Changing Technology Transfer Strategies in a Non-profit Organization – An Examination of ITRI

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Abstract: With the emergence of global competition, a non-profit organization (NPO) must adapt its strategies of technology transfer to suit the change of global economic environment so as to enhance benefits of technology transfer. The Industrial Technology Research Institute (ITRI) is the leading non-profit R&D organization in Taiwan. This current research studies ITRI's strategies of major technology transfer and then divides these strategies into three stages in accordance with Taiwan's stages of industrial development. This paper aims to measure the strategic changes employed every ten years and assesses the impact level of each strategy at each stage. This research applies Fuzzy and AHP theories to survey ITRI's technology transfer strategies over the past thirty years and to analyze the future strategy for technology transfer. We conclude that a new pattern of technology transfer strategies has served as a means for more balanced innovative capabilities among sectors. Furthermore, the value-added IPRs and spin-offs are the most important factors for future technology transfer when Taiwan evolves toward knowledge economy era. In addition, an open model for future technology transfer is proposed and discussed in this paper.

1. ITRI - the leading NPO in Taiwan

In the 1960s, Taiwan was an important sugar exporting country, but it is now a high-tech manufacturing center for integrated circuits (ICs), TFT/LCDs, PCs and notebook computers. ITRI played an essential role in transforming this island-nation from an agricultural-based economy to an industry-oriented economy. It is believed that without ITRI, rapid development of the semiconductor and information industries would have been impossible in Taiwan. Despite ITRI's noteworthy contribution to the above-mentioned industries, ITRI's technology transfer strategies have been scarcely researched. This paper applies seventeen important criteria of technology transfer, Fuzzy and the Analysis Hierarchy Process (AHP) to measure these strategies at ITRI from the 1970s to the present, and to the future.

ITRI was established in 1973 as a non-profit organization through an act promoting industrial technology in Taiwan. Currently, ITRI is Taiwan's leading R&D organization employing a staff of 6000, working in its eleven research organizations sponsored by the government, particularly the Ministry of Economic Affairs (MOEA). The government sponsors roughly 50% of the institute's budget and industrial firms sponsor the rest. In 1976, ITRI started transferring IC fabrication technology from RCA, with a technology transfer team consisting of approximately forty people. Since there was no residual manpower available for technology transfer pursuits, R&D personnel were responsible for tasks related to both technology transfer from RCA and technology transfer to domestic industry. At first, ITRI aggressively cooperated with industries, academia, and other research sectors. As ITRI grew to an organization of 6,000 staff members, the number of people directly responsible for technology transfer increased to about 200, accelerating the commercialization of R&D results at ITRI.

Since ITRI transferred manufacturing technology from RCA and completed the country's first mass production line for chipsets in 1976, it has played an important role in the nurturing and development of high-tech industries. Consequently, the generation of spin-off companies may be the most dominant feature of ITRI's strategy for technology transfer during this period, particularly in the case of UMC in 1980 and TSMC in 1987.

2. Uncertainty of Future Technology Transfer at ITRI

To maintain continuous and rapid technological advances, ITRI was required to develop an effective measure of technology transfer to meet the new challenges of Asia-Pacific's "New Economy." One must consider, however, fluctuations of ITRI's strategies every ten years. In addition, it is necessary to determine the impact level of each strategy at each stage of development. There is also a need to examine technology transfer trends for signs of continuity while the lifecycle of technologies and products is reducing. This research aims to provide cogent and practical responses to these issues through the collective knowledge and wisdom of dozens of leading experts in ITRI.

There are several research models which evaluate technology transfer, such as the nationwide technology focal survey model of the National Science Council in 1999 [1], the Data Envelopment Analysis (DEA) performance evaluation model of Banker R.D., et al. [2]. These models, however, are limited by their lack of breadth and accuracy. This paper, therefore, applies the Fuzzy and AHP theories to survey ITRI's technology transfer strategies over the past thirty years. To understand the variation of strategy during the past thirty years, we temporally delineated ITRI's growth into three stages, set up a panel of experts to define the strategic tools at each stage, and ranked the impact level of each strategic tool through the Fuzzy and AHP theories. Each expert's service commitment to ITRI amounts to, or exceeds twenty years, and they come from the upper management of six laboratories and five focus centers at ITRI. This approach, we claim, provides an accurate and detailed strategic viewpoint. In terms of the structure of this discussion, the research methodology-and-process is introduced in section 3 and our results are described in section 4.

3. Identify Strategies for Technology Transfer

3.1 Defining the strategic tools of technology transfer

Due to the discrete management system used in the past and currently at work in ITRI, it is very hard to collect the complete data of the past thirty years for technology transfer. Furthermore, it is problematic for the selected experts, to identify the past decades and future strategies of technology transfer on their own. Therefore, the approach of a panel of experts was selected to identify the past and future technology transfer strategies.

Theoretically, Probert, et al. [3], "technology transfer" refers to the transfer of commercialized technology from the supply side to the demand side, including the development of product and manufacturing lines to increase their function and efficiency levels. Based on Amesse and Cohendet [4] state that technology transfer is essentially considered as a specific knowledge transfer process that depends on the ways firms and other institutions manage knowledge, in particular the co-evolution of their absorptive capabilities and their knowledge-transmission strategies. The former, it should be noted, are the primary objectives of technology R&D. For technology not creating production value, R&D is a deficit in financial reporting. That is, it has no value whatsoever to the research agency or society in general.

Practically, if we further delineate "technology transfer" according to technology development, technology transfer strategies show how technology is used to create economic value. Compared to technology transfer and "technology expansion," our understanding of "technology transfer" sufficiently encompasses all transfer and diffusion activities. Based on ITRI's present and historical operational requirements, technology transfer strategies in this discussion include spin-offs, patent licensing, cooperative research, open laboratories, technology training, and other strategic tools [5,6,7,8]. These all, however, require a measure of qualification. In accordance with the research panel and references [8,9], we identified four categories with seventeen tools to estimate ITRI's technology transfer strategies:

A. Knowledge Diffusion:

A-1. *Organizing technology symposia/reports:* A technology symposium presents and discusses ITRI's researcher's work with industrial users and experts. Together with technology reports, symposia provide an important channel for exchange of R&D information between researchers and users. [8,9]

A-2. *Technology training:* Technology training focuses on sharing technical information by means of education and training. A series of special training courses are conducted by ITRI to train personnel from the industry or academic sector, for new technology or technology needed by an industry. [8,9]

A-3. *Technology promotion:* Technology promotion is a term referring to methods of bringing a technology, prototype or commercial idea to the public's attention, including advertising, personal selling, sales promotion, and publicity. ITRI's newly developed technology or technology needed by industry are managed through technology advertisements, such as direct mail, websites, etc. The needed technological information is made available to the industrial sector via domestic advertisement channels or other international communication channels. [8,9]

A-4. *Thesis publishing:* A thesis is a dissertation advancing an original point of view as a result of research. Newly developed technologies in ITRI are presented in local and international professional journals, increasing the worldwide interaction between institutes and academia. [8,9]

A-5. *Exhibitions:* An Exhibition is a large-scale public show of industrial products or engineering ideas. Through participation in local and international exhibitions, ITRI is able to display and promote its R&D results domestically and abroad. [8,9]

B. Tech Transfer & Service:

B-1. *Industrial services:* According to Carayannis and von Zedtwitz [14], entrepreneurs need business facilitation services, such as funding, office space, IT infrastructure, coaching, etc., from an incubator or other service providers. On the other hand, the industrial sector provides ITRI with knowledge of industrial service needs, enabling ITRI to provide the most efficient solutions. [8,9]

B-2. *Cooperative research (industry, academia, and research sectors):* ITRI engages in R&D with industry and academia. [8,9]

B-3. *Testing certification (after service):* Through certified laboratories, ITRI assists industry with various testing or certification processes. [8,9]

B-4. *Early license:* During the initial stages of R&D, firms may invest a small amount of capital to work with ITRI, gaining corresponding rights to use the research results. [10,11,12]

B-5. *Technological strategic alliance:* A technological strategic alliance is a mutually beneficial long-term formal relationship formed between two or more parties to pursue a set of agreed upon technological goals or to meet a critical business need while remaining independent organizations. It is a synergistic arrangement whereby two or more organizations agree to cooperate in the carrying out of a business activity where each brings different strengths and capabilities to the arrangement. By signing an alliance contract, ITRI is able to proceed with technology cooperation, joint procurement, and technology transfer. [10,11,12]

C. IPR License & Value-added:

C-1. *Patent licensing (one-directional; few companies):* ITRI grants local companies a license to use its patents. [10,11,12,13]

C-2. *Cross license (bilateral; few companies):* ITRI and local companies sign a cross-license agreement with an influential foreign corporation under the condition that local companies are allowed to use the patents of that corporation, at a reduced royalty rate. [10,11,12,13]

C-3. *IP pool (multi-directional; many companies):* An IP pool or quoted patent pool is a consortium of at least two companies agreeing to cross-license patents and other IP rights relating to a particular technology. The creation of a patent pool can save patentees and licensees' time and money. Competition law issues are usually considered when a large consortium is formed. Patent pooling has recently become a highly debated field. Companies owning patents may grant each other a right to use patents from a designated pool. [10,11,12,13]

D. Shifts in human capital & Incubation:

D-1. *Technology transfer through shifts in human capital:* Personnel/researchers who resign from ITRI and enter the public and/ or private sectors take with them training and skills. Araj [14] outlines that one of the major achievements of Japan's technology transfer strategy is the cultivation and shift of human resources. In the past decades, ITRI has shifted more than 900 employees every year. [8,9]

D-2. *Spin-offs:* A spin-off is a new organization or entity formed by a split from a larger one or a new company formed from an institute or university. ITRI unifies capital, technology, and manpower to promote effective connections between R&D and production, directly creating industry investment and value-added services. [5,6,7,8,9]

D-3. *Open laboratories:* This system is part of ITRI's industrial service, aimed at assisting companies during the entrepreneurial stage while creating an environment to promote ITRI's resources to the industrial sector. [8,9,10]

D-4. *Incubators:* Carayannis and von Zedtwitz [15] stress that incubation has recently experienced attention as a model of start-up facilitation. ITRI's incubator, one of the biggest incubators in Taiwan, has stimulates lots of small and medium-sized high tech companies to successfully move to Hsinchu Science Park or IPO. [8,9,10]

These seventeen strategic tools were the basis of our questionnaire, which was based on the responses of experts from six laboratories and five focus centers at

ITRI. The results helped to determine the key factors for the design of the AHP questionnaire.

3.2 Fuzzy AHP analysis

We applied the Fuzzy and AHP theories to evaluate hierarchical strategies. The evaluation process consists of the following stages:

A. Evaluating weights for the hierarchy relevance system by AHP:

AHP weighting is determined by pair-wise comparisons to reveal the comparative importance of two criteria. Such comparisons allow a certain degree of inconsistency within a domain. Saaty (1980) used the principal eigenvector of the pair-wise comparison matrix derived from the scaling ratio to find the comparative weight among criteria of the hierarchical system [16].

In equation (1), A stands for a data matrix collected from questionnaires; W represents the weights for the criteria.

$$(\boldsymbol{A}-\lambda_{\max} I)\ W = 0 \qquad (1)$$

And, Consistency Index (C.I.) measures the consistency of responses.

$C.I. = \dfrac{\lambda_{\max} - n}{n-1}$. If $C.I. \le 0.1$ then the consistency is acceptable.

B. Evaluating weights for the hierarchy relevance system by Fuzzy:

We can obtain performance values by measuring the fuzzy number (x) from the evaluators (a linguistic variable, in our case) and defuzzying their fuzzy numbers by the following calculation.

$$\mu_{\tilde{A}}(x) = \begin{cases} (x-L)/(M-L) & L \le M \le M \\ (U-x)/(U-M) & M \le x \le U \\ 0 & otherwise \end{cases} \qquad (2)$$

We may also apply the triangular fuzzy number (TFN) to express the linguistic variable in equation (2). Each linguistic variable is given a TFN within the range from 0 to 100 to show its degree of importance, as it is shown in the following figure 1:

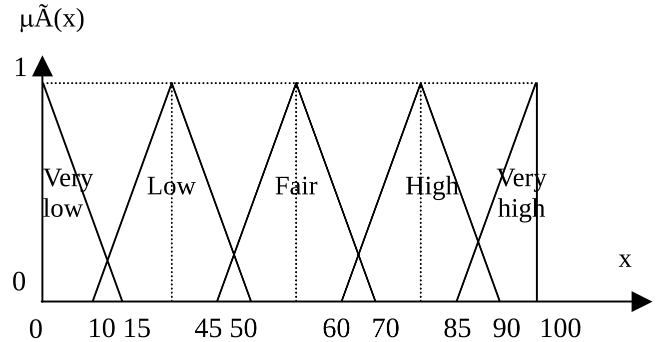

Figure 1 TFN

The membership function of the five levels of each linguistic variable measures the achievement of the performance value for each objective and criteria. As such, we can measure the credit point (weights) of each strategy. Each linguistic variable may be indicated by a TFN, or evaluators can subjectively assign weights to linguistic variables. Assuming there are m evaluators, the fuzzy performance value of evaluator k toward strategy i under objective/criteria j is calculated according to equations (3)-(8). The signs, ⊙ and ⊕ , denote fuzzy multiplication and fuzzy addition, respectively.

$$E_{ij}^{k} = (LE_{ij}^{k}, ME_{ij}^{k}, UE_{ij}^{k}),\ j \in S \qquad (3)$$

$$E_{ij} = (1/m) \odot (E_{ij}^{1} \oplus E_{ij}^{2} \ldots \oplus E_{ij}^{m}) \qquad (4)$$

$$E_{ij} = (LE_{ij}, ME_{ij}, UE_{ij}) \qquad (5)$$

$$LE_{ij} = (1/m) \odot (\sum_{k=1}^{m} LE_{ij}^{k}) \qquad (6)$$

$$ME_{ij} = (1/m) \odot (\sum_{k=1}^{m} ME_{ij}^{k}) \qquad (7)$$

$$UE_{ij} = (1/m) \odot (\sum_{k=1}^{m} UE_{ij}^{k}) \qquad (8)$$

Defuzzification occurs with the location of the Best Nonfuzzy Performance (BNP) value, shown in equation (9),

$$BNPi = [(UEi - LEi) + (MEi - LEi)]/3 + LEi\ , \forall i \qquad (9)$$

4. Analysis of questionnaire results

Based on the survey results from the selected laboratories and research centers, ITRI's thirty years of technology transfer strategies can be categorized into three stages, assigning each a specific position and term. There are seven strategic tools related to the first stage, namely: (1) organizing technology symposia/reports, (2) technology training, (3) technology promotion (in standard form or on the web), (4) thesis publishing,(5) exhibitions,(6) technology transfer personnel and (7) industrial services. A total of ten strategic tools are related to the second stage, which supplements the first stage tools with three more items: (8) spin-offs, (9) cooperative research (industrial, academic, and research sectors), and (10) testing certification. For the third stage, the strategic tools include the entire list in section 3.1. Based on this temporal delineation, we labeled ITRI's three stages of technology transfer as follows: the "mass production trial/commercialization stage" of the 1970s; the "spin-off/new business stage" of the 1980s; and the "cooperative research and knowledge value added stage" of the 1990s. Following is a more comprehensive analysis of each stage's results, which should be considered in the context of the AHP analysis of section 4.4.

4.1 Technology transfer of the 1970s

ITRI utilized seven strategic tools, namely: (1) organizing technology symposia/reports, (2) technology training, (3) technology promotion, (4) thesis publishing, (5) exhibitions, (6) testing certification and (7) industrial services. In addition, some respondents pointed out the importance of increasing the amount of new technology transferred from other countries, with particular reference to the RCA case. During this period, ITRI brought in new technology from abroad, paying careful attention to timing and taking advantage of business opportunities.

4.2 Technology transfer in the 1980s

During the second stage, ITRI had already established five laboratories in the fields of chemical engineering, mechanics, electronics, energy–and-resources, computers-and-communications. Furthermore, five research centers were created in the following fields: opto-electronics, measurement technology, industrial safety-and-hygiene, aerospace technology, and pollution prevention. Ten strategic tools are related to the second stage, namely: (1) organizing technology symposia/reports, (2) technology training, (3) technology promotion, (3) thesis publishing, (4) exhibitions, (5) testing certification, (6) industrial services, (7) cooperative research, (8) technology transfer through shifts in human capital, (9) spin-offs.

4.3 Technology transfer in the 1990s

By the third stage, ITRI had already established seven research laboratories and six research centers. All seventeen strategic tools are related to this stage, showing a progression from the 1970s in increased utilization and application of a variety of strategic tools of technology transfer. Looking beyond, it is also necessary to identify and prioritize strategic tools for future technology transfer.

4.4 The trends of future technology transfer

More than forty questionnaires were distributed; thirty-five were returned. According to the Consistency Index (CI) check, thirty copies were partially valid (some CI number > 0.1, which is suggested by Saaty that the data is inconsistent) for further analysis; and eleven questionnaires were fully valid (all CI < 0.1; CI=0.1~0.7). The process and results of evaluating technology transfer strategies for the future are shown as follows:

A. Evaluating the weights of each tool for future technology transfer by AHP:

Table 1 Analysis of eleven questionnaires:

	Strategic Tool	Weights	Total Weights; wj
A-1.	Organizing technology symposia/reports	0.175	0.008 (15)
A-2.	Technology training	0.207	0.009 (14)
A-3.	Technology promotion (direct mail, website, etc.)	0.100	0.005 (17)
A-4.	Thesis publishing	0.358	0.016 (13)
A-5.	Exhibitions	0.160	0.007 (16)
		CI=0.074	
B-1.	Industrial services	0.166	0.047 (9)
B-2.	Cooperative research (industry, academia, and research sectors)	0.249	0.070 (6)
B-3.	Testing certification (after services)	0.091	0.026 (12)
B-4.	Early license	0.212	0.060 (7)
B-5.	Technological strategic alliance	0.282	0.079 (5)
		CI=0.040	

C-1.	Patent licensing (one-directional; few companies)	0.268	0.120 (3)
C-2.	Cross license (bilateral; few companies)	0.272	0.122 (2)
C-3.	IP pool (multi-directional; many companies)	0.459	0.205 (1)
		CI=0.034	
D-1.	Technology transfer through shifts in human capital	0.133	0.030 (11)
D-2.	Spin-offs	0.428	0.096 (4)
D-3.	Open laboratories	0.189	0.042 (10)
D-4.	Incubators	0.250	0.056 (8)
		CI=0.016	

Numbers in parentheses represent the ranking of weights among the criteria/strategic tools from greatest to smallest. The weighted importance of the first eleven tools is 92.9%; the first four items represent 54.3%. To exclude inconsistent data, the analysis of eleven questionnaires is selected for further analysis.

B. Estimating the performance matrix by Fuzzy Measure:

Numbers gathered from Fuzzy measure questionnaire represent the importance of each technology transfer tool. The defuzzying number can be calculated from Defuzzification, i.e. equation (9). According to the analysis, nine tools are recommended as very essential for future technology transfer, namely: industrial services, cooperative research, early license, technological strategic alliance, patent licensing, cross license, IP pool, technology transfer through shifts in human capital, spin-offs.

4.5 Comparison of Fuzzy & AHP analysis

Eleven highly consistent AHP analysis (logically trusted) and thirty Fuzzy questionnaires (represented majority opinions) were chosen to make an appropriated comparison. Besides, the analysis of the thirty AHP questionnaires also showed a very similar result.

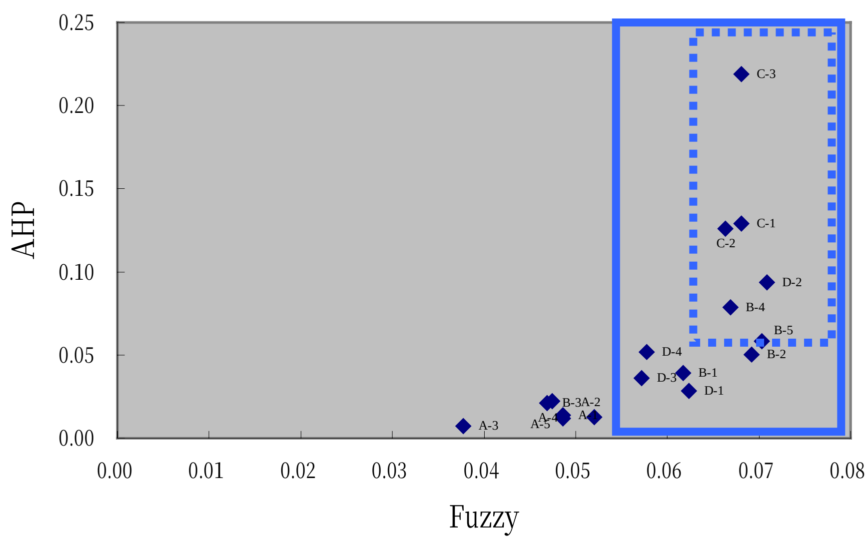

Figure 2 Comparisons between Fuzzy (horizontal axis) and AHP (vertical axis) of future technology transfer

The weighted importance of the first eleven tools by AHP (within the solid line box) is 91.1%; the first four items (within the dashed lined box) by AHP represents 56.7%. Meanwhile, the weighted importance of the first eleven tools by Fuzzy (within the solid line box) is 71.9%, which implied the importance of the first eleven tools. According to the above analysis, IPR strategy and Spin-off play an important role in future technology transfer, representing 50% of the importance of the strategy for technology transfer. And, cooperative research, early licensing, technology strategic alliance, incubator, open lab and shift in human capital, and industrial service share 40% of the importance of the strategy for technology transfer. The importance of the remaining five tools represents the remaining 10% importance.

The weight obtained from Fuzzy and AHP analysis can be further applied to design the mechanism for technology transfer in ITRI (see Figure 3) based on Chesbrough's open model [17,18]. The first thirteen tools shown on the left side of Figure 3, sharing 50% of the importance, are already implemented in the organization (named strategy C and strategy B). However, on the right hand side, another four tools (strategy A), especially IPRs strategies, are new strategic tools, which share 50% importance. The tapered pyramid in the middle of figure 3 represents the convergence of the design for technology transfer.

We classified the seventeen tools into three groups (in Figure 3): Strategy A, B and C. Strategy C includes six strategic tools, namely: holding symposia, thesis, technologies' promotion, attending exhibition, testing & certification and training. These six items are common and basic tools in NPOs. Therefore, we named this group "basic service for T.T. (technology transfer)." The weighted importance of this group is about 10%, calculated by AHP. Strategy B, called "middle impact of T.T.", includes the following seven tools: technology alliance, cooperative research, early licensing, incubator, open laboratories, shifts in human capital, industrial services (customized R&D). The weighted importance of group B is about 40%, calculated by AHP. Strategy A, named "major impact of T.T.", represents more than 50% of the importance of the information, and is constructed from four tools, namely: IP pool, patent licensing, cross licensing and spin-off. On the other hand, these four tools, IPR strategies & spin-offs are the most important strategic tools for future technology transfer.

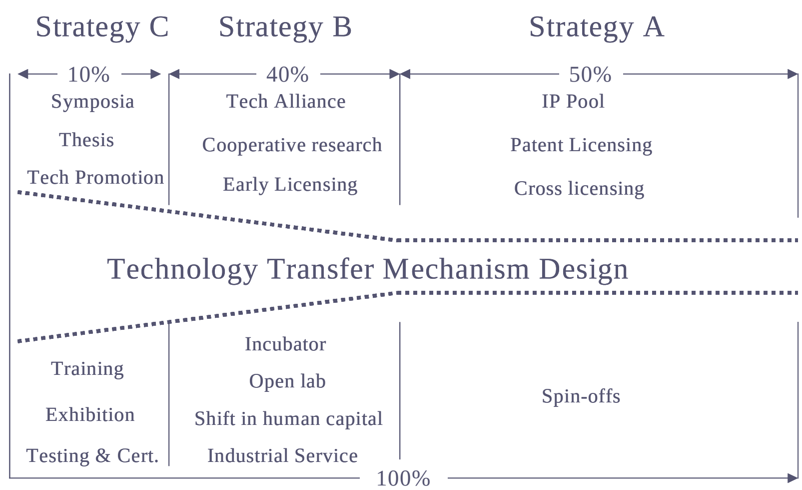

Figure 3 The weight of strategies and the mechanism design for technology transfer in ITRI

This research successfully applies the Fuzzy and AHP theories to classify and analyze the strategies of technology transfer in a non-profit organization. Results have shown that this model can help identify the trends of decision-making. Furthermore, we can also apply other analytical tools to compare the result with the result of the AHP analysis for a further similar study. Moreover, the new open model for technology transfer is a new domain for further studies; the ITRI case is the development of a series of further studies with respect to this topic.

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