |
|---|---|---|---|---|---|---|
| Basal metals | 18.08 | 18.08 | 22.95 | 22.95 | 30.31 | 37.23 |
| Machines and equipments | -5.55 | -5.55 | 14.12 | 14.12 | 19.62 | 27.54 |
| Chemical products | 35.61 | 35.61 | 17.57 | 17.57 | 16.09 | 11.82 |
| Food and drinking products | 26.59 | 26.59 | 46.43 | 46.43 | 28.63 | 32.36 |
| Medical products | 17.19 | 17.19 | 17.66 | 17.66 | 11.98 | 19.9 |
| Cement | 126.61 | 126.61 | 101.51 | 101.51 | 70.5 | 106.94 |
| Average | 31.13 | 31.13 | 33.76 | 33.76 | 28.22 | 36.36 |

**Table 4 compare of results of portfolio's return with average return in 2003**

| Industry | input-oriented portfolio's return CCR | output-oriented portfolio's return CCR | input-oriented portfolio's return BCC | output-oriented portfolio's return BCC | Average return of industry end of the term | Size effect of portfolio's return |
|---|---|---|---|---|---|---|
| Basal metals | 39.6 | 39.6 | 50.18 | 50.18 | 44.27 | 73.42 |
| Machines and equipments | 42.62 | 42.62 | 44.1 | 44.1 | 51.16 | 59.09 |
| Chemical products | 70.01 | 70.01 | 56.38 | 56.38 | 54.23 | 52.48 |
| Food and drinking products | -14.98 | -14.98 | -1.02 | -1.02 | 0.15 | 2.42 |
| Medical products | 20.34 | 20.34 | 8.94 | 8.94 | 9.69 | 10.67 |
| Cement | 6.69 | 6.69 | -2.98 | -2.98 | -8.05 | -4.18 |
| Average | 24.34 | 24.34 | 23.45 | 23.45 | 22.61 | 28.82 |

**Table 5 compare of results of portfolio's return with average return in 2004**

| industry | input-oriented portfolio's return CCR | output-oriented portfolio's return CCR | input-oriented portfolio's return BCC | output-oriented portfolio's return BCC | Average return of industry end of the term | Size effect of ortfolio's return |
|---|---|---|---|---|---|---|
| Basal metals | -10.33 | -10.33 | -5.89 | -5.89 | -19.85 | -18.41 |
| Machines and equipments | -20.1 | -20.1 | -5.92 | -5.92 | -15.48 | -9.1 |
| Chemical products | -13.76 | -13.76 | -13.35 | -13.35 | -9.06 | -9.97 |
| Food and drinking products | -2.95 | -2.95 | 1.08 | 1.08 | -2.17 | 3.56 |
| Medical products | -1.9 | -1.9 | -1.85 | -1.85 | -13.3 | -6.24 |
| Cement | -15.77 | -15.77 | -13.45 | -13.45 | -8.85 | 4.03 |
| Average | -11.04 | -11.04 | -6.72 | -6.72 | -11.63 | -6.35 |

**Table 6 compare result of maiden portfolio's return with average return in 2005**

| Industry | input-oriented portfolio's return CCR | output-oriented portfolio's return CCR | input-oriented portfolio's return BCC | output-oriented portfolio's return BCC | Average return of industry end of the term | Size effect of portfolio's return |
|---|---|---|---|---|---|---|
| Basal metals | 87.14 | 87.14 | 44.63 | 44.63 | 33.57 | 26.99 |
| Machines and equipments | 11.88 | 11.88 | 15.66 | 15.66 | 25.15 | 28.04 |
| Chemical products | 57.98 | 57.98 | 27.19 | 27.19 | 20.13 | 6.88 |
| Food and drinking products | 54.14 | 54.14 | 23.04 | 23.04 | 12.65 | 13.72 |
| Medical products | 64.52 | 64.52 | 79.19 | 79.19 | 77.54 | 83.14 |
| Cement | 3.76 | 3.76 | 0.21 | 0.21 | -8.62 | -6.9 |
| Average | 43.42 | 43.42 | 29.43 | 29.43 | 24.2 | 22.44 |

**Table 7 compare of results of portfolio's return with average return in 2006**

| Industry's name | input-oriented portfolio's return CCR | output-oriented portfolio's return CCR | input-oriented portfolio's return BCC | output-oriented portfolio's return BCC | Average return of industry end of the term | Size effect of Portfolio's return |
|---|---|---|---|---|---|---|
| Basal metals | -22.49 | -22.49 | 9.83 | 9.83 | 4.49 | 3.57 |
| Machines and equipments | 47.61 | 47.61 | 28.07 | 28.07 | 9.13 | 15.76 |
| Chemical products | -5.6 | -5.6 | -2.98 | -2.98 | 0.48 | 5.76 |
| Food and drinking products | 12.37 | 12.37 | 7.54 | 7.54 | 2.04 | 15.53 |
| Medical products | 20.95 | 20.95 | 27.5 | 27.5 | 36 | 52.12 |
| Cement | -7.74 | -7.74 | 2.48 | 2.48 | -1.11 | 7.68 |
| Average | 5.18 | 5.18 | 11.46 | 11.46 | 7.83 | 15.71 |

**Table 8 compare of results of portfolio's return with average Return in 2007**

| Industry's name | input-oriented portfolio's return CCR | output-oriented portfolio's return CCR | input-oriented portfolio's return BCC | output-oriented portfolio's return BCC | Average return of industry end of the term | Size effect of portfolio's return |
|---|---|---|---|---|---|---|
| Basal metals | -29.51 | -29.51 | -14.83 | -14.83 | -10.9 | -7.23 |
| Machines and equipments | 0 | 0 | 2.89 | 2.89 | -0.84 | 2.55 |
| Chemical products | -27.29 | -27.29 | -15.39 | -15.39 | -17.4 | -13.83 |
| Food and drinking products | 7.15 | 7.15 | 5.04 | 5.04 | 4.56 | 4.76 |
| Medical products | -9.32 | -9.32 | -7.04 | -7.04 | -3.54 | 0.3 |
| cement | 24.8 | 24.8 | 1.123 | 1.123 | 7.73 | 27.22 |
| average | -7.62 | -7.62 | -5.06 | -5.06 | -3.79 | 1.54 |

The results of Wilcoxon test shows that Z value obtained from comparing return of CCR portfolio with the average return of industry equals (.569) and its probability is (Sig=289) which shows that the portfolios created using CCR model were unable to gain the return more than the average of market return. Z value obtained from comparing return of BCC portfolios to average return of industry and its probability value equals (1.657) and (Sig=.049), respectively which shows that using this model, a return is gained that is higher than the average return of market. Z value obtained from comparing return of portfolios of small companies and return of industry and its probability value equals *(-3.857)* and (Sig0.000), respectively which shows that these companies gain a return that is higher than the average return of market.

**Results of Sharpe Test**

William Sharpe offered a combined criterion of portfolio performance called Reward-to- Variability Ratio (RVAR), which is based on investment market theory.

$$SR_p = \frac{r_p - r_f}{\sigma_p}$$

where, $\mathbf{r_p}$ is the average return of the created portfolio, $\mathbf{r_f}$ is risk-free rate of return, **Sigma** is the standard deviation of efficiencies in portfolio.

Here, Sharpe Test was used to measure the performance of portfolios created using data envelopment techniques and the portfolio created using size effect variable. The following Table shows the results of the test.

**Table 9 – results of sharpe test**

| portfolio | R | $R-R_f$ | Sigma | Sharp |
|---|---|---|---|---|
| CCR | 21.15 | 8.15 | 37.18 | 0.22 |
| BCC | 19.75 | 6.75 | 29.64 | 0.23 |
| Small | 22.66 | 9.66 | 31.91 | 0.3 |
| market | 17.31 | 4.09 | 29.98 | 0.14 |

The results of the test shows that Sharpe criterion for the portfolios created using data envelopment analysis is greater than market Sharpe criterion and this indicates the appropriate performance of these portfolios. In addition, Sharpe criterion for size effect portfolio is greater than Sharpe index of market, which indicates the appropriate performance of this portfolio.

**Conclusion and Recommendations**

Generally, the results indicated that the portfolio created by data envelopment analysis has an appropriate performance and a higher return of industry average can be obtained using this technique. Moreover, stock selection based on size variable of companies is an appropriate strategy for selecting stock and creating portfolio in Tehran Stock Exchange.

**A.** As it was claimed that the portfolio created by data envelopment analysis offers a higher return than the average return of industry, the results show that BCC model of data envelopment analysis confirms the claim and the portfolio created using this model had a better performance using Sharpe criterion.

However, the portfolio created by CCR model of data envelopment analysis was unable to create a return higher than the average of industry. It seems that it occurred due to the weakness of distinctive power in the model. In the model, the higher the number of decision-making departments is, the higher the efficiency of the model will be. Two problems usually occur in applying classic models of data envelopment analysis. These two problems are related to resolution weaknesses and unreal weight distribution of the inputs and output of the model. Such a weakness occurs when the number of units under evaluation is not sufficiently as large as the total number of inputs and outputs. Under this condition, a large number of the decision-making units are considered efficient. According to Table 1, as in some industries (such as cement, lime and plaster industries in 2002 & 2003), the number of decision-making units is fewer than the expected level, the model efficiency is reduced which is one of the limitations of this research. However, this portfolio had an appropriate performance with respect to Sharpe criteria. The results show that data envelopment technique is a suitable pattern for creating portfolio in Tehran Stock Exchange and investment companies and private investors are able to use it in order to gain appropriate return in stock exchange.

**B.** As it was claimed that the portfolio created by small companies offers a higher return than the average of industry, the results showed that the portfolio made of small companies created a return higher than the average return of industries. The results obtained from Sharpe criterion shows that this portfolio has also an appropriate performance. This result corresponds to result obtained from a research conducted by Ahmadpour and Rahmani in 2007 in which they discussed the effect of company size and book value to market value on stock return in Tehran Stock Exchange.

Comparing the performance of portfolio created by data envelopment analysis approach and size effect strategy with respect to Sharpe criteria, we notice that in spite of Chen's study in Taiwan in 2008, the portfolio created using size effect strategy in Tehran Stock Exchange has a better and more acceptable performance than the one created by data envelopment analysis approach.

Using advanced information and information systems and decision-making advanced techniques including Multi Objective Decision Making and Multi Attributive Decision Making for analysis investment opportunities and risks are of crucial importance for investors and managers in financial services industries. For instance, Ferruz and Vegas (2008) realized that further integration of technology and information systems would improve clarification power of economic macro variables in predicting the expected returns of investment funds. Lin and Chen (2008) developed a new method based on the genetic algorithm for predicting the possibility of company's financial pressure to avoid investment risks. Charnes *et al.* (1978) used data envelopment analysis technique to evaluate efficiency of companies and stock selection. Considerable development of information systems and related software during recent years has facilitated evaluation of efficiency and performance of companies and institutes. Therefore, investors and financial managers in financial services industry find better and simpler investment opportunities using data envelopment techniques models. The empirical results of the present research show that the portfolios created using data envelopment analysis technique are able to create considerably high returns and this method can be used in selecting an optimum portfolio for investment.

The weaknesses of this method are detected using this method and by knowing the influence of these variables, necessary measures can be taken to promote relative efficiency level of companies. For example, *average variables of assets, average salaries of stockholders,* and *sale costs* were used as input variables in this research. By improving these factors, managers of inefficient companies can improve their management performance and efficiency. On the other hand, variables of income and operating profit were used as outputs in

this research. Managers of companies should consider these three variables given that they have high correlations.

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