THE EMPIRICAL STUDY OF R&D INPUT- OUTPUT LEVEL IN DIFFERENT INDUSTRIES — BASED ON THE DATA FROM EVALUATION OF THE ENTERPRISE TECHNOLOGY CENTER

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ABSTRACT

In this paper, based on the data from the evaluation of provincial enterprise technology center in China in 2013, seven industries are classified; and indicators measuring the input and the output of R&D are determined. And then, the input-output of R&D in different industries are empirically studied using the factor analysis and cluster analysis. Four common factors are used in evaluating the input–output of R&D in different industries. And the results show that the output of R&D varies significantly with industries. The overall score for the input-output level of R&D in the Electronic Information sector is the highest, but the poor in terms of product returns; the scores in machinery, building materials, chemical industry and medicine sectors are ranked from two to five; the light industry and the textile industry are the last two sectors, the nature of the industry and the status of in China are inseparable. Finally, the suggestions to improve the input-output level of R&D in different industries and the decisions to be made more scientific are proposed.

Key words: R&D input performance; technology innovation; factor analysis; cluster analysis

INTRODUCTION

Innovation is the source to the enterprise, research and development (R&D) plays an important role to affect not only the enterprise performance but also the competitive position in the process of innovation (Boer, 1994). Innovation is an important index to measure the level of development in an enterprise, and the factors influencing the innovation are also varied. The factors influencing innovation have been researched and analyzed by many scholars, the R&D input is one of the important factors.

Current researches suggest that R&D input can affect the innovation ability of enterprise, but how to achieve the optimal input-output R&D level and the difference between industries need further study. This article selects seven industries to do comparative analysis, not only can guide national R&D policy and the R&D investment of different industries, also can provide theoretical reference to optimize industry and R&D resource configuration. The suggestions to guide enterprises to adopt effective R&D investment and improve the enterprise technology innovation ability can be given.

LITERATURE REVIEW

Since 1912, Austrian economist Schumpeter put forward to the theory that innovation is the core of economic development. The study of innovation behavior in enterprise has always been the hottest issue. A series of theoretical and empirical researches emerged. Most scholars prove that the positive relationship between R&D investment and enterprise performance (Zhang *et al*., 2013). Ren *et al* (2010) study the enterprise R&D input and performance on the manufacturing, they find that manufacturing is positively related with the company's R&D investment and firm performance. The results show that the R&D cycle is short, the independent innovation ability is insufficient, R&D is the obviously short-term benefits and so on. Liang *et al* (2006) examine the correlation between R&D expenditure and firm development, the results support that R&D expenditure is positively related with the technology assets, company's profitability and its growth. Huang *et al* (2010) examine the relationship between R&D input-output of high technology industry in China, the results show that the R&D spending has a strong promoting role on output, and the investment in personnel contributes less in some industries. Xiang (2011) studies the efficiency of technological innovation by SFA, the results show that the technology innovation in different industries is inefficient and imbalance.

Harhoff (1998) studies the relationship between the R&D and productivity with German manufacturing panel data during the period of 1979 to 1989, the results prove that R&D is a key issue about productivity growth. Wakelin (2001) researches 170 British companies by Douglas function formula, proves that R&D spending has a significantly positive effect on productivity growth. Lee *et al* (1995) test the effect of R&D on the long-term performance and competition in the high technology industry of United States and Japan, they find that R&D spending has positive relationship with the enterprise market growth in the United States, and in Japan remains the same. Wang *et al* (2003) study the relationship between technology investment and productivity growth in high technology industry, prove that R&D spending in electronics industry is more significantly positive with productivity growth than other high technology industries. Technology input is weaker than the effect of R&D investment on productivity growth. R&D spending activities, however, result with the characteristics as high risk and uncertain. Most successful enterprises are not willing to take risks, they spend little in terms of R&D investment, the negative relationship between R&D and performance can be shown (Song *et al*., 2011).

There are three main reasons produced so many different results. Frist, one of the important factors is that the enterprises are in different industries. Because of the different scientific nature, industry competition structure and R&D structure, they lead to different results which R&D input influence the enterprises performance (Moncada - Paterno - Castello *et al*., 2010). Second, different authors select the data which time, regions and methods are not the same in the existing literature. Third, most existing studies evaluate overall national or regional R&D input-output from the macro level, or focus on a particular industry. It is lack of comparative study of different industries, so it lead to different results while the choice of variables is similar (Zhao *et al*.,2013).Based on the above problems, the contribution of this paper lies on the evaluation of R&D input-output with the industry division, comparing the difference with industries. It is significantly important for industrial structure adjustment and improvement of industry competitiveness.

DESIGN

i. Data Collection

In order to establish innovation system which market oriented and enterprises are the mainstay, the technology center of eligible enterprises is evaluated to establish the subject status of the enterprise. The enterprises report to the government for the establishment of technology, the enterprise can get the qualification by pass the government check. The data of this article is from the check of technology center in Hubei province. This article selects the sample of 438 enterprises, in which 323 enterprises belong to technology center review in 2013, and 115 enterprises are as the new. These ensure the strong credibility with accuracy and authenticity of the data.

According to industry classified standard of the national enterprise technology center, this paper gets rid of the small number of industry enterprises involved 10 enterprises to guarantee the representativeness, and classifies the remaining 428 companies into medicine, light industry, building materials, machinery, chemical, textile (industry enterprise sample size is shown in Table 1). This paper evaluates the effect of the R&D input-output with the seven sectors. After the unified data processed into the computer, this paper uses SPSS18.0 software for sorting, data processing and statistical analyzing.

Table 1: Statistic Enterprises of Sample

Project	Medicine	Light industry	Building materials	Machinery	Chemical	Textile	Electronic information	Total
Sample	56	68	31	132	36	39	66	428
Proportion	13.08%	15.89%	7.24%	30.84%	8.41%	9.11%	15.42%	100%

ii. Method

Efficiency evaluation is to measure the benefit of a unit input. In the practical application of the data, however, the studies usually collect relevant variables as much as possible, these variables may not be able to play the role as forecasted, on the contrary, it may bring problems. This article uses the method of combining the factor analysis and cluster analysis for data processing to greatly reduce the number of variables and guarantee the reliability of the information (Zhao *et al*., 2010).

This paper, firstly, according to the contribution of the common factor to assess information, evaluates the overall score of the samples. Secondly, industries are classified and evaluated the technology innovation ability based on the score by system clustering.

iii. Variable

In the studies of the R&D input-output about the enterprise, R&D input mainly refers to the R&D personnel and R&D spending, and they are the core indexes of science and technology activity (Huang *et al*., 2010; Wu *et al*., 2010; Zhong *et al*., 2007). R&D personnel is an important performance of enterprise technology innovation ability. R&D spending is a general index to measure regions, science and technology strength and the level of development (Zhong *et al*., 2007). According to most scholars' views (Liu *et al*., 2010), this paper also chooses the R&D personnel and R&D spending as R&D input. The importance of research and development to enterprises and the independent innovation ability of the enterprise can be illustrated (Zhong *et al*., 2007). Because the R&D activities are partly cumulative and path dependence, it is possible that R&D spending of last year influence this year on the degree, and the different size has totally different results (Tang *et al*., 2009). So these two absolute indexes, the percentage of R&D spending to the total sale revenue of last year and this year, can reflect the R&D spending better.

Now the competition is increasingly characterized by competition for talent. Training is an important mean to enhance the core competitiveness of enterprises and improve staff quality. R&D personnel training is in terms of skills and culture quality, it is an important way to improve the whole research strength and create a good culture. Given the different size in the same industry, considering both the absolute and relative index, this paper chooses the R&D personnel training cost and the ratio of R&D training to the total revenue.

R&D output refers to the innovational results acquired by various effective resources developed and configured on the basis of the innovation ability which economic subject has (Zhao *et al*., 2011).In the past literatures, the measures of enterprise R&D output mainly fall into two categories: the level of scientific research in enterprise and economic benefits of new products (Liu *et al*., 2007; Wang *et al.,* 2007; Xie *et al*., 2008).This article selects the valid invention patents and the invention patents accepted this year in terms of the scientific research level. The patent is an important standard to assess the level of scientific research. Invention patent can represent a higher technical level compared with the general patent indicators. Particularly the effective of invention patent is a new index to measure the independent innovation ability and market competitiveness of enterprise, region, and nation (Yang *et al.,* 2010). It is more authoritative and convincing when evaluating the comprehensive strength and competitiveness of science and technology economic. Therefore the variables about effective invention patents and the invention patents accepted this year are selected as the output of technological innovation.

The fundamental purpose of R&D activities is to carry out economic benefits of the new products with the market competitiveness (Zhao *et al.,* 2011). Sales income and profit of new products directly reflect the revenue generated by the R&D activities, they are extremely dominant indexes to measure technology innovation performance (Yan *et al*., 2013). The competition and development ability of R&D activities reflected by the sales profit of products as the final operating results can be seen as the output of industry (Tang *et al*., 2009), so the indicators of R&D input-output show in Table 2:

Table 2: The Evaluation Index Table of R&D Input-Output Level

Item	Indicators
R&D input：	The percentage of R&D spending to the total sales revenue of last year (X_1)
	The percentage of R&D spending to the total sales revenue of this year (X_2)
	R&D personnel (X_3)
	The ratio of R&D training cost to the total revenue (X_4)
	R&D personnel training cost (X_5)

Item	Indicators
R&D output：	Effective invention patents (X_6)
	Invention patents accepted this year (X_7)
	Sales profit of products (X_8)
	Sales profit of new products (X_9)
	Sales income of new products (X_{10})

TEST

i. Factor Analysis

KMO and Bartlett inspections are for the applicability of the factor analysis. KMO value of factor analysis is 0.717. The probability given by Bartlett sphericity test is 0.000, less than the significance level of 0.05. These show that the index of correlation coefficient matrix has significant difference with the unit matrix, so that is suitable for factor analysis.

Common degrees represent the original information of the variables can be extracted by the common factors. The common degrees of all the variables almost are more than 70% showed in Table 3. So the ability of these common factor extracted to explain every variable is strong.

Table 3: Communality

	original	Extract
The percentage of R&D spending to the total sales revenue of last year	1.000	.952
The percentage of R&D spending to the total sales revenue of this year	1.000	.955
R&D personnel	1.000	.585
R&D personnel training cost	1.000	.990
The ratio of R&D training cost to the total revenue	1.000	.989
Effective invention patents	1.000	.743
Invention patents accepted this year	1.000	.750
Sales profit of products	1.000	.956
Sales profit of new products	1.000	.938
Sales income of new products	1.000	.889

The extraction methods: principal component analysis

Four common factors are chosen according to the principle of characteristic values greater than 1.00. The cumulative contribution rate of the variance is 87.459%, it means the first four common factors can reflect the 87.459% information of the original index. In general, when the total variance (the contribution rate) of common factors is 80% or more, it means that these common factors focus most information of the research questiones, and they are not related with each other nor overlapped.

Table 4: Total Variance Explained

	The initial eigenvalue			Extract the sum of squares loaded			Rotate the sum of squares loaded		
	Total	Variance %	Cumulative %	Total	Variance %	Cumulative %	Total	Variance %	Cumulative %
1	3.111	31.106	31.106	3.111	31.106	31.106	2.785	27.849	27.849
2	2.258	22.583	53.689	2.258	22.583	53.689	2.012	20.121	47.970
3	1.959	19.591	73.280	1.959	19.591	73.280	1.978	19.781	67.751
4	1.418	14.179	87.459	1.418	14.179	87.459	1.971	19.708	87.459
5	.606	6.055	93.514						
6	.343	3.430	96.945						
7	.163	1.631	98.575						
8	.074	.737	99.312						
9	.050	.499	99.810						
10	.019	.190	100.00						

Extraction method: principal component analysis

The connection between common factors and original variables is represented by the factor loading value. The higher the factor loading value is, the more information the factors include. The load coefficient of common factor is more close to 1 or 0 through rotation transformation of the factor model. Common factor obtained by this way is easier to name and explain for variables. Table 5 is factor loading matrix for the variance of the maximum orthogonal rotation.

Table 5: Rotate Component Matrix [a]

	Ingredients			
	1	2	3	4
Sales profit of products	.971	-.016	.118	.020
Sales profit of new products	.962	-.011	.108	.015
Sales income of new products	.934	-.023	.122	.015
The percentage of R&D spending to the total sales revenue of last year	-.029	.974	.070	-.004
The percentage of R&D spending to the total sales revenue of this year	-.022	.971	.095	.000
Effective invention patents	.060	.040	.859	.017
Invention patents accepted this year	.096	.336	.792	-.029
R&D personnel	.159	-.076	.744	.029
The ratio of R&D training cost to the total revenue	-.025	-.008	-.039	.993

	Ingredients			
	1	2	3	4
R&D personnel training cost	.067	.002	.064	.991

The extraction methods: principal component analysis.
Method: Kaiser standardized orthogonal rotation method.
a. rotating convergence after five iterations.

Common factor 1 (F_1) is greater than 0.93 on the amount of load in three factors about the sales profit of products, sales profit and income of new products. The common factor 1 represents enterprise innovation absolute output.

Common factor 2 (F_2) is greater than 0.97 on the amount of load in the percentage of R&D spending to the total sales revenue of last year and this year. The common factor 2 represents enterprise innovation relative input.

Common factor 3 (F_3) is greater than 0.74 on the amount of load in three factors about effective invention patents, invention patents accepted this year and R&D personnel. The common factor 3 represents the field of patent output of the R&D personnel.

Common factor 4 (F_4) is greater than 0.9 on the amount of load in two factors about the ratio of R&D training cost to the total revenue and R&D personnel training cost. The common factor 4 represents the personnel training.

According to factor score coefficient estimated by component analysis in Table 6, the common factor score can be worked out, the functions of the factor score are as following:

$$F_1 = 0.017X_2+0.018X_1-0.032X_3+0.003X_5-0.020X_4-0.079X_6-0.045X_7+0.359X_8+0.357X_9+0.344X_{10}$$
$$F_2 = 0.494X_2+0.499X_1-0.120X_3+0.003X_5+0.006X_4-0.077X_6+0.086X_7+0.015X_8+0.018X_9+0.009X_{10}$$
$$F_3 = -0.057X_2-0.070X_1+0.409X_3+0.020X_5-0.026X_4+0.473X_6+0.397X_7-0.049X_8-0.054X_9-0.041X_{10}$$
$$F_4 = 0.006X_2+0.004X_1+0.006X_3+0.502X_5+0.506X_4+0.001X_6-0.020X_7-0.005X_8-0.007X_9-0.008X_{10}$$

Table 6: Component Score Coefficient Matrix

	Ingredients			
	1	2	3	4
The percentage of R&D spending to the total sales revenue of this year	.017	.494	-.057	.006
The percentage of R&D spending to the total sales revenue of last year	.018	.499	-.070	.004
R&D personnel	-.032	-.120	.409	.006
R&D personnel training cost	.003	.003	.020	.502
The ratio of R&D training cost to the total revenue	-.020	.006	-.026	.506
Effective invention patents	-.079	-.077	.473	.001
Invention patents accepted this year	-.045	.086	.397	-.020
Sales profit of products	.359	.015	-.049	-.005

	Ingredients			
	1	2	3	4
Sales profit of new products	.357	.018	-.054	-.007
Sales income of new products	.344	.009	-.041	-.008

The extraction methods: principal component analysis.
Rotated method: Kaiser standardized orthogonal rotation method.

According to the formula, the common factor score and the composite score of R&D ability can be concluded in each enterprise. It calculates the average of each factor score and the average of the composite score in each industry with industry classification, and then rank the industries according to the composite score. The results show in Table 7. The R&D input and output capacity calculate through the following model:

$$F=\frac{27.849\%}{87.459\%}F_1+\frac{20.121\%}{87.459\%}F_2+\frac{19.781\%}{87.459\%}F_3+\frac{19.708\%}{87.459\%}F_4$$

Table 7: Common Factor Scores and Composite Scores

Industry	Innovation output(F_1)	Innovation input(F_2)	Patent output(F_3)	Personal training(F_4)	Total score	Rank
Electronic information	-0.14639	0.07220	0.04508	0.51373	0.09596	1
Textile	-0.09333	-0.03877	-0.33985	-0.11955	-0.14244	7
Chemical	-0.06571	-0.08903	-0.14864	-0.01219	-0.07777	4
Machinery	0.13256616	-0.0454332	-0.0668623	-0.0440774	0.00670	2
Building materials	-0.05303	-0.11880	-0.09276	-0.03656	-0.0734	3
Light industry	-0.05360	-0.08246	-0.34632	-0.05469	-0.12669	6
Medicine	-0.10792	-0.04197	-0.10674	-0.09451	-0.0896	5

Many information can be read through factor analysis above, the input-output level of R&D differs significantly in different industries. The composite score of only two is positive in seven industries from the entire samples, these mean the R&D is inefficient in different industries. The top three industries are the electronics information, machinery and building material. There are five industries which comprehensive scores are negative, the textile industry is the last one.

ii. Cluster Analysis,

In this article, the technology innovation level of enterprise center can be divided into three categories by system cluster analysis of group connection. Cluster analysis tree is shown in Figure 1:

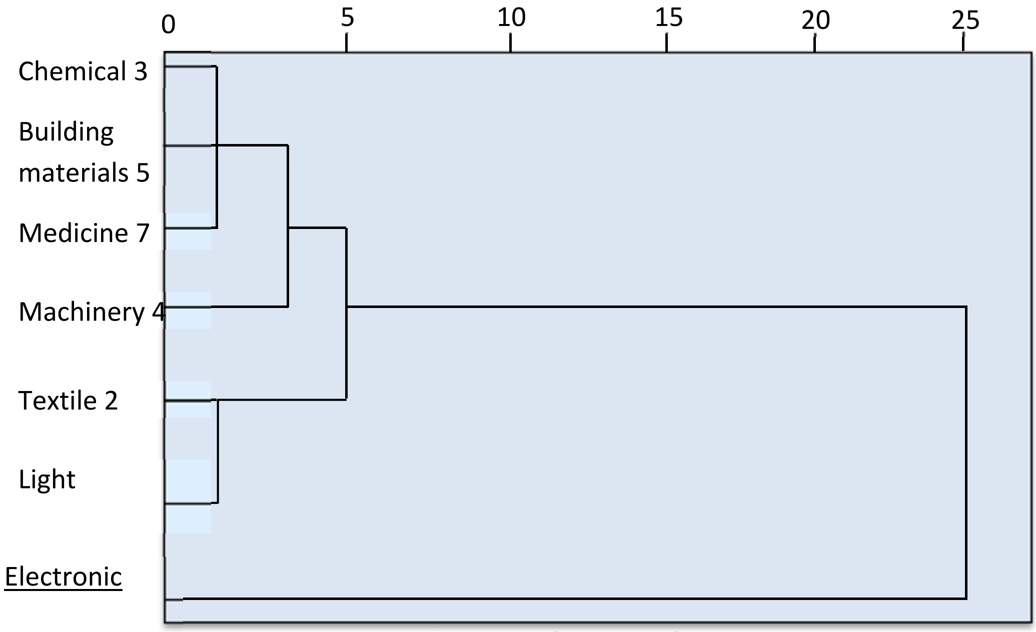

Figure 1: Cluster Analysis

The Figure 1 shows that electronic information is for a class. Chemical industry, building materials, medicine and machinery are classfied for one category, and textile, light industry are an another category.

iii. Results

a. From the results of factor analysis and cluster analysis it can be seen: electronic information industry is divided into one class, and is the first one in seven industries. It means that the technology innovation ability of electronic information industry is strong. This is closely related to the status of the electronic information industry. "Wuhan · China Optical Valley" significantly influence at home and abroad, it is an important hub of the optoelectronic industry. Optical communication, energy photoelectron industry develop rapidly, the optical fiber production is the first one in China and the second one in the world. Wuhan is the only city grasped all-optical networks communication technology about the transmission, and the devices to exchange. Electronic information industry has good momentum to develop, good development environment and room to improve. However, the score of innovation output(F_1) is negative and the lowest, the possible reasons are following: first, the conversion or transformation of R&D fruit is too long for electronic information industry; Second, the production and sales of new products is not enough; Thrid, the benefit of new products is too low. So it should improve profit margins of new products and adjust the product structure to find some way out. The enterprise should increase the technology import, transformation and absorption. Improving the utilization rate of digestion and absorption rate about the imported technology is also important. At the same time, the enterprise should pay more attention to both the investment and the economic benefits of the product. Only do these can make investment and benefits proportional to satisfy the enterprise of for-profit business needs.

b. From the results of clustering analysis, machinery, building materials, chemical and medicine are classified into a class. Mechanical industry ranks the second, this is mainly due to the leading status. At the same time, China is already the largest producer and consumer of building materials in the world, therefore the building materials industry is also ranked in the top. R&D innovation output and patent output score is high, it shows that industry gains better in terms of sales profit and income of new products. The enterprise can increase investment in R&D personnel to improve the quality and quantity of invention patent, to make a virtuous circle.

c. Medicine and chemical are the industries which base on science and technology, rely on technological innovation to develop new products to meet customer requirements. Therefore, the enterprises in medicine and chemical should attach great importance to research and development and technological innovation. The best way is to increase the investment of scientific research personnel and funds from the nature and the living environment of the industry itself.

d. Clustering analysis classfies textile, light industry into one catogory and these two industries rank in the final, these mean the innovation efficiency is not high. Textile and light industries are not pillar industries, so they pay insufficiently attention to technology innovation. The technology innovation foundation of these two industries is weak and the technology upgrade is slow, so the technological innovation is difficult. In addition, textile and light industry belong to the typical labor-intensive industries, the vast majority staff engage in first-line production activities, and the proportion of R&D personnel is relatively low. These two industries in the common factor 3 about patent output are ranked for the last two. Because of the difficulty and risk to technology innovation, they do not have the advantage compared with other industries. To change this situation, therefore, the industries must change the industrial structure from labor-intensive to knowledge-intensive. The advanced knowledge about high technology should play the key role in the industry development to improve the added value of industry products. Notably, the score of common factor 4 about personal training is also low in these two industries, the reasons for this result have two aspects: First, due to the nature of the industry, enterprises input little in the development of personnel training; Second, the generated effect of the enterprise into the training expenses is not well. This requires enterprises to improve the quality of training and assess the effect of training on R&D personnel, to achieve the desired goal.

CONCLUSION

Innovation and development of the industry is the key to the country to build an innovation-oriented society, it is an important force to improve the comprehensive national power and international competitive advantage. This paper carries out empirical research about R&D effective level of seven industries by factor analysis and cluster analysis. It can draw the following conclusions: (1) The overall efficiency of R&D input-output is not very good, most industries are in a state of poor technical efficiency. (2) The R&D efficiency of electronics information industry is the best; Machinery, building materials, chemical and medicine are ranked from two to five; Light industry and textil are the last two sectors. The following four aspects should be taken action to improve R&D input-output efficiency for whole enterprise:

i. According to the calculation results in this paper, R&D funds input intensity is an important factor to affect technology innovation ability in the evaluation process. Therefore, in order to improve the technical innovation ability, the enterprise must continue to strengthen the scientific research activities, the enterprise also should maintain and provide better conditions to attract more R&D personnel.

ii. The government should strengthen the guiding role, enhance the enterprise's technology innovation consciousness, and issue preferential policy in the field of R&D project. Enterprise R&D investment should be encouraged, the environment of high-tech enterprise innovation will be optimized. The government should formulate and implement policies and measures which conducive the high-tech enterprise to innovate. The industry which the composite score of R&D efficiency is high should be supported to improve the resources allocation efficiency. For the low-ranking industries, it is difficult to set up their own research and development institutions due to its low degree of dependence on technology. The cluster innovation activities of these industries shall be conducted with the help of the government, public research and development platform can be built to realize the industrialization development. On the basis of the nature of different industries, the government should also be differentiated to develop industries instead of the "one size fits all" policy.

iii. The enterprises should also establish the feasible R&D efficiency assessment mechanism. Through the adjustment of R&D input factors and efficiency evaluation, the resources achieve the most effective configuration state to achieve the best utility level with a more scientific mechanism and the method.

iv. Talent is the key to the enterprise technology innovation. Only one industry is positive and other industries are no efficiency in patent output of R&D personnel from the common factor 3 score. Research and development personnel have barriers to improve technical level in these industries. Therefore, these industries should further optimize the configuration and structure of R&D personnel to utilize the talent better. Enterprise should master international talents with cutting-edge technology and international vision to join the R&D organizations to enhance the overall knowledge level and the R&D team atmosphere.

Due to the length of this paper, there are some research limitations .The reasons of the differences which this paper argued still depend on the position of the enterprise in the industry, the technology level of enterprise in the industry which belonged to the technology leader or follower, the degree of enterprise competition in the industry and so on, these also need to be further discussed.

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